Machine Elements Instruction Material – Fits, Bolt & Screw, Shaft & Hub, Coupling, Belt Drive, Gears, Bearings, Gear Box

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Moyens didactiques,
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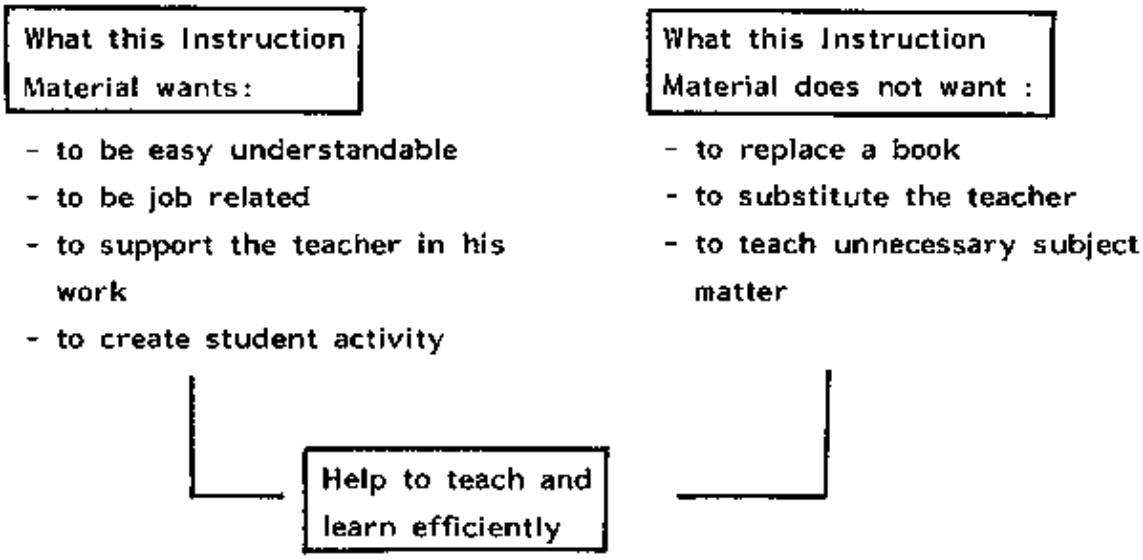
Feedback: TGTAC Thailand

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

Introduction



• This Instructional material is developed by experienced specialists of the Thai–German Teaching Aid Centre. It can be used with a minimum of preparation.

• Selecting the objectives, we concentrated on the most important ones. An industrial survey helped us in finding them.

• If the teacher thinks that an objective is less important, he can teach this objective less intensively.

• The teaching method, which should be used, is the "questioning technique" Please do not only lecture.

Hints for the teacher

There are 6 parts for each topic:

1. List of objectives
2. Information sheets
3. Task sheets
4. Activity sheets
5. Teaching aids (transparencies, models, etc.)
6. Solutions

1. A list of objectives shows the teacher what the student should know after the lesson.

2. Information sheets show pictures with a short explanation of the subject matter. These information sheets should be given to the student after the lesson as a summary.

3. Task sheets help the teacher to check the learning progress. They should be used at the end of one period. It is necessary to discuss the solutions with the students. Please do not use them as a test,

4. Activity sheets are offered for particular objectives only. Based on information already taught before the student should find new information by themselves. Only after the student failed to find the intended solution by themselves, the teacher will explain it in the normal manner.

5. Teaching aids make the subject matter better understandable and motivate the students.

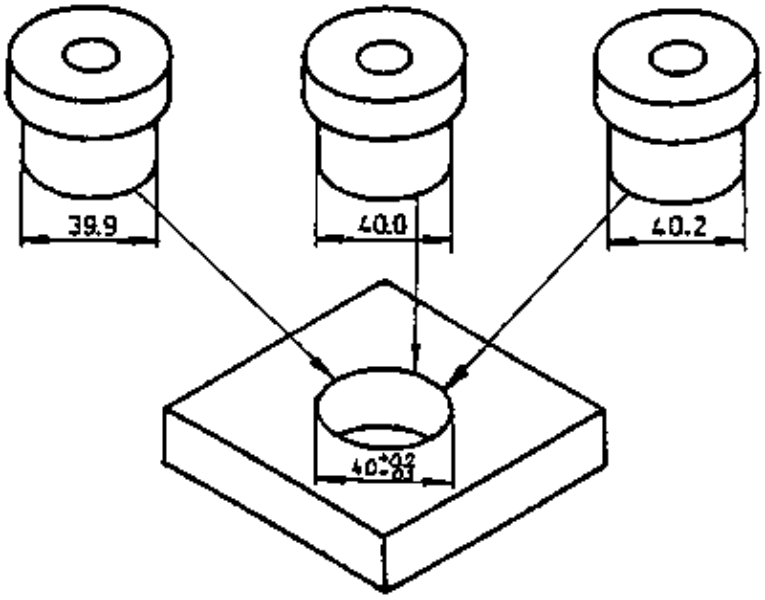
6. Solutions for the task and activity sheets.

1. Fit

Information sheet

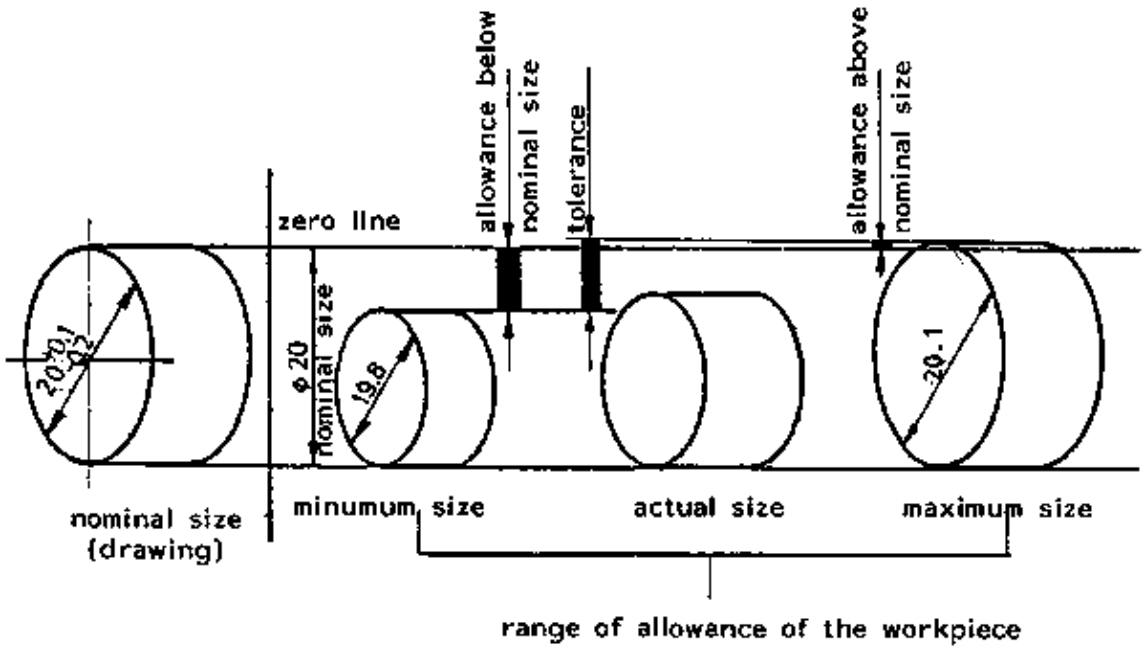
1. Purpose of fit

When producing workpieces, it is impossible to make them all in the same size. As they must be interchangeable (e.g. spare parts), a system of fit is needed.



2. Basic principle

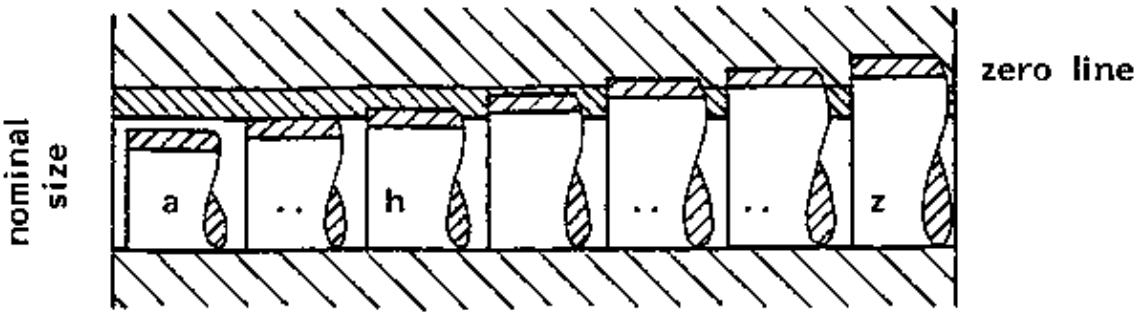
2.1 Tolerance system



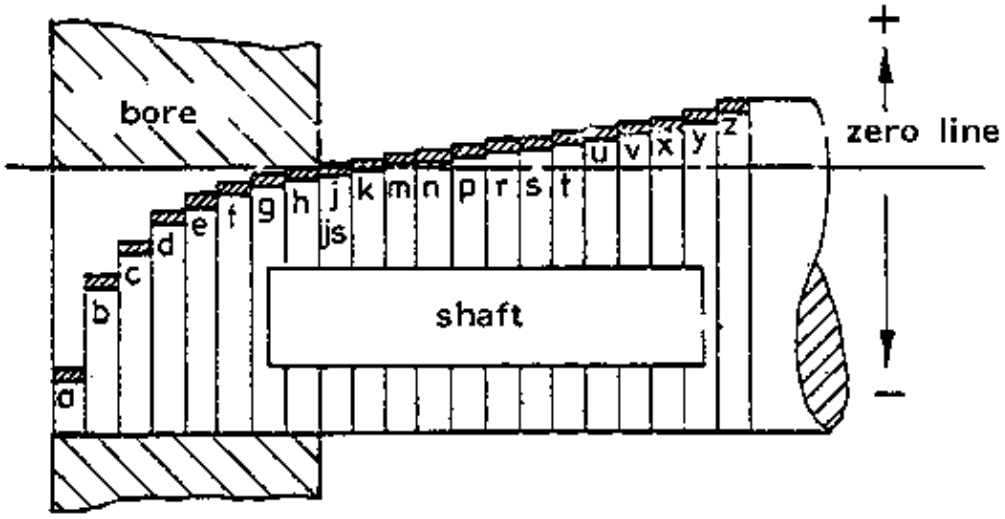
– nominal size is the dimension specified in the drawing (e.g. 20 mm)
– allowance below nominal size is the distance between zero line and minimum sized workpiece.
– allowance above nominal size is the distance between zero line and maximum sized workpiece.
– tolerance is the difference between minimum and maximum sized workpiece.
– actual size is the real size of the workpiece,
– zero line is the line which indicates the nominal size.

2.2 Specification of tolerance range

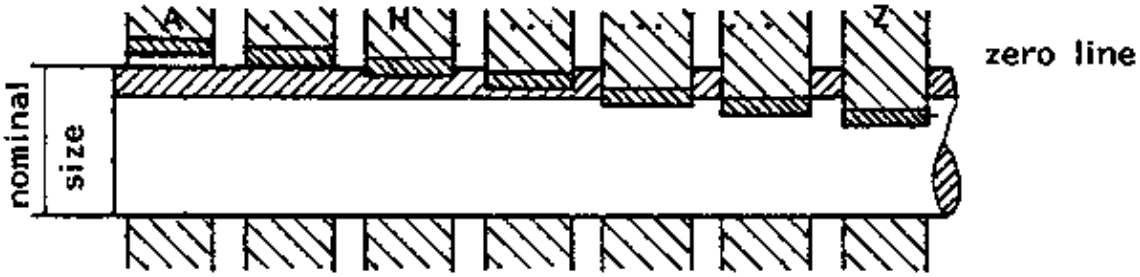
2.2.1 of a shaft (specified by small letters)



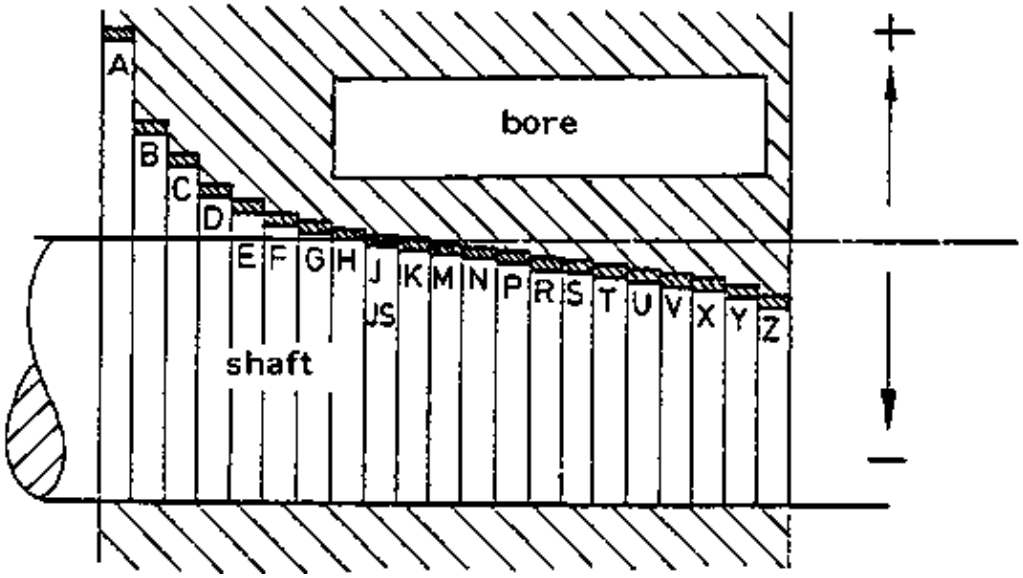
a - z indicates the position of the shaft tolerance range



2.2.2 of a bore (specified by big letters)



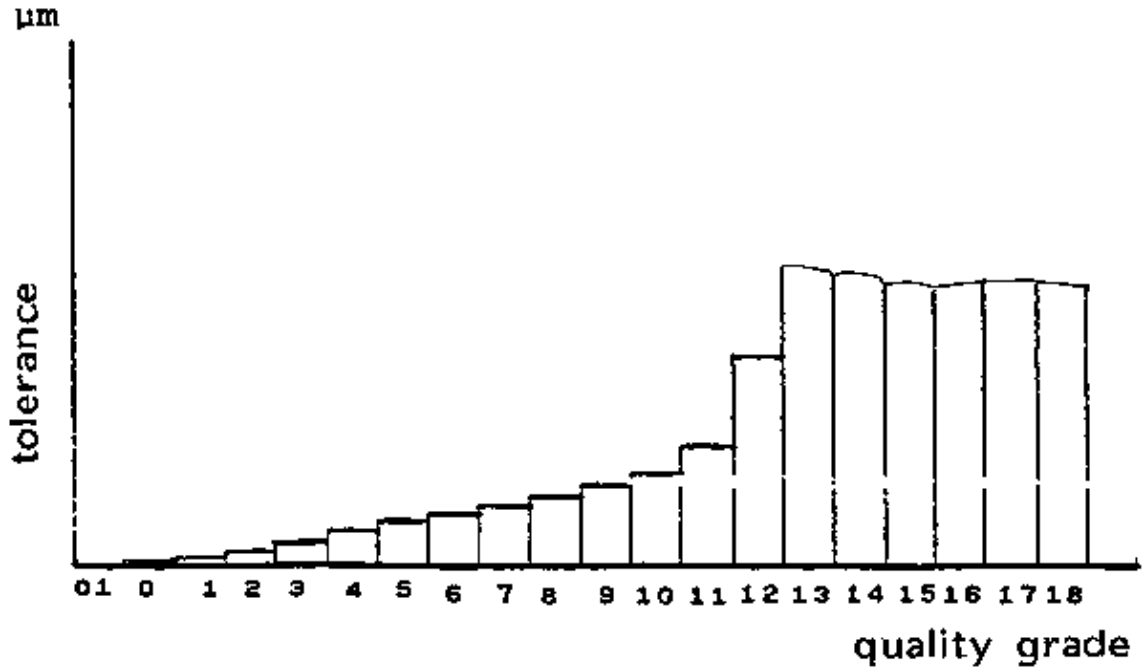
A - Z indicates the position of bore tolerance range



2.3 Accuracy level of tolerance

The tolerance value is related to the nominal size of a workpiece, it increases with the nominal size.

The tolerance system is divided into 20 quality grades:

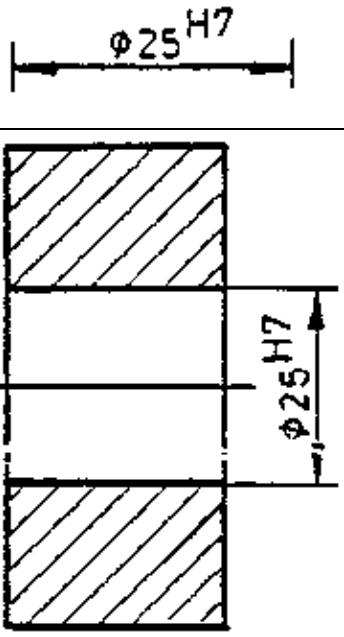
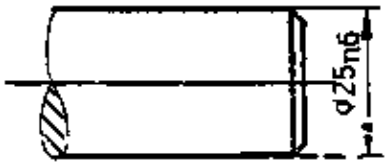
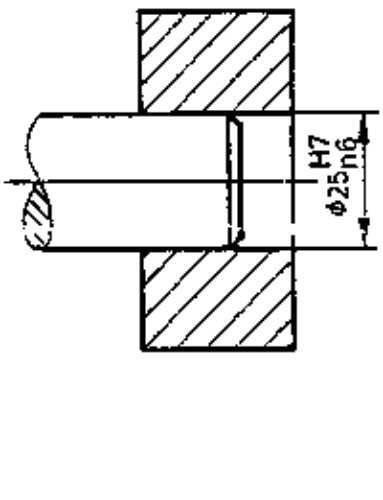


01 – 5 is used for high precision such as production of measuring instruments
6 – 11 is used for machine parts
12 – 18 is used for low precision such as casting and welding

ISO basic standard, tolerance in 1 mm																				**DIN 7151 (11.64)**
nominal size from.. to		**IT**																		
		01	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
mm	1..3	0,3	0,5	0,8	1,2	2	3	1	6	10	14	23	40	60	100	140	250	400	600	–
	3..6	0,4	0,6	1	1,5	2,5	4	5	8	12	18	30	48	75	120	180	300	480	750	–
	6..10	0,4	0,6	1	1,5	2,5	4	6	9	15	22	36	58	90	150	220	360	580	900	150
	10..18	0,5	0,8	1,2	2	3	5	8	11	18	27	43	70	110	180	270	430	700	1100	180
	18..30	0,6	1	1,5	2,5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300	210
	30..50	0,6	1	1,5	2,5	4	7	11	16	25	39	62	100	160	250	360	620	1000	1600	250
	30..80	0,8	1,2	2	3	3	8	13	19	30	46	74	120	190	300	460	740	1200	1900	300
	80..120	1	1,5	2,5	4	6	10	15	22	35	54	87	140	220	350	340	870	1400	2200	350
	120..180	1,2	2	3,5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500	400
	180..250	2	3	4,3	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900	460
	250..315	2,5	4	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200	520
	315..400	3	5	7	9	13	18	23	36	57	89	140	230	360	570	890	1400	2300	3600	570
	400..500	4	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1350	2500	4000	630

Example: If the nominal size is 20 mm and we choose quality grade 6, we will get a tolerance of 13 mm (= 0.013 mm)

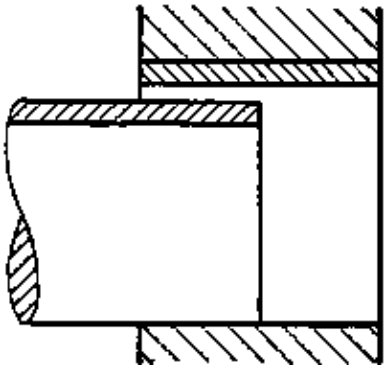
2.4 Inscription of tolerance on drawings

bore	shaft	fitting
		

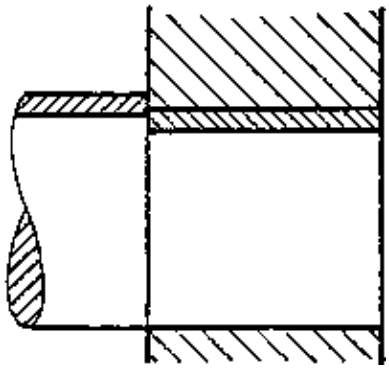
Note: A bore tolerance is defined by a big letter and must be located in the right corner above the nominal size. For shaft tolerance small letter are used.

3. Type of fit

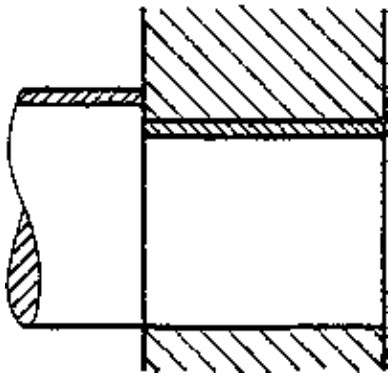
3.1 clearance fit



3.2 transit fit

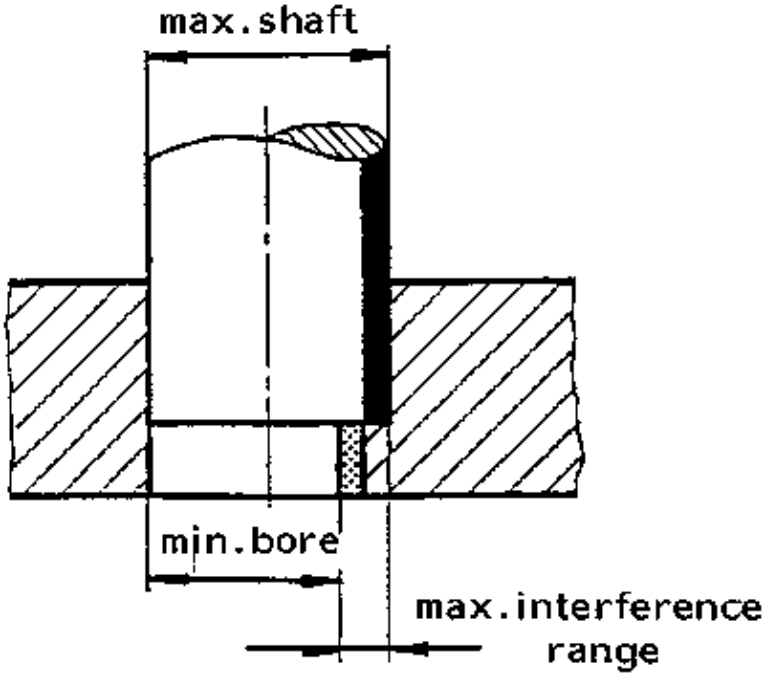


3.3 interference fit

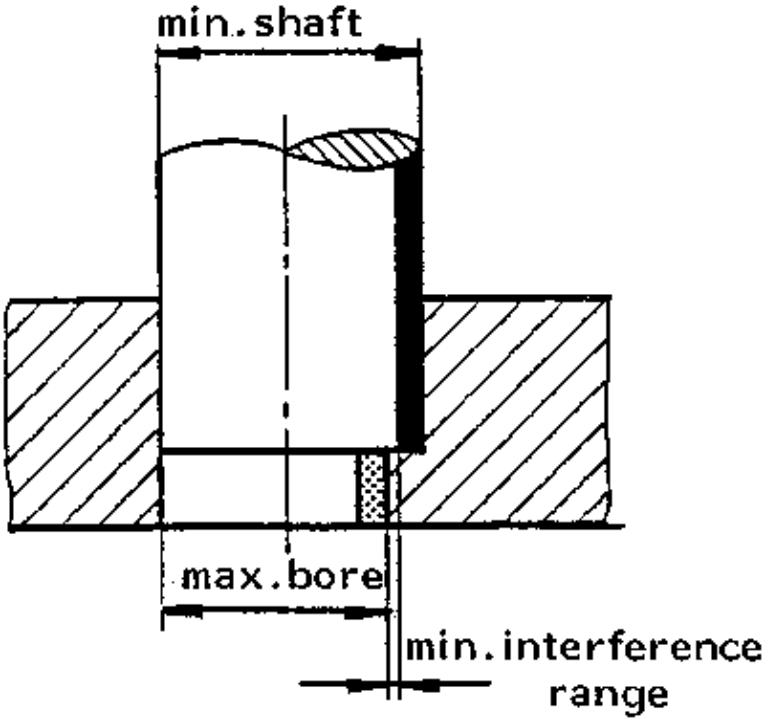


Note: There is no clear line between the various types of fit because the tolerance is varying.

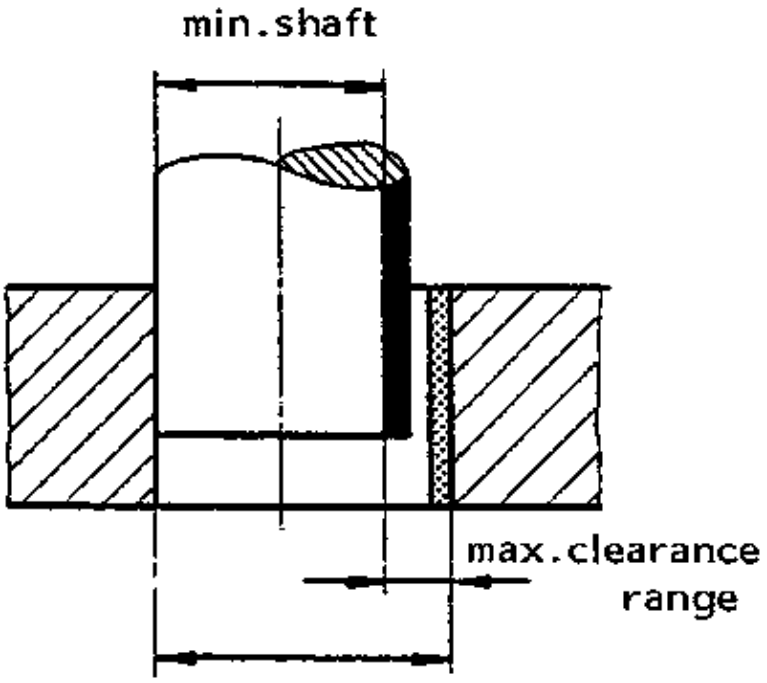
3.4 Clearance range



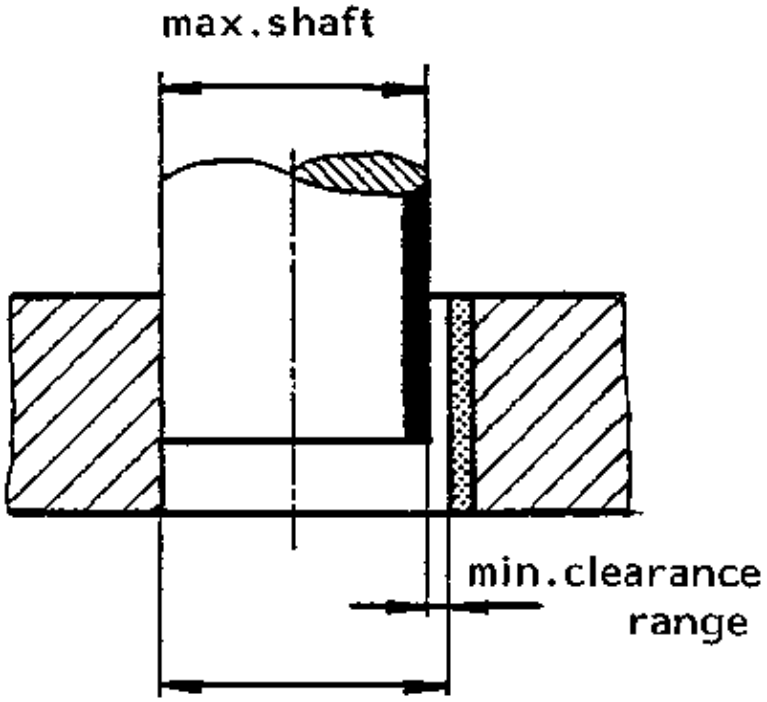
max.interference range = max.shaft – min.bore



min.interference range = min.shaft – max.bore



max.clearance range = max.bore – min.shaft

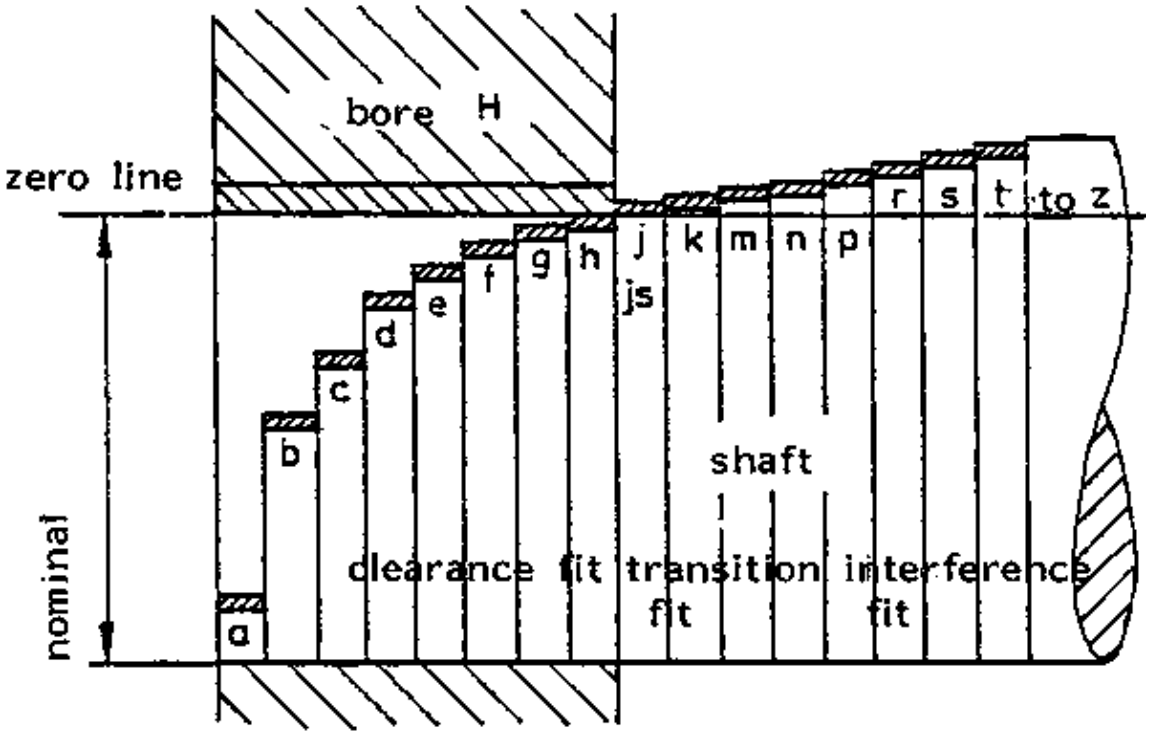


min.clearance range = min.bore – max.shaft

4. Fit systems

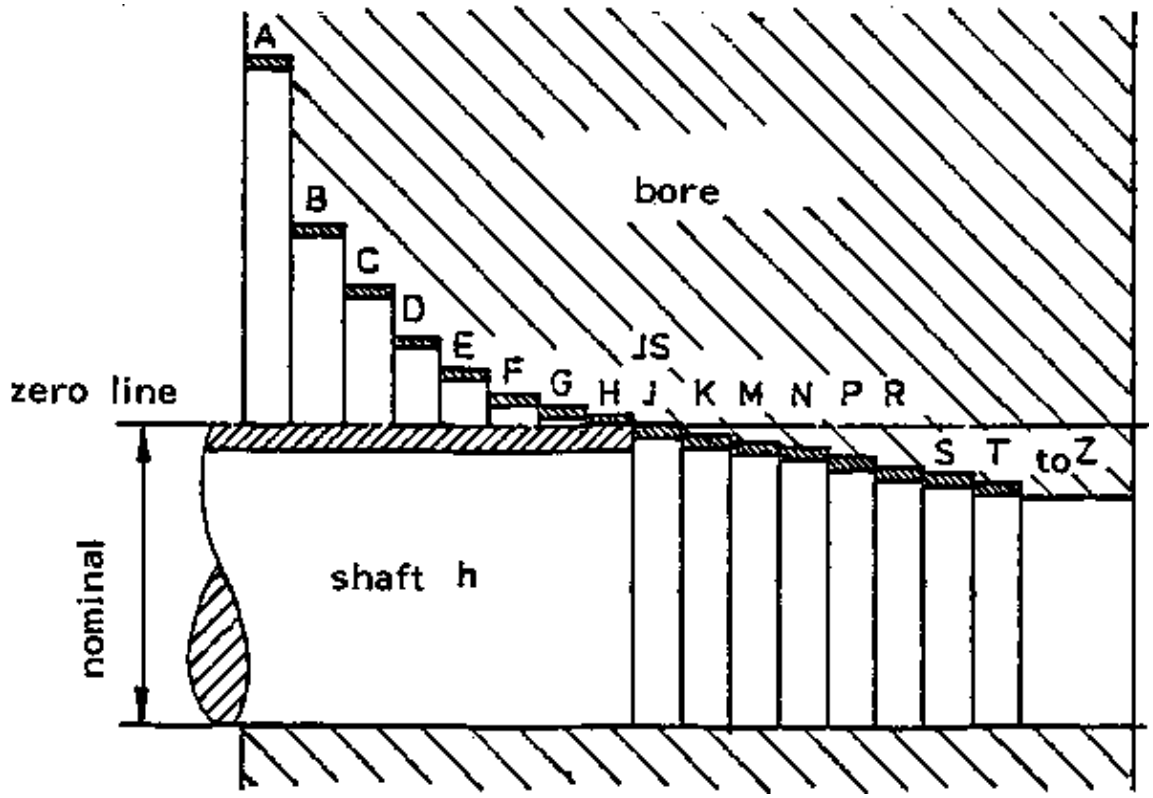
In order to lown production costs the number of possible pairs is limited by using two fit systems:

4.1 Hole basis fit system



is used in mechanical engineering, machine tools and cars because it is easier to produce different exact shaft diameters than to produce different exact hole diameters.

4.2 Shaft basis fit system



is used in textile and agriculture machinery because long shafts with constant diameters which are provided in h6, h7, h8.... by the steel mills are used.

4.3 Examples

bore basis		tolerance µm ($\frac{1}{1000}$ mm.)		max. size	min. size	max. clearance	min. clearance	max. interf.	min. interf.	type of fit
20	H7	bore	+ 21 0	20.021	20.000	0.082	0.020			clearance fit
	f7	shaft	- 20 - 41	19.980	19.959					
12	H7	bore	+ 18 0	12.018	12.000			0.034	0.006	interference fit
	r6	shaft	+ 34 + 23	12.034	12.023					
32	H6	bore	+ 16 0	32.016	32.000	0.021		0.011		transition fit
	j6	shaft	+ 11 - 5	32.011	31.995					
25	H8	bore	+ 33 0	25.033	25.000	0.150	0.065			clearance fit
	d9	shaft	- 65 -117	24.935	24.883					
shaft basis		tolerance µm ($\frac{1}{1000}$ mm.)								
35	F7	bore	+ 50 + 25	35.050	35.025	0.082	0.025			clearance fit
	h6	shaft	0 - 16	35.000	34.984					
8	P6	bore	- 12 - 21	7.988	7.979			0.021	0.008	interference fit
	h5	shaft	0 - 8	8.000	7.994					
28	E9	bore	+ 92 + 40	28.092	28.040	0.144	0.040			clearance fit
	h9	shaft	0 - 52	28.000	27.948					
40	j6	bore	+ 10 - 6	40.010	39.994	0.021		0.006		transition fit
	h5	shaft	0 - 11	40.000	39.989					

4.4 Free tolerance

is used with work without assembling such as welding, casting, rolling, etc.

Standard table of free tolerance:

dimension in mm accuracy	0.5 to 3	3 to 6	3 to 30	30 to 120	120 to 315	315 to 1000	1000 to 2000	2000 to 4000	4000 to 3000	8000 to 12000	12000 to 16000	16000 to 20000
precise	±0.05	±0.05	±0.1	±0.15	±0.2	±0.5	±0.5	±0.8	–	–	–	–
medium	±0.1	±0.1	±0.2	±0.3	±0.5	±0.8	±1.2	±2	±3	±4	±5	±6
rough	–	±0.2	±0.5	±0.8	±1.2	±2	±3	±4	±5	±8	±7	±8
very rough	–	±0.5	±1	±1.5	±2	±3	±4	±6	±8	±10	±12	±12

Example: A shaft with 60 and medium accuracy will have a tolerance of ± 0,3.

5. Application

Type of fit	Fitting character	Example	Bore basis	Hole basis
interference	When high pressure is needed	shaft–hub connection by shrink fit	H7 – z8 H7 – x7	Z8 – h6 X7 – h6
	When medium pressure is needed	bush in housing	H7 – s6 H7 – r6	S6 – h6 R7 – h6
transition	To assemble must be hit hard with a hammer.	hub which is fixed on the shaft against axial movement by fit	H7 – m6	M7 – h6
	To assemble must be hit with a hammer	normal shaft–hub connection	H7 – k6	K7 – h6
	To assemble must be hit soft with a hammer	hub must slide oh the shaft during work	H7 – j6	J7 – h6
clearance	must have some clearance	bush bearing with shaft	H7 – f7	F7 – h6
	big clearance	screw in a hole	H11 – c11 H11 – a11	C11 – h11 A11 – h11

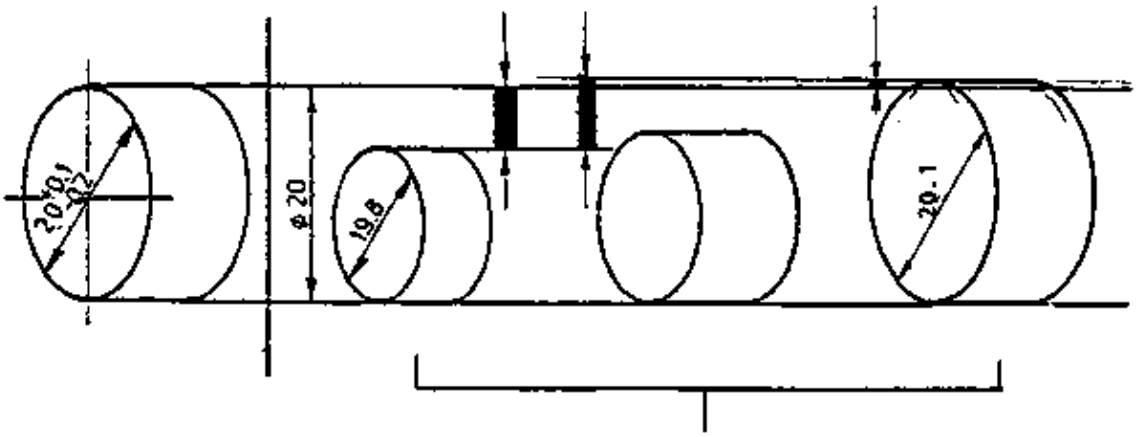
Note: For more details have a look in the table book

Task sheet

1. A fit system is used: to minimise tolerance
to make spare parts interchargeable
to make the workpieces more precisely

2.1 Complete the drawing with the following terms:

nominal, actual, min. and max. size, allowance above and below nominal size tolerance, zero line



2.2

a) The position of tolerance range of a shaft is specified with big/small letters
b) The letter a Indicates that the tolerance range is under/above the zero line
c) Which tolerance ranges are touching the zero line?

2.3

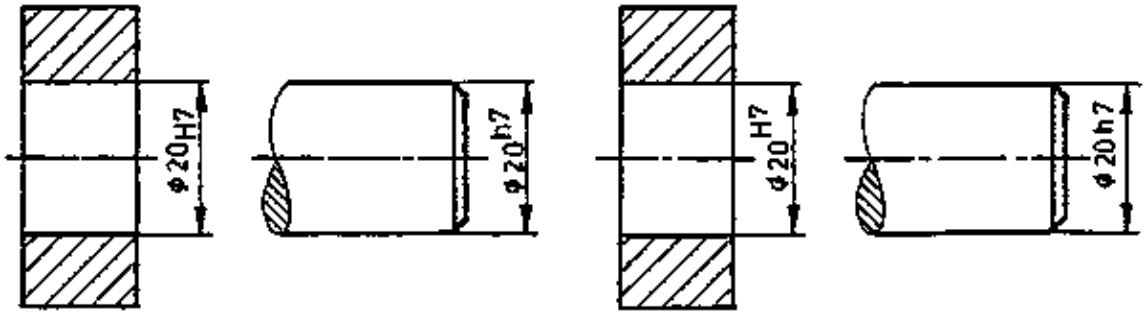
a) The level of accuracy is indicated by _____ from _____ to _____ and it depends on _____ of workpiece _____

b) The accuracy level used for machine parts is normally _____ to _____

c) A high accuracy level is indicated by _____, a low accuracy level is indicated by _____

2.4

a) Which tolerance inscription is correct?



b) Which tolerance inscription is correct? 20^{H7}_{j6} 20^{j6}_{H7}

3.1

a)There are 3 types of fit, they are: _____
b)When the shaft is always bigger than the bore, the type of fit is on _____

3.2 The min. clearance range is given by min. bore – min./max. bore

4.

a) A fit system in which the shaft is adjusted to the bore is called it is used with _____

b) For a shaft basis fit system the letter f/h/n will be used.

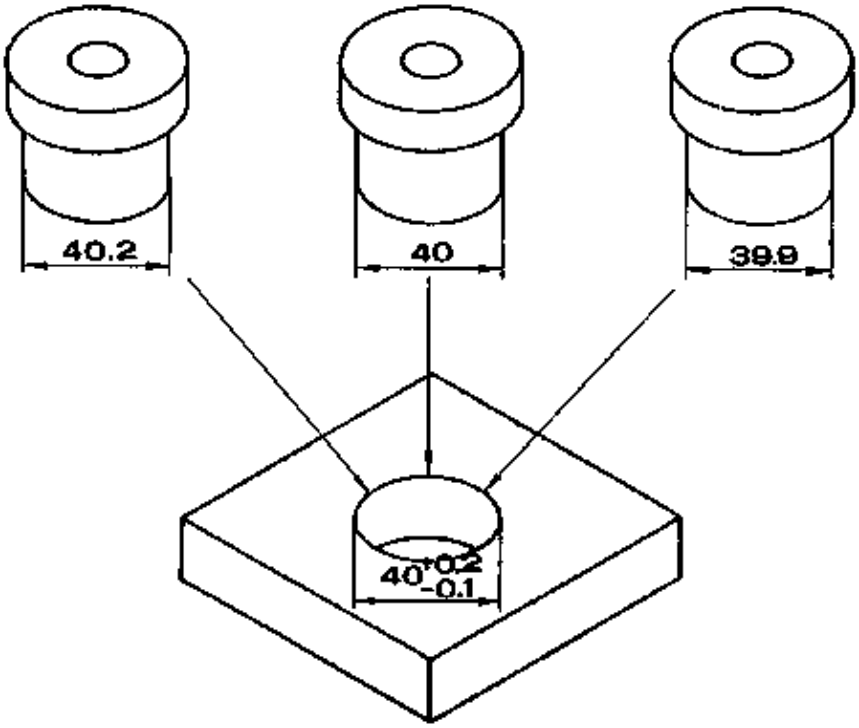
c) For a workpiece 20^{H6}_{g5} – the max. bore is _____
– the min. bore is _____
– the tolerance of the shaft is _____

size (mm)	tolerance (mm)
20^{H6}	0 +13
20_{g5}	–7 –16

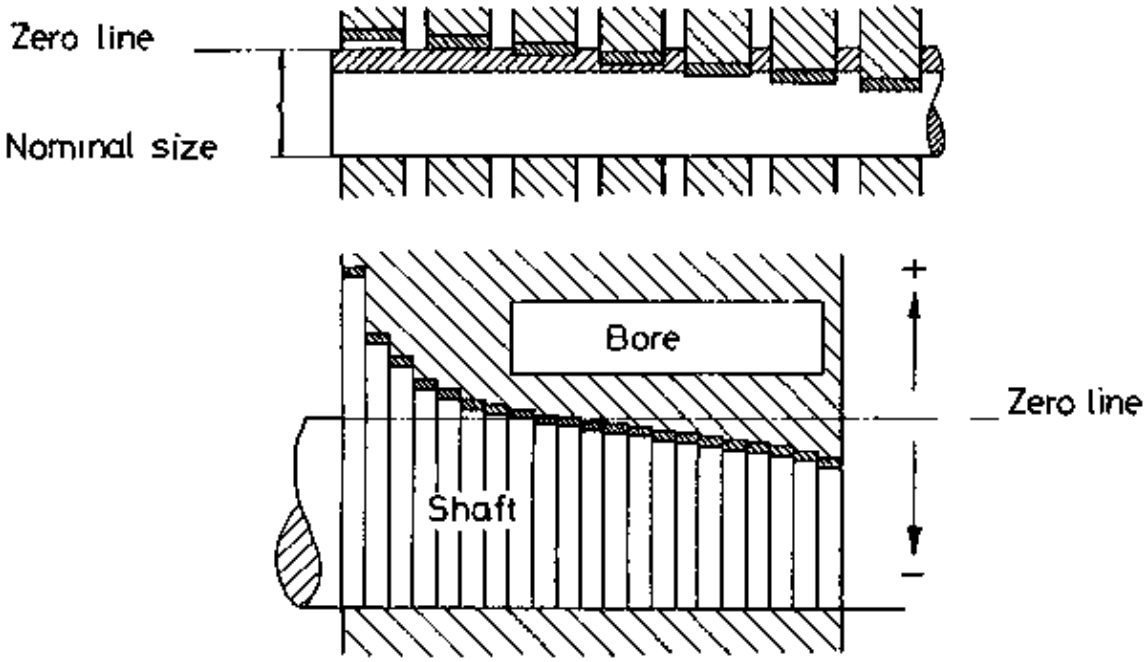
4.1 20^{H6}_{g5} is a clearance–/transition–/interference– fit

4.2 Free tolerance is used for:
high precision work
textile machines
forming work

TOLERANCE IN FIT SYSTEM



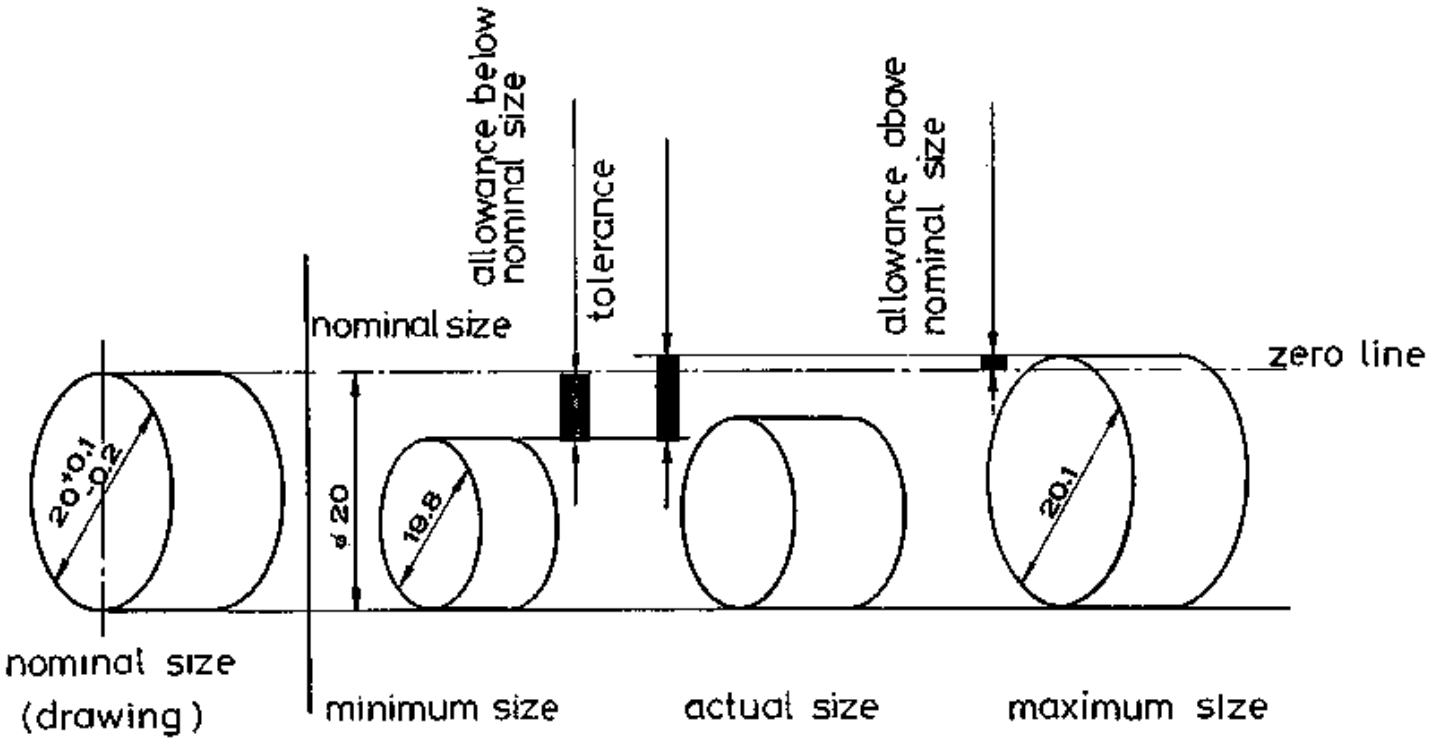
SPECIFICATION OF TOLERANCE OF SHAFT



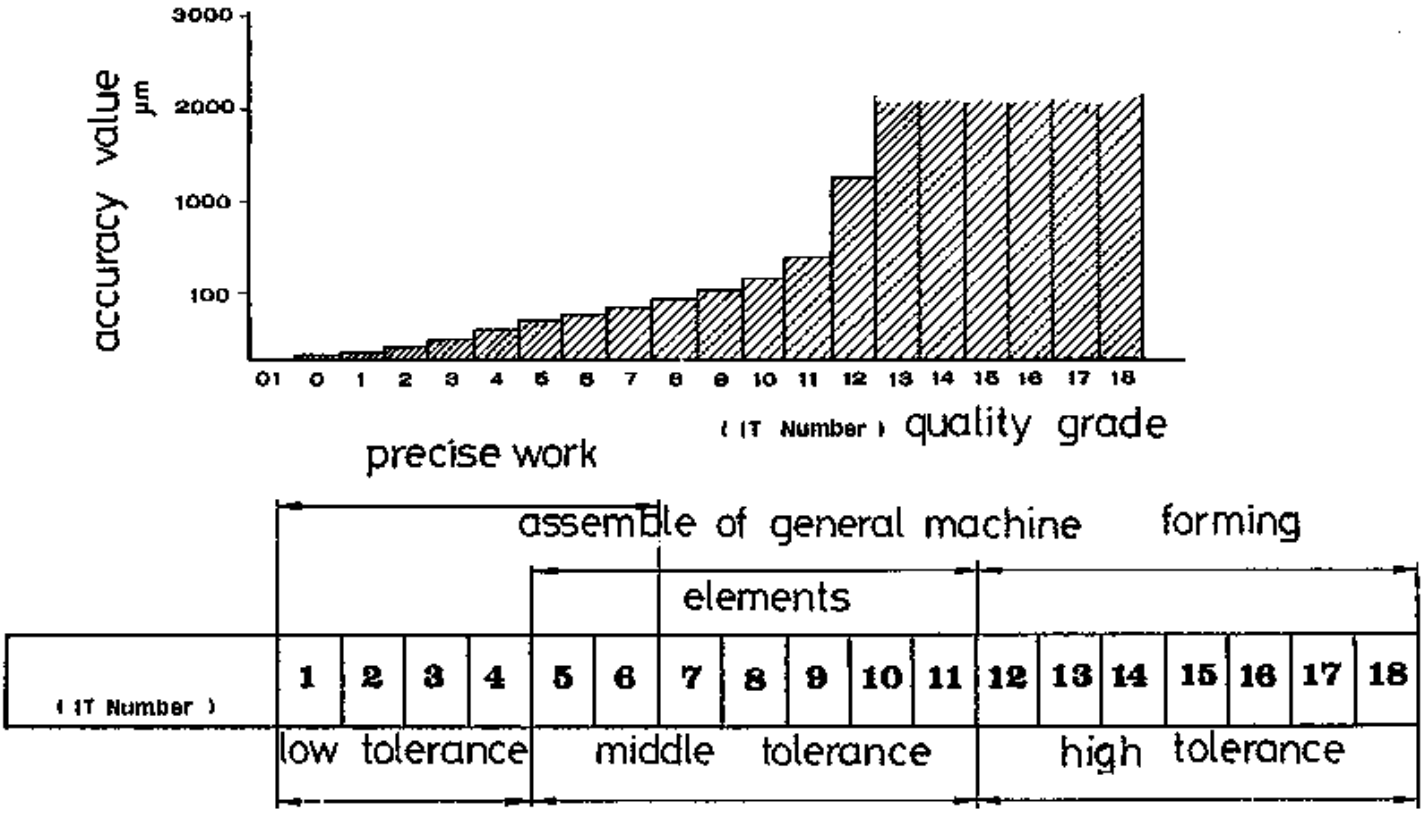
FREE TOLERANCE

	dimension in mm.											
accuracy	0.5	3	6	30	120	315	1000	2000	4000	8000	12000	16000
	3	6	30	120	315	1000	2000	4000	8000	12000	16000	20000
precise	± 0.05	± 0.05	± 0.1	± 0.15	± 0.2	± 0.3	± 0.5	± 0.8	–	–	–	–
medium	± 0.1	± 0.1	± 0.2	± 0.3	± 0.5	± 0.8	± 1.2	± 2	± 3	± 4	± 5	± 6
rough	–	± 0.2	± 0.5	± 0.8	± 1.2	± 2	± 3	± 4	± 5	± 6	± 7	± 8
very rough	–	± 0.5	± 1	± 1.5	± 2	± 3	± 4	± 6	± 8	± 10	± 12	± 12

TOLERANCE SYSTEM



ACCURACY GRADE OF TOLERANCE



	IT																			
size	01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1..3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	100	140	250	400	600	–	–
3..6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750	–	–
6..10	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900	1500	–
10..18	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	150	270	430	700	1100	1800	2700

bore basis		tolerance µm ($\frac{1}{1000}$ mm.)		max. size	min. size	max. clearance	min. clearance	max. interf.	min. interf.	type of fit
20	H7	bore	+ 21 0	20.021	20.000	0.082	0.020			clearance fit
	f7	shaft	- 20 - 41	19.980	19.959					
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	r6	shaft	+ 34 + 23	12.034	12.023					
32	H6	bore	+ 16 0	32.016	32.000	0.021		0.011		transition fit
	j6	shaft	+ 11 - 5	32.011	31.995					
25	H8	bore	+ 33 0	25.033	25.000	0.150	0.065			clearance fit
	d9	shaft	- 65 -117	24.935	24.883					
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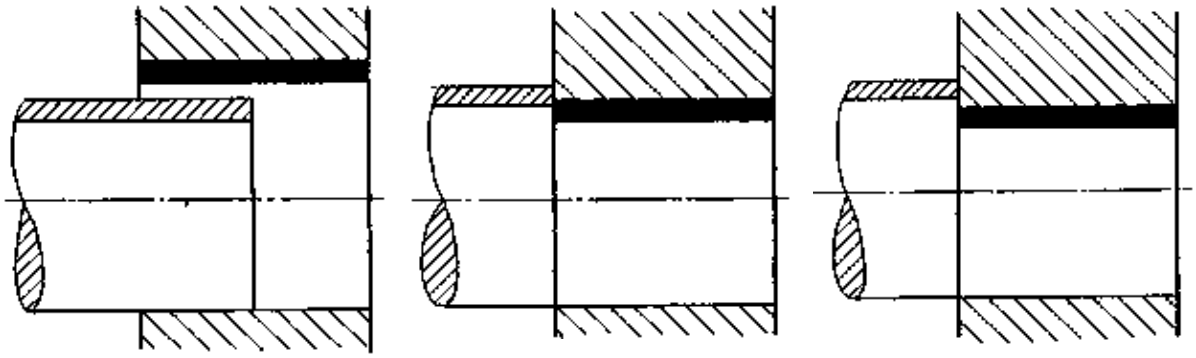
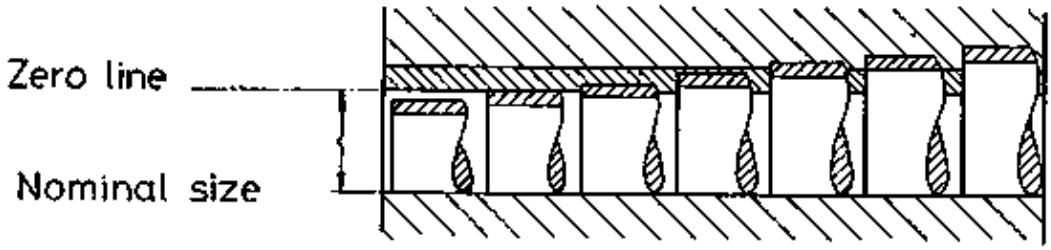
8	P6	bore	- 12 - 21	7.988	7.979			0.021	0.006	interference fit
	h5	shaft	0 - 6	8.000	7.994					
28	E9	bore	+ 92 + 40	28.092	28.040	0.144	0.040			clearance fit
	h9	shaft	0 - 52	28.000	27.948					
40	j6	bore	+ 10 - 6	40.010	39.994	0.021		0.006		transition fit
	h5	shaft	0 - 11	40.000	39.989					

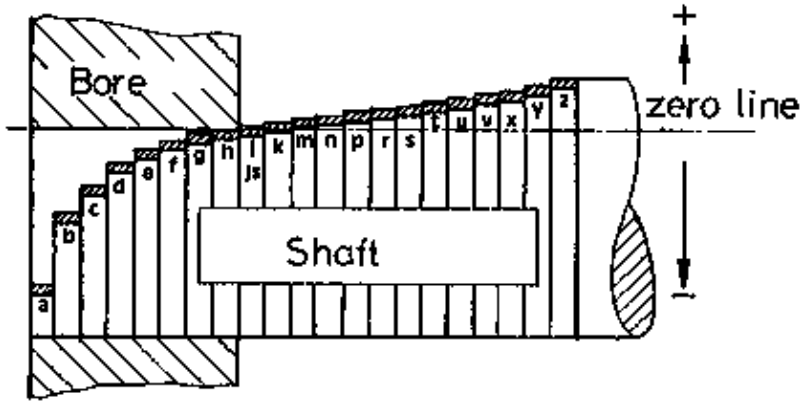
TYPE OF FIT



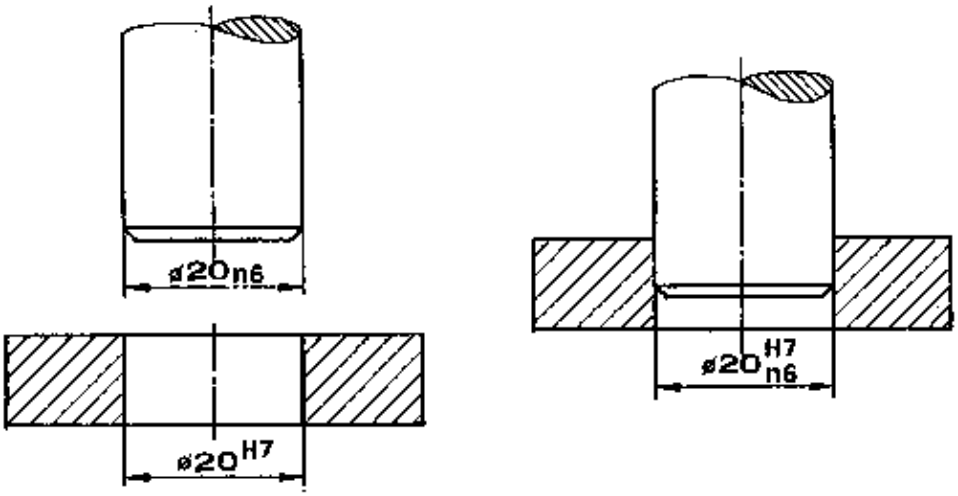
Clearance fit Transit fit Interference fit

SPECIFICATION OF TOLERANCE RANGE OF BORE



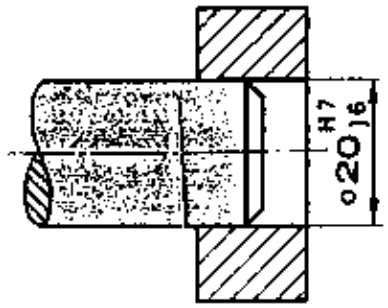
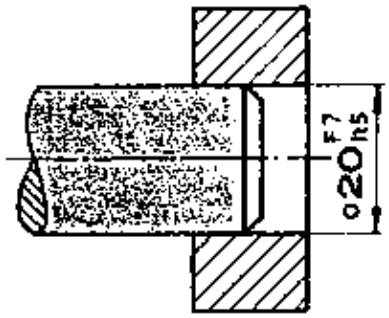


INSCRIPTION OF TOLERANCE AN DRAWING

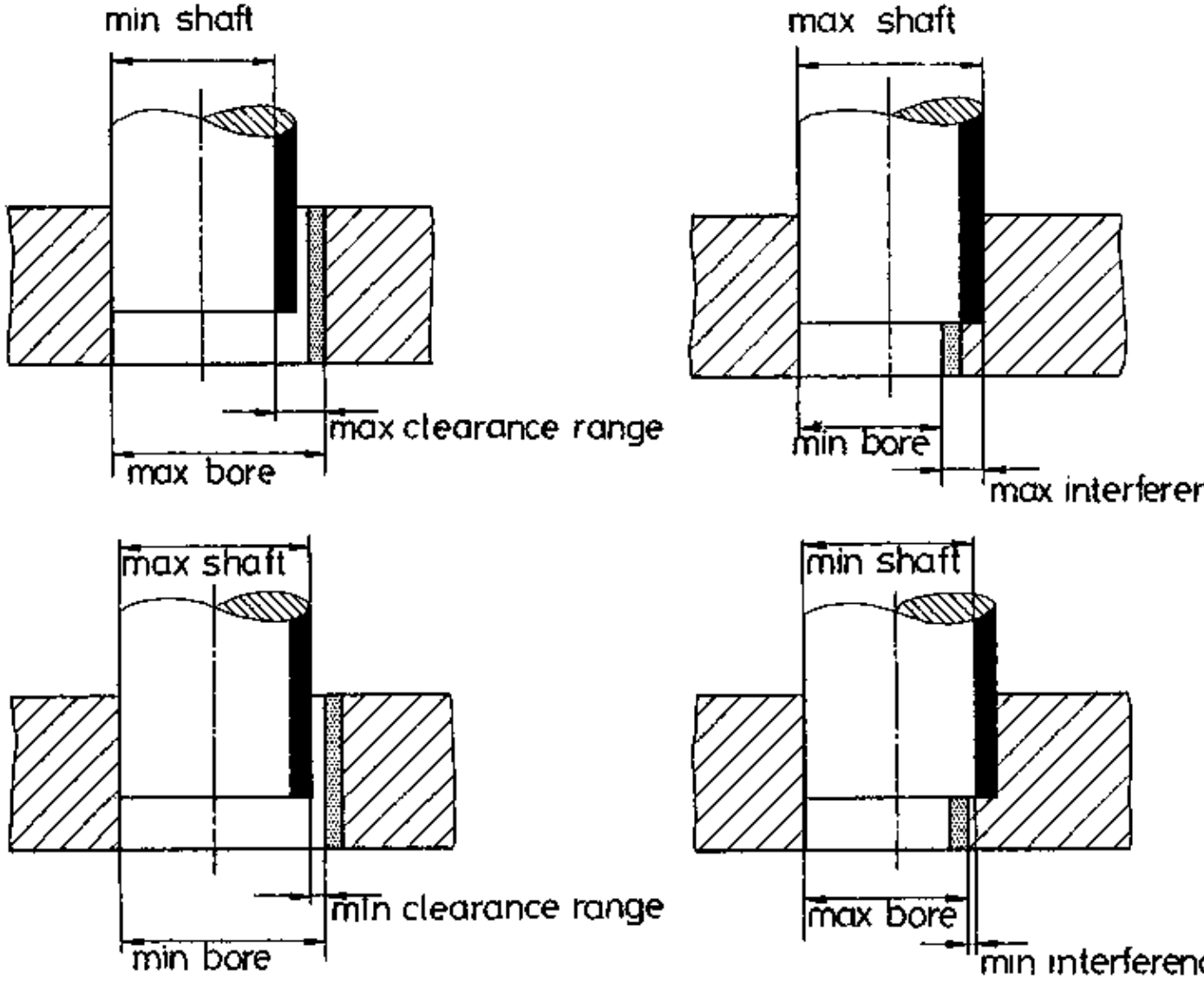


ADVANTAGE AND DISADVANTAGE OF FIT IN BORE BASIS SYSTEM AND SHAFT BASIS SYSTEM

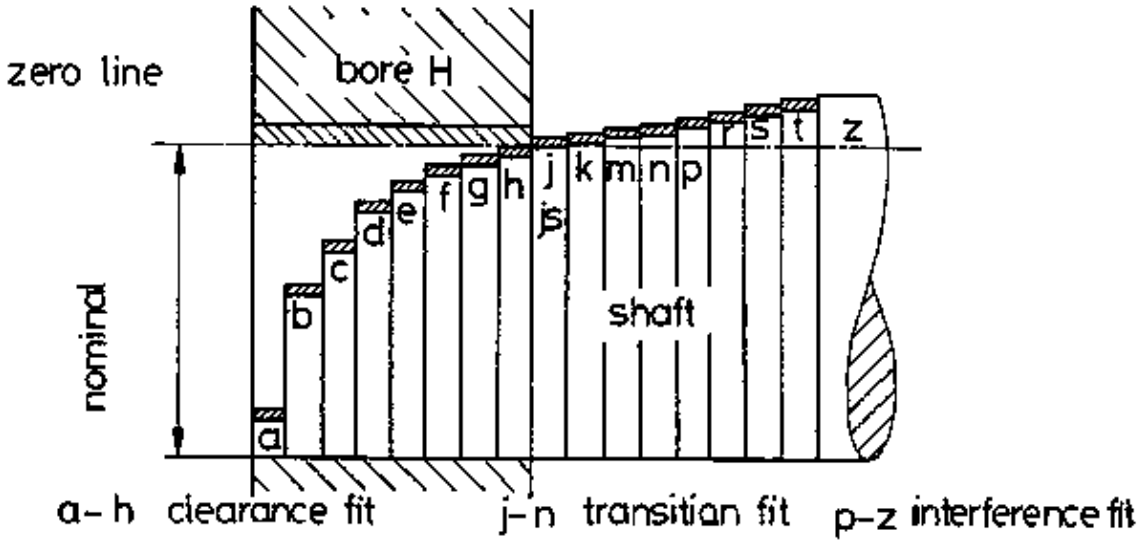
	Advantage	Disadvantage

 bore basis system	– the shaft can be easily adjusted to the housing – cheap tools will be used	– the shaft size varies
 shaft basis system	– the shaft size will be constant	– the housing can hardly be adjusted to the shaft – expensive tools will be used

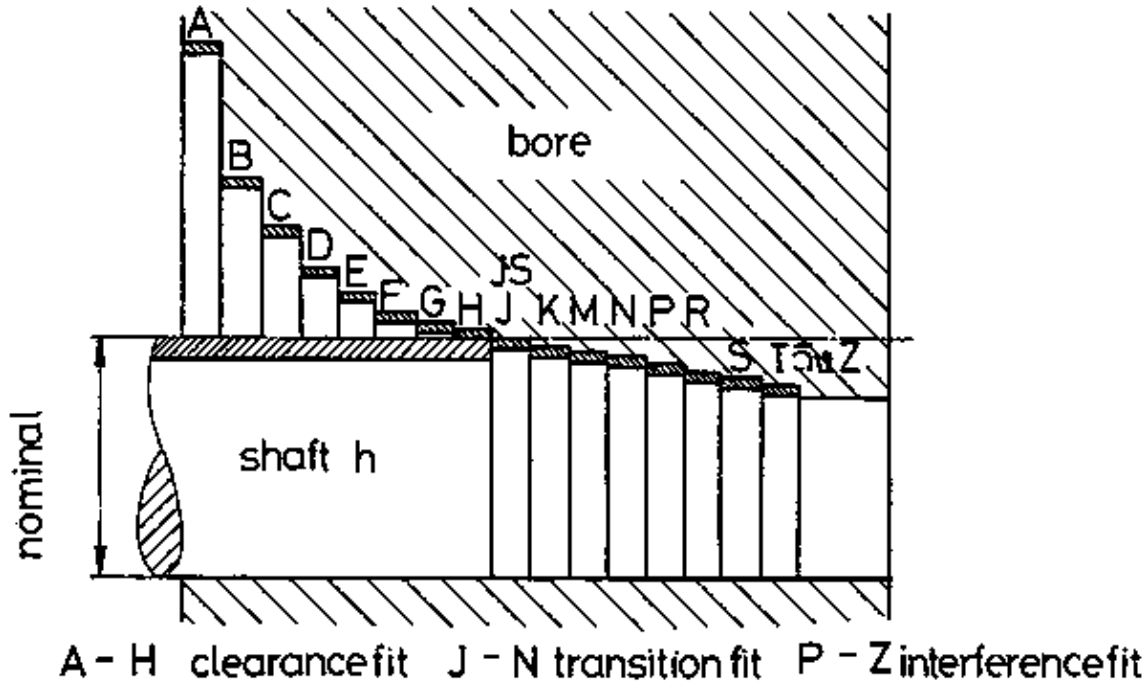
CLEARANCE RANGE INTERFERENCE RANGE



Bore basis fit system



Shaft basis fit system



2. Bolt and screw connections

Objectives

The student should be able to

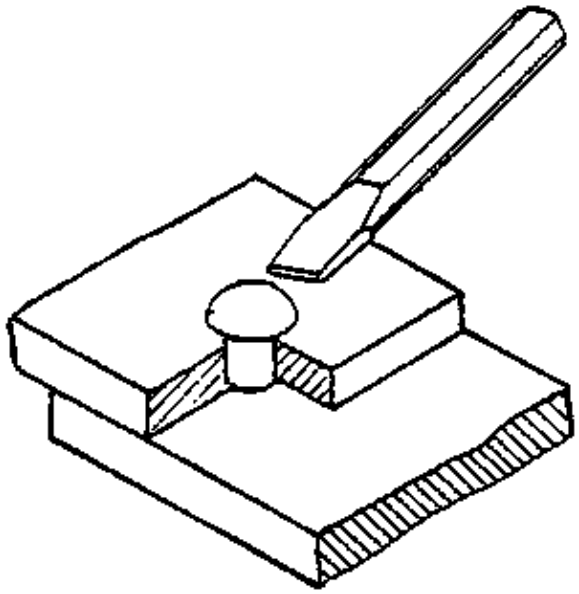
1. explain the difference between permanent and detachable joint
2. understand the effect of the internal forces in a cross loaded connection
3. understand the effect of the internal forces in an axial loaded connection
4. differentiate between screw, bolt and stud
5. describe the use of a fitting bolt
6. name 7 types of screws and describe a typical application
7. name 8 types of nuts and describe a typical application
8. attach 5 screws (bolts) to this application
9. explain the meaning of the screw code

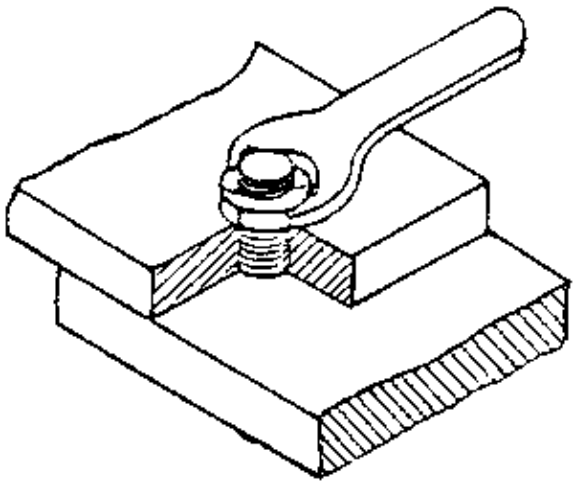
10. explain why the washer is placed under the nut rather than under the bolt head
11. differentiate between form fitting and friction lock
12. choose the right tool for 6 different screws (nuts)
13. explain the effect of rust or oil in a bolt thread to the clamping force
14. explain the advantage of a torque wrench
15. choose the right sequence of tightening nuts (screws)
16. find out the reason for typical bolt defects
17. describe 2 methods to extract broken screws
18. describe 2 methods to repair internal threads
19. explain why bolt connections of new machines must be retightened after some service time

Information sheet

1. Purpose and basic function

1.1 Permanent joint–detachable joint





1.1.1 Permanent joint

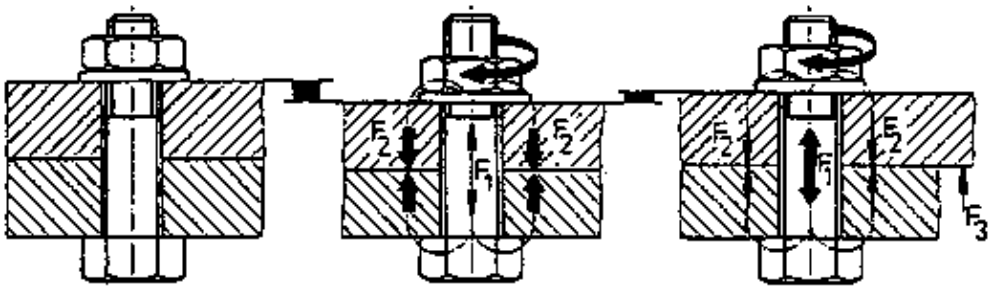
The joint is destroyed when loosened.

1.1.2 Detachable joint

The joint is not destroyed when loosened.

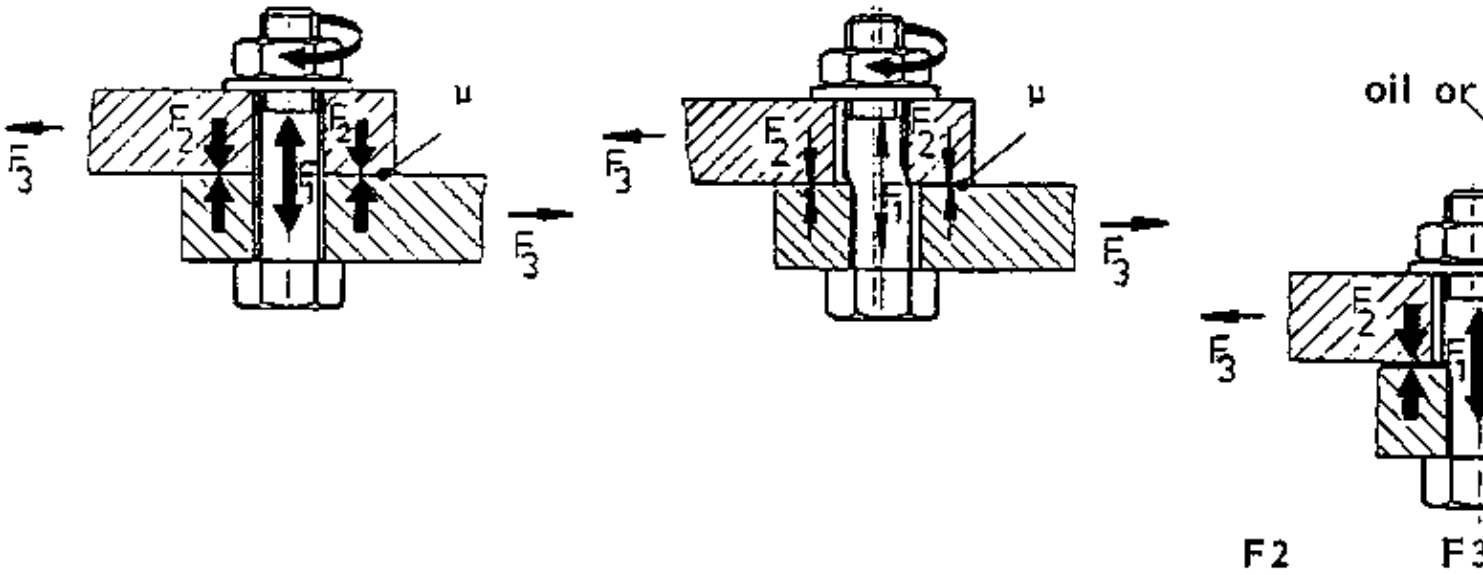
1.2 Internal forces in a bolt joint

1.2.1 Clamping force and load in axial direction



no preload	preload	preload + outside force F3
- load of bolt F1 = 0	F2 = F1	F2 = F1 - F3
- clamping force F2 = 0		F1 F3

1.2.2 Preload force and cross load



$F_2 \cdot \mu > F_3$

(μ = coefficient of friction)

$F_2 \cdot \mu < F_3$

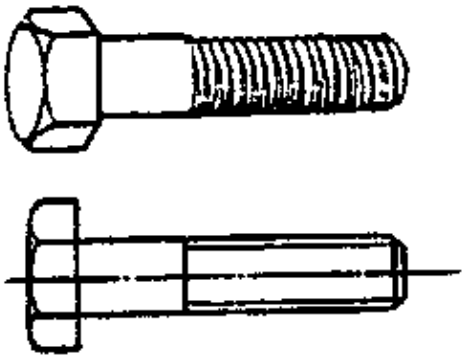
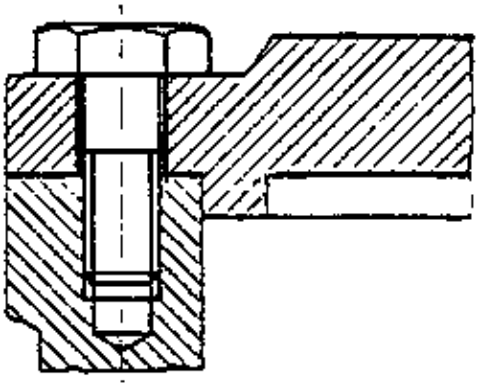
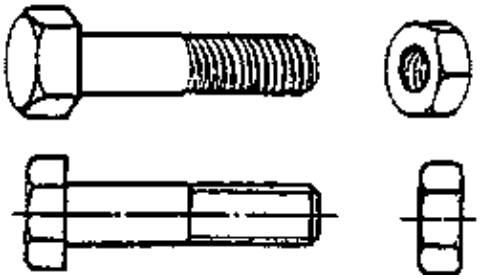
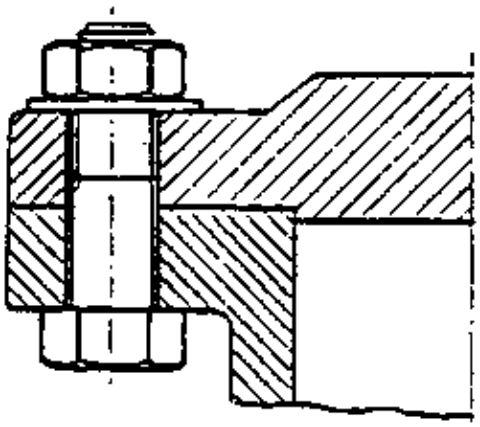
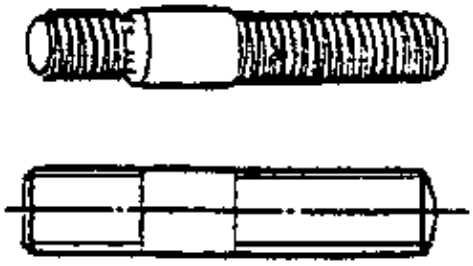
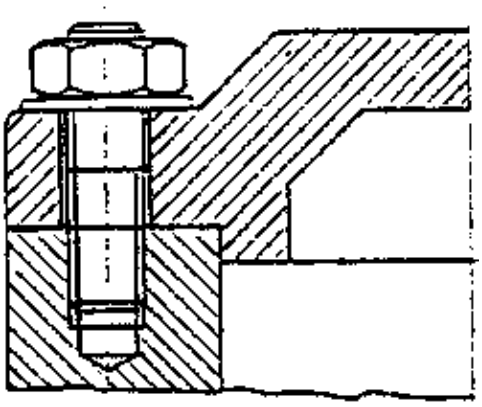
Clamping force to low

– sufficient clamping forc
surface

2. Types and main design

2.1 Screw, bolt and stud

Type	Application	
		– is used in threaded holes

 Figure 1. Screw		
 Figure 2. Bolt = Screw = Nut		– is used with through holes
 Figure 3. Stud		– is used when the joint is separated frequently.

2.2 Fitting Bolt

Figure
Bolt

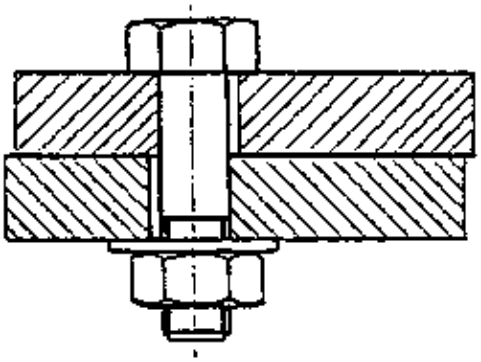


Figure
Workpiece are not centered

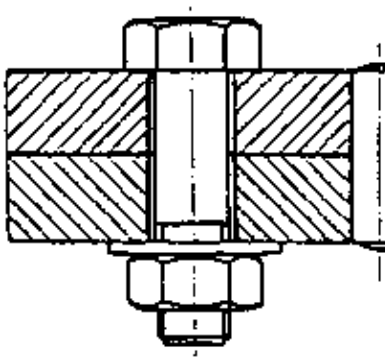


Figure
Workpiece is centered

Figure
Fitting bolt

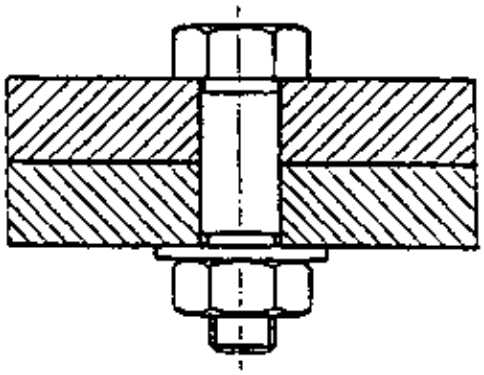


Figure
Workpiece is centered

Note: The hole must be reamed!

2.3 Types of screws

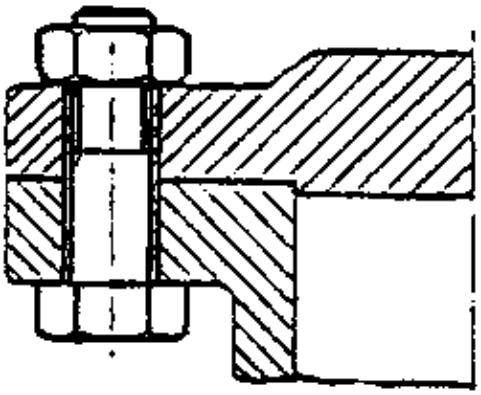
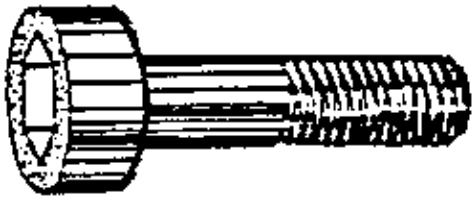
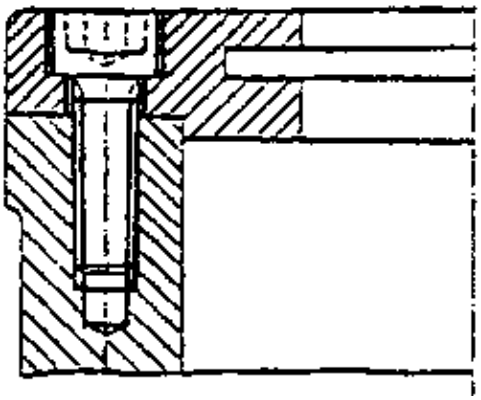
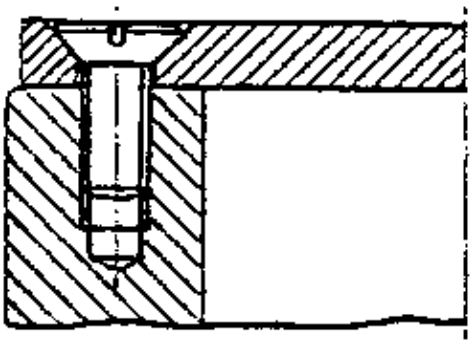
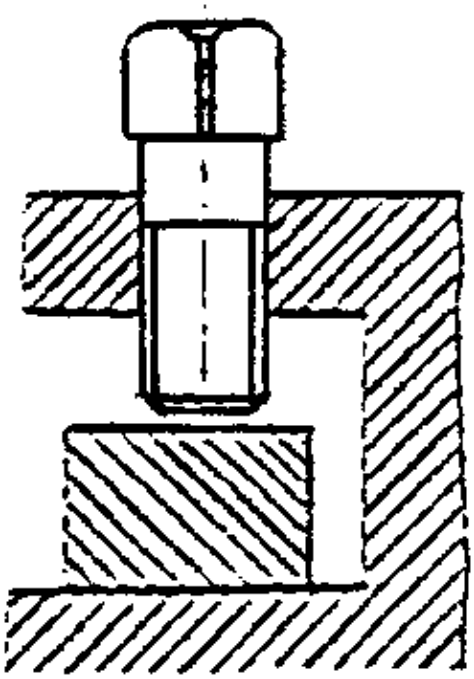
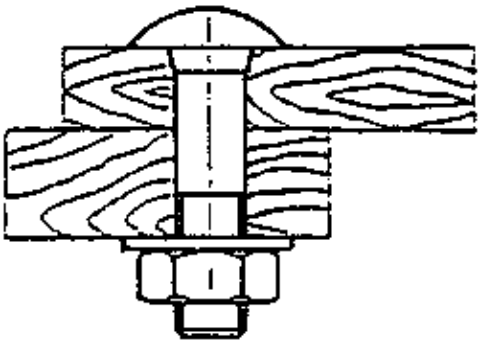
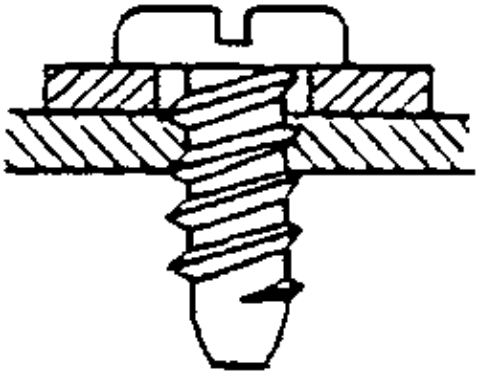
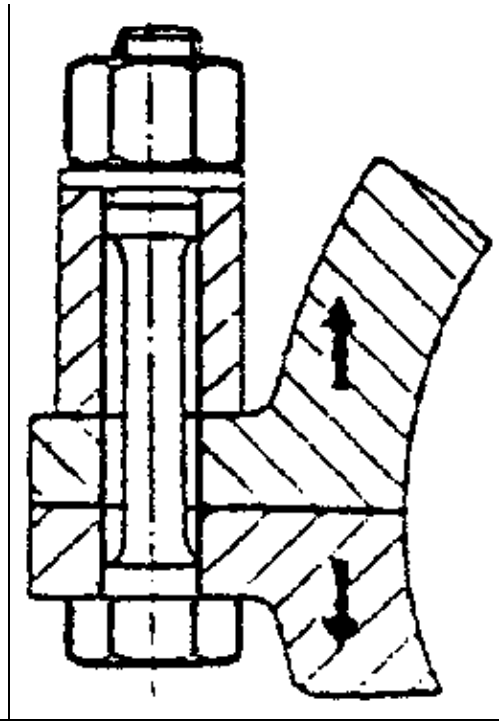
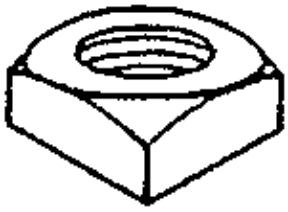
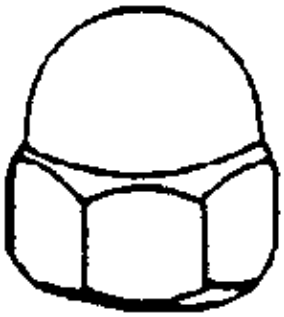
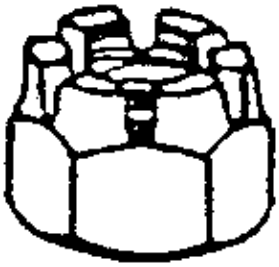
Type	Application	
 Figure 1. Hexagon bolt		– is used with a through hole
 Figure 2. Socket head screw		– save space – the head can be countersunk to get a flat surface
 Figure 3. Countersunk head screw		– is centering the workpiece – flat surface

 Figure 4. Square head shoulder screw		– is used in clamping tools
 Figure 5. Square neck carriage bolt		– is used with wood
 Figure 6. Sheet metal screw		– is clamping sheet metal – self tapping
 Figure 7. Anti fatigue bolt		– is used in screw joints subjected to continuous alternating load

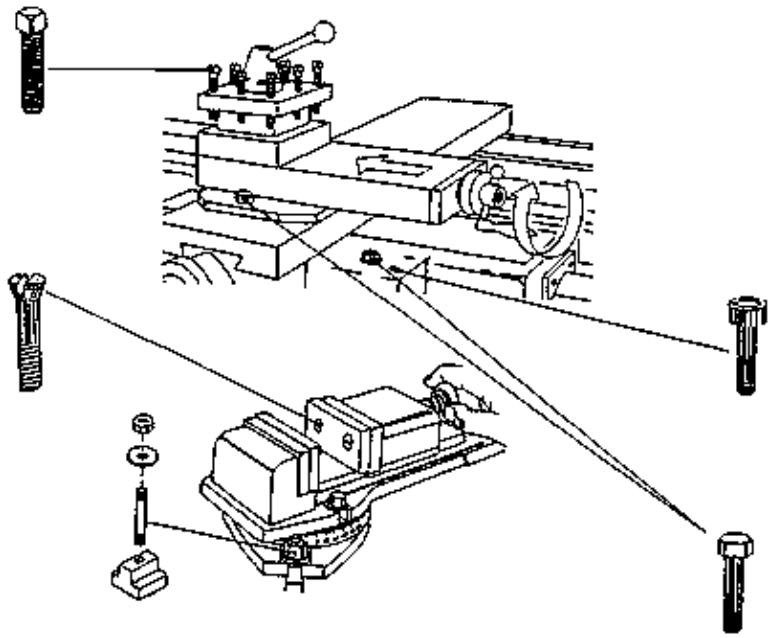


2.4 Types of nuts

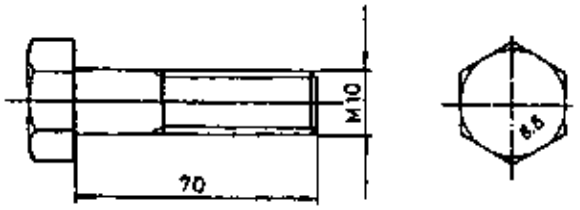
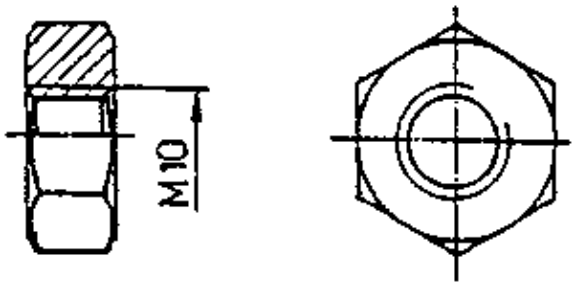
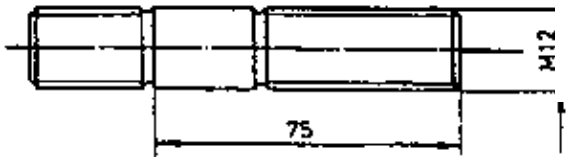
Types	Application
angular nuts	– normally used in machine mechanic
 Hexagon nut	
 square nut	– used for low load
round nuts	– used when only limited space is available.
 two hole nut  slotted nut	
tightening by hand–nuts	– used when often tightened and retightened – for low load only

<table>
<tr><td> 
wing nut</td><td> 
knurled nut</td><td></td></tr>
<tr><td colspan="2"> 
cap nut</td><td>– protects the thread against damage</td></tr>
<tr><td colspan="2">locking nut</td><td>– protection against loosening</td></tr>
<tr><td colspan="2"> 
castel nut</td><td></td></tr>
</table>

2.5 Application



2.6 Screw code

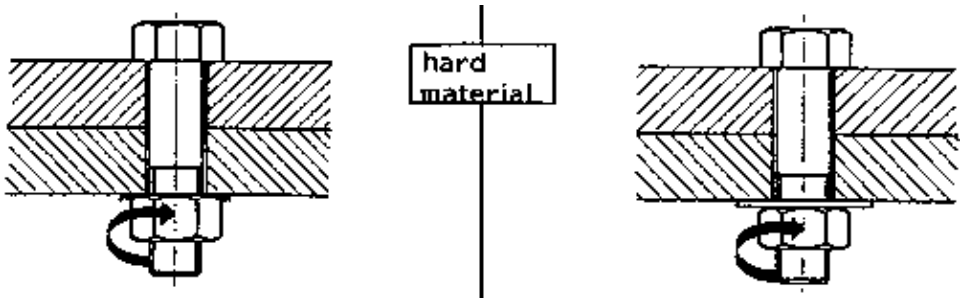
	Hexagon screw	M 10 x 70 length 70 mm. outer diameter 10 mm. metric thread
	Property class	8.8 yield point ratio 8×8×10 N/mm^2 tensile strength 8×100 N/mm^2
	Hexagon nut:	M 10 Major diameter 10 mm.
	Stud : M 12 x 75 length 75 mm. major diameter 12 mm.	

Note:

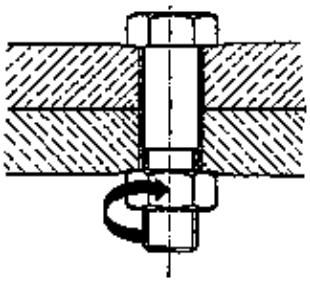
The code M10 × 1.25 × 70 indicates a fine thread, the pitch is 1.25 mm.
The pitch of M10 × 70 can be found in the table book (p = 1.5 mm.)

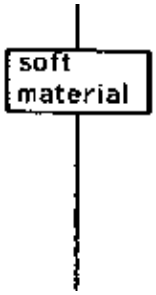
2.7 Washer

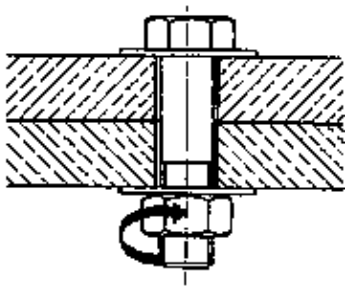
When tightening or loosening a bolt joint, always turn the nut.



The surface is damaged The washer protects against damage.







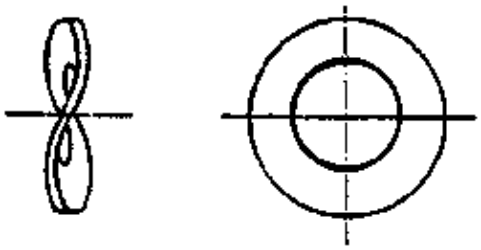
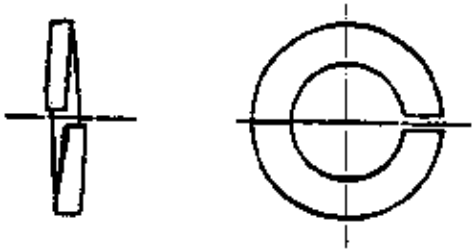
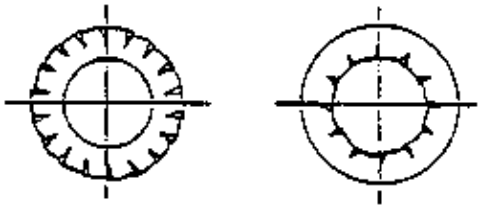
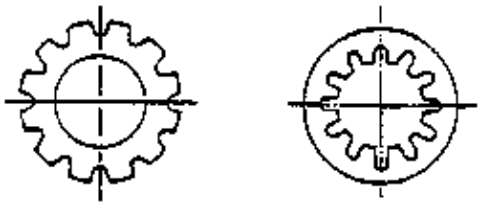
The surface is deformated

Washer at both sides prevent deformation

2.8 Locks

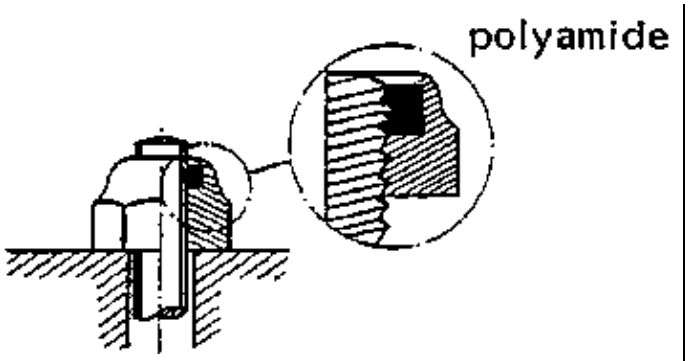
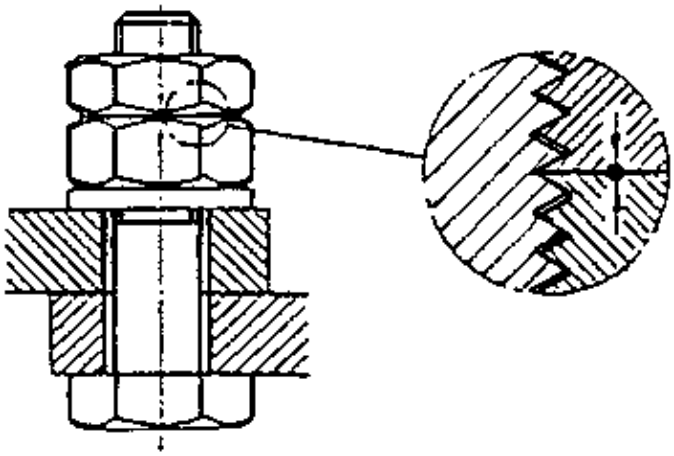
2.8.1 Friction locks

a) Washers

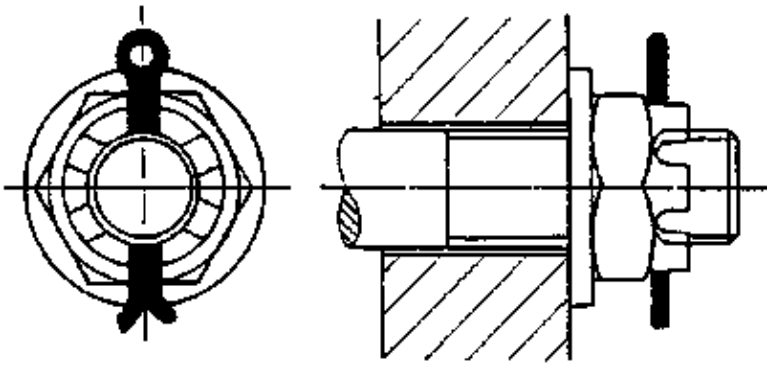
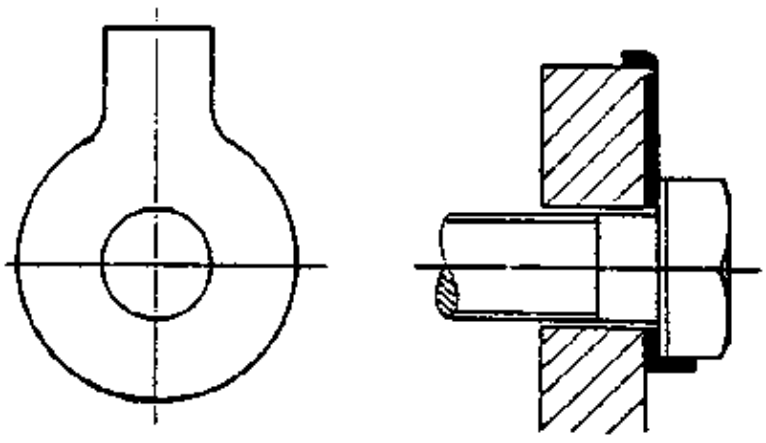
Spring washers		joint can be loosened several times without damaging the surface of the workpiece
		
Fan discs		when loosening the joint, the surface of the workpiece is damaged.
		

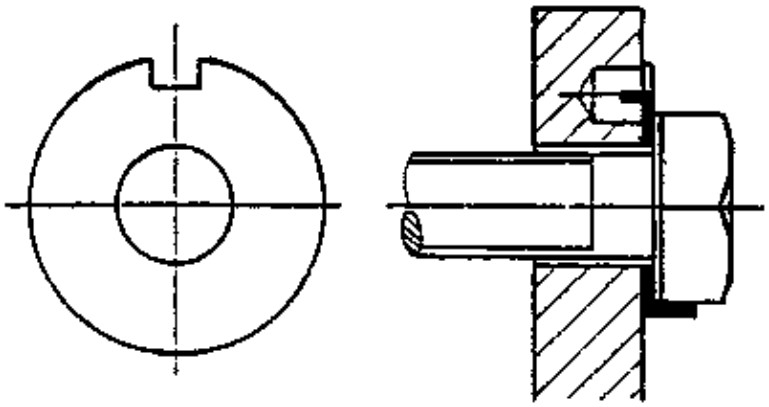
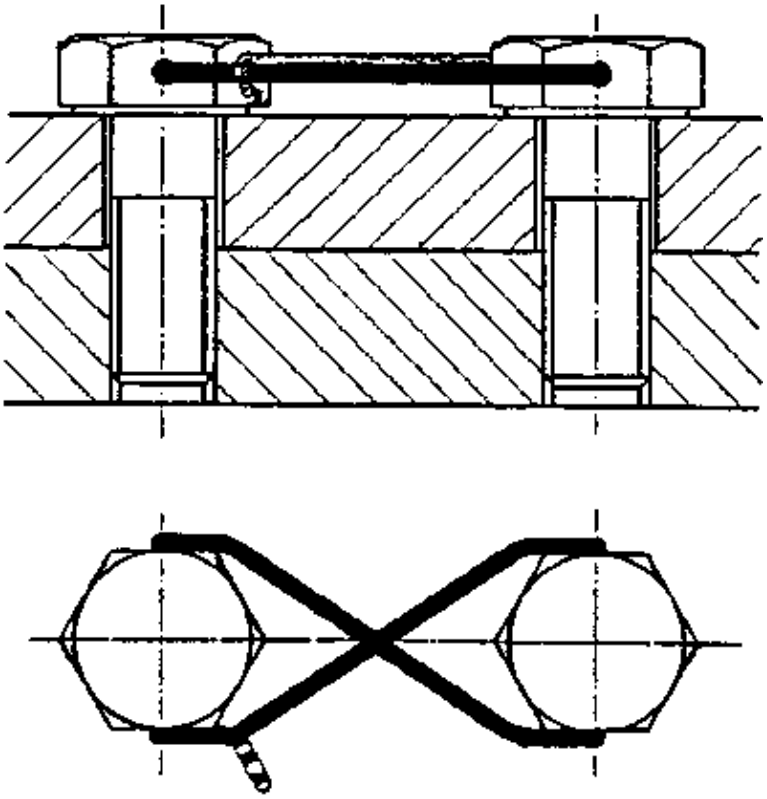
b) Nuts

Self locking nut		Friction between polyamide and thread prevents loosening

		
Counter nut		Friction between the nuts prevents loosening

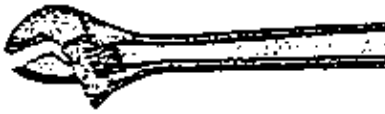
2.8.2 Fitting locks

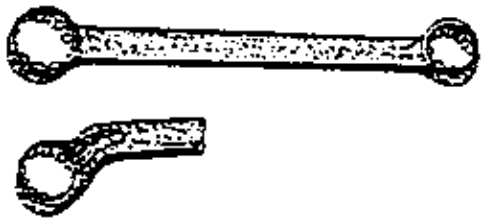
Split pin		– is used when the lock must be very safe, e.g. car steering
Tab washer		– is used when the screw head is near the edge.

Locking plate		– is used when the screw head is far away from the edge.
Safety wire		– two screw heads are necessary. This is a very safe lock.

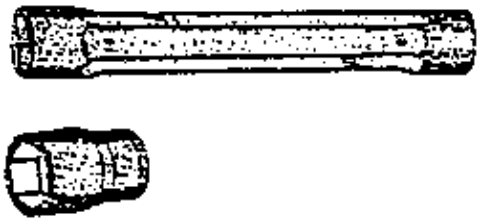
3. Assembling, repair and maintenance

3.1 Tools

Bolt/screws/nuts	Tools	
 1. Hexagon head bolt	 open end wrench	 adjustable wrench



ring spanner



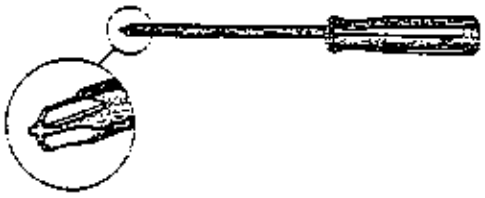
box spanner

Diameter of thread	M4	M5	M6	M8	M10	M12	Ml 4	M16	M20
Wrench size	7	8	10	13	17	19	22	24	30

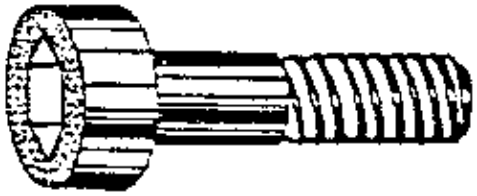
2. Round head with slot

Screw driver

3. Phillips head screw



Phillips screw driver

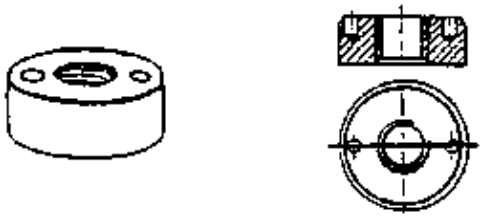


4. Socket head screw

Allen key

5. Slotted nut

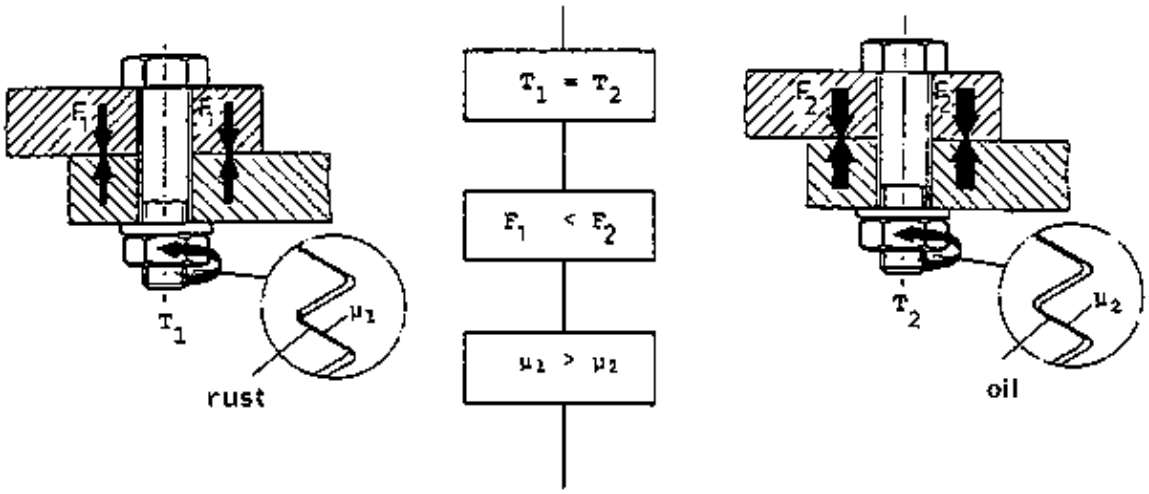
Hook wrench



6. Two hole nut

two hole key

3.2 Effect of rust and oil in the thread



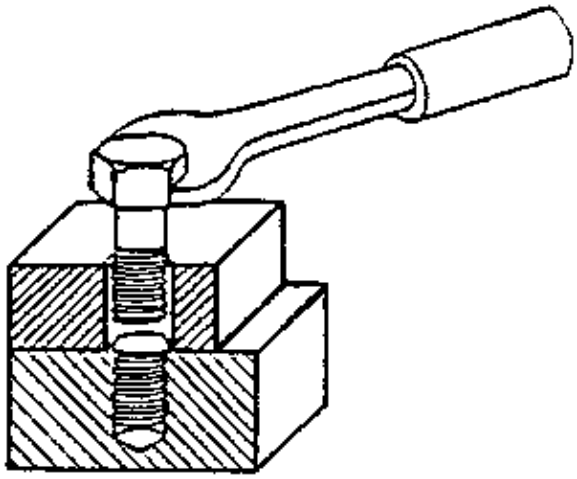
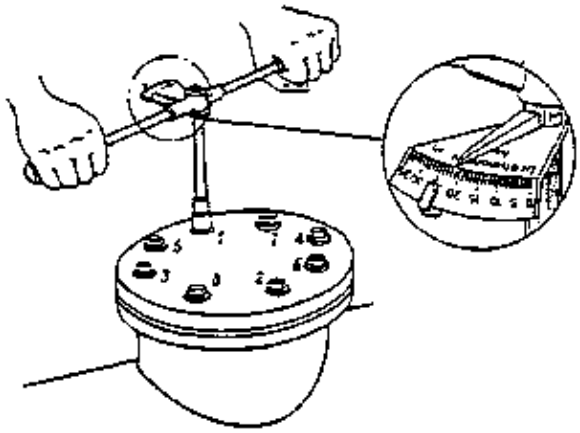
T = torque

F1, F2 = clamping force

= coefficient of friction

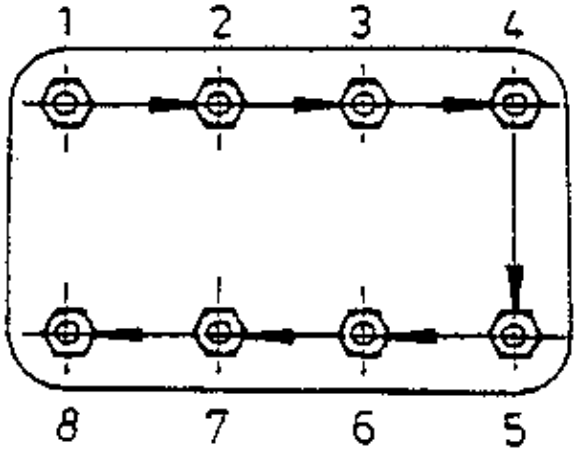
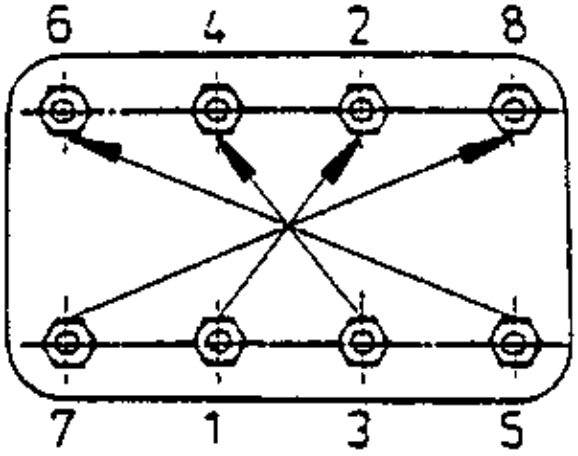
Summarize:

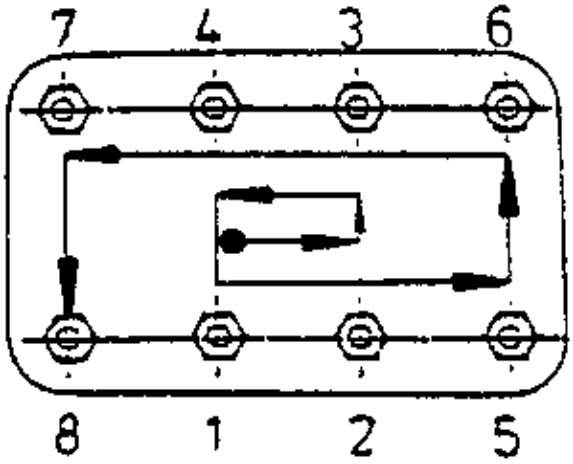
3.3 Torque wrench

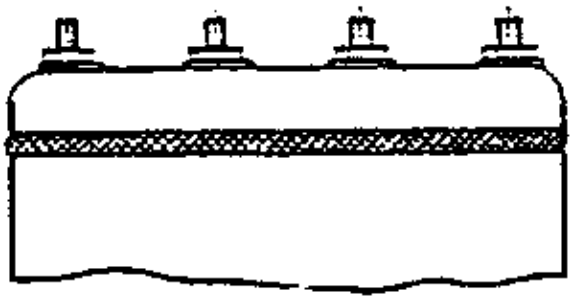
Wrench	Torque wrench
	
– Torque can only be estimated. When torque is too high, the screw brakes.	Torque can be measured exactly, clamping force is optimum.

3.4 Tighten nuts and screws in a certain order

wrong	right

<table>
<tr>
<td> 
</td>
<td> 

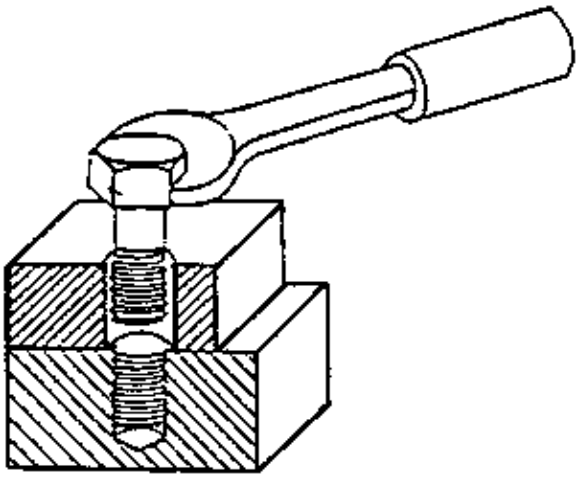
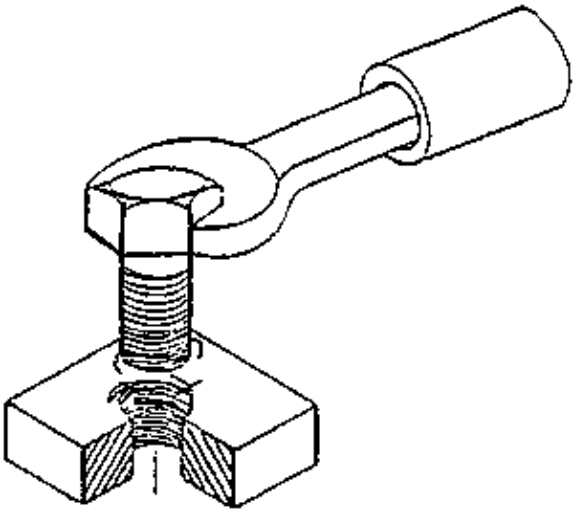
1. over cross</td>
</tr>
<tr>
<td></td>
<td> 


2. circular</td>
</tr>
<tr>
<td></td>
<td>Steps:

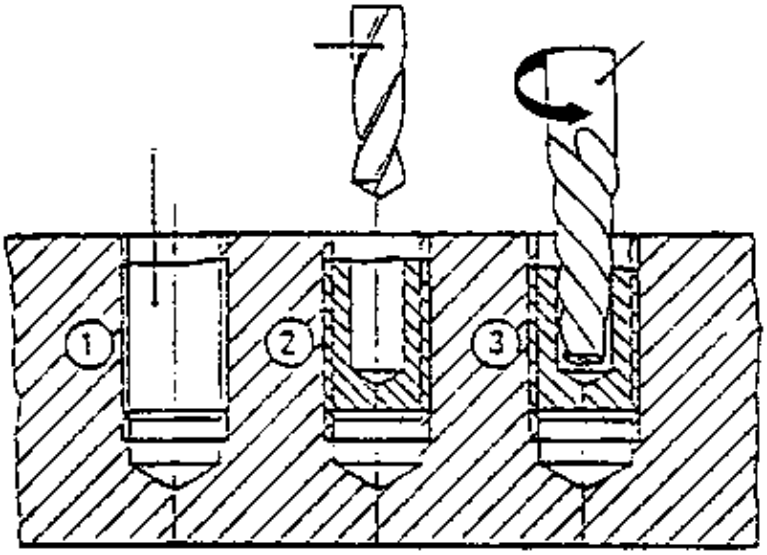
1. tighten all nuts moderate in one of the ways shown above

2. tighten all nuts till full torque is achieved</td>
</tr>
</table>

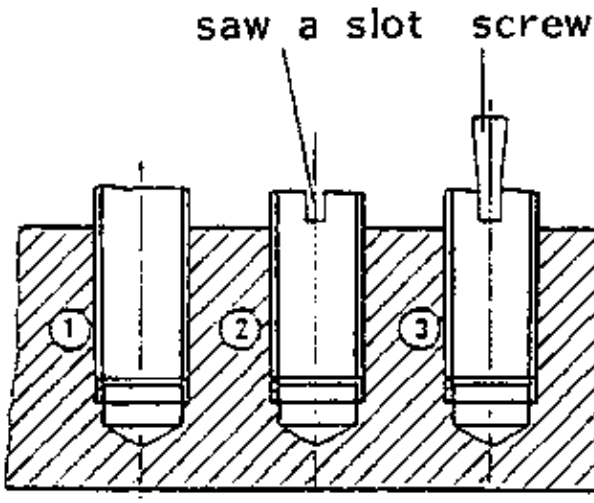
3.5 Typical screw defects

kind of damage	 bolt breaks	 thread is damaged
reasons	too much torque	– too much torque – two different threads – dirty or rusty thread – screw not applied correctly

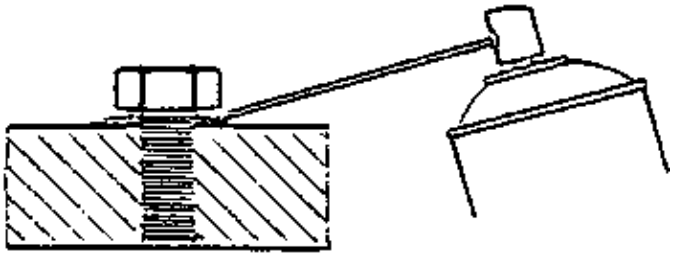
3.6 Extract broken bolts and repair internal threads

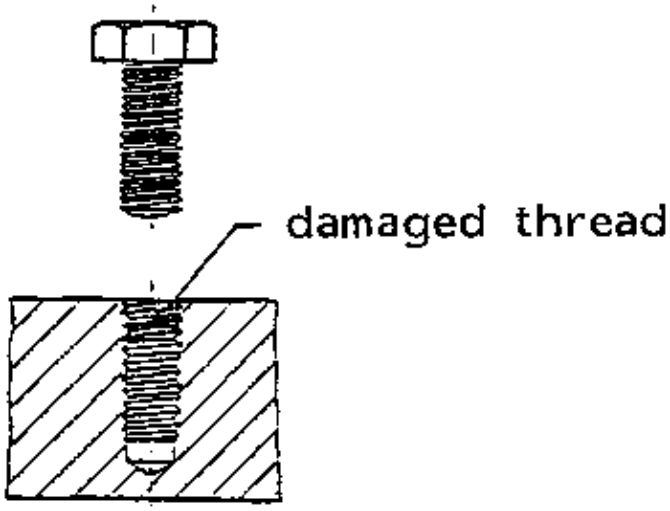
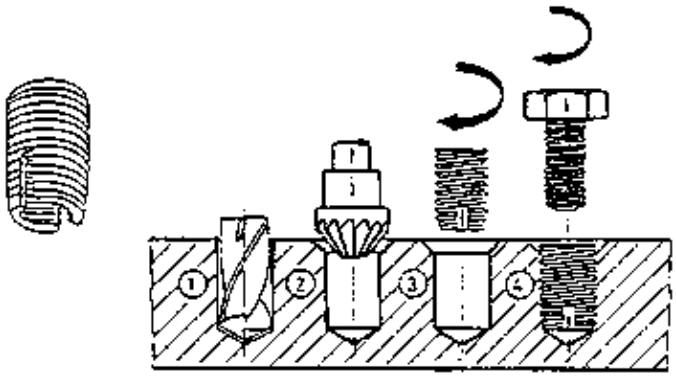
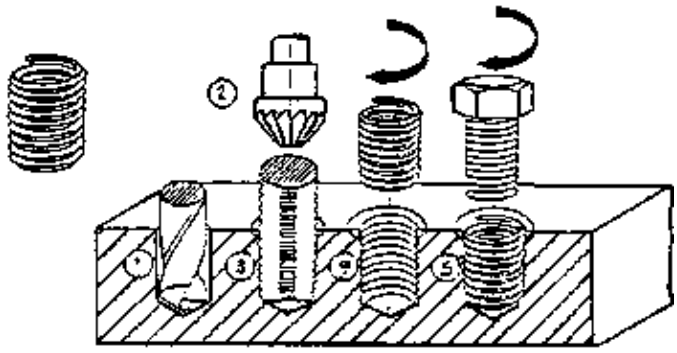


a) Extractor



b) slotting

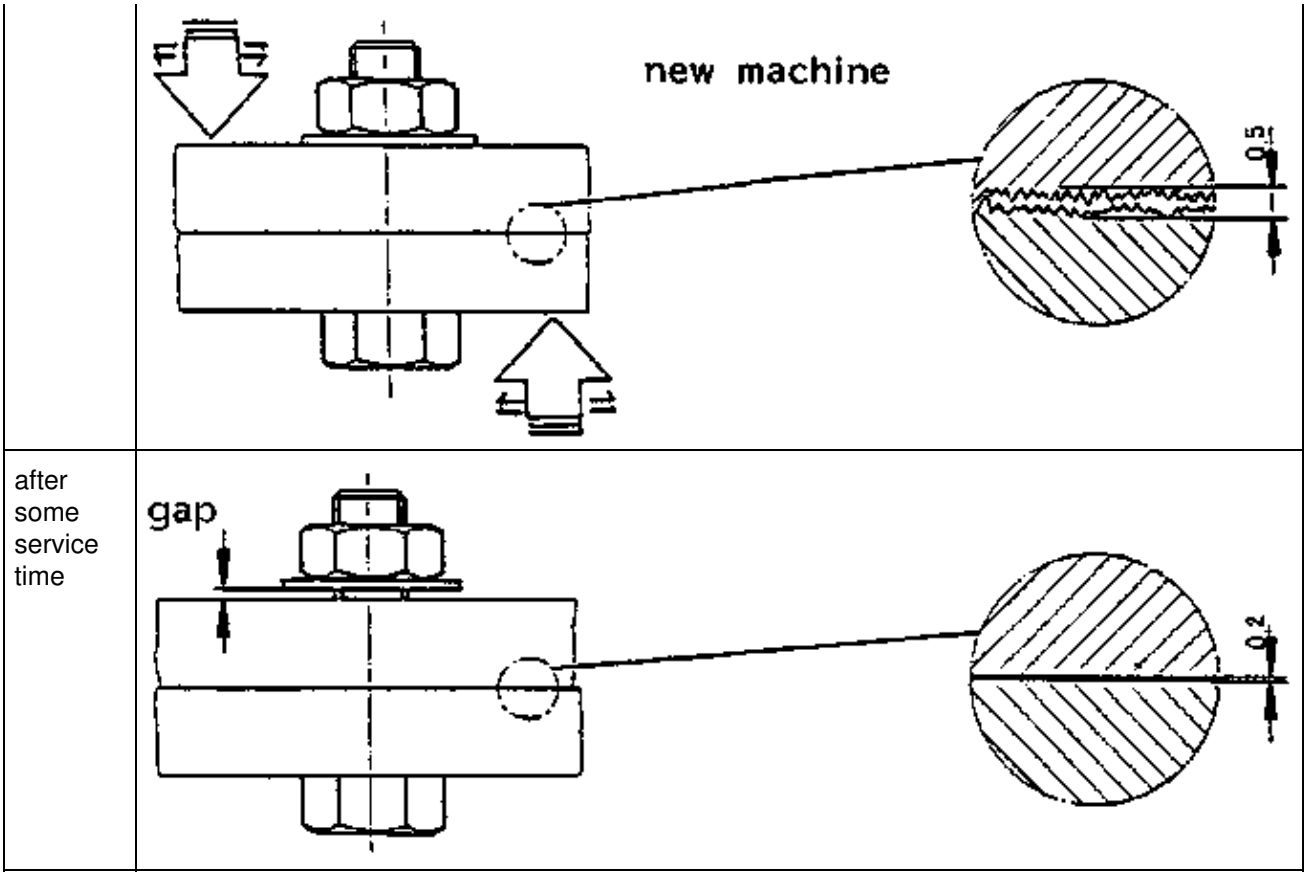

c) pente trating oil

		– happens especially when the material of the workpiece is soft (e.g. aluminium)
repair	 1. Screw bush	– a screw bush acts like a self–cutting screw
	 2. Helicoil	– for a helicoil a thread must be tapped

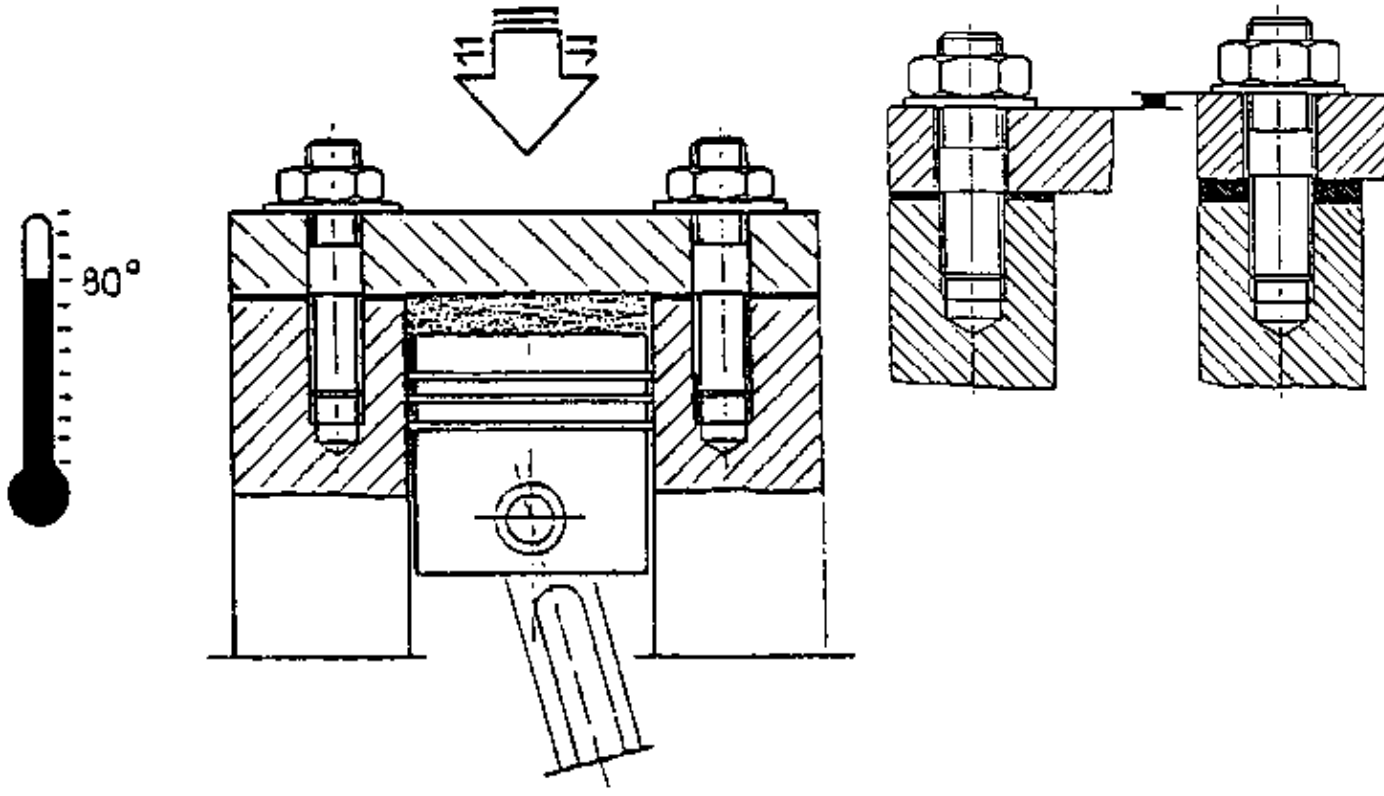
3.7 Retightening the nut after some service time

a) Vibration during work

during work	



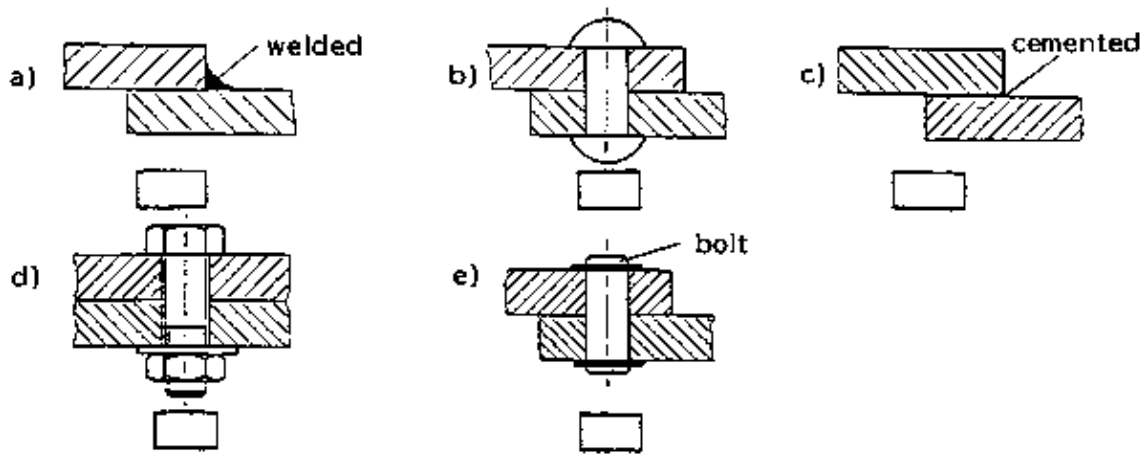
b) Vibrations and heat during work



Task sheet

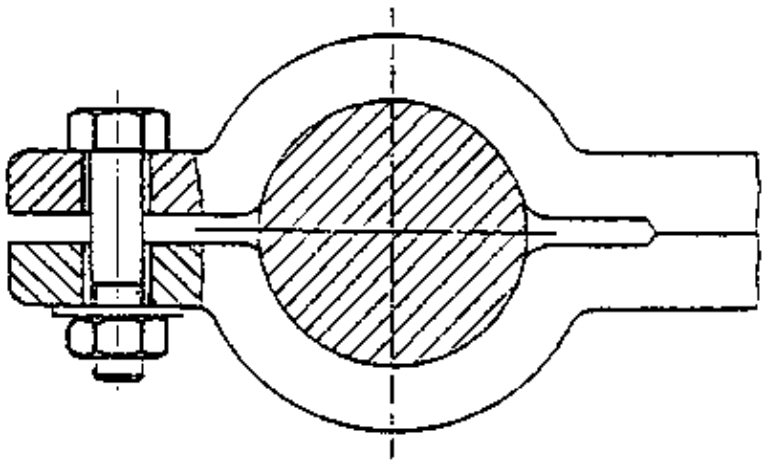
1.1.a) A joint, which must be destroyed when dismounting is called permanent/detachable

1.1.b) Mark the permanent joints with P and the detachable joints with D!



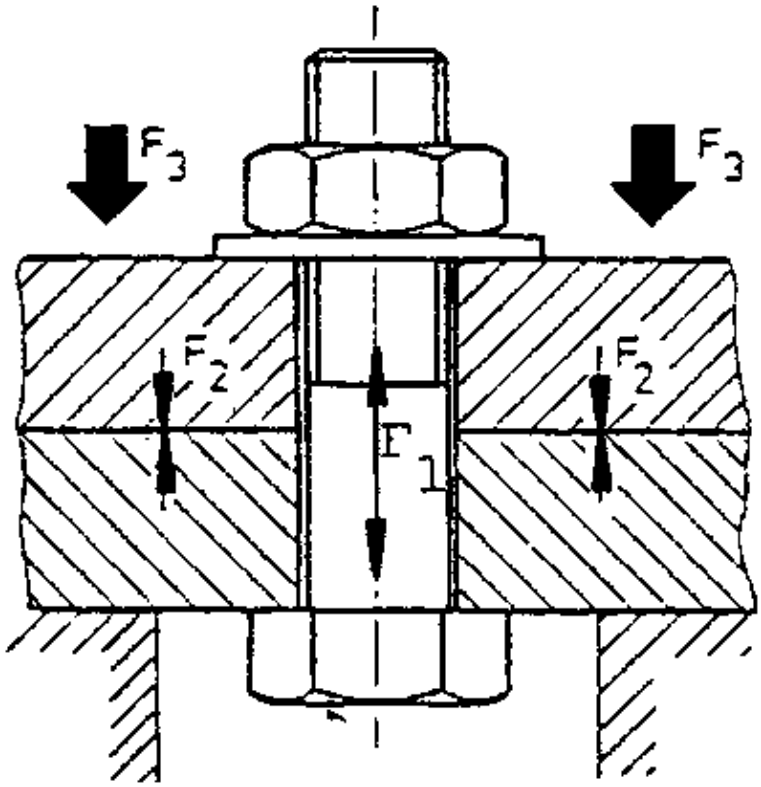
1.2.

a) In the bolt occurs axial/cross load.

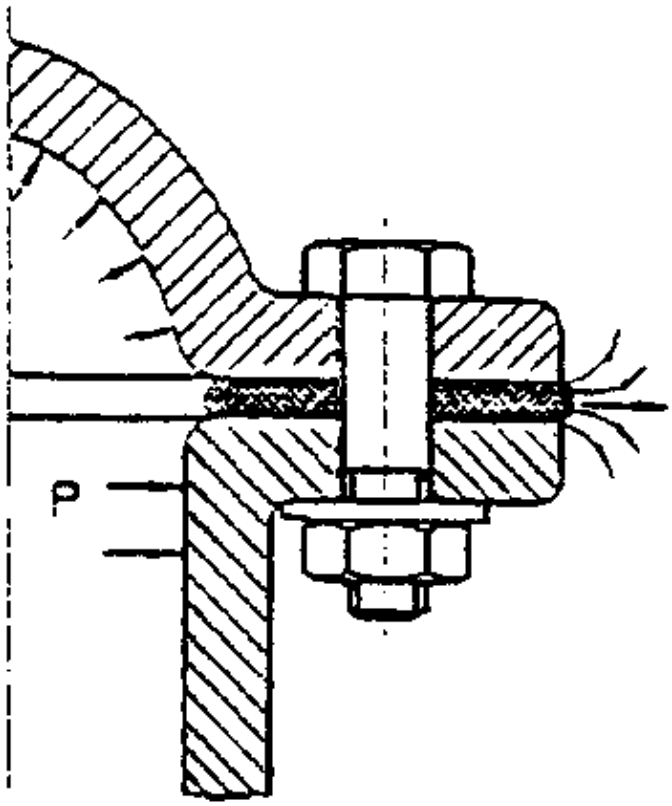


b) What happens, when the load F3 is rising?

a) Clamping force F2 is higher/constant/lower
b) Bolt gets longer/constant/shorter
c) Load F1 of the screw is higher/constant/lower



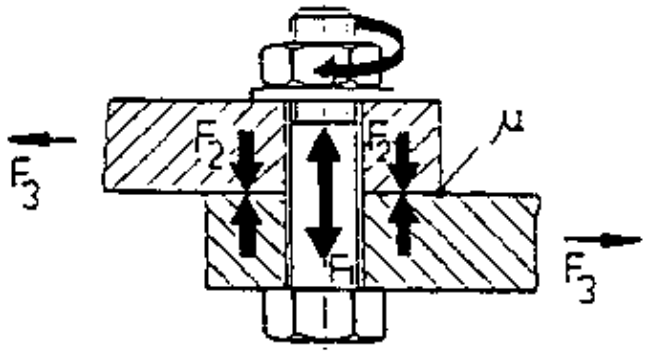
c) The tank is leaking when the force of pressure is higher/equal/lower than the preload of the screw.



1.2.2

a) If clamping force is not sufficient, the workpieces can slip. In that case, the bolt carries cross/axial load.

b) The workpieces do not slip when

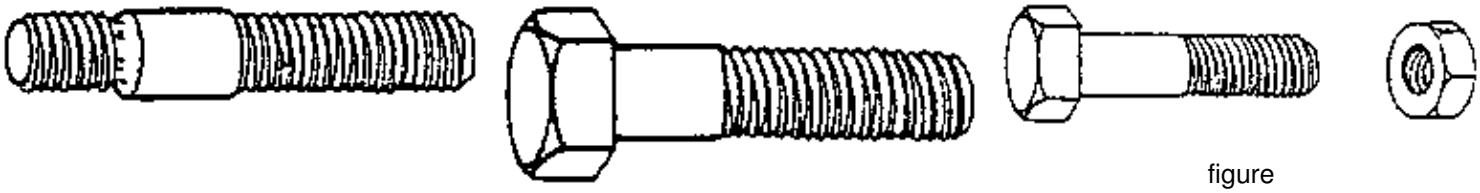


c) If the surface of the workpieces is dirty or oily, the clamping force F2 will be lower/equal/higher and is lower/equal/higher

d) Capacity of a bolt connection to carry cross load is higher/equal/lower when the surface of the workpiece is dirty or oily.

2.1

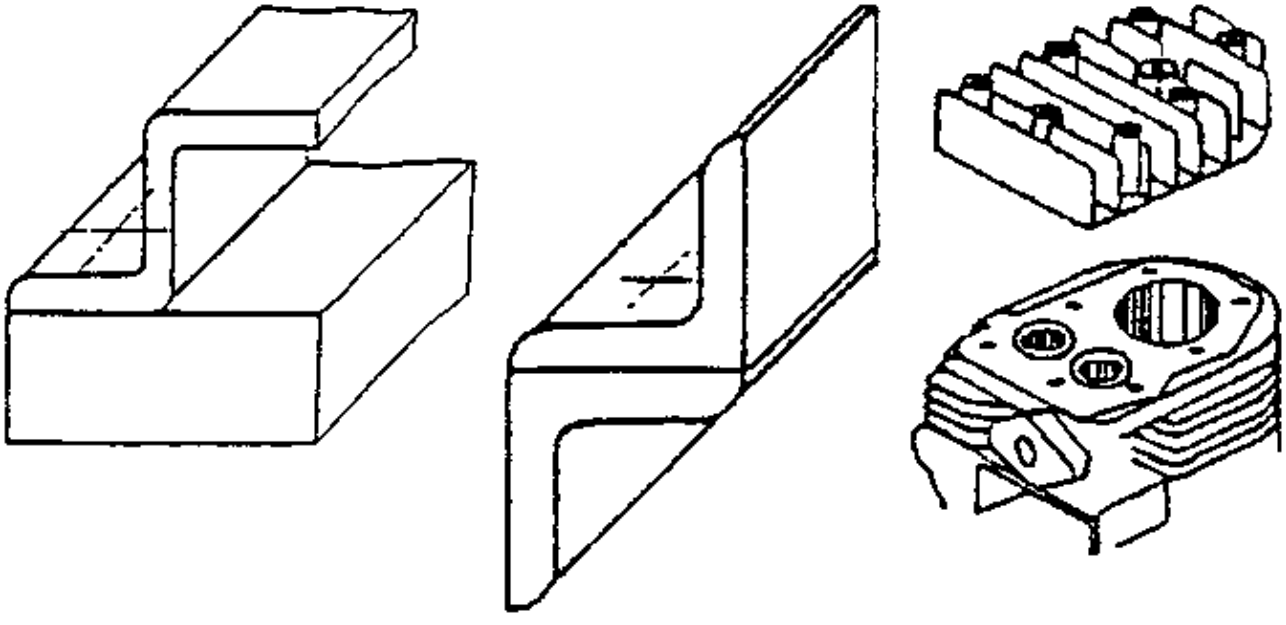
a) Write one of the following names under the picture: Tab bolt, Through bolt, Stud bolt



figure

1 _____ 2 _____ 3 _____

b) Which of the screws mentioned above is used?

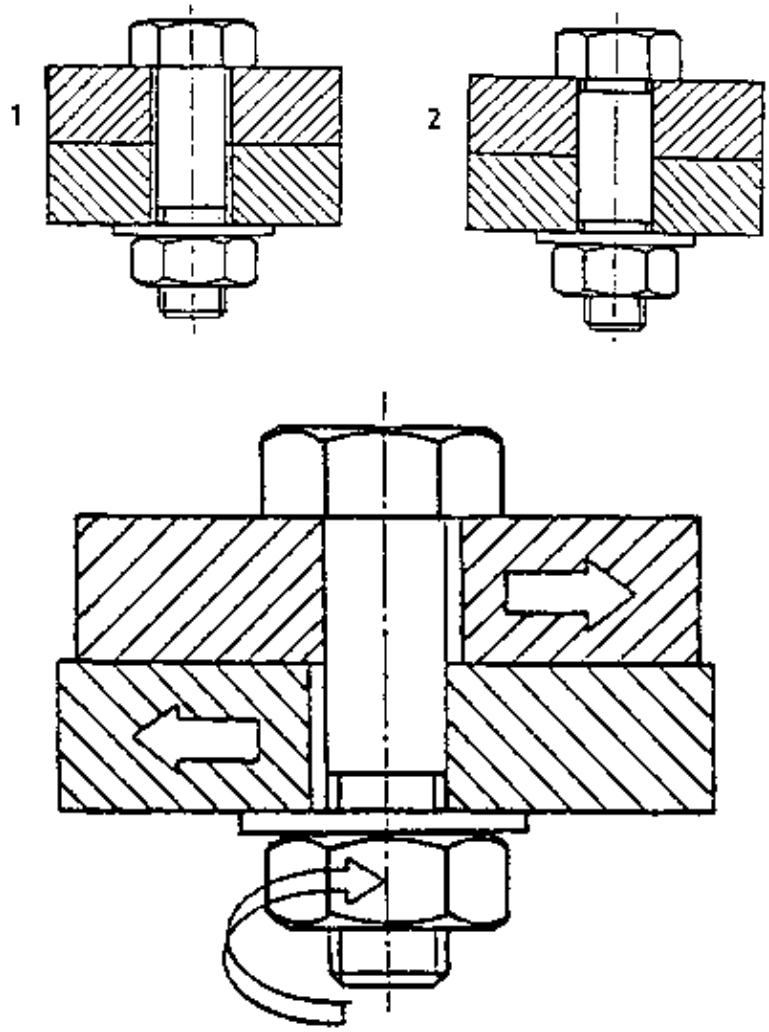


1 _____ 2 _____ 3 _____

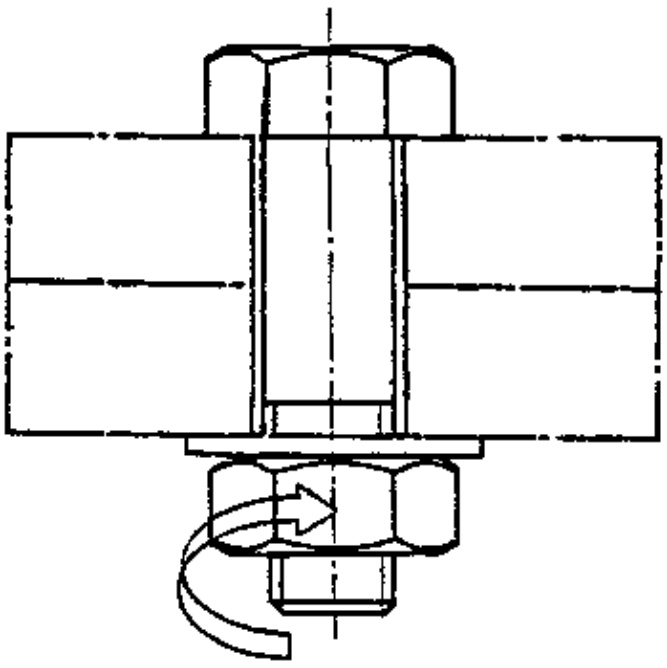
2.2

a) The bolt which prevents movement of the workpieces is called screw/fitting bolt/stud bolt

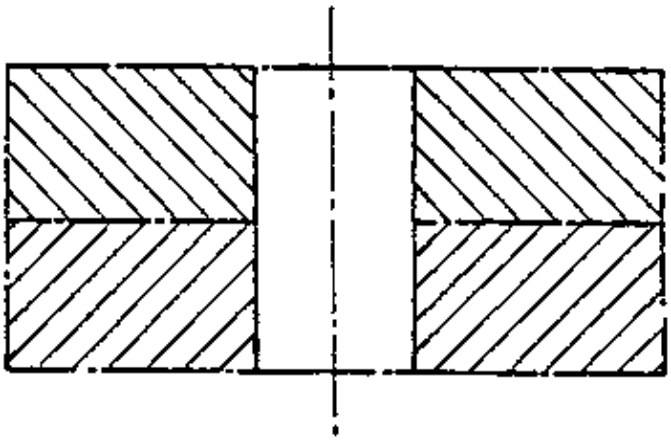
b) Which drawing shows a fitting bolt?



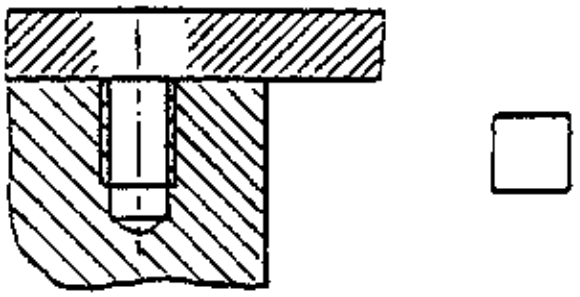
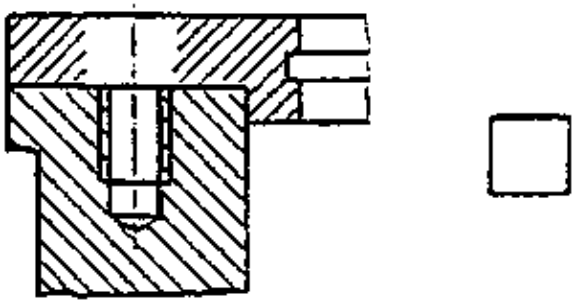
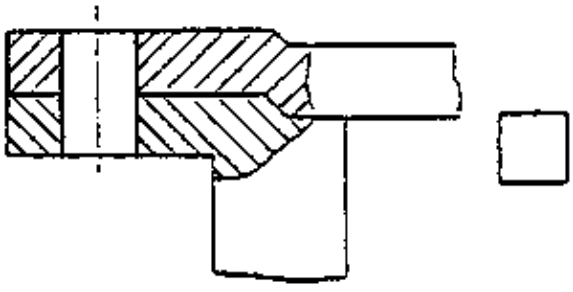
1.

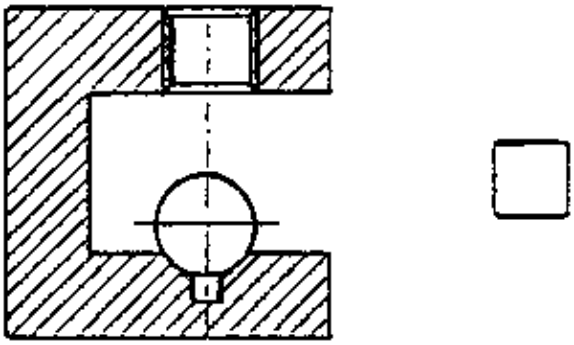


2.

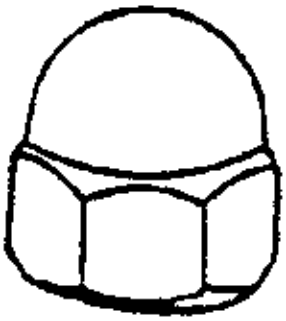


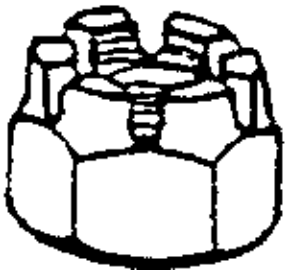
2.3 Which screws fit in the following applications? Write the correct number in the square!

a) 	1. 
b) 	2. 
c) 	3. 
d) 	4. 

e)	5.
	

2.4 Relate the text on the right hand side to the Nuts on the left hand side

----------  a) protects from water and dirt

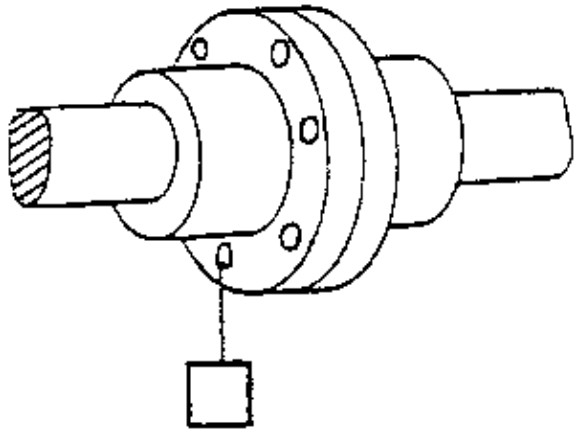
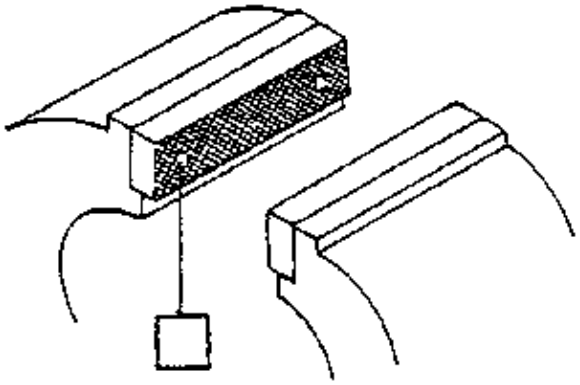
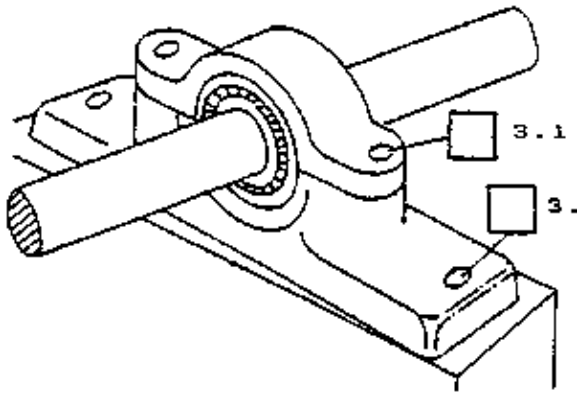
----------  b) for general use

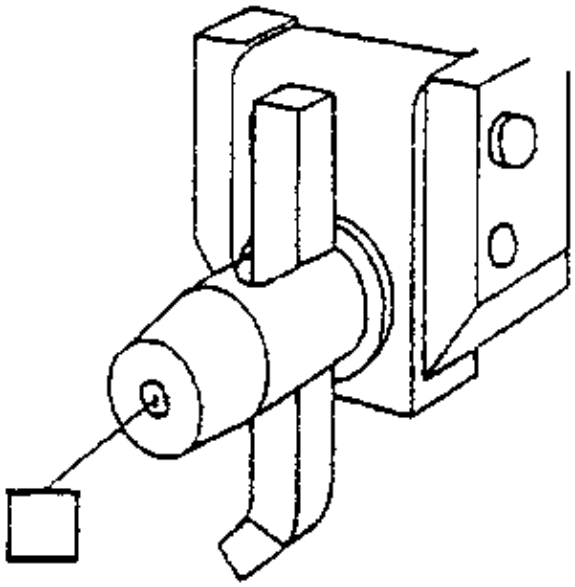
----------  c) protects from loosening

----------  d) can be tightened by hand

2.5 Write the letter in the square!

a) Which screws (bolts) fit in the following applications?

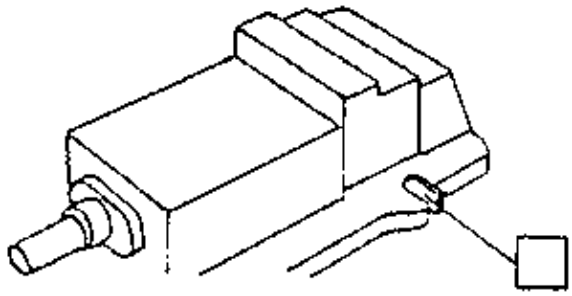
1. 	a) 
2. 	b) 
3. 	c) 
4.	d) 



e)

b) Which nuts fit in the following applications?

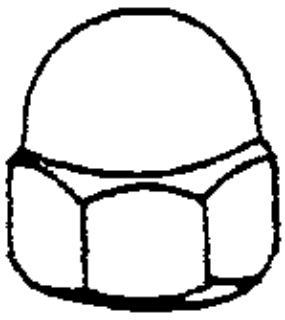
1.

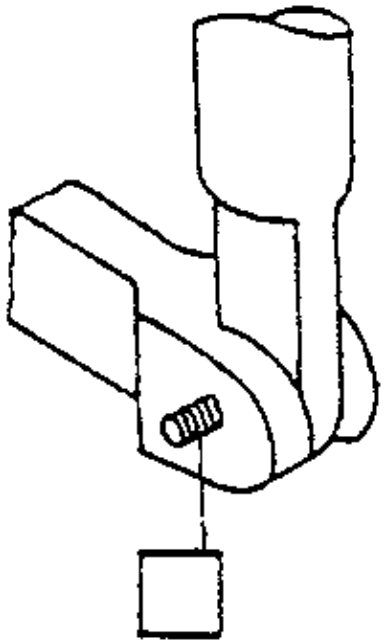


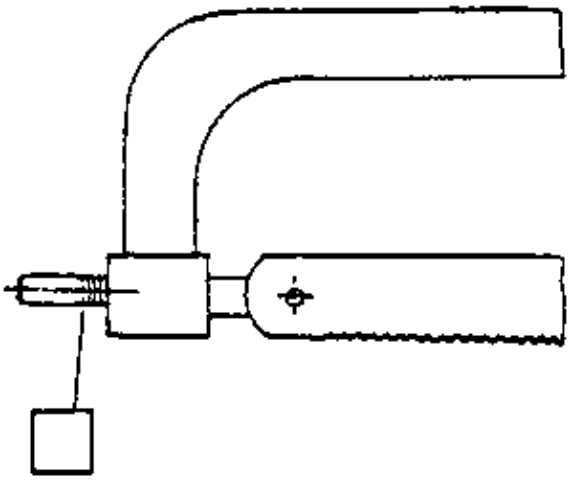
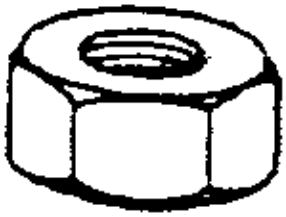
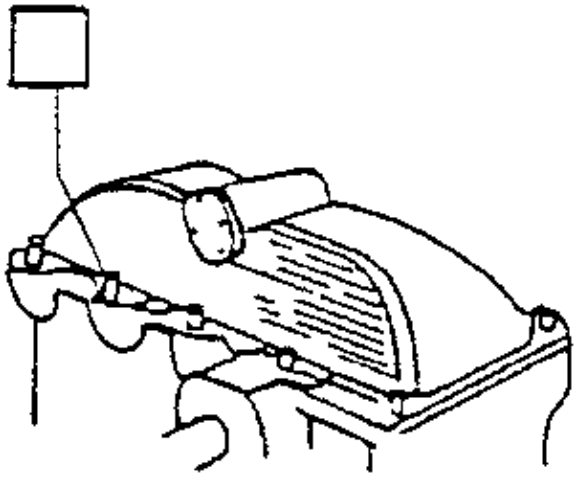
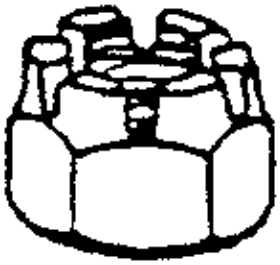
a)

2.

b)

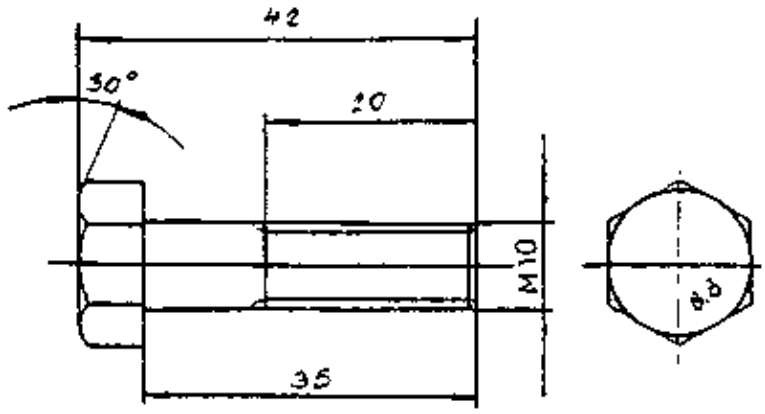


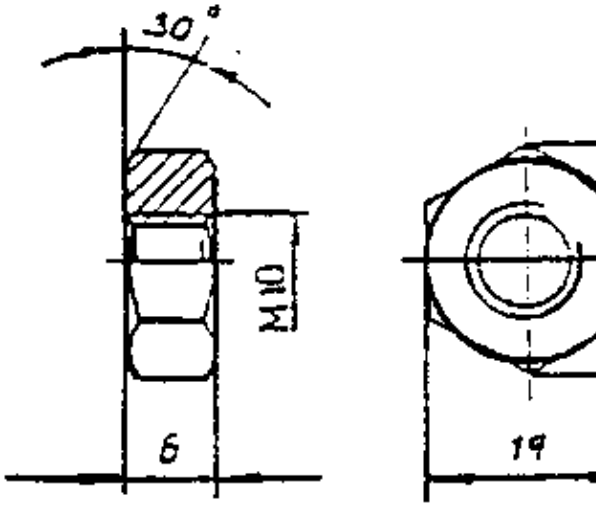


3. 	c) 
4. 	d) 

2.6

a) Complete the code!





a) Code: M.....

b) M.....

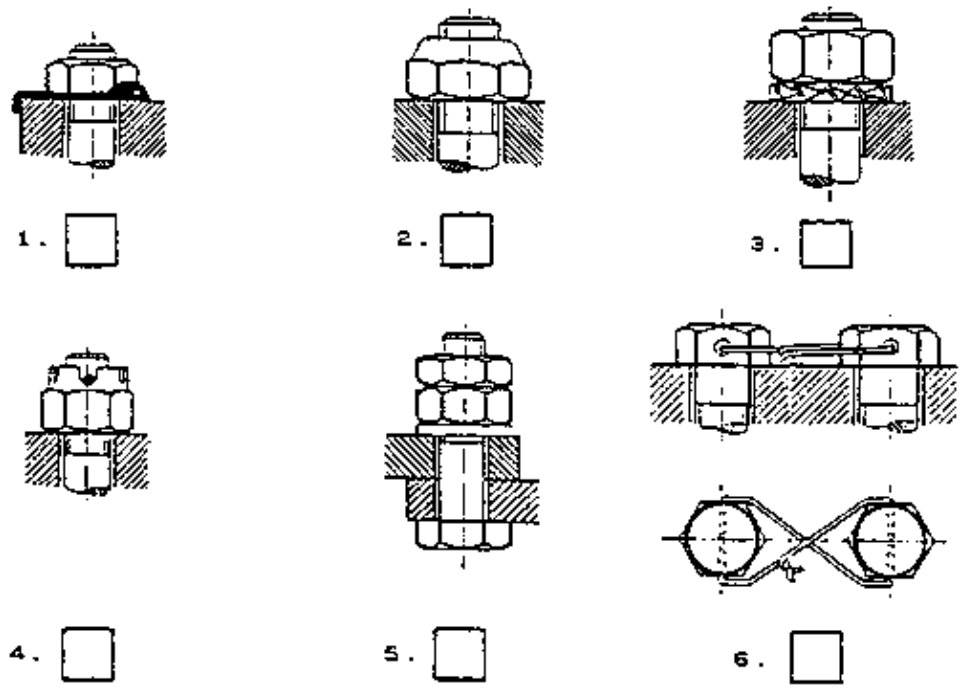
b) You need a screw with a tensile strength of 500 N/mm^2 and elastic limit of 300 N/mm, which marking must the screw–head have?

2.7 The nut/screw is normally tightened at a screw joint. The washer must be placed under the screw head/nut to

a) protect the surface of the workpiece under the nut
b) protect the surface of the workpiece under the screw–head
c) protect from loosening
d) protect from friction between screw–head and hole

2.8

a) Relate the types of lockings to the Nuts!

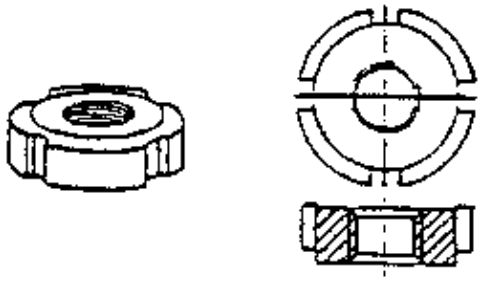
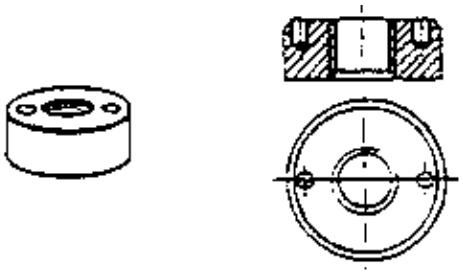


a) from fitting lock
b) friction lock

b) Fill in the numbers 1.2, 3, 4, 5, 6 of 2.8.a) in the empty lines below!

a) Makes use of the friction between the nuts
b) Use when heavy vibration occurs
c) Makes use of the friction of deformed plastic
d) Permanent joint will be destroyed when loosened

3.1 a) Relate the right tool to the screws in the table below!

Types of screws		Tools
a) 	b) 	1. Open end wrench 2. Two–hole–key 3. Hook wrench
c) 	d) 	4. Ring spanner 5. Screw driver 6. Alien key
e) 	f) 	7. Phillips screw driver 8. Adjustable wrench 9. Vise grip wrench

Types of nuts & screws	a)	b)	c)	d)	e)	f)
Tools						

b)

For a hexagon screw M10 a wrench No. – 13/17/19 – is used.
For a hexagon screw M12 a wrench No. – 15/17/19 – is used.

3.2

a) When tightening 2 screws with the same torque, the friction in an oily screw is higher/lower than in a rusty one.

b) When they should have the same clamping force, the torque at a rusty screw must be higher/lower than at a oily one.

3.3

a) We are using the torque wrench to

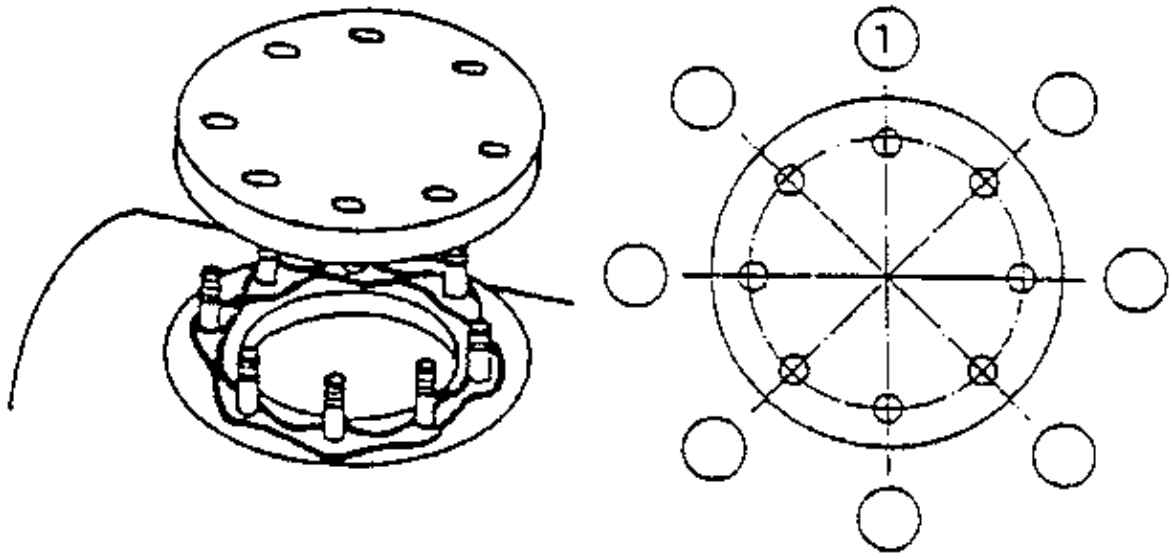
a) tighten nuts when only limited space is available
b) reach a higher torque
c) reach the desired torque
d) tighten faster than with a usual wrench

b) Where do you get the information about the correct torque from?

– scale of torque wrench/Machine manual/screw–head

3.4

a) Write the correct tightening sequence in the circles!



b) Mark the correct answers with!

When tightening in the wrong sequence!

1. the flange might leak
2. the clamping pressure is higher
3. the clamping force is unsymmetrical
4. the screws are overloaded

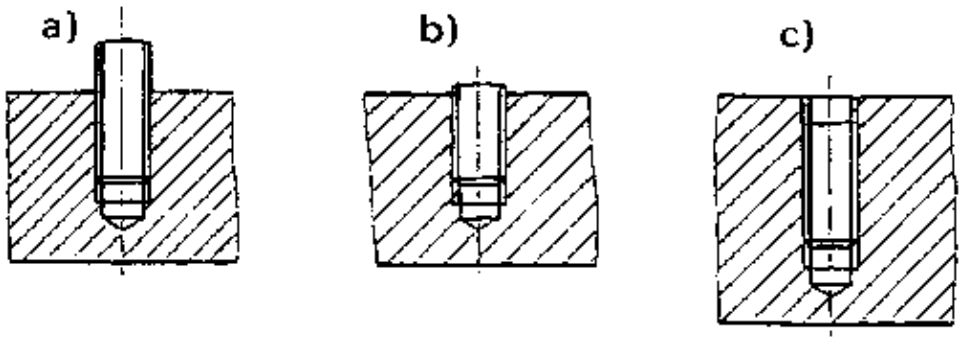
3.5 Mark the correct answers with!

To prevent the thread of a screw from damage, you should

a) center the wholes before inserting screw
b) use a bigger wrench
c) pay attention to the maximum tensile strength
d) choose the right type of screw (e.g. Hexagonal screw)
e) pay attention to the kind of thread

3.6

a) Relate the drawings to the text

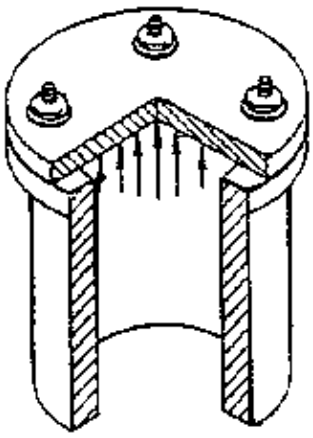


1. Saw a slott and loosen the screw by screw driver
2. Weld a piece of iron on the screw and loosen by pliers
3. File across flats and open by wrench
4. Drill a whole and loosen by extractor

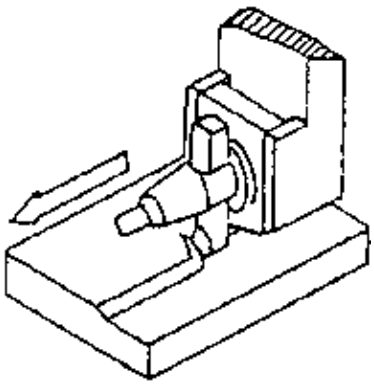
b) Which method would you use for repairing thread without tap? helicoil/thread bush

c) Which method of thread repair requests a tap? helicoil/thread bush

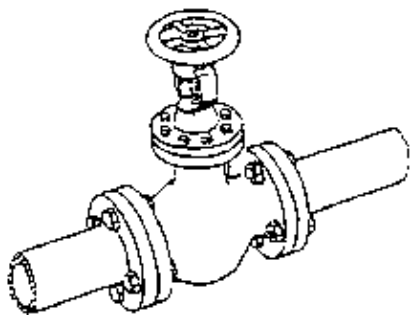
3. 7 Mark the correct answer with Which connection must be tightened after some service time?



a) boiler



b) shaper tool



c) water pipe

Solutions

1.1

a) permanent

b)

a) P b) P c) P d) D e) D

1.2

a) axial

b)

a) higher
b) shorter
c) lower

c) higher

1.3

a) cross load
b) F_2 F_3
c) equal lower
d) lower

2.1

a) 1. stud 2. screw 3. bolt

b) 1. screw 2. bolt 3. stud

2.2

a) fitting bolt
b) b)

2.3

a) 3 b) 5 c) 2 d) 4 e) 1

2.4

a) c) d) b)

2.5

a) 1. c) 2. d) 3.1 b) 3.2 e) 4. a)

b) 1. c) 2. d) 3. a) 4. b)

2.6

a) a) M10 × 35 b) M10 c) M12 × 60

b) 5.6

2.7

Nut Nut a)

2.8

a) 1. a) 2. b) 3. b) 4. a) 5. b) 6. a)

b) a) 5 b) 4, 1, 6 c) 2 d) 1, 6

3.1

a) a) 7 b) 5 c) 6 d) 1 e) 3 f) 2

b) 17 19

3.2

a) lower
b) higher

3.3

a) c)

b) Machine
manual

3.4

a)

b) 1 2 3 4

3.5

a) b) c) d) e)

3.6

a) 1.a) 2.b) 3.a) 4.c)

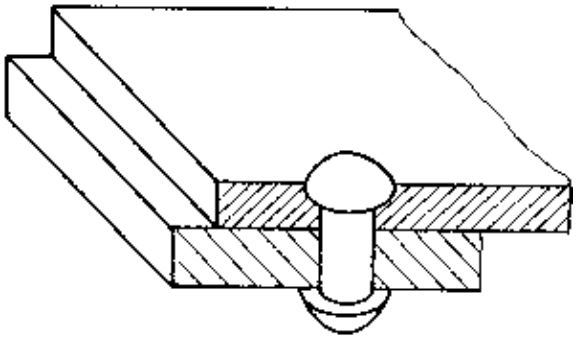
b) thread bush

c) helicoil

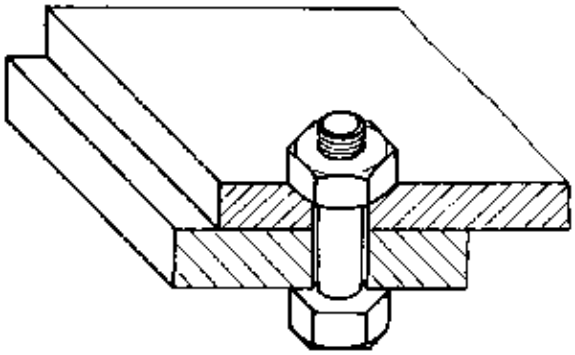
3.7

a, b

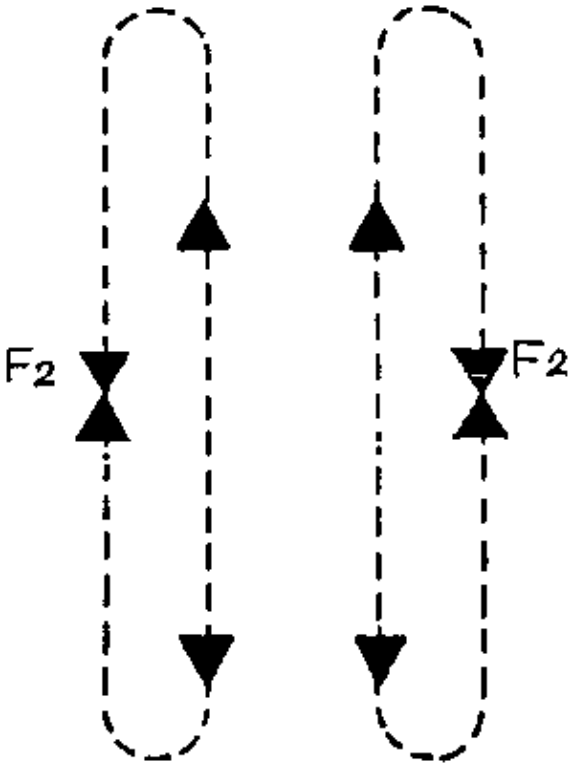
FEATURE OF WORKPIECE CONNECTIONS



Permanent joint

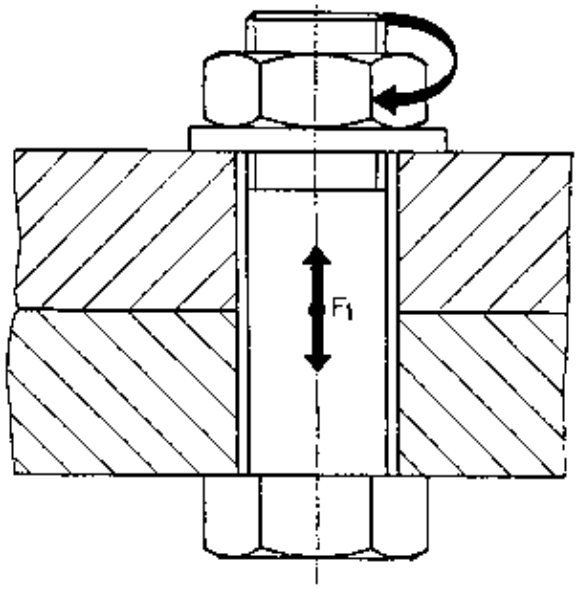


Detachable joint



F_2 = Clamping force

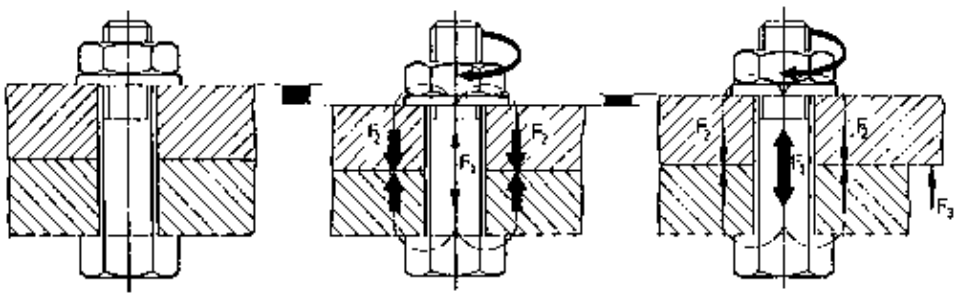
INTERNAL FORCE IN BOLT



F_1 = Load of bolt

AXIAL LOAD

No preload Preload Preload and outside force

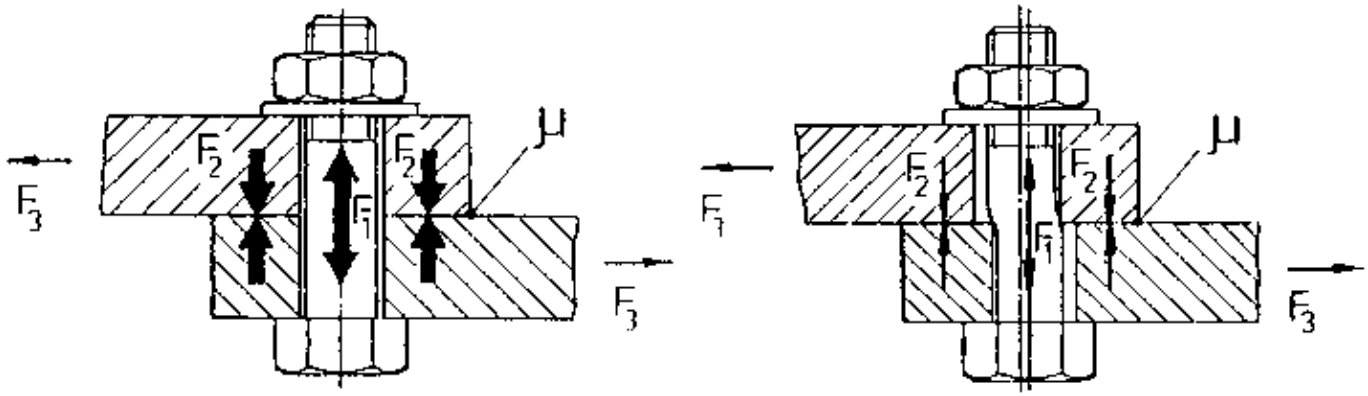


F_1 = load of bolt
F_2 = clamping force
$F_1 = F_2$

$F_2 = F_1 - F_3$
$F_1 > F_3$

CROSS LOAD

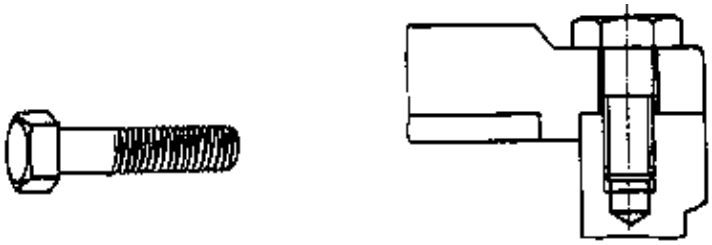
Clamping force Clamping force to low



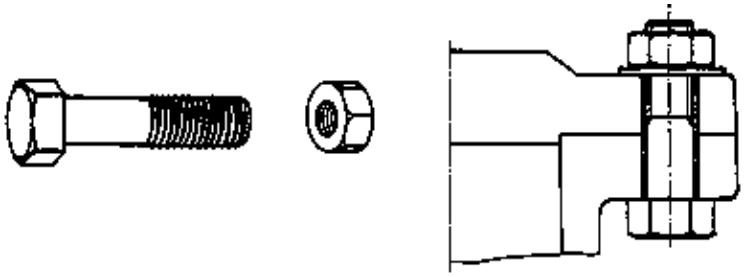
F_3

$F_2 \cdot \mu > F_3$ $F_2 \cdot \mu < F_3$

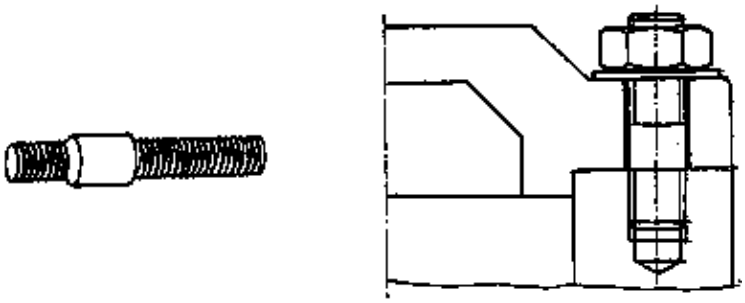
Screw



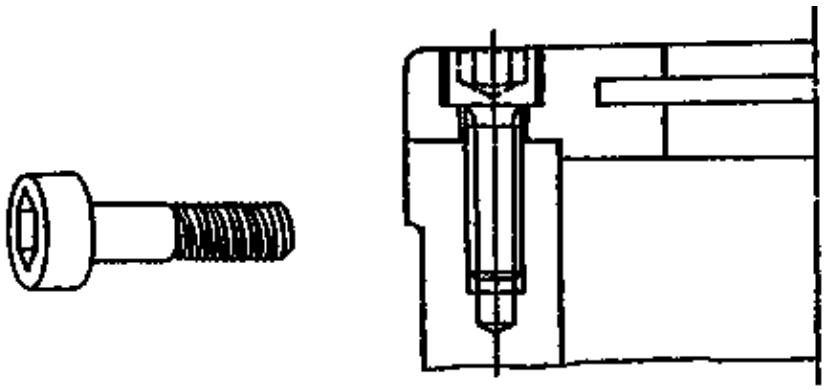
Bolt



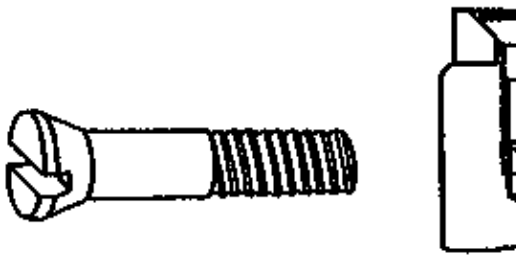
Stud



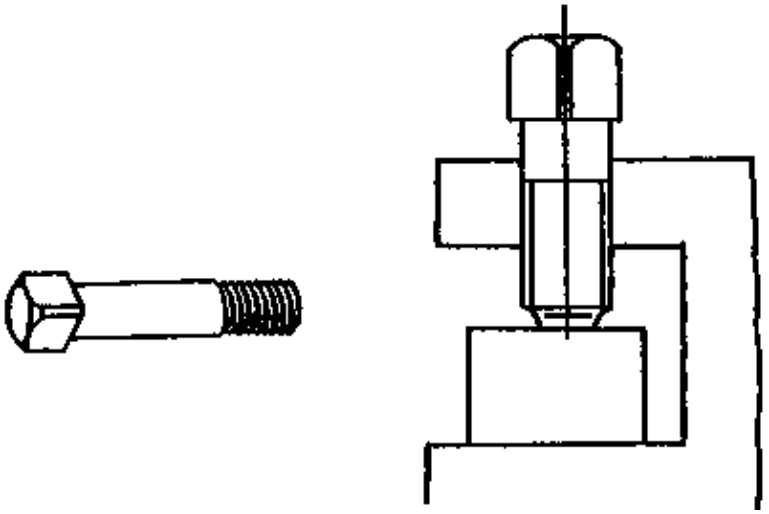
TYPES OF SCREWS



socket head screw



countersunk head scr



square head shoulder screw

sheet metal screw

TYPES OF NUT

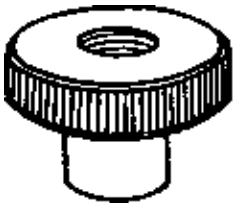
hexagon nut

Square nut

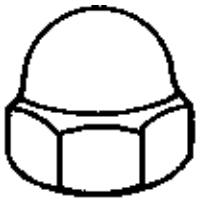
Two hole nut

Slotted nut

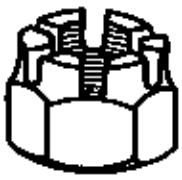
Wing nut



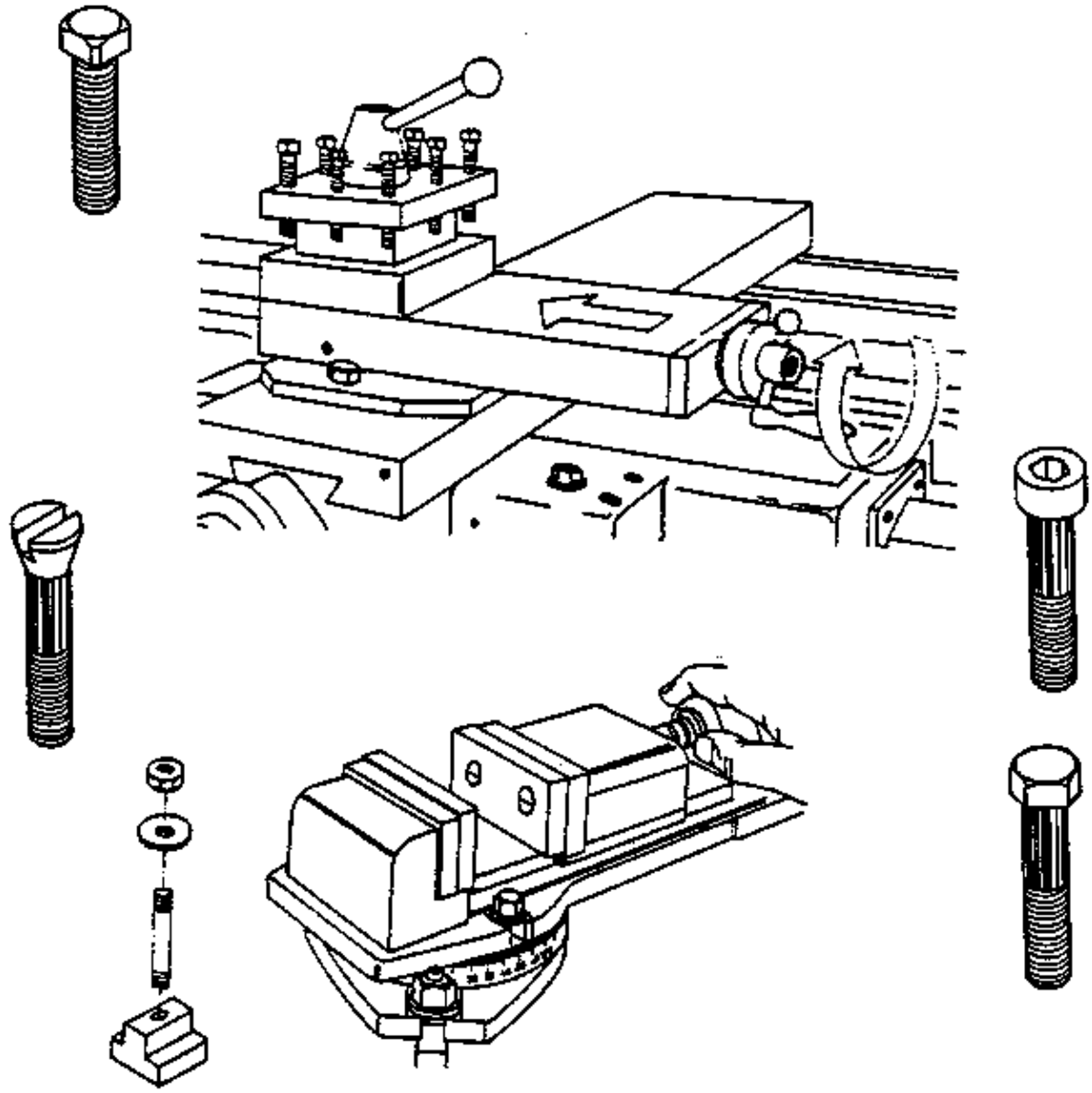
Knurled nut



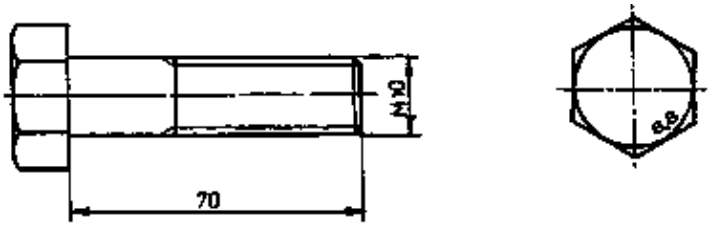
Cap hut

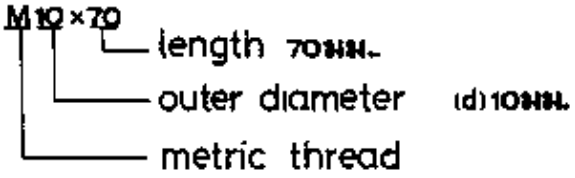


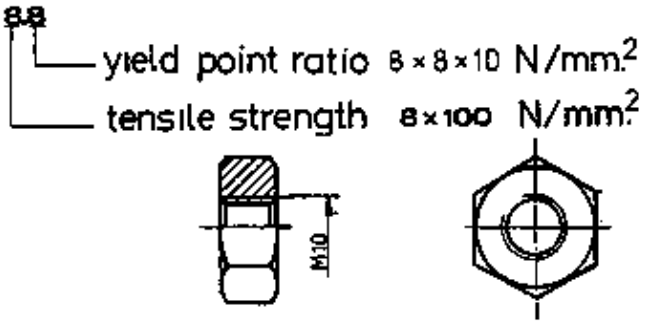
Castel nut

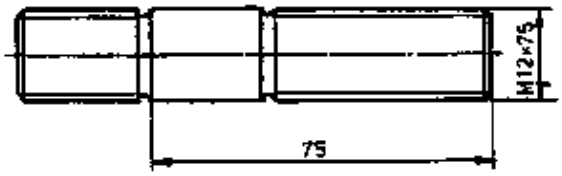


STANDARD OF SCREW, NUT AND STUD

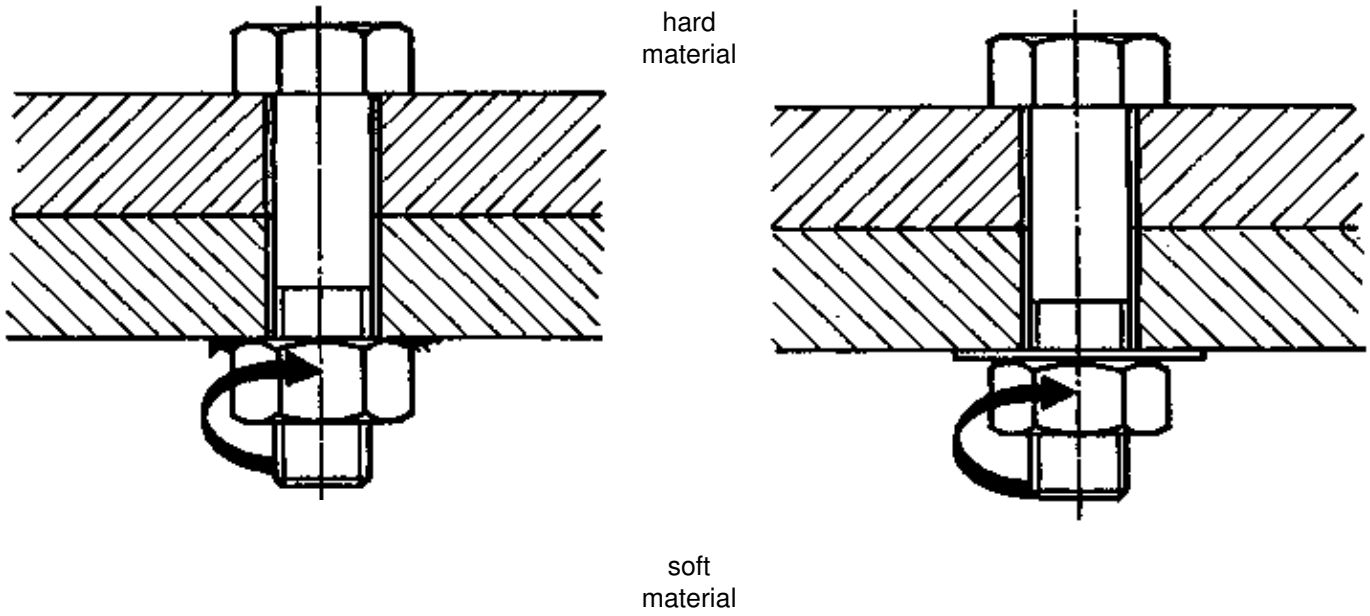


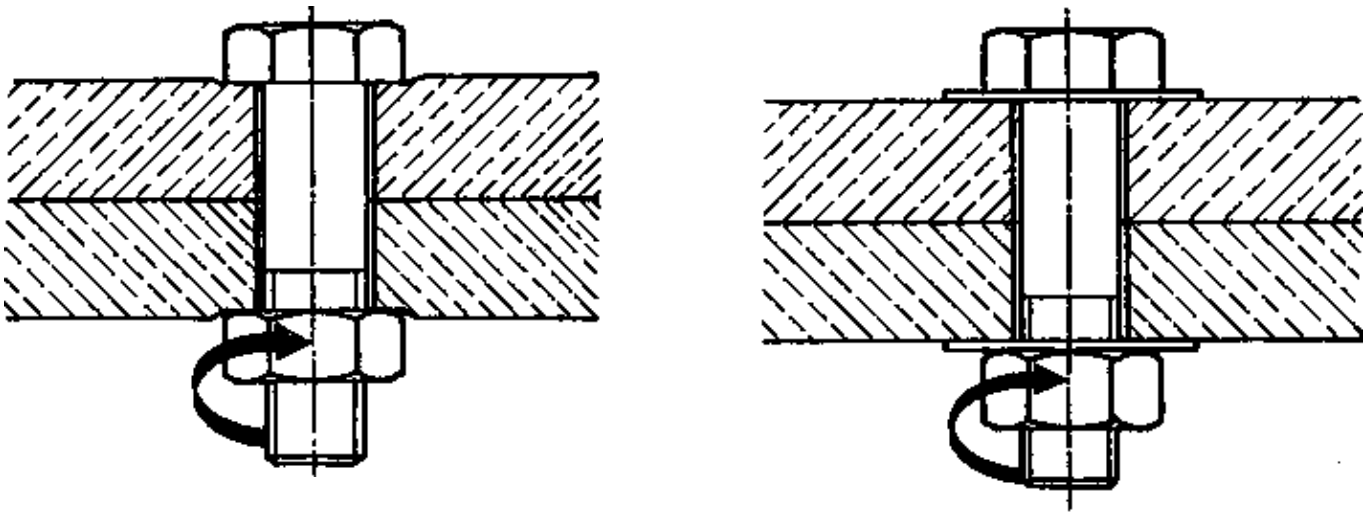




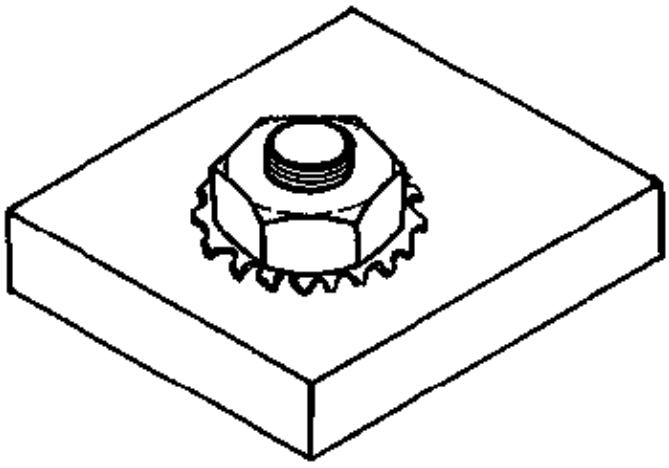


USAGE OF WASHER

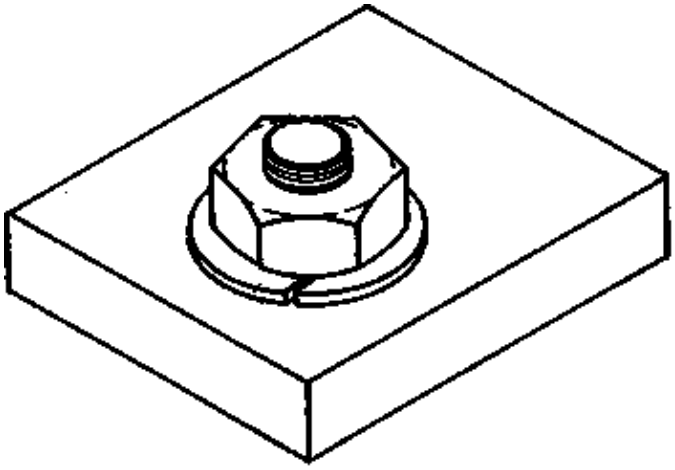




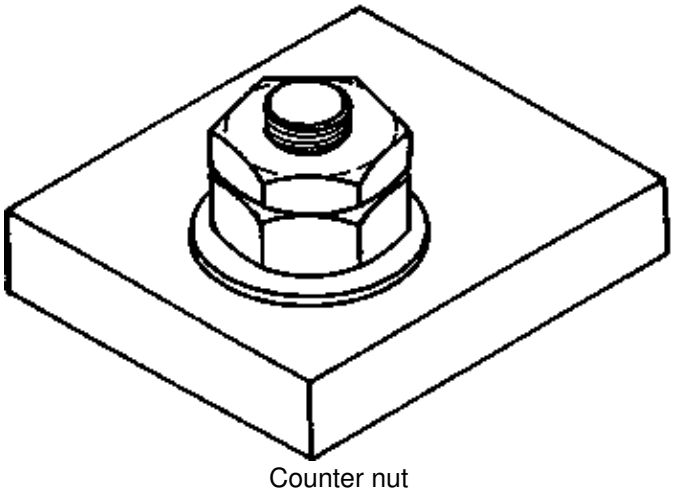
FRICTION LOCKS



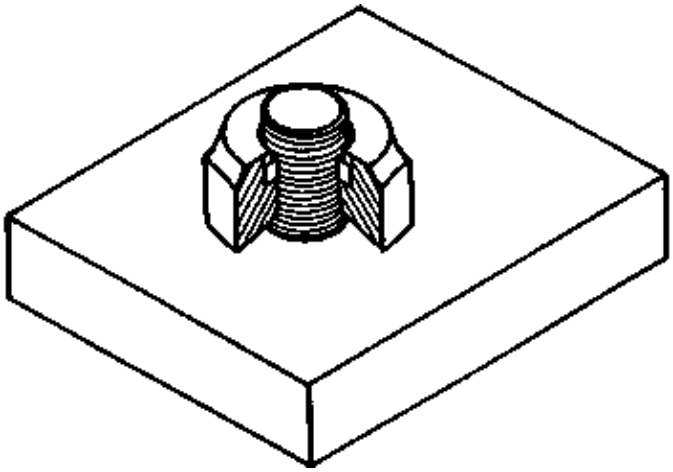
Fan discs



Spring washers

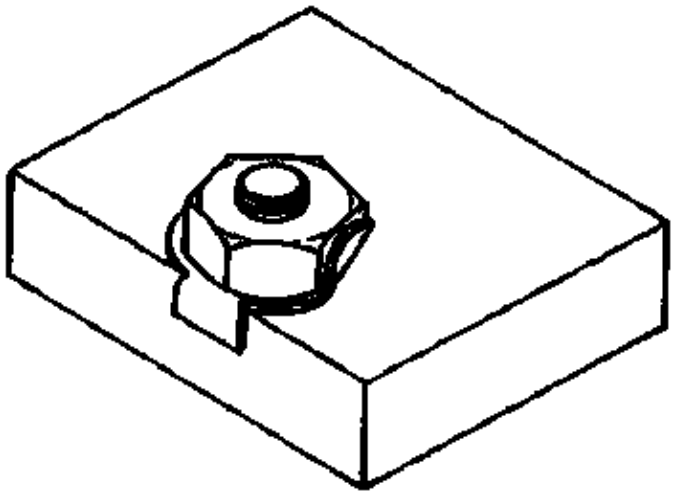


Counter nut

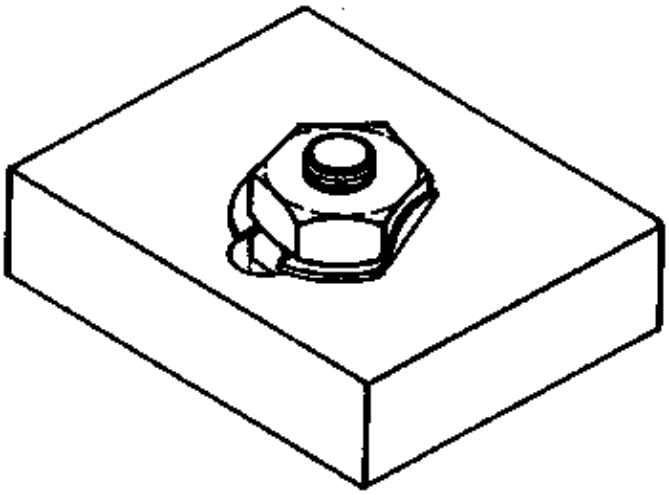


Self locking nut

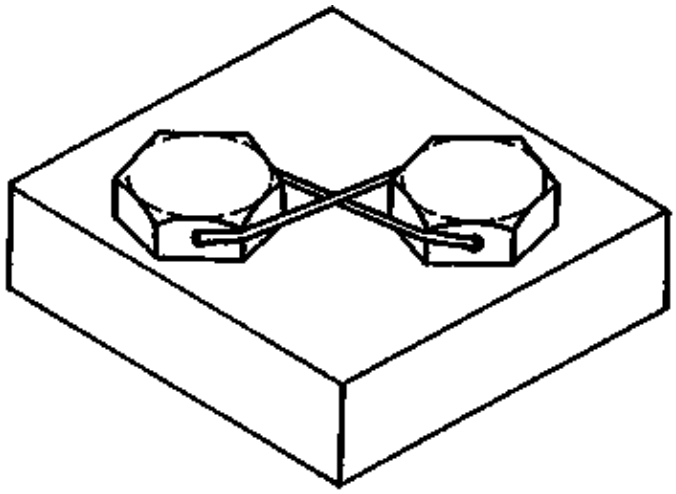
FITTING LOCKS



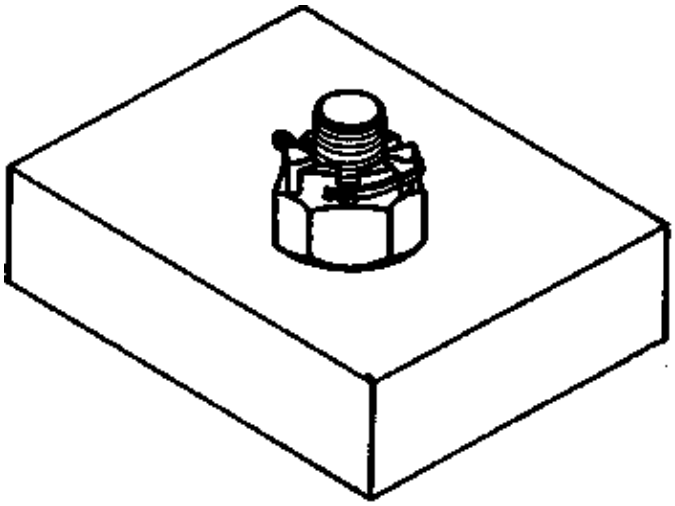
Tap washer



locking plate

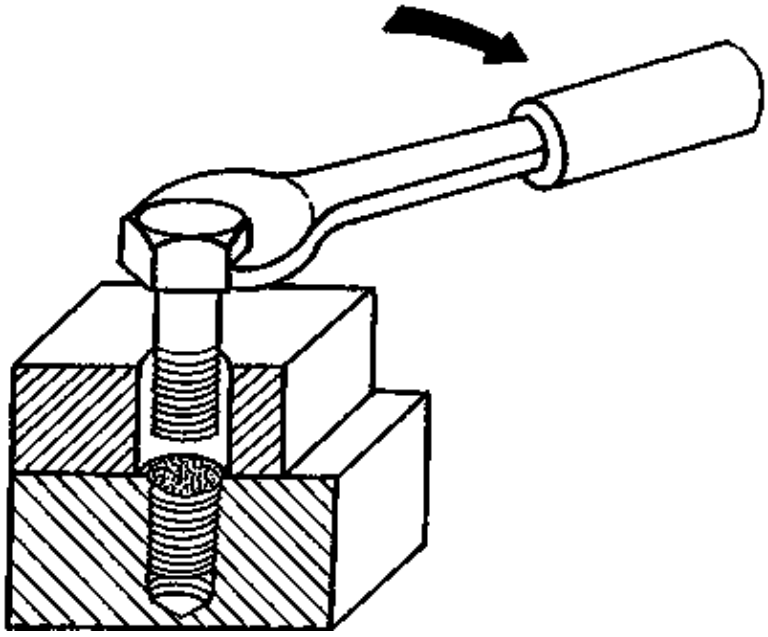


Safety wire

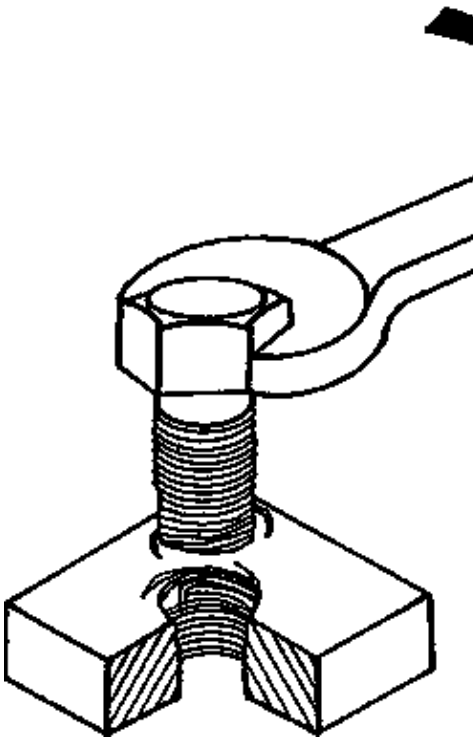


Split pin

FEATURE OF BOLT AND SCREW DEFECTS



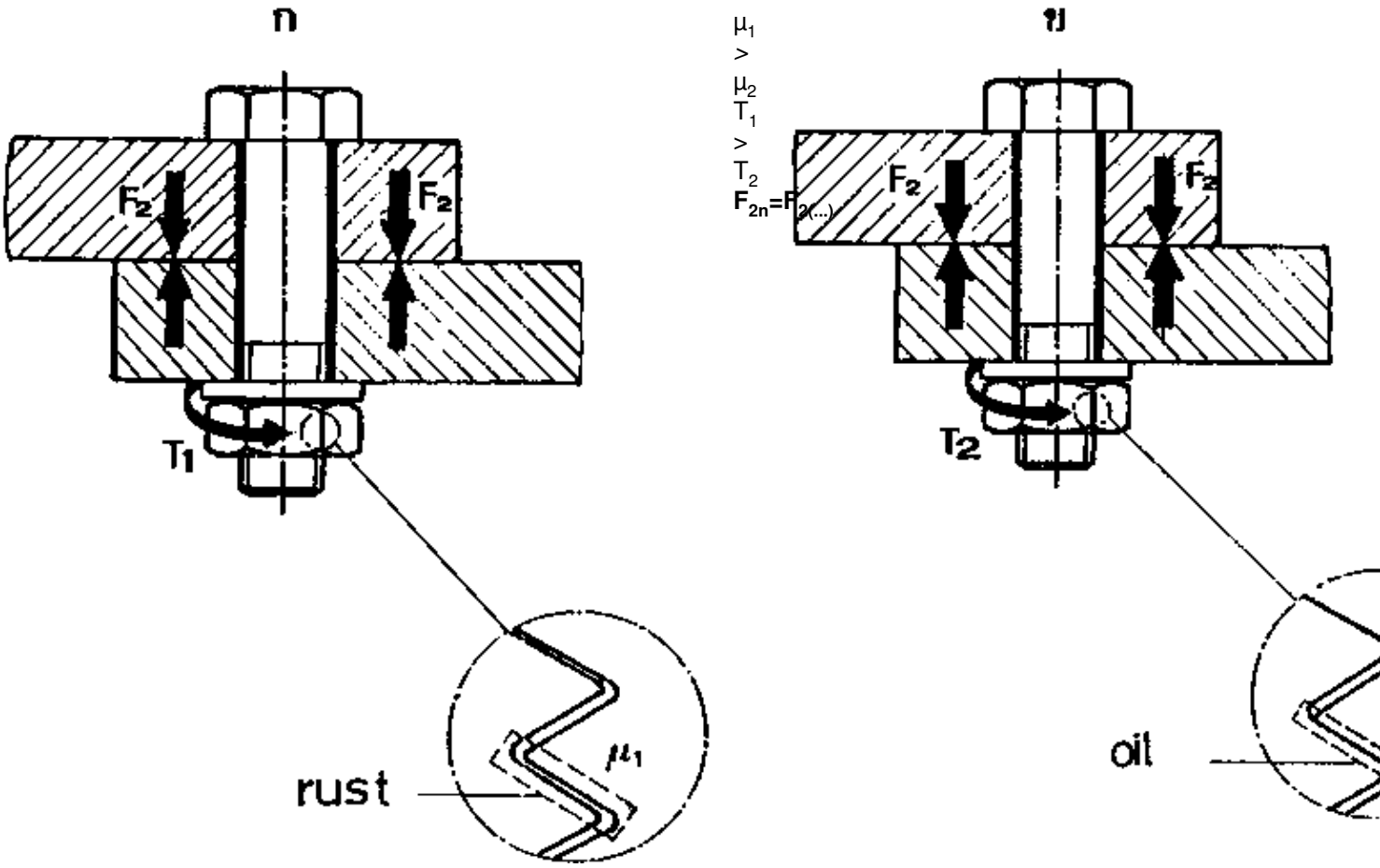
Reasons – too much torque



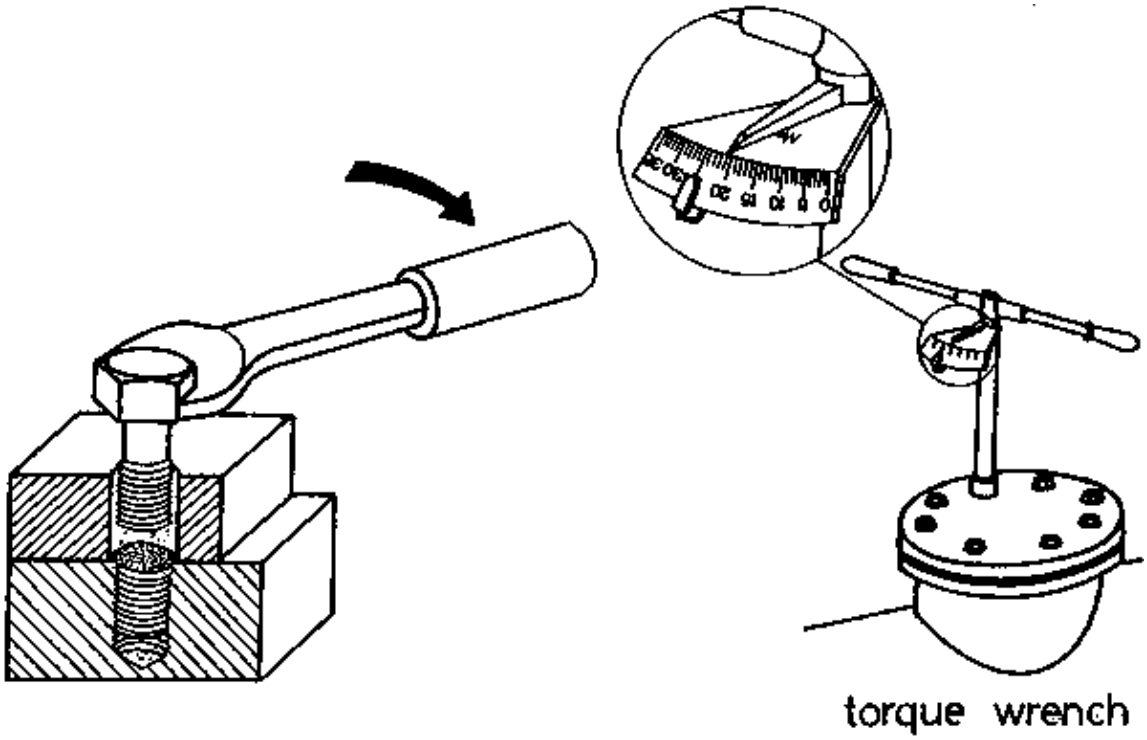
– too much torque

– two different thread
– screw not applied correctly
– dirty or rusty thread

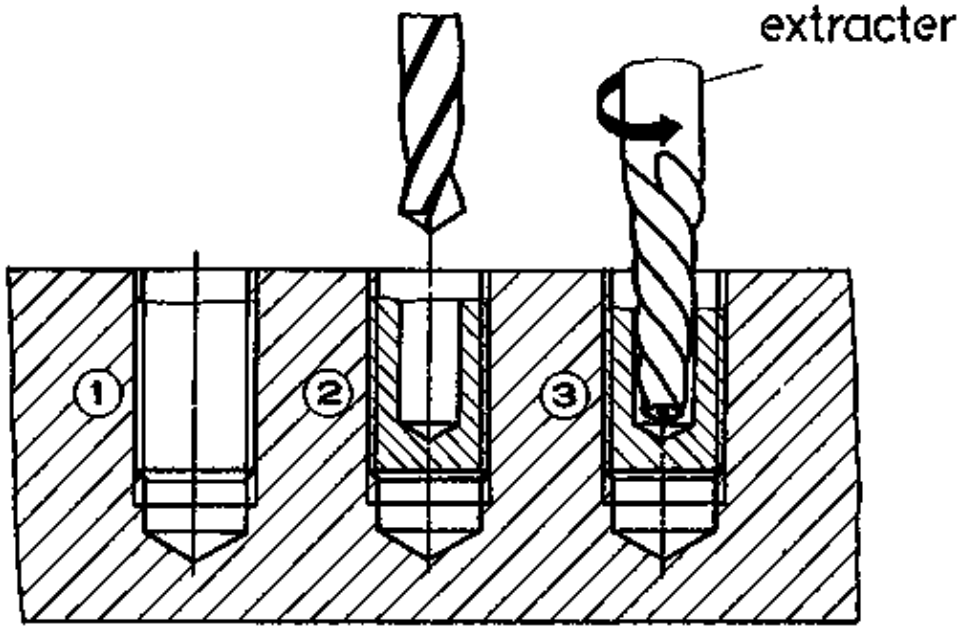
RUST AND OIL IN THREAD



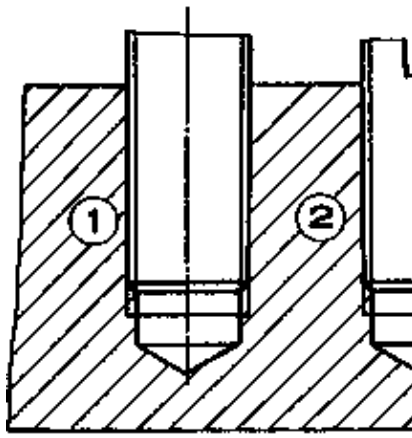
USAGE OF TORQUE WRENCH



EXTRACT BROKEN BOLTS FROM WORKPIECE



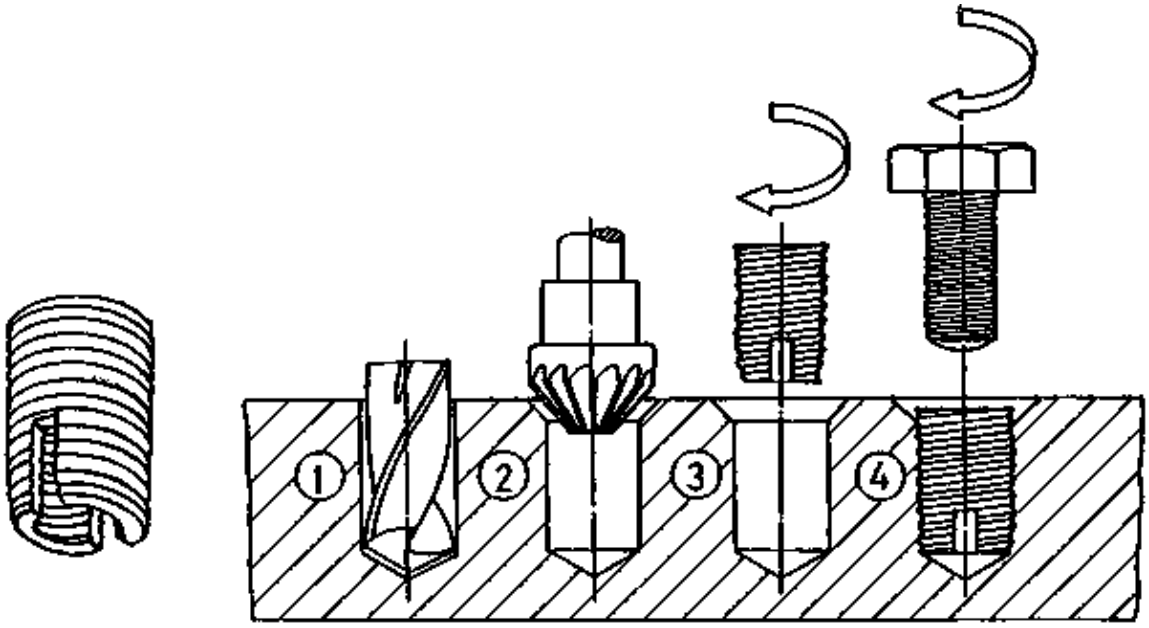
use extracter



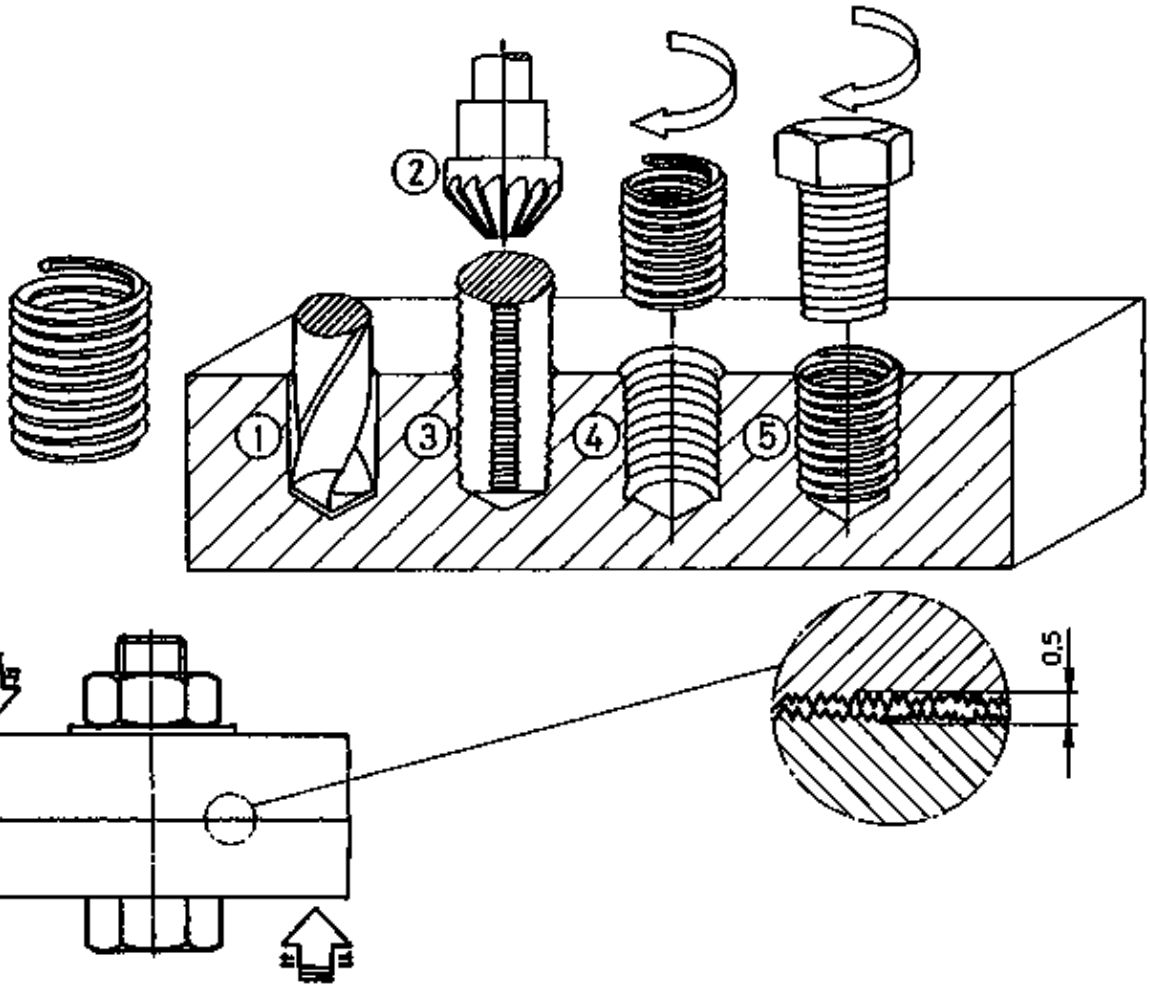
use saw and

REPAIR INTERNAL THREAD

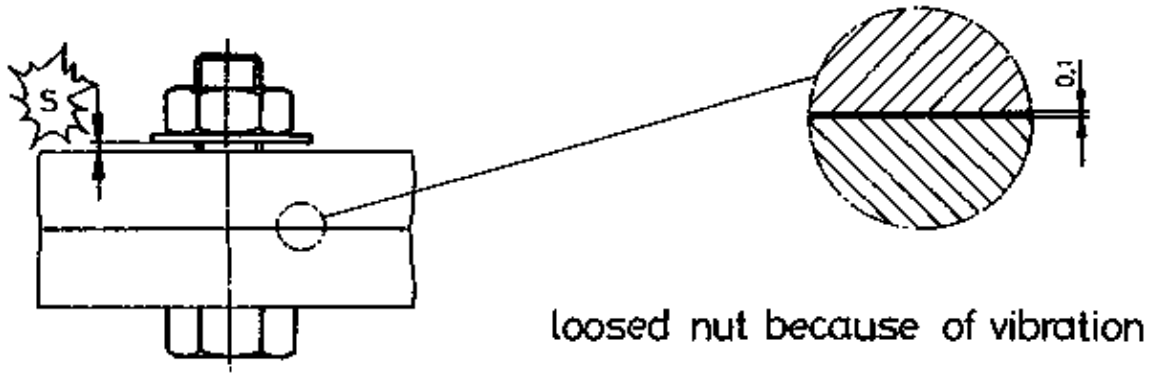
1 Screw bush



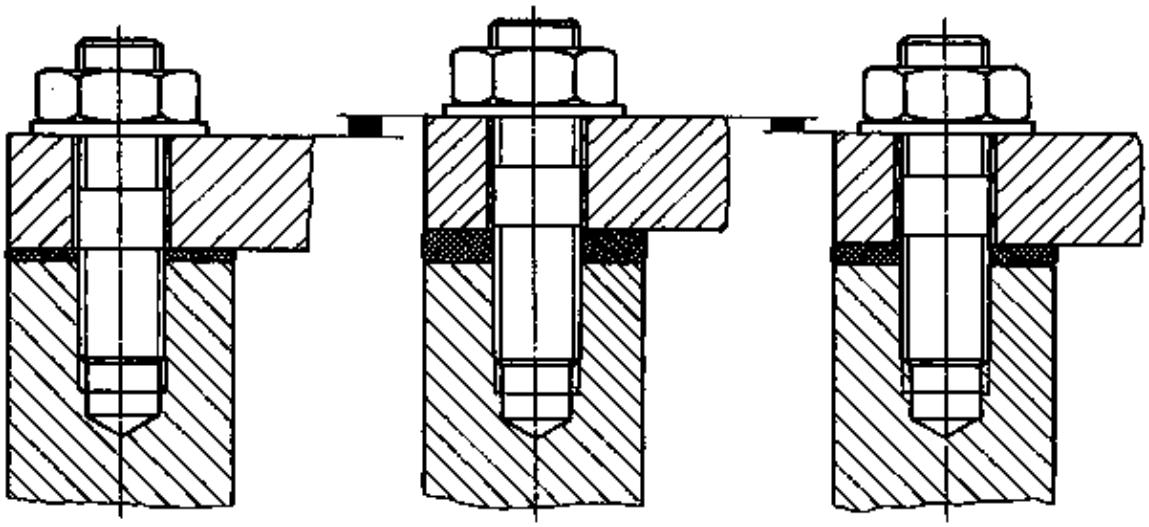
2 Helicoil



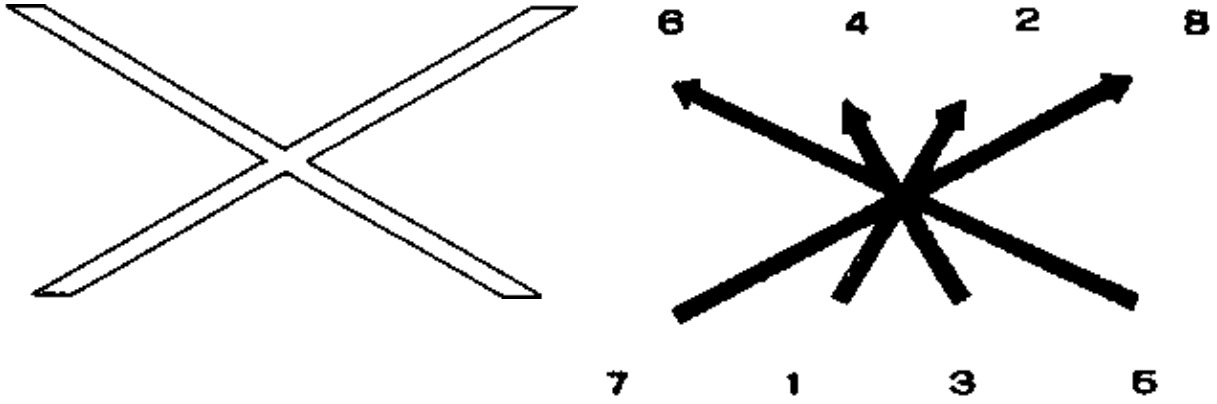
during work



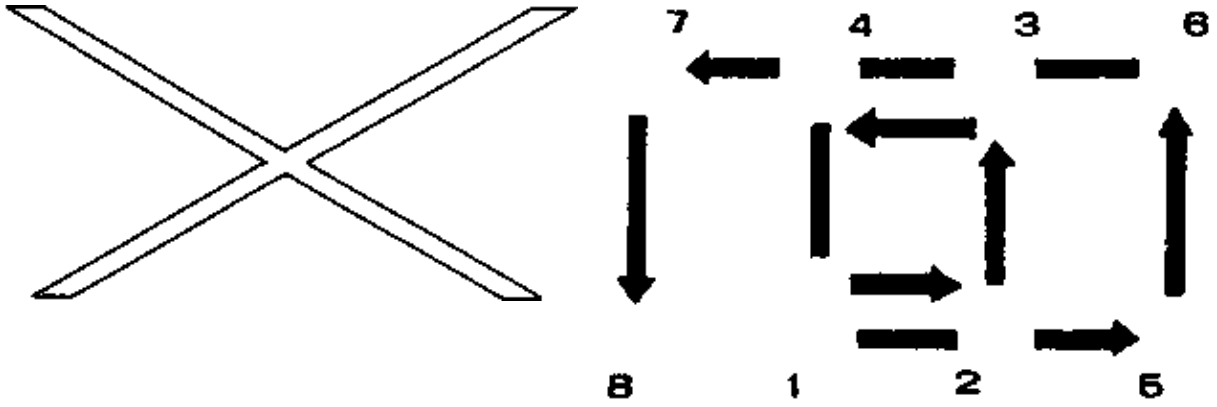
after some service time



When heated and vibrated, stud will be elongated

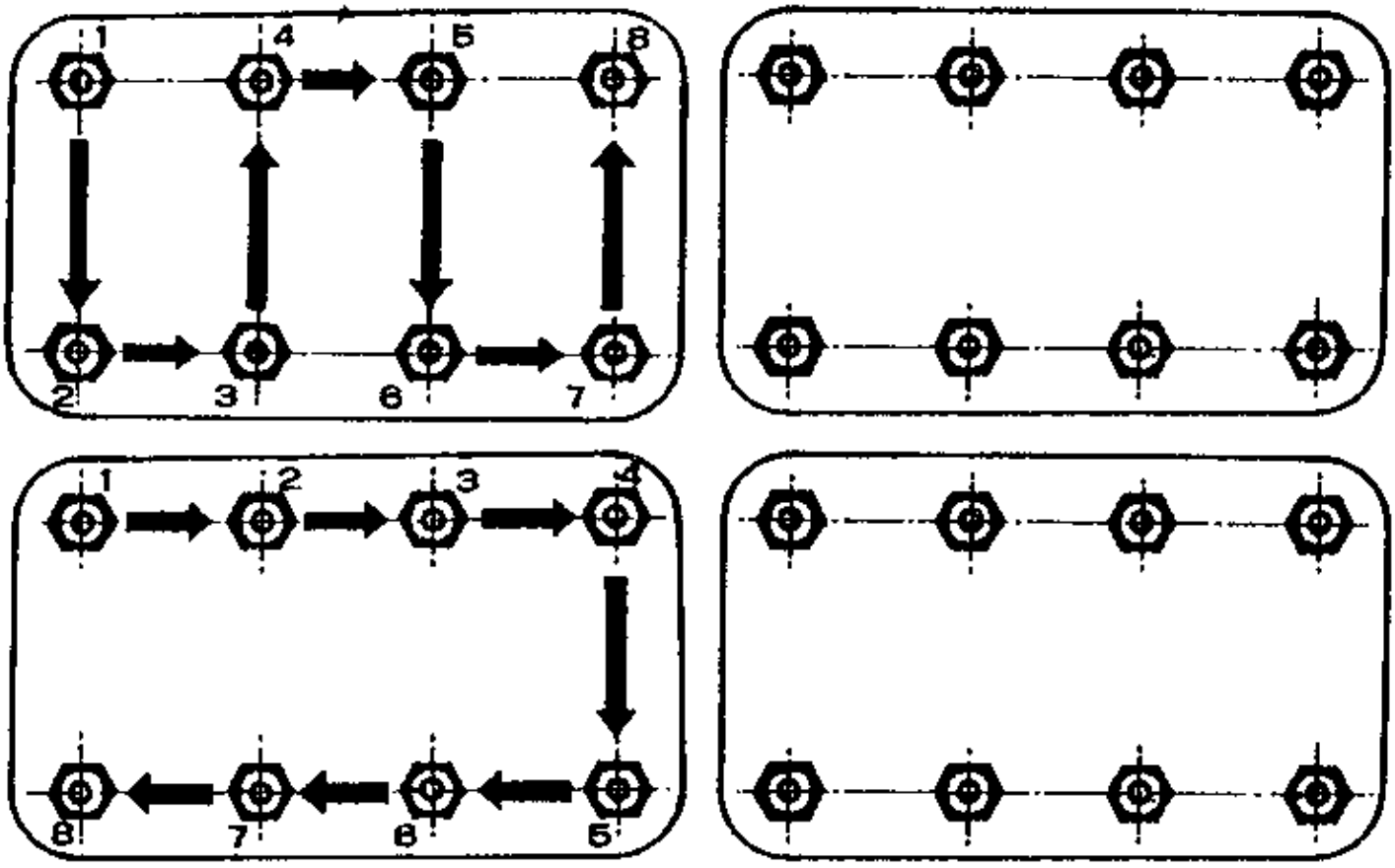


1. Over cross



2. Circular

TIGHTEN NUTS AND SCREWS IN A CERTAIN ORDER



3. Shaft–hub connections

List of objectives

I Purpose and basic principle

1. Explain the purpose of shaft–hub connections
2. Explain the basic principle of form fitting and friction transmission
3. Explain the difference between parallel and taper key in terms of

    a) torque transmission
    b) internal force
    c) shape

4. Explain why a taper key has an inclination of 1: 100

II Type and design

5. Distinguish between parallel and woodruft key in terms of shape and application
6. Distinguish between involute tooth and serration tooth profile in terms of shape and application
7. Distinguish between nose taper and saddle key in terms of shape and application
8. Explain the function of a woodruft key
9. Describe the application of shrink fit connections

III Assembly and repair

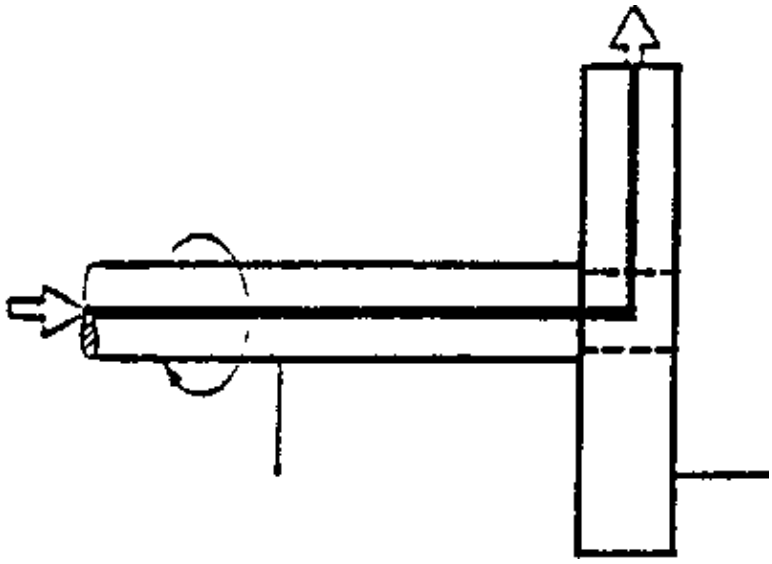
10. Describe the assembling of keys
11. Describe the disassembling of keys

12. Explain which fits are used with parallel and taper keys
13. Compare the application of parallel keys attached with and without screws
14. Describe the assembling and disassembling of parallel keys attached with screws
15. Describe the assembling of a shrink fit
16. Describe the disassembling of a shrink fit

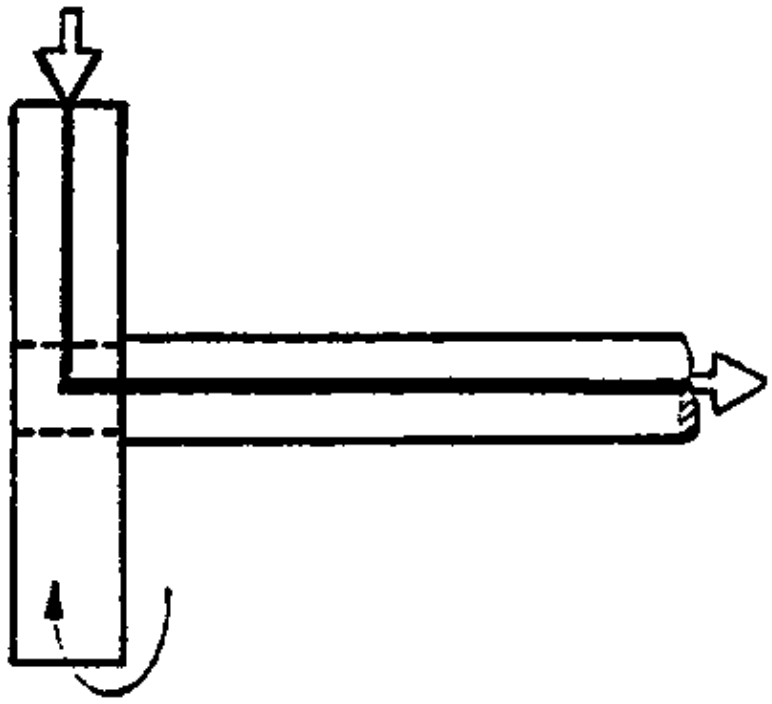
Information sheet

1. Purpose and basic principle

1.1 Torque transmission between shaft and hub

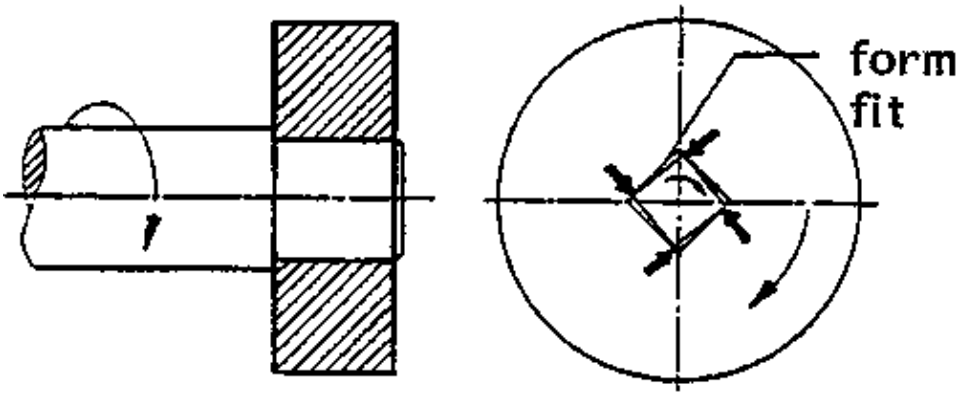


– Torque transmission from shaft to hub

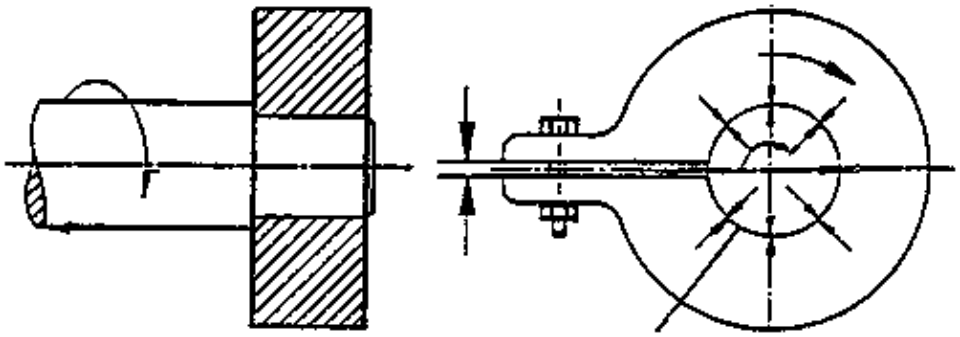


– Torque transmission from hub to shaft

1.2 Two ways of torque transmission

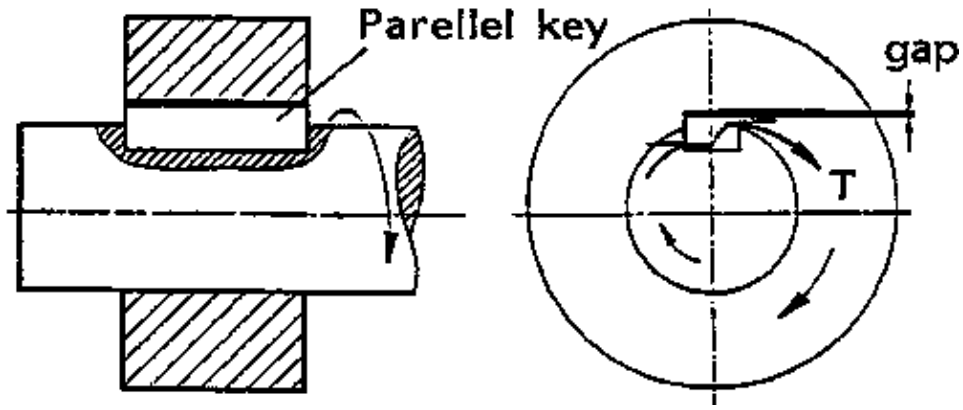


1.2.1 by form



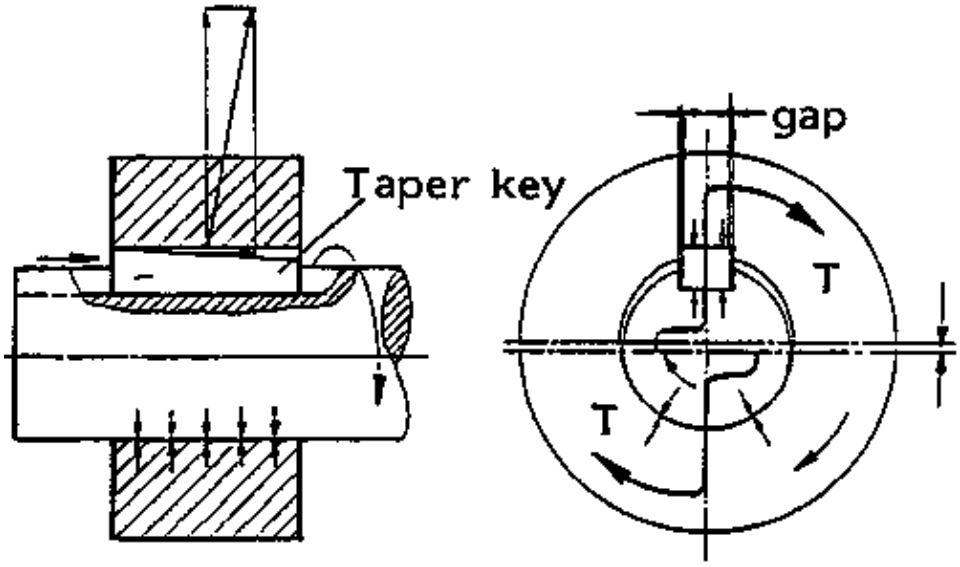
1.2.2 by friction

1.3 Internal force and flow of torque



1.3.1 Parallel key

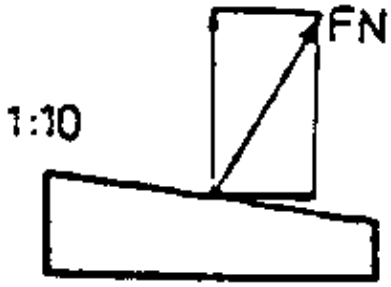
– rotating centre of hub true
– all torque (T) flows through the parallel key



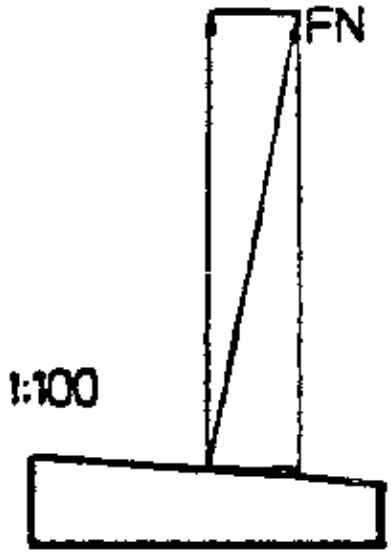
1.3.2 Taper key

– rotating centre out of true because of excentricity between shaft and hub
– torque flow is divided

1.4 Key slope

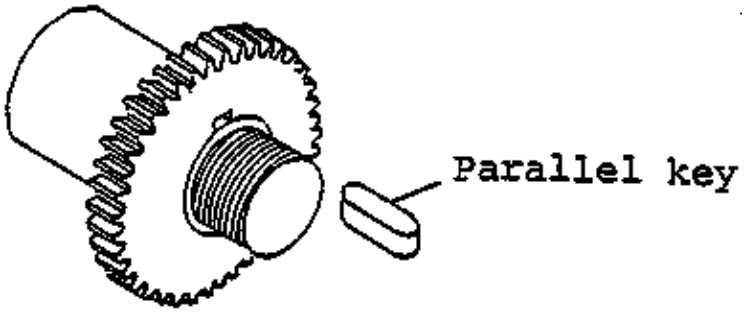


– low force due to high inclination
– not self locking

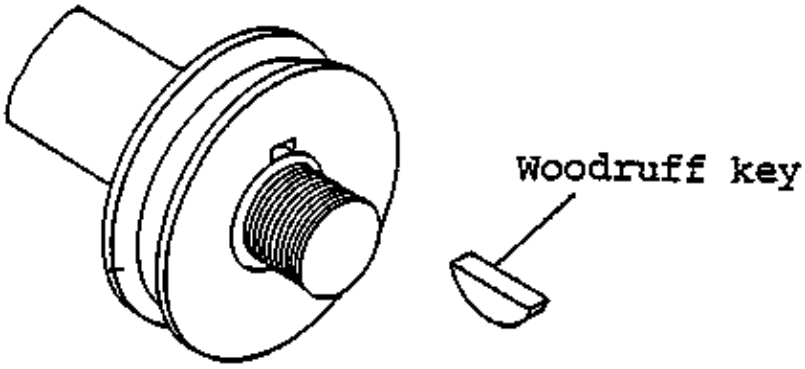


– high force due to low inclination
– self locking

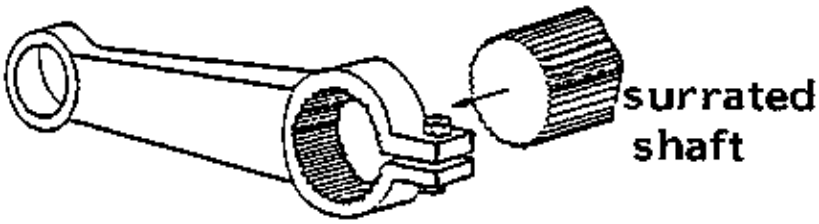
2.1 Design and application form fitting joints



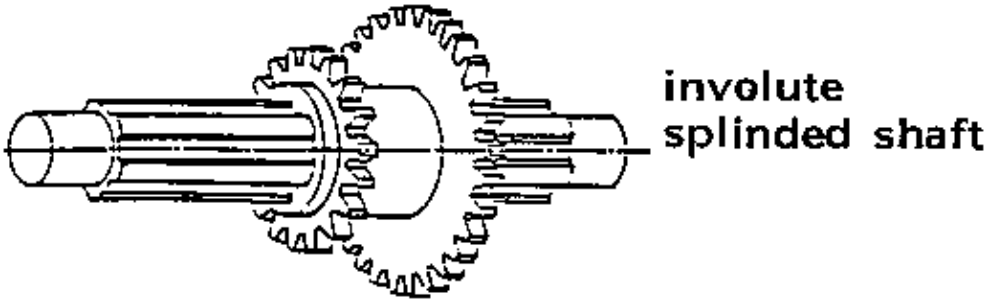
– used for high torque transmission



– used for low torque transmission. Due to the key groove depth, the strength of shaft is reduced.

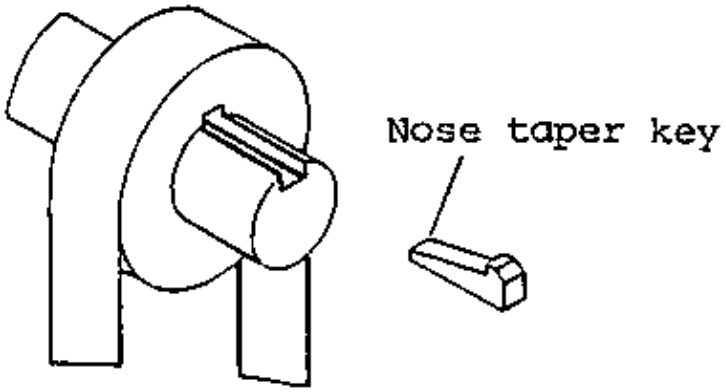


– used for high torque and lever connection

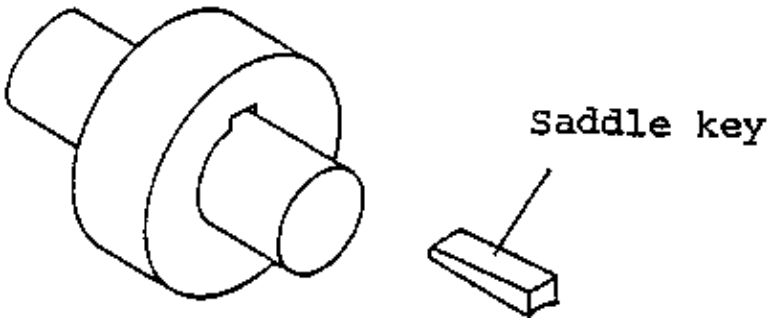


– used for very high torque transmission and as a slide way for gear wheels

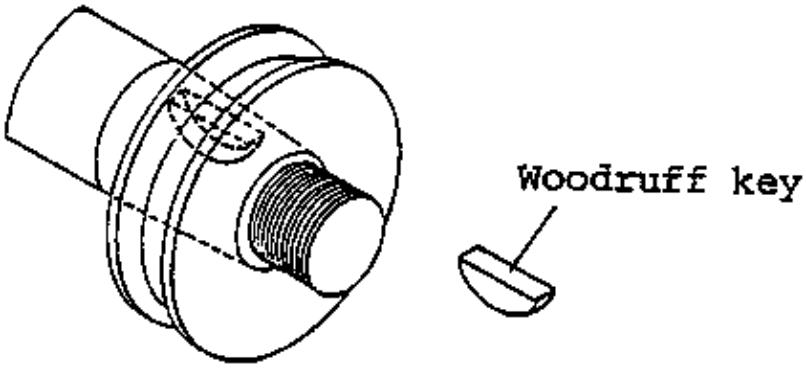
2.2 Shape and application of friction joints



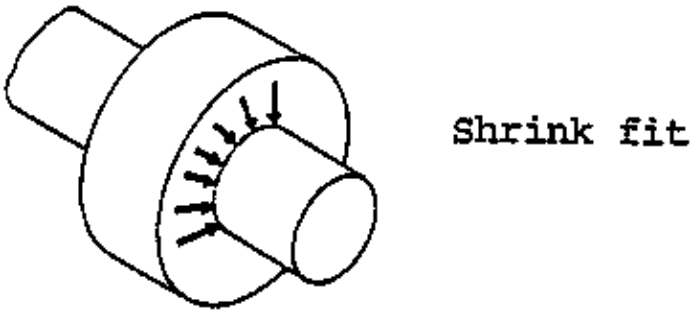
– is used for high torque transmissions and low revolutions



– is used for low torque transmission and low revolution
– shaft and hub can slip in case of high torque



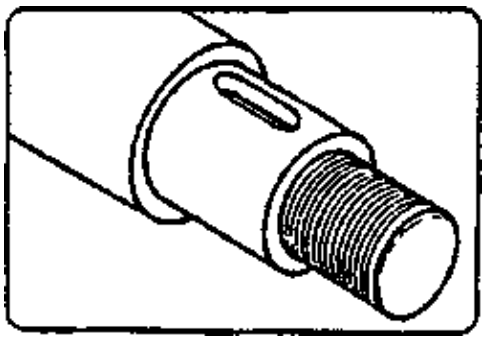
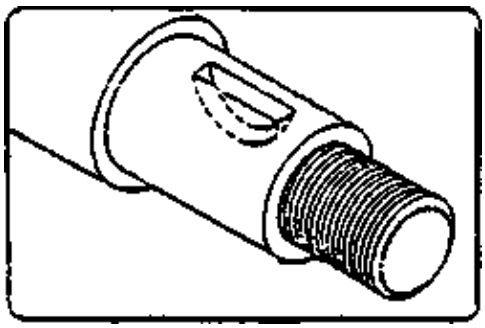
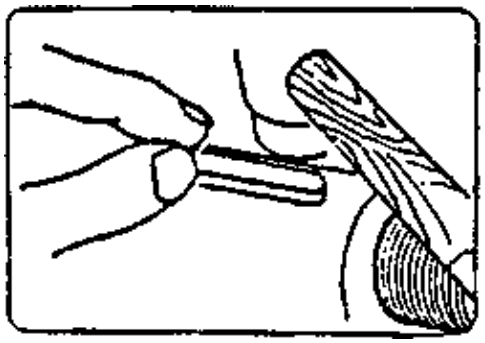
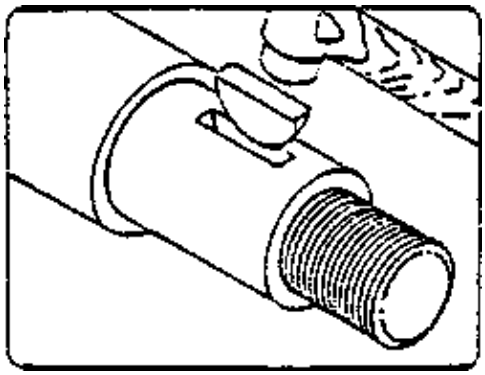
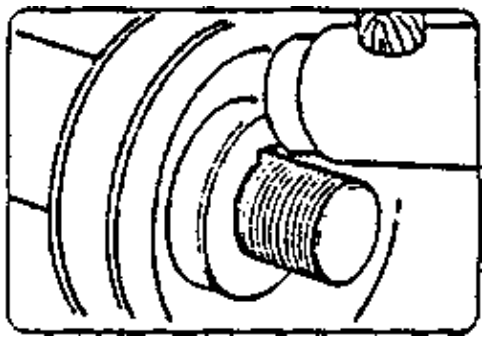
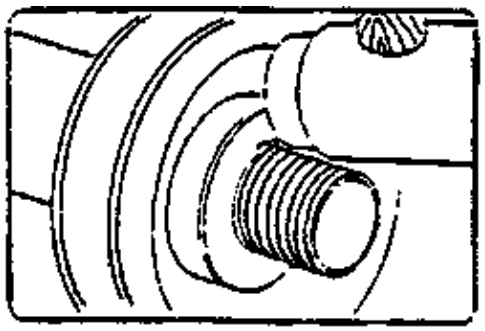
– used with taper shaft function as locating element. Torque transmission due to the friction between tapered wheel and shaft.



– is used, when the connection is not disassembled very often.

3.1 Assembling of keys

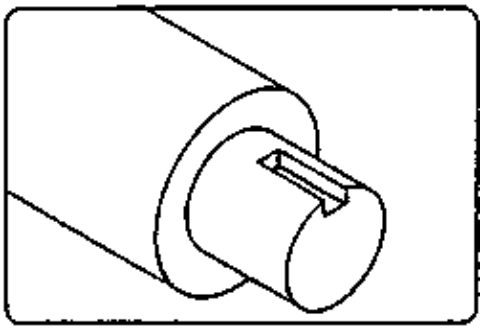
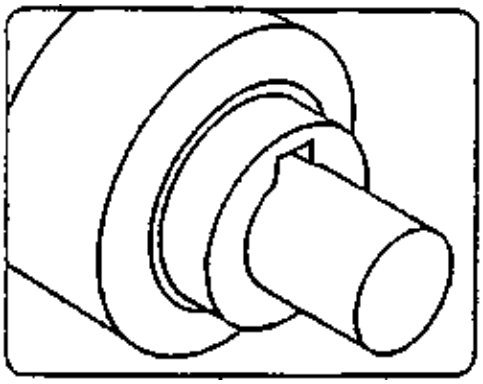
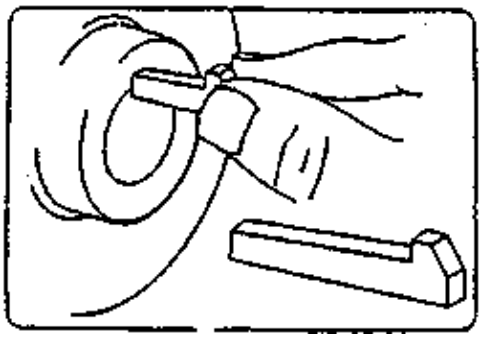
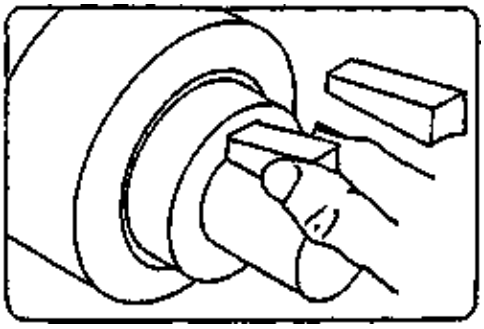
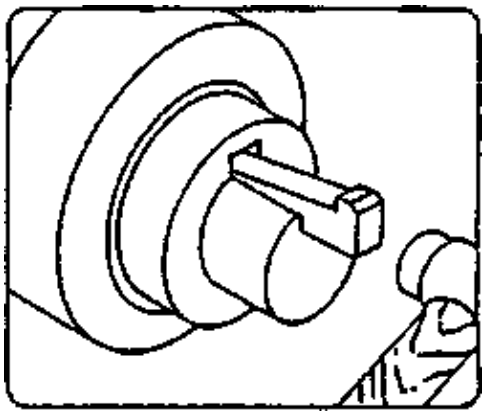
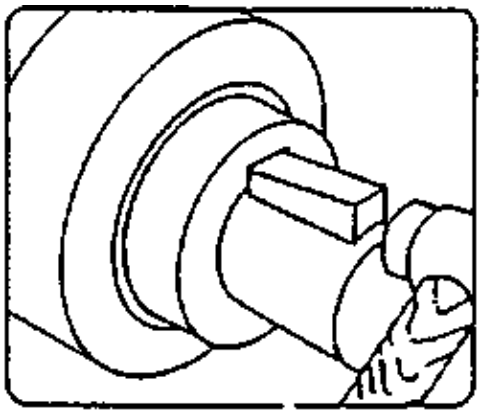
3.1.1 form fitting joints

1. 	– put the key in the keyway	1. 	– put the key in the keyway
2. 	– fit it with a soft hammer	2. 	– fit it with a soft hammer
3. 	– hammer* around the hub until it fits on the shoulder, then look it with a nut	3. 	– hammer* around the hub until it fits on the shoulder then lock it with a nut

* use only a soft hammer

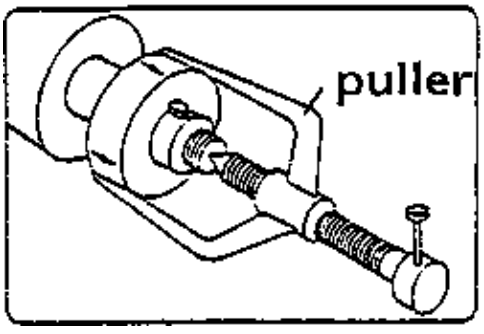
3.1.2 Friction joints

	– cut a keyway		– assemble hub and shaft

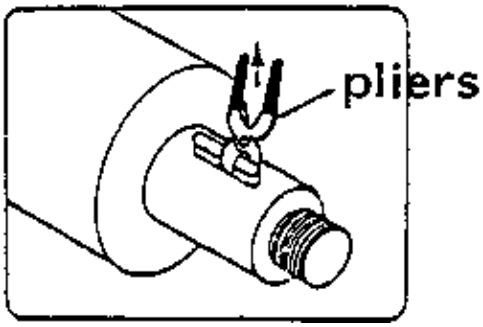
			
	– assemble hub and shaft, then put a nose taper key in the keyway		– put a taper key in in the key way
	– hammer on the key grip until it fits		– hammer on the key till it fits

3.2 Disassembling of Keys

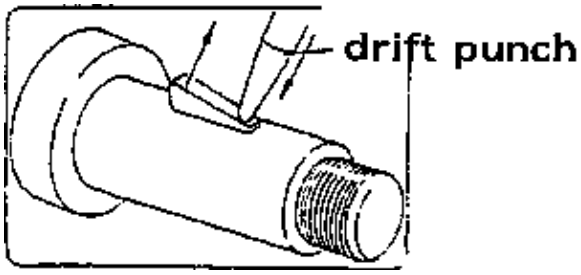
3.2.1 Form fitting joints



– disassemble the hub with a puller

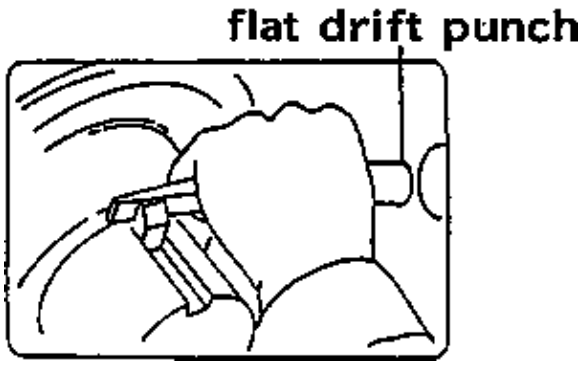


– remove the key with pliers

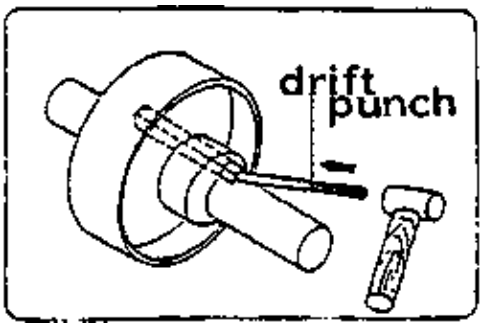


– remove the wood ruft key with a drift punch flat drift punch

3.2.2 Friction joints

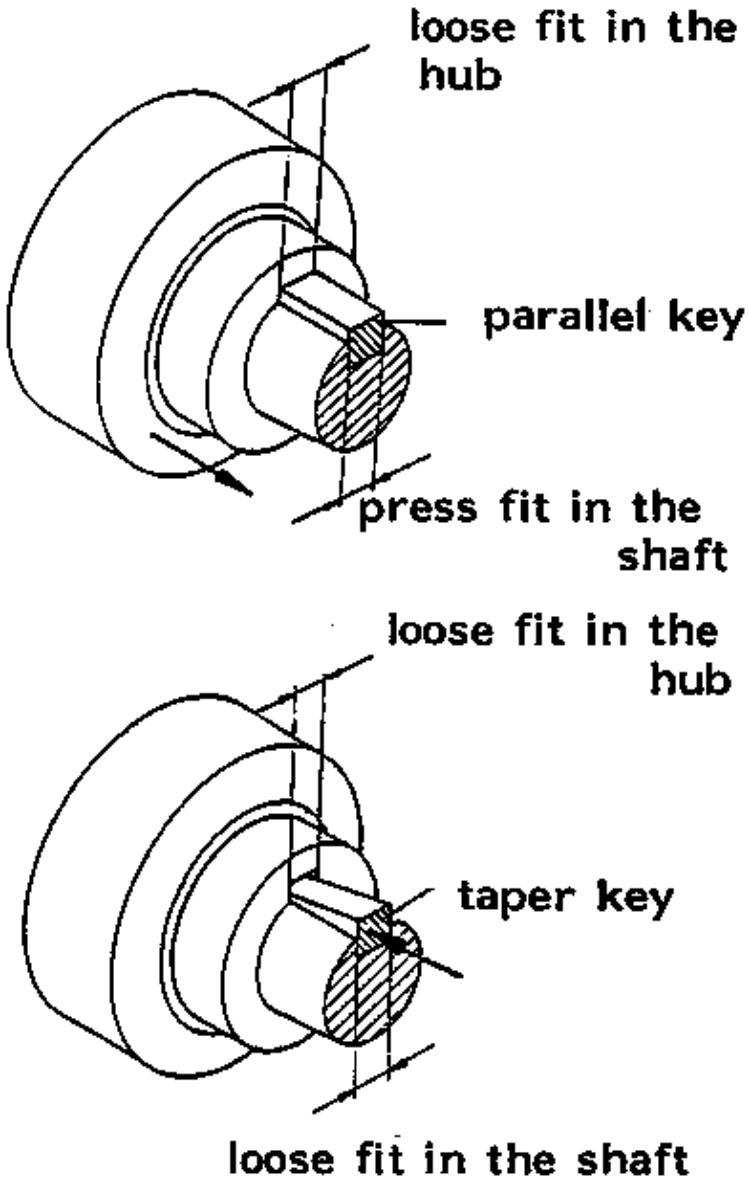


– loosen the key with a flat drift punch



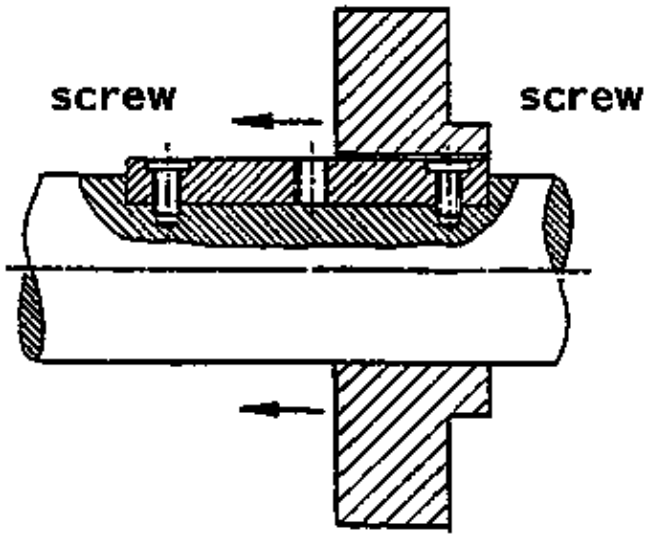
– push the key at its lower side

3.3 Fits of keys and keyways

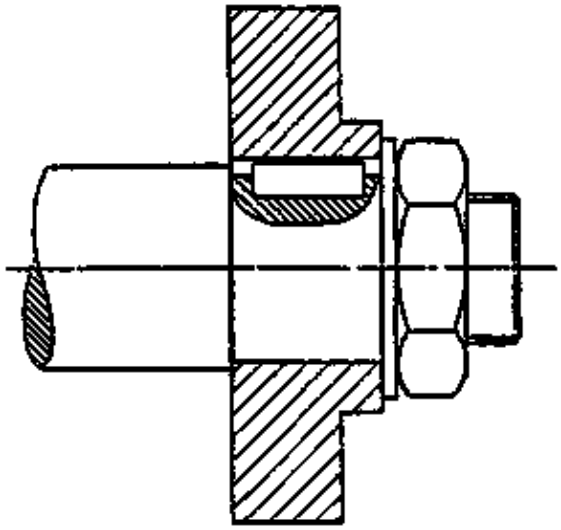


Note: The fits can be found in the table book

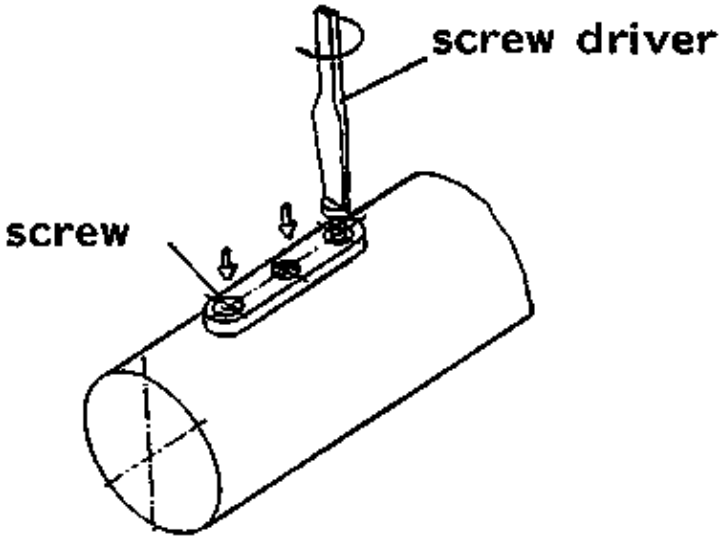
3.4 Parallel Keys fixed with screws



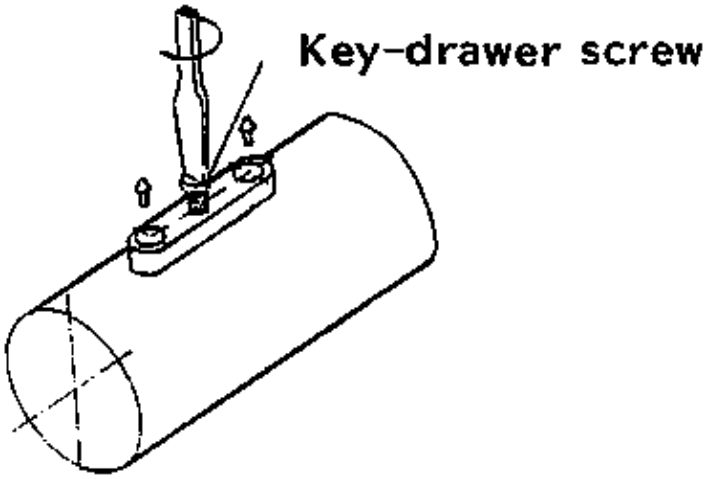
– the screws are fixing the key while the hub is moving



– parallel key without screw is used for a fixed hub

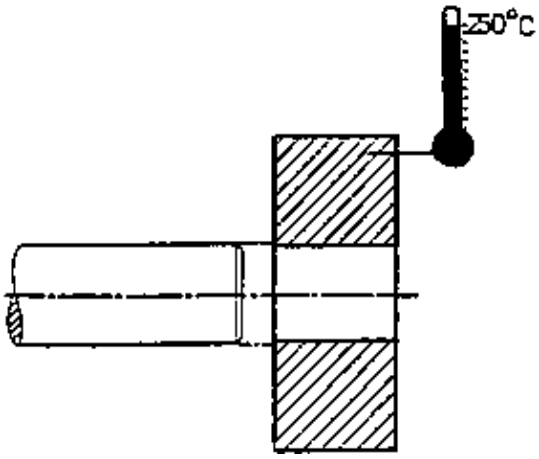


– assembling of a parallel key by tightening the screws

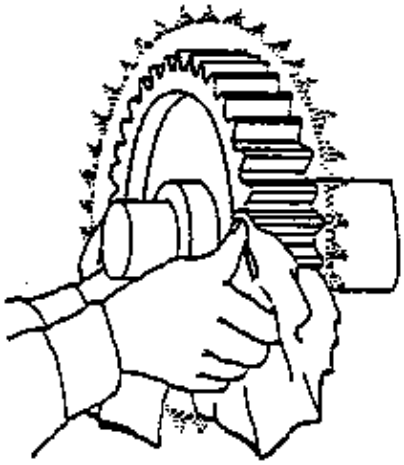


– disassembling of a parallel key by tightening the key–drawer screw

3.5 Assembling and disassembling of a shrink fit

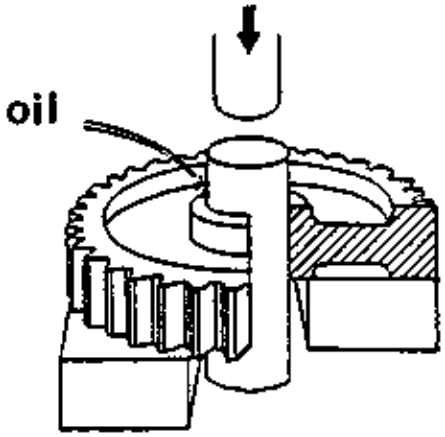


– heat the hub before assembling



– put the hub on the shaft immediately
– let it cool down in the atmosphere

3.6 Disassembling a shrink fit



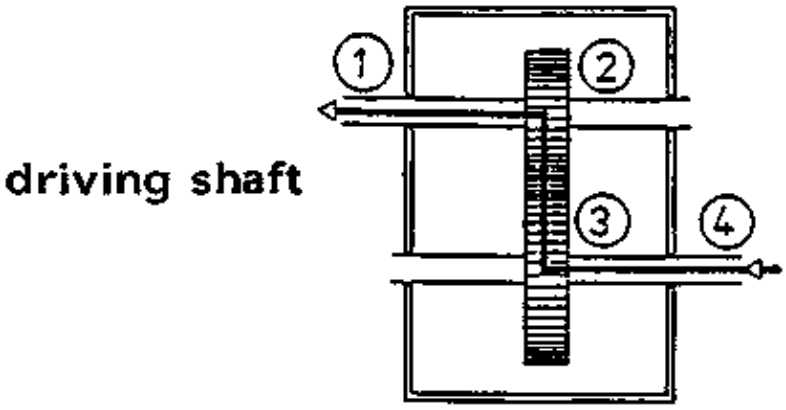
– disassemble the shaft with a press

Note: Lubricate with oil to avoid damage of hub and shaft.

Task sheet

1.1

a) The purpose of a shaft – hub connection is to _____
b) Fill in the works "Shaft" or "bus" in the emty lines below!



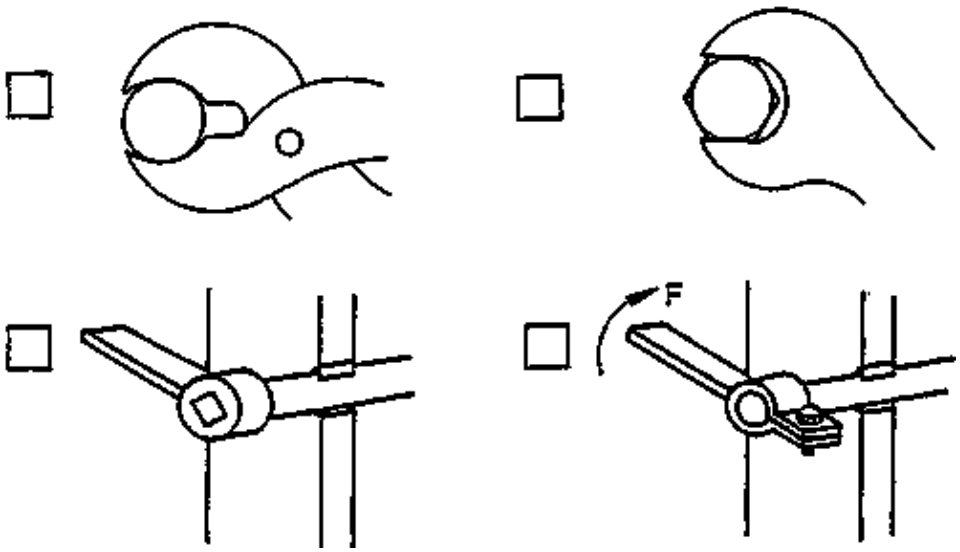
Torque transmission from 1 to 2 transmits from _____to _____
Torque transmission form 3 to 4 transmits from _____to_____

1.2

a) There are two principles of torque transmission

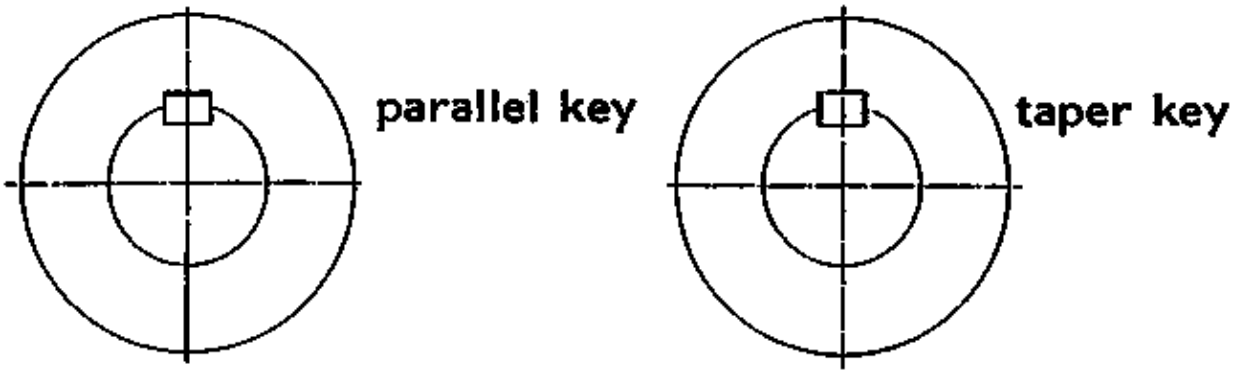
1. _____
2. _____

b) Mark the example where torque is transmitted by friction!



1.3

a) Torque transmission by friction is done by parallel key/taperkey
b) Using a taper key for power transmission leads to true/untrue running
c) Show the flow of torque by drawing an arrow in the drawing below

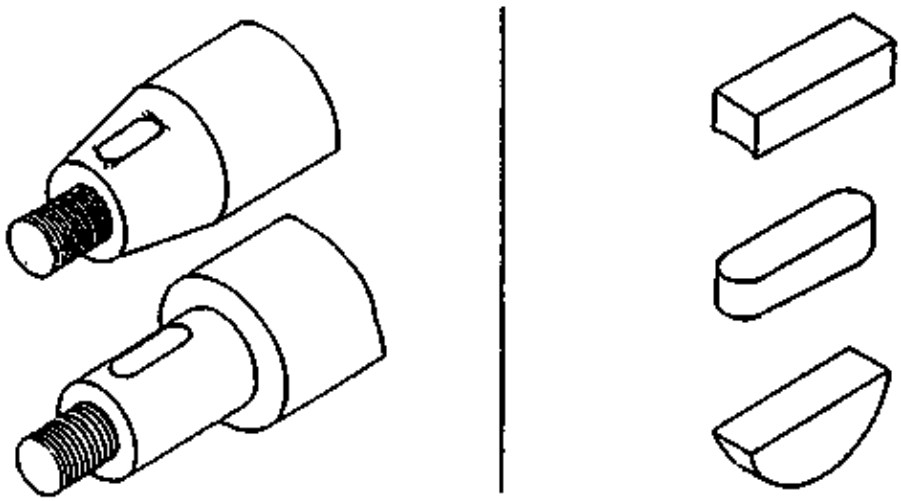


1.4

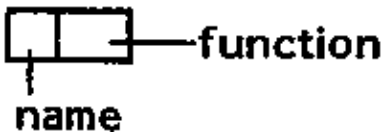
a) Taper keys normally have inclinations of 1:50/1:100/1:200
b) An inclination of 1:50 creates move/lessforce than one of 1:100

2

a) Relate the appropriate key to the drawings by connecting them with a line

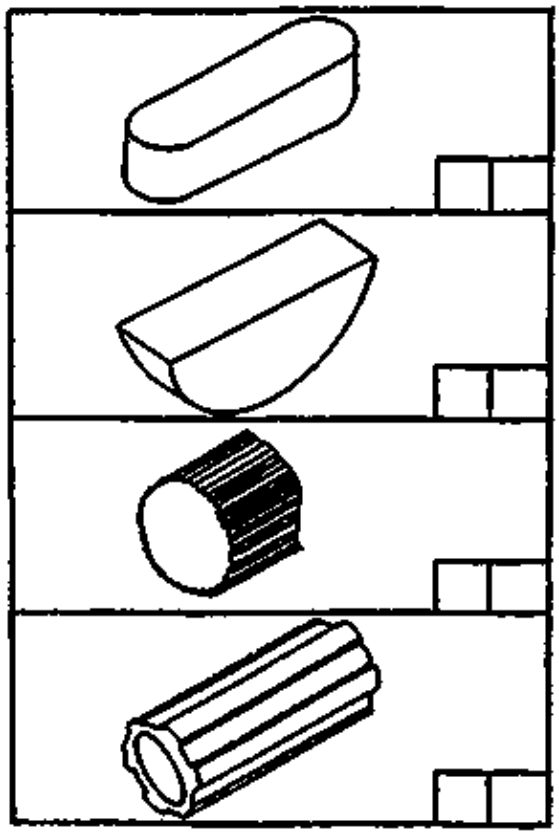


Name the keys and add their applications by filling in the appropriate letters and numbers

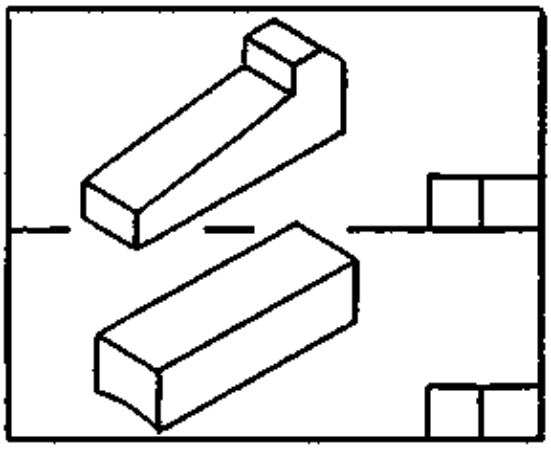


b)

Name	Application
a) saddle key	1. for high torque and revol.
b) nose taper key	2. for high torque and low revolution
c) parallel key	3. for high torque and axial movable
d) woodruft key	4. for low torque
e) involute splind shaft	5. for high torque and lever connection
f) survateted shaft	6. for low torque and low revolution



c)



d) A woodruft key which is used with a tapered shaft

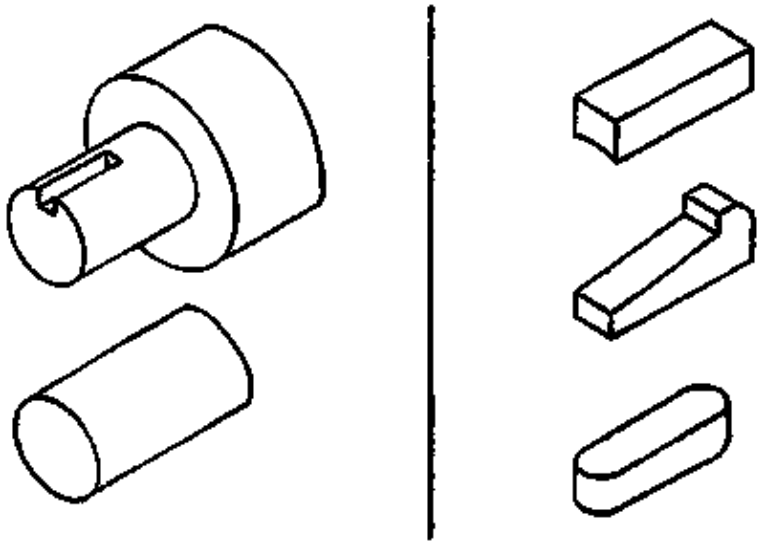
is fixing the hub in the center
is fixing the hub in a certain position to the shaft
prevents axial movement of the hub

e) A shaft–hub connection which is very seldom disassembled can be realized as a tapered shaft/shrink fit/involute spline shaft

f) Which type of key can be used easily at any position of the shaft? A nose taper key/a woodruft key/a saddle key

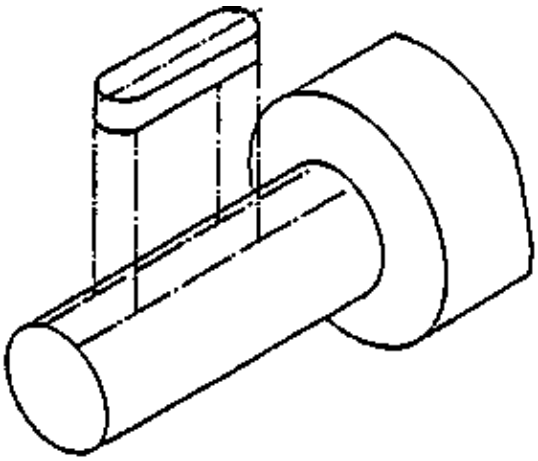
g) Which type of key is located at the end of a shaft without any additional fixing elements? A nose taper key/a parallel key/a woodruft key

h) Relate the appropriate key to the drawings by connecting them with a line!

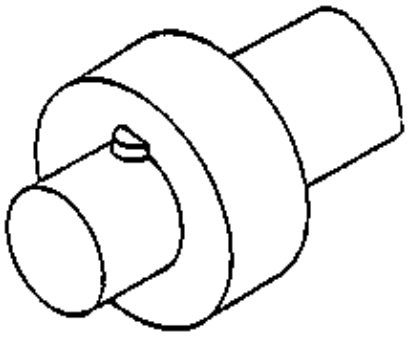


3.1

a) Sketch the appropriate key way on the shaft!

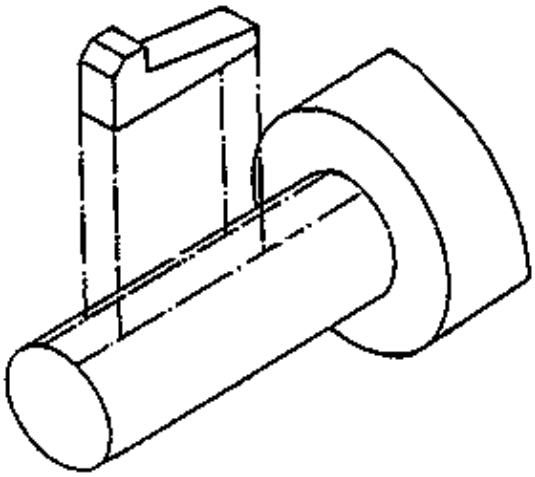


b) Write the correct sequence of assembling a parallel key in the lines

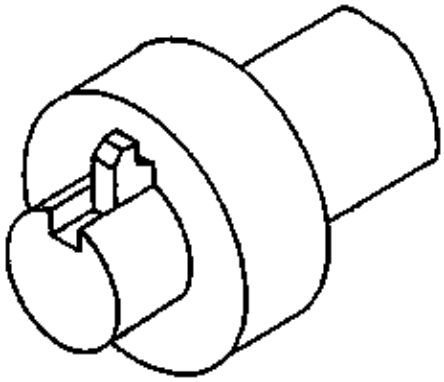


1. _____
2. _____
3. _____

c) Sketch the appropriate key way on the shaft!



d) Write the correct sequence of assembling a taper key in the lines!



1. _____
2. _____
3. _____

3.2

a) How is a parallel key dismounted?

By using a drift punch to remove the key
By sliding a wheel along the shaft axis
By using pliers to remove the key

b) Which type of key is disassembled by pushing it out along the shaft axis with a drift punch?

a parallel key
a saddle key
a woodruft key

3.3

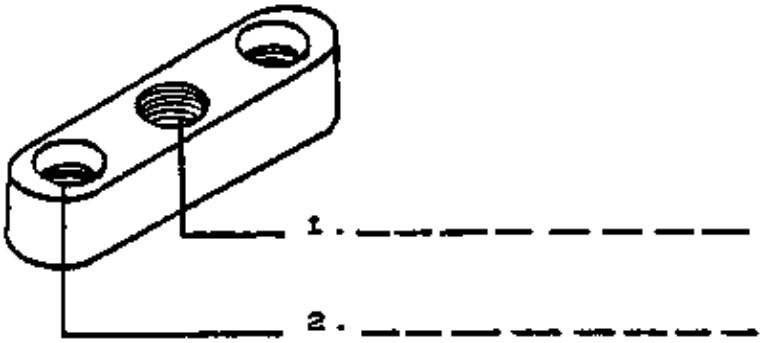
a) A parallel key is mounted in the key way of the shaft with a press fit/loose fit
b) A taper key is mounted in the key way of the hub with a press fit/loose fit

3.4

a) A parallel key with fixing screw is suitable for

a wheel which moves on the shaft
low torque transmission
a joint which is often dismounted

b) Describe the function of the threads in the key shown in the figure below.



3.5 When assembling shaft and hub by shrink fit the following jobs must be done:

heat the shaft/mount the hub on the shaft by hand
heat the hub/mount the hub on the shaft by a press
heat the hub/mount the hub on the shaft by hand

3.6. What must be considered to avoid damage of shaft and hub when dismounting them with a press?

Solutions

1.1

a) transmit torque

b) shaft to gear wheel
gear wheel to shaft

1.2

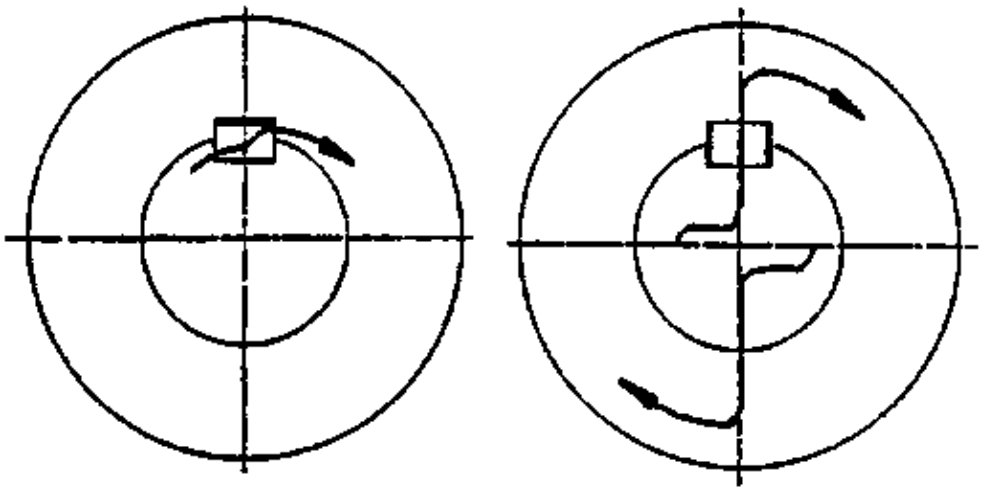
a) torque
transmission
by interlock
torque
transmission
by friction

b) x

x

1.3

a) taper key
b) untrue running
c)



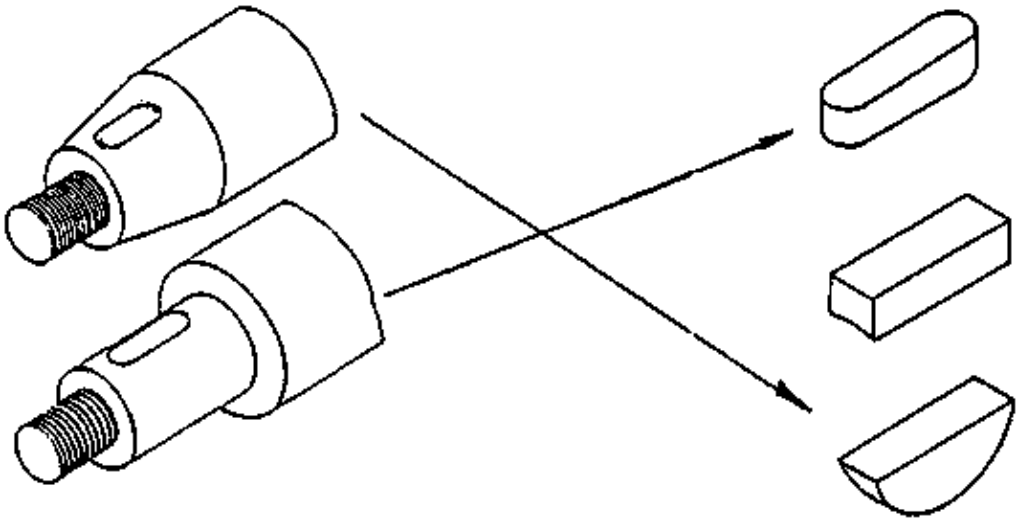
1.4

a) 1:100

b) less

2.

a)



b)

b	1
d	4
f	5
e	3

c)

6	2
a	6

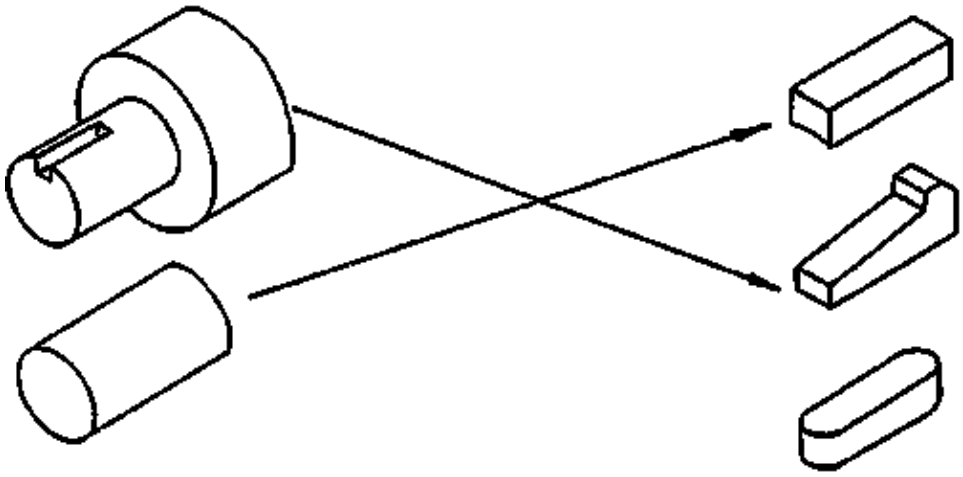
d) x is fixing the hub in a certain position to the shaft

e) shrink fit

f) saddle key

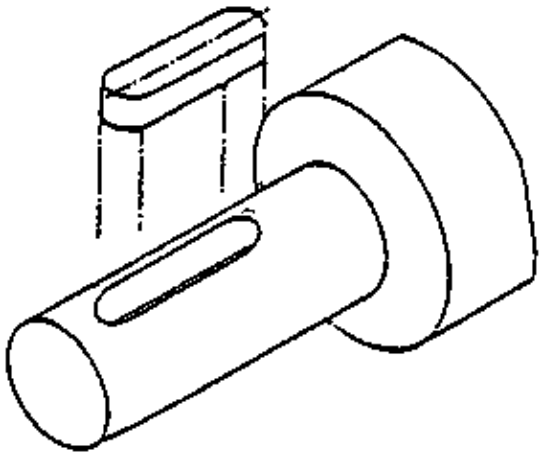
g) nose taper key

h)



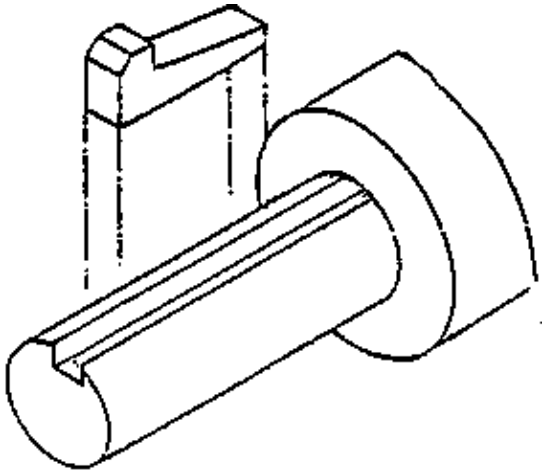
3.1

a)



b) 1. put a parallel key in the key way
2. fit it with a soft hammer
3. hammer around the hub until it fits on the shoulder and lock it

c)



d) 1. mount hub with shaft
2. insert the key in key way
3. hit it with a hammer until it fits

3.2

a) x By using pliers to remove the key

b) x a saddle key

3.3

a) press fit

b) loose fit

3.4

a) x a wheel which moves on the shaft

b) 1. thread for dismounting key
2. thread for fixing screw

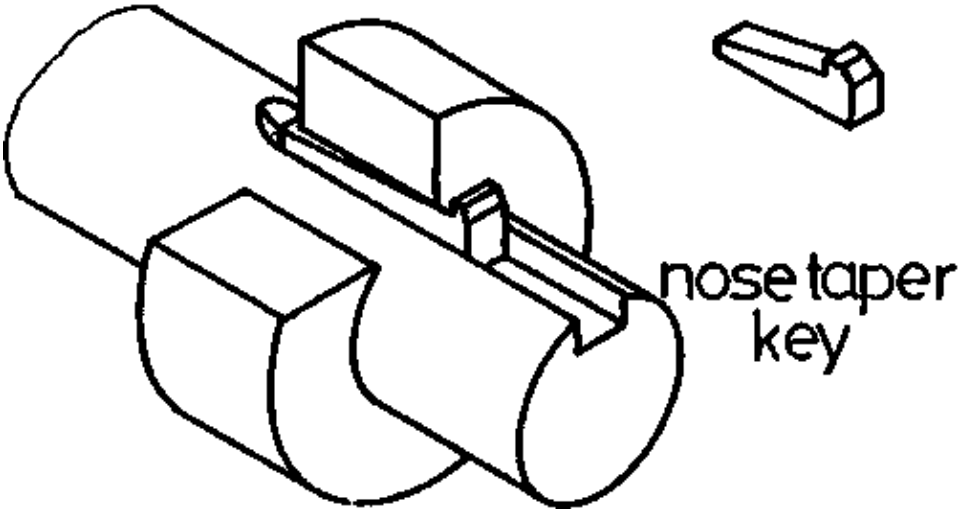
3.5

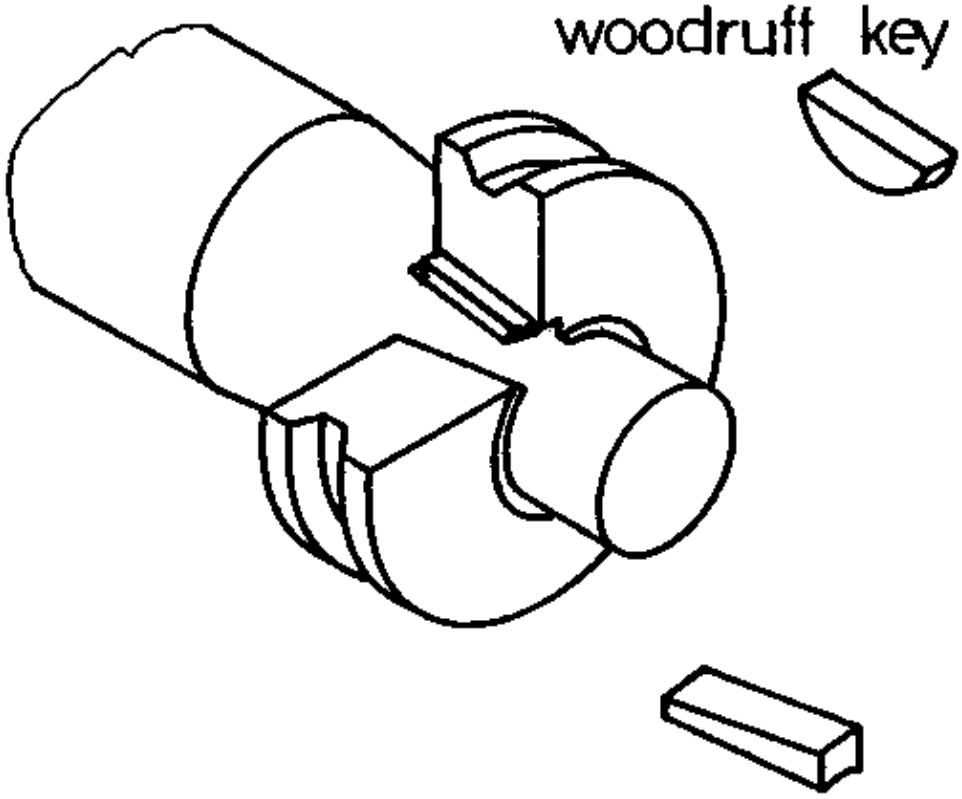
x heat the hub/mount the hub on the shaft by hand

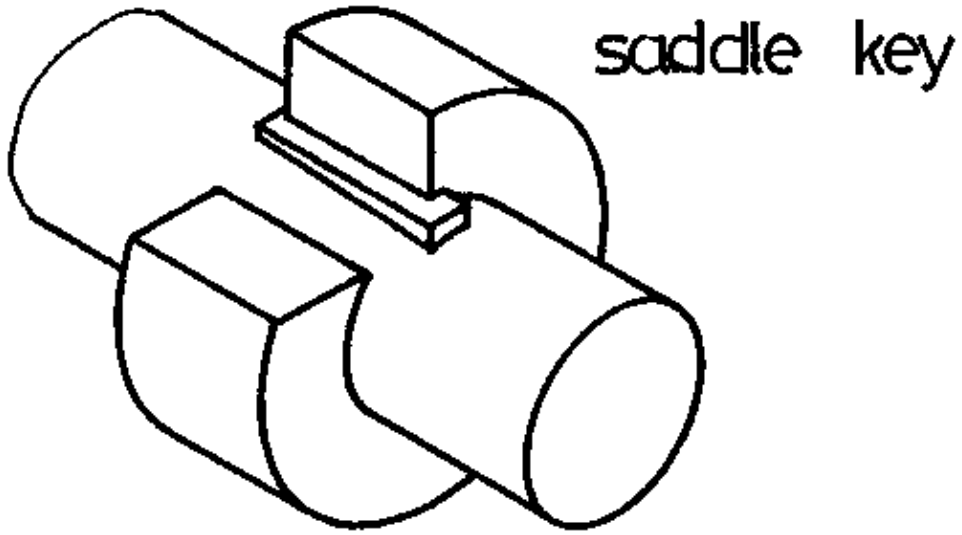
3.6

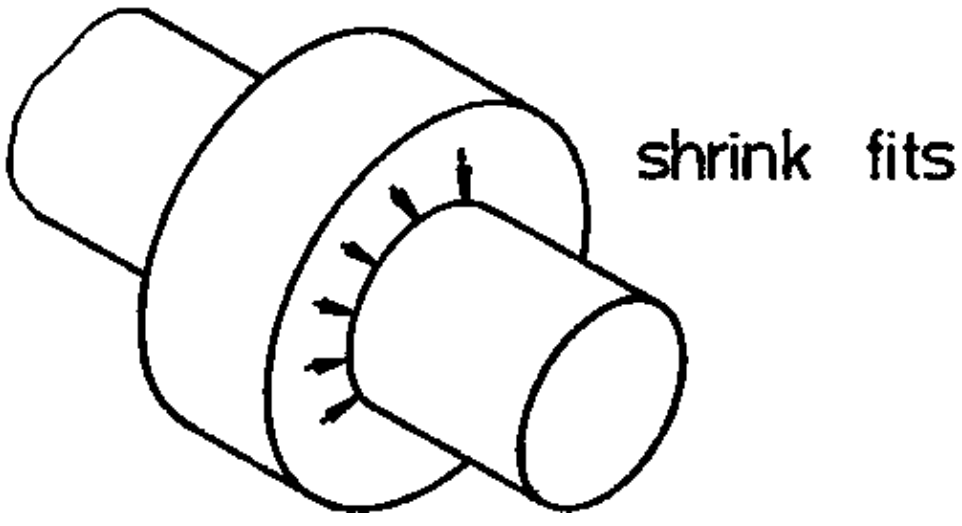
to put oil on the shaft

Form Friction Transmission

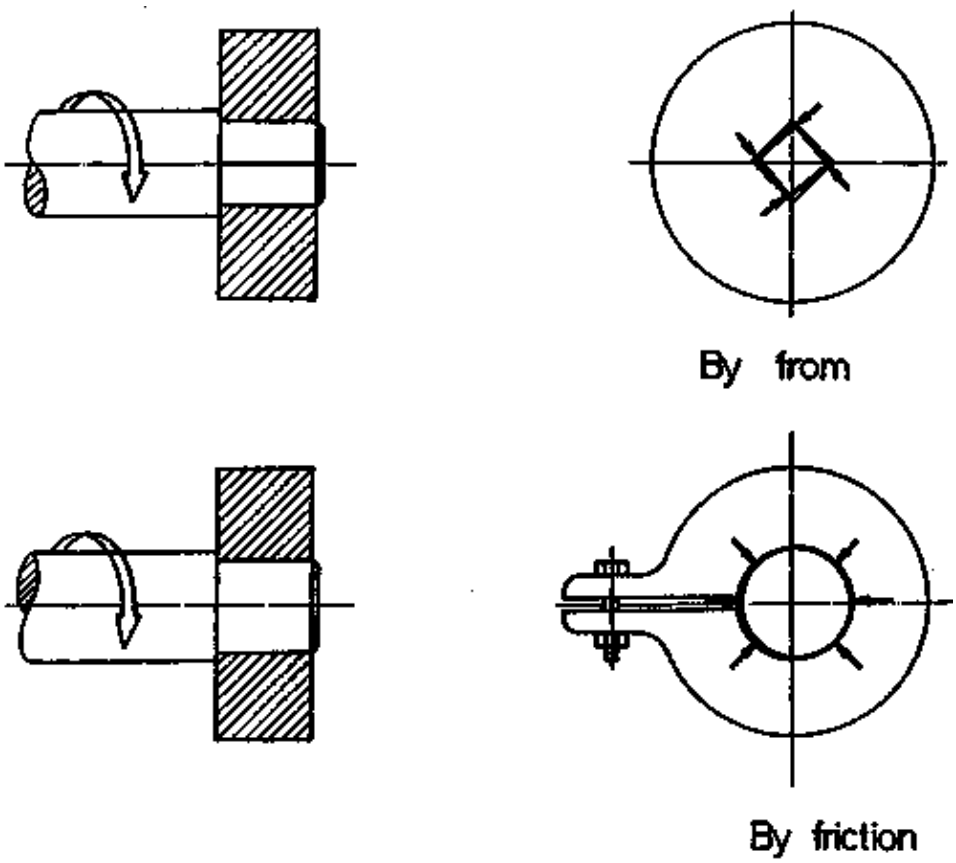



woodruff key


saddle key


shrink fits

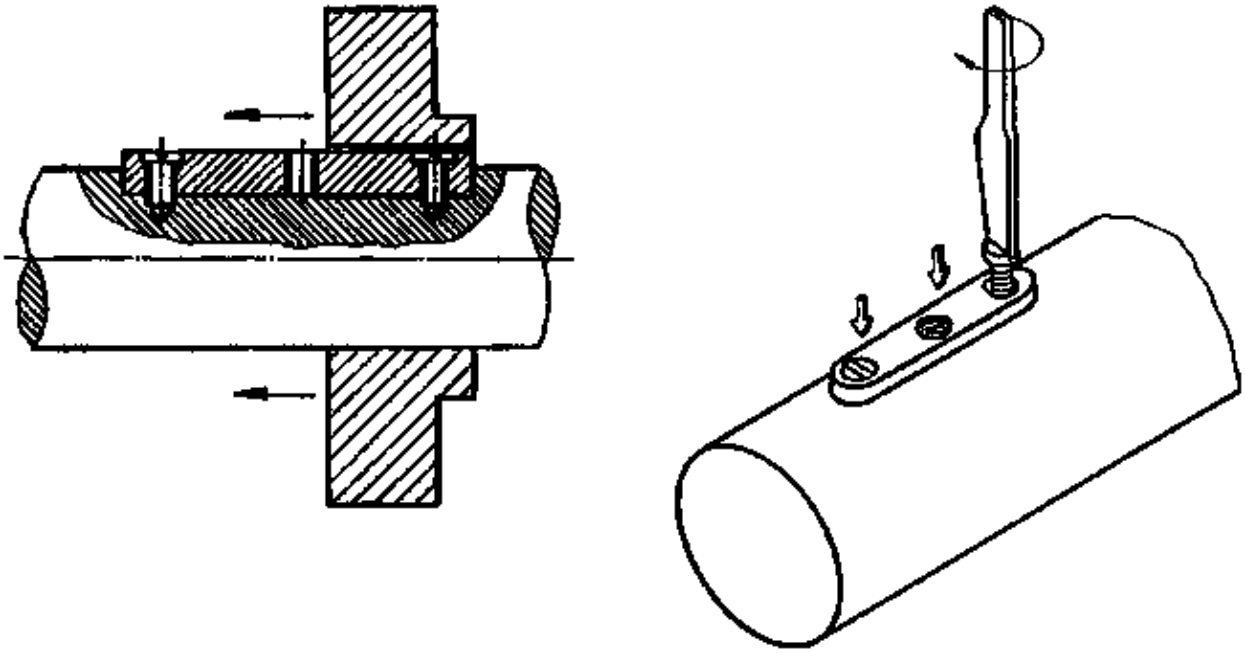
Torque Transmission

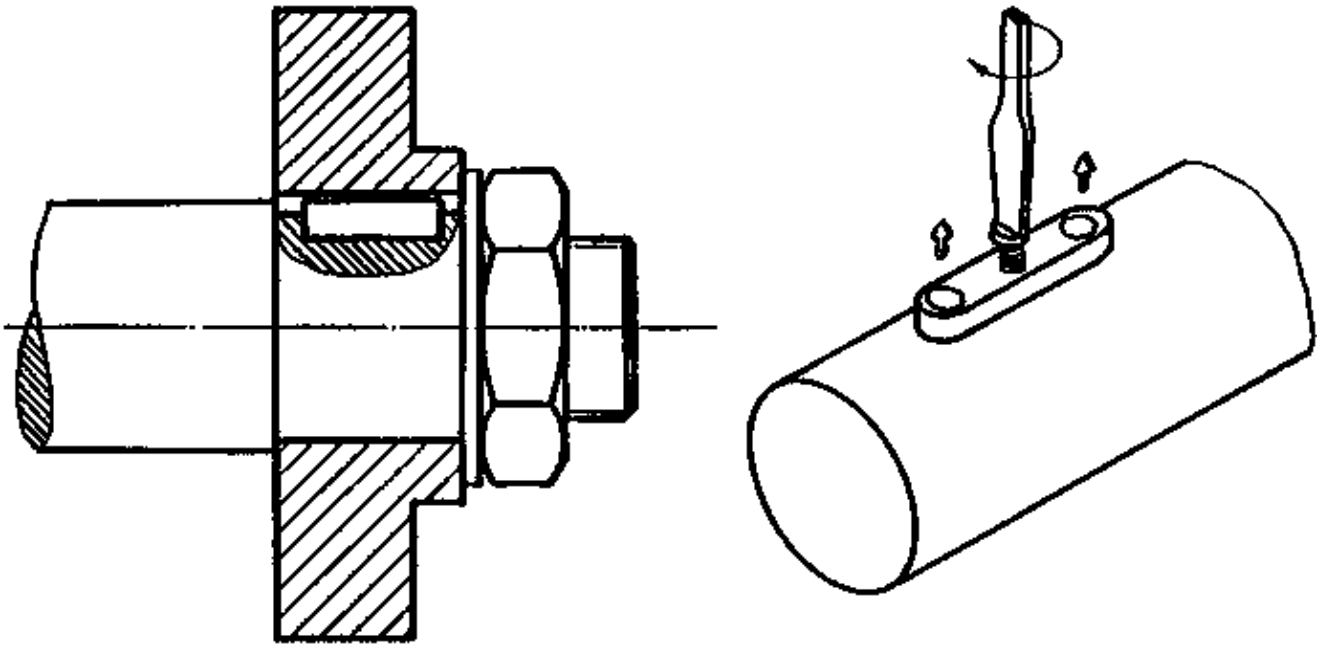


Parallel Keys fixed with serews

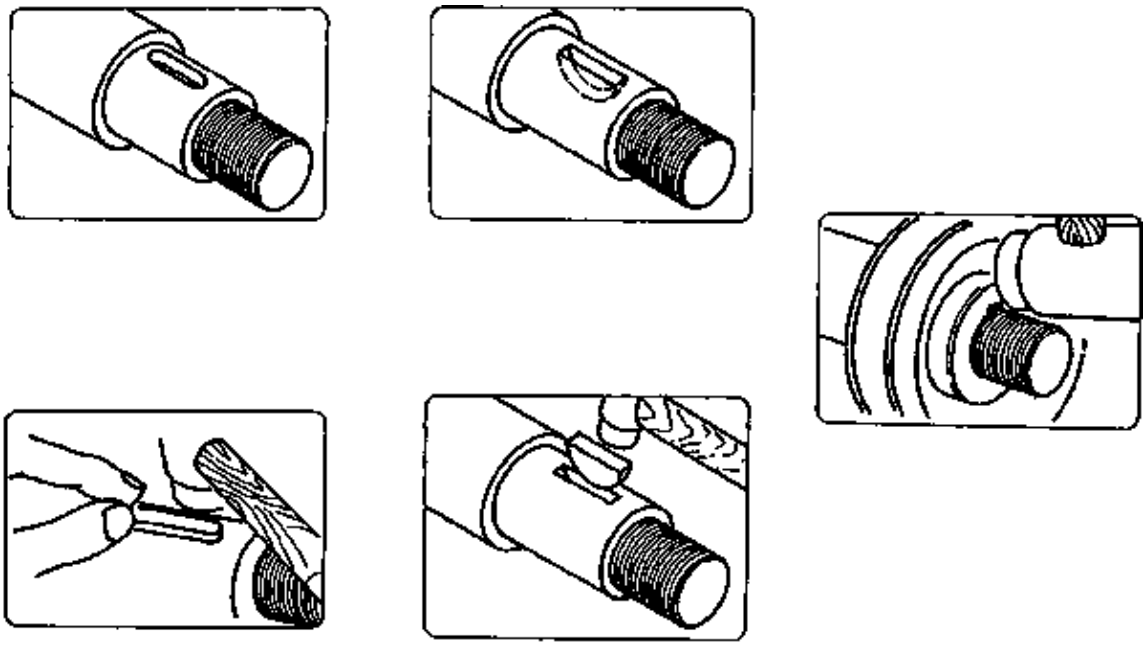
Usage

assembly and disassembly

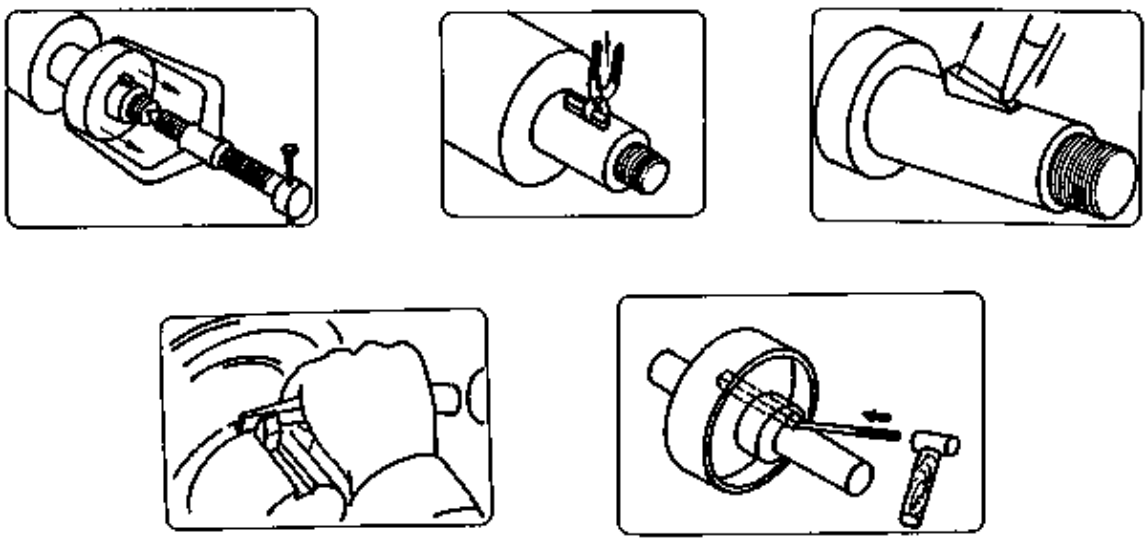




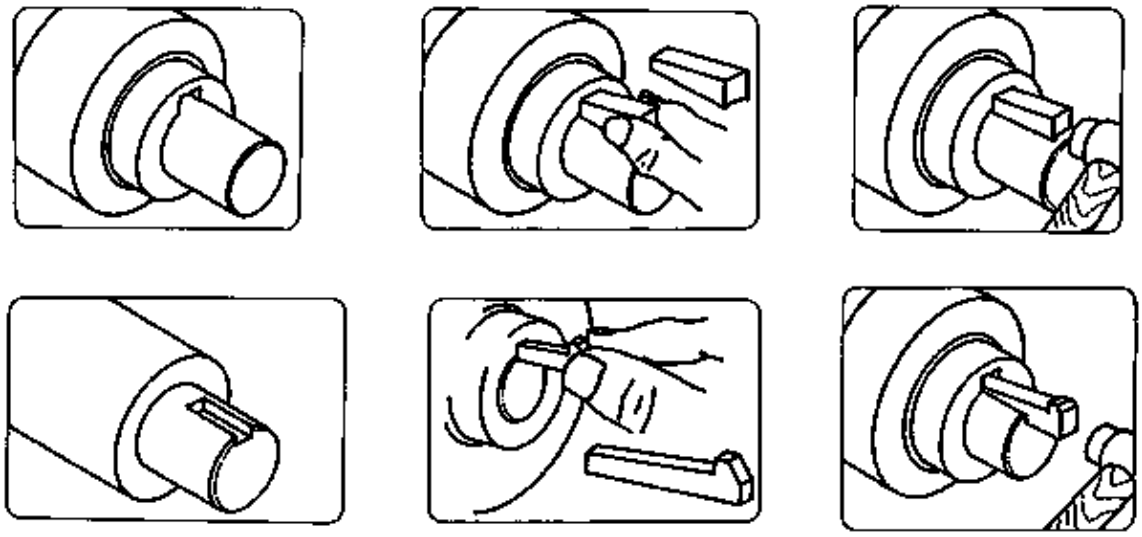
Form Fitting Keys Assembly



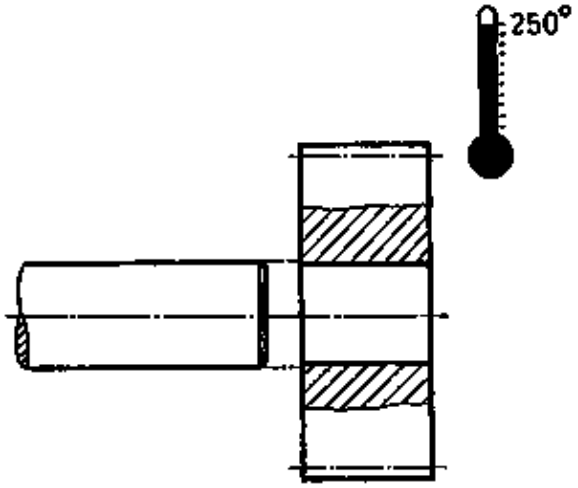
Keys Disassembly



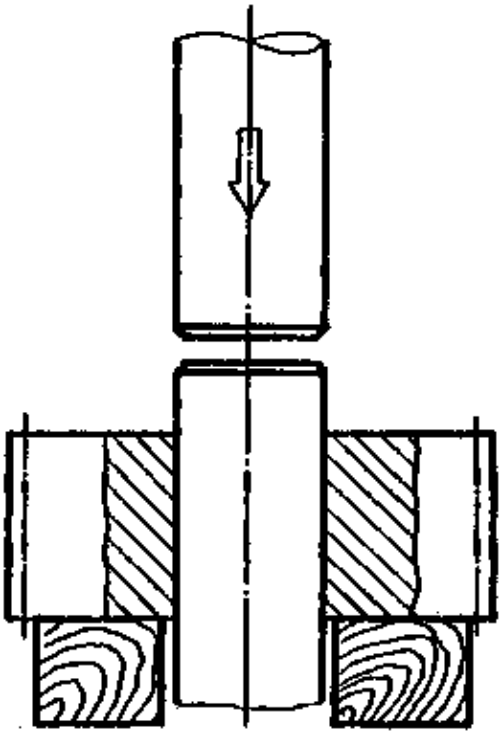
Form Friction Keys Assembly



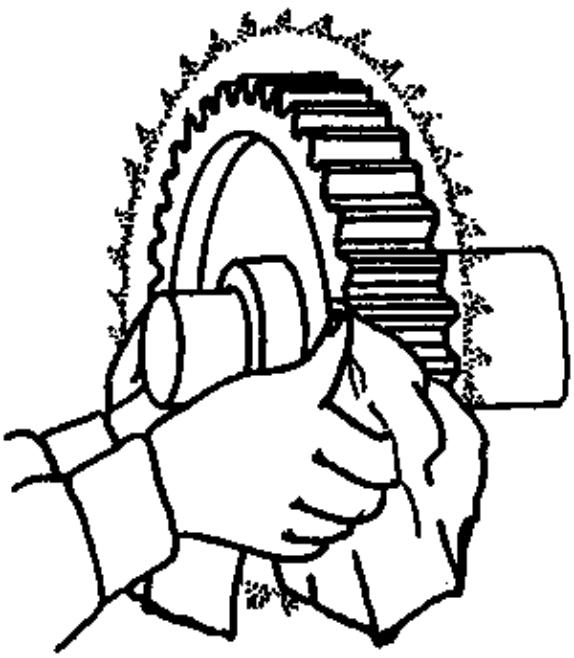
Hub Assembly and Disassembly

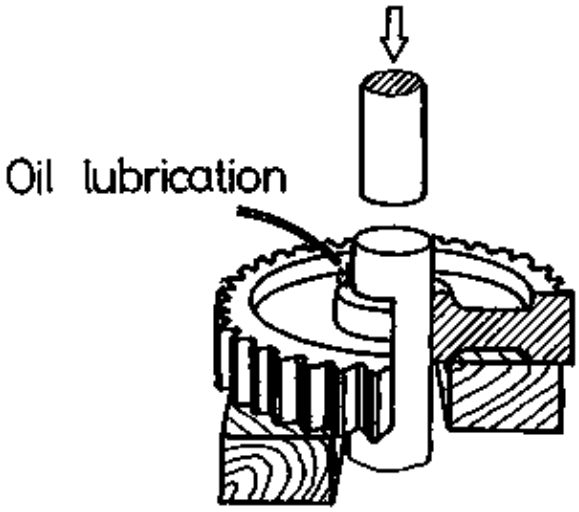


Assembly with heat

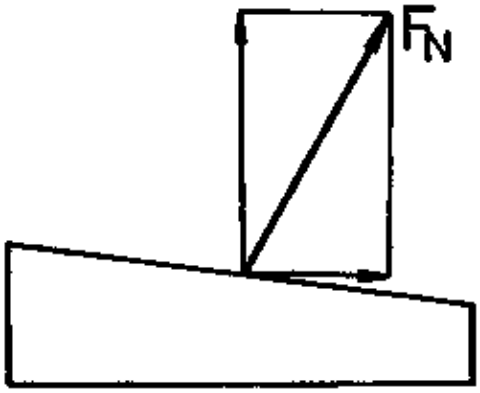


Disassembly with press



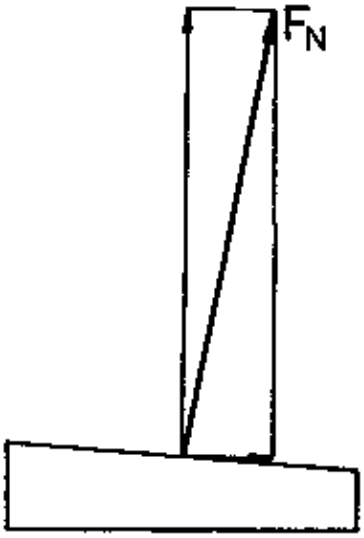


Key Slope



slope 1:10

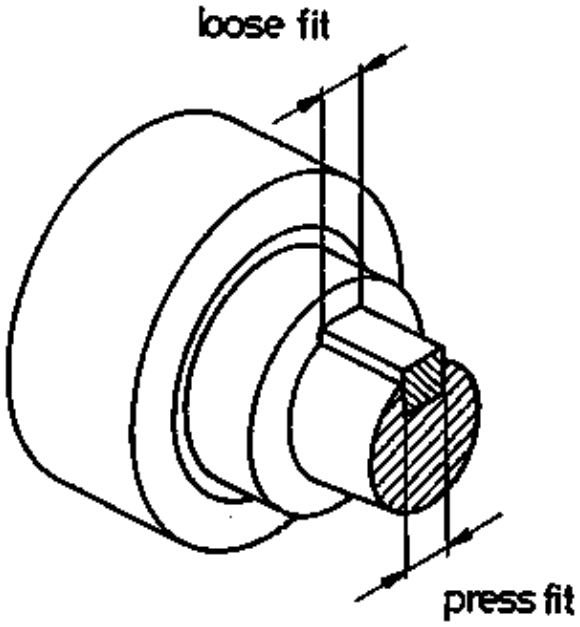
low force due to high inclination



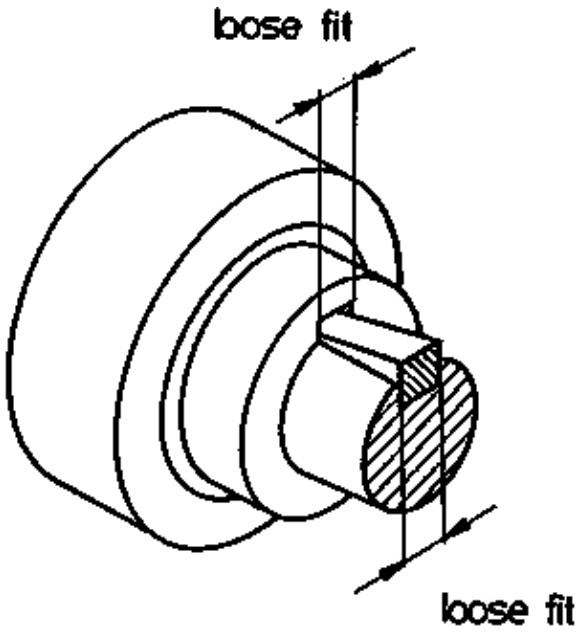
slope 1:100

high force due to low inclination

Fit For Keys Assembly

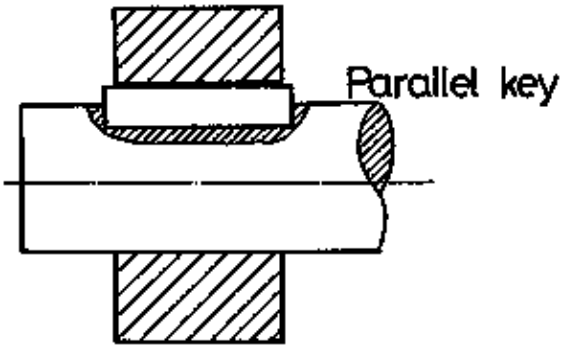


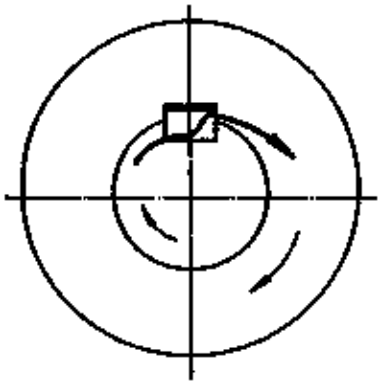
Parallel key



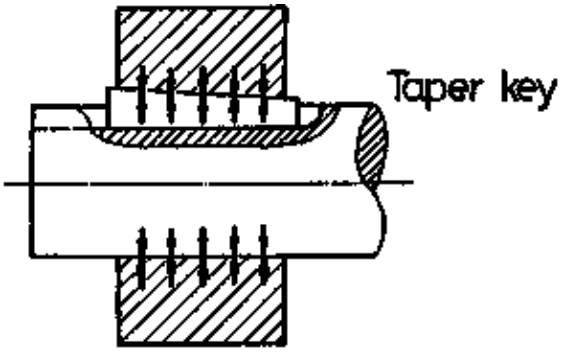
Taper key

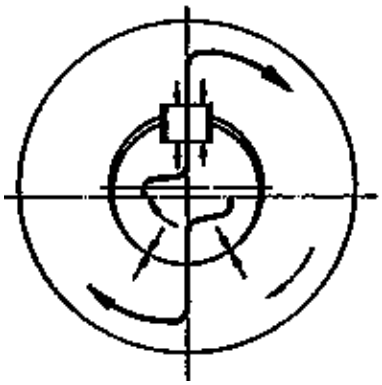
Flow of torque





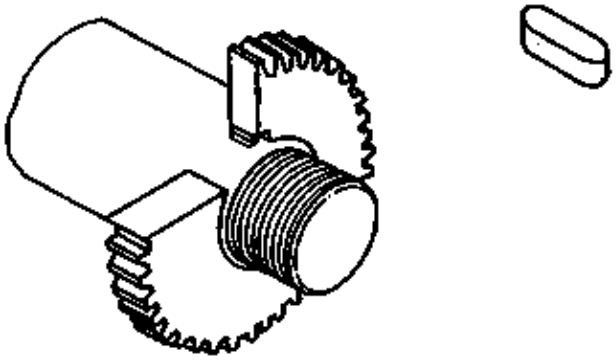
rotating centre of hub true



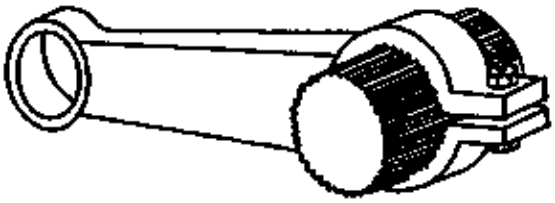


rotating centre out of true

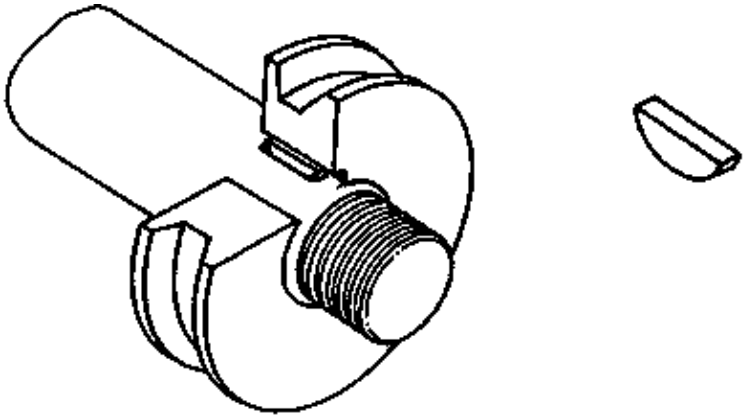
Form Fitting Transmission



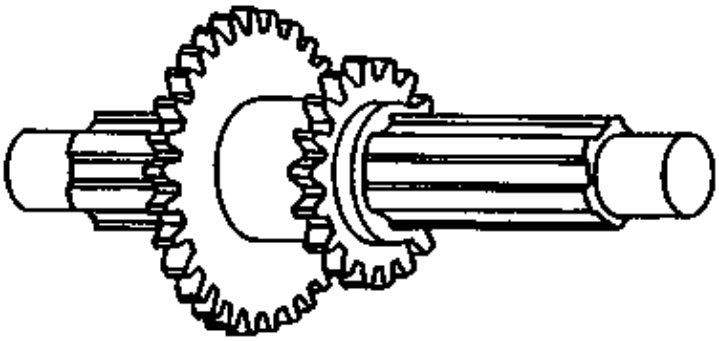
parallel key



surrated shaft

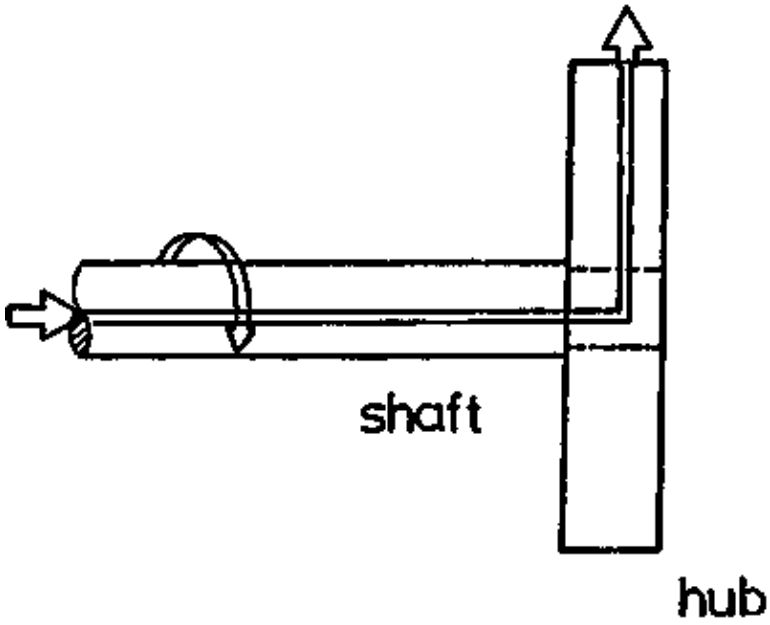


woodruff key

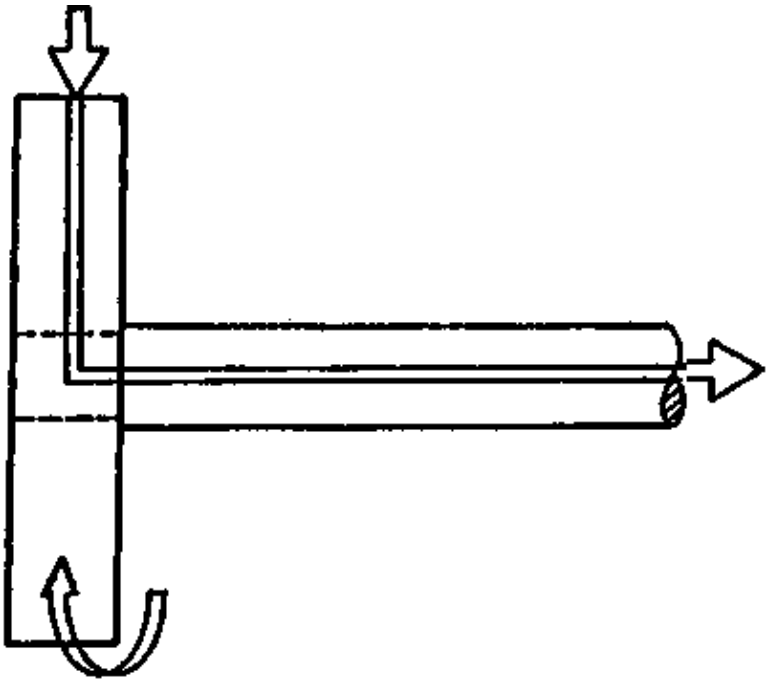


involute splinded shaft

Shaf–hub Connections



Torque transmission shaft to hub



Torque transmission from to shaft

4. Couplings and Clutches

List of Objectives

I Purpose and basic function

1. Explain the main functions of couplings and clutches
2. Explain the differences between couplings and clutches
3. Explain the different principles of friction and form clutch

II Types and design

4. Name the parts of a single disc clutch and explain their function
5. Explain which factors effect the efficiency of a friction clutch
6. Name the parts of a multiple disc clutch and explain their function
7. Show the flow of torque in a friction clutch
8. Show the flow of torque in a form clutch
9. Explain the function of a safety clutch
10. Distinguish between rigid and flexible couplings
11. Describe the feature of plate and clamp couplings
12. Describe the feature of rubber and spring couplings
13. Describe the feature of an universal joint

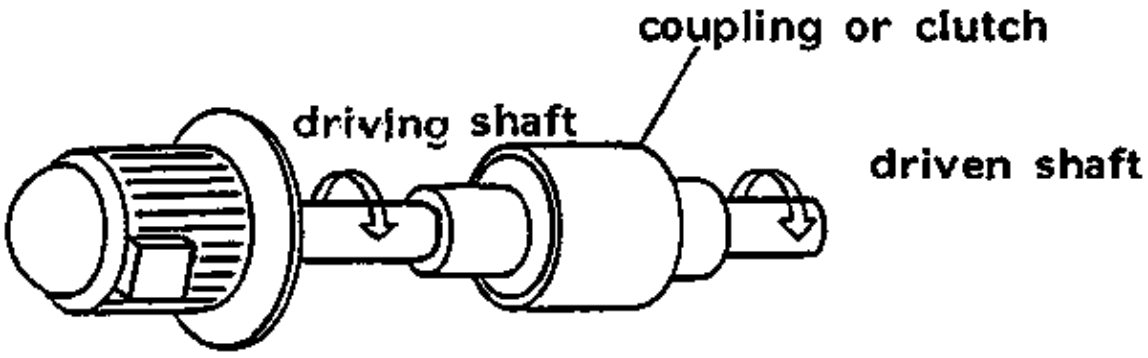
III Maintenance and repair

14. Explain how to maintain a single disc clutch
15. Explain how to maintain a multiple disc clutch
16. Explain how to maintain an universal joint
17. Explain how to repair a rubber coupling

Information sheet

1. Purpose and basic function

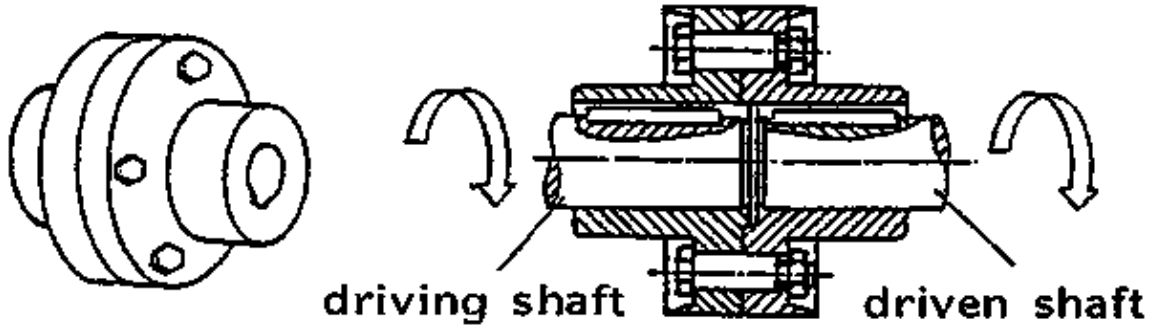
1.1 Purpose



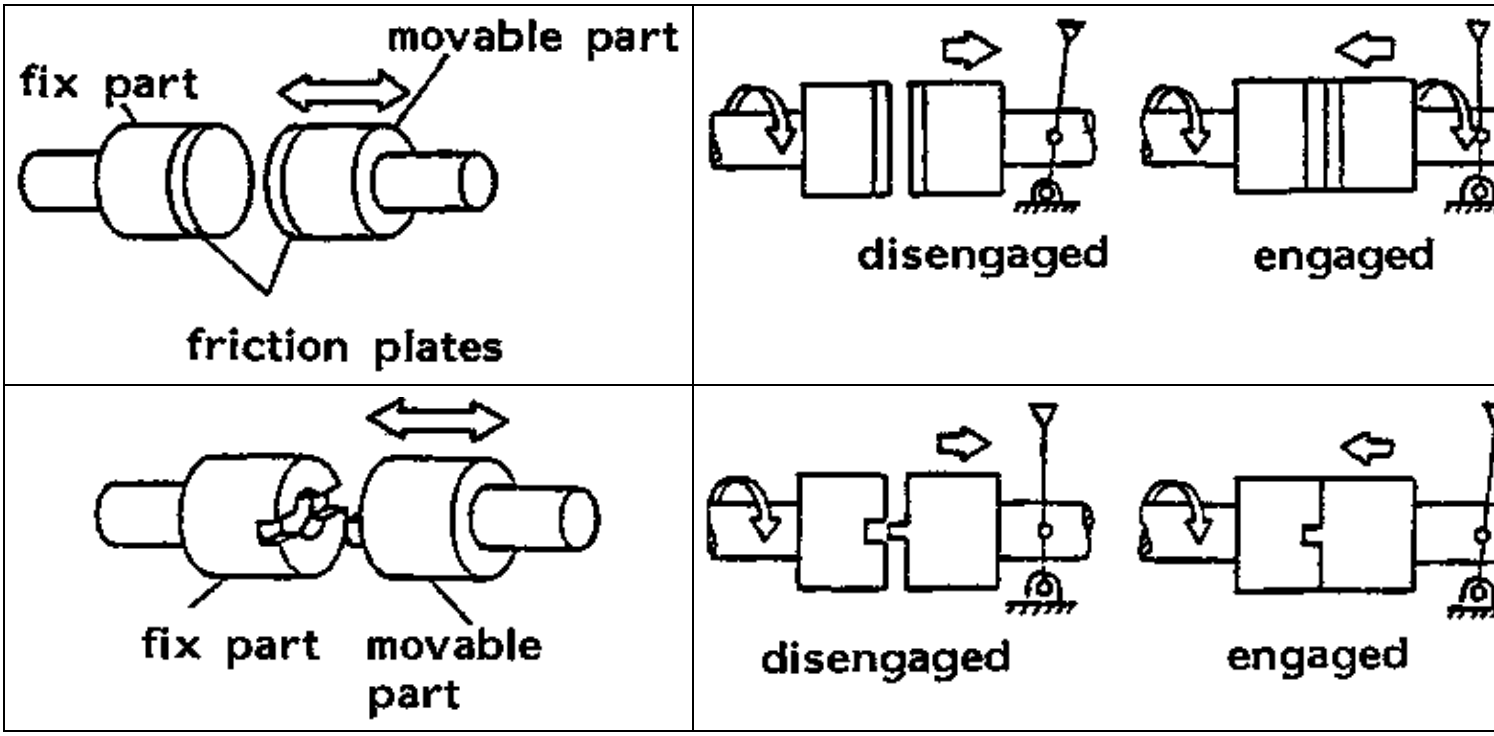
Couplings and clutches are machine elements, which transmit torque from the driving shaft to the driven shaft.

1.2 Difference between couplings and clutches

Couplings are not shiftable during work



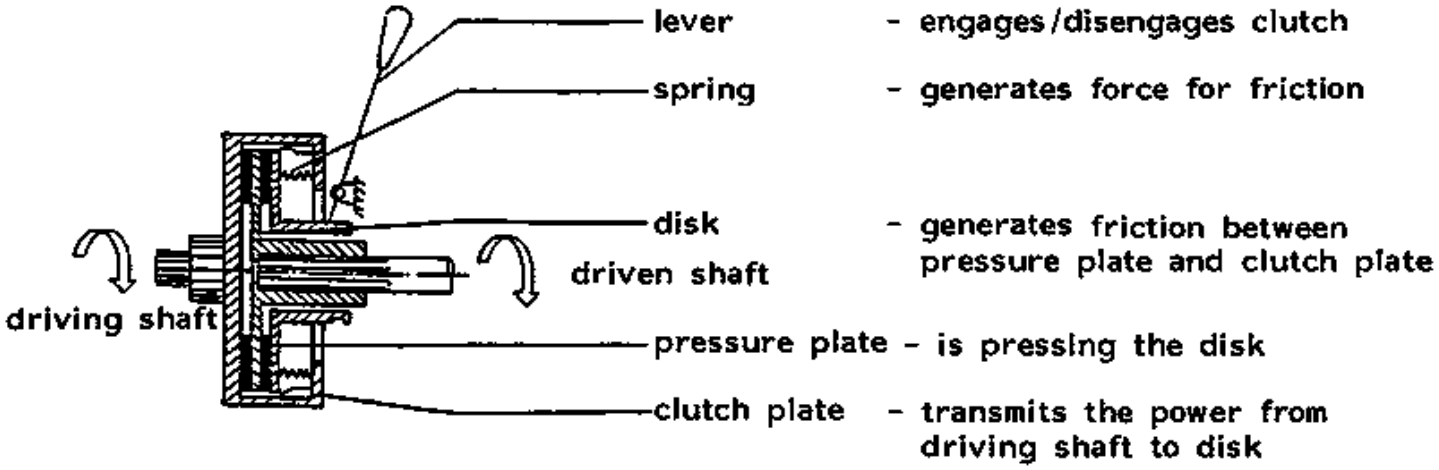
Clutches are shiftable during work



2. Types and design of clutches and couplings

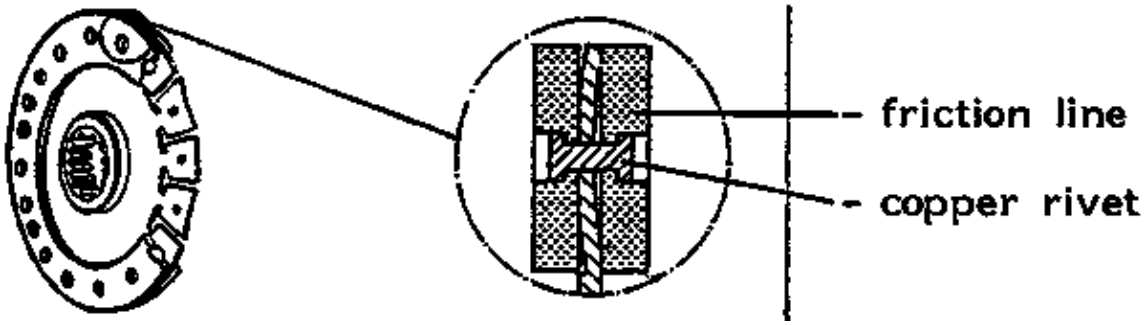
2.1 Friction clutches

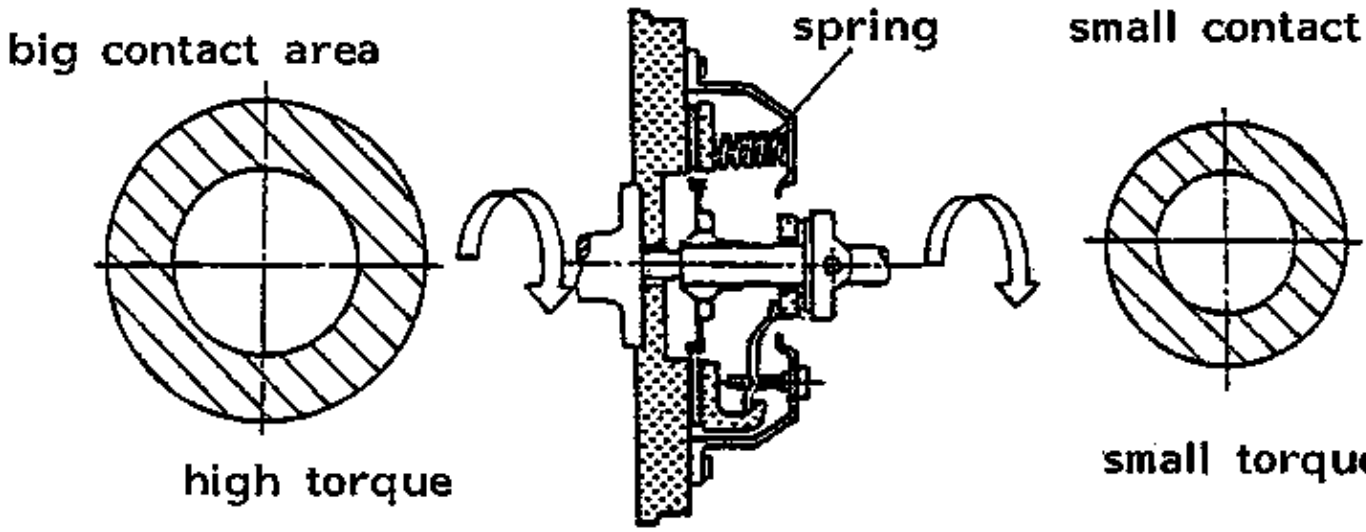
2.1.1 Single disk clutch



a friction clutch

– can be engaged and disengaged while rotating
– can be engaged and disengaged under load
– is starting smoothly big contact area small contact area





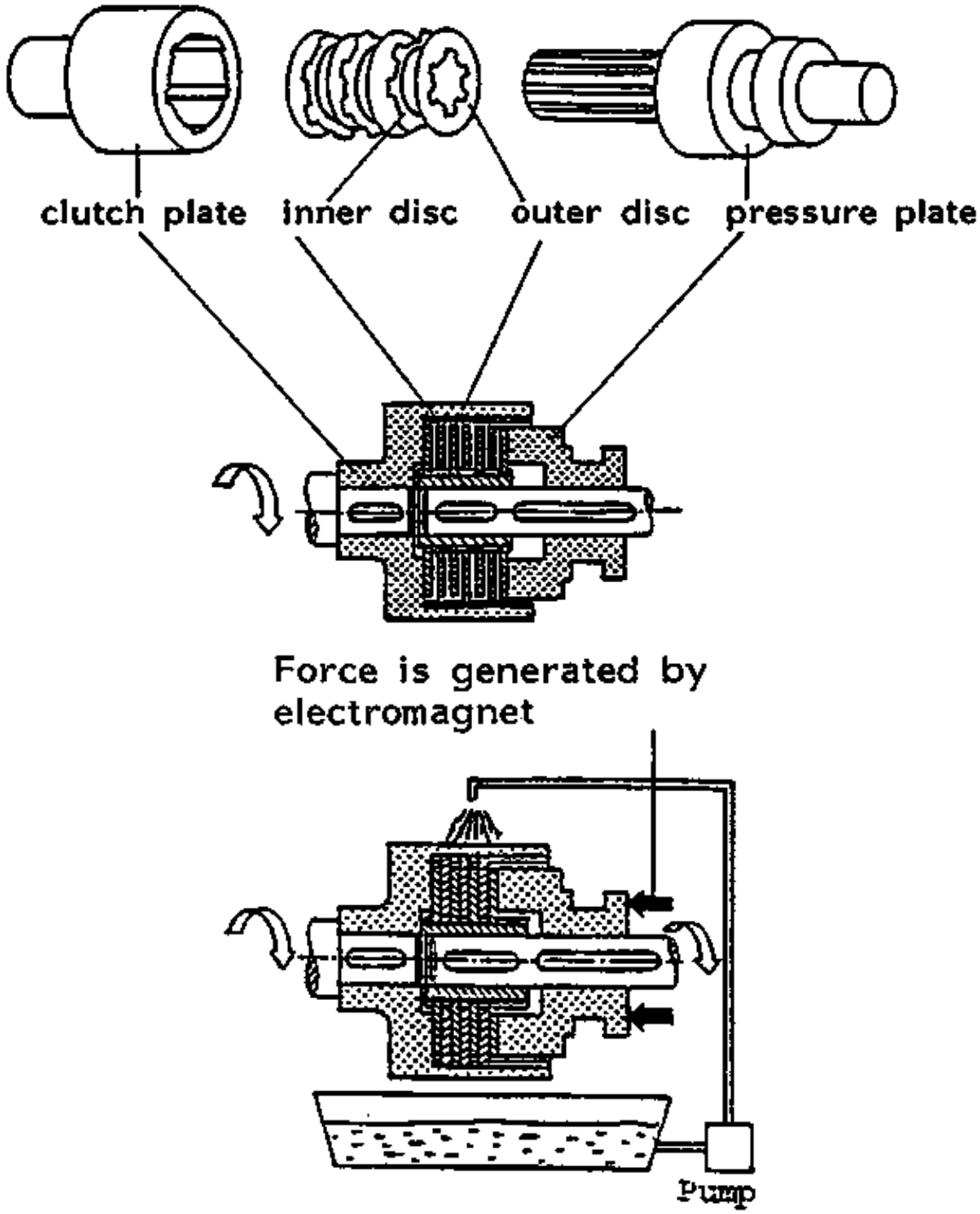
Torque transmission depends on:

– contact area (friction area)
– force which is pressing the disk (spring)

Note: Don't put oil or grease on the disk!

To get a large contact area, it is possible to
– enlarge the disk
– use more than 1 disk

2.1.2 Multiple disc clutch



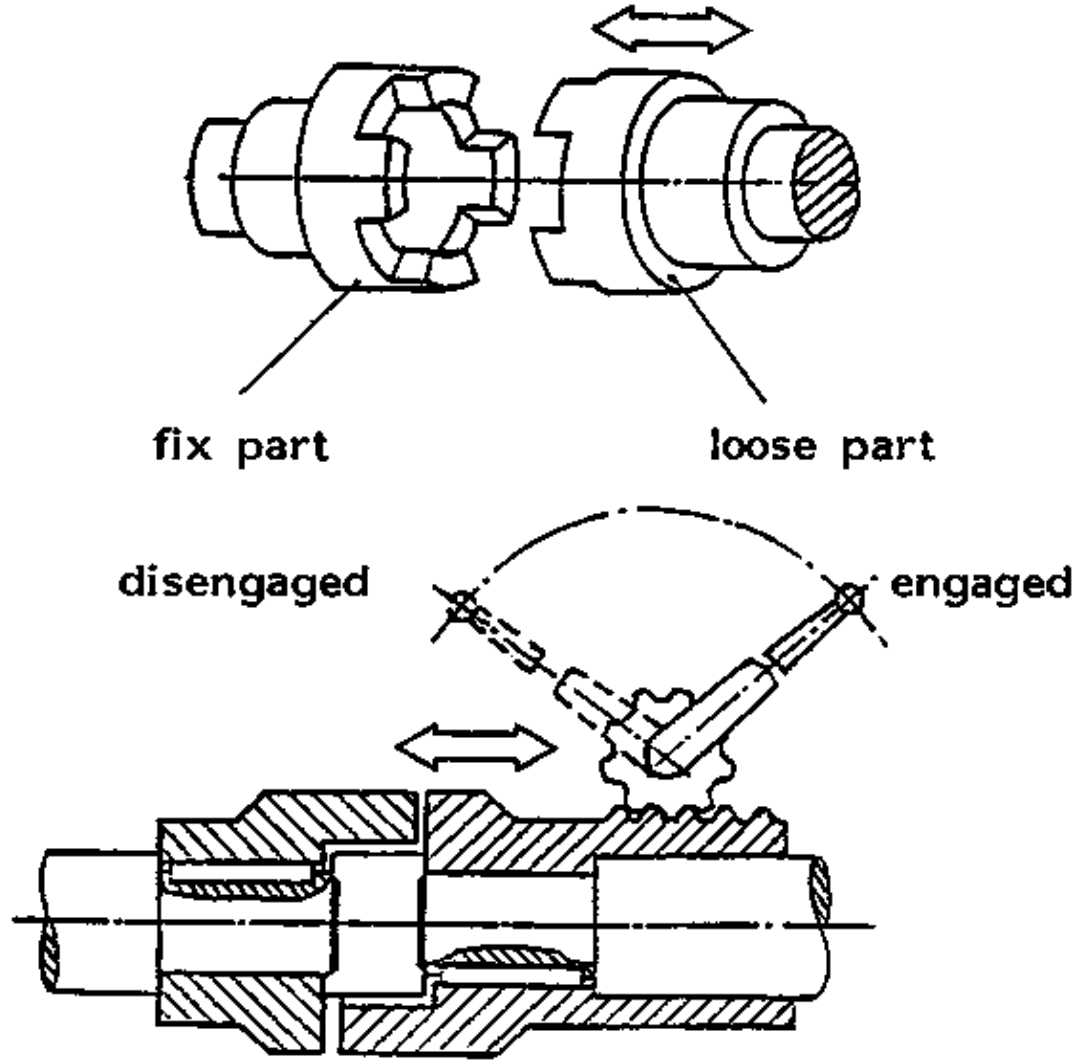
Note: Inner and outer discs need oil for cooling during work

2.2 Form fitting clutch

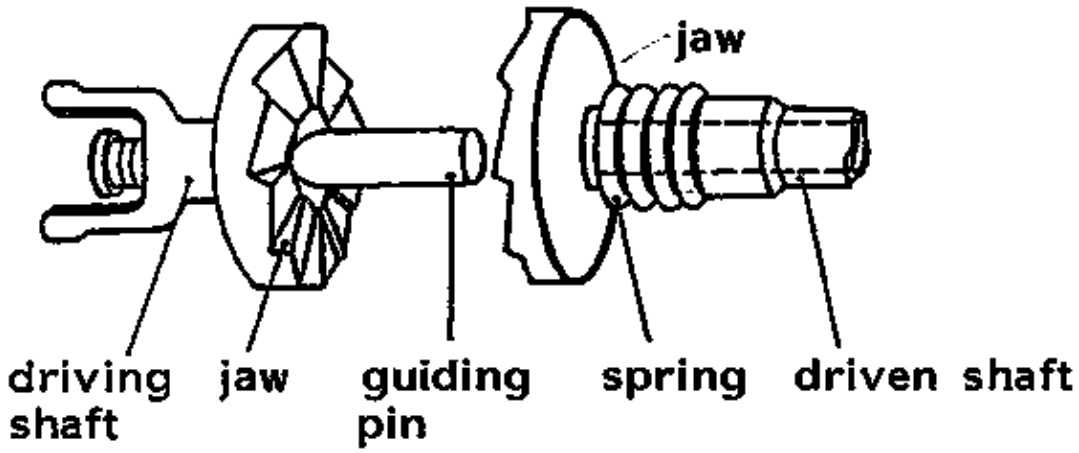
2.2.1 Jaw clutch

A form clutch

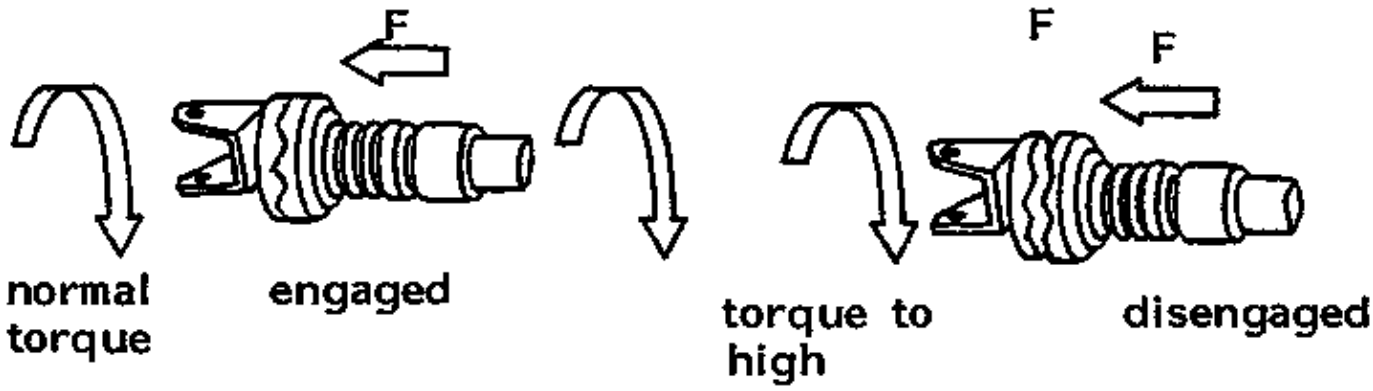
- can be engaged while rotating
- cannot be engaged or disengaged under load



2.2.2 Safety clutch

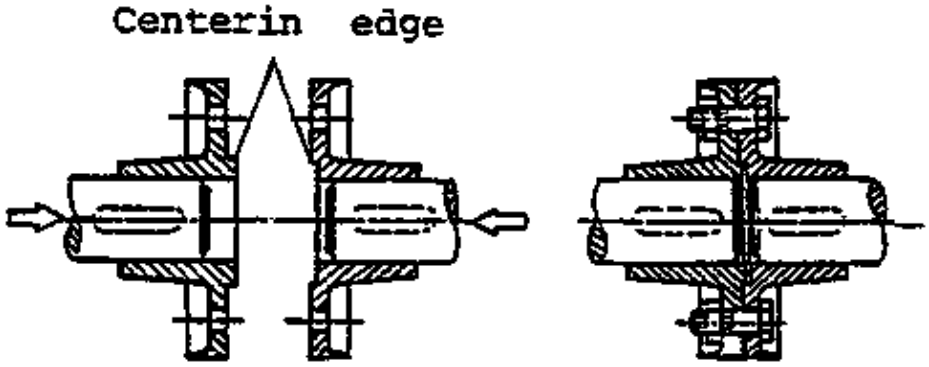


A safety clutch is self−disengaging when the torque is higher than the friction generated by spring and jaws.



2.3 Rigid coupling

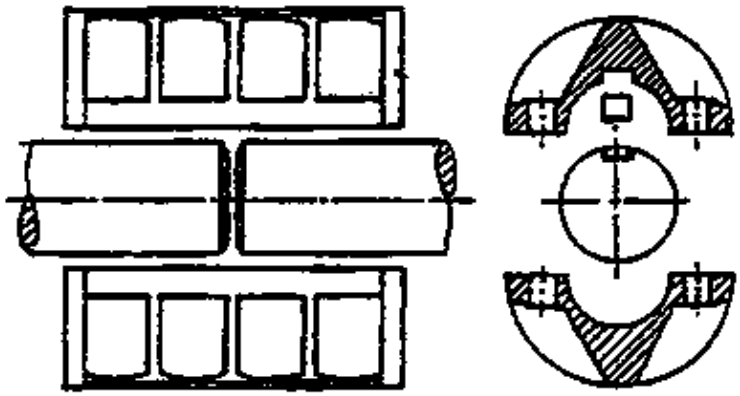
2.3.1 Plate coupling

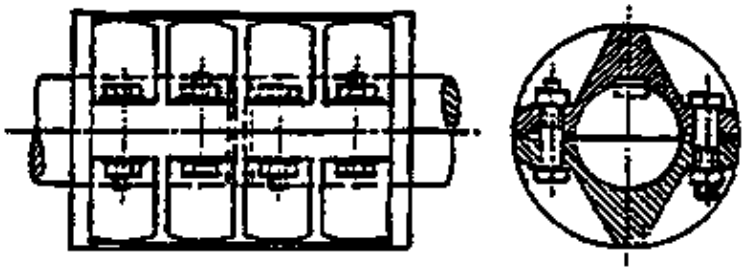


When mounting or dismounting:

- shafts must be in alignment
- 1 shaft must be shiftable in a axial direction.

2.3.2 Clamp coupling



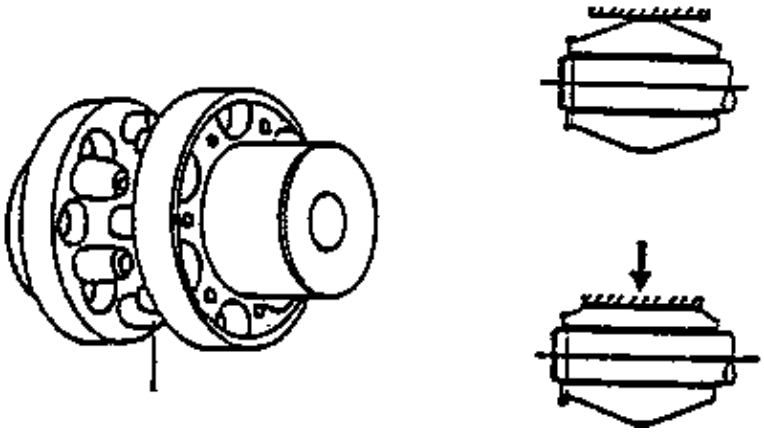


– shafts must be in alignment

– shaft must not be shifted in axial direction.

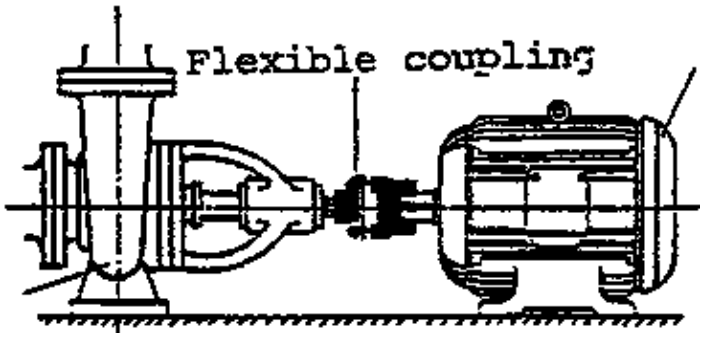
2.4. Flexible coupling

2.4.1 Rubber type

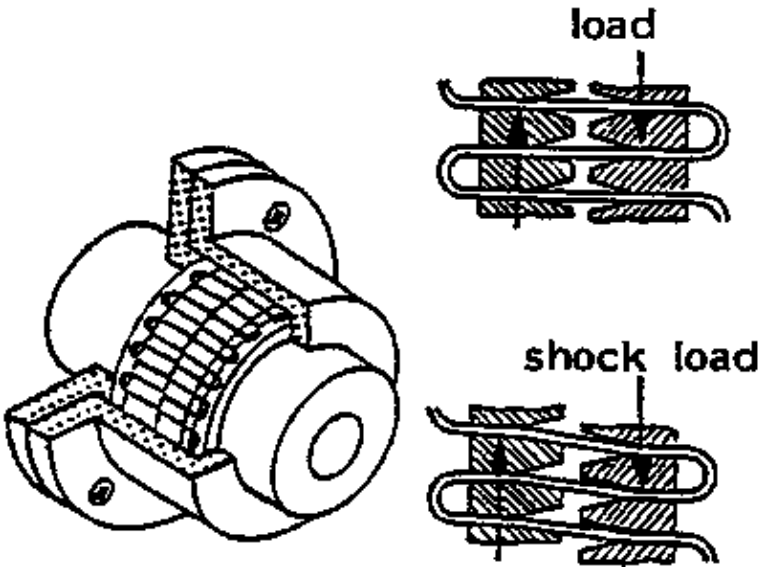


– absorbs shocks and vibrations

– shafts must not be exactly in alignment.

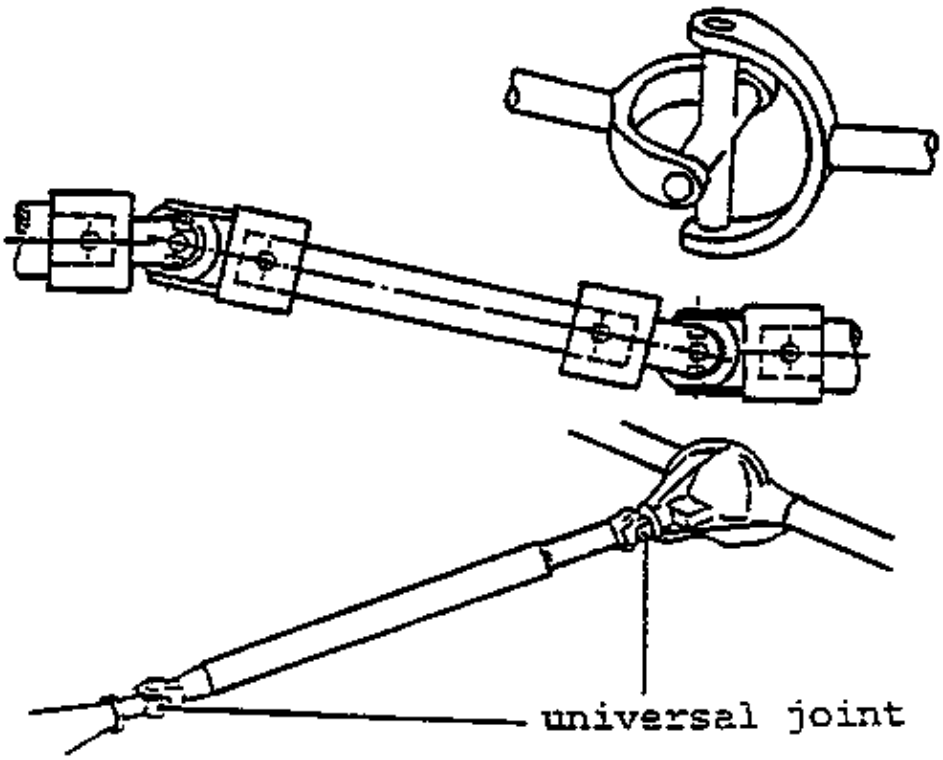


2.4.2. Steelband type



– absorbs shocks and vibrations

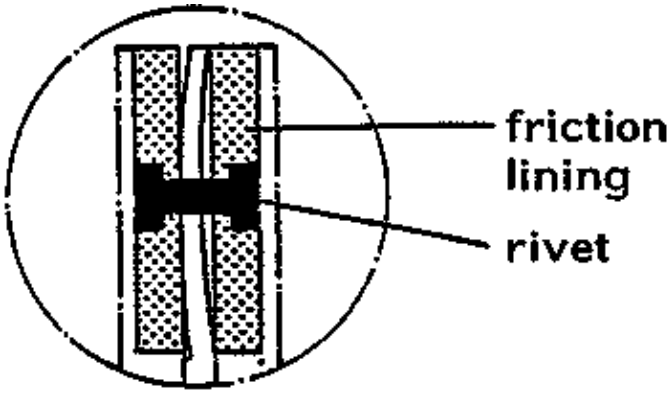
2.4.3 Universal joint



The shafts can be misaligned and excentric.

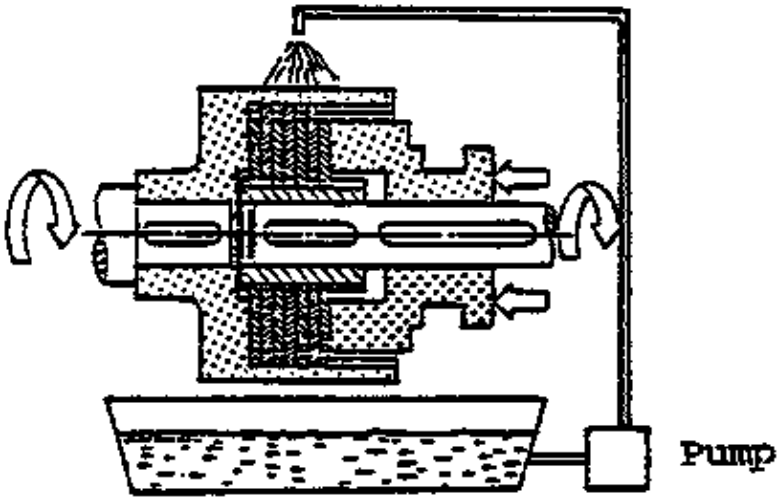
3. Maintenance and Repair

3.1 Single disc clutch



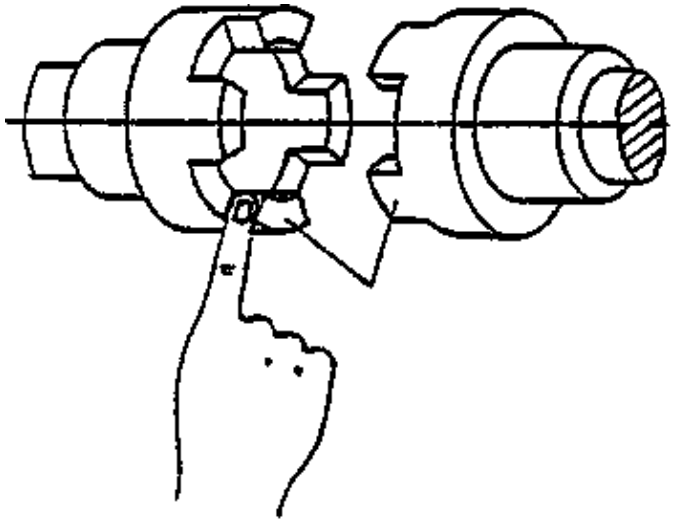
When the friction lining is worn till the rivet, it must be replaced.

3.2 Multiple disc clutch



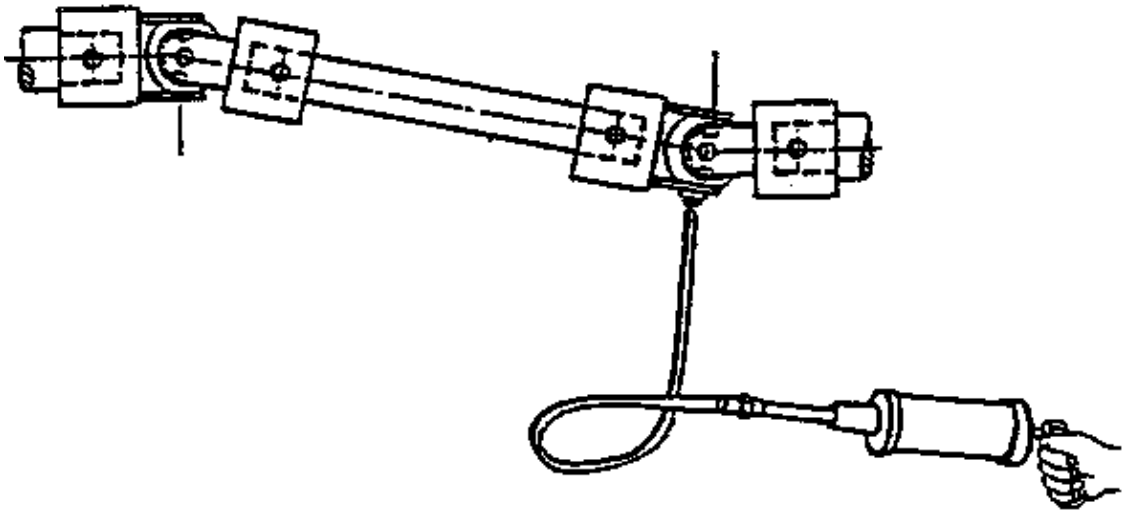
Change oil according to the manual

3.3 Jaw clutch



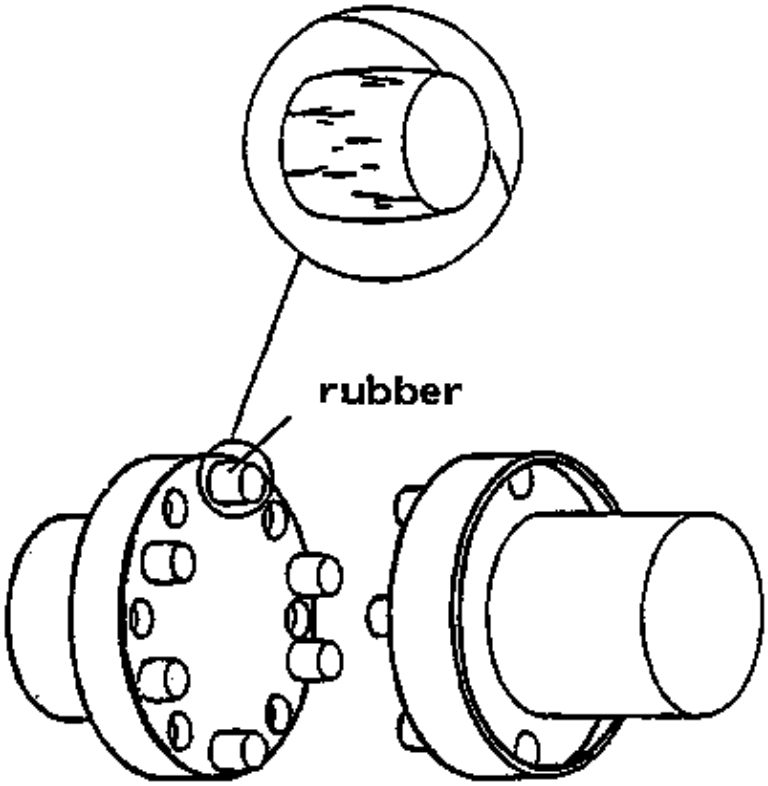
Grease the teeth of the clutch

3.4 Universal joint



Grease it according to the manual

3.5 Flexible coupling



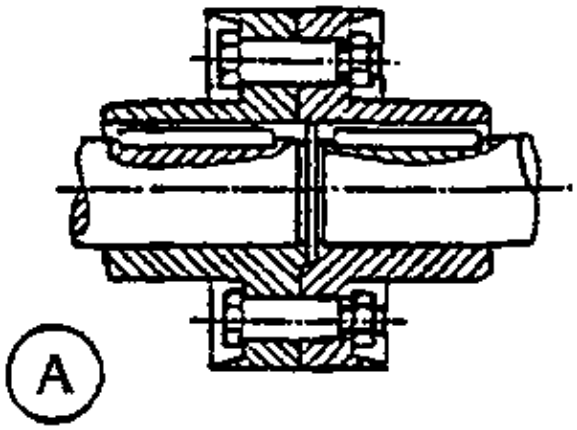
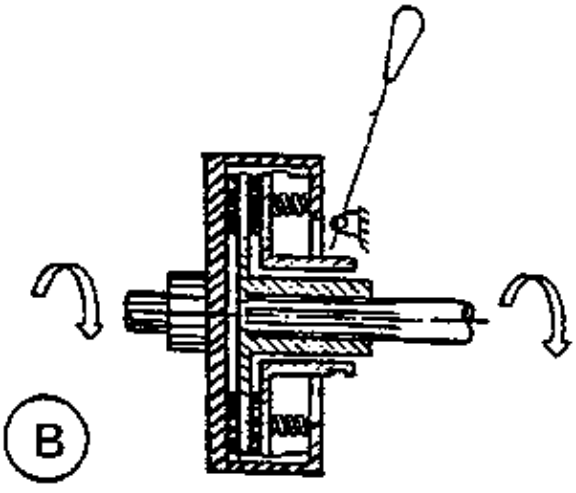
Replace the rubbers when they are damaged.

Task sheet

1.1 The main task of couplings and clutches is _____

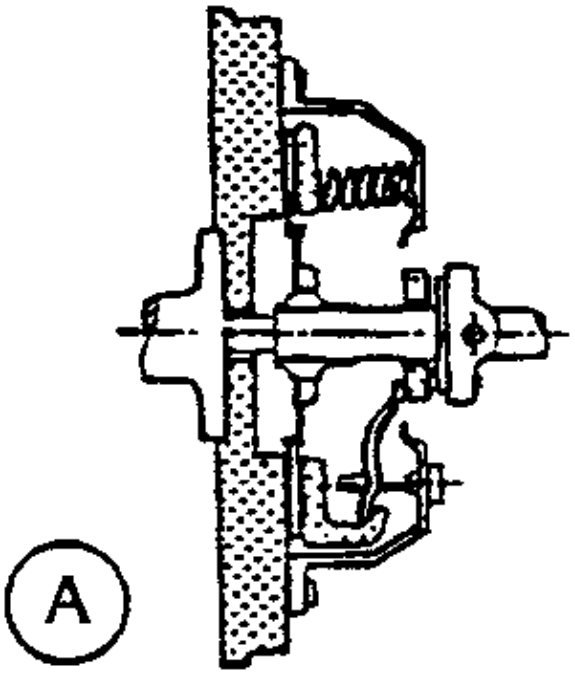
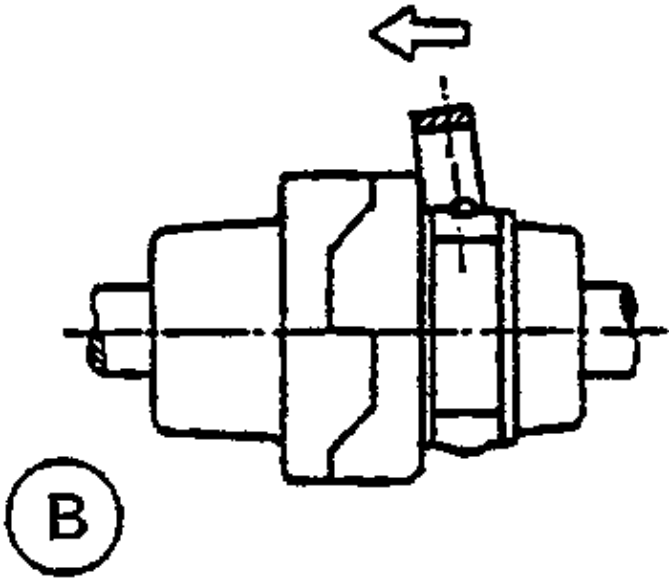
1.2

a) Mark the correct answer with X!

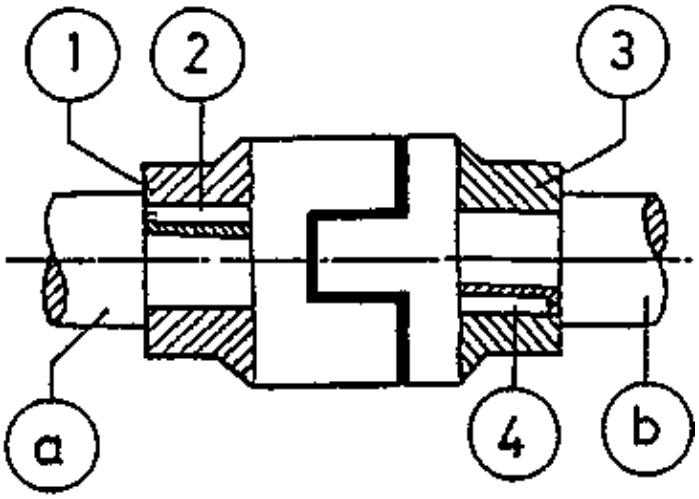
		
1. Coupling	☐	☐
2. Clutch	☐	☐
3. can be engaged and disengaged while rotating	☐	☐

4. can be engaged and disengaged under load	☐	☐

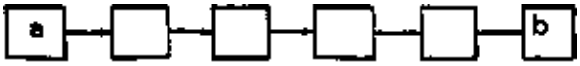
b) Mark the correct answer with X!

		
1. can be engaged or disengaged under load	☐	☐
2. can be engaged while rotating	☐	☐
3. can be disengaged while rotating	☐	☐
4. reduces starting torque	☐	☐
5. transmits torque by form	☐	☐
6. transmits torque by friction	☐	☐
7. can be engaged only when n = 0	☐	☐

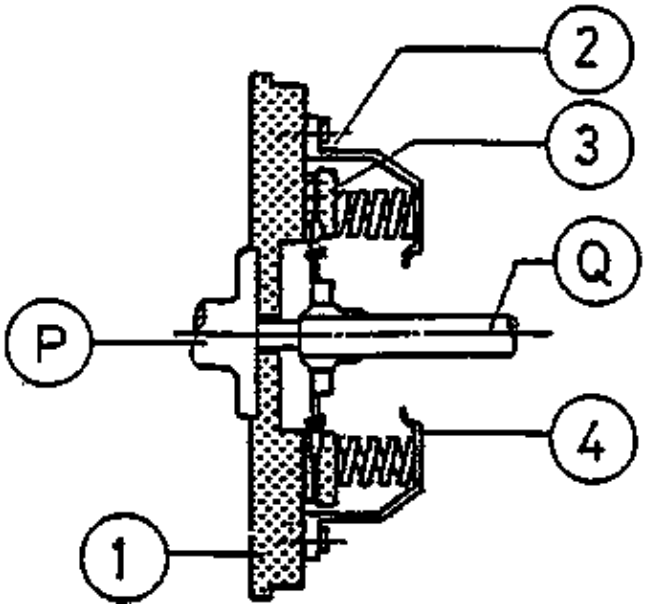
c)



Torque is transmitted from shaft a to shaft b by 4 different parts. Show the flow of torque by arranging the numbers in the correct sequence!



d)

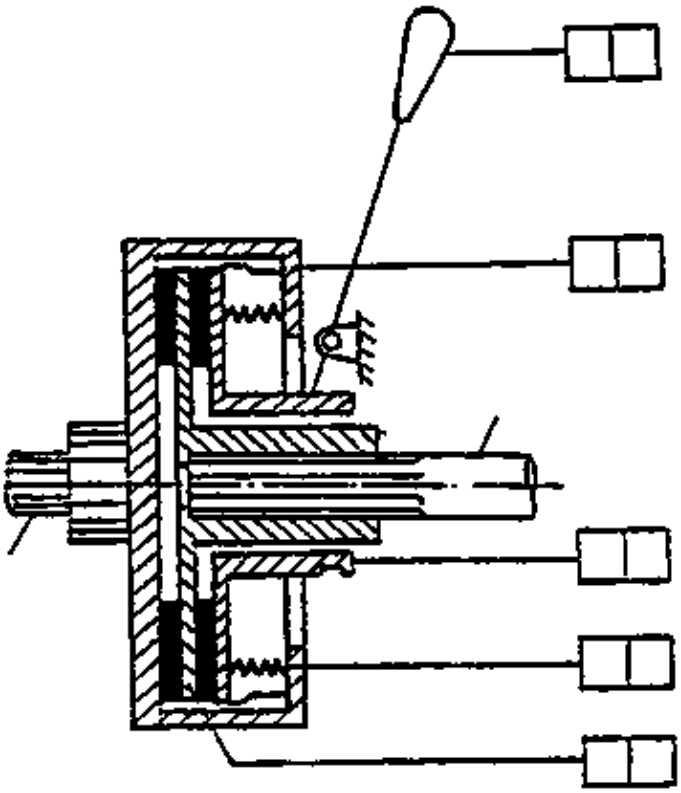


Show the flow of torque from shaft P to shaft Q by arranging the numbers in the correct sequence!

2.1

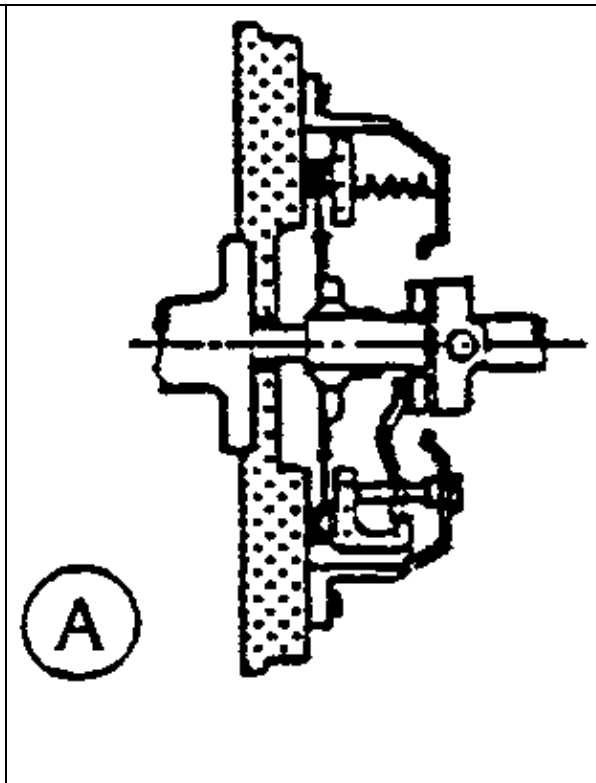
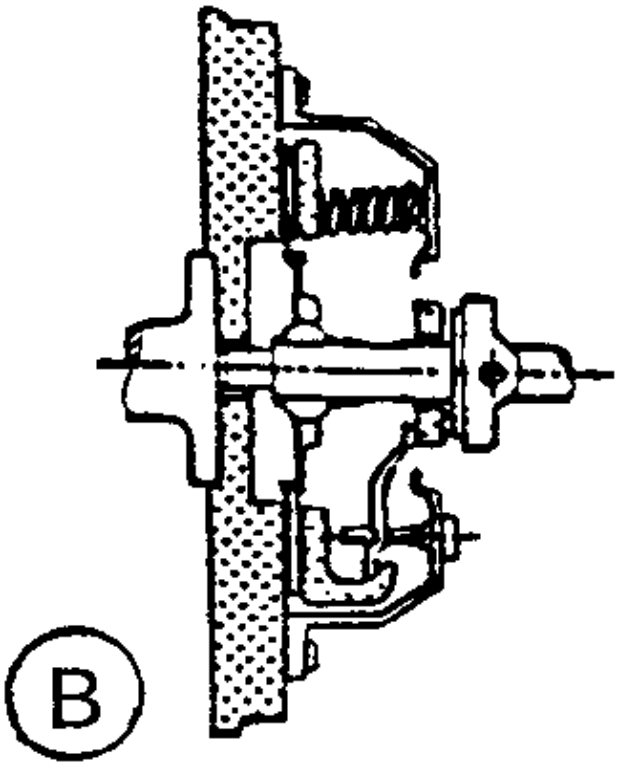
a) Name the parts and add their functions by filling in the appropriate letters and numbers.

name function



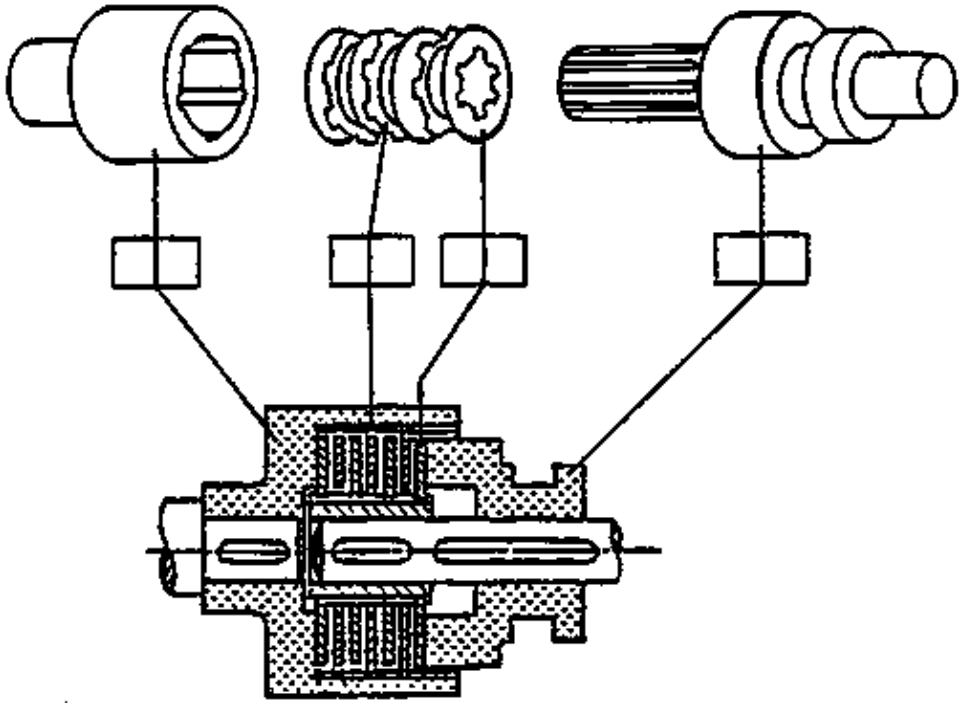
a) spring	1. transmits torque through the disc to driven shaft.
b) disc	2. engages/disengages clutch
c) clutch plate	3. generates friction
d) lever	4. generates pressing force
e) pressure plate	5. presses the disc

b) Mark the correct answer with X!

		
1. big contact area	☐	☐
2. small contact area	☐	☐
3. hard spring	☐	☐
4. soft spring	☐	☐

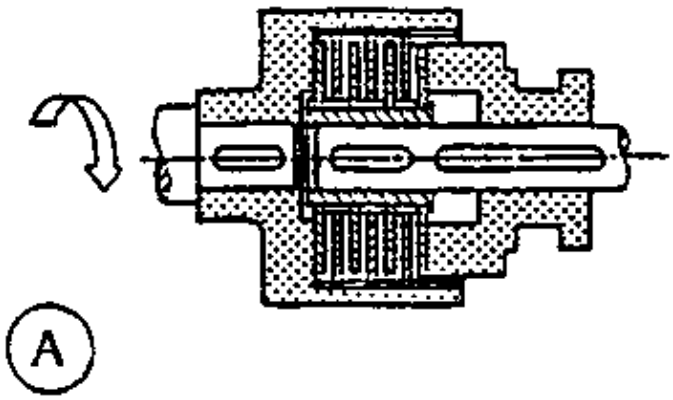
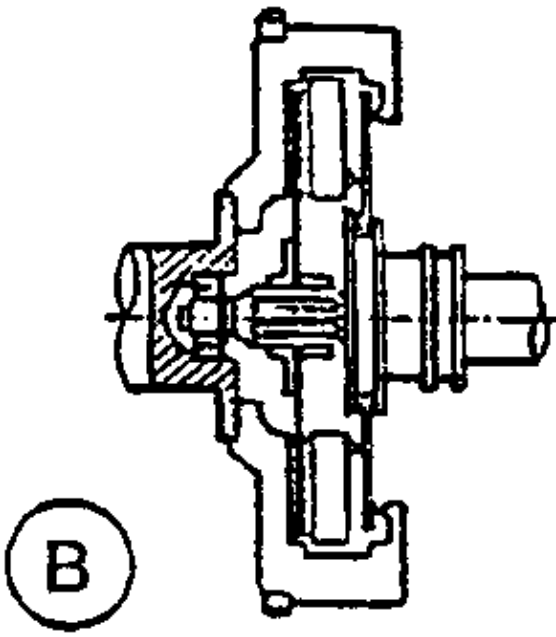
5. low torque transmission	☐	☐
6. high torque transmission	☐	☐

c) Name the parts and add their functions by filling in the appropriate letters and numbers



name	function
a) inner disc	1. transmits torque through disc to driven shaft
b) outer disc	2. generates friction and rotates with clutch plate
c) pressure plate	3. generates friction and rotates with pressure plate
d) clutch plate	4. presses disc

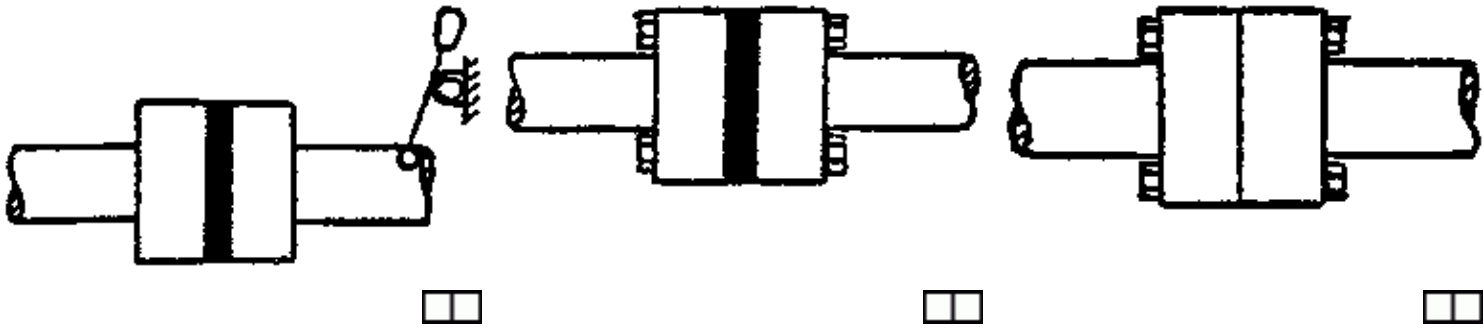
d) Mark the correct answer with X!

		
1. contact area can be varied by the diameter of disc	☐	☐

2. contact area can be varied by the number of discs	☐	☐
3. cooled by air	☐	☐
4. cooled by oil	☐	☐
5. the disc material is steel	☐	☐
e. the disc material is asbestos	☐	☐

2.

a) Name the couplings/clutches and add their functions by filling in the appropriate letters and numbers



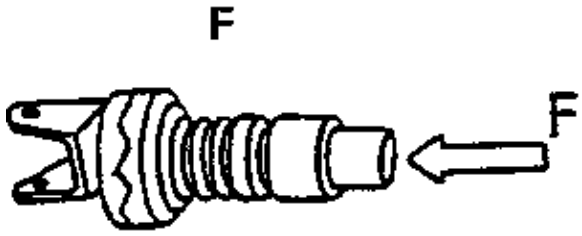
☐☐ ☐☐ ☐☐

name function

a) form clutch 1. eliminates vibration
b) friction clutch 2. can be engaged or disengaged under load
c) rigid coupling 3. assembled shafts can have little misalignment
d) flexible coupling 4. is reducing starting torque

Note: A coupling/clutch can have various or none of the mentioned functions!

b) When does the safety clutch interrupt torque transmission?



– If the vibrations are too high
– If the torque is higher than the friction generated by spring and jaws
– If the pressure F generated by the spring is too high

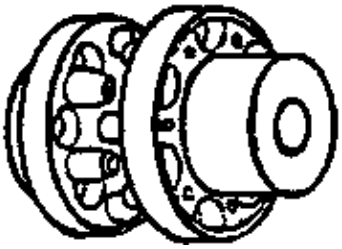
c) Mark with R for rigid coupling and F for flexible coupling!

Shafts must be in alignment for assembling
Shafts can be a little misaligned
Absorbs shocks and vibrations

d) Name the couplings/clutches and add their functions by filling in the appropriate letters and numbers

name:
a) plate coupling
b) flexible coupling
c) universal joint

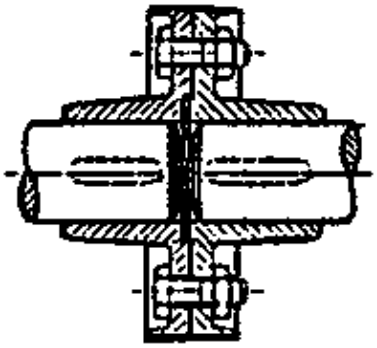
1 ☐☐



2 ☐☐

function:
1. Absorbs shocks and vibrations
2. Shafts can be excentric
3. For assembling/disassembling shafts must be shifted in axial directions

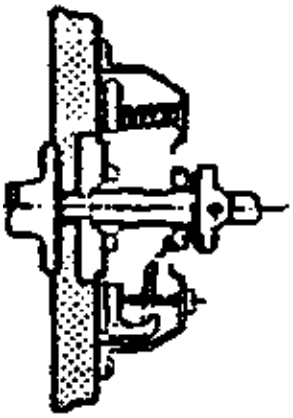
3 ☐☐



Note: A coupling can have various functions

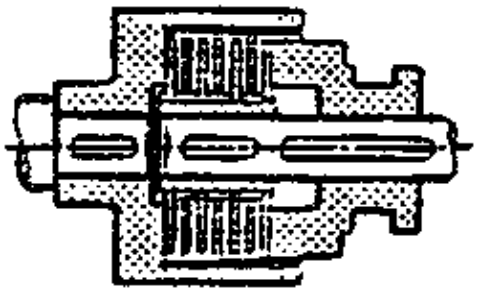
3. Explain how the couplings/clutches are maintained by filling in the appropriate letter

_____ 1.

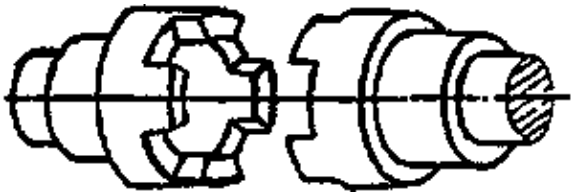


Maintenance:
a) smear with grease
b) change disc (or lining)
c) change rubbers
d) change oil
e) inject grease

_____ 2.

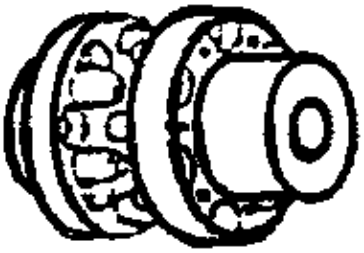


_____ 3.



_____ 4.

_____ 5.



Solutions

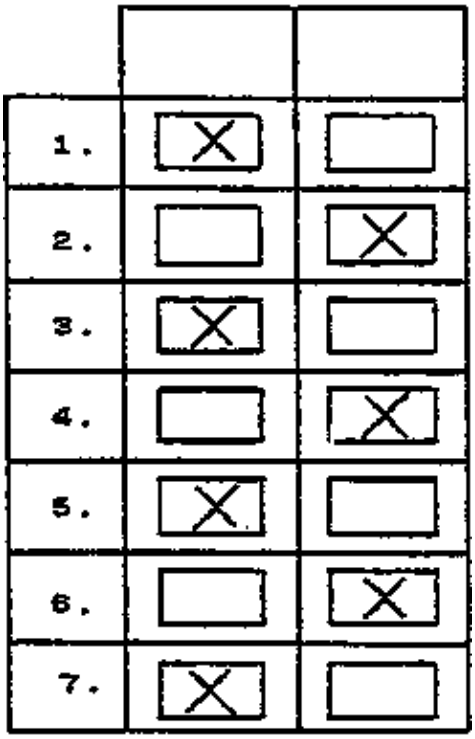
1.1 ..... to transmit torque

1.2

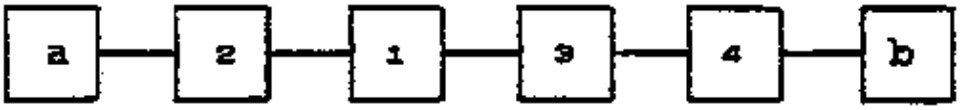
a)

1.	X	
2.		X
3.		X
4.	X	

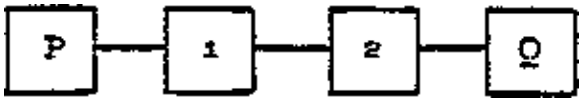
b)



c)

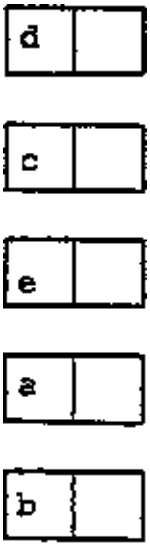


d)



2.1

a)



b)

1.		X
2.	X	
3.		X
4.	X	
5.	X	
6.		X

c)

d	1

b	2

a	3

c	4

d)

1.		X
2.	X	
3.		X
4.	X	
5.	X	
6.		X

2.

a)

b	2	4

d	1	3

c	-	-

a	2	-

b) If the torque is higher than the friction generated by spring and jaws.

c)

R

F

F

d)

c	2	–
b	1	3
a	3	–

3.

b

d

a

e

c

Safety clutch

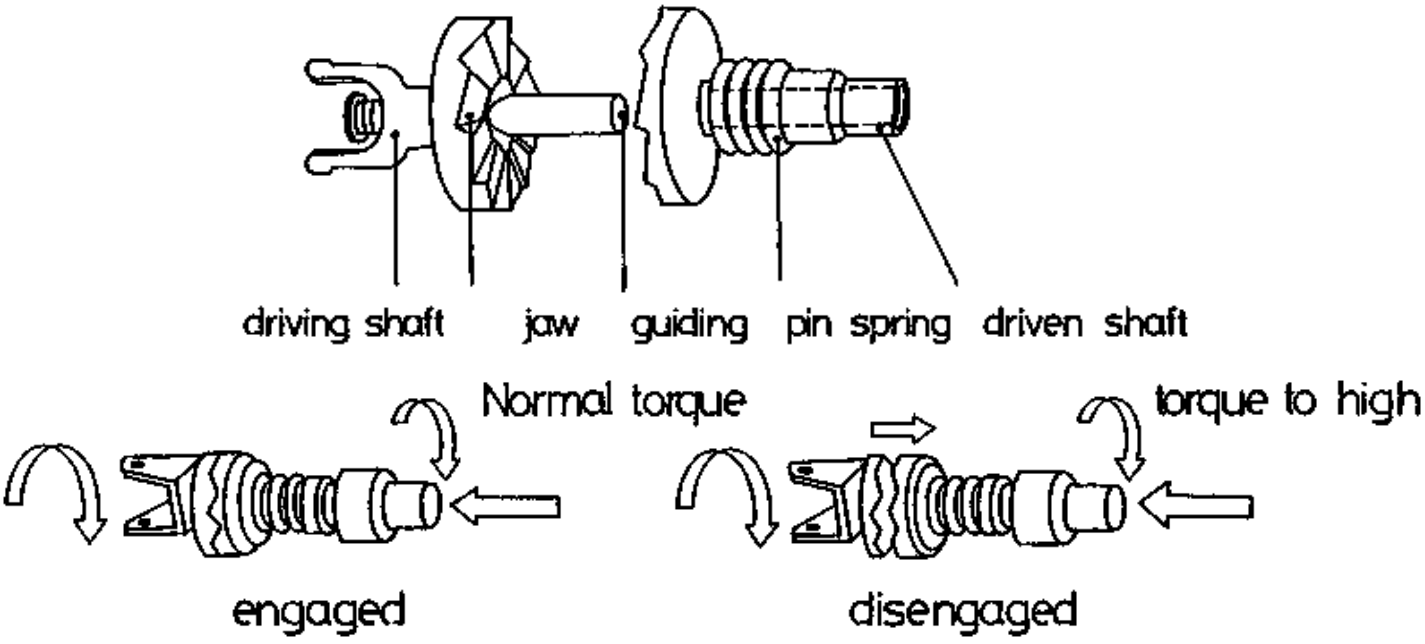
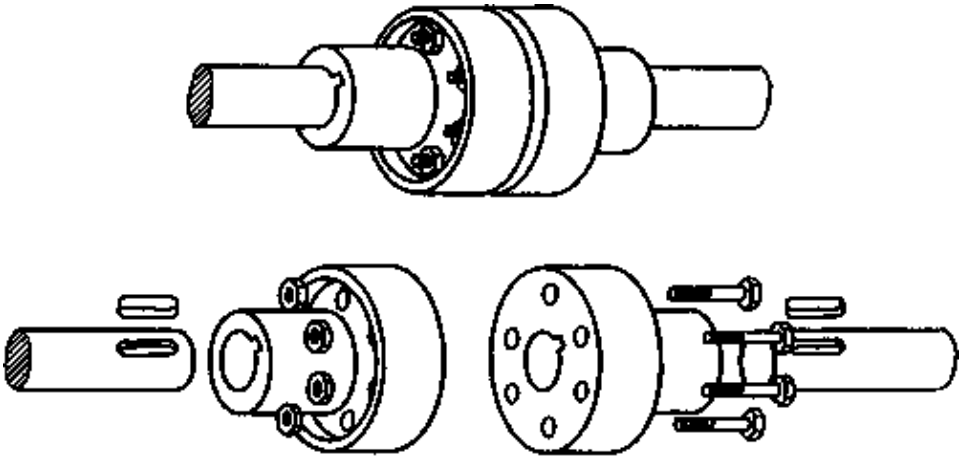
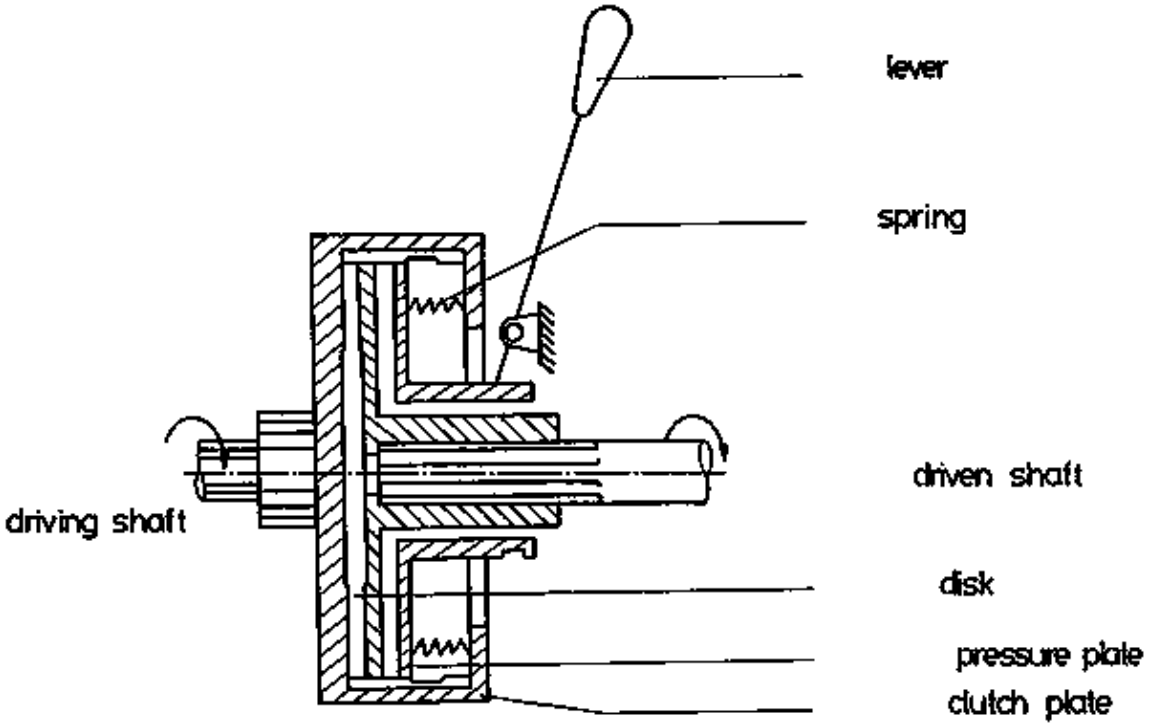


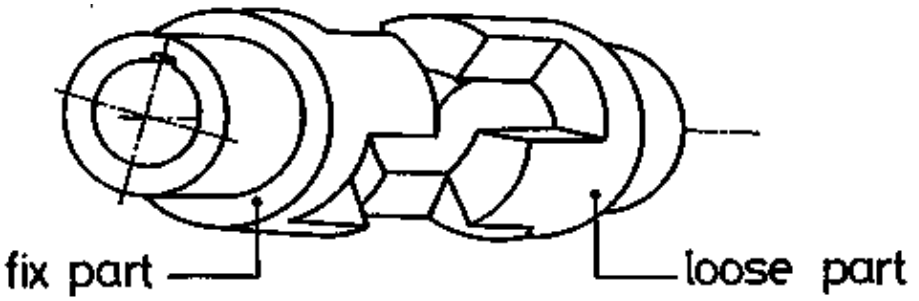
Plate coupling

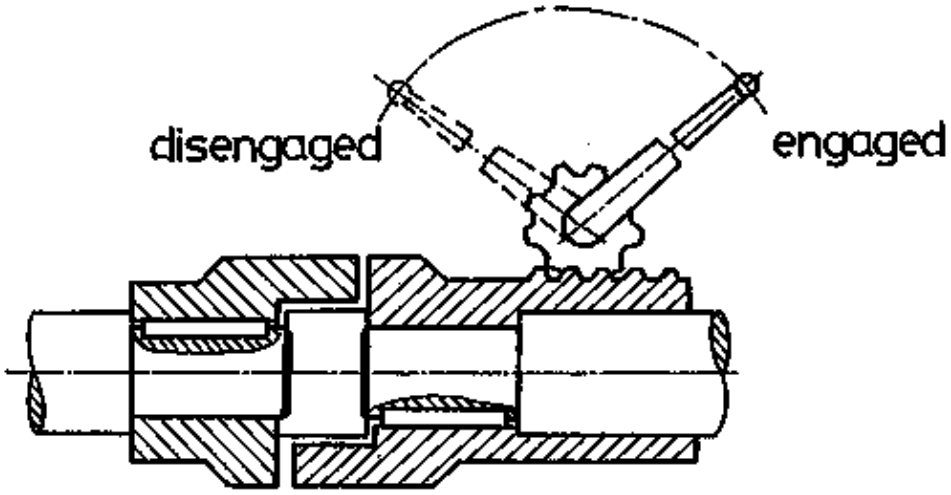


Friction clutches: Single disk clutch

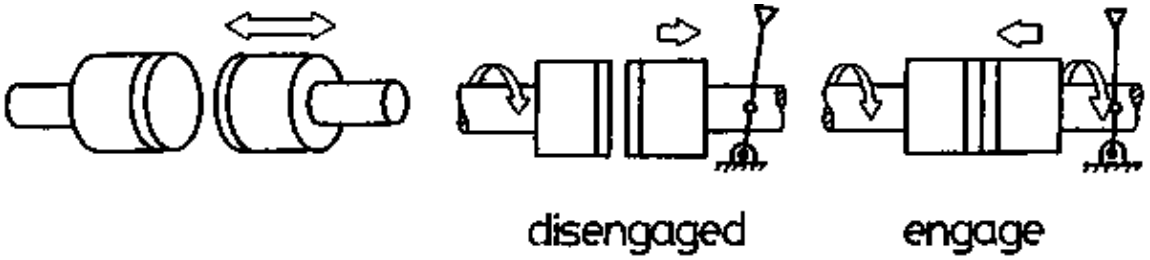


Form fitting clutch: Jaw clutch

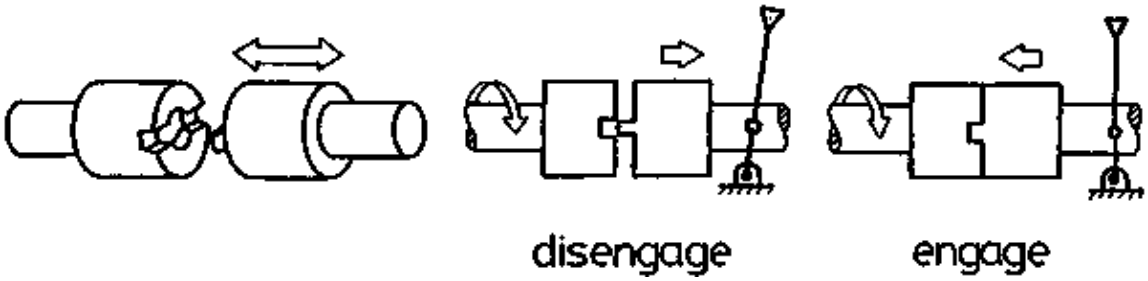




Type of Clutch

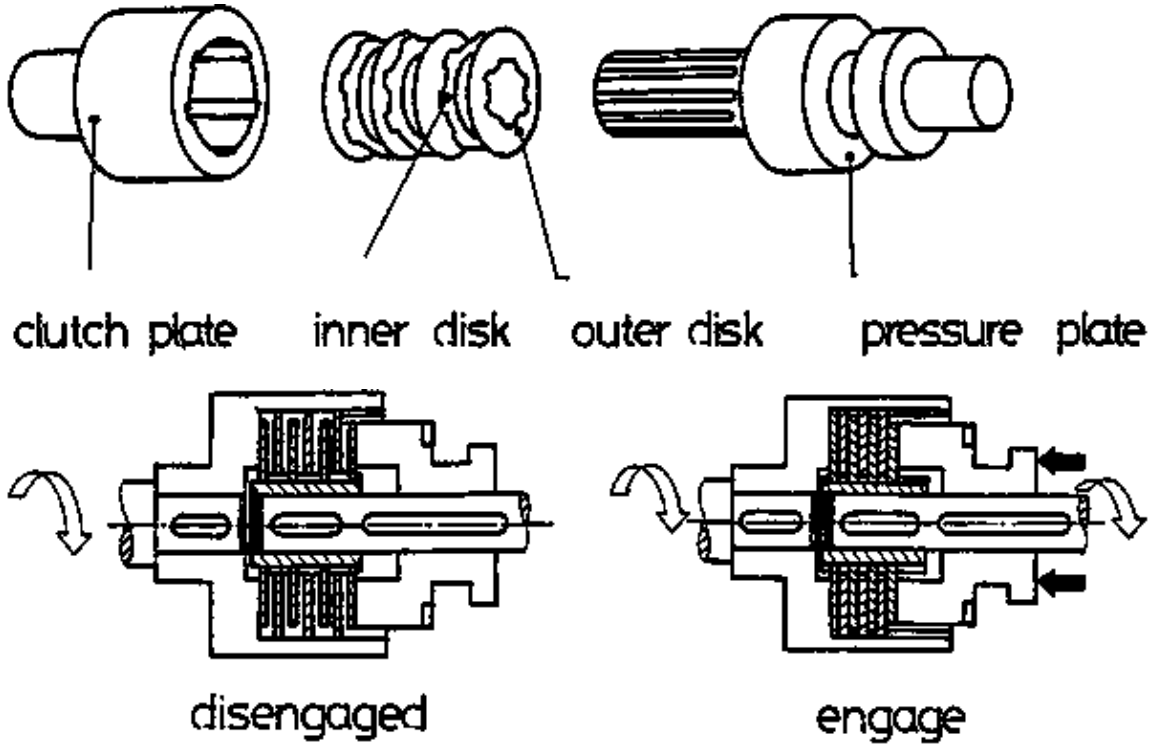


Friction clutch



Form fitting clutch

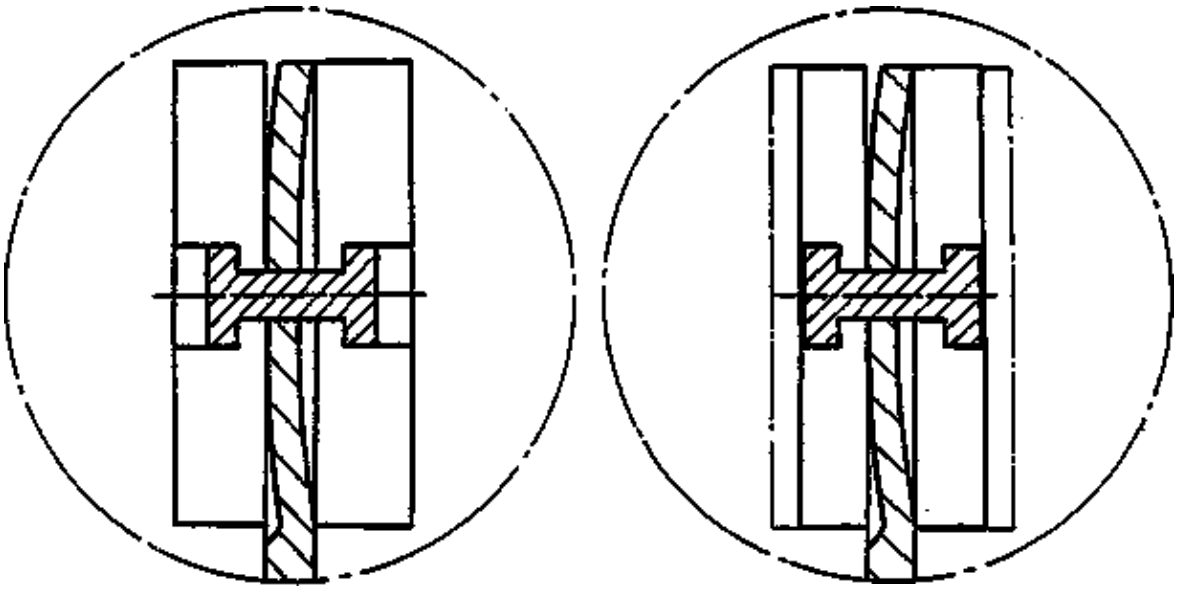
Friction clutches Multiple disk clutch



To get a large contact area by use more than 1 disk

Clutch Maintenance

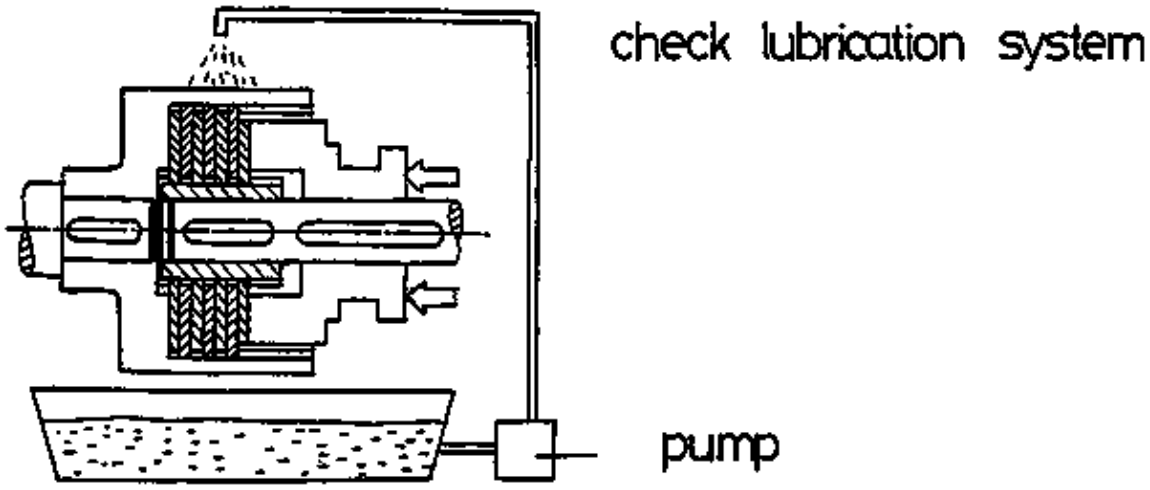
Single disk clutch



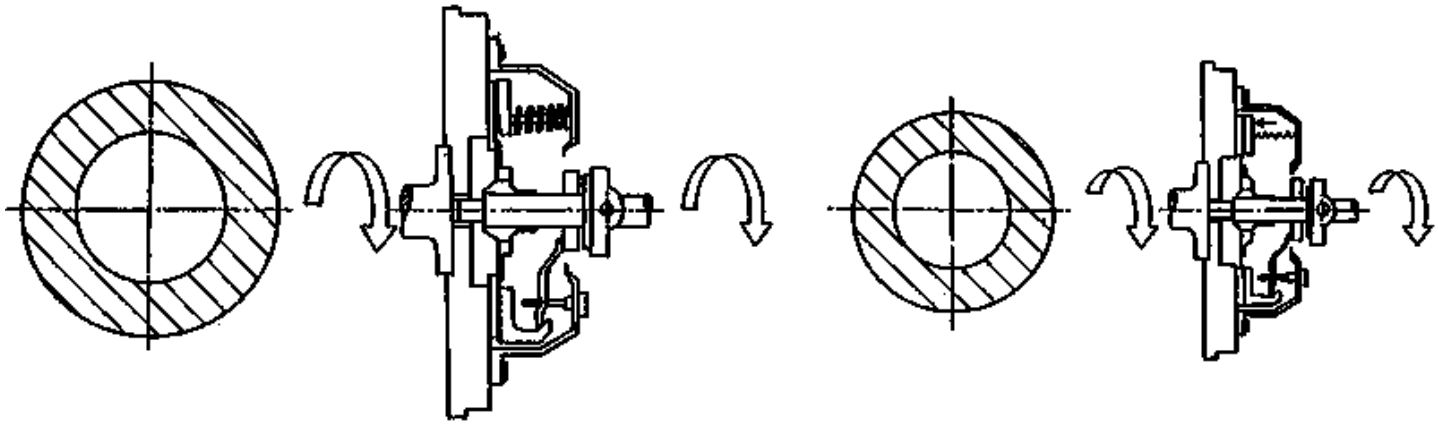
Before use

After use for a while

Multiple disk clutch



Factor which in effect to torque transmission of Single disk clutch

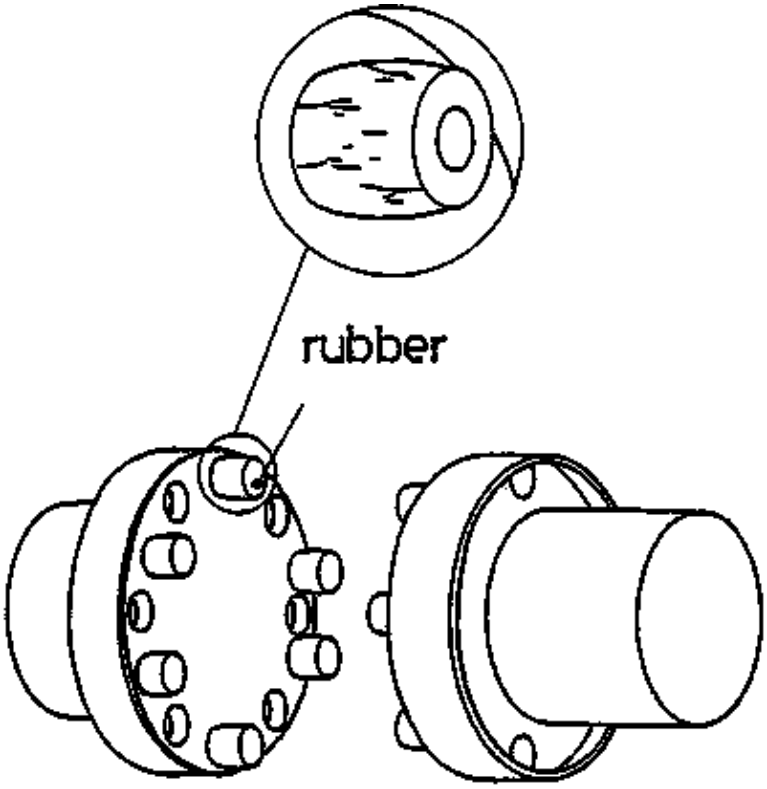


Efficiency of torque transmission depends on:

- Contact area
- Force which is pressing the disk

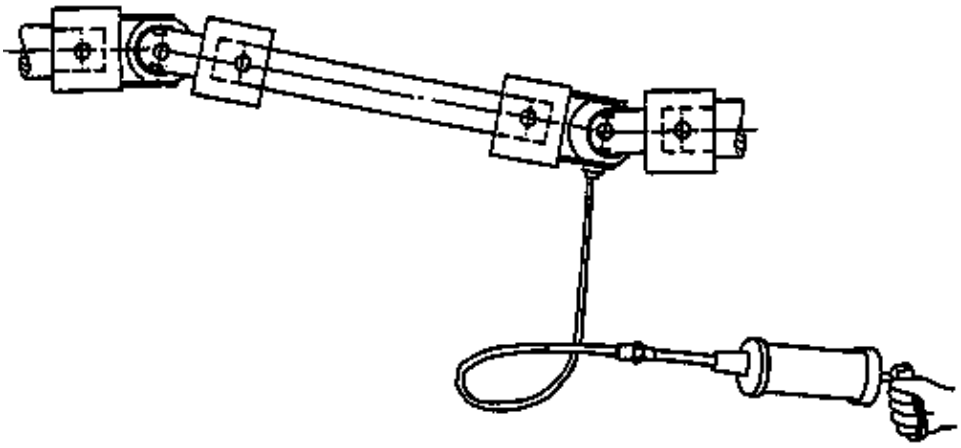
Maintence Flexible Coupling

Rubber coupling



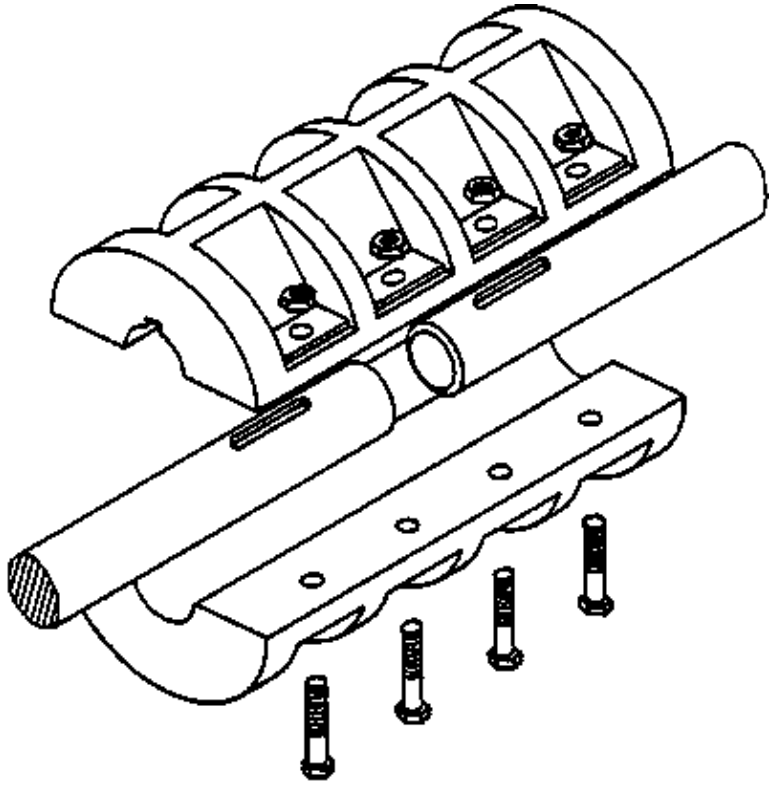
Replace the rubbers when they are damage

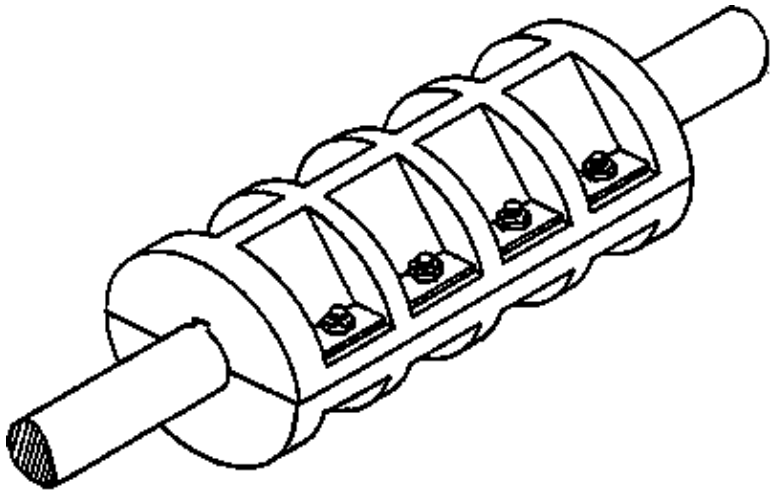
Universal joint



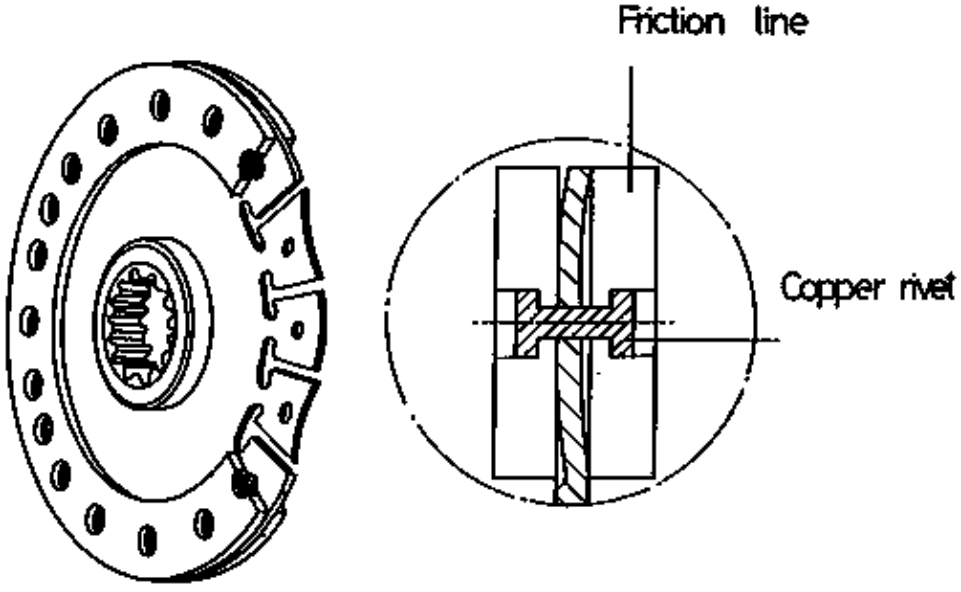
Grease it according to the manual

Clamp coupling





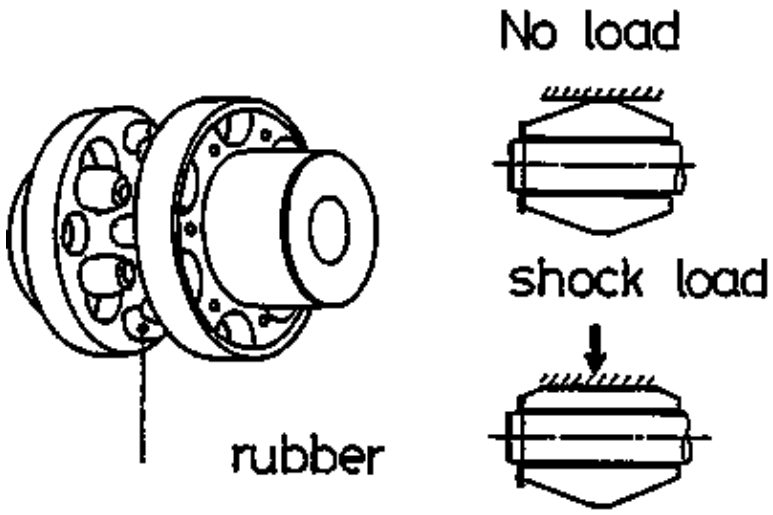
Material of Single disk clutch



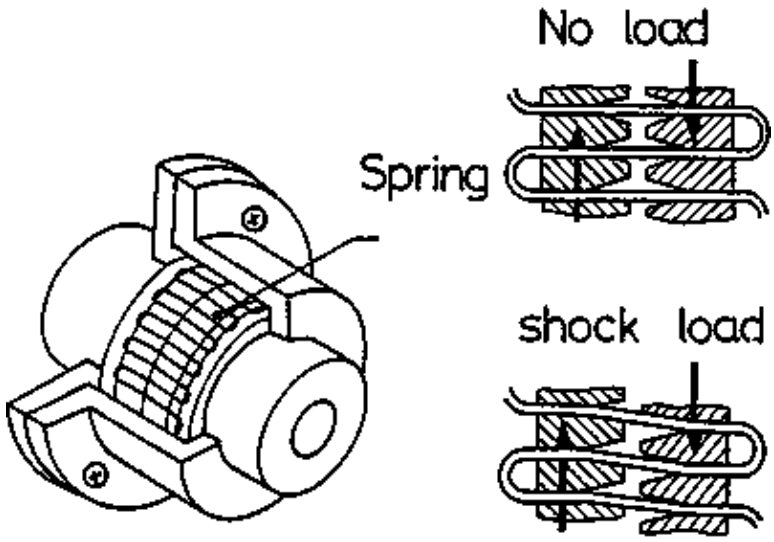
Note: Don't put oil or grease on the disk

Rubber coupling

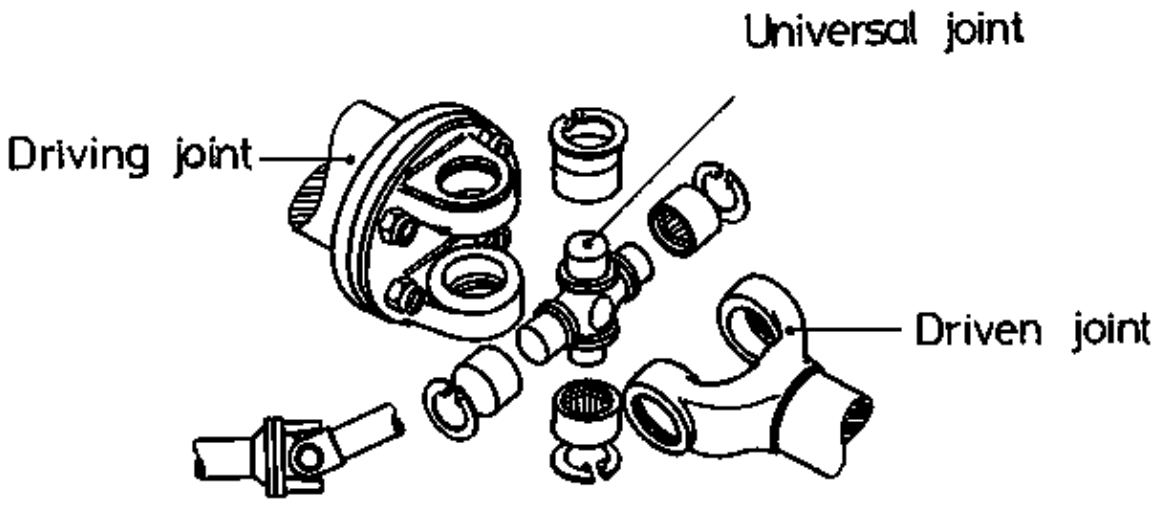
(Flexible coupling)



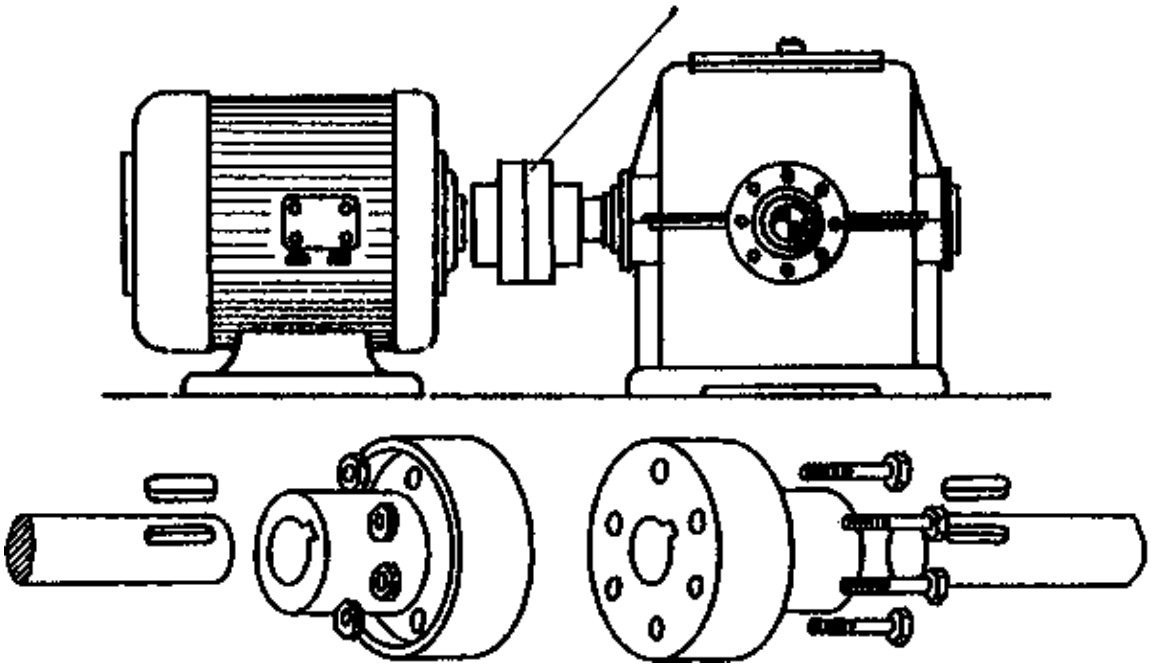
Steelband type



Universal joint



Couplings or Clutches



5. Belt drive

List of objectives

The student should be able to:

Purpose and basic function

1. Explain the use of the belt drive for

    a) transmission of torques
    b) modification of speeds/rpm
    c) reduction of vibrations/shocks

2. Give reasons for the need of tension in the belt.
3. Describe the effect of the wrapping angle to the transmissible force.
4. Explain the reasons why the idler pulley must act on the slack side.
5. Describe the effect of idler on the wrapping angle.
6. Explain the increase of friction caused by the component forces in V−grooves.
7. Describe the possible material for belt effecting friction and wear.

Types and main design

8. Describe the common material structure of flat and V−belts.
9. Express the standard codes for ordering a new V−belt.
10. Explain why the groove angle depends on the pulley diameter.

Assembling, repair and maintenance

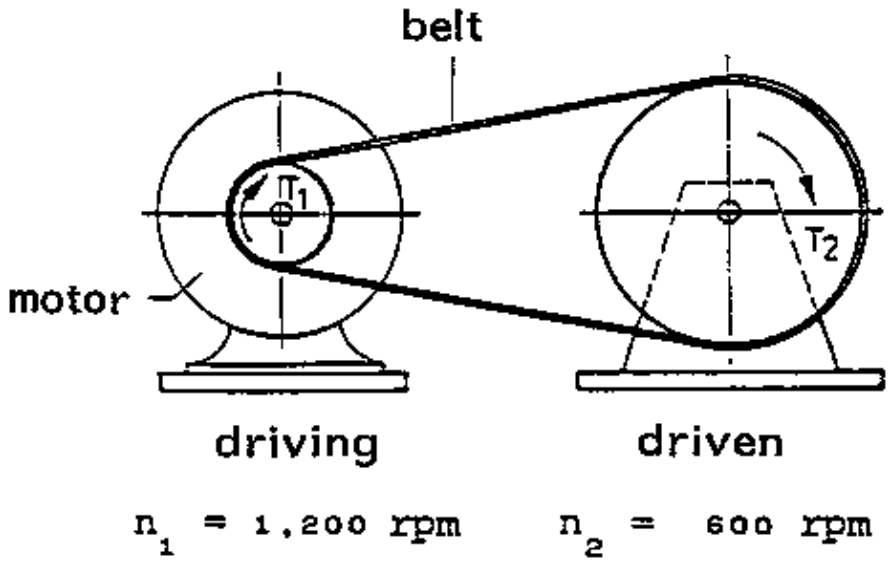
11. Describe the provision of tension by either shifting driver or swinging idler.
12. Give reasons why the idler for V−belts are positioned at the inner side of the belt.
13. Explain preconditions for centre running of flat belts,
14. Describe linkage to connect ends of flat belts.
15. Explain why dust, oil and heat must be kept away from belts.

Necessary preknowledge: Concepts of force, torque, power, friction, speed revolutions per minute.

Information sheet

1. Purpose and basic function

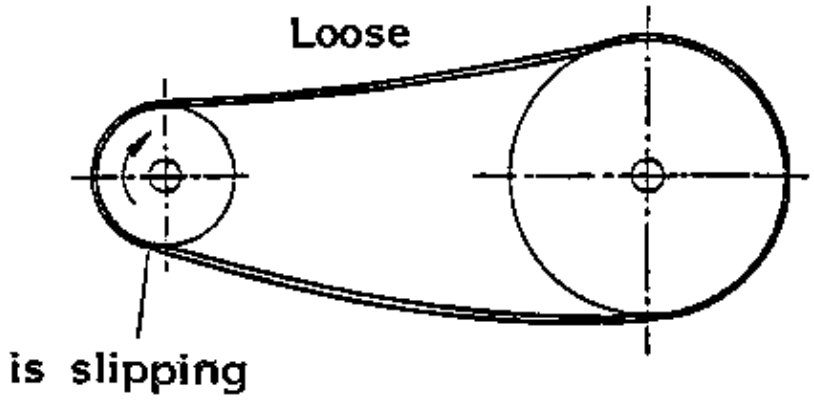
1.1 Purpose



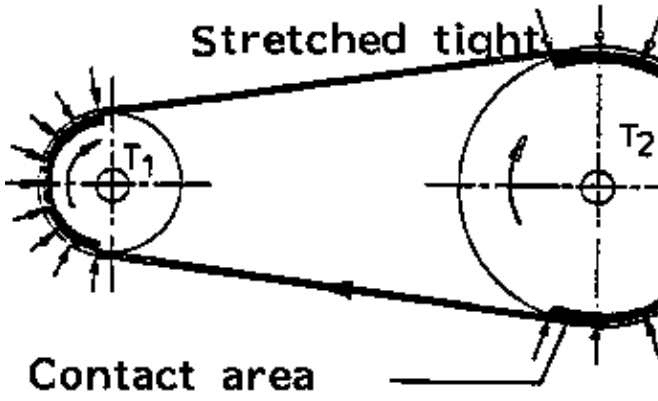
– Torque transmission from driving pulley to driven pulley
– Changing the RMP's
– Absorb vibration or shock load

1.2 Basic function

1.2.1 Tension

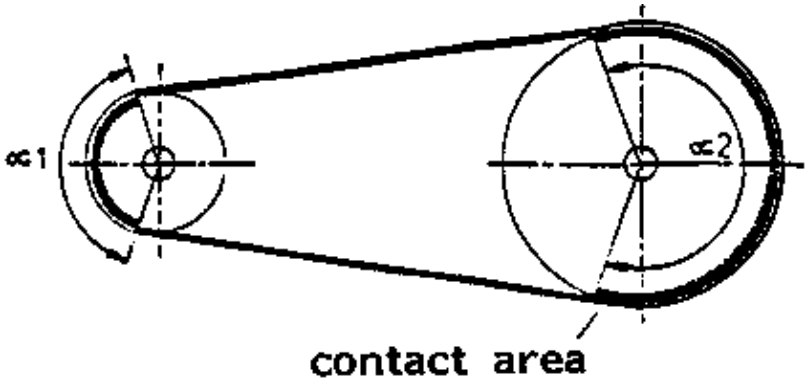


– Low torque transmission
– The belt slips



– Torque is transmitted by adherence.
– The tension is necessary to create friction between pu
belt.

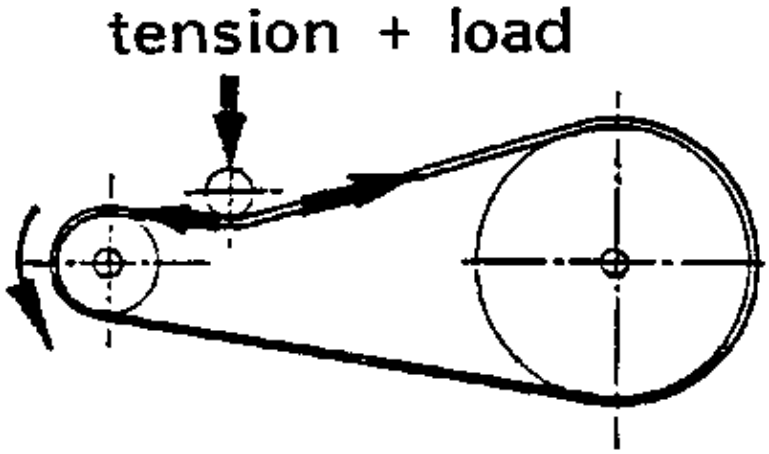
1.2.2 Wrapping angle



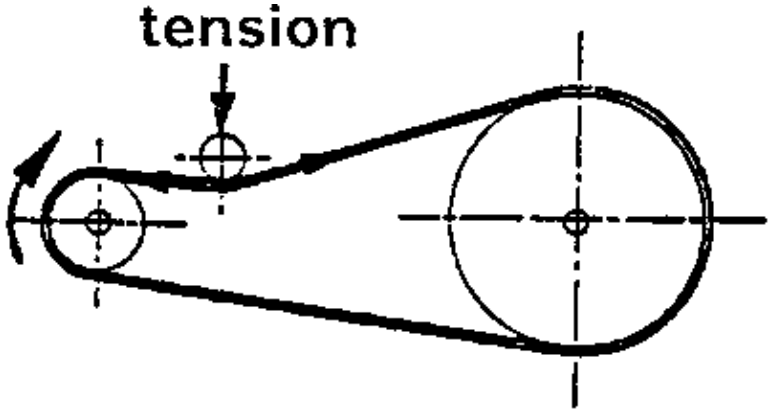
– Wrapping angle 1 2
– If the wrapping angle is big, the pulley can transmit high torque.

1.2.3 Idler

Idler position

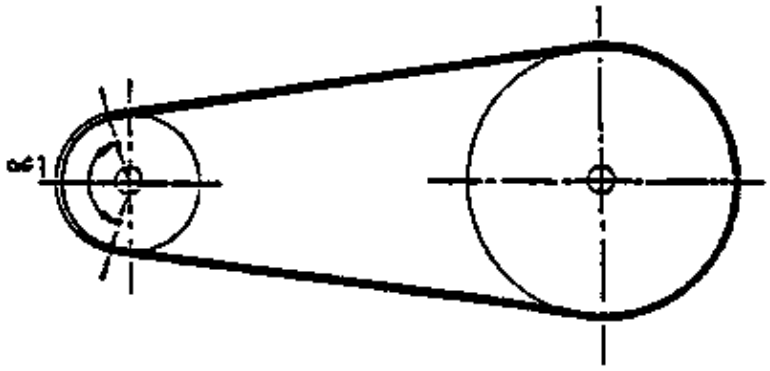


– When pressing on a belt's tight side with an idler, it will be high load on the idler.

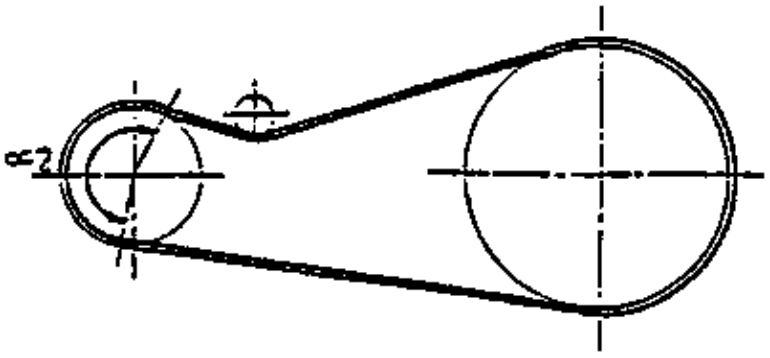


– When pressing on a belt's slack side with am idler, it will be low load on the idler.

Effect of an idler

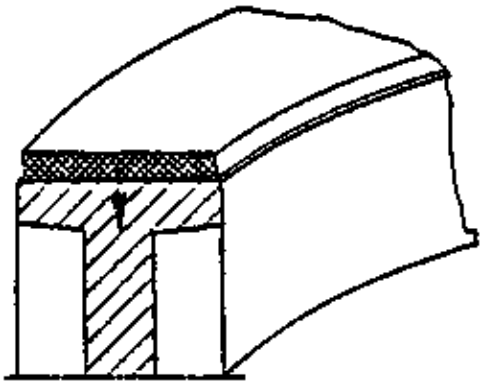


– small wrapping angle less contact – surface low torque transmission

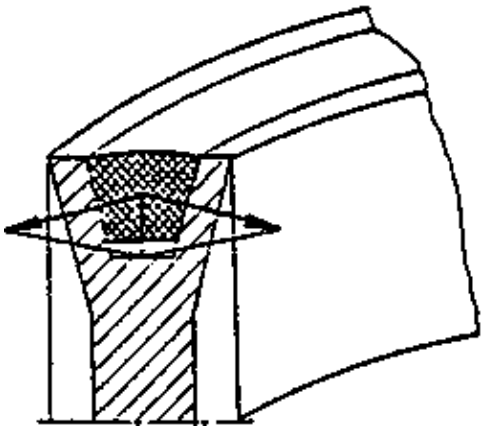


– big wrapping angle more contact surface high torque transmission

1.2.4 V–groove



– low pressing force low friction low torque transmission

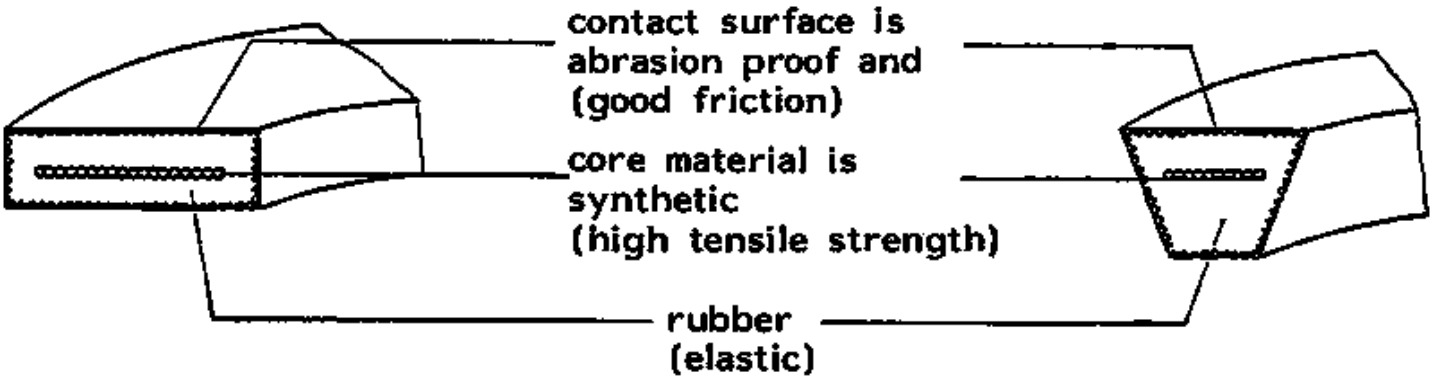


– high pressing force high friction high torque transmission

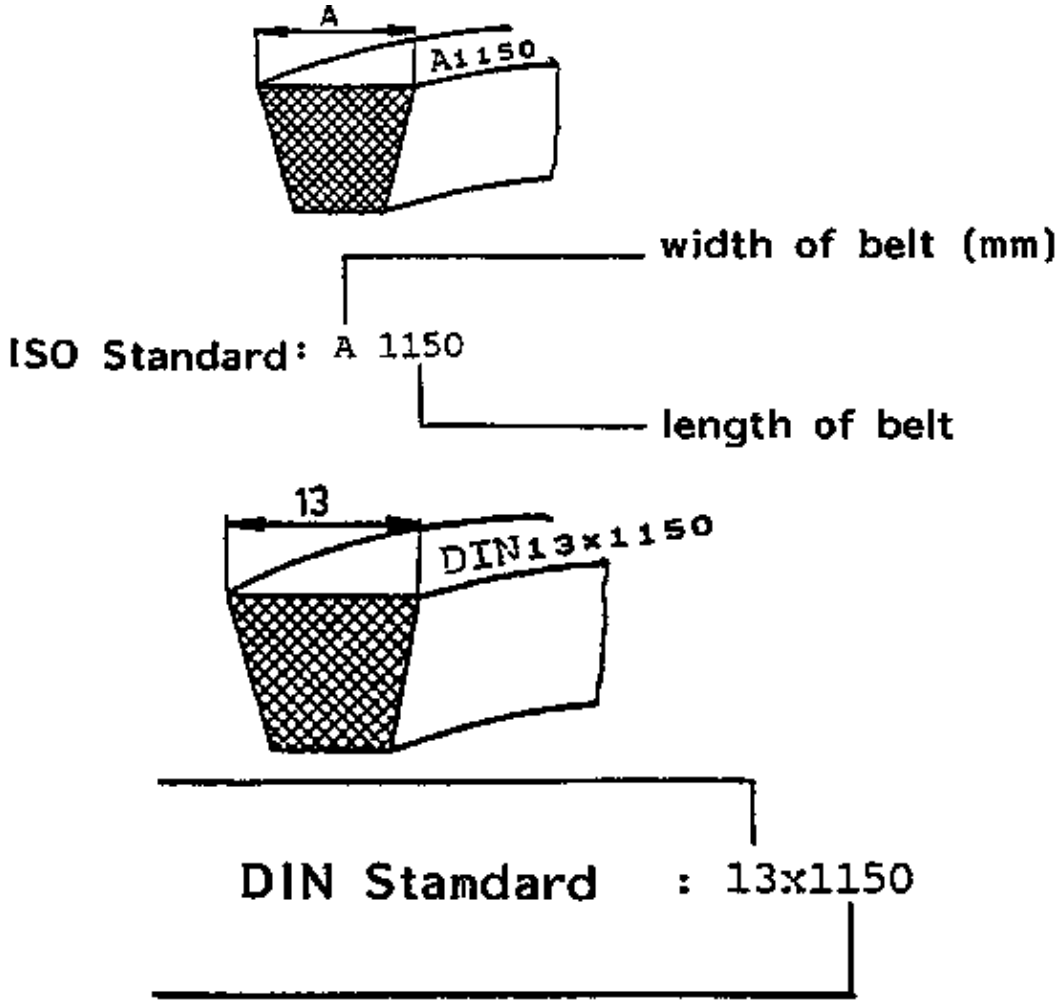
1.2.5 Materials and its property

Property	**Friction coefficient (μ)**	**Tensile strength**	**Elasticity**	**Wear resistance**
Material				
leather	0.6	medium	low	medium
rubber	0.4	low	high	medium
synthetic	0.2	high	low	high

2.1 Material – structure of belts



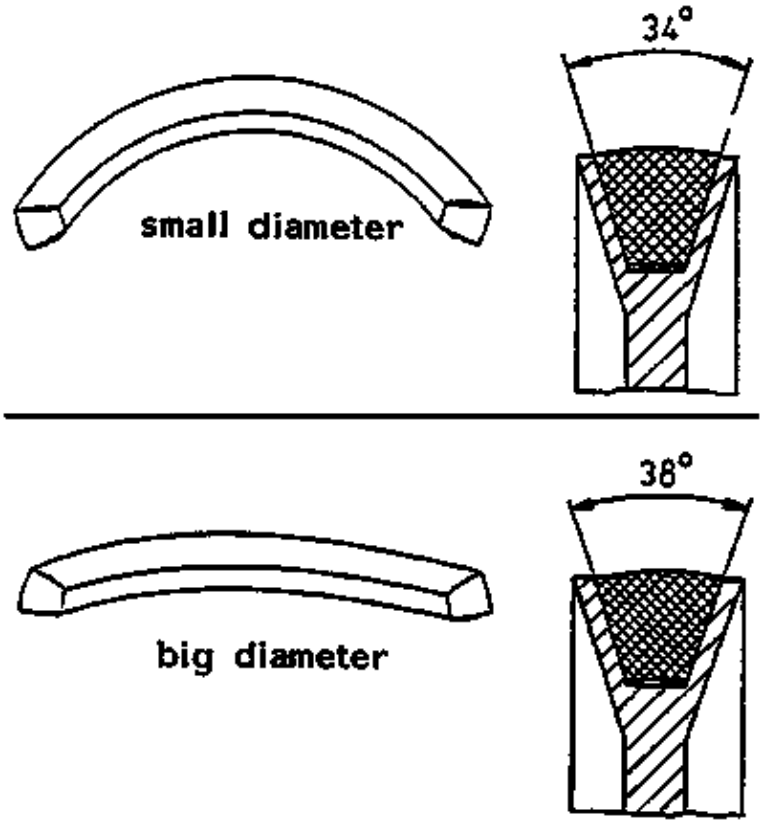
2.2 V–belt code



ISO	A	B	C	D
DIN	13	17	22	32

Note: ISO Standard specifies the length in inch and mm.

2.3 Groove angle and pulley diameter

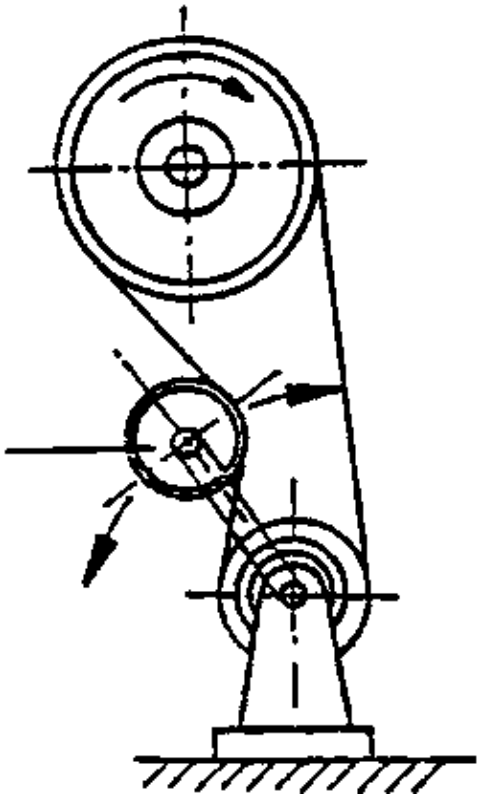


– The groove angle depends on the pulley diameter, a pulley with small diameter will have a smaller groove angle than one with big diameter.

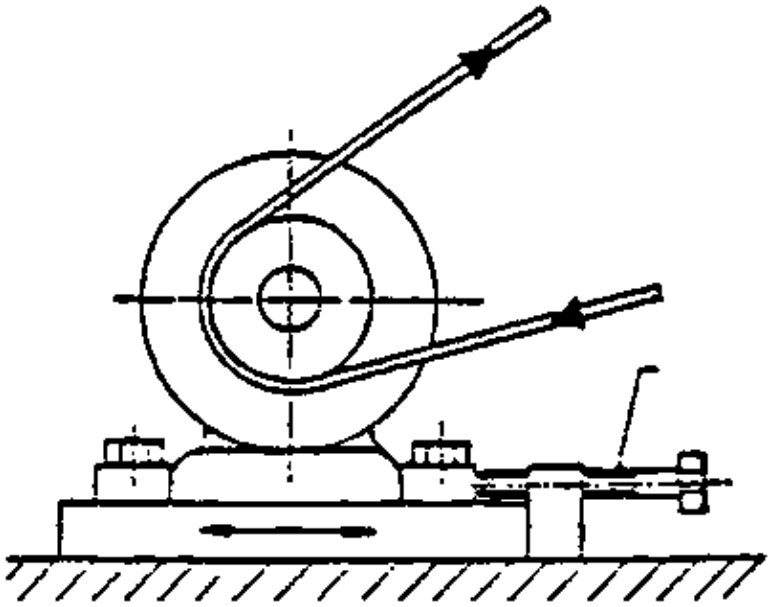
Note: For more detailed information see table book!

3. Assembling and repair

3.1 Adjustment of tension



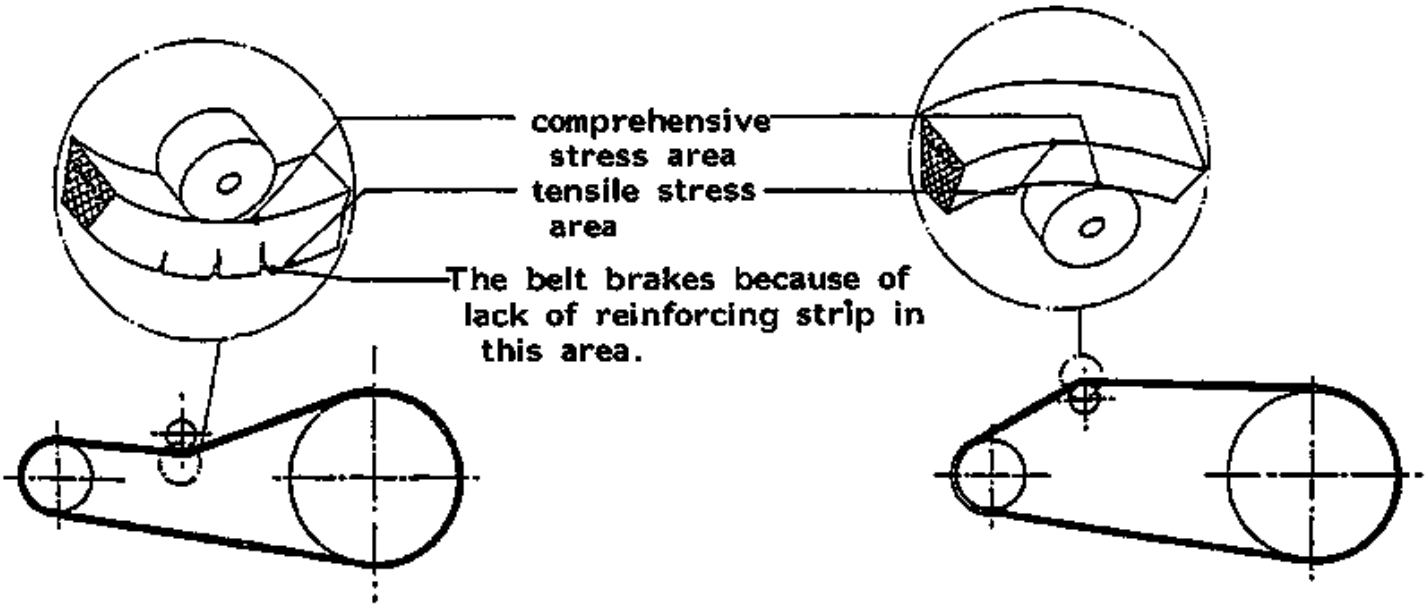
When the distance between two pulleys is fixed, the tension of a belt is adjusted by an idler.



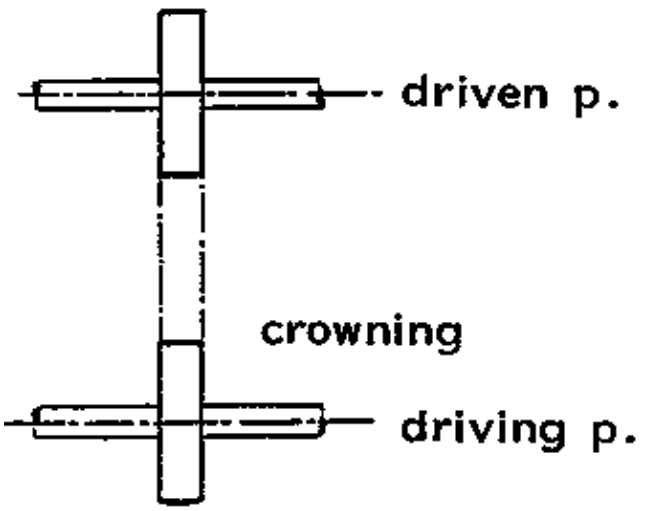
When the distance between two pulleys is not fixed, the tension of a belt is adjusted by adjustment screw.

Note: If the belt is flattering or squeaking, it must be adjusted.

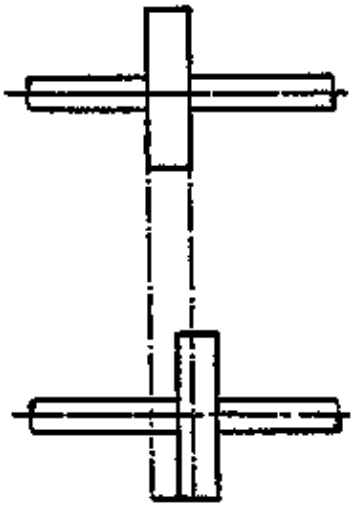
3.2 Idler position for V−belts



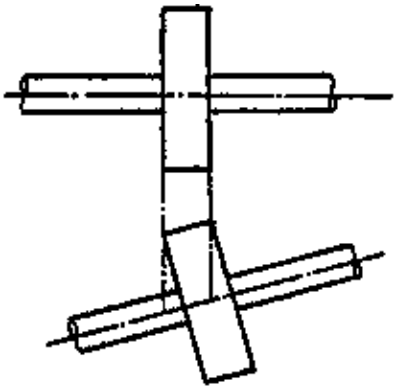
3.3 Centre running of a flat belt



Driving pulley must have crowning to centre the belt.

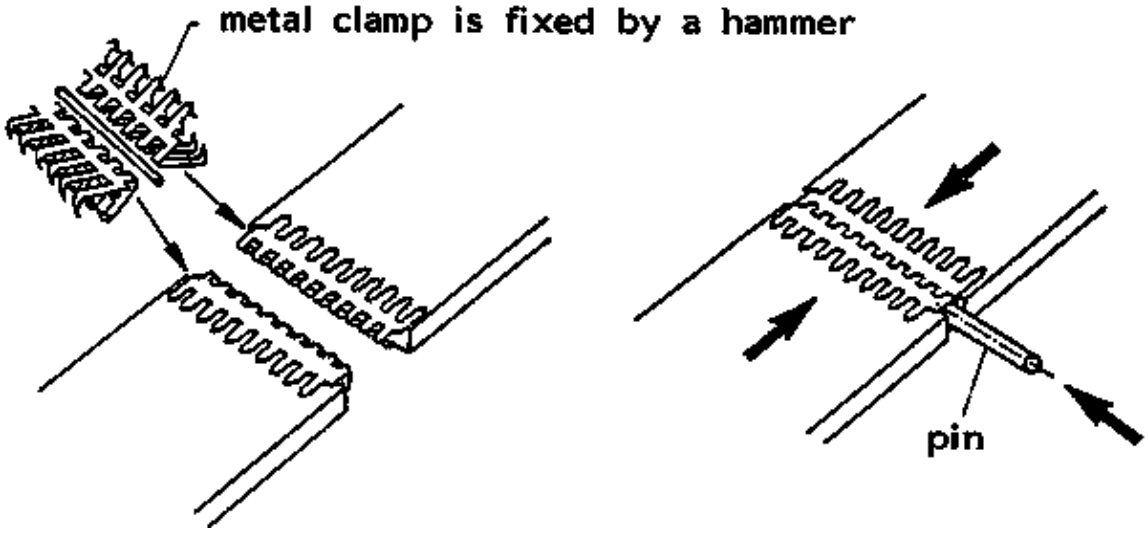


Pulleys are not in line belt will slip–off.



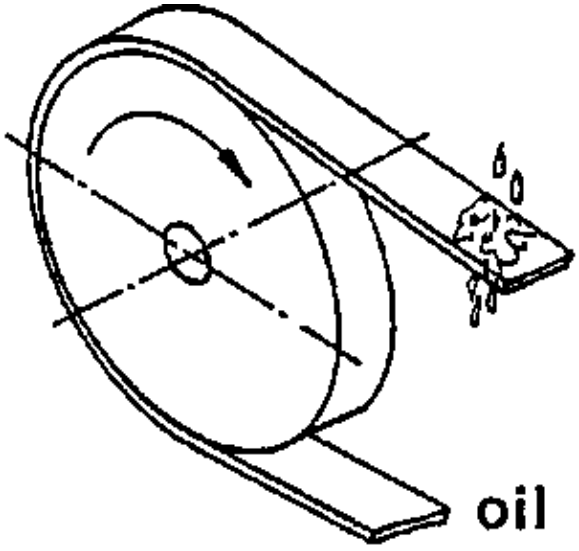
Pulleys are shew belt will slip–off.

3.4 Linkage of flat belt

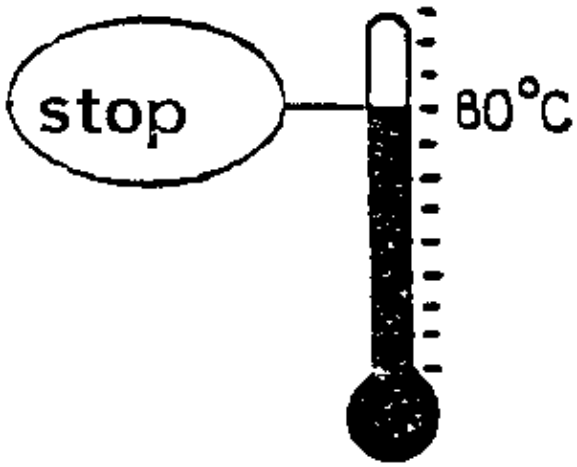


Note: Modern belts are endless

3.5 Effect of oil, dust and heat to the belt



Protect the belt from dust, oil and dist because this is reducing the friction the belt slips.

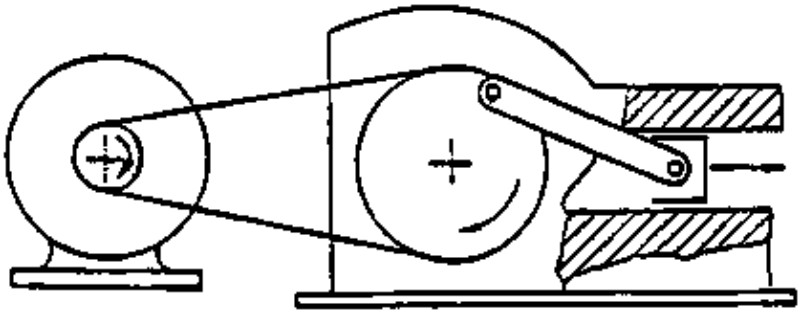


When the belt gets hot, it will loose tension and strength.

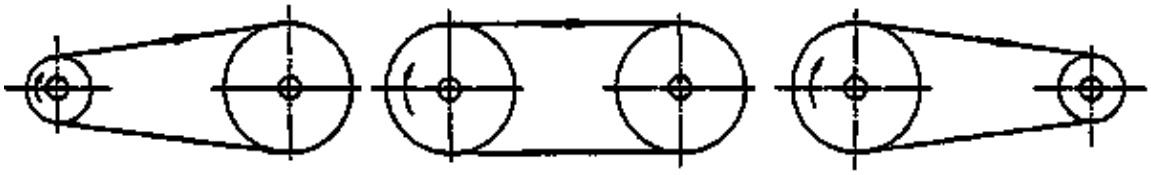
Task sheet

1.1

a) The purpose of a belt drive is to _____



b) In which of the pictures below the transmitted torque remains constant?



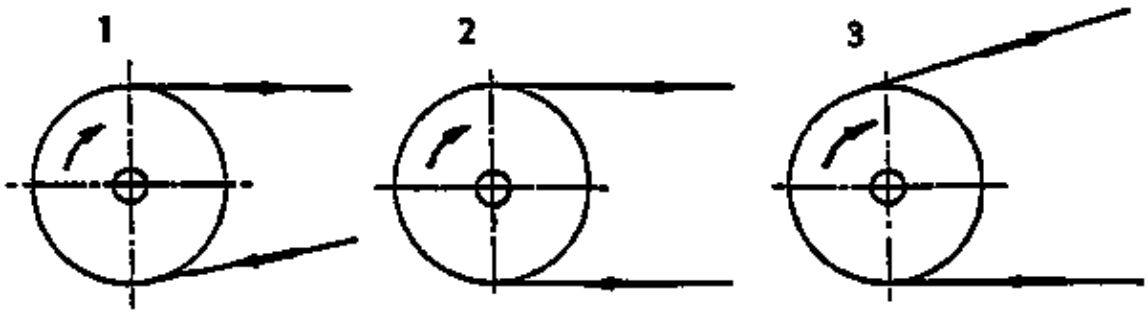
1.2

a) Power transmission is insufficient when

1. a belt is too tight
2. a belt is loose
3. the belt is too wide

b) For torque transmission by a belt its length/friction coefficient/elasticity is important.

c) Which pulley transmits maximum torque

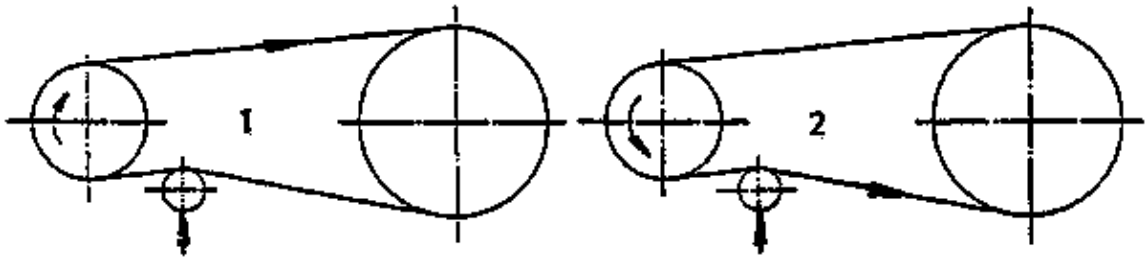


d) Which belt has the smallest wrapping angle?

e) When using an idler at the slack side of *a* belt drive, the consequence is that

1. the belt slips
2. the belt is overloaded
3. the pressure at the idler is high
4. the pressure at the idler is low

f) Which figure shows the correct rotating direction?



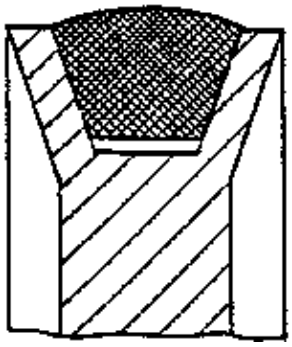
g) When using an idler, the contact surface between belt and pulley will increase/decrease and torque transmission will increase/decrease.

h) Which belt must be more tight?

1. V–belt 2. Flat belt

i) A V–belt creates more/equal/less friction than a flat belt.

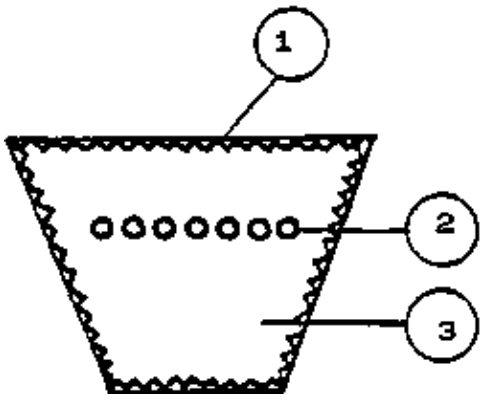
j) Indicate the component forces by drawing arrows.



k) Pair the belt material with its specific property:

1. high friction _____ leather
2. high elasticity ____ plastic/fiber
3. high tensile strength ____ rubber
4. high wear resistance

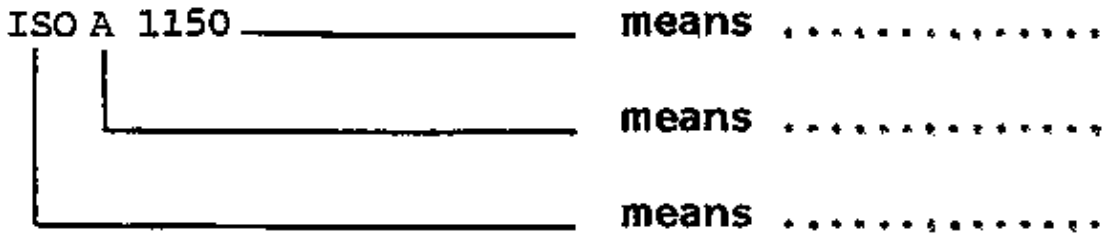
2.1 Which parts of a V–belt are related to the following properties?



– tensile strength
– wear resistance
– elasticity

2.2

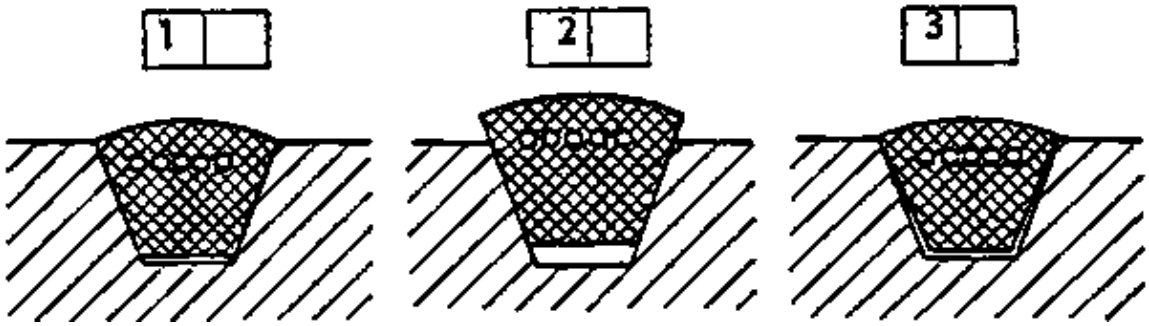
a) Explain the belt code!



b) Write a code to order a belt according to DIN whose width is 17 mm and length 900 mm.

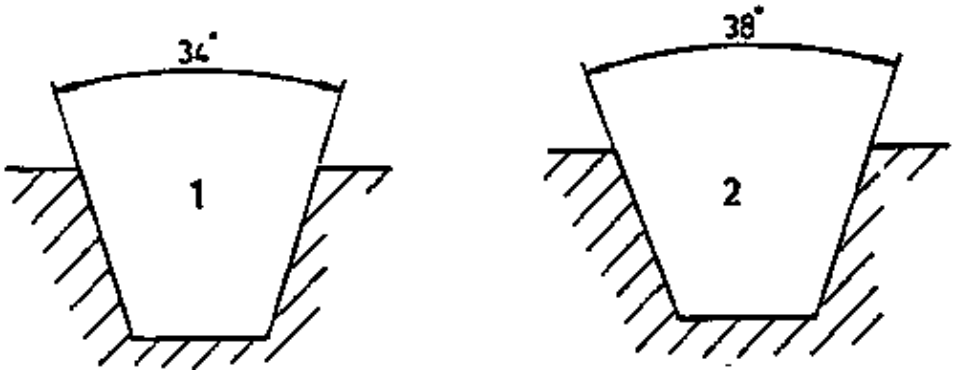
2.3

a) Which belt fits?



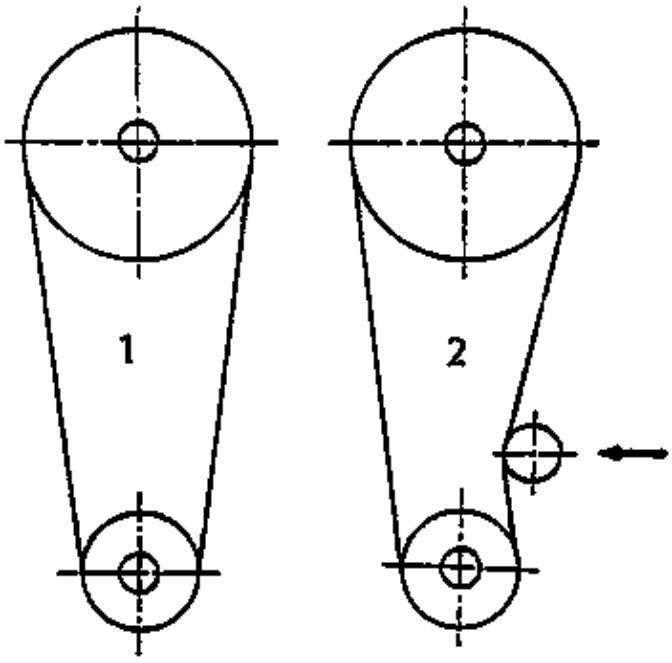
1 = _____
2 = _____
3 = _____

b) Which picture shows a pulley with big diameter?



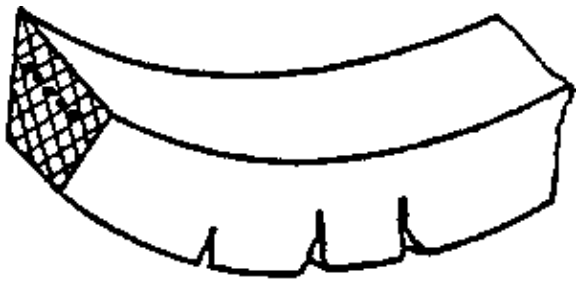
3.1 Fill in the right number to the statements

___ Wrapping angel and tension increases
___ Only tension of the belt increases
___ Adjustment by screw
___ Transmits maximum torque
___ Distance between pulleys remains constant



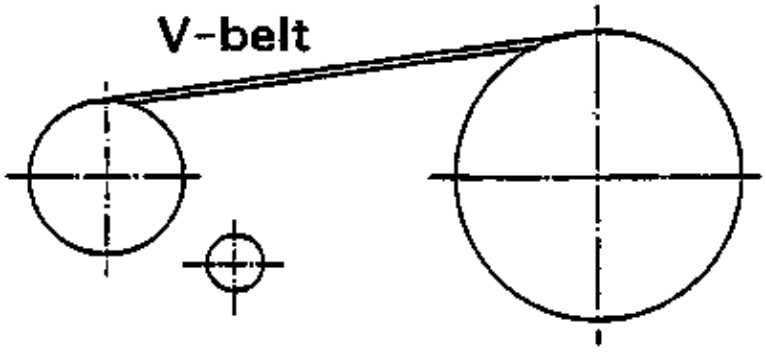
3.2

a) This damage happens to a V–belt when



not using an idler
the belt is too tight
idler is located outside of belt
idler is located inside of belt

b) Complete the drawing!



c) A flat belt will slip because

the belt is too tight
the pulley has no crowning
there is no idler
the pulleys are not in line

3.3

a) What will be the effect when the pulleys are not poraxial?

The ratio of power transmission will decrease
The belt will slip–off from the pulley
The belt will slip
The belt will wear

b) The pulley with crowning is used for driving/driven pulley.

Its purpose is to prevent the belt from slipping/slip–off.

3.4 Write down the steps of joining a flat belt with a steel clamp:

_____

3.5

a) Which effect has oil and dust on a belt?

_____

b) Which effect has overheating to the belt drive?

_____

Solutions

1.1

a) – transmit torque from the driving to the driven pulley
– change RMP's
– absorb vibrations or shock load

b) 2

1.2

a) 2

b) friction coefficient

c) 1

d) 3

e) 4

f) 2

g) increase – increase

h) 2

i) more

j)

k) – leather 3, 4 plastic/fiber 1, 2 rubber

2.1

2 tensile strength 1 wear resistance 3 elasticity

2.2

a)

international standard
width
length

b) DIN 17 × 900

2.3

a) 1

b) 1

3.1

2 wrapping angel and tension increases
1 adjustment by screw
1 only tension of the belt increases
2 transmits maximal torque
2 distance between pulleys remains constant

3. 2

a) the idler is located outside the belt

b)

c) there is no idler

3.3

a) the belt will slip−off from the pulley

b) driving pulley slip−off

3.4

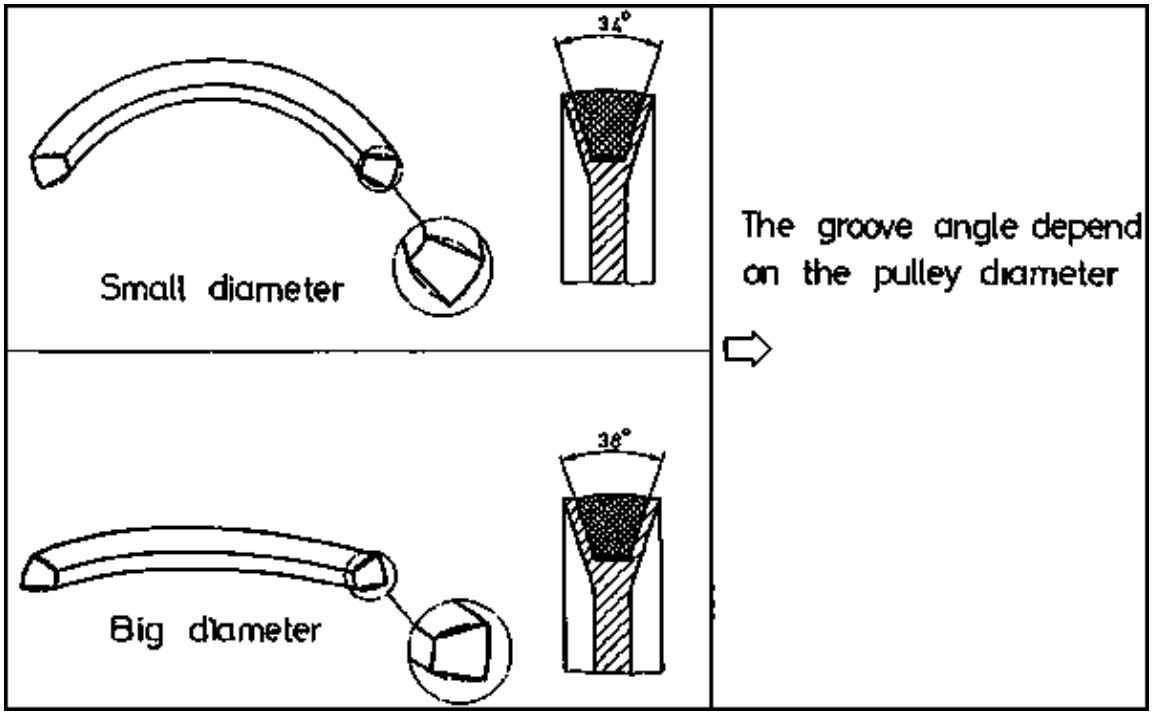
fix metal clamps with a hammer and connect them with a pin

3.5

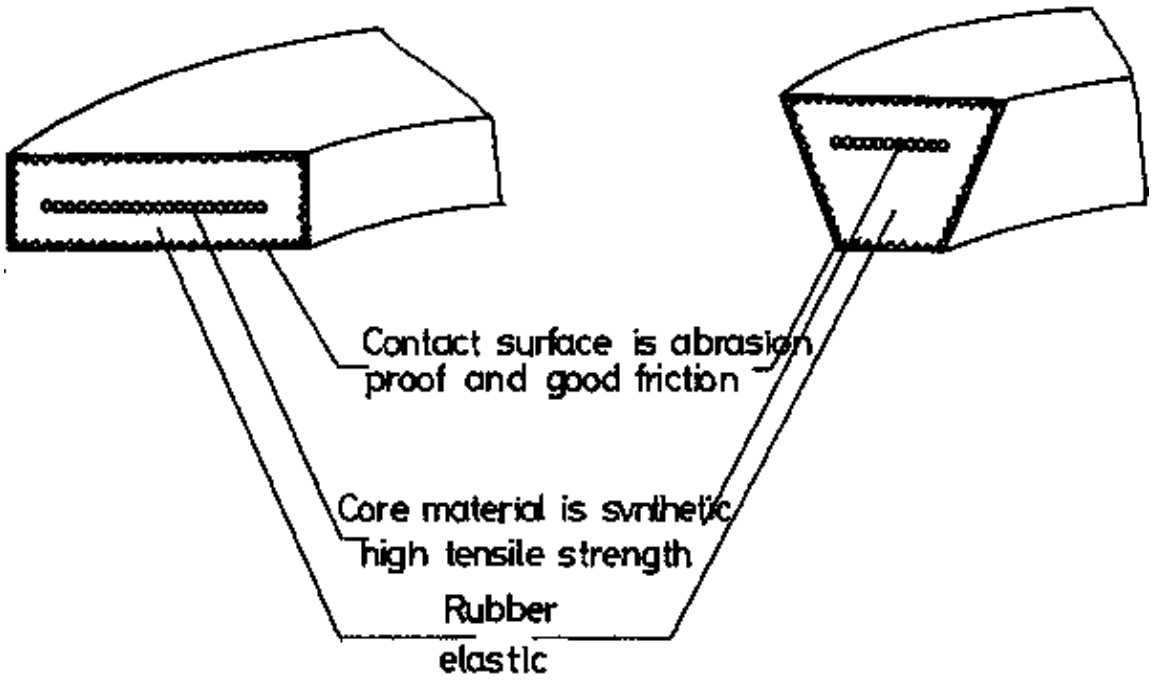
a) the belt slips

b) the belt will loose tension and strength

THE GROOVE ANGLE DIAMETER OF PULLEY

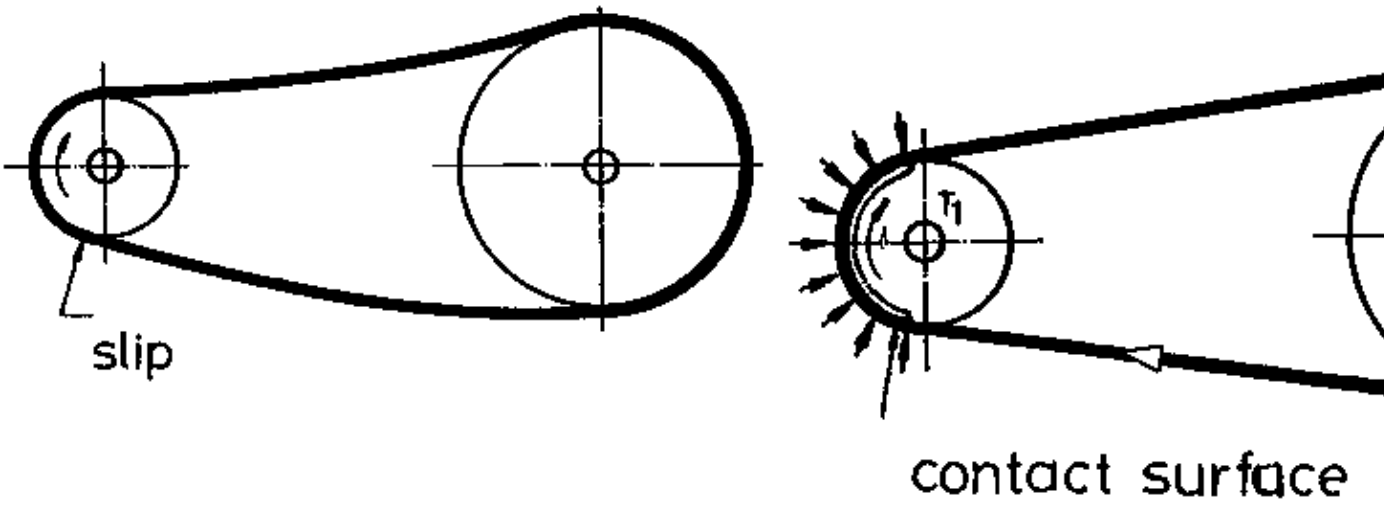


STRUCTURE OF BELTS



THE REASON WHY IT IS NECESSARY TO ADJUST THE TENSION IN BELT

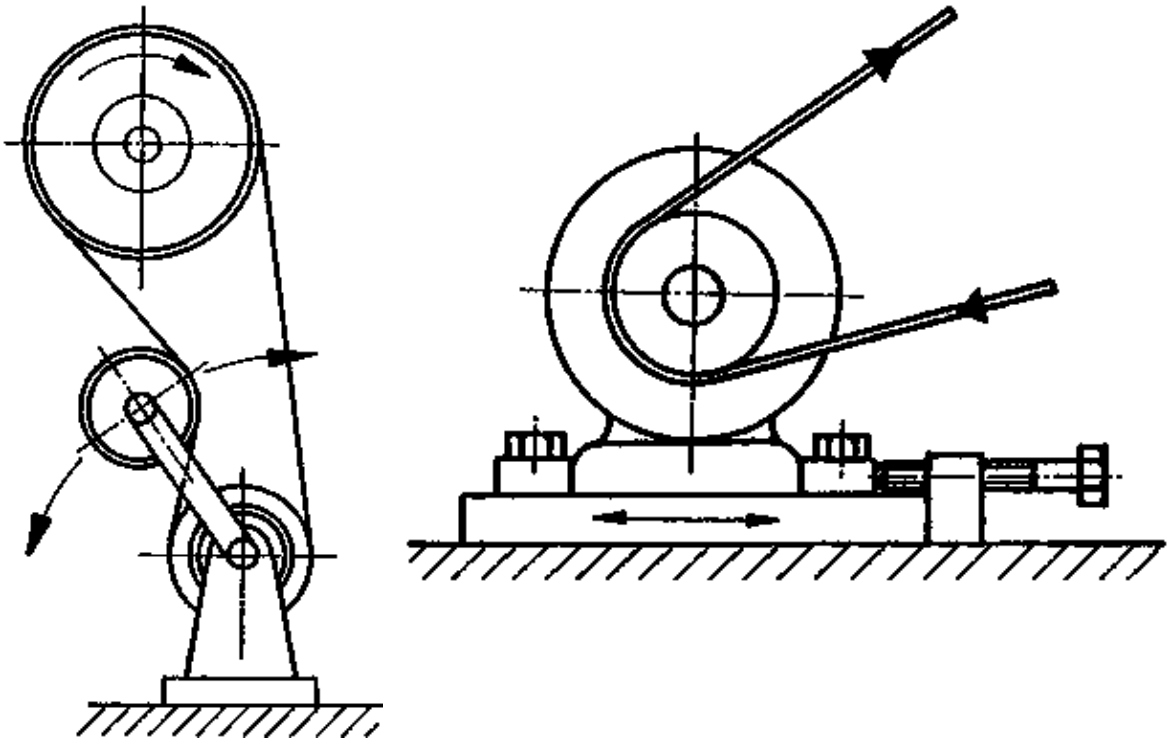
belt slack side belt tight side



slip ⇩ power cannot transmission

have friction at contact su ⇩ (T_1 ⇨ T_2) power can transmissio

ADJUSTMENT OF TENSION



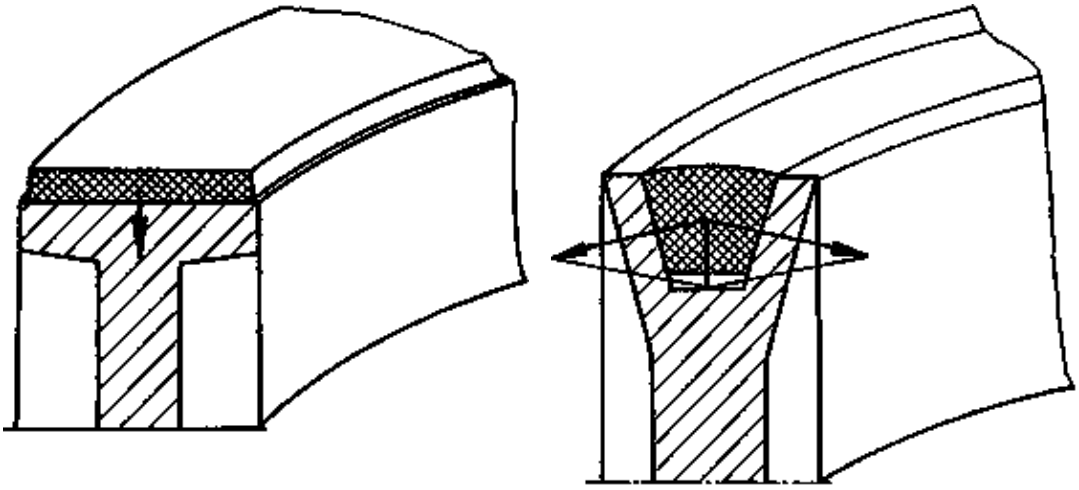
By idler

By adjustment screw

HIGH FRICTION OF BELT

Flat belt

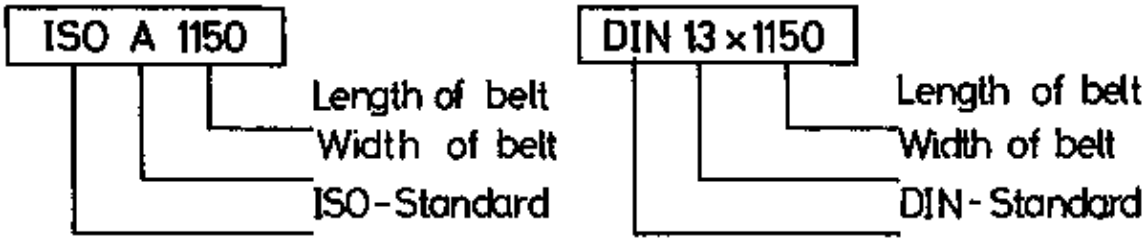
V – belt



Low friction force

High friction force

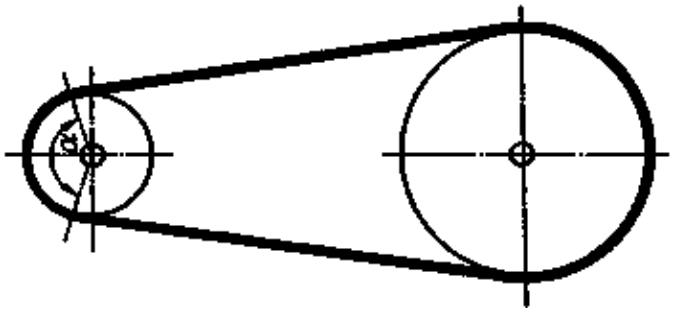
CODE OF V–BELT



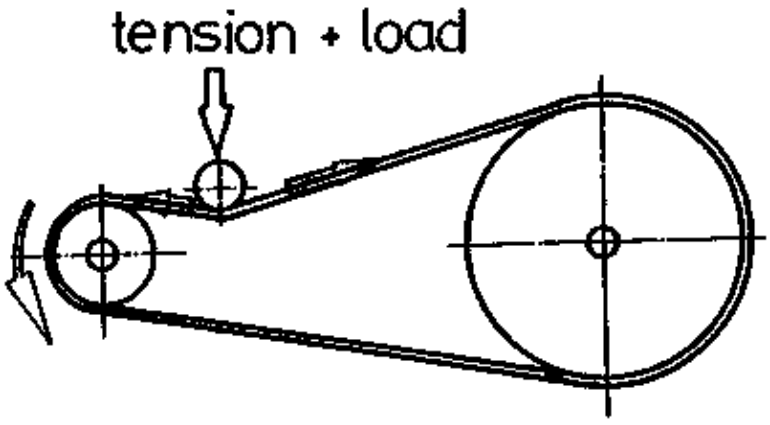
Comparison table of ISO and DIN standard

ISO	A	B	C	D
DIN	13	17	22	32

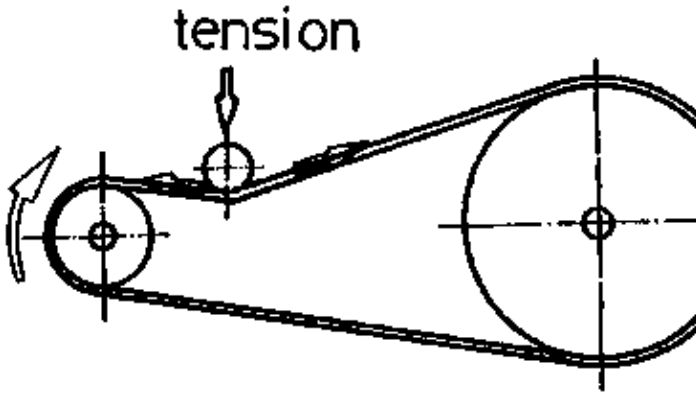
IDLER POSITION



normal wrapping angle

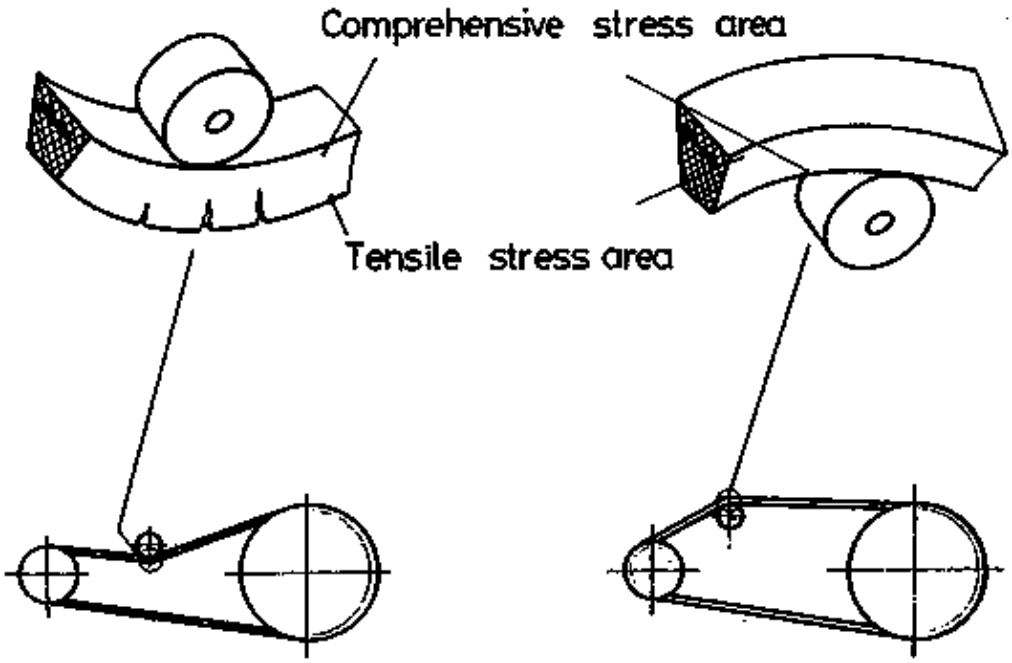


increase wrapping angle ?

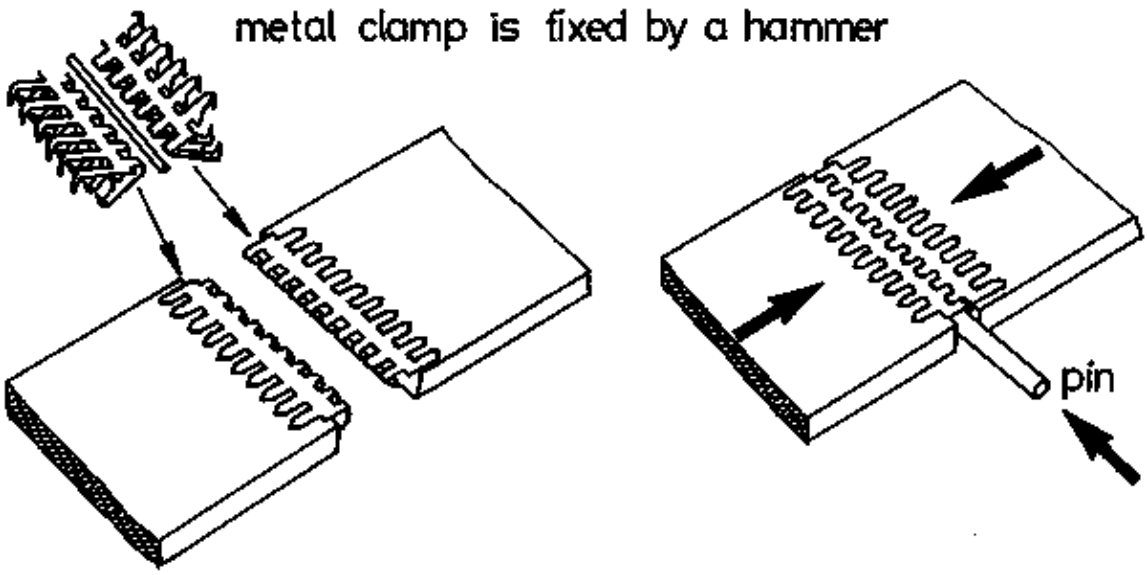


pressing on belt slack side
near the driving pulley

IDLER POSITION OF V–BELT

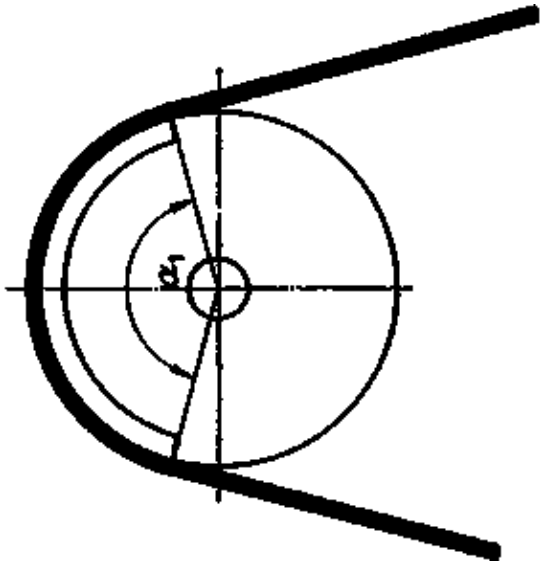


LINKAGE OF FLAT BELT



WRAPPING ANGLE OF PULLEY

Wrapping angle is small ($?_1$)



low contact surface

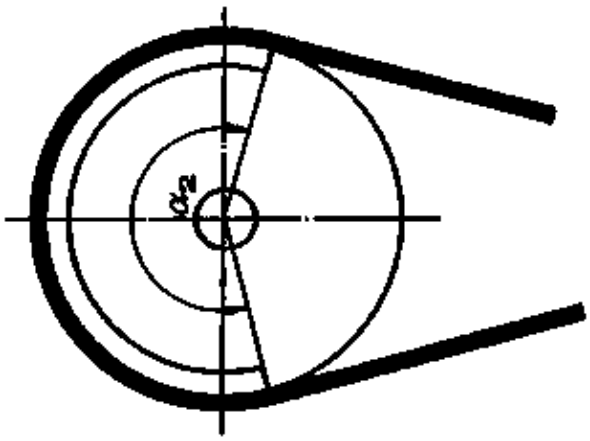
⇩

slip

⇩

low power transmission

Wrapping angle is big ($?_2$)



high contact surface

⇩

no slip

⇩

high power transmission

6. Gears

List of objectives

I. Purpose and basic principle

1. To describe the purpose of power transmission by gear according to the following subjects:

   – transmission of torque
   – change of revolution

2. To distinguish between friction transmission and form transmission according to the following subjects:

   – slip
   – revolution
   – torque transmission
   – transmission character

II. Design

3. To explain how to construct an involute curve
4. To describe the definition of the following dimensions: p, d, h, ha, hf, b, da, and df
5. To explain the pressure angel
6. To determine the above mentioned dimensions with the help of a formula–table
7. To explain why a pair of gear can only be engaged when they have the same module
8. To explain the definition of module
9. To describe the negative effect of undercut at gears with less with less than 14 teeth

10. To explain how to prevent undercut

III. Types and application

11. To describe shape and application of the following gears: spur, helical, bevel and worm
12. To describe shape and application of rack and pinion
13. To explain the advantage and disadvantage of torque–transmission by different types of gears

IV. Types of gear boxes

14. To describe the character and application of the following types of gears: fix ratio, change gear, shift gear, driving gear, norton gear, planetary gear, back gear and idle gear,

15. To explain how to change the revolution of a shifting gear

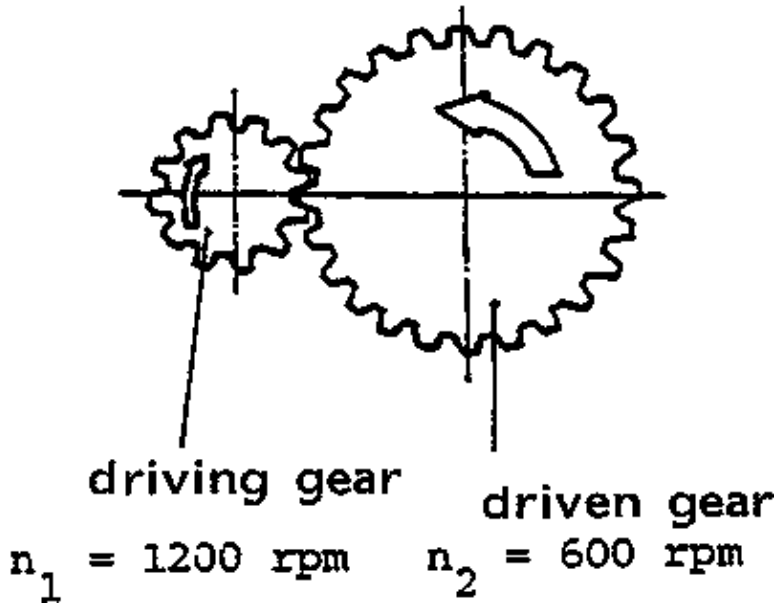
V. Maintenance and repair

16. To describe how to check pitch, module and backlash of a gear
17. To explain the need of backlash
18. To describe how a gear is repaired
19. To name at least 3 types of gear–material and consider their selections
20. To explain why the material of a small gear should have better quality than a big one
21. To explain at least 3 methods of lubrication
22. To choose the right lubrication method for different jobs

Information sheet

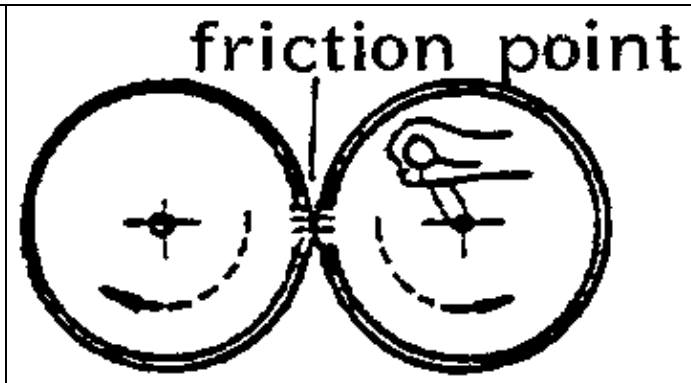
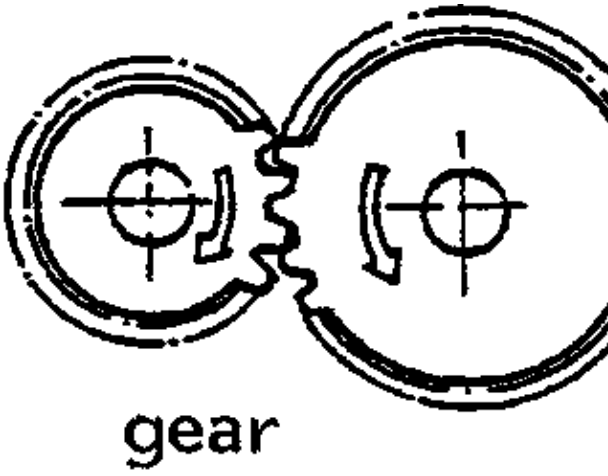
1. Purpose and basic principle

1.1 Purpose



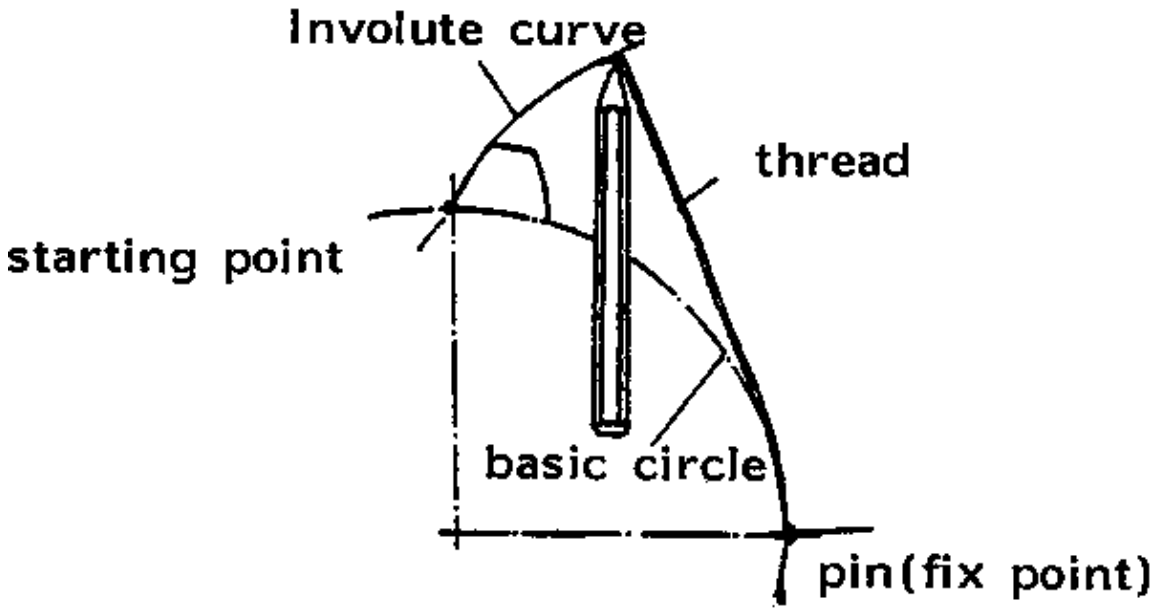
– to transmit torque from the driving to the driven gear
– to change the revolution

1.2 Basic principle

		
slip revolution power transmission lock	Yes not constant low friction	No constant high form fitting

2. Design

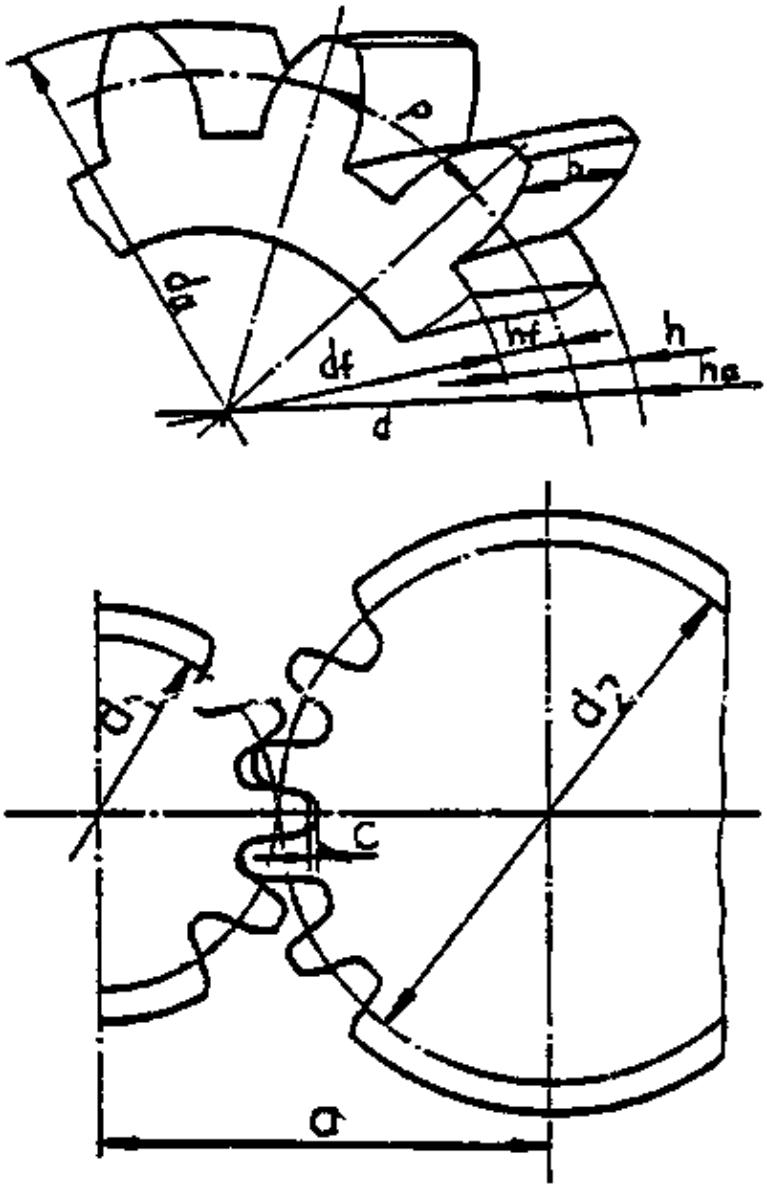
2.1 Construction of involute curve



An involute curve is generated by unwinding from the circumference of a circle

Note: Gears with involute teeth are widely used because of minimum friction.

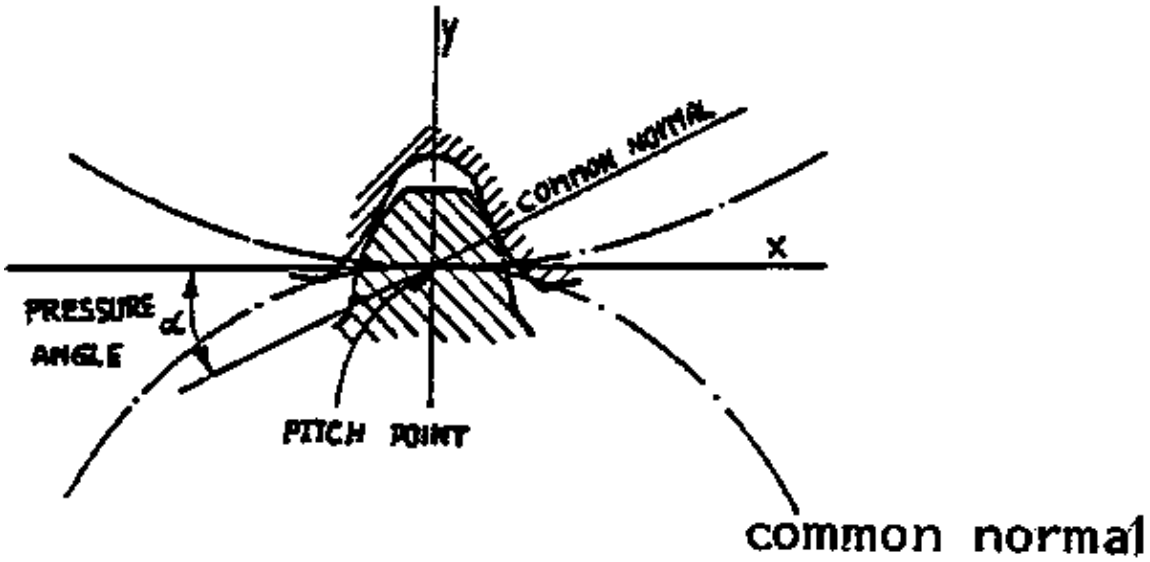
2.2 Dimensions and calculation of spur gear



Name	Symbol	Formula	Size	
			gear[1]	gear[2]
pitch	P	$P = \frac{\pi d}{z}$	15.7	
number of teeth	z	$z = \frac{\pi d}{P}$	20	30
module	m	$m = \frac{d}{z}$	5	
pitch circle diameter	d		100	150
height of tooth	h	$h = h_a + h_f$	11	
addeudum	h_a	$h_a = 1m$	5	
dedendum	hf	$hf = \frac{7}{6}m$	5.83	
width of face	b		40	

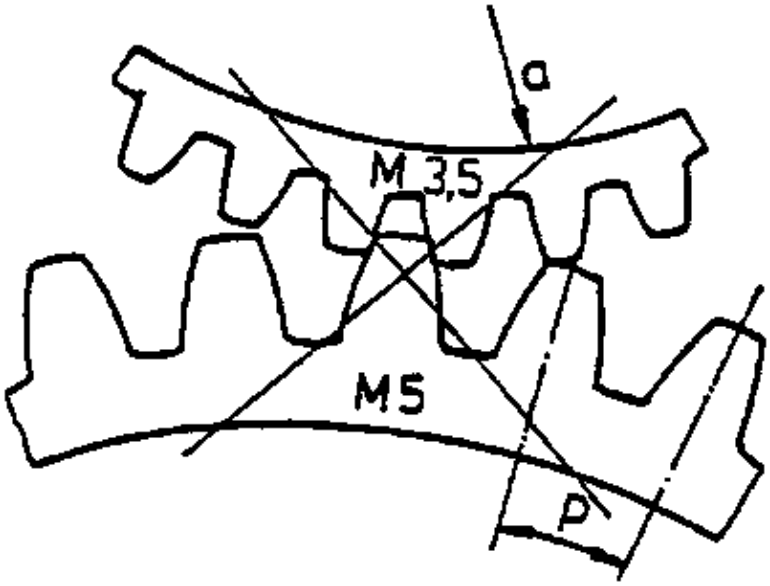
outside diameter	d_a	$d_a = d + 2m$	110	160
root diameter	d_f	$d_f = d - 2hf$	98.34	148.34
crest clearance	c	$c = \frac{1}{6}m$	0.83	
axial distance	a	$a = \frac{d_1 + d_2}{2}$	125	
pressure angel	?		20º	

2.3 Pressure angel



Along the common normal, the teeth are in contact (pressure) while the gears rotate.
The angel between tangent x and common normal is the pressure angel

2.4 Module and pitch



U = d.?

$$P = \frac{\pi d}{z}$$

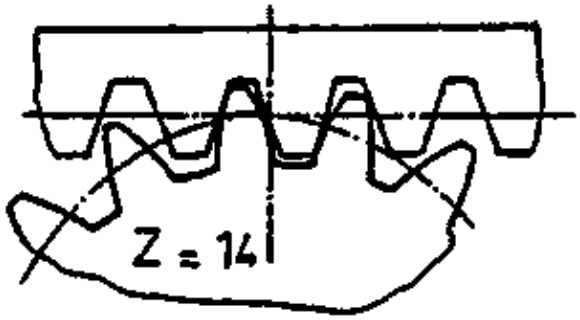
$$m = \frac{P}{\pi} = \frac{\frac{d.\pi}{z}}{\pi} = \frac{d}{z}$$

module table (mm)							
module	1.0	1.25	1.5	2.0	2.5	3.0	4.0
pitch	3.142	3.927	4.712	6.283	7.854	9.425	12.588
module	5.0	8.0	8.0	10.0	12.0	18.0	
pitch	15.708	18.850	25.132	31.416	37.699	50.265	

Note: gears with different module dp not fit

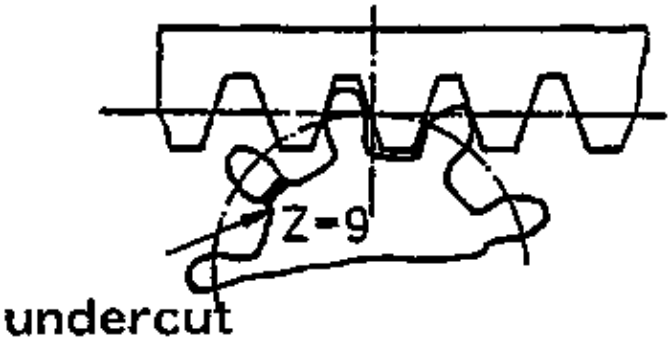
2.5 Undercut modification

a) normal gear



gear tooth is normal

b) gear with less than 14 teeth



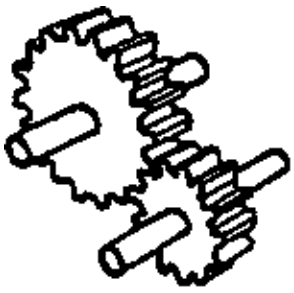
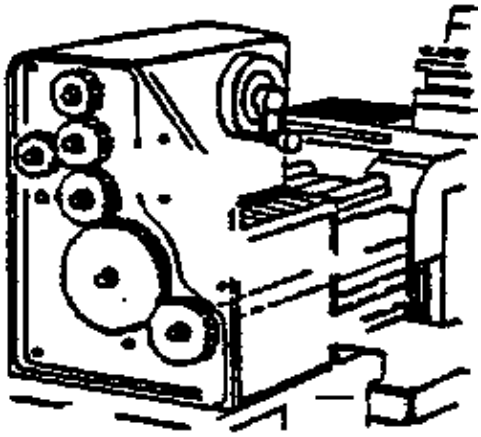
gear tooth is weakened

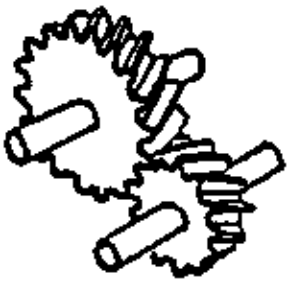
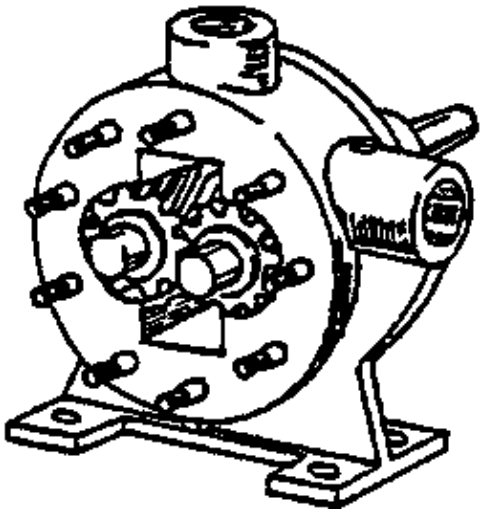
c) under

gear too

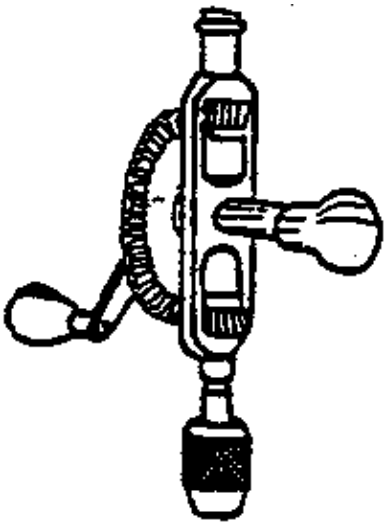
3. Types and application

3.1 Paraxial

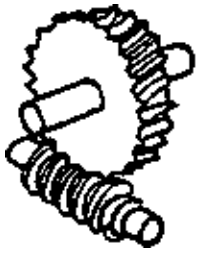
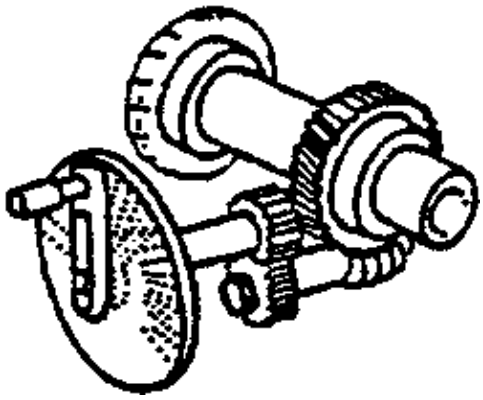
Type	Application	Advantage	Disadvantage
 Spur gears	 feed gear box	easy to produce	noisy

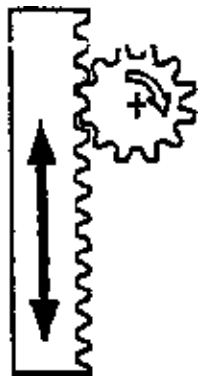
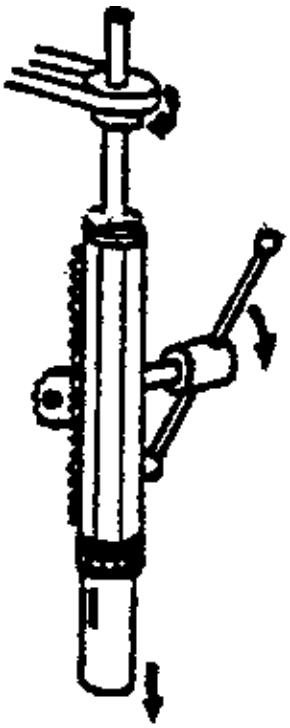
 Helical gears	 oil pump	runs more silently than a spur gear	– axial force – more difficult to produce than a spur gear

3.2 Intersection axis

Type	Application	Advantage	Disadvantage
 Bevel gear	 hand driller	can transmit torque when shafts cross each other	– difficult to produce – axial force

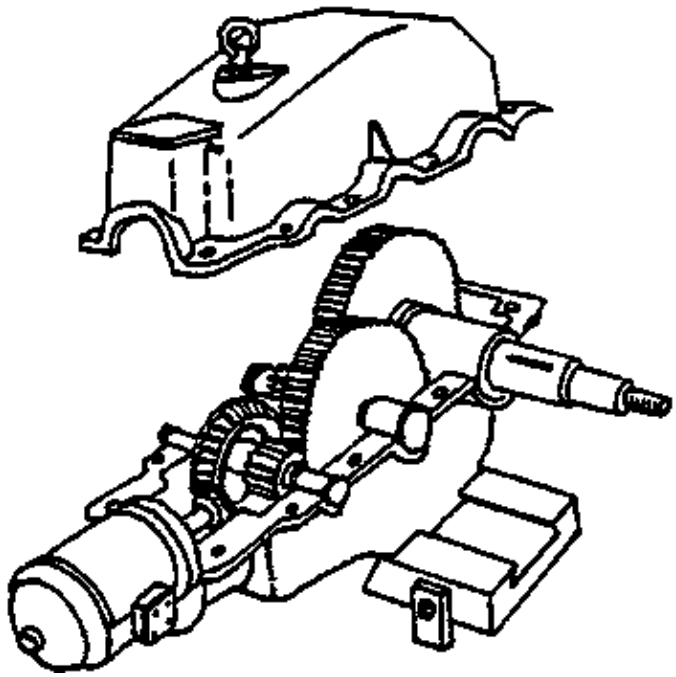
3.3 Cross axis

Type	Application	Advantage	Disadvantage
 Worm gear	 dividing head	– high transmission ratio for speed and torque – silent	– high friction

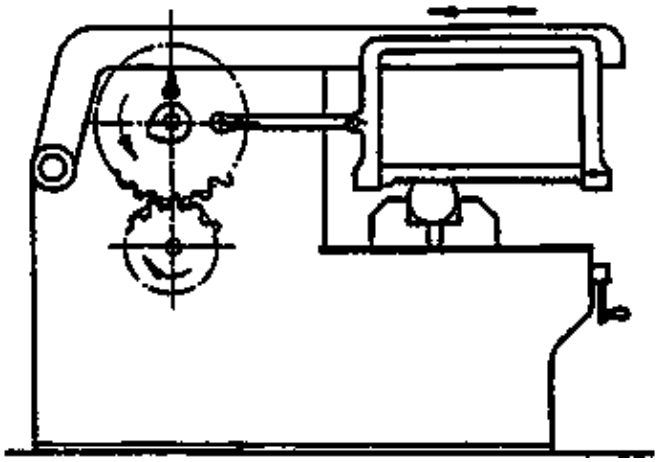
 Rack and pinion	 driller	– can change rotary into linear movement and vice versa	___

4. Types of gears

4.1 Fix ratio

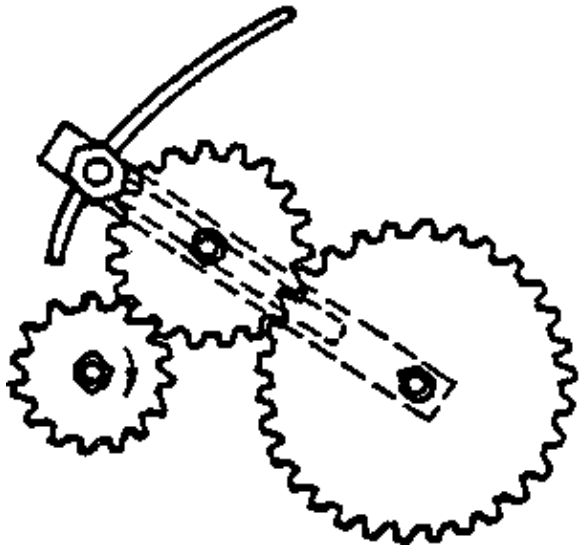


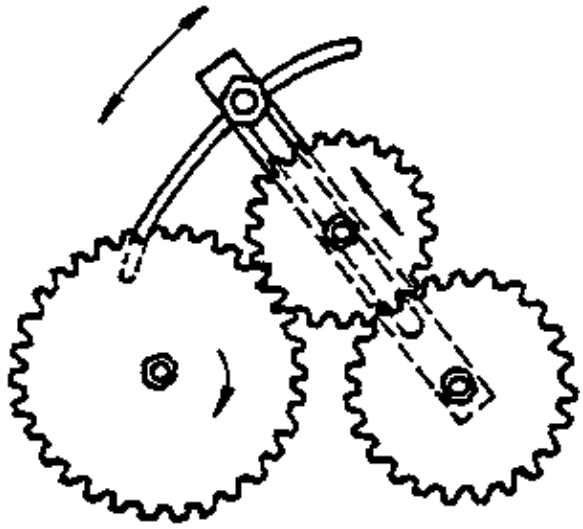
gear cannot be changed

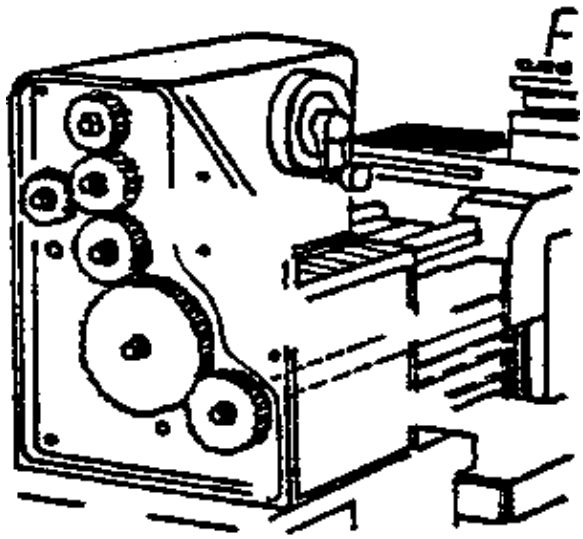


Sawing machine

4.2 Change gears

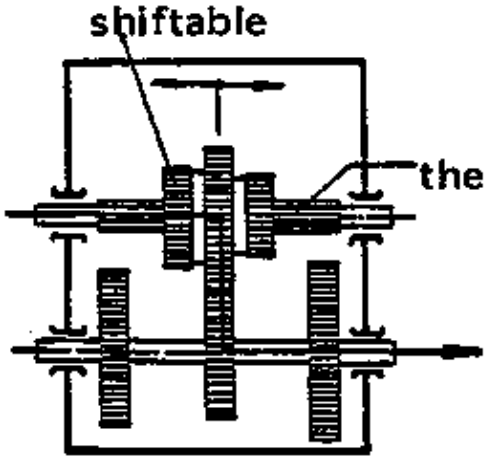


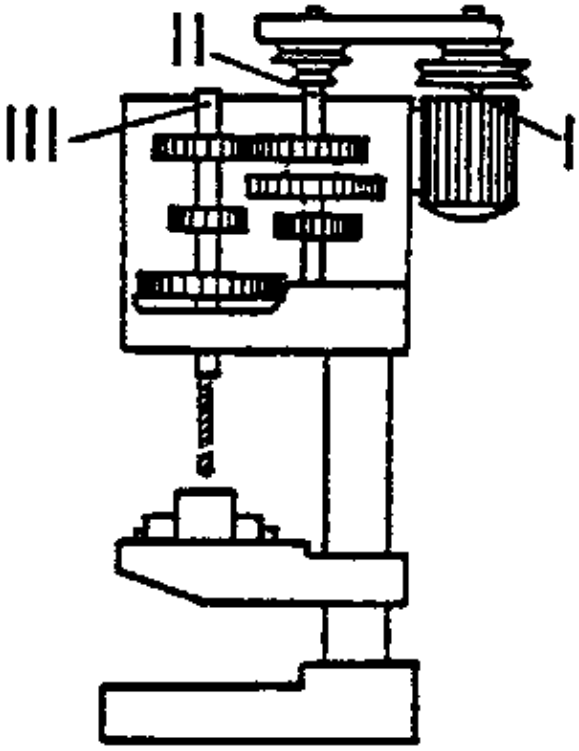




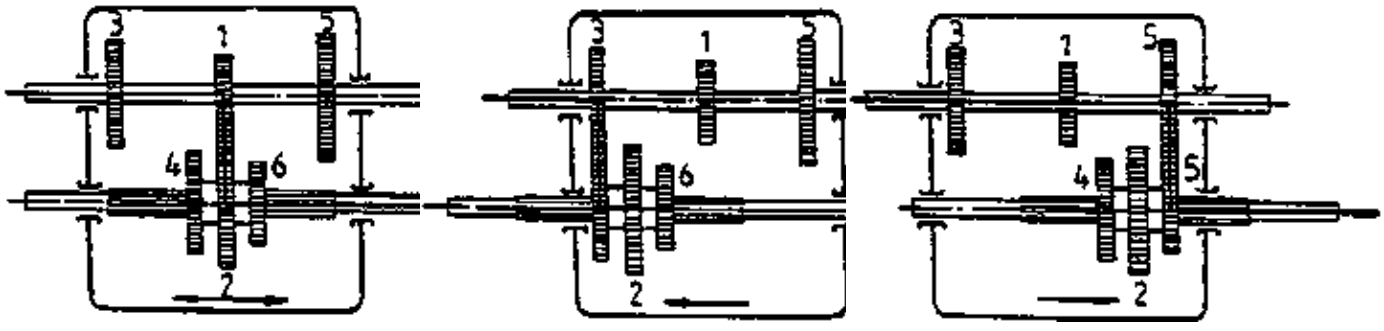
Revolution is changed by changing gear set.

4.3 Shift gear



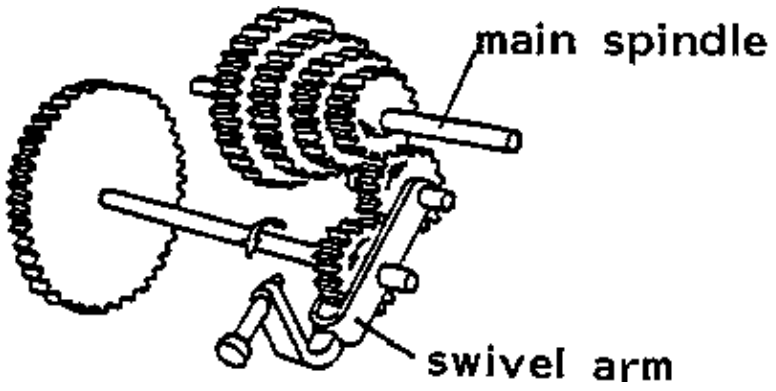


Steps of changing gear

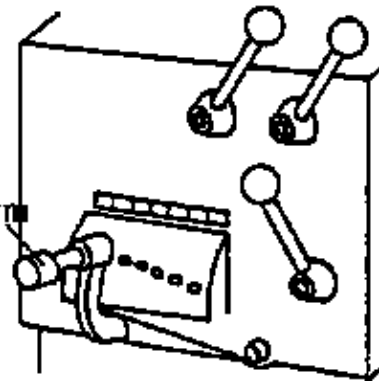


1st speed: 1 2 2nd speed: 3 4 3rd speed: 5 6

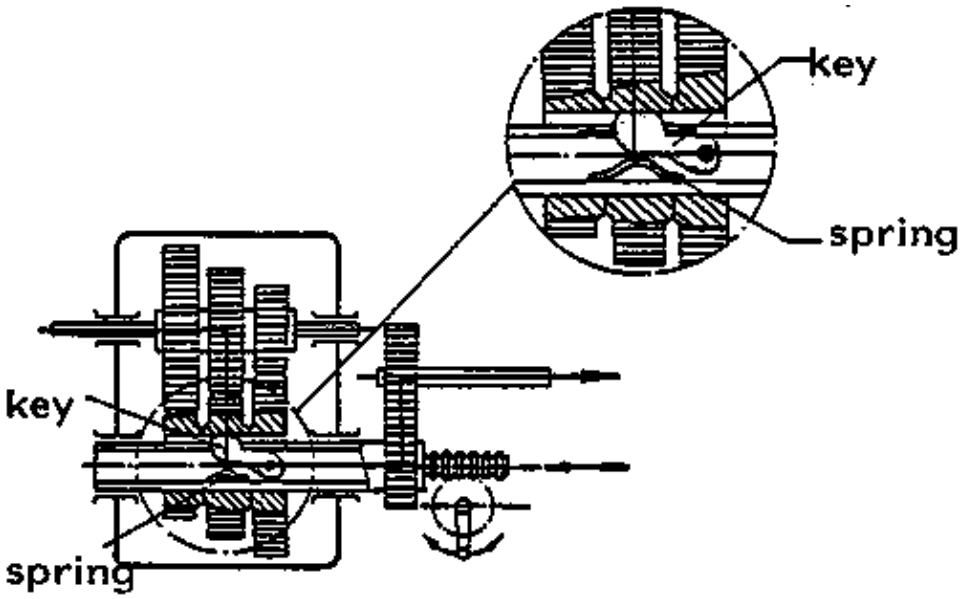
4.4 Norton gear



speed change by swiveling and sliding the swivel arm

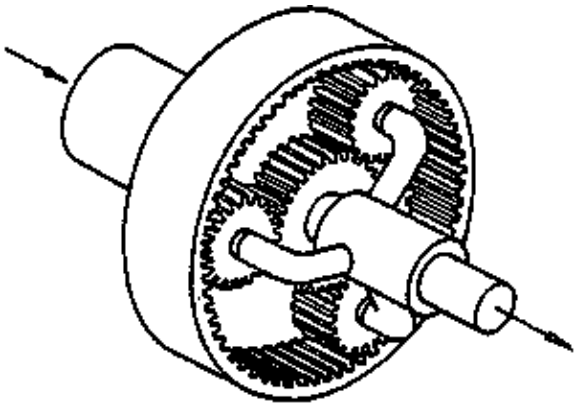


4.5 Driving key gear

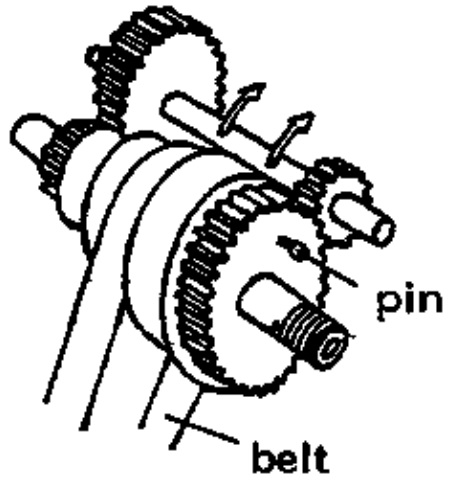


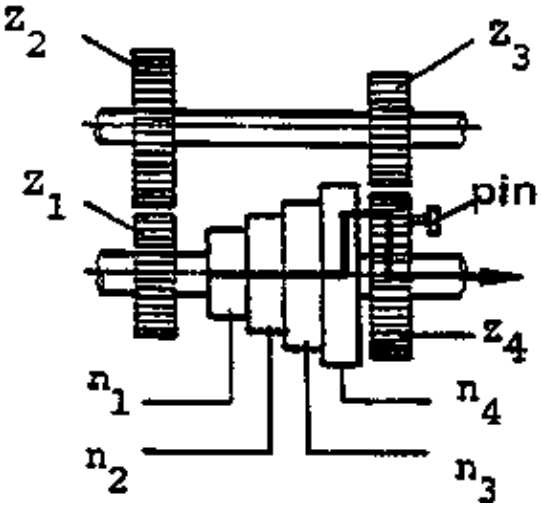
The key is sliding in the hollow axle

4.6 Planetary gear

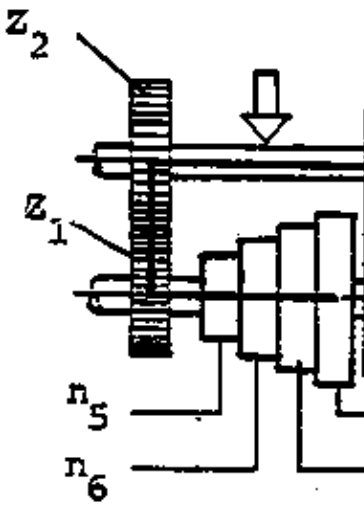


4.7 Back gear





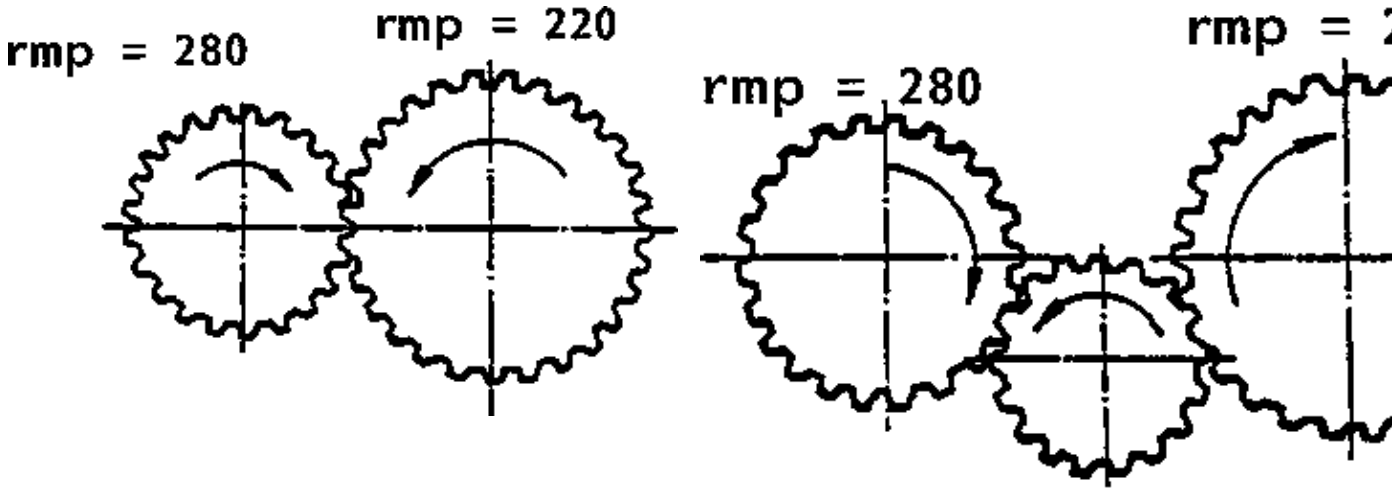
non−working position



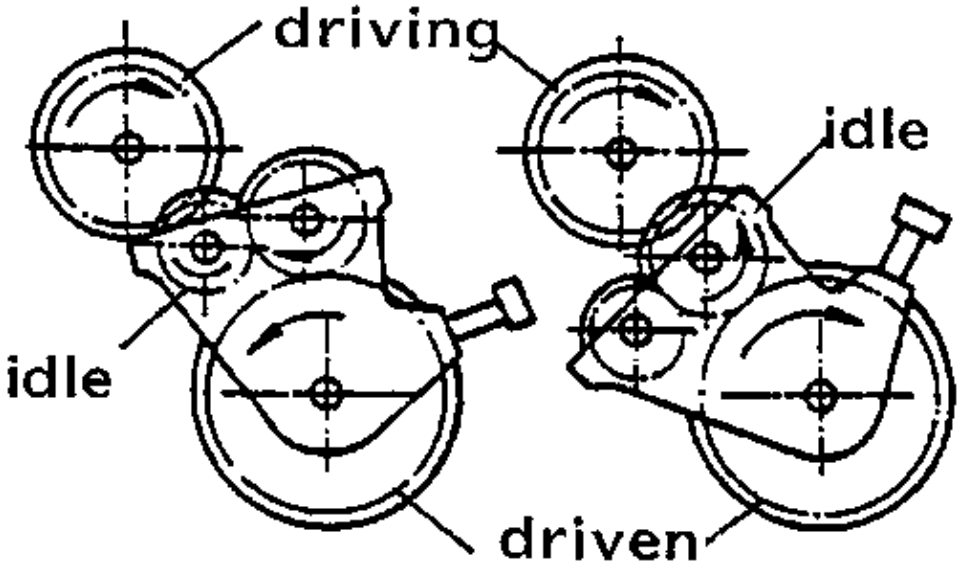
working position

With the back gear the number of speeds can be doubled.

4.8 Idle gear



Lathe

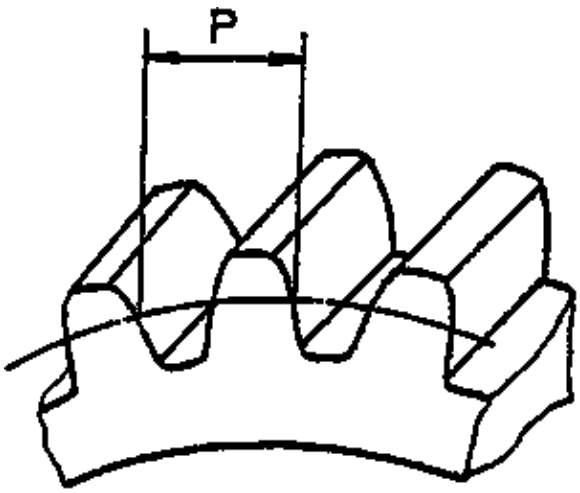


With an idle gear the direction of rotation can be changed, the number of revolutions remains constant.

5. Maintenance and repair

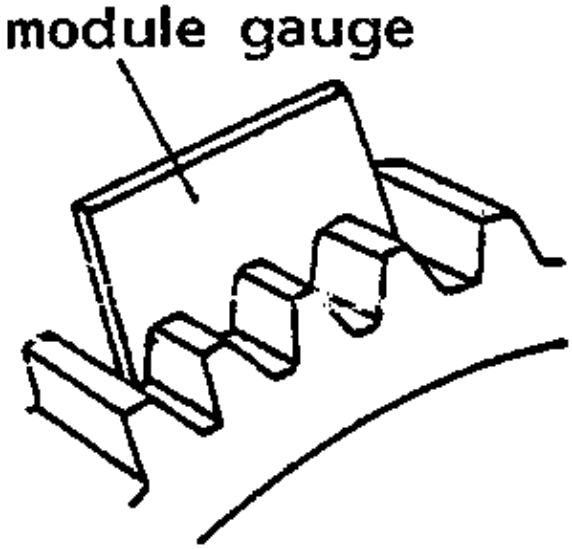
5.1 Check gear

1



Pitch can be checked only by a special measuring tool.

2



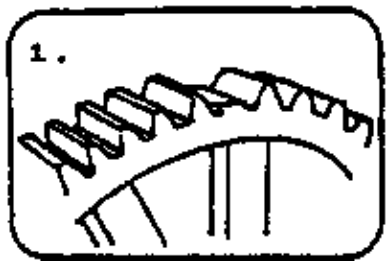
Module can be checked by simple gauge.

5.1.2 Backlash can be checked by filler gauge.

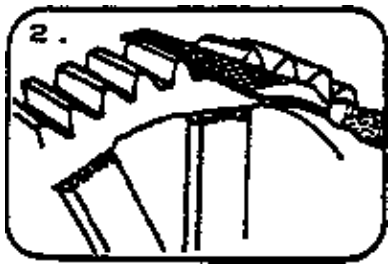
Some backlash should be given to prevent pressing between the teeth of gears

pitch diameter	backlash	pitch diameter	backlash
25	0.635 – 1.016	127	0.152 – 0.229
38	0.457 – 0.686	152	0.127 – 0.203
51	0.356 – 0.508	178	0.102 – 0.178
64	0.279 – 0.406	203 – 229	0.102 – 0.152
76	0.229 – 0.356	254 – 330	0.076 – 0.127
102	0.178 – 0.279	356 – 813	0.051 – 0.102

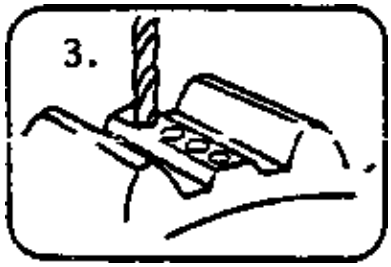
5.2 Repairing a gear



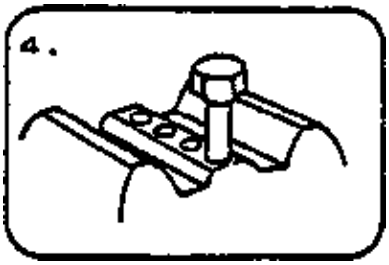
tooth is broken



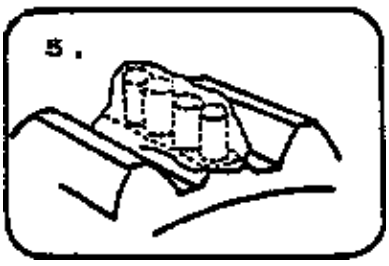
file the broken surface smooth and lay out the centre of the holes



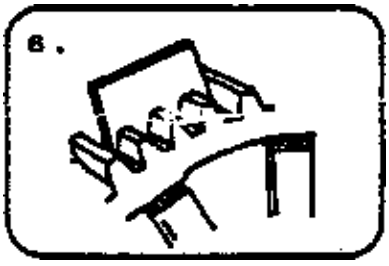
drill the holes



Tighten the bolts and cut their heads so that the bolts are not longer than the tooth dept.



Weld around the bolts and finish the tooth form with a miller or a file.



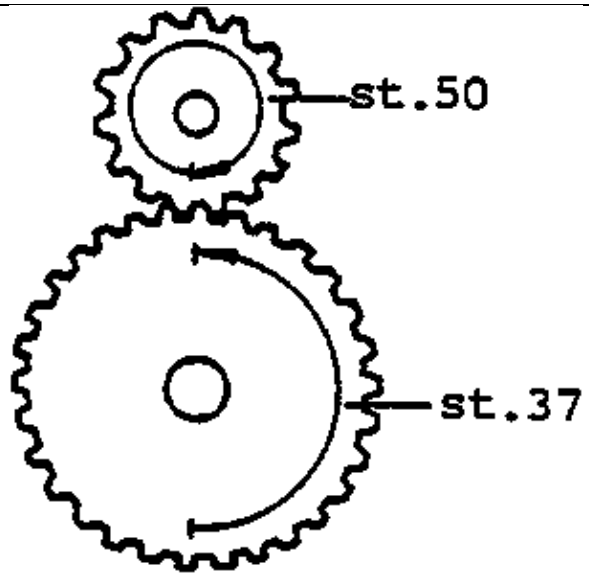
Check the shape of the tooth with a gauge.

Note:

Only slow running big gears should be repaired.
Small gears, fast running gears and heavy duty gears should be, replaced by a new one.

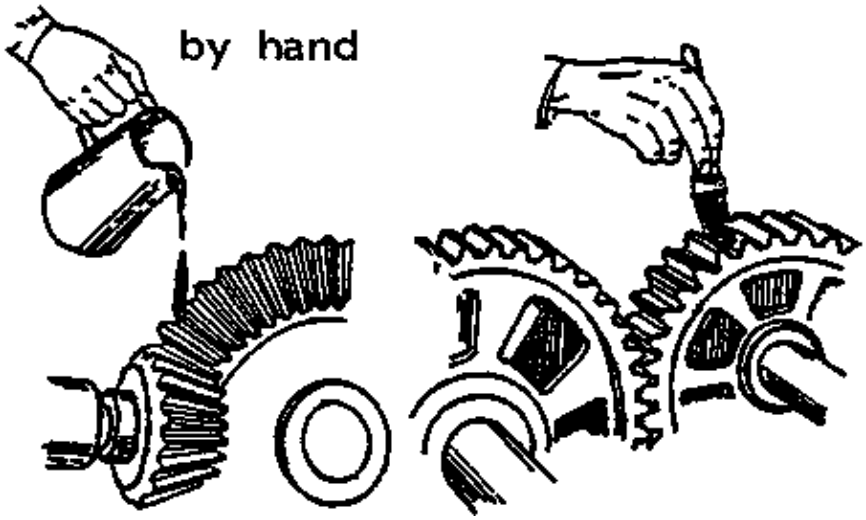
5.3 Material of gear

Material	Advantage	Disadvantage
1. cast ivon	easy to finish, low friction, sound absorbing, can *be* hardened	brittle, break easily
2. steel	high strength, can be hardened	friction
3. non ferrous	low friction	high casts
4. plastic	vibration and sound absorbing, low friction	low strength, bad heat–conductor

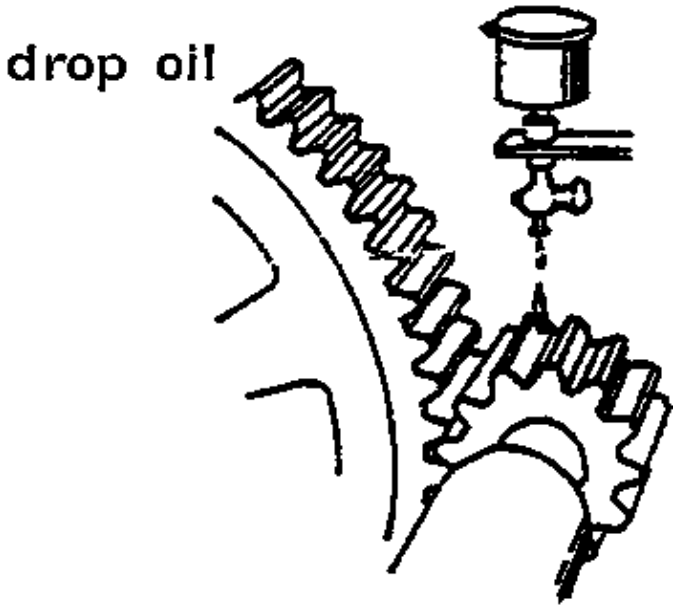


The revolution of the small gear are higher; therefore, their materials must be stronger.

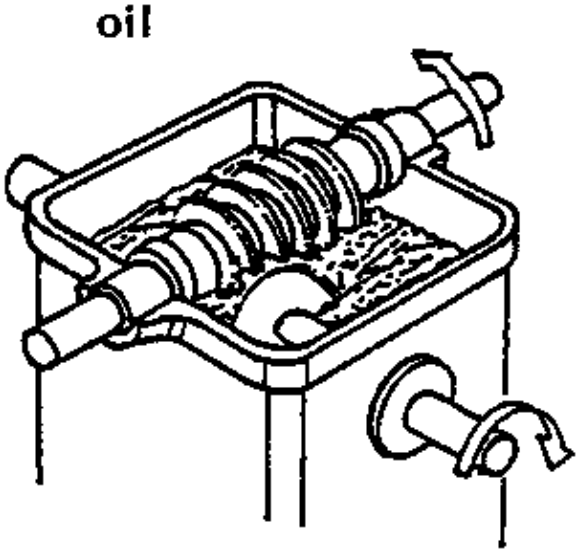
5.4 Lubrication



suitable for low revolutions only

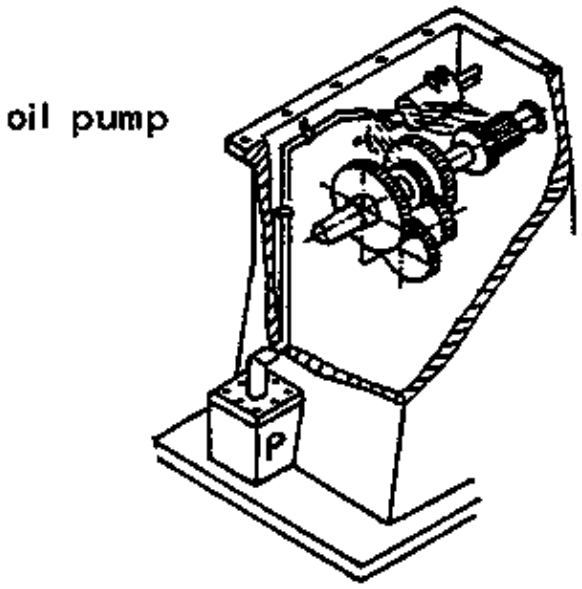


suitable for low and medium range revolutions



suitable for:

- small gear box
- medium to high revolations



suitable for:

– big gear box
– different level of gear sets
– high turning speed

Task sheet

1. Complete the text or choose the correct answer

a) The duty of a gear box is to increase or decrease

1..... 2.....

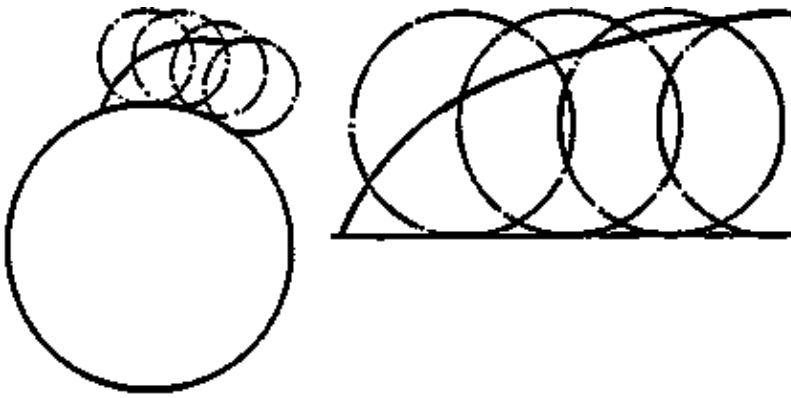
b) If the number of teeth of the driving gear is bigger than the one of the driven gear, the rmp's of the driving gear is bigger/smaller than the one of the driven gear.

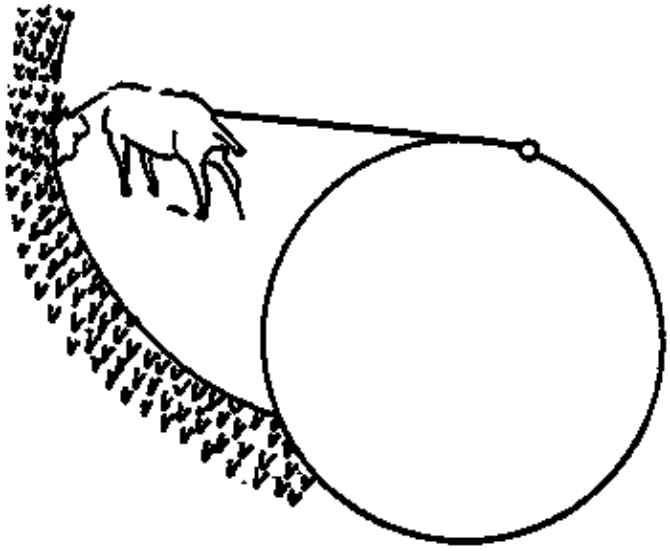
c) The advantages of power transmission by gear are:

1..... 2..... 3.....

2.1 Which picture shows the generation of an involute curve?

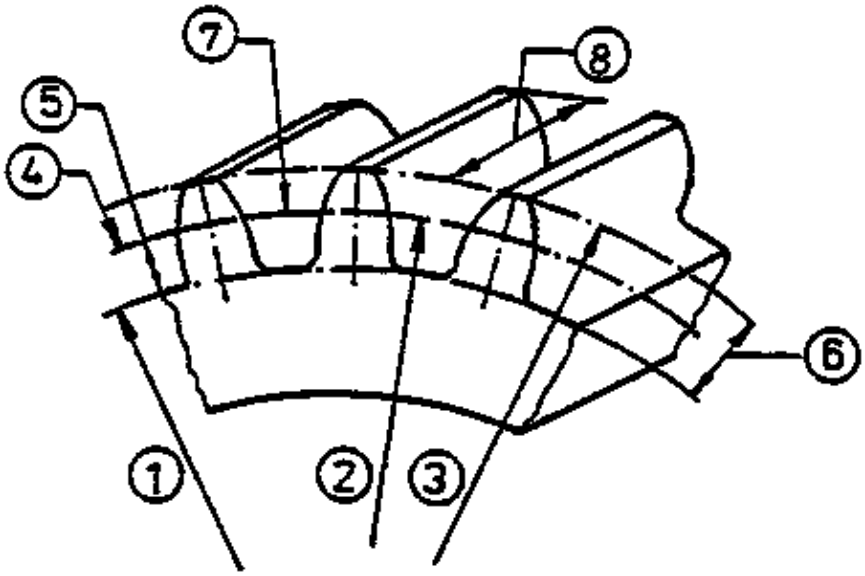
a) b) c)





2.2

a) Relate the right symbols to the dimensions in the table below



d = pitch circle diameter
b = width of gear
p = pitch
h = height of tooth
d_a = outside diameter
d_f = root diameter
h_a = addendum
h_f = dedendum

1	2	3	4	5	6	7	8

b)

$$m = \frac{p}{\pi}$$

$$z = \frac{\pi d}{P}$$

$$a = \frac{d_1 + d_2}{2}$$

$d = m.z$

$h = h_a + h_f$

$ha = 1m$

$$hf = \frac{7}{6}m$$

$da = d + 2m$

Symbol	Size	
	driving gear	driven gear
m	4	4
z	24	36
d		
da		
ha		
hf		
h		
a		

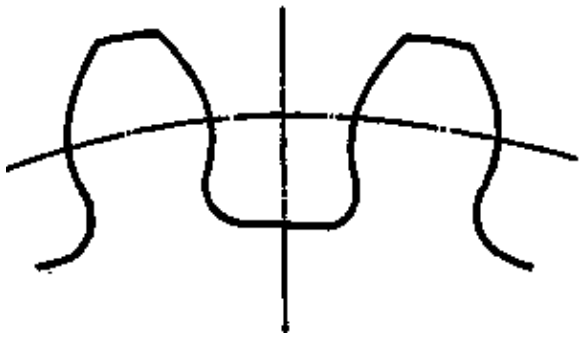
2.3

a) The line along the teeth are in contact is called _____
b) Normally, the pressure angel is 10°/20°/30°

2.4

a) A pair of gears must have the same d/z/m
b) Gears with big module have smaller/equal/bigger size than gears with small module.
c) Gears with the same pitch have the same d/z/m

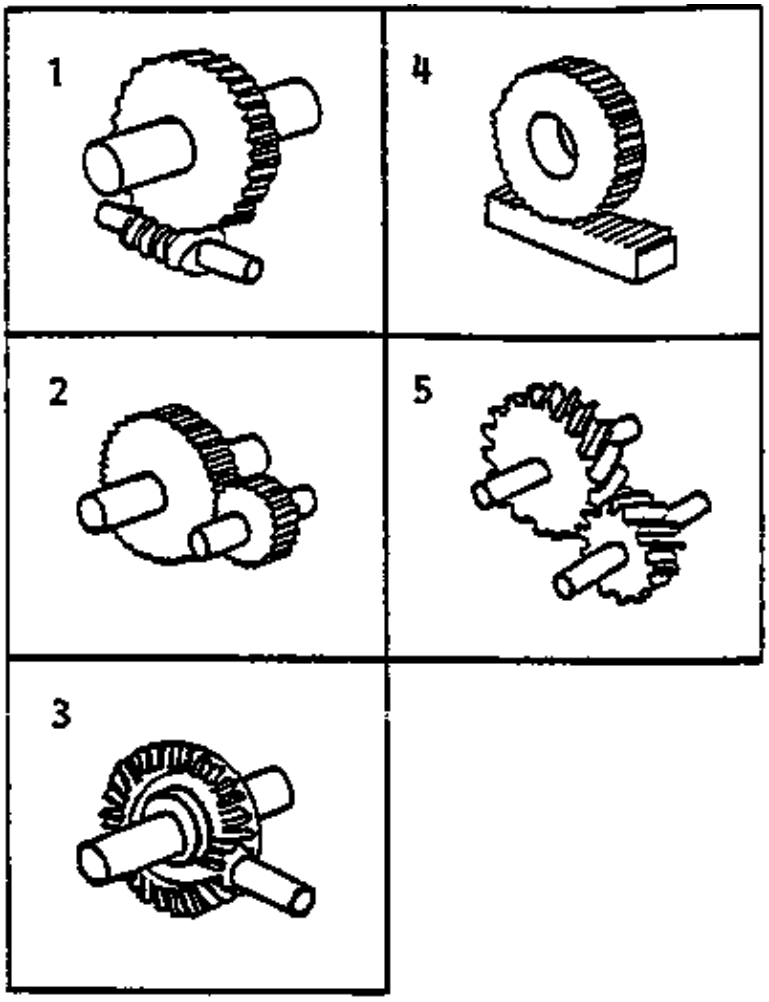
2.5



a) This shape of teeth show up when the number of teeth is less than _____
b) This shape is called _____
c) Indicate in the drawing where the strength of teeth will decrease.
d) To prevent undercut the cutting tool is moved towards/away from/to the right of/to the left of/the gear.

3

a) Relate the number in the picture to the gears in the table!



Gear	spur	bevel	worm	rack	helical
Picture					
Property					

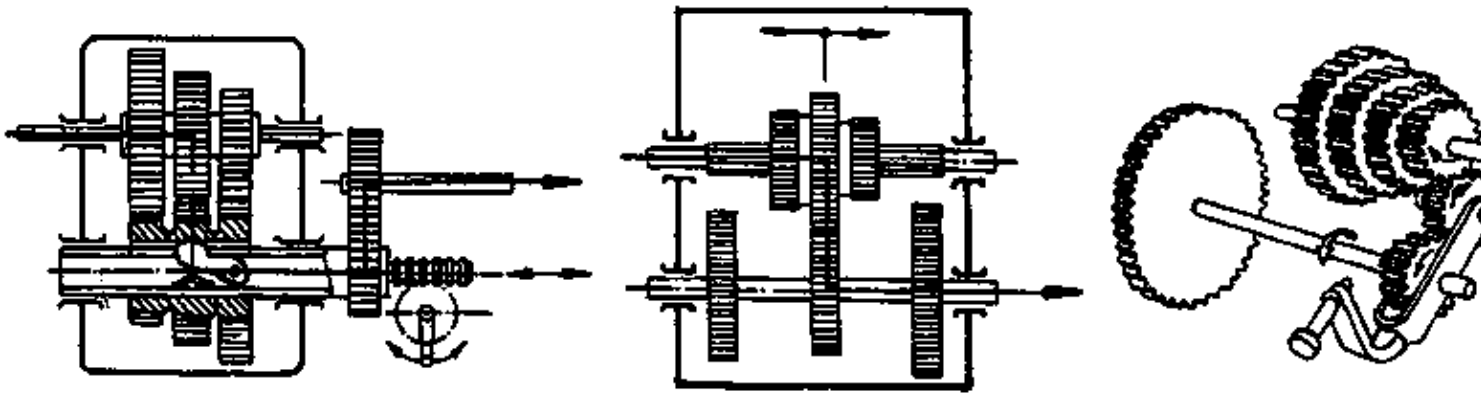
b) Relate the property of the gears to the names in the table above!

(A gear can have various properties)

1. Transmit power when two axles are angeled
2. Axial force is arising
3. Easy to produce
4. High transmission ratio for speed and torque
5. Changes rotary movement into a linear one and vice versa
6. One way power transmission
7. Silent

4

a) Name the gears!

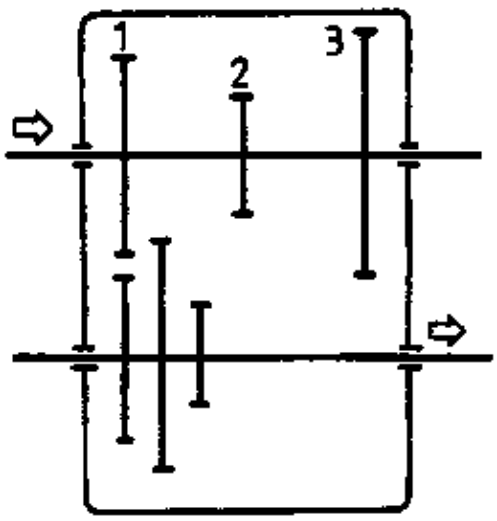


b) Match the type of gear to the specified application (one type of gear can have various applications)

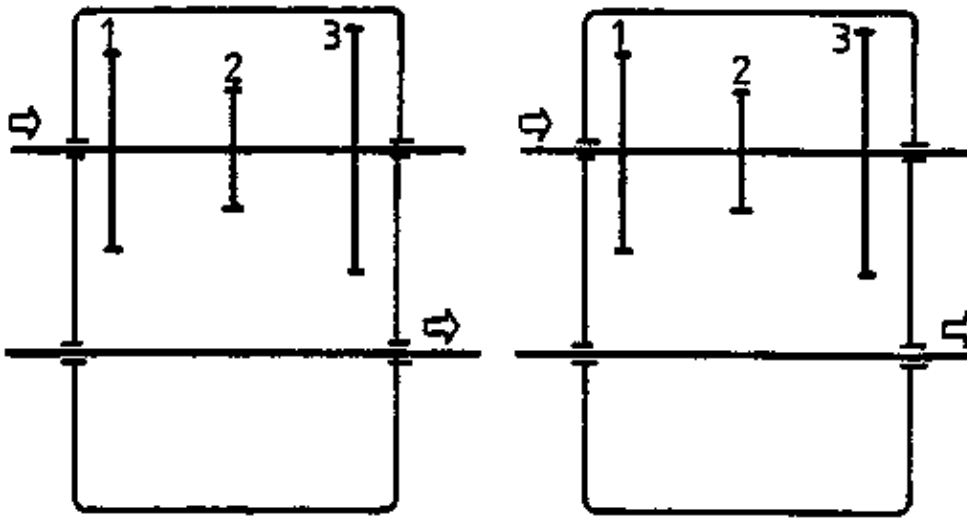
1. Lathe	____ Planetary gear
2. Drilling machine	____ Shifting gear
3. Automobile automatic	____ Norton gear
4. Sawing machine	____ Fix ratio
	____ Back gear

c) Sketch the gears to

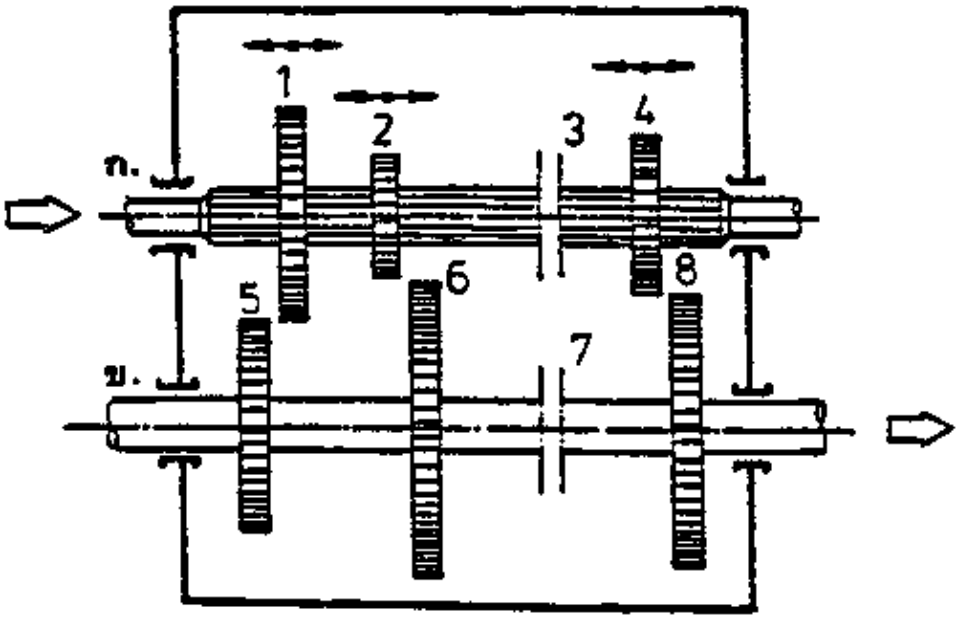
1. Maximum speed



2. Minimum speed

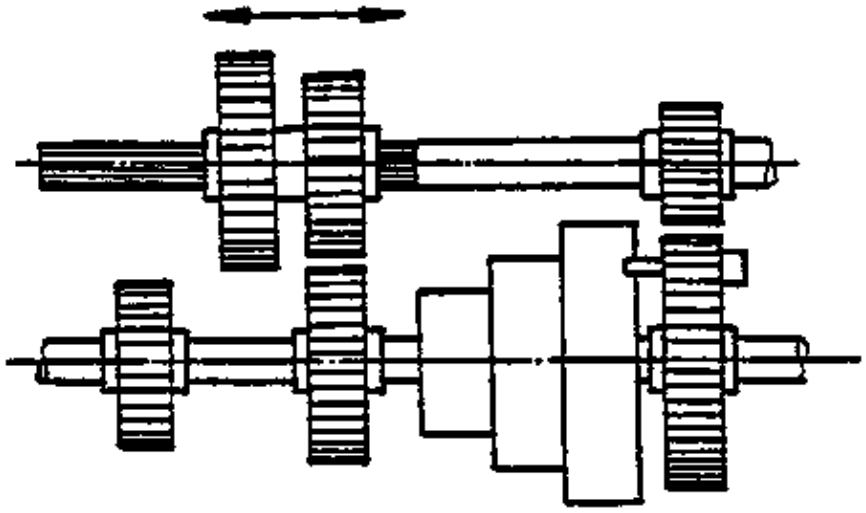


d)



– Sketch the gears number 3 and 7 so that the axle 8 has maximum speed.
– How many steps of speed reduction can be realized by this gear box?
– The gear drives at lowest speed when gear number ____ and number _____ match.
– The type of the gear box is _____

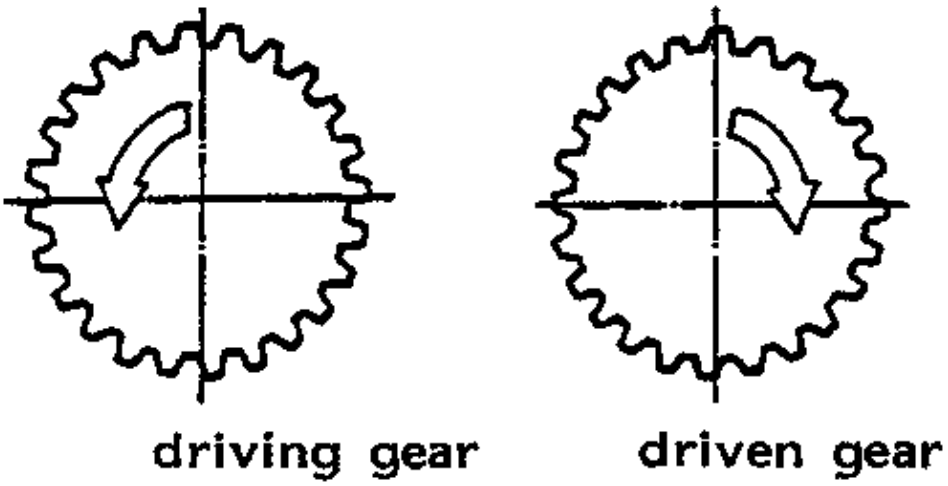
e)



* power–input

– Show the flow of power by sketching arrows.
– How many steps of speed reduction can be realized by this gear box?
– The type of the gear box is ____

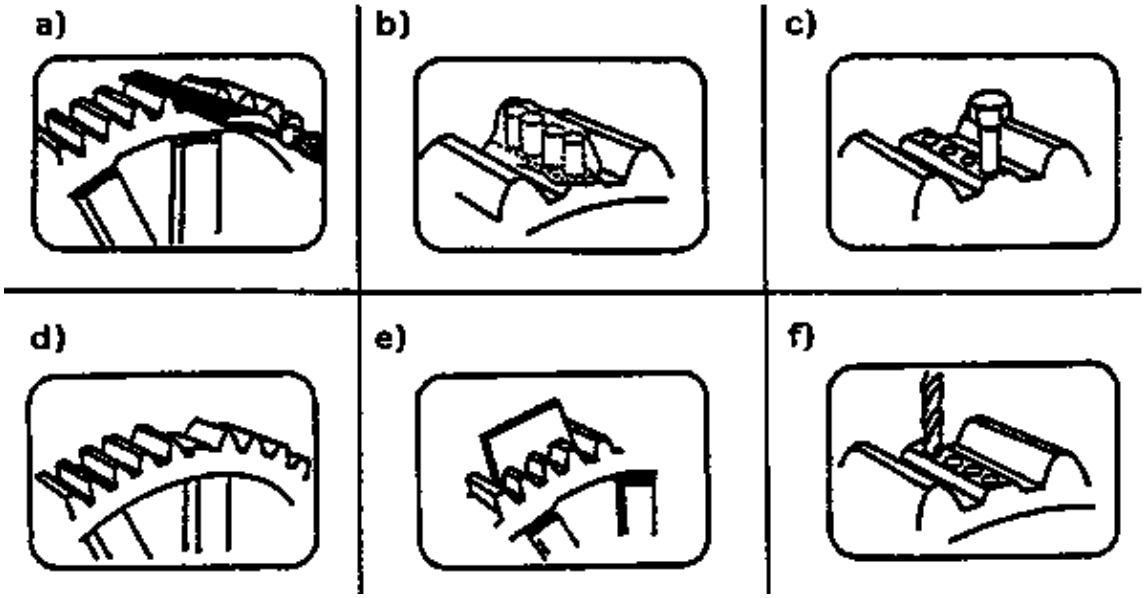
f) Sketch idle gear(s) between driving and driven gear without changing the transmission ratio.



5.1

a) Module can be checked with vernier/gauge/filler gauge
b) Backlash can be checked with vernier/gauge/filler gauge
c) A pair of gears must have some backlash to avoid noise/friction
d) Which one of the following pictures shows the correct backlash?

5.2 Arrange the repair of a gear in the right sequence!



Step	1	2	3	4	5	6
Picture						

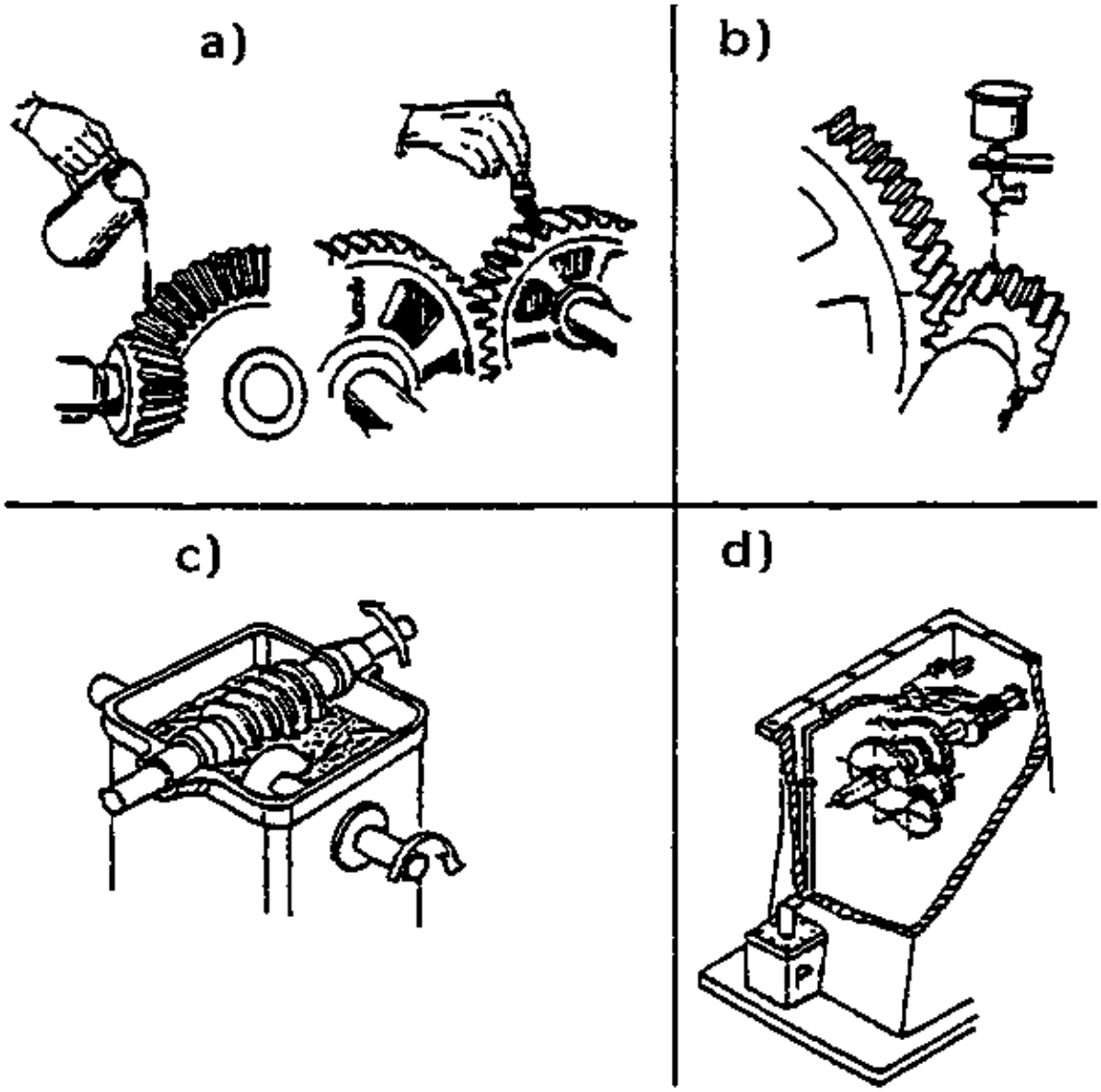
5.3

a) Match the material to its property by filling in the numbers

1. Cast iron	____ high strength, can be hardened
2. Steel	____ low strength, bad heat conductor
3. Non ferrous metal	____ brittle (breaks easily)
4. Plastic	____ high costs
	____ easy to finish, low friction, can be hardened, sound absorbing
	____ Vibration and sound absorbing, low friction

b) The revolutions of a small/big gear are higher/lower; therefore, its material must be stronger.

5.4 Match the lubrication–systems to their application! (more than one answer is possible)



_____ suitable for low and medium range revolution
_____ suitable for big gear box
_____ suitable for low revolutions only
_____ suitable for small gear box and medium to high revolutions
_____ suitable for different levels of gear sets
_____ suitable for high revolutions

Solution sheet

1.1

a) 1. torque

2.
revolutions

b) smaller

1.2

c) 1. no slip 2. high power transmission 3. constant revolutions

2.1

a)

2.2

a)

1	2	3	4	5	6	7	8
df	d	da	ha	hf	h	p	b

b)

Symbols	Size	
	driving	driven
m	4	4
z	24	36
d	*96*	144
da	104	152
ha	4	
hf	7/3	
h	28/3	
a	240	

2.3

a) common normal

b) 20°

2.4

a) m

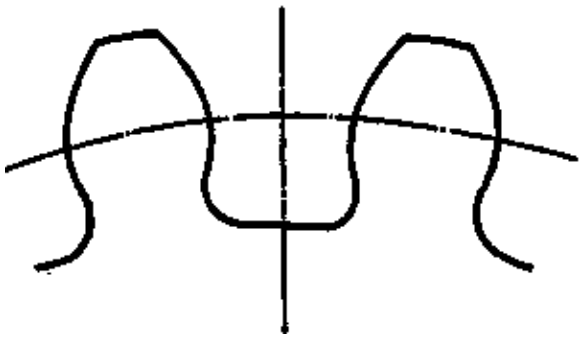
b) bigger

c) m

2.5

a) 14

b) undercut



c) (at the tooth foot)

d) away from

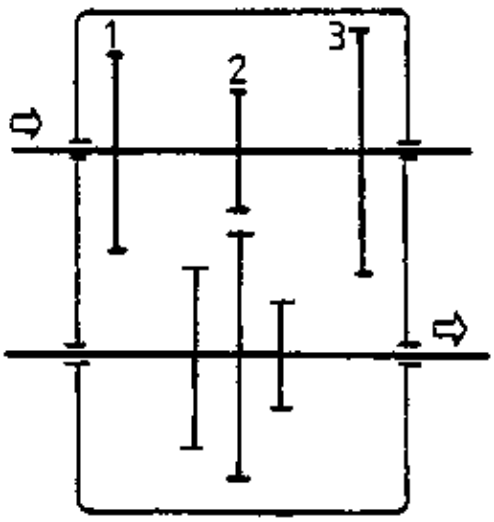
3

	Gear type	spur	bevel	worm	rack	helical
a)	Picture	2	3	1	4	5
b)	Property	3	1, 2	1, 2, 4, 6, 7	5	7

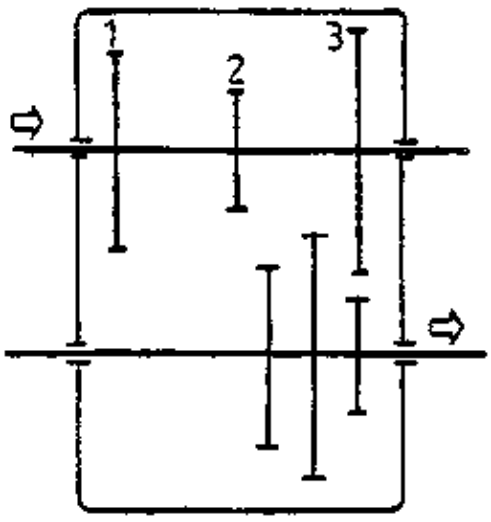
4

a)	Driving key	Shifting gear	Norton gear
b)	3	planetary gear	
	2,1	shifting gear	
	1	norton gear	
	1, 2, 3, 4	fix ratio	
	1	back gear	

c)

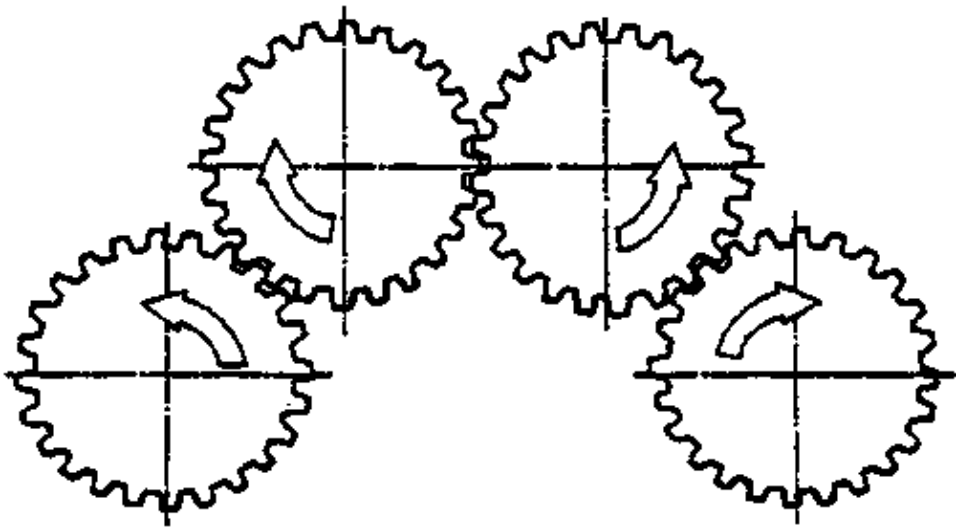


1. maximum speed

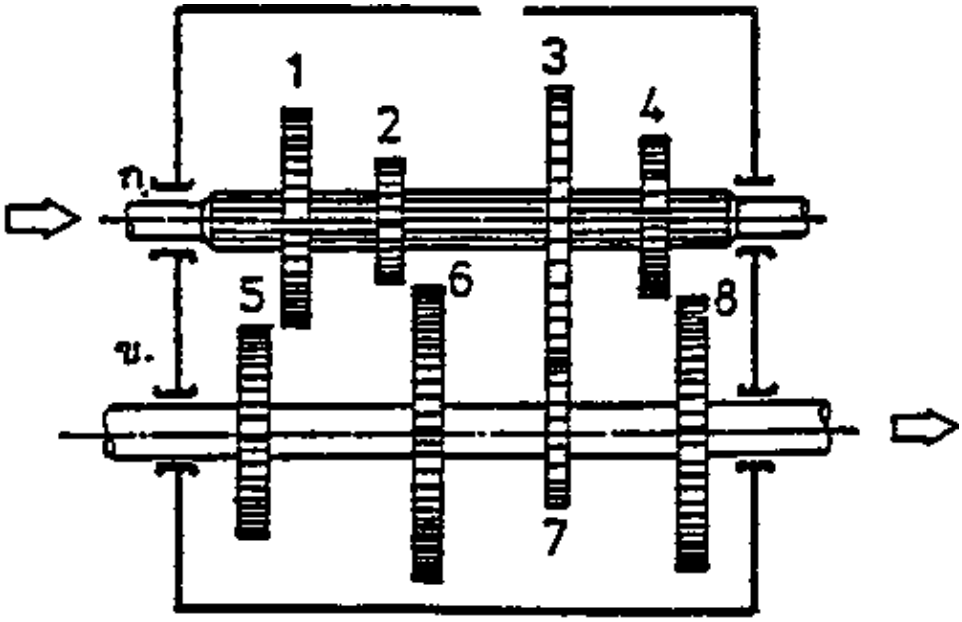


2. Minimum speed

d)



e)



5.1

a) gauge

b) filler gauge

c) friction

d) a)

5.2

step	1	2	3	4	5	6
picture	d	a	f	c	b	e

5.3

a) 2 high strength, can be hardened

4 low strength, bad heat conductor

1 brittle (breaks easily)

3 high costs

1 easy to finish, low friction, can be hardened, sound absorbing

4 vibration and sound absorbing, low friction

b) small/higher

5.4

b suitable for low and machine range revolutions

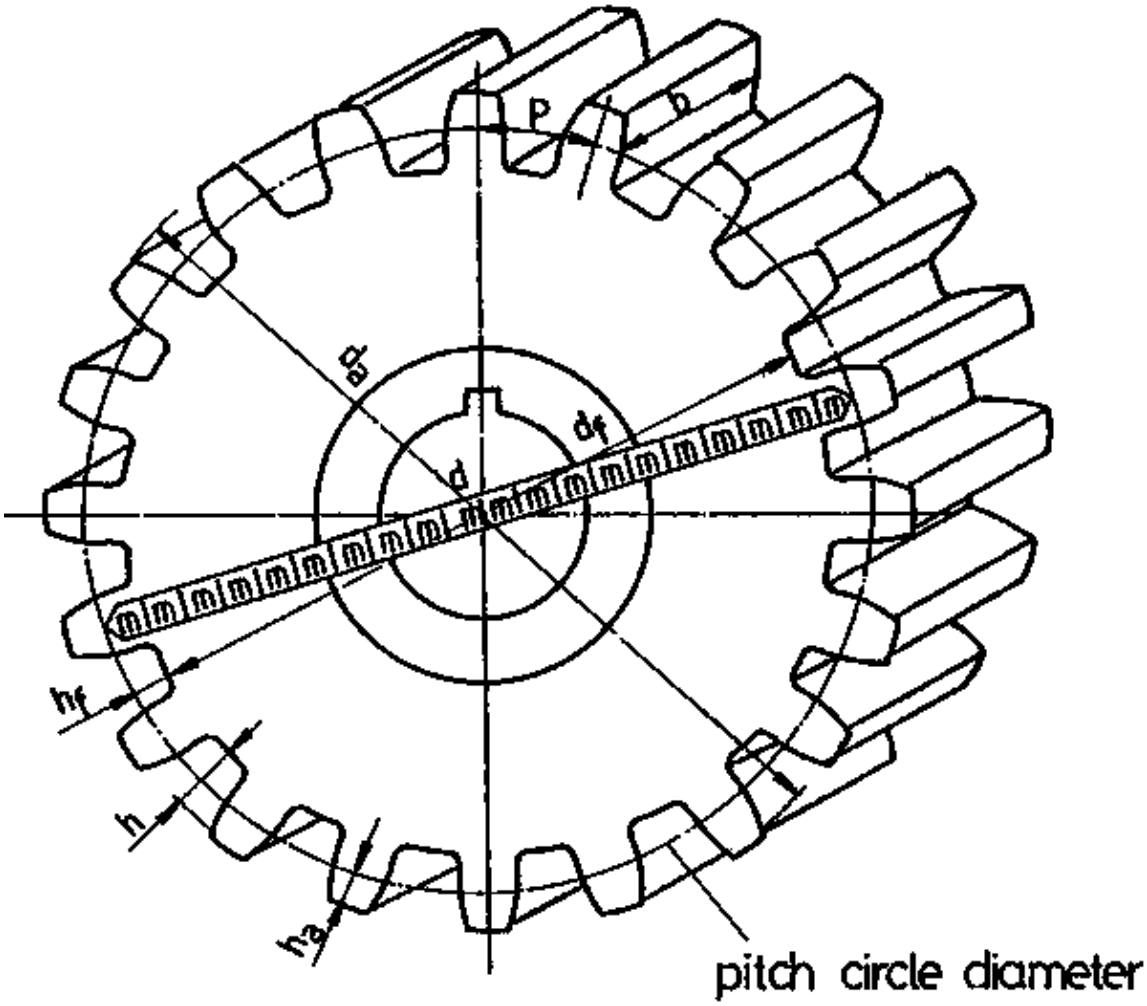
d suitable for big gear box

a suitable for low revolutions only

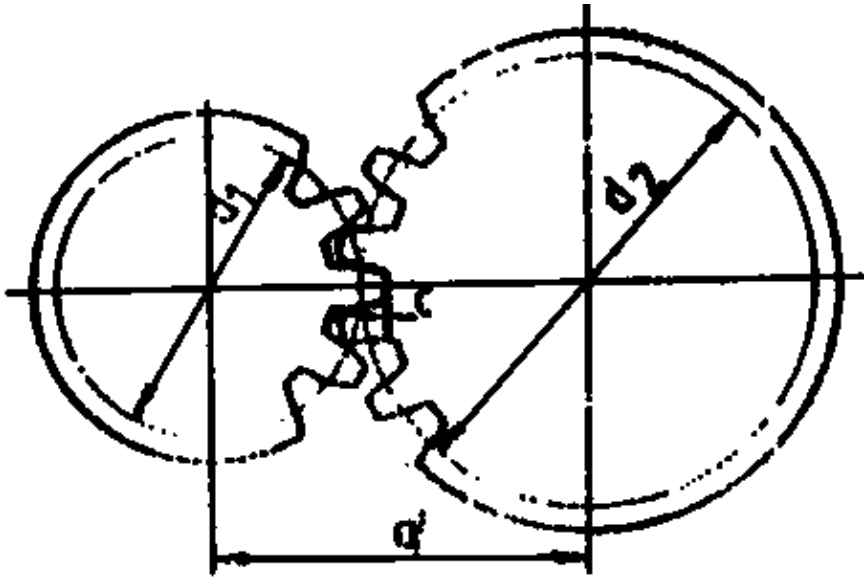
c suitable for small gear box

d suitable for different levels of gear sets

d suitable for high revolutions

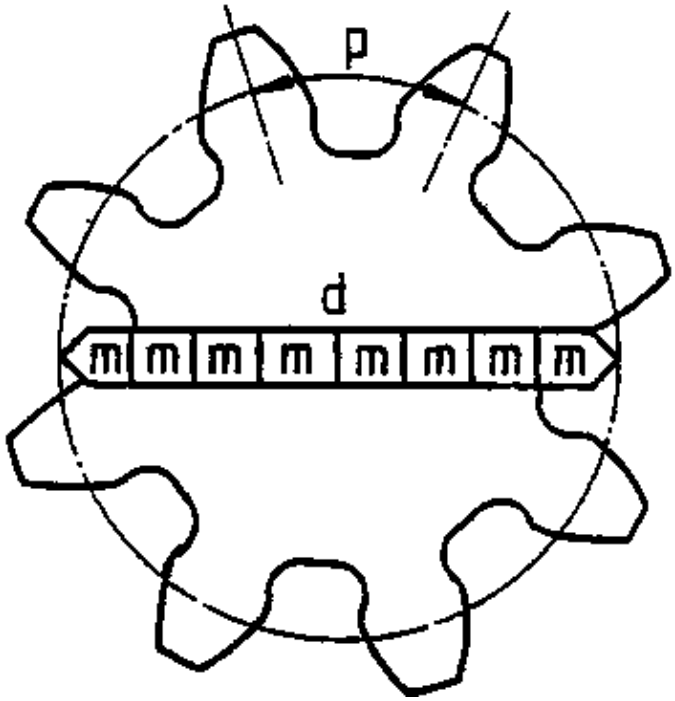


p = pitch
z = Number of teeth
m = Module
d = Pitch circle diameter
h_a – Addendum
h_f = Dedendum
h = Height of tooth
d_a = Outside diameter
d_f = Root diameter
b = Width of face

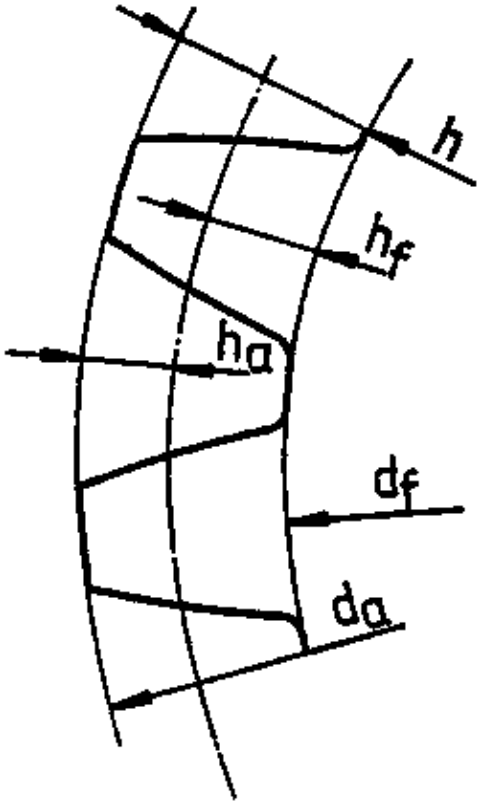


c = Crest clearance
d = pitch circle diameter

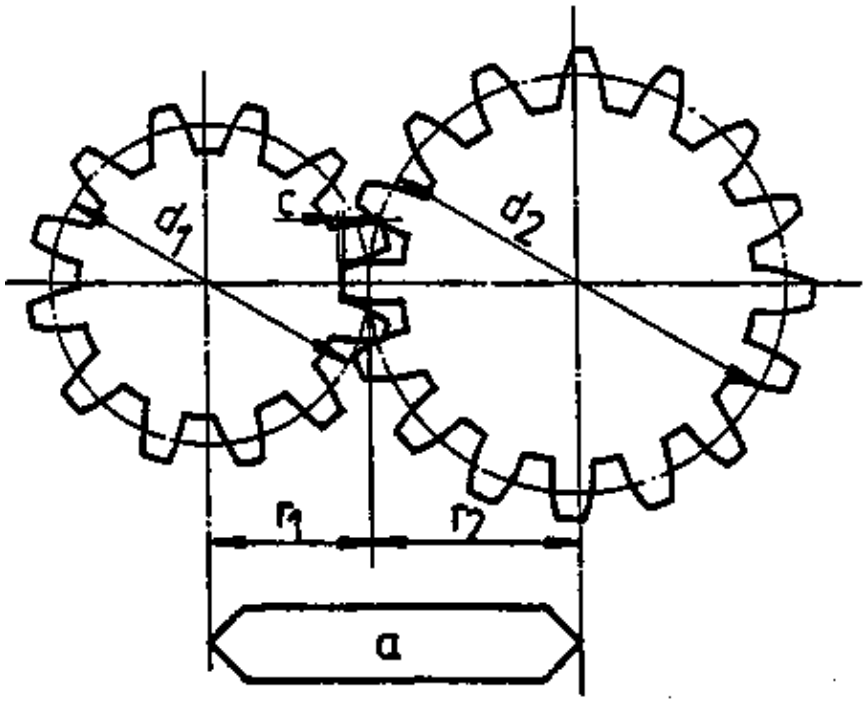
Formula



p = _____
m = _____
d = _____
b = ____given__

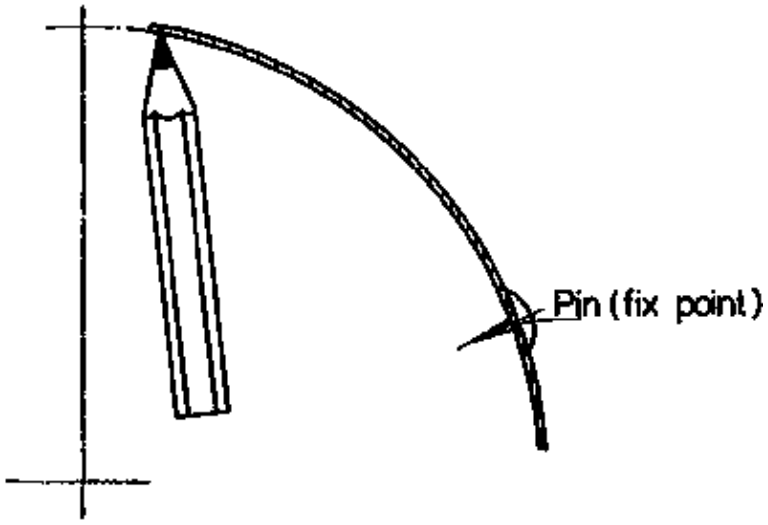


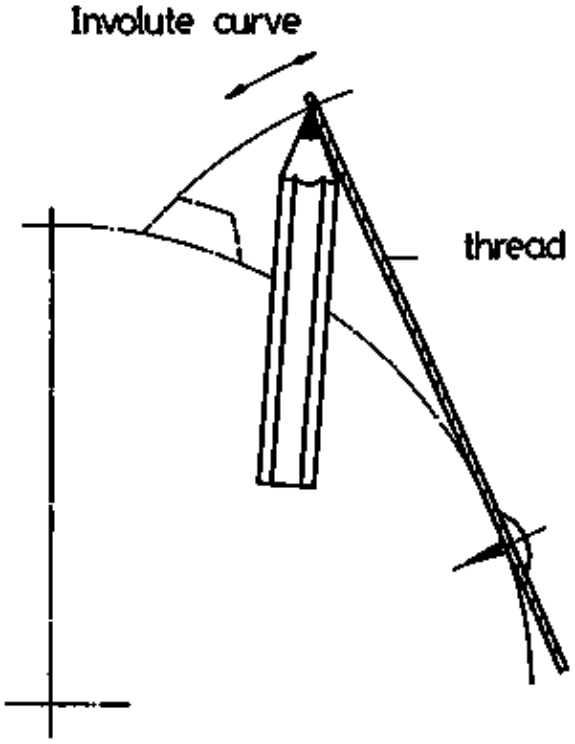
h_a = _____
h_f = _____
h = _____
d_a = _____
d_f = _____



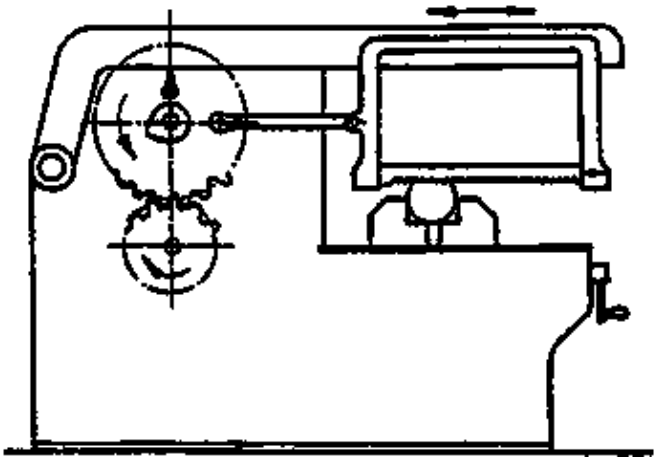
c = _____
a = _____

Construction of Involute curve

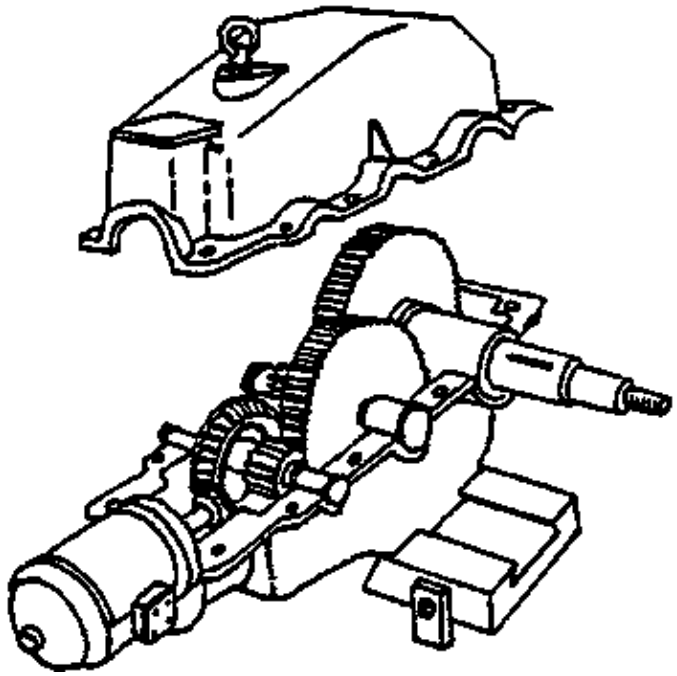




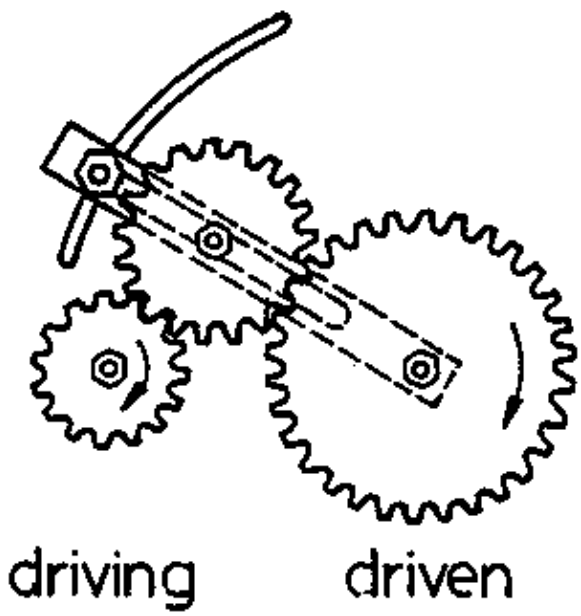
Type of gears

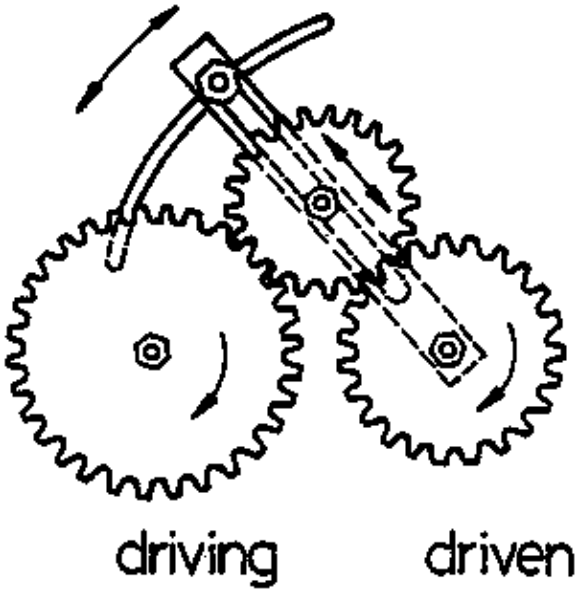


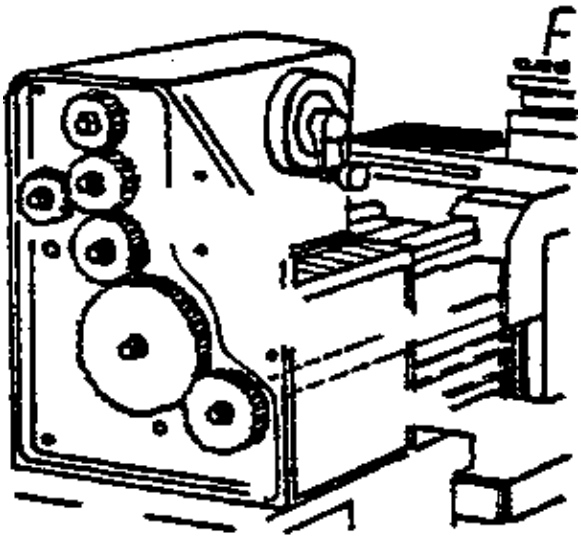
Sawing machine



Fix ratio



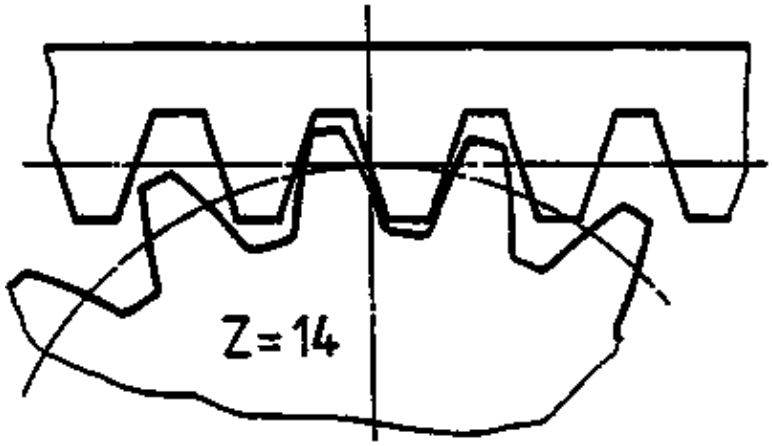




Lathe

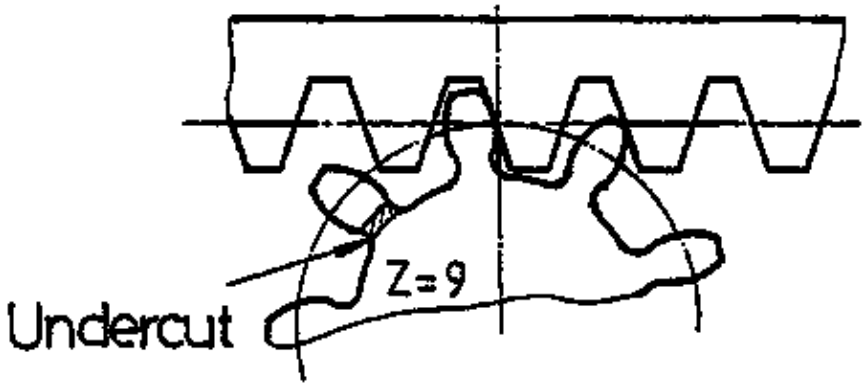
Undercut modification

1. Normal gear



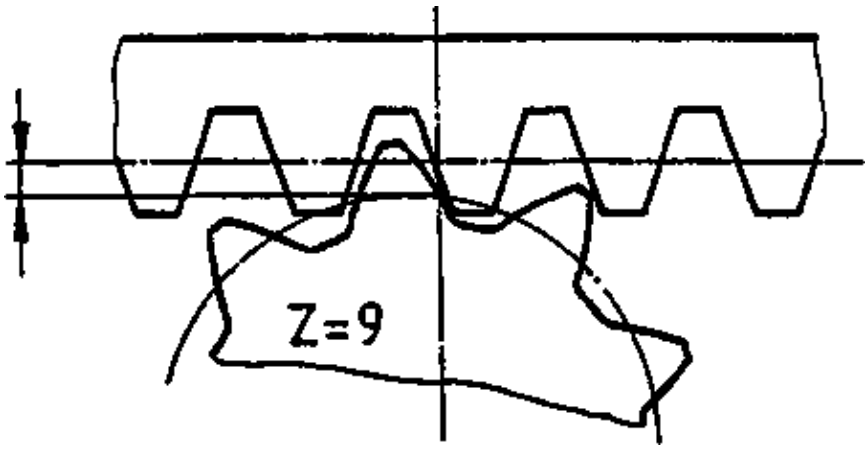
gear tooth is normal

2. Undercut gear with less than 14 teeth

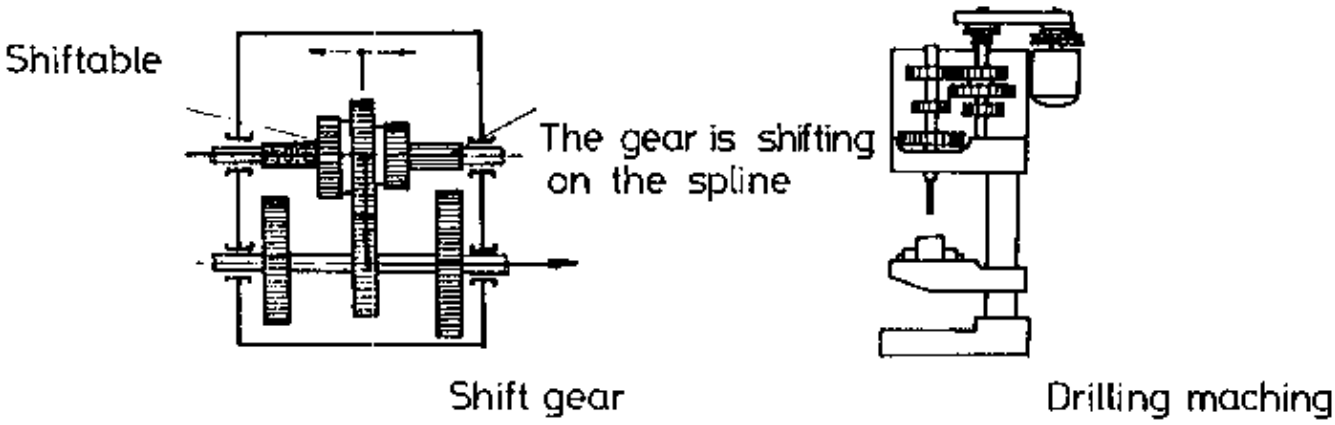


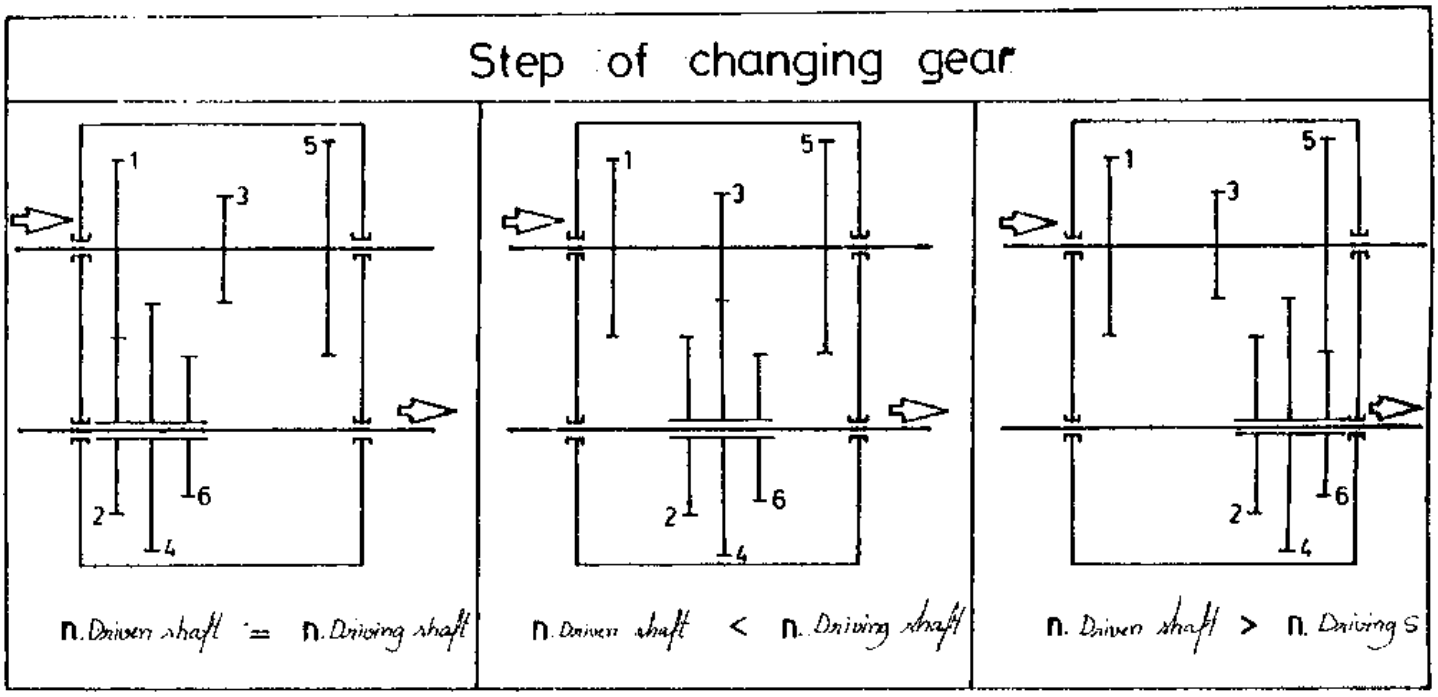
gear tooth is weakened

3. Undercut is avoided by shifting the pitch circle

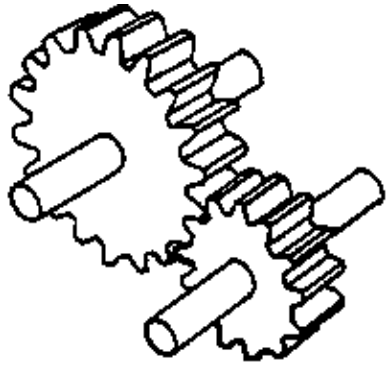


gear tooth is strong

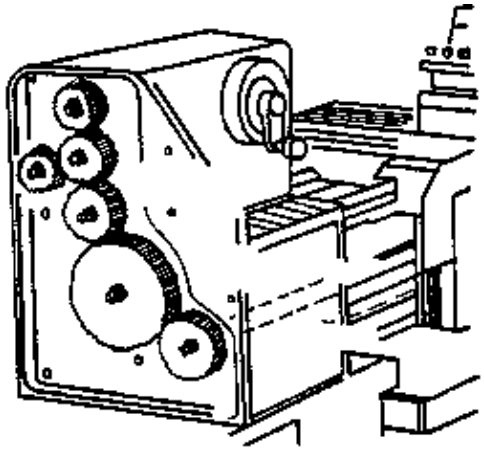




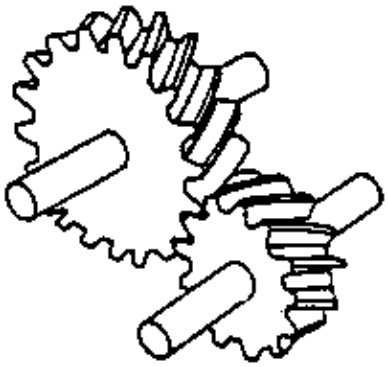
Types and Usage of Gear



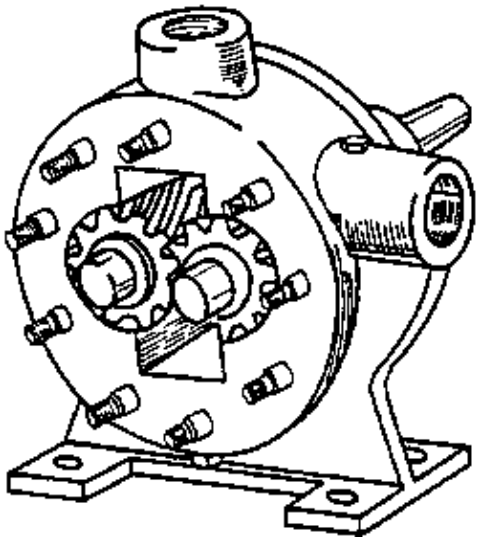
Spur gear



Feed Gear Box In Lathe

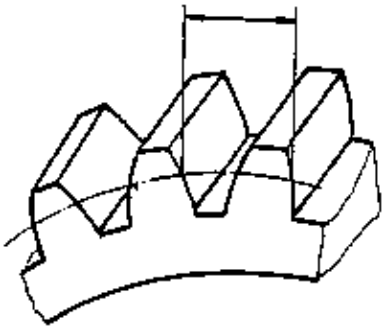


Helical gear

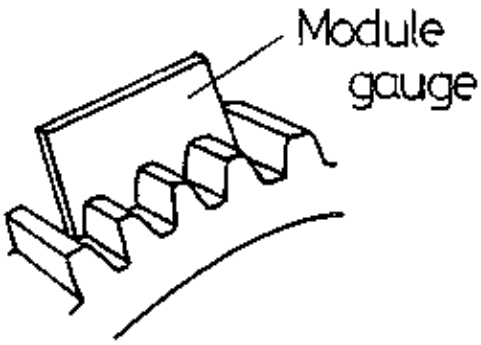


Oil pump

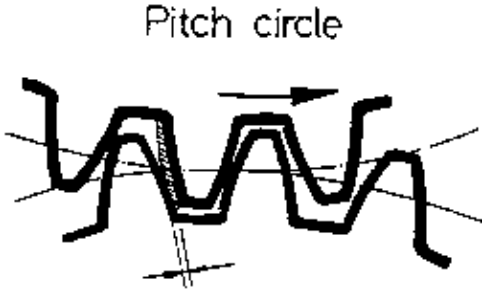
Measuring and Checking Gear



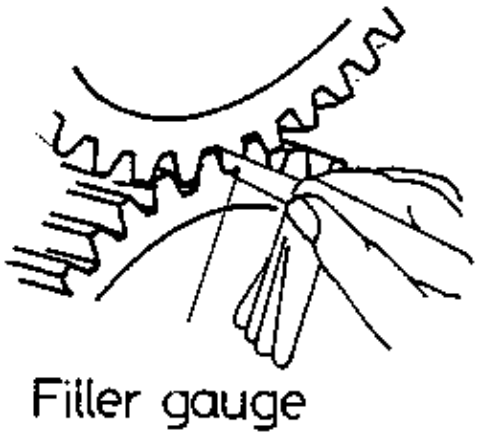
Pitch can be checked only by a special measuring



Module can be checked by simple gauge

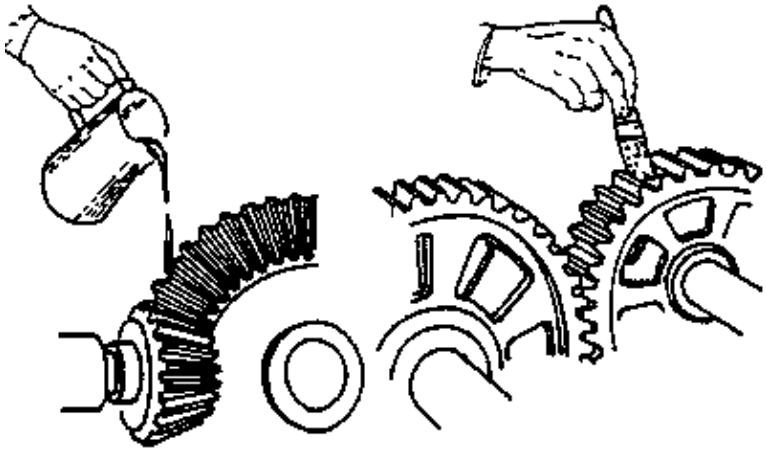


Backlash

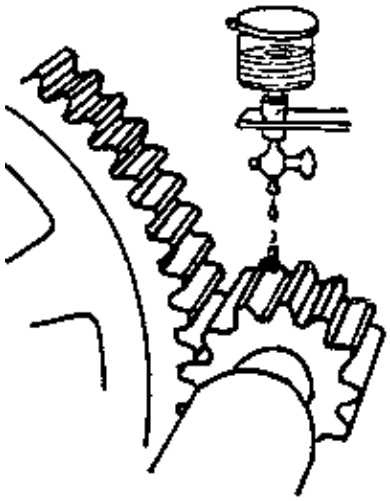


Backlash can be checked by filler gauge

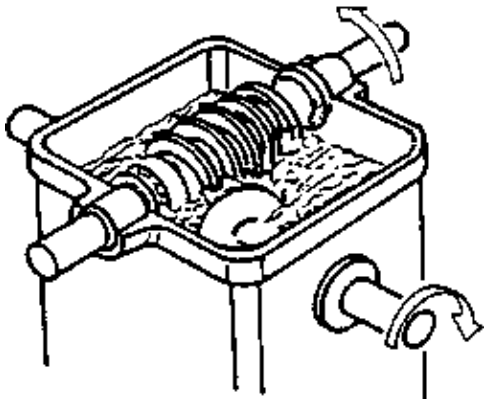
Lubrication



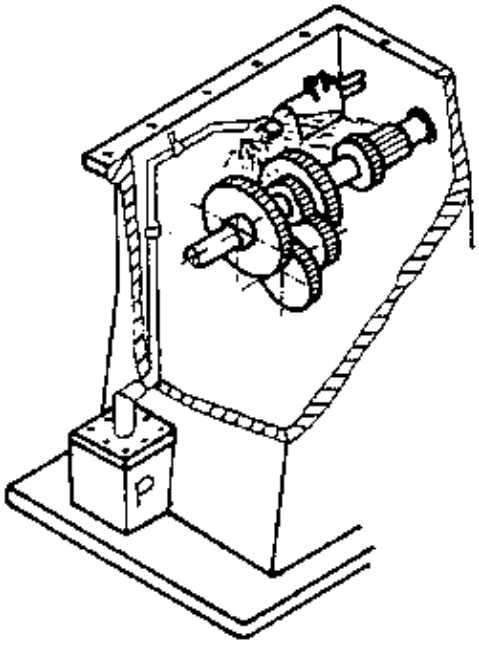
By hand



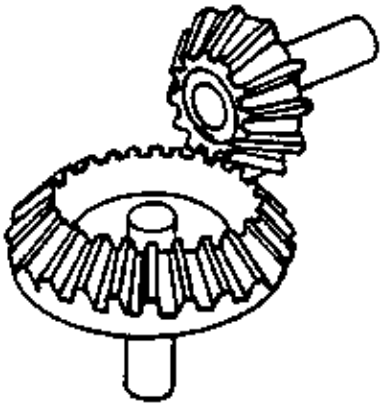
Drop oil



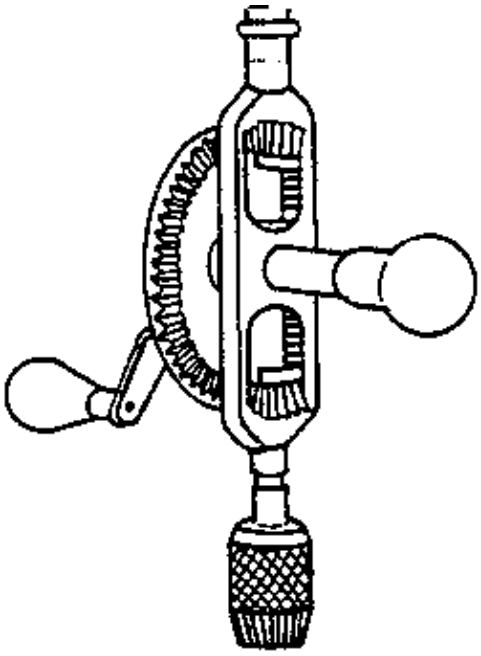
Oil bath



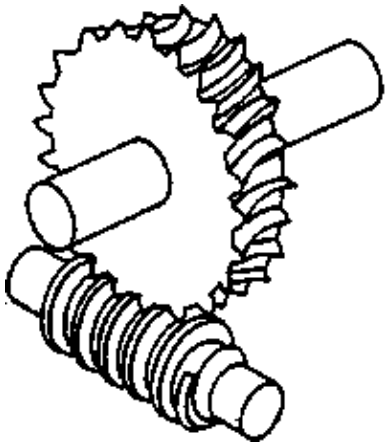
Oil pump



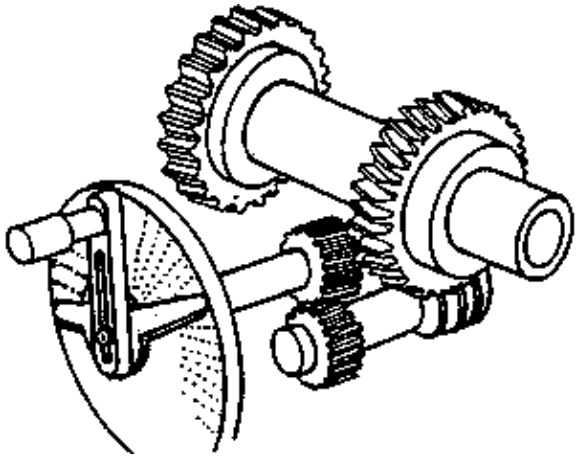
Bevel gear



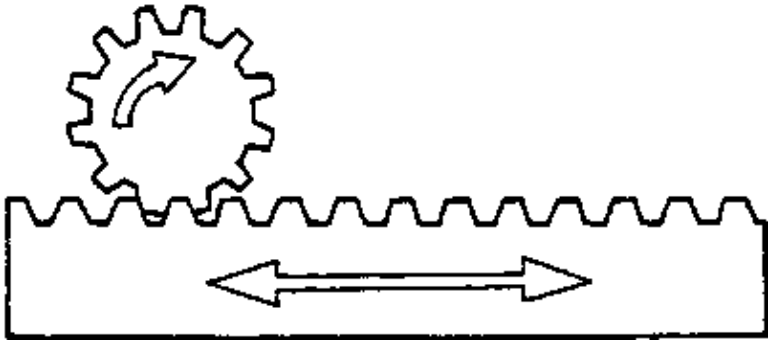
hand driller



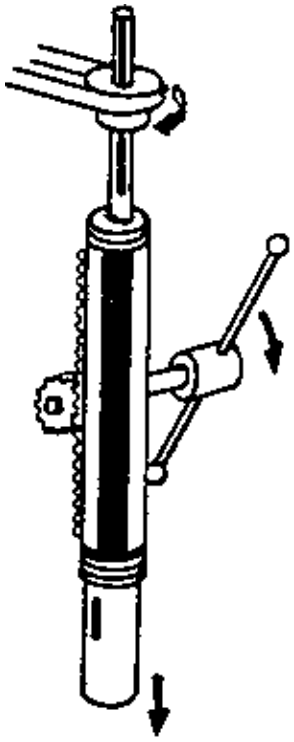
Worm gear



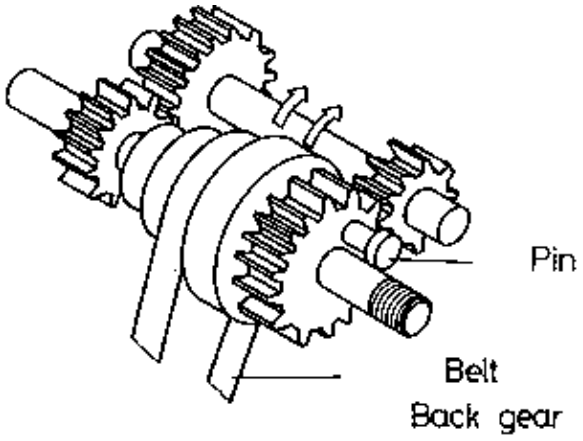
Dividing head

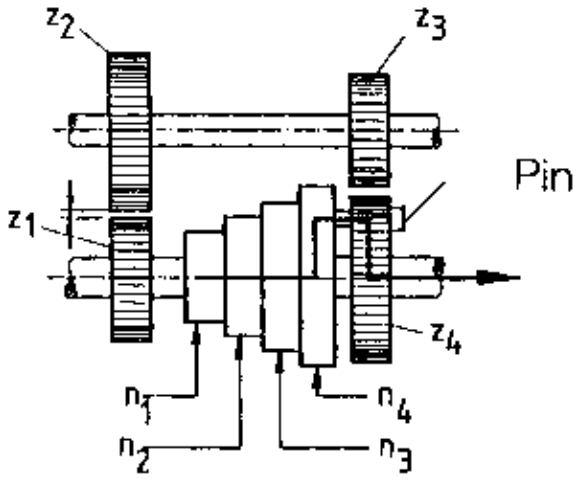


Rack and pinion

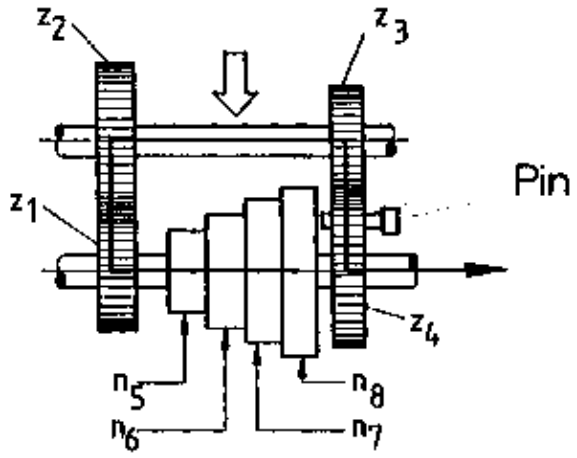


Driller

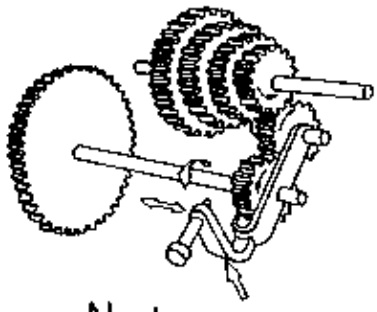




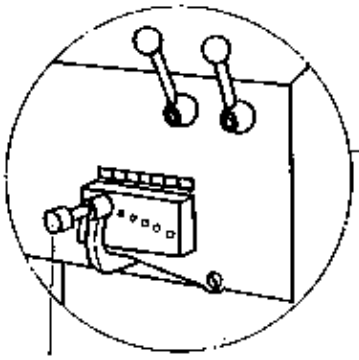
Non working position



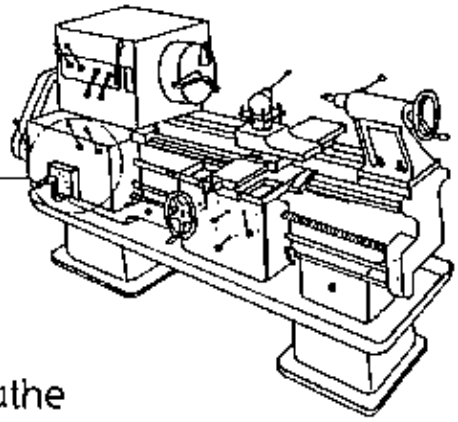
Working position



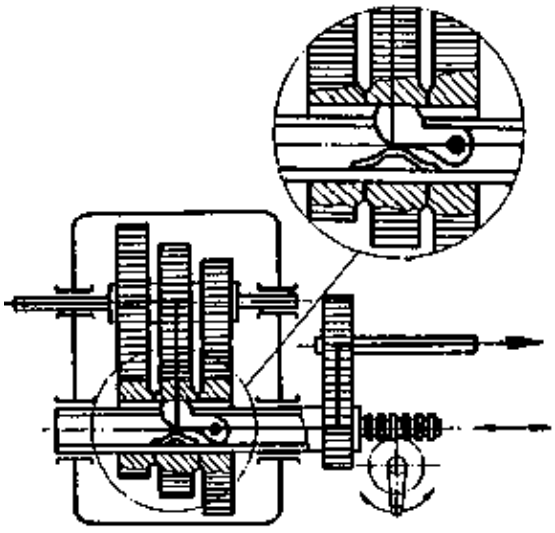
Norton gear

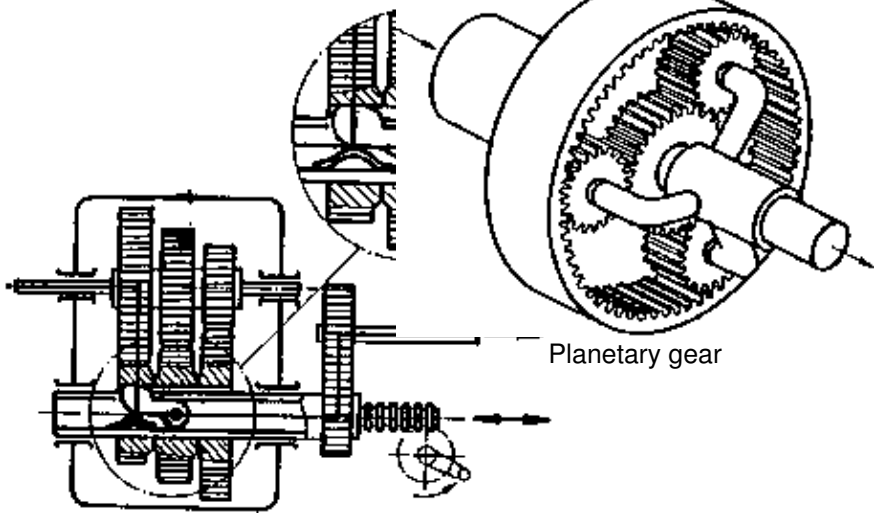


Swivel arm



Lathe



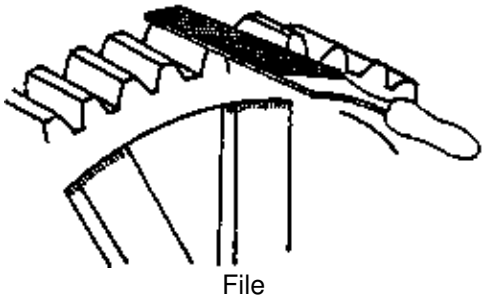


Planetary gear

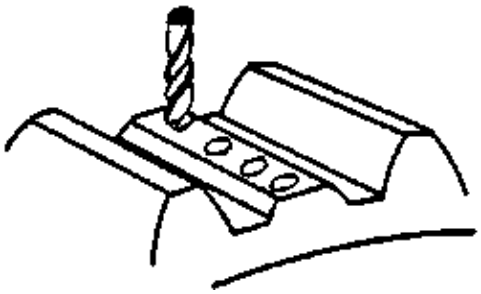
Driving key gear

Repairing a tooth broken gear

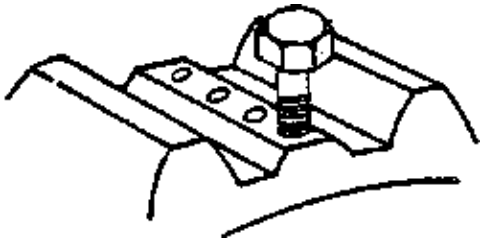
tooth is broken



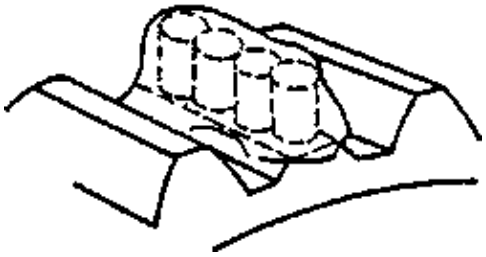
File



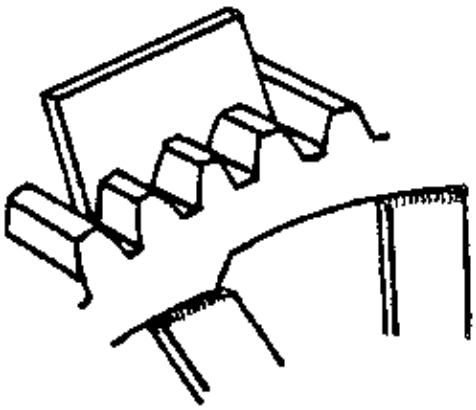
Drill the holes



Bolt



Weld



Gauge

7. Roller bearings

Objectives

I. Purpose and basic function

1.

a) Describe the difference of friction in *a* roller bearing and in a bush bearing
b) Describe the position of a shaft and the friction coefficient of bush bearing and roller bearing when revolution is changing.

2.

a) Name the parts of roller bearing
b) Describe the property and the function of the components of a roller bearing

II. Type and design

3. Show the difference between deep groove ball bearing and cylindrical roller bearing according to

– direction of load
– contact area

4. Give reasons for the selection criteria of deep groove ball bearing and needle bearing according to

– quantity of load
– outer diameter of the bearing

5. Compare load capacity of thrust ball bearing, cylindrical roller bearing & tapered roller bearing

6. Explain why a spherical roller bearing is chosen when the shaft is misaligned.

7.

a) Explain the load capacity of the following bearings:

deep groove ball bearing, cylindrical roller bearing, tapered roller bearing, needle roller bearing, thrust ball bearing, spherical roller bearing

b) Name the above mentioned bearings

III. Assembly, repair and maintenance

8. Explain why one of two bearings must be arranged floating.

9. Describe two different ways of realizing floating arrangement.

10. Explain the difference between point load and circumferential load at the inner and outer race when direction of load is constant,

11. Explain why a tight fit is used when the load at the race is circumferential and a loose fit for point load.

12. Explain why interference fit is needed on bearing ring which is subjected to rolling force, and transition fit for the ring which is subjected to stationary point load.

13. Explain reason for exerting force directly on either inner or outering of bearing when dismounting it.

14. Explain the use of tools for mounting and dismounting bearings

15. Explain reasons for provision of clearance between balls and race of rolling bearings.

16. Explain techniques of clearance adjustment of rolling bearings by back to back and taper sleeve methods.

17. Tell how bearings are mounted to shaft or housing by means of warming and cooling techniques.

18.

a) Tell 5 methods in lubricating bearings with oil or grease,
b) Give reasons for the use of oil or grease or lubricating medium for bearings.

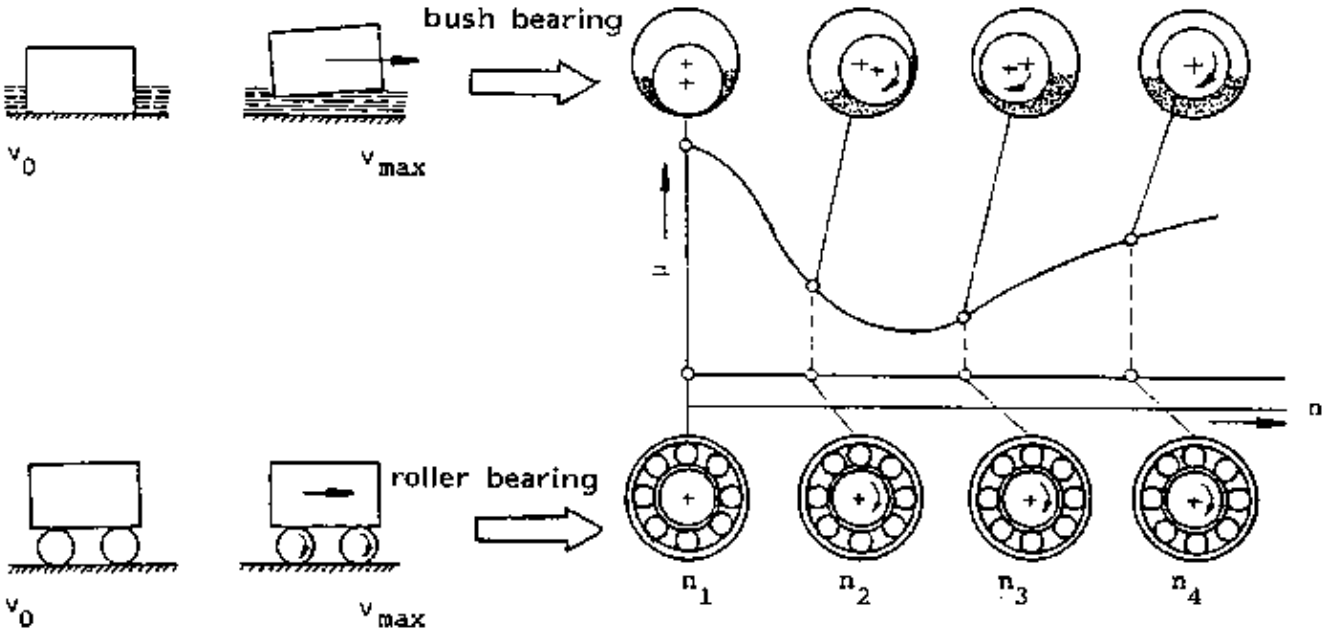
19. Explain how to mount seal to shaft and housing.

20. Explain at least 3 methods in diagnosing faults of bearings during its operation.

Information sheet

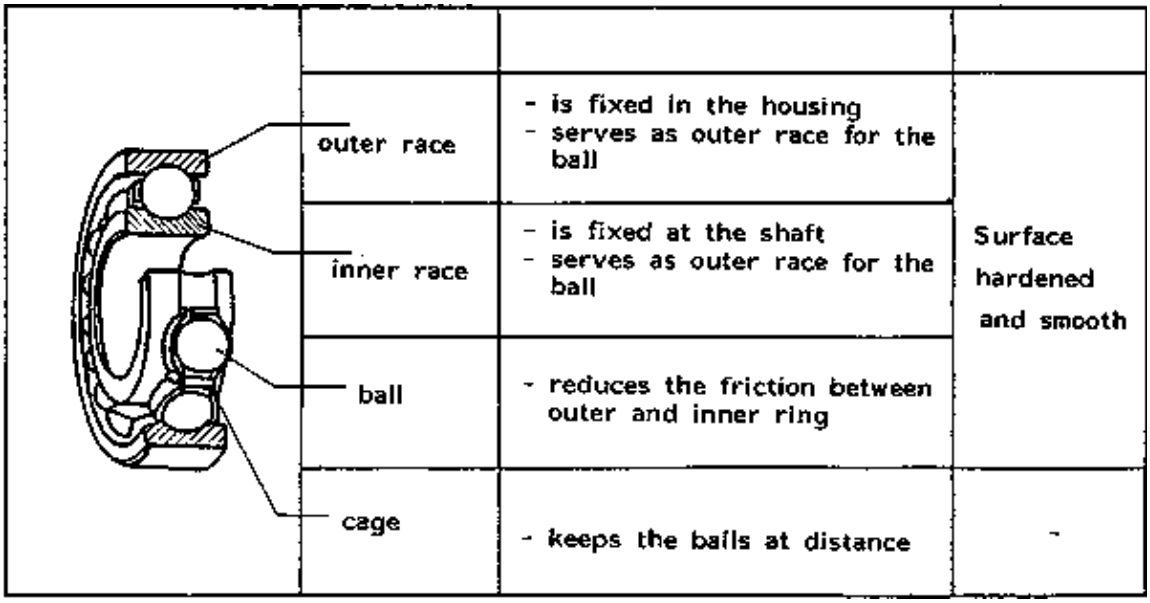
1. Purpose and basic function

1.1 Comparison roller bearings – bush bearings



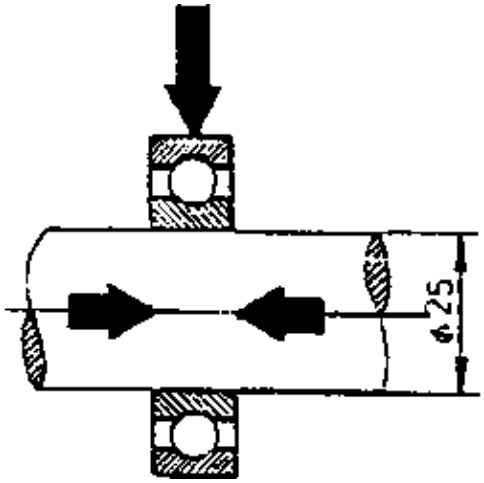
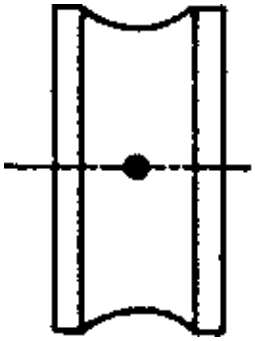
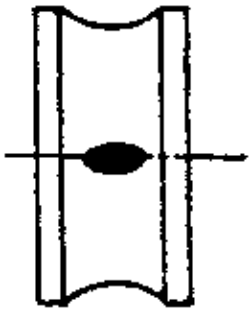
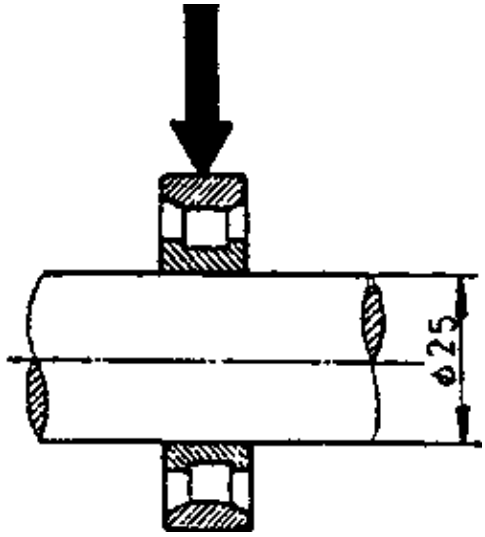
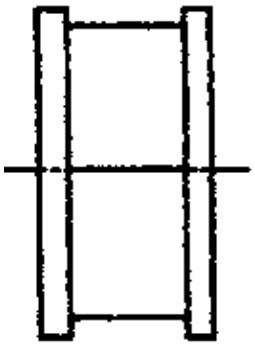
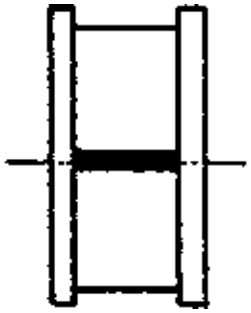
n = revolution per minute (1/min)
v = speed (m/min)
μ = coefficient of friction

1.2 Types and design



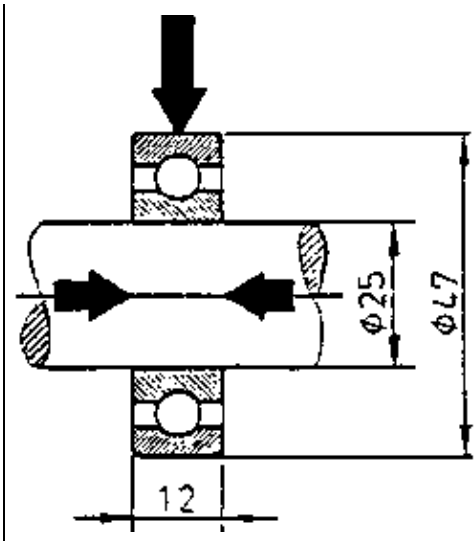
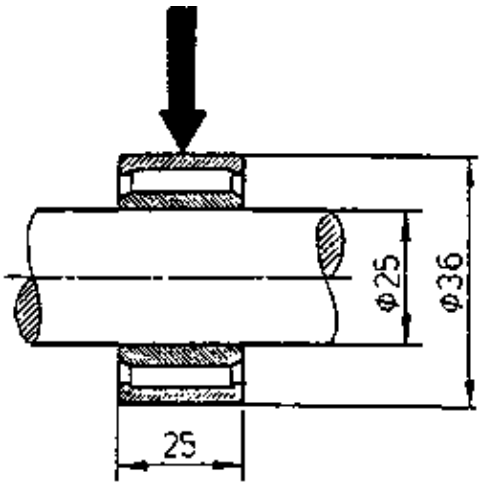
2. Types and design

2.1 Deep groove ball bearing and cylindrical roller bearing – direction and capacity of load, contact surface

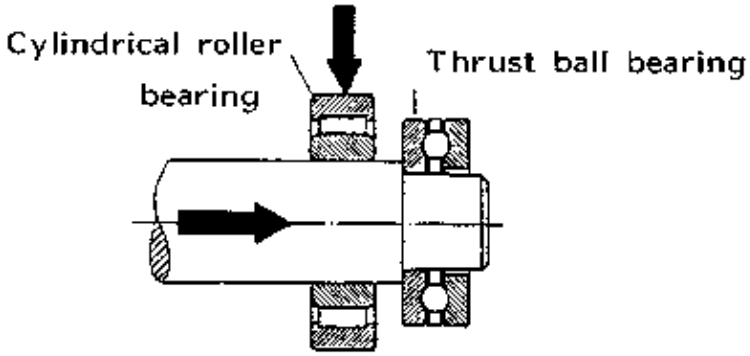
Name	Load capacity	contact areas	
		load	no load
Deep groove ball bearing			
	can support more radial than thrust load	pressure area is a point	pressure area is an ellipse
Cylindrical roller bearing			
	can support only radial load	pressure area is a line	pressure area is a square

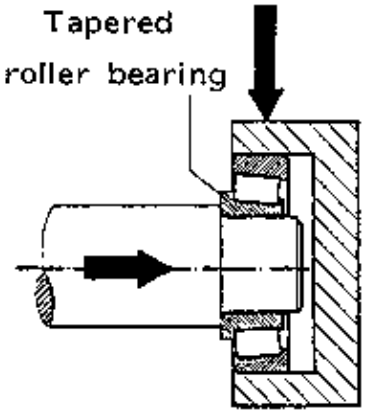
2.2 Deep groove ball bearing and needle bearing – direction of load and outer diameter

	Deep groove ball bearing	Needle roller bearing
diameter of the shafts are equal		

		
outer diameter	big	small
width of bearing	small	big
radial load	big	very big

2.3 Thrust ball bearing and tapered roller bearing – direction of load



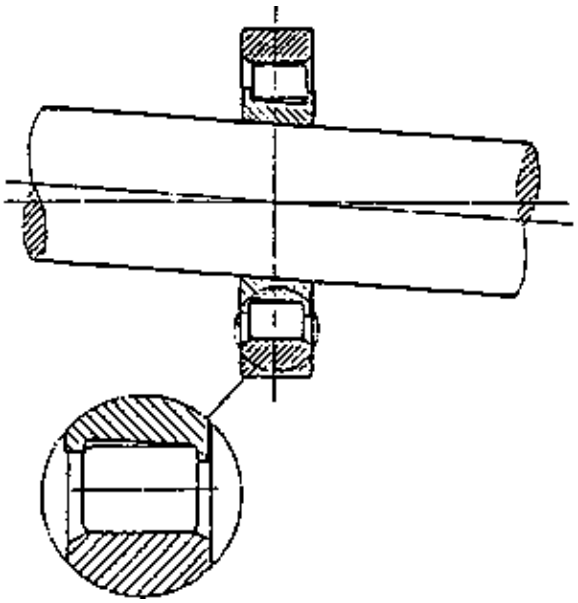


Type of bearing	direction of load	
Thrust ball bearing	→	axial (thrust)
Cylindrical roller bearing	↓	radial
Tapered roller bearing	↓→	axial and radial

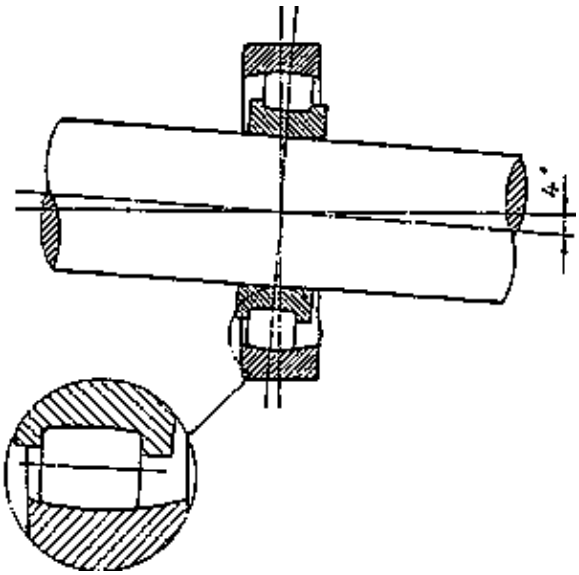
2.4 Spherical roller bearing

Cylindrical roller bearing

Spherical roller bearing

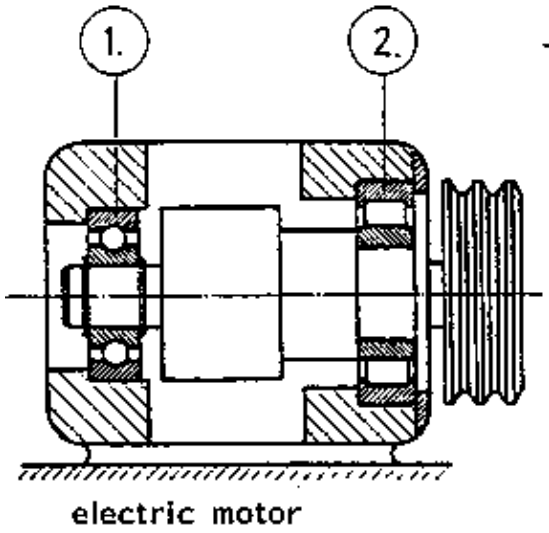


The load is concentrated at one point, the bearing will be destroyed soon.



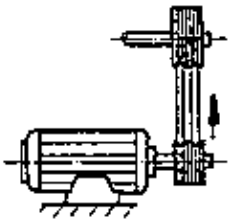
Remedy: Using a spherical roller bearing, the misaligning should not be bigger than 4°.

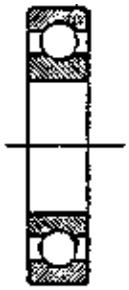
2.5 Rolling bearings and their application electric motor



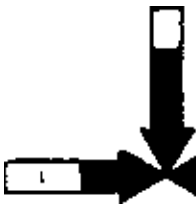
Type of bearing **Amount and di load**

1.

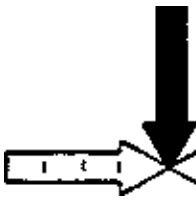




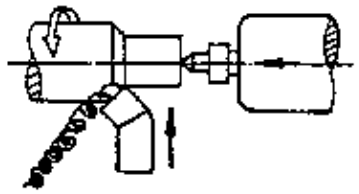
Deep groove ball bearing

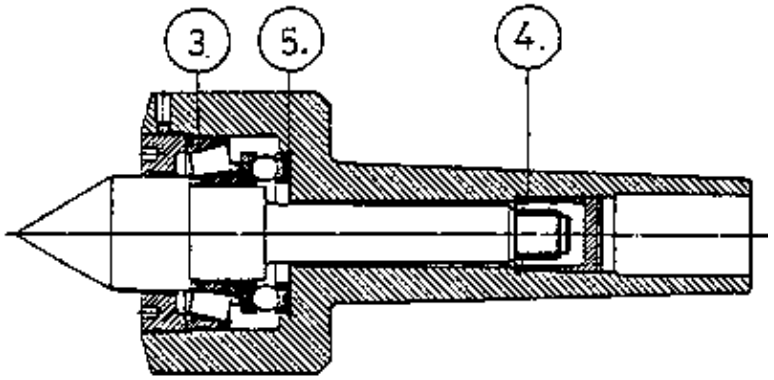


2.



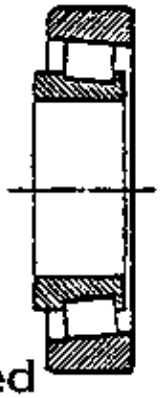
Cylindrical roller bearing

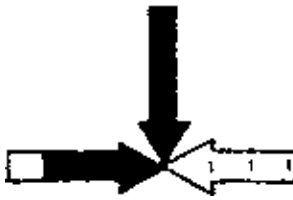




Lathe dog

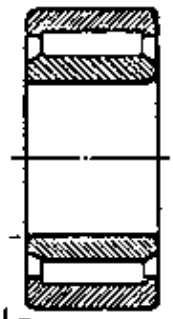
3.

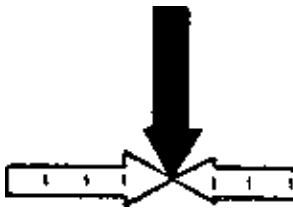




Tapered roller bearing

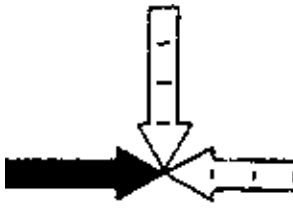
4.

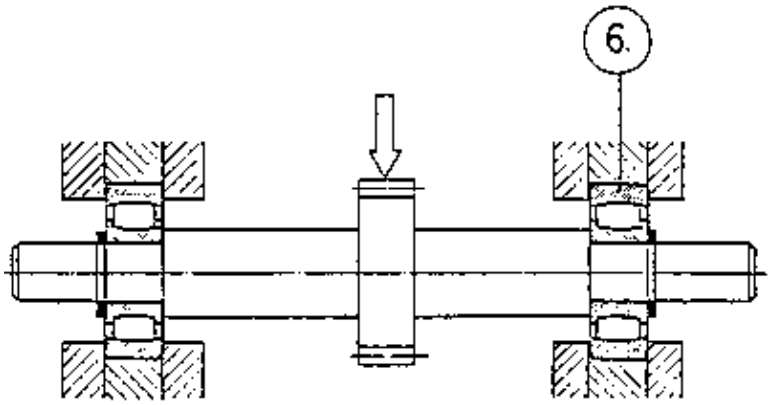




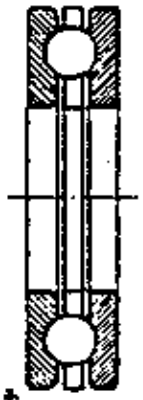
Needle roller bearing

5.



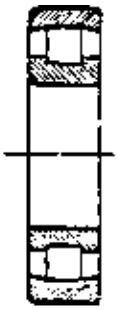


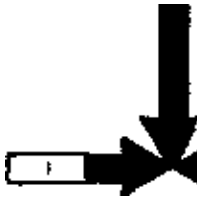
Long shaft



Thrust
ball bearing

6.

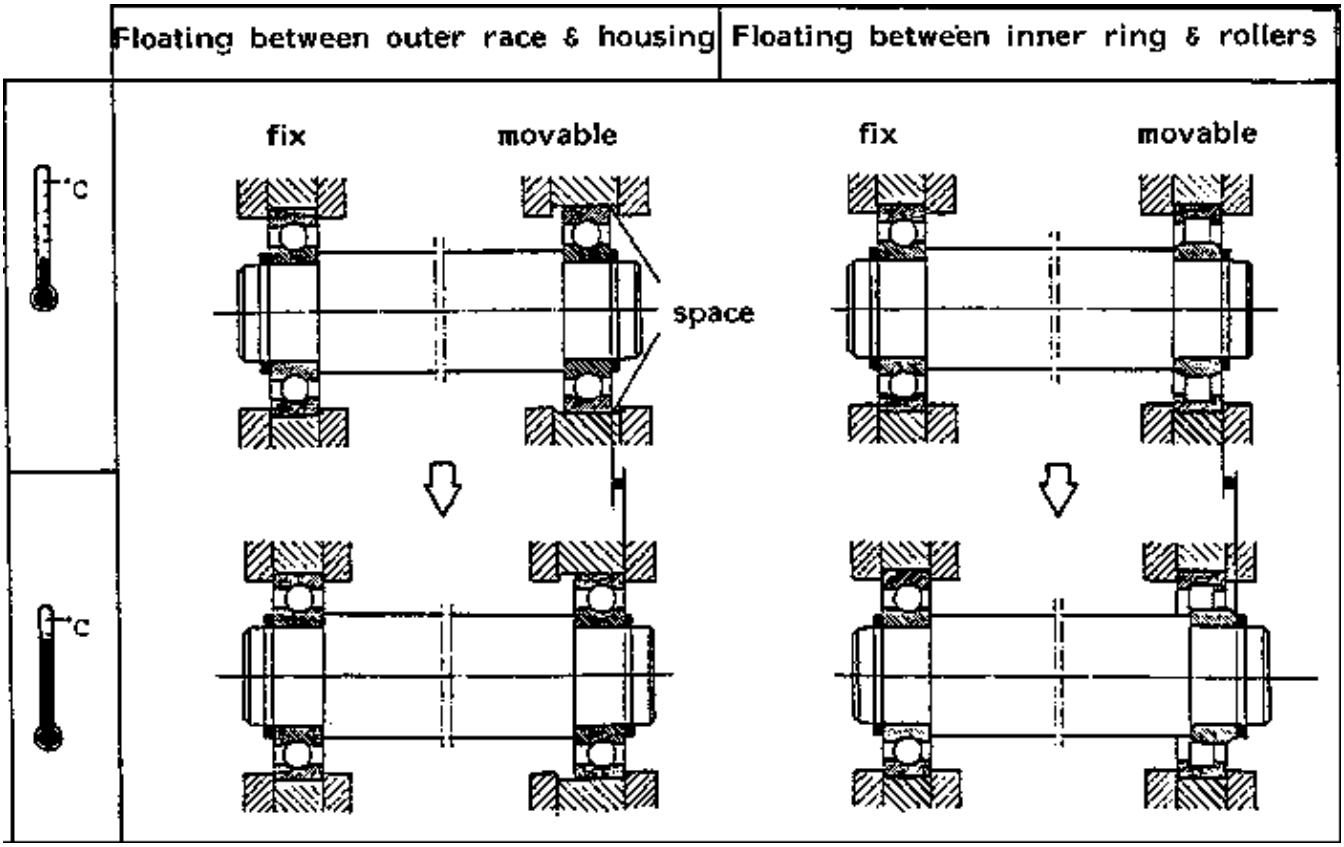




Spherical roller
bearing

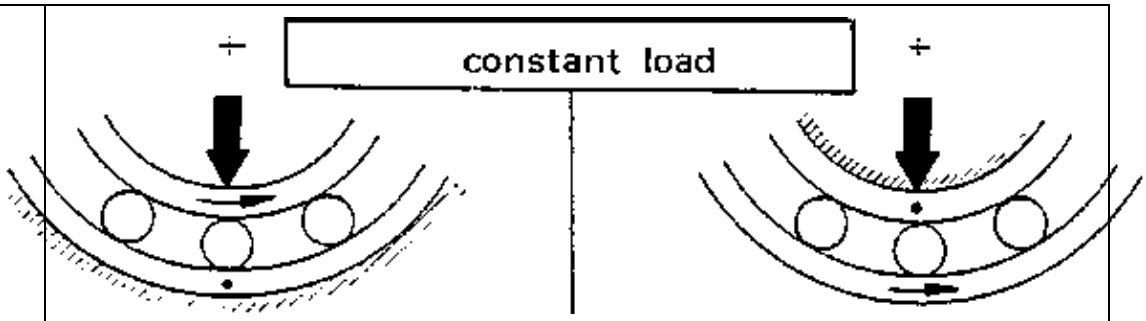
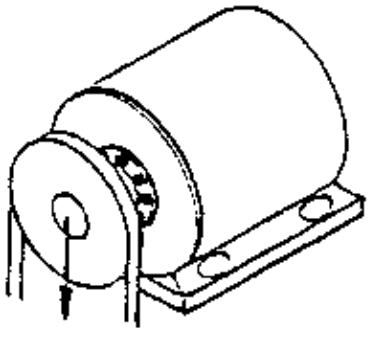
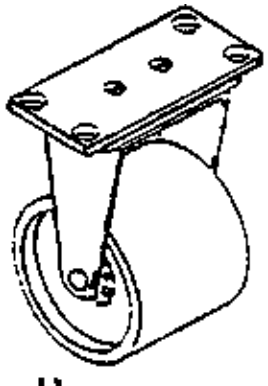
3. Assembly, repair and maintenance

3.1 Floating bearing

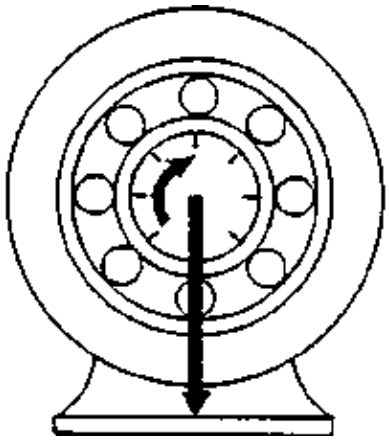
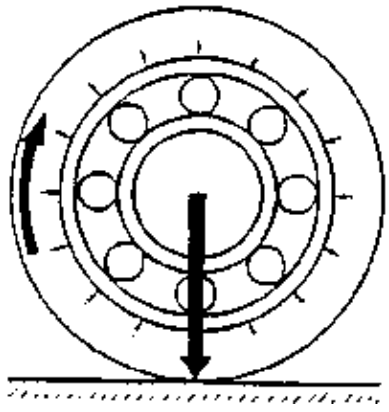


When the temperature increases, the shaft extends. If this is not possible, the bearing will be destroyed.

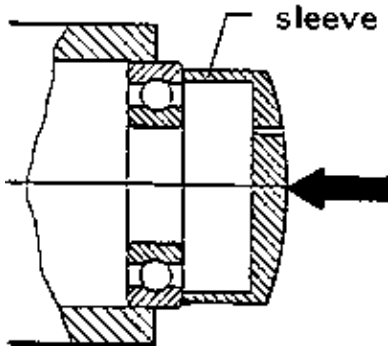
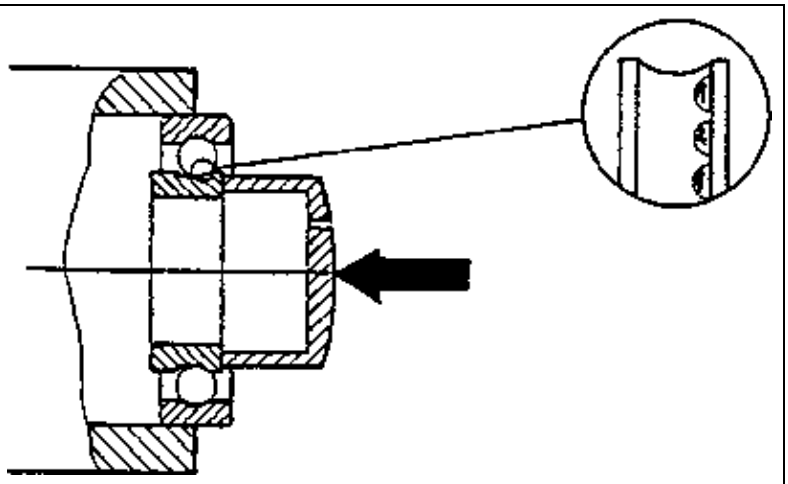
3.2 Point load and circumferential load constant load

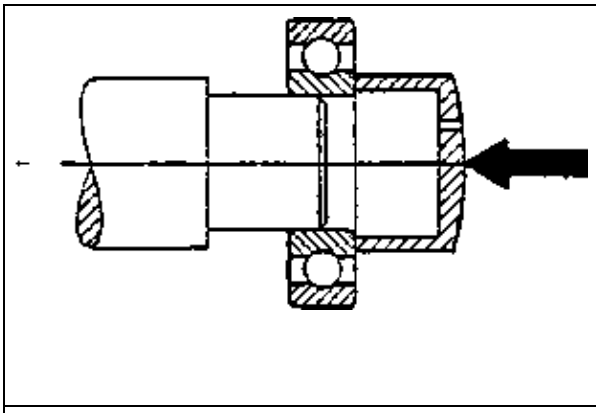
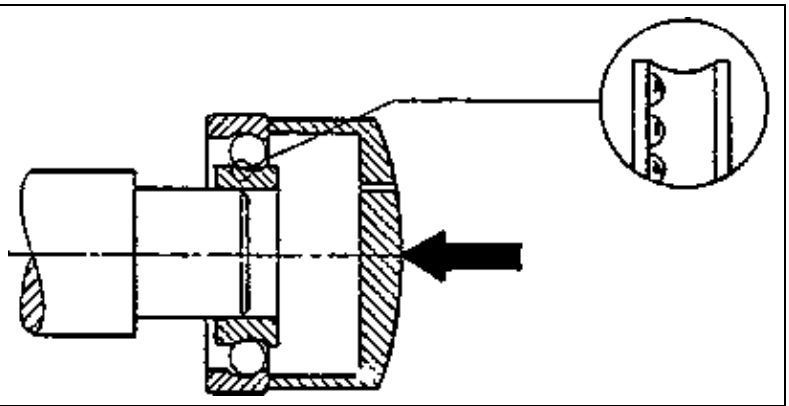
				
	Shaft and inner ring are rotating		Housing and outer ring are rotating	
Load on the bearing races	inner ring: along circumference	outer ring: point load	inner ring: point load	outer ring: along circumference
application	 electric motor		 roller	

Influence of point load and circumferential load to the fit of a bearing:

		fit	reason
	inner ring: circumferential load	tight	protection against twisting of the wheel in the inner ring, which destroys the wheel
	outer ring: point load	loose	simple assemble the outer ring is fixed by the cover.
	inner ring: point load	tight	simple assemble the inner ring is fixed by a nut.
	outer ring: circumferential load	loose	protection against twisting of the outer ring in the housing which destroys the wheel.

3.3 Assembling by sleeve

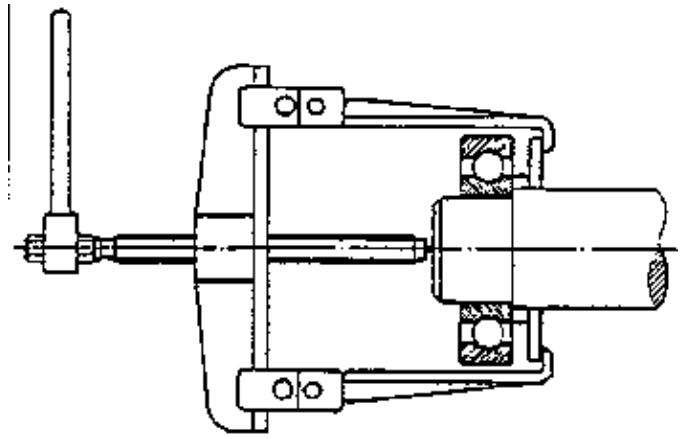
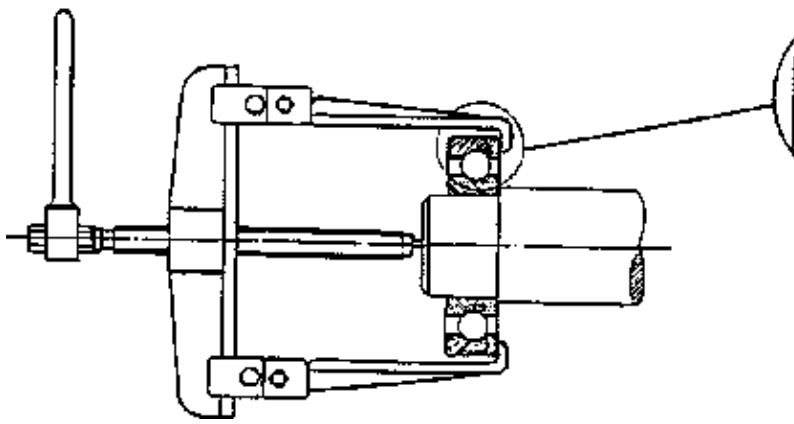
	
When assembling, the force must act on the outer ring.	When the force acts on the inner ring, the race way will be damaged.

	
When assembling, the force must act on the inner ring.	when the force acts on the outer ring, the race way will be damaged.

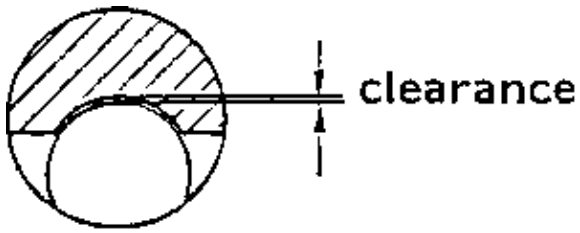
Note: A sleeve is used for mounting small bearings.

3.4 Disassembling by puller

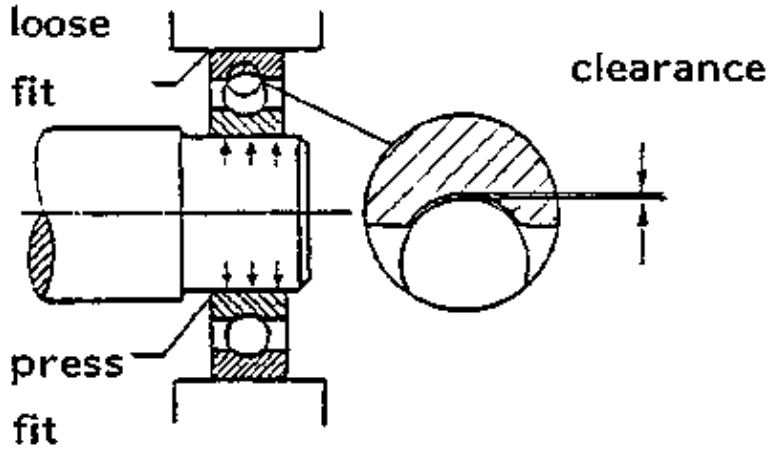
When dismounting, the force directly acts at the tightly fit ring.

	
The bearing is dismounted by a puller and a puller plate.	When dismounted without puller plate, the race way and rolling ele damaged.

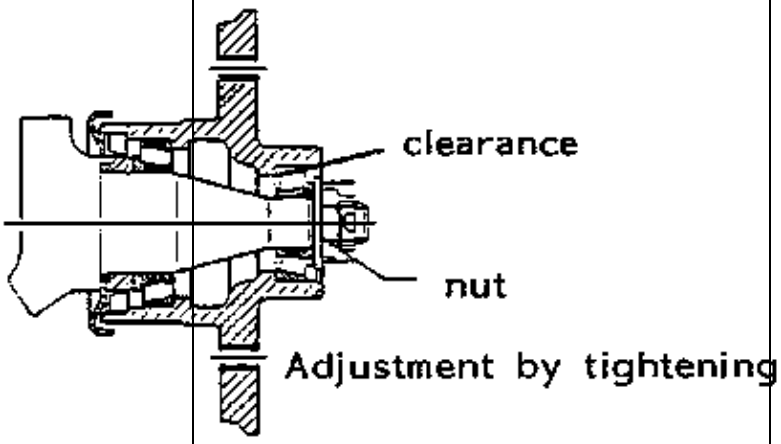
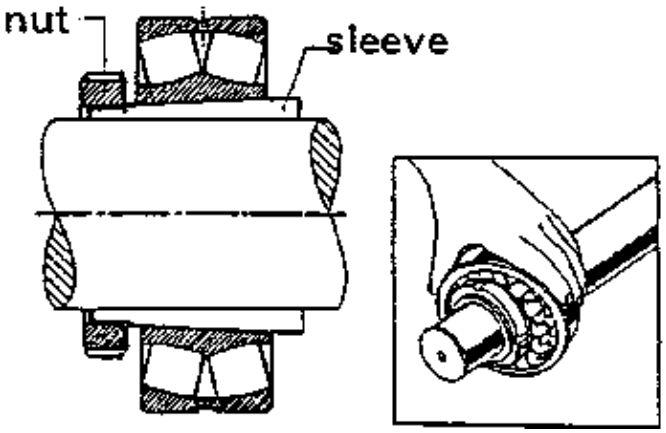
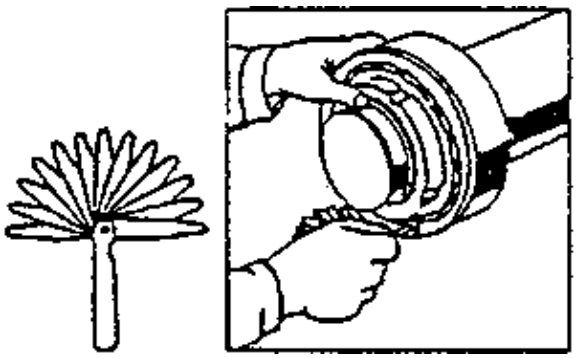
3.5 Clearance of roller bearings



– mounted bearings should have very low clearance. However, they must have some to enable the expansion from getting warm.



– generally fits of bearings (e.g. shaft J5, housing I6) ensure sufficient clearance.

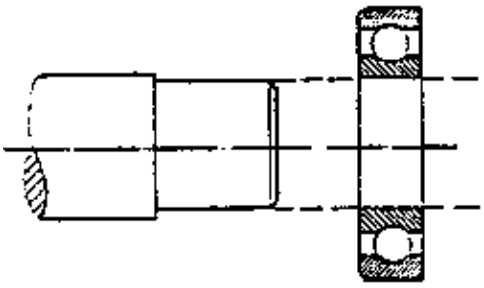
Assembly of bearings		
back to back arrangement		sleeve mounted bearing
		
Small bearings	Clearance value can be found in the machine manual. For car wheel: tighten the nut, then loose it ca. 1/12 round.	Correctly tightened, the outer race must turn easily, but there must be some resistance to swivel it.
big bearings	check clearance with filler gauge	check clearance with filler gauge 
	The clearance can be found in the machine manual.	The clearance will be found in the table below.

Inner diameter of bearing	minimum clearance
30 – 40	0.015
40 – 50	0.020

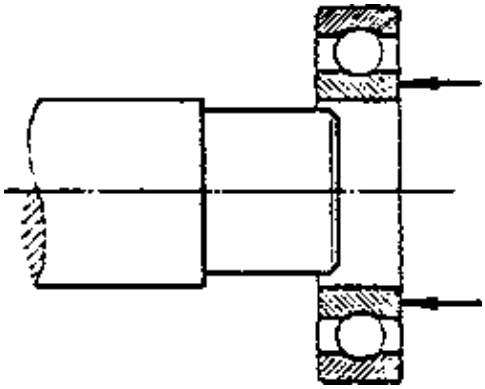
50 – 85	0.025
3 – BO	0.025
80 – 100	0.035
100 – 120	0.050

3.6 Assembling by warming and cooling

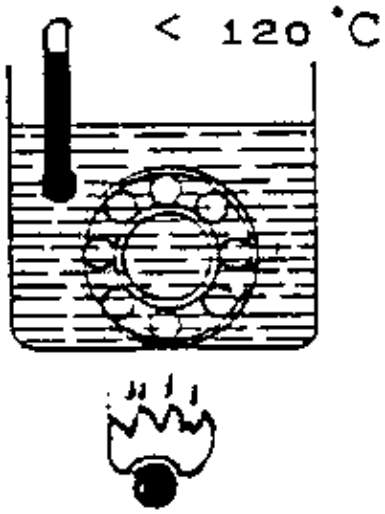
Assembling by warming



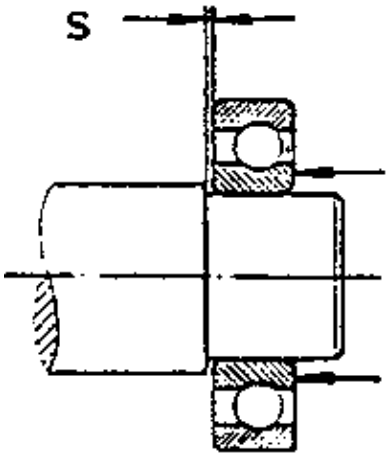
– before assembling



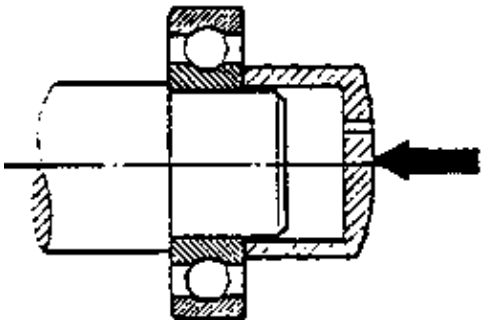
– assembling after warming up in oil



– the flash point of the. oil should be higher than 250° C.

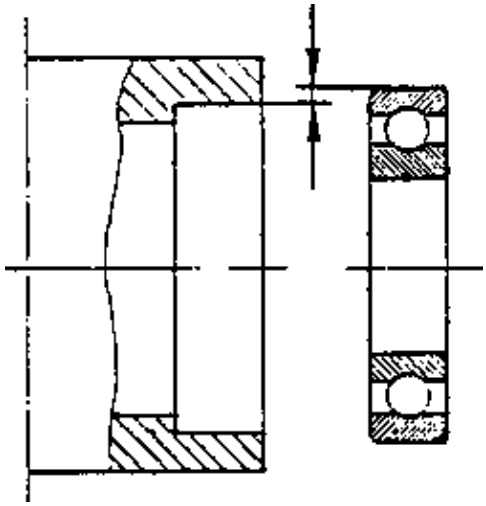


– after assembly cooling to room temperature

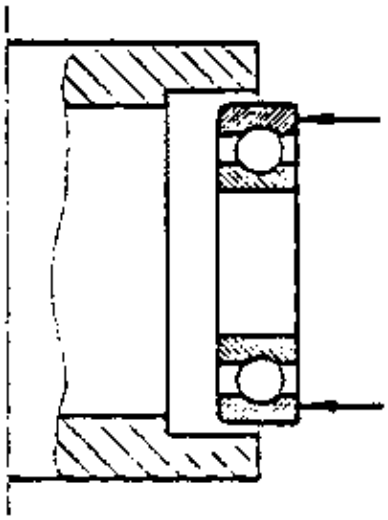


– drive the bearing with mounting sleeve to avoid gap "s"

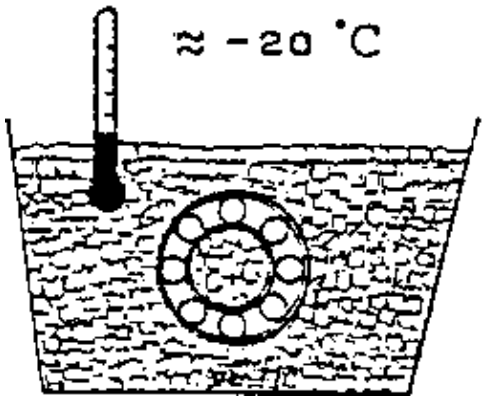
Assembling by cooling



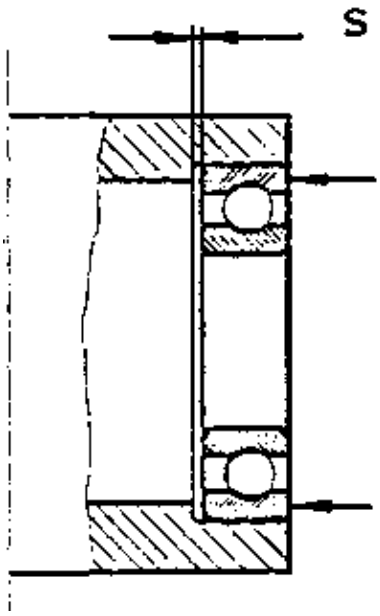
– before assembling



– assembling after cooling in ice.



– cooling the bearing with dry ice at –20 °C



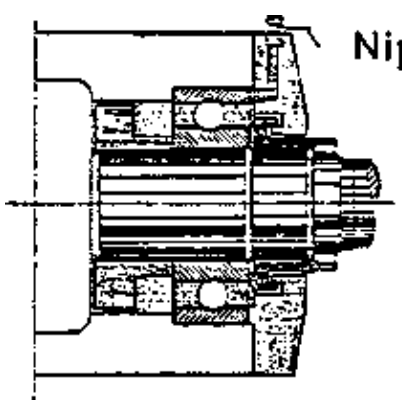
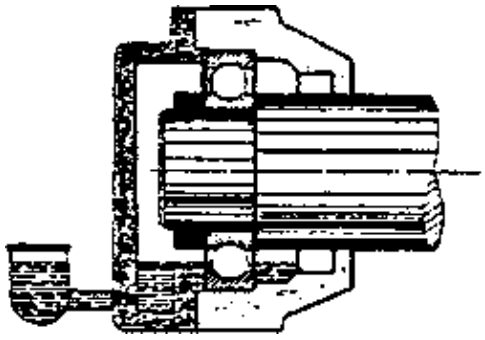
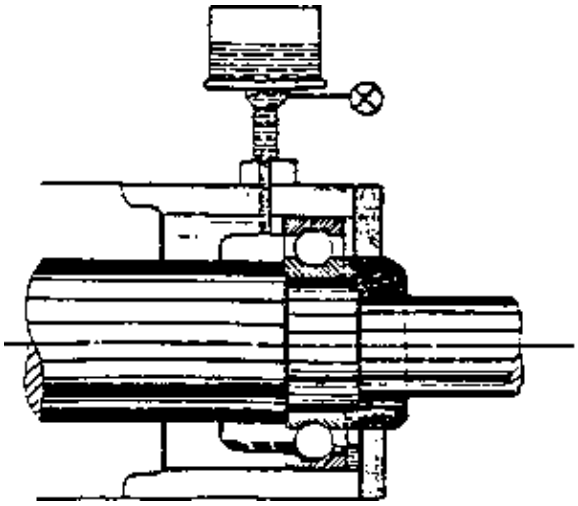
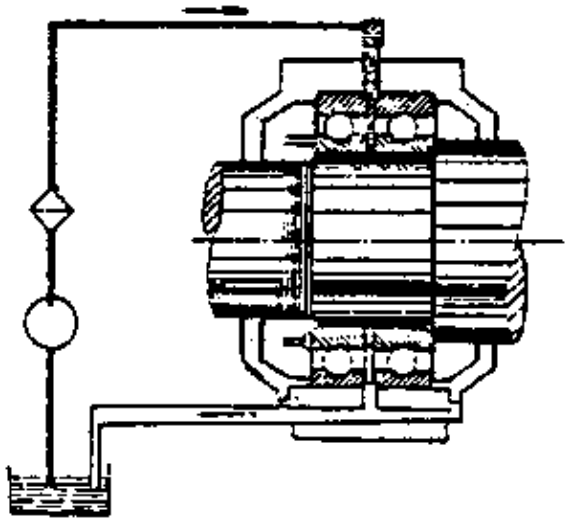
– after assembly warming up to room temperature

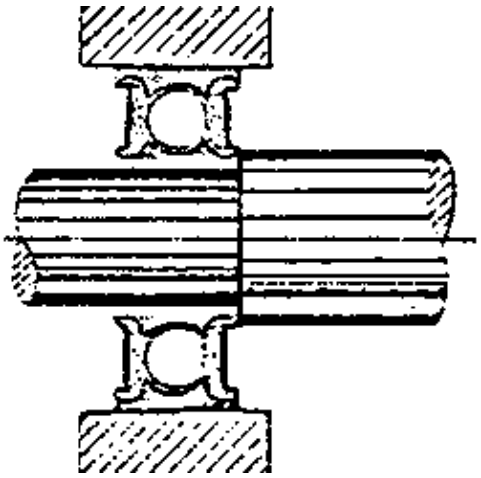
drive the bearing with sleeve to avoid gap "s"

Note: only big bearings are mounted by warming or cooling.

3.7 Lubrication systems

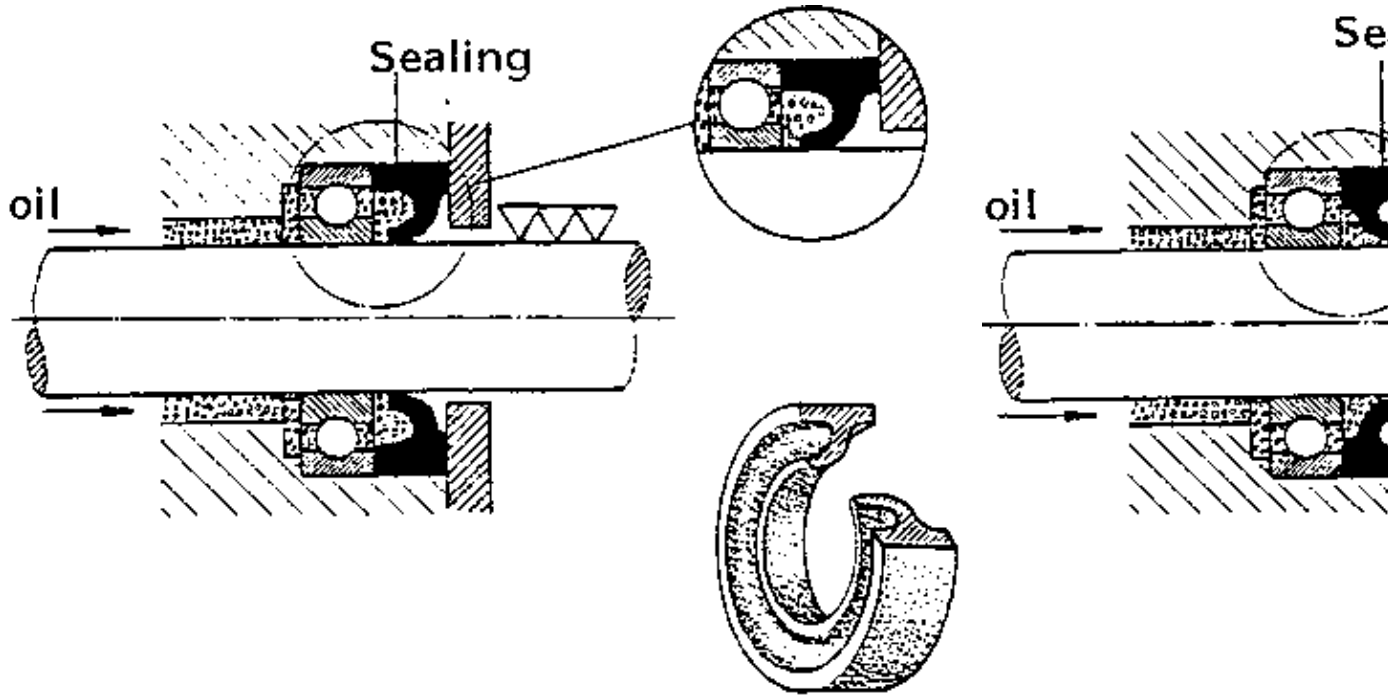
picture	lubrication method
	grease lubrication

	
	splash lubrication
	drip feed lubrication
	pressure oil lubrication



grease filling for lifetime

3.8 Sealings



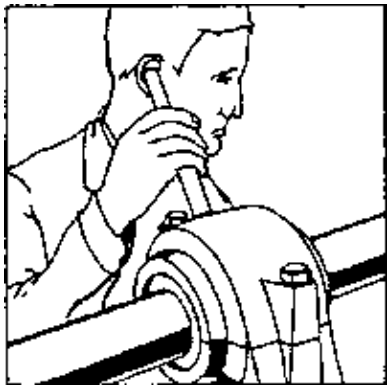
assembled in the correct way

assembled in the wrong way

Note: A fine shaft–surface increases working life of the sealing

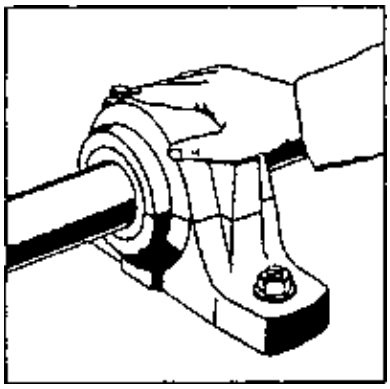
3.9 Inspection of defect roller bearings during work

Sound–check



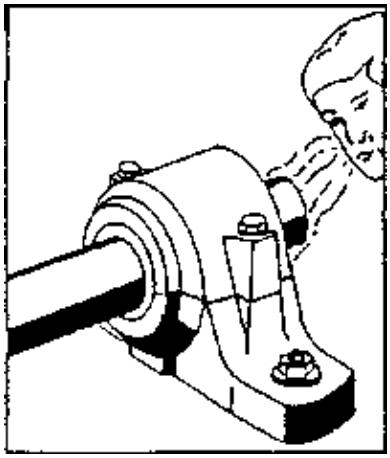
When the bearing runs noisily, it might be damaged.

Temperature–check



When the bearing gets hot, it might be damaged.

Odour–check

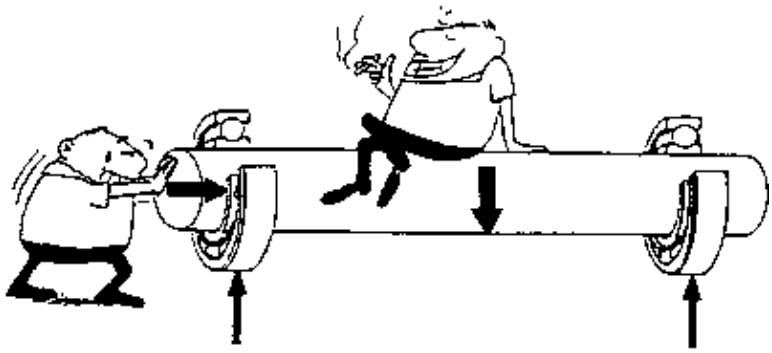


When the bearing gets very hot, the grease starts burning and smelling.

Activity sheet

2.1 Direction and capacity of load

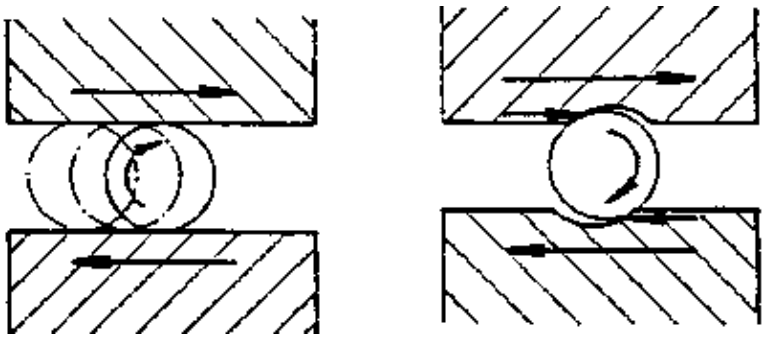
Activity: Discuss the following problems in groups of 4 to 5 students:



There are two directions of load:

– radial load
–thrust load

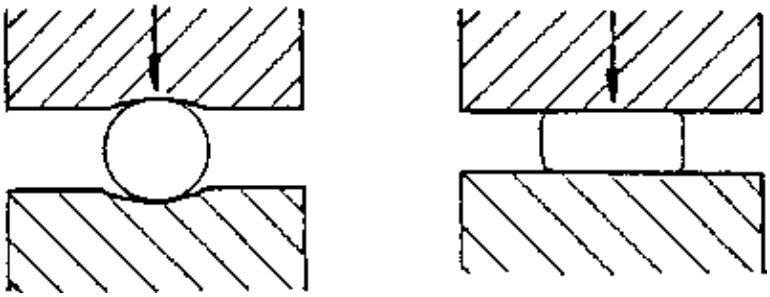
1.



– The load in picture a) and b) is radial/thrust.
– Compare the load capacity and give reasons:

_____
_____

2.

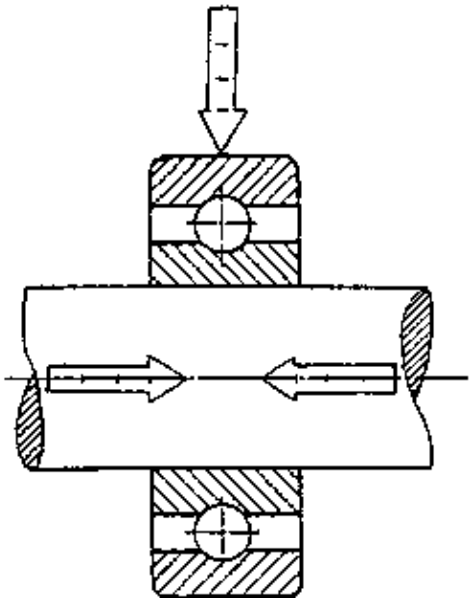


– The load in picture a) and b) is radial/thrust.
– Compare load capacity and give reasons:

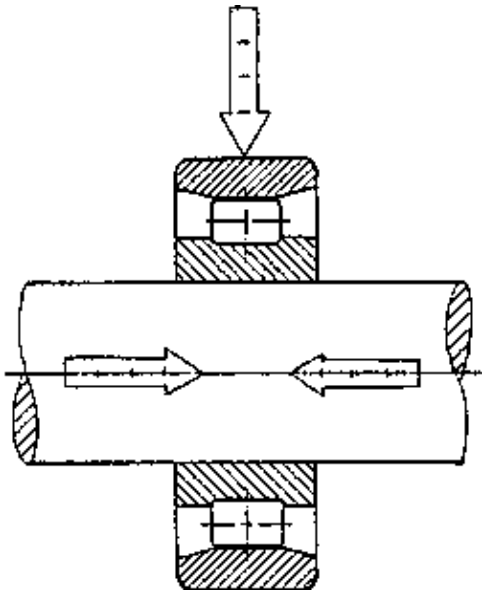
_____
_____

3.

a)



b)



Show the direction and capacity of load by

filling in  and give reasons

_____

_____

Remark:

 = cannot support any load

 = can support low load

 = can support moderate load

 = can support high load

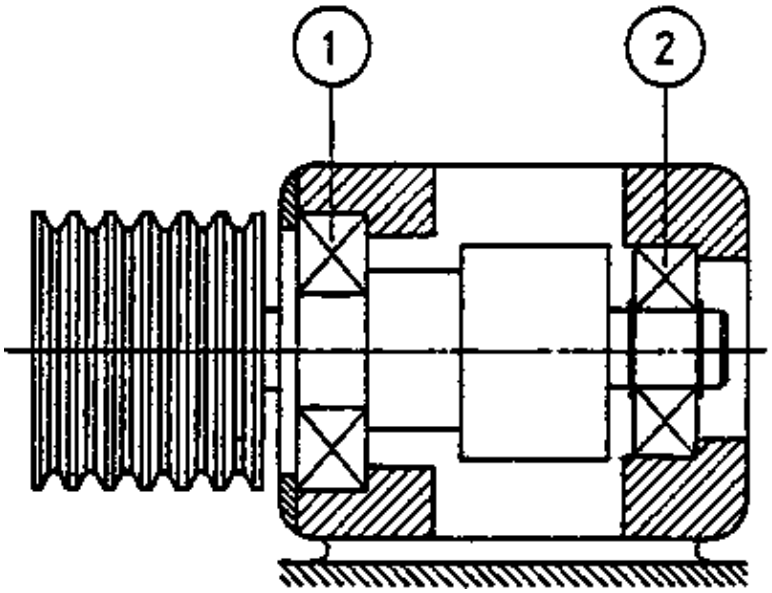
4. What has to be considered when using the bearings of task No. 3?

_____

_____

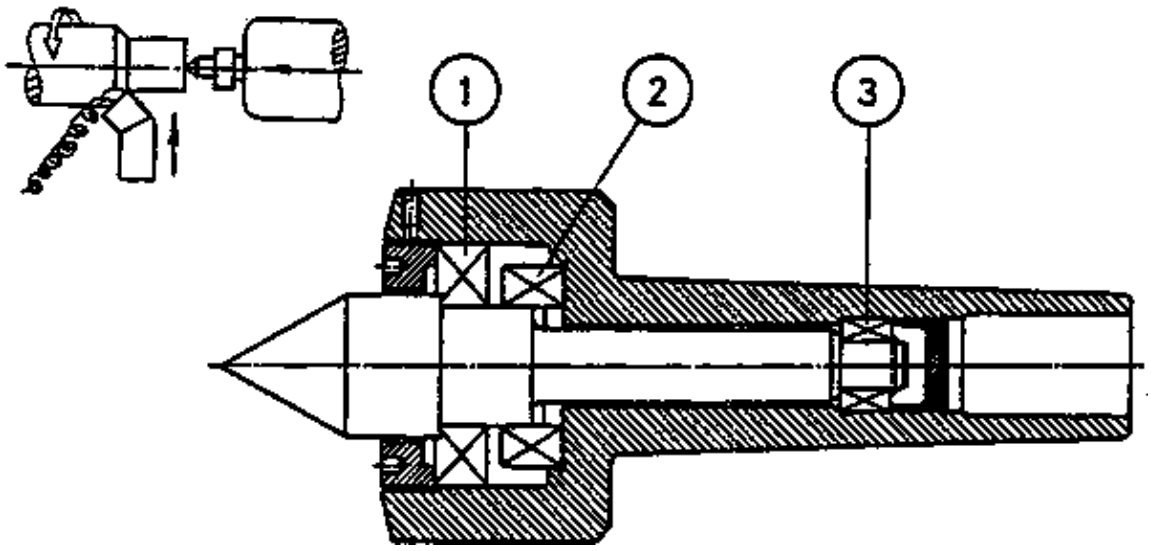
2.5 Roller bearings and their application

1. Choose the appropriate bearings for the electric motor.



1 _____
2 _____

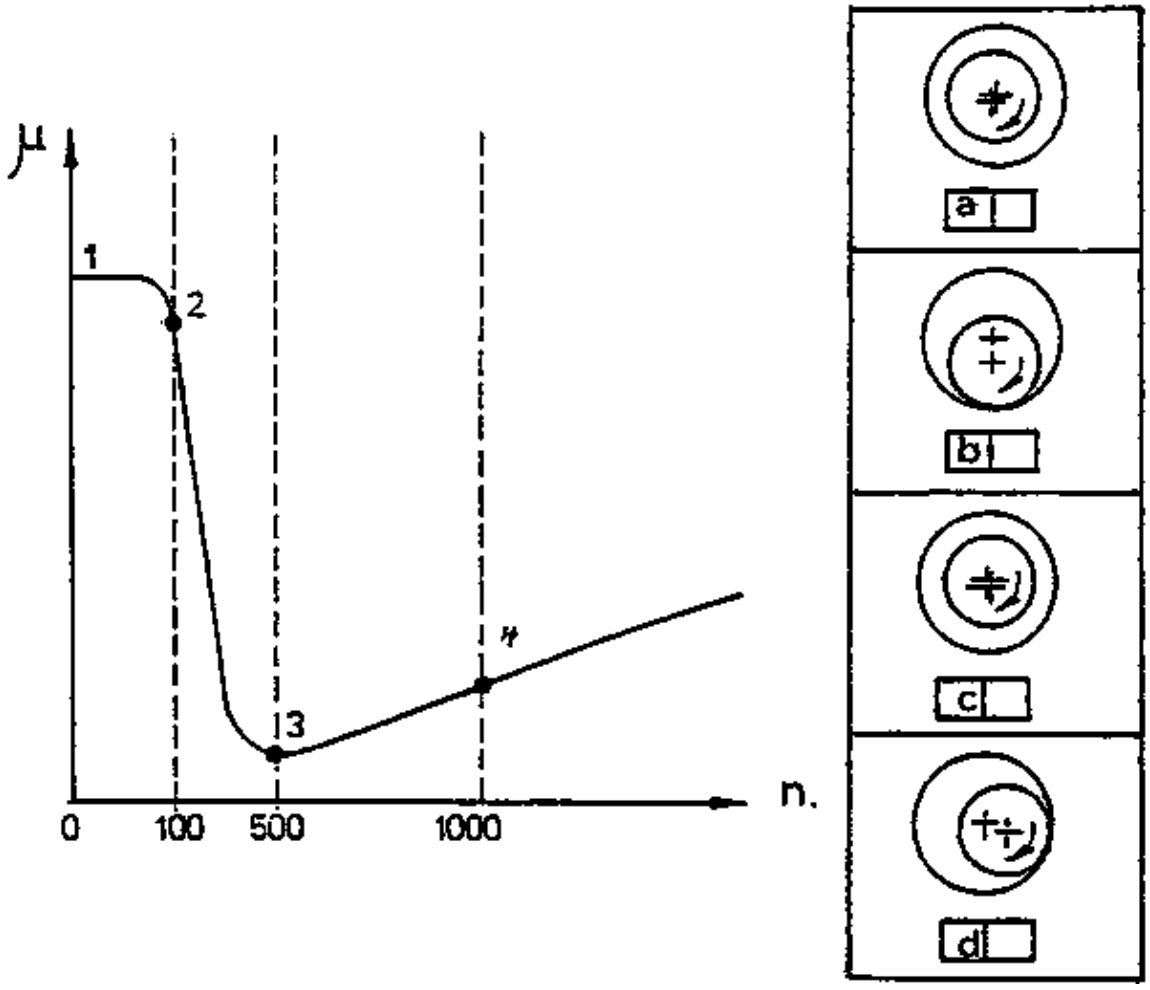
2. Choose the appropriate bearings for the lathe dog.



1 _____
2 _____
3 _____

Task sheet

1.1.1 Which point (1, 2, 3 or 4) is related to the drawings at the right side? Insert the right numbers.

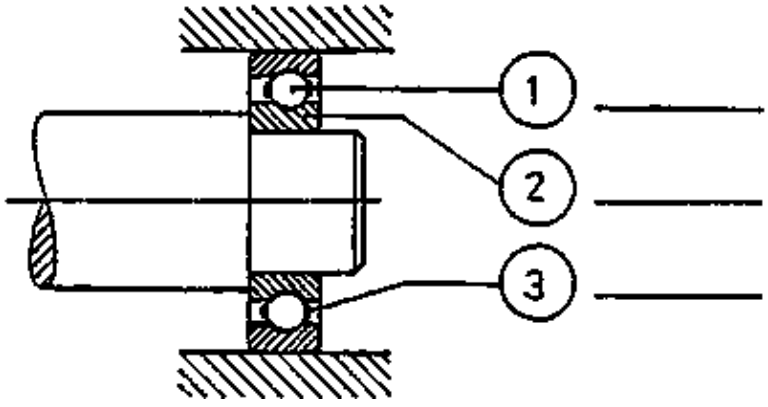


1.1.2 At low rpm the friction of a bush bearing is high/constant/low

1.1.3 At low rpm the friction of a roller bearing is high/constant/low

1.1.4 Centering of a roller bearing/bush bearing is independent from rpm.

1.2.1 Name the numbered parts in the picture.

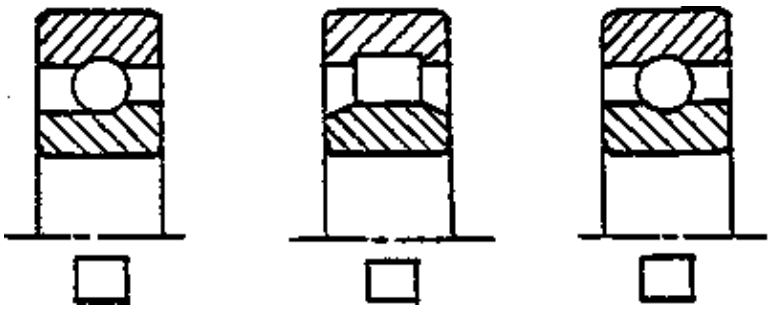


1.2.2 Put the numbers in the appropriate square.

- ☐ race of the rolling element
- ☐ keeps distance between rolling elements
- ☐ reduces friction between inner and outer race

1.2.3 Which part of the bearing is not necessary hardened and polished – inner race/outer race/rolling element/cage?

2.1.1 Write the appropriate letter in the square under the drawings.



a) cannot support thrust load
b) can support thrust load in one direction
c) can support thrust load in two directions

2.1.2 A deep groove ball bearing/cylindrical roller bearing can support more radial load.

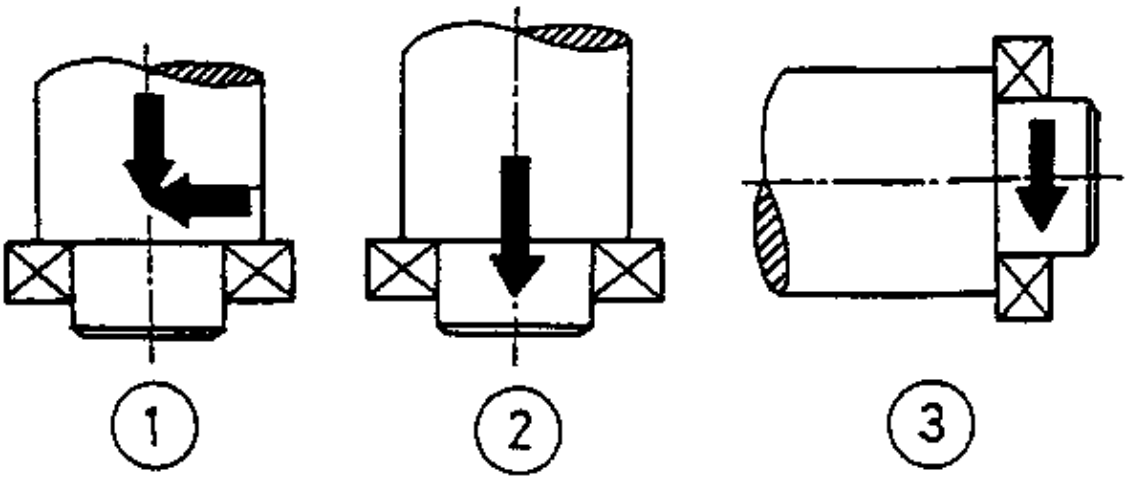
2.1.3 The contact area between rolling element and race of a ball bearing is bigger/equal/smaller than the one of a cylindrical roller bearing.

2.2.1 When the diameter of the housing is limited a ball bearing/needle bearing is suitable.

2.2.2 A needle bearing can support more/equal/less load than a ball bearing.

2.2.3 A deep groove ball bearing/needle bearing can support thrust load.

2.3 Attach the suitable bearing to the drawings.

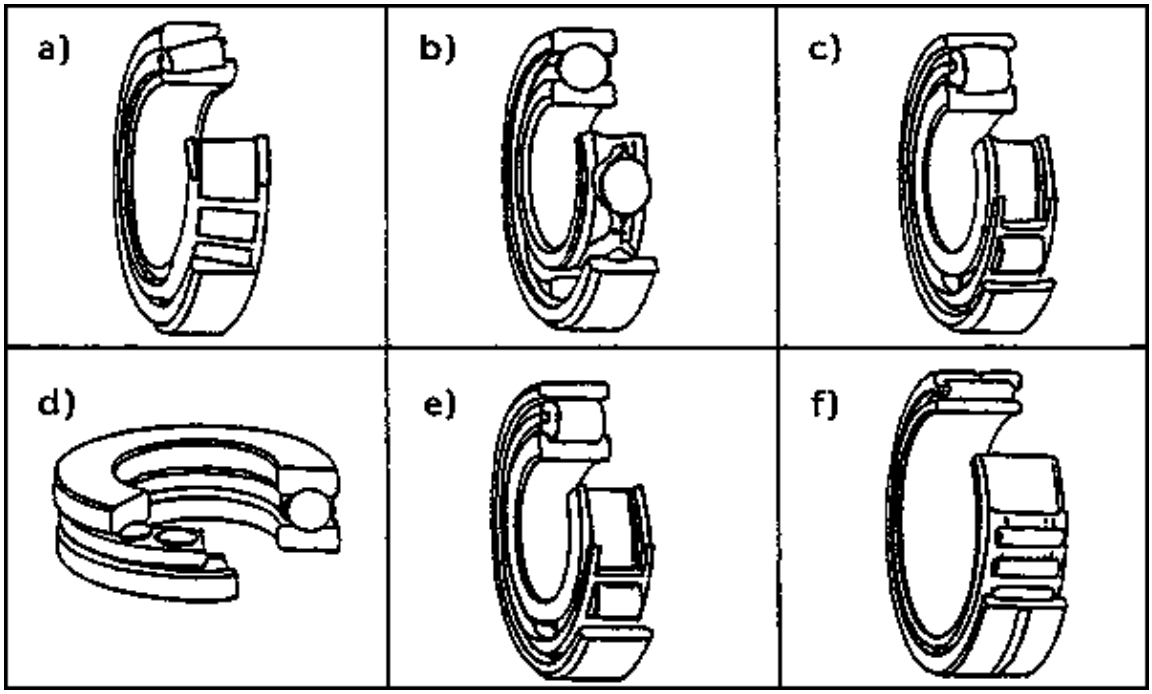


deep groove ball bearing
tapered roller bearing
thrust ball bearing

2.4 If a long shaft bends during work, which bearing would you choose?

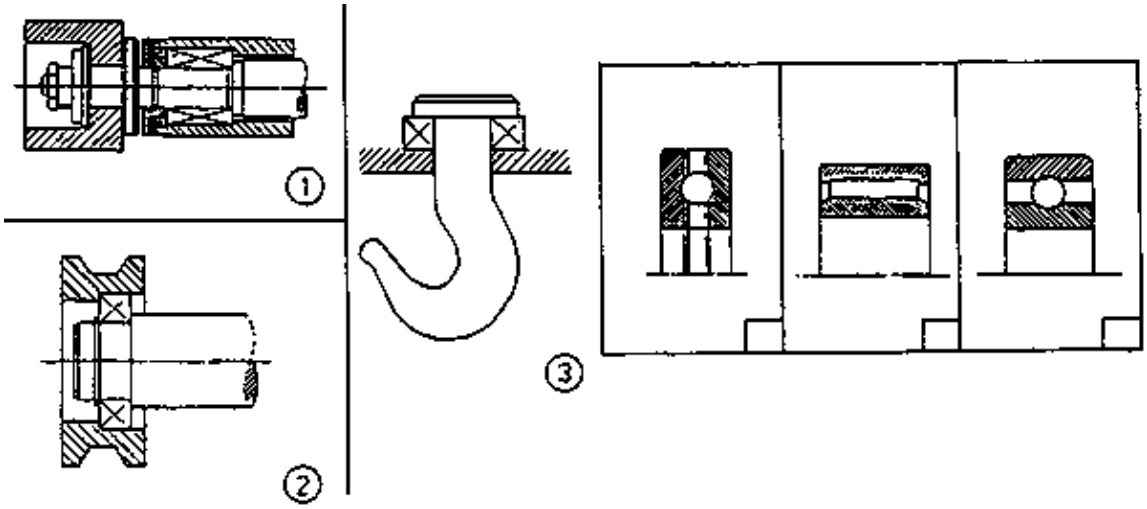
a) Needle bearing
b) Spherical roller bearing
c) Cylindrical roller bearing
d) Tapered roller bearing

2.5.1 Fill in the appropriate letter and mark the load capacity with



Name of bearing	ball	cylindrical	tapered	needle	spherical	thrust ball
letter						
thrust load capacity						
radial load capacity						

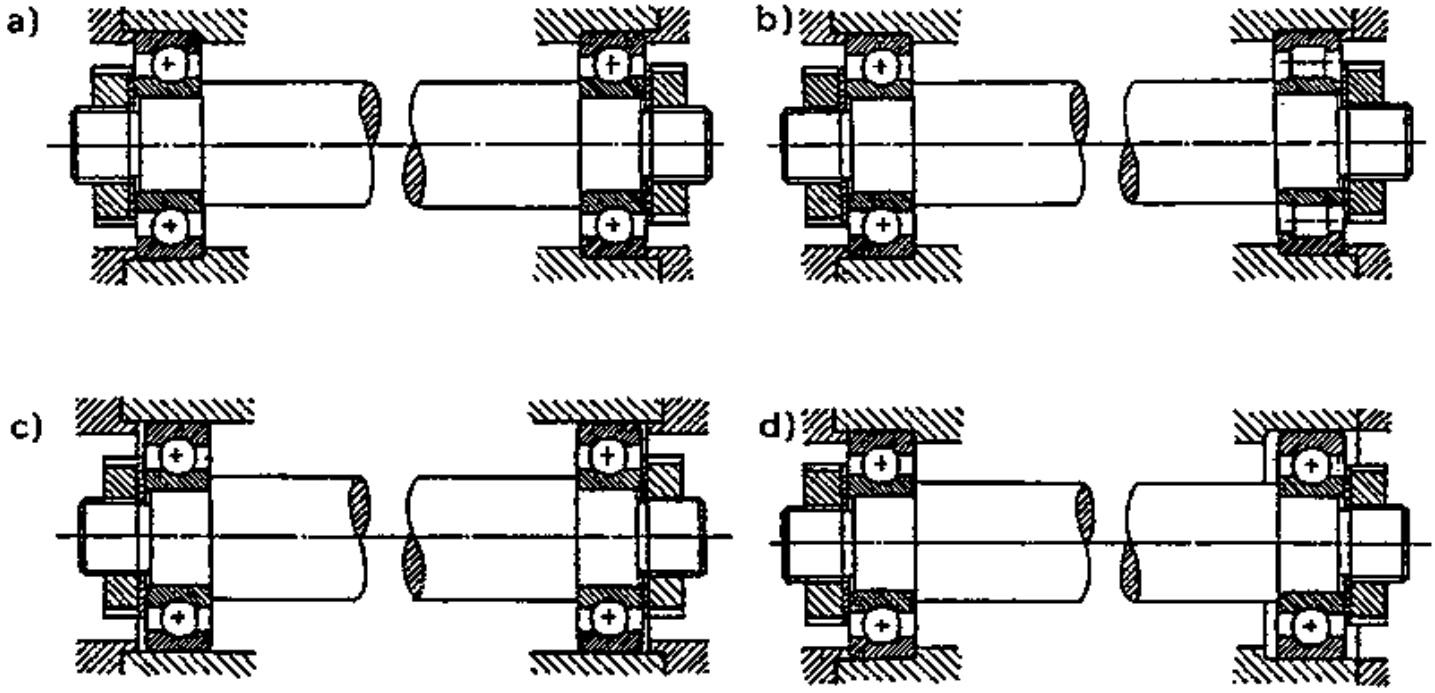
2.5.2 Attach the applications 1, 2 and 3 to the appropriate bearing.



3.1.1 Mark the correct reason for floating arrangement with ?.

a) The shaft rotates easily.
b) It is simple to assemble and disassemble.
c) It prevents damage of the bearing.

3.1.2 Which of the following applications is wrong?



3.1.3 A ball bearing can act as floater by

a) sliding between inner race and shaft
b) sliding between inner race and roller element
c) sliding between outer race and roller element
d) sliding between outer race and housing

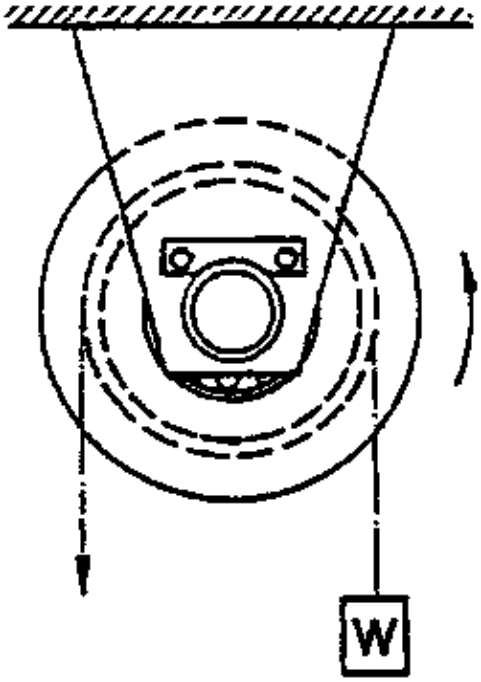
3.1.4 A cylindrical roller bearing can act as floater by

a) sliding between inner race and shaft
b) sliding between inner race and roller element
c) sliding between outer race and roller element
d) sliding between outer race and housing

3.2.1 The load on a turning race of a bearing is called point/circumferential load

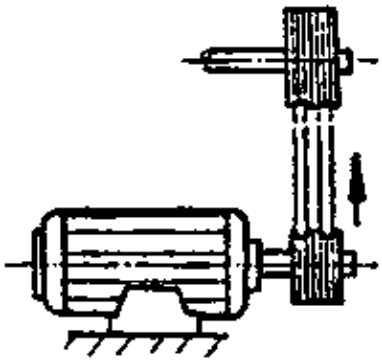
3.2.2 When the inner race is fixed and the outer race turns, point load occurs at the inner/outer race.

3.2.3



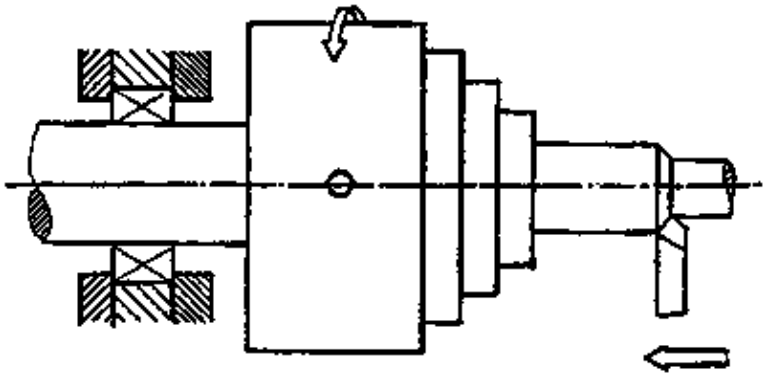
When lifting the block W, circumferential load occurs at the inner/outer race of the bearing.

3.2.4



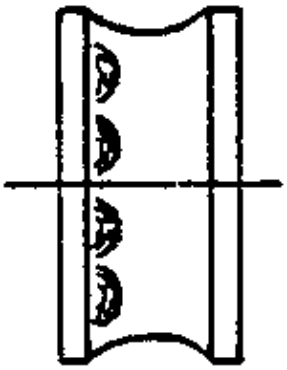
At the bearing circumf. load occurs at the inner/outer ring; therefore, a loose fit must be chosen for the inner/outer ring.

3.2.5



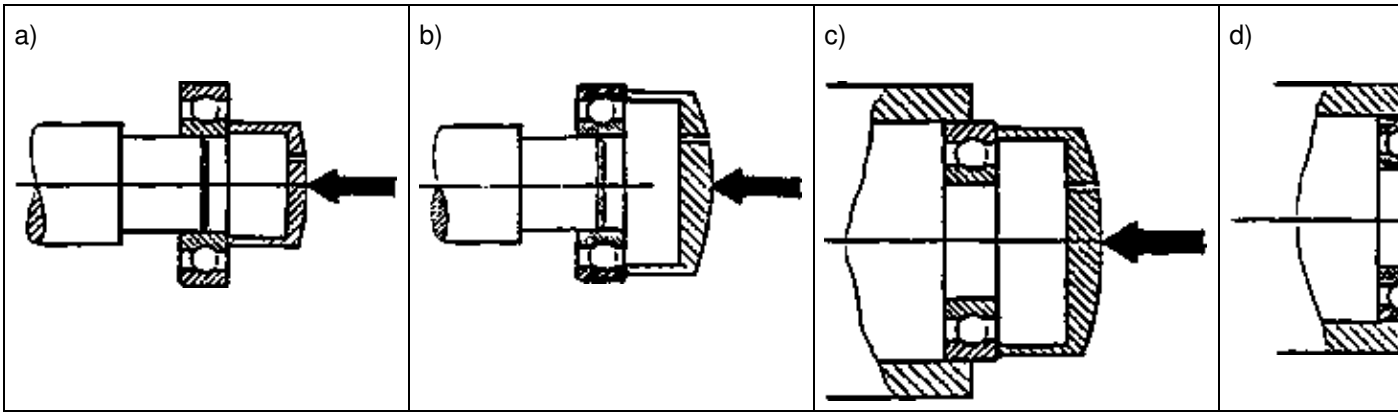
At the bearing circumferential load occurs at the inner/outer ring; therefore, a tight fit must be chosen for the inner/outer ring.

3.2.6

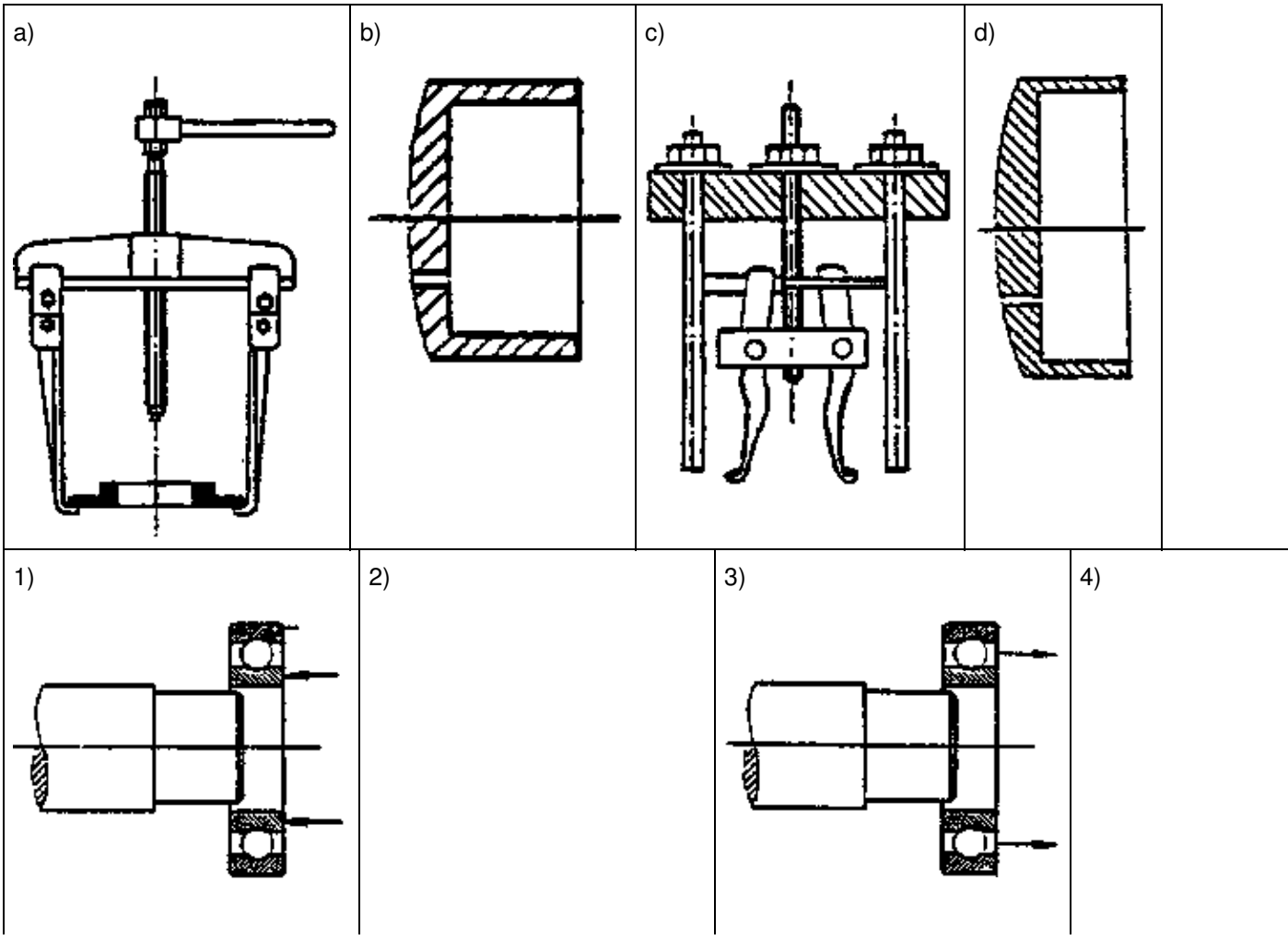


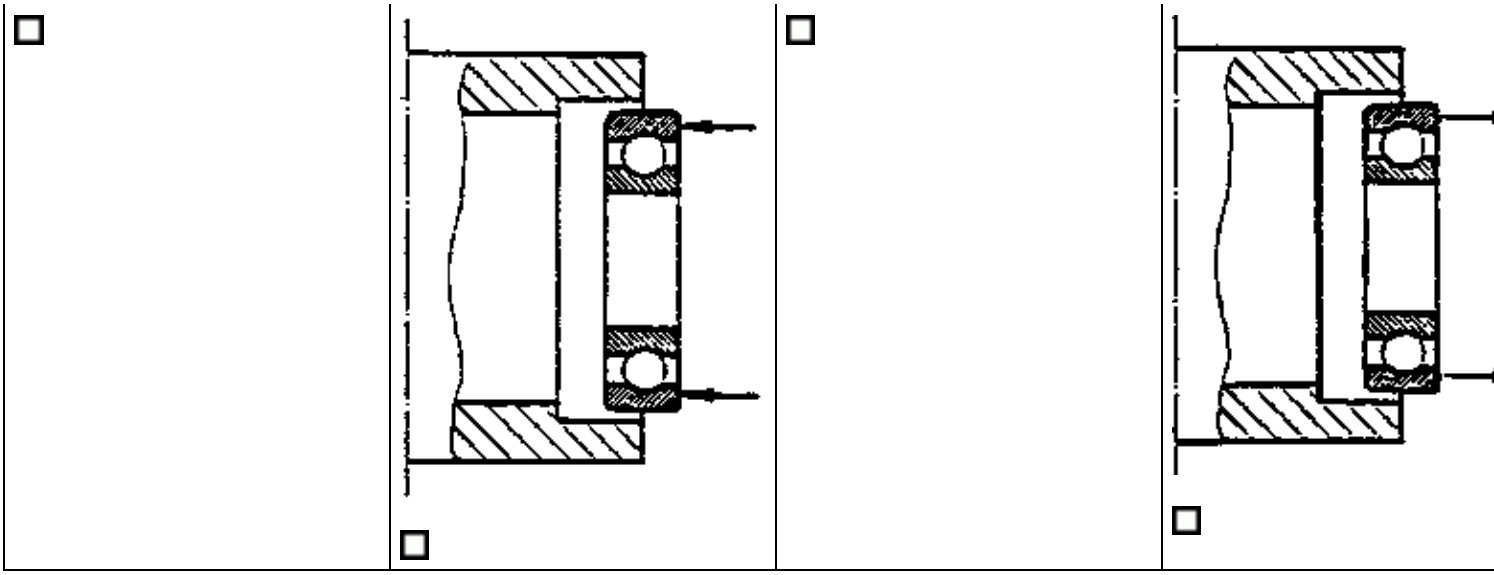
Such damage is a result of the assembling method

a) b) c) d)



3.4 Relate the tools a, b, c, d to the appropriate examples 1, 2, 3, 4.





3.5.1 Clearance of roller bearings is necessary

a) to provide the rolling elements with lubricant
b) to provide sufficient space for heat expansion
c) for easy and comfortable assembling

3.5.2 A roller bearing runs loud when there is no/too much/too low clearance.

3.5.3 A bearing will not have sufficient clearance when it is assembled at both rings by tight fit/loose fit.

3.5.4 Back to back assembled bearings for car wheels must be tightened and released for 1/12, 1/3, 1 round.

3.5.5 Checking of radial clearance by swiveling the outer ring will be done with

a) small bearings, which are assembled back to back
b) big spherical roller bearings
c) small spherical roller bearings
d) big bearings, which are assembled back to back

3.5.6 Clearance of bearing is not related to working–temperature/direction of load/size of bearing.

3.6.1 Mounting of bearings with shaft by heat will be done by _____

3.6.2 Mounting of bearings with housing by cooling will be done by _____

3.7.1 Write down 3 methods of lubricating a bearing

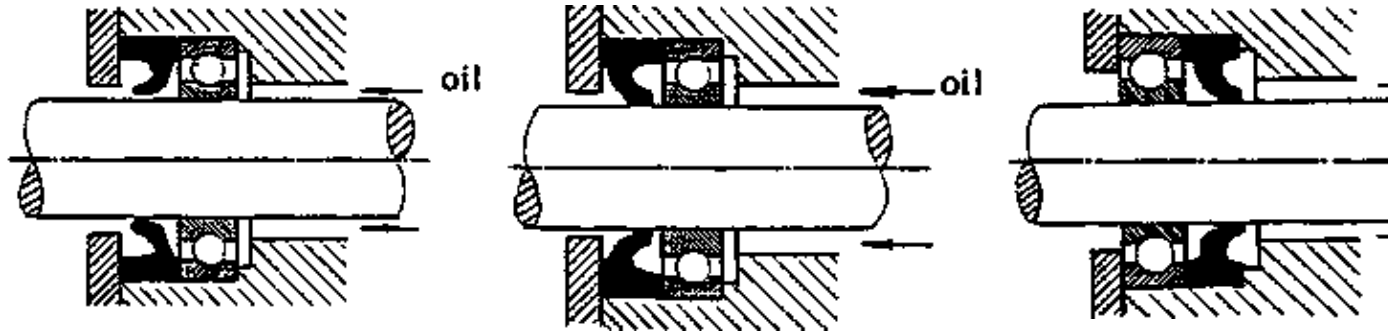
1._____ 2. _____ 3._____

3.7.2 Bearings working at high revolutions and high temperature should be lubricated by

a) splash
b) drip feed
c) pressure oil
d) grease

3.8.1 In which picture is the scaling mounted correctly?

a) b) c)



3.8.2 The correct assembly of a seal should consider flow direction of lubricant/direction of load

3.9 Simple methods to check a working bearing are

1. _____
2. _____
3. _____

Solutions

1.1.1

a) 3

b) 1

c) 4

d) 2

1.1.2 high

1.1.3 constant

1.1.4 roller bearings

1.2.1

① rolling elements ② inner ring ③ cage

1.2.2

1.2.3 cage

2.1.1

b a c

2.1.2 cylindrical roller bearing

2.1.3 smaller than

2.2.1 needle roller bearing

2.2.2 more than

2.2.3 deep groove ball bearing

2.3

2.4

c) spherical roller bearing

2.5.1

Name of bearing	ball	cylindrical	tapered	needle	spherical	thrust
letter	b	e	a	f	c	d
thrust load capacity	?		?		?	
radial load capacity	?	?	?	?	?	

2.5.2

3.1.1 c) ?

3.1.2 a)

3.1.3 d)

3.1.4 c)

3.2.1 circumferential load

3. 2. 2 inner race

3.2.3 outer race

3.2.4 inner ring/outer ring

3.2.5 inner ring/inner ring

3.3 b)

3.4

a) 3

b) 1

c) 4

d) 2

3.5.1 b)

3.5.2 too much

3.5.3 tight fit

3.5.4 1/12

3.5.5 c)

3.5.6 direction of load

3.6.1 warning the bearing in oil

3.6.2 cooling the bearing in dry ice

3.7.1

– grease lubrication
– drip feef lubrication
– grease filling for life time
– splash lubrication
– pressure oil lubrication

3.7.2 c)

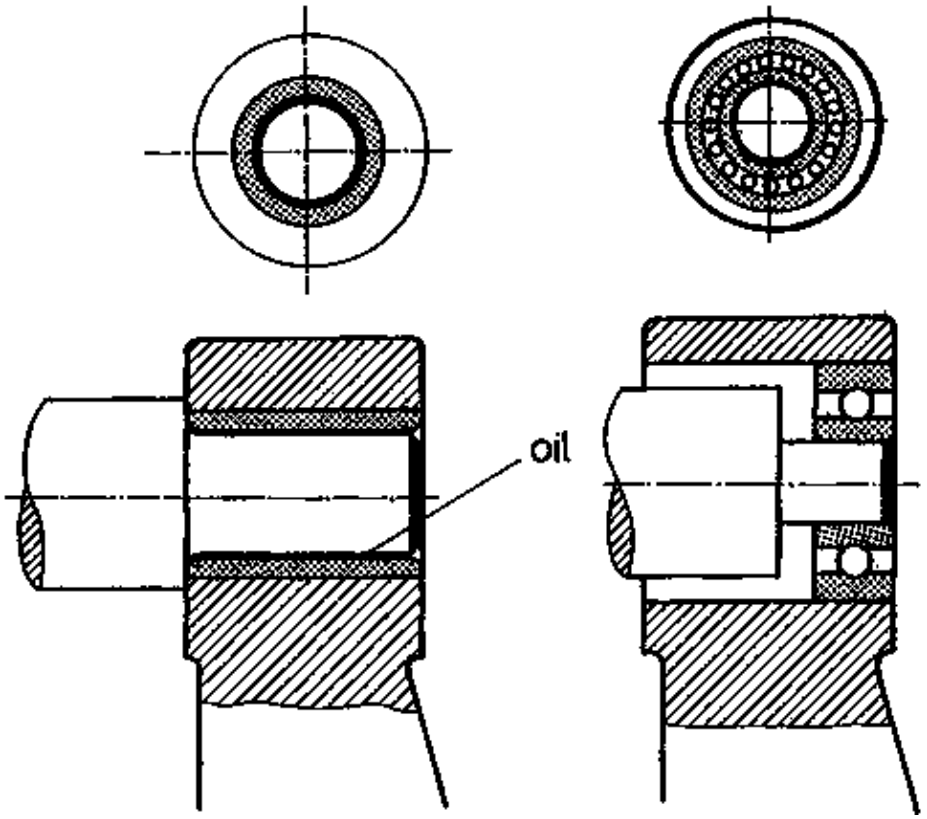
3.8.1 b)

3.8.2 flow direction of lubricant

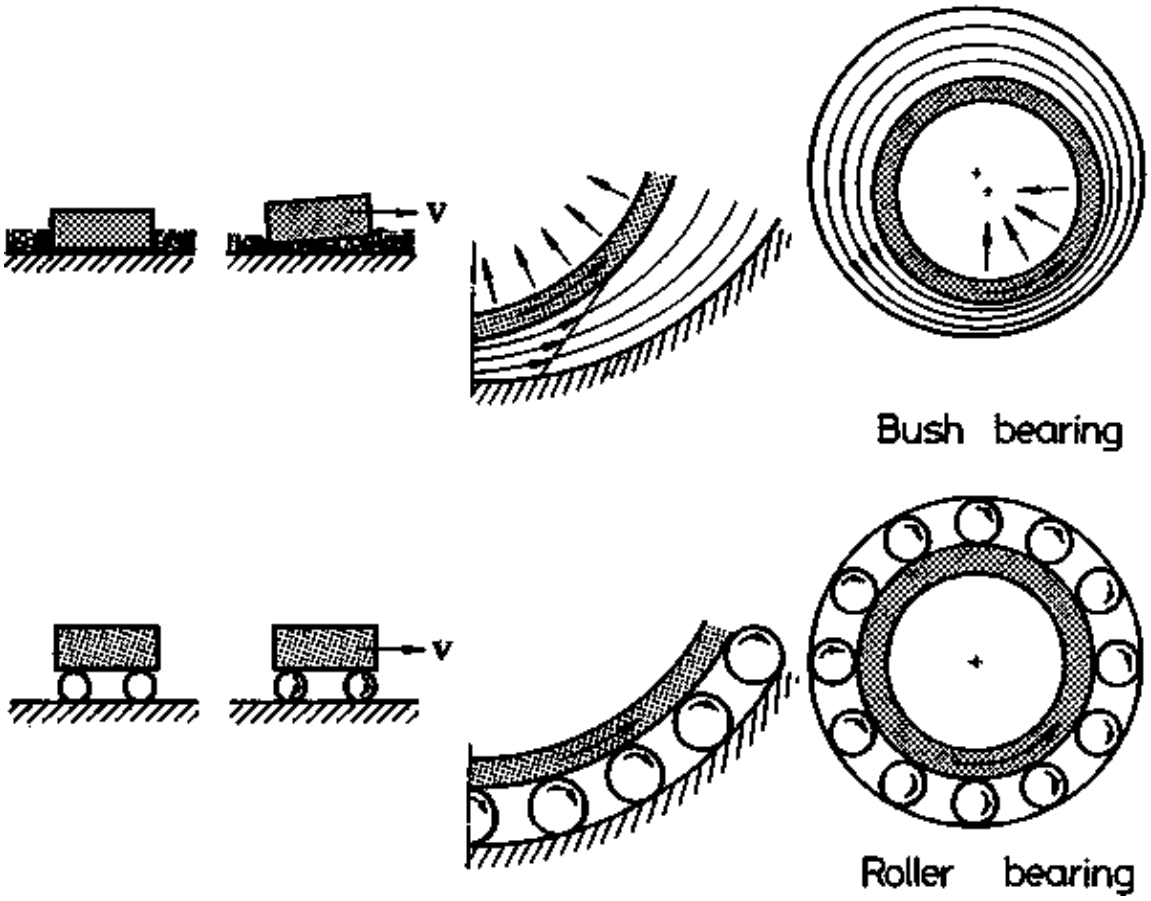
3.9

1. sound–check
2. temperature–check
3. odour–check

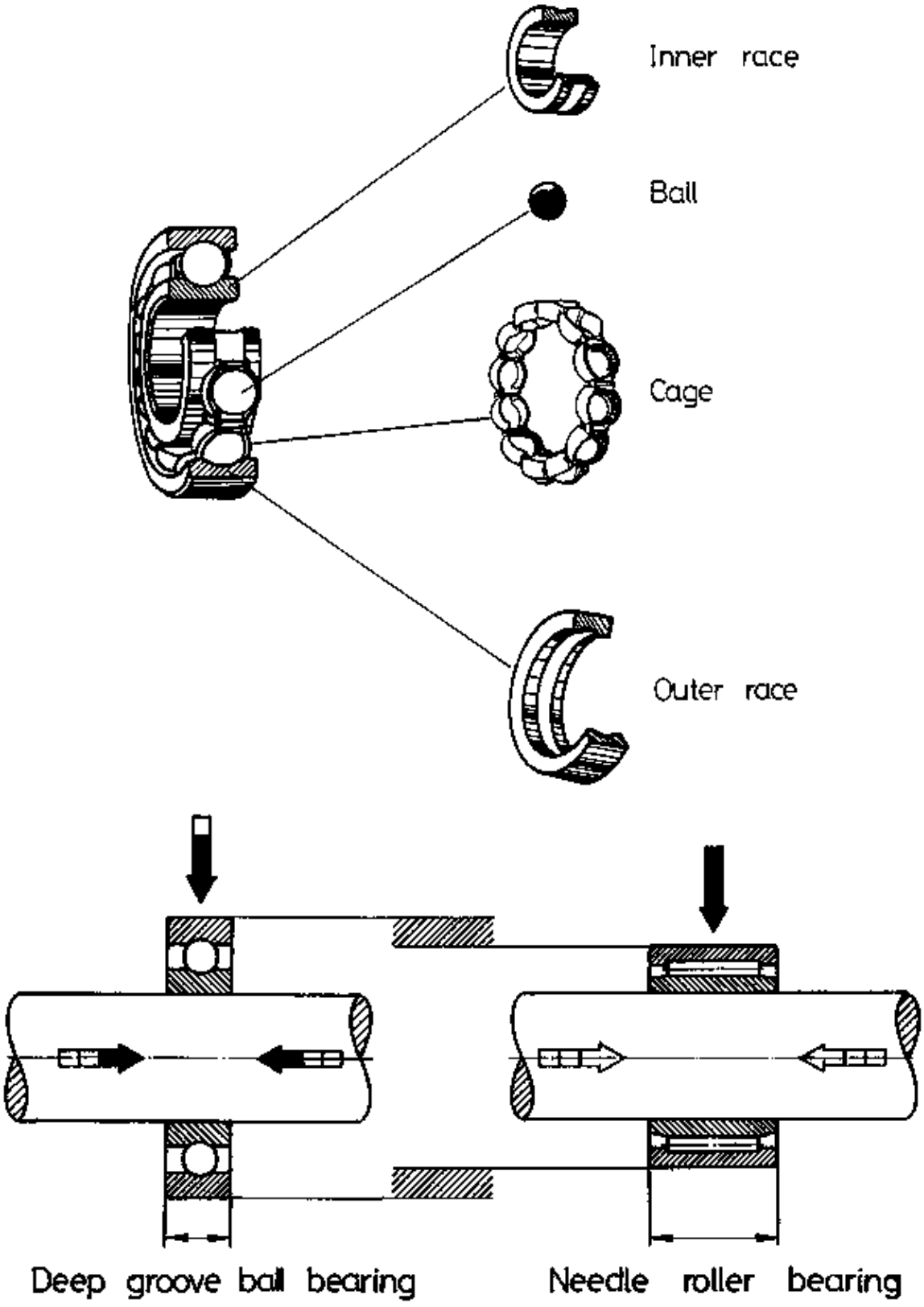
Feature of Bearing

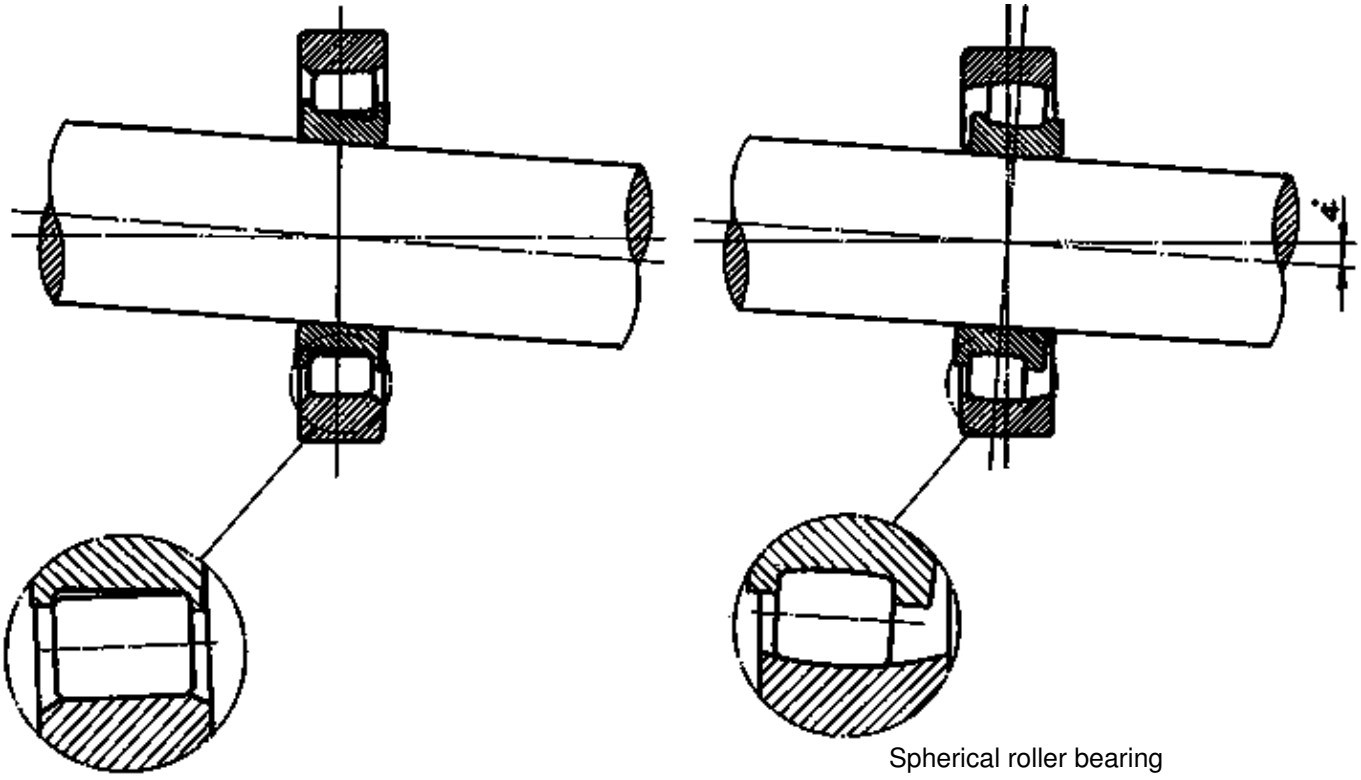


Bush bearing Roller bearing



Component of roller bearing

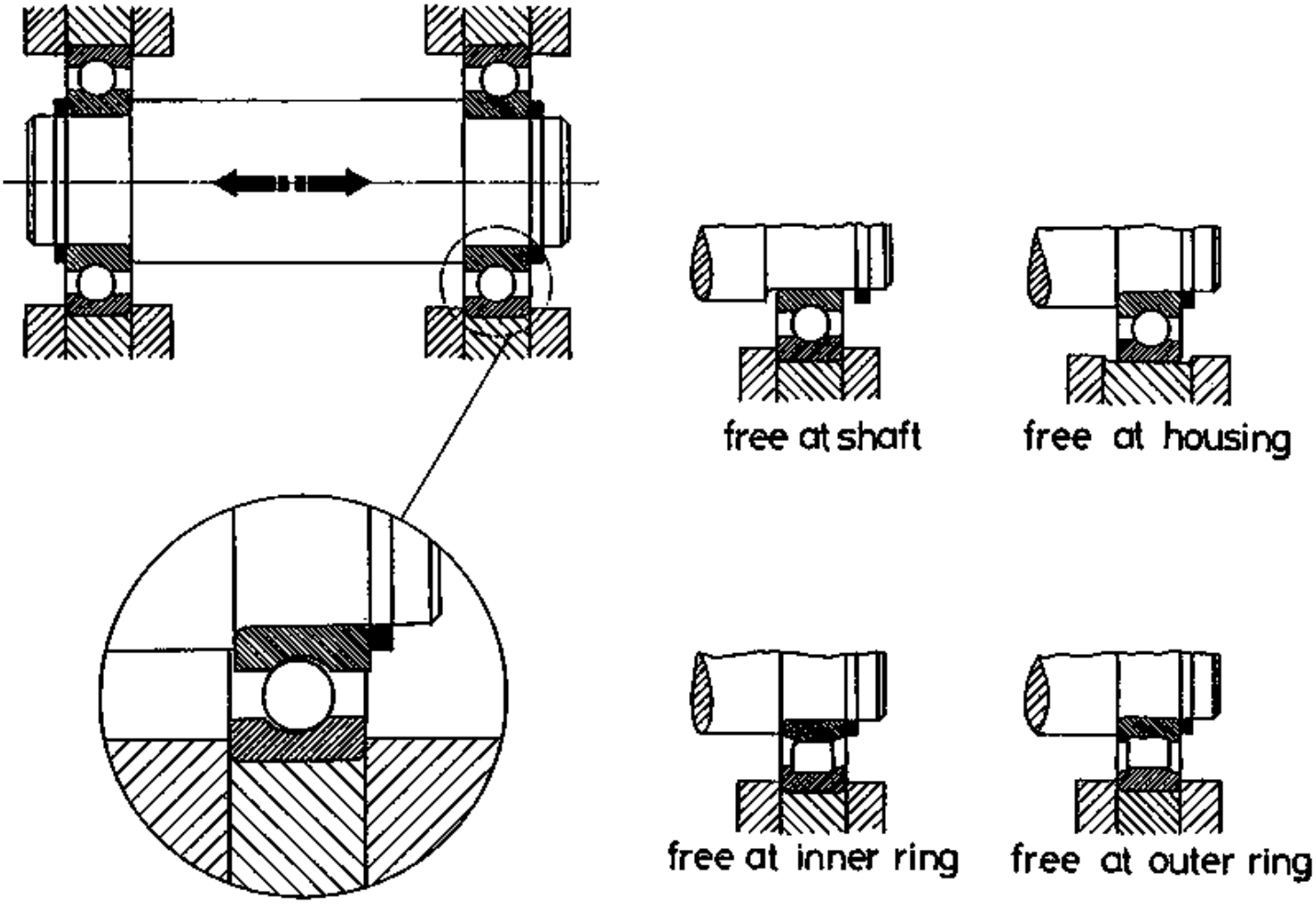

Inner race
Ball
Cage
Outer race
Deep groove ball bearing
Needle roller bearing



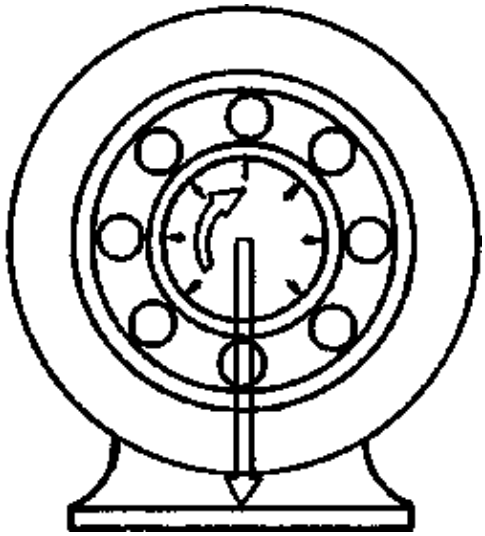
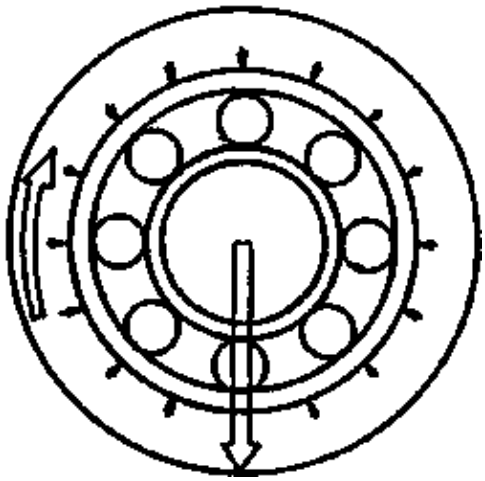
Cylindrical roller bearing

Spherical roller bearing

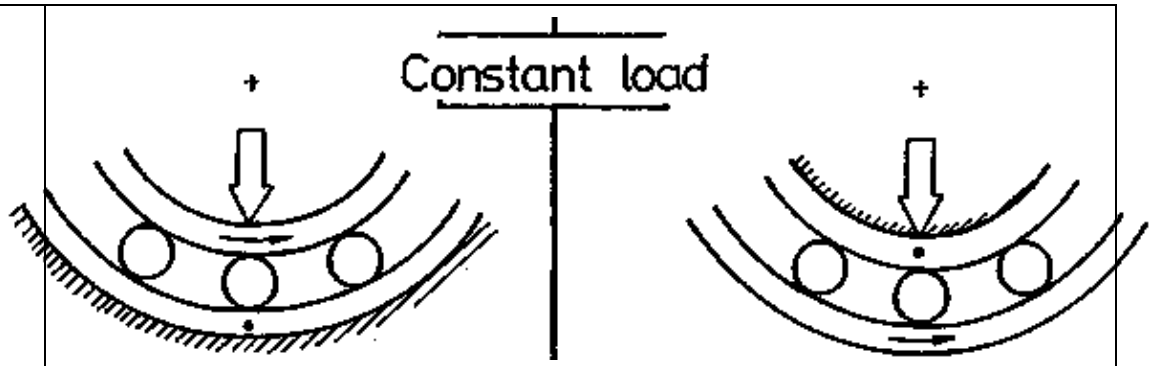
FLOATING BEARING



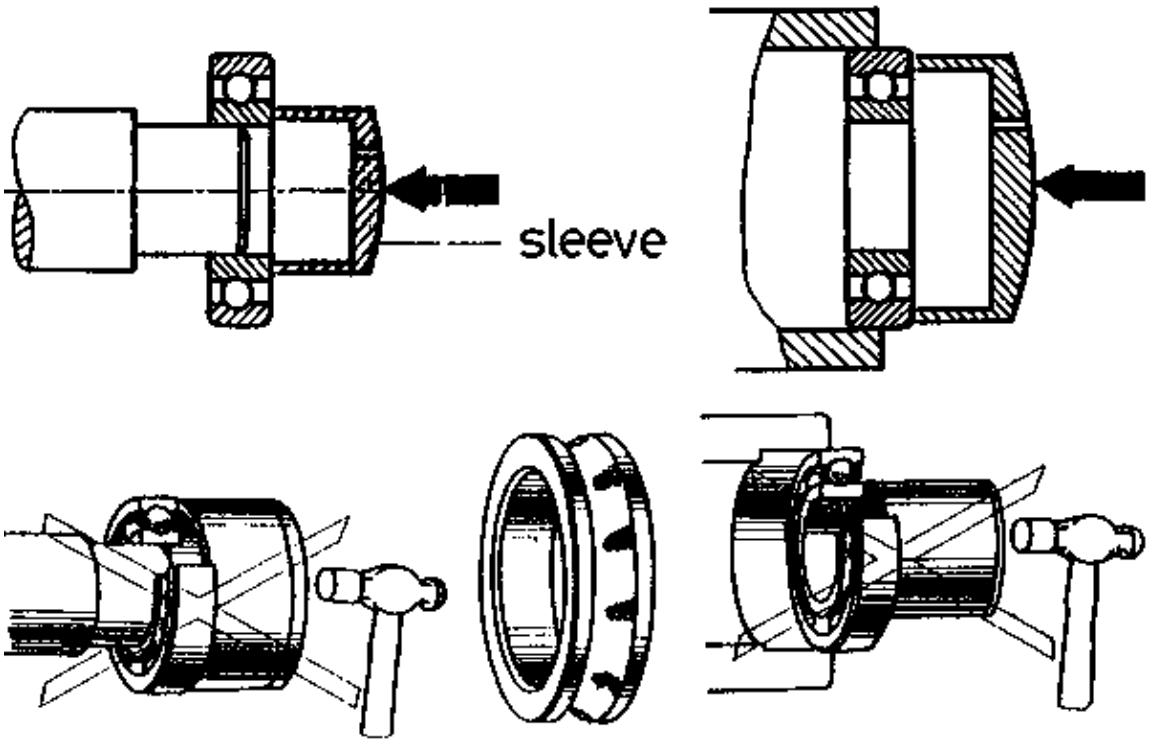
CIRCUMFERENTIAL LOAD AND POINT LOAD

		Fit
	Inner ring circumferential load	tight
	Outer ring point load	loose
	Inner ring point load	loose
	Outer ring circumferential load	tight

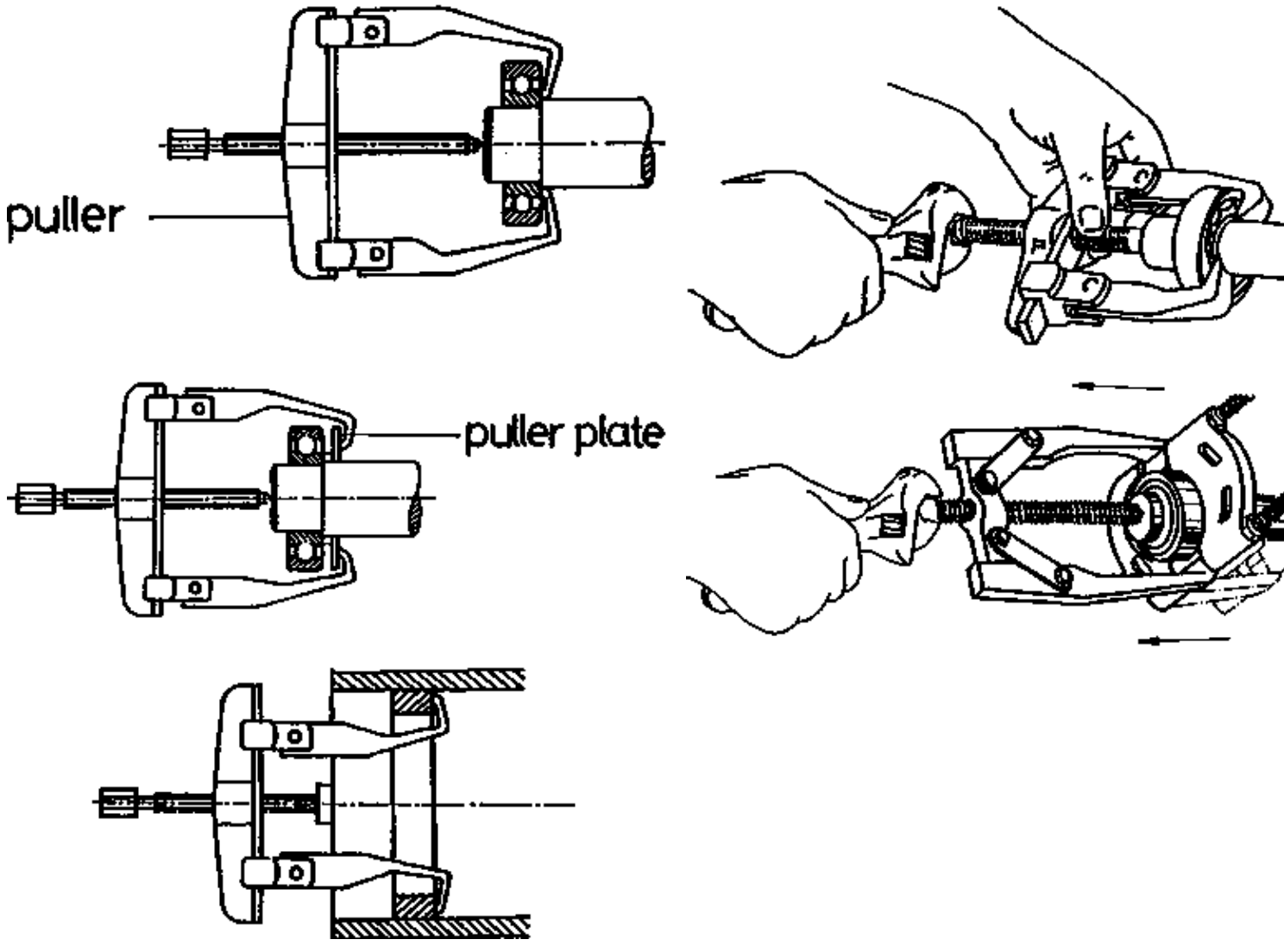
POINT LOAD AND CIRCUMFERENTIAL LOAD

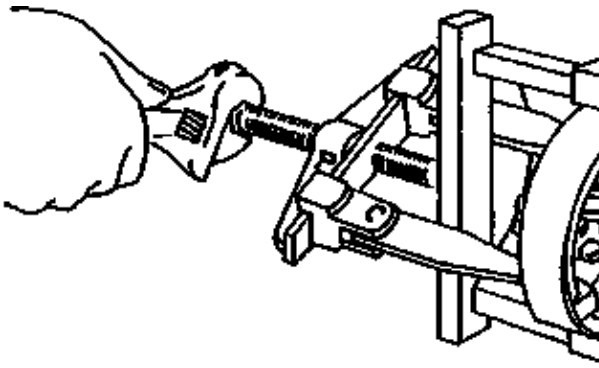
				
	Shaft and inner ring are rotating		Housing and outer ring are rotating	
Load on the bearing races	inner ring circumference load	outer ring point load	inner ring point load	outer ring circumference load

Bearing Assembly

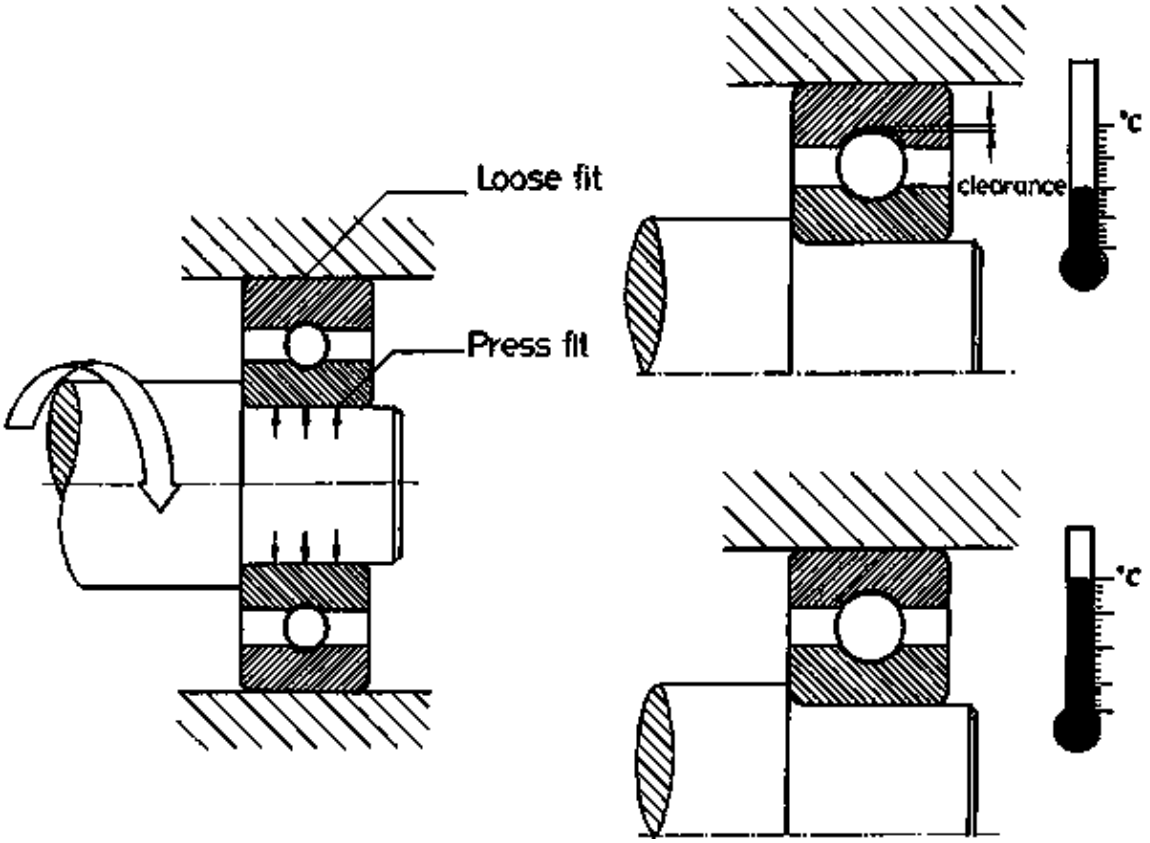


Bearing Disassembly

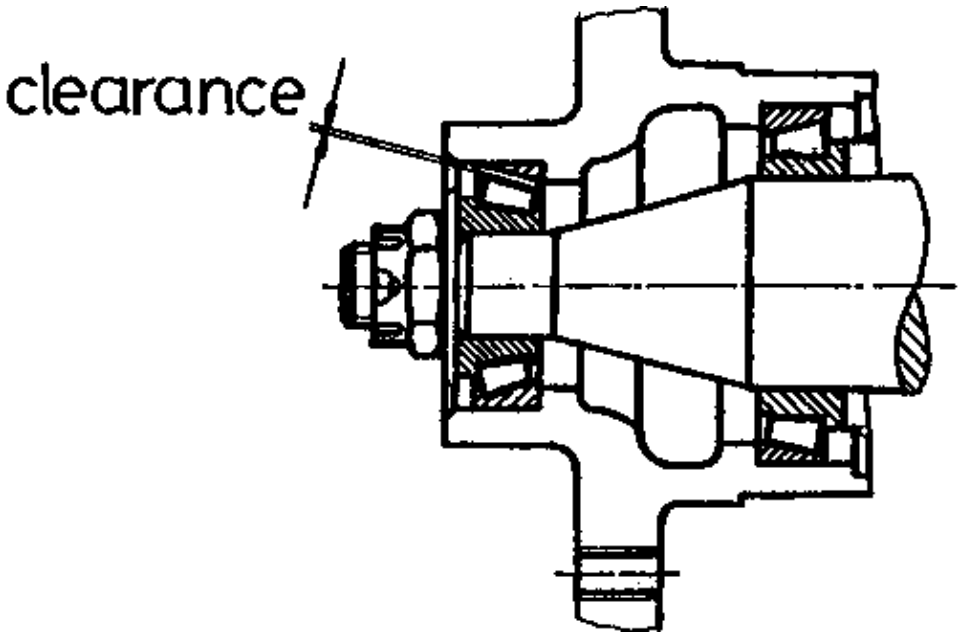




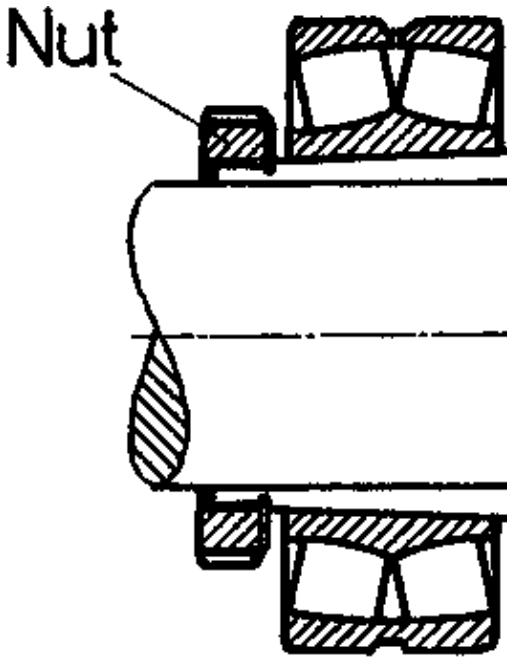
CLEARANCE OF ROLLER BEARING



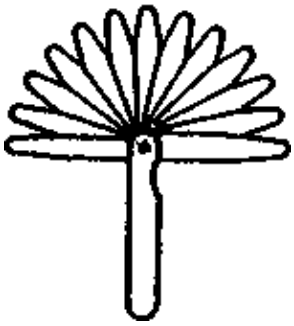
ADJUSTMENT CLEARANCE OF BEARING



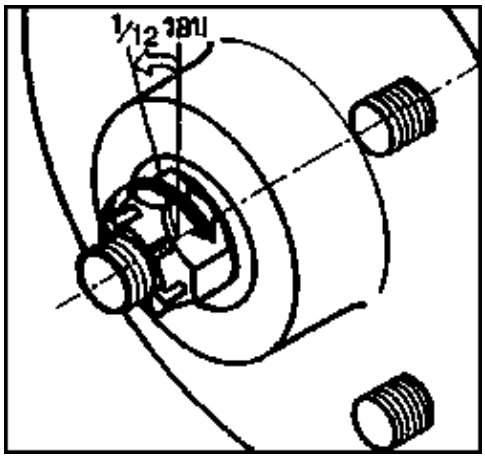
Back to back arrangement



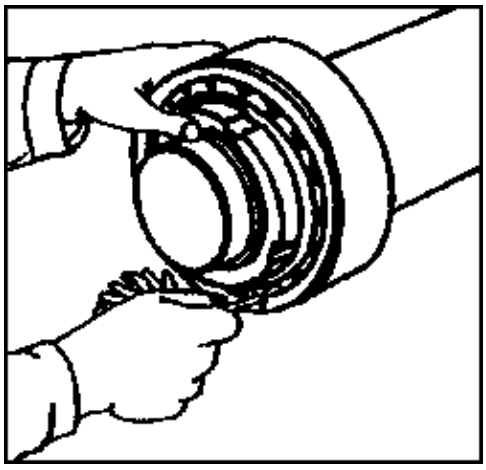
Sleeve mounte



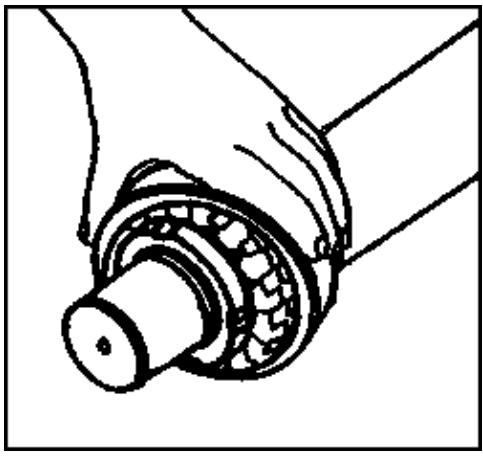
Filler gauge



Small bearing

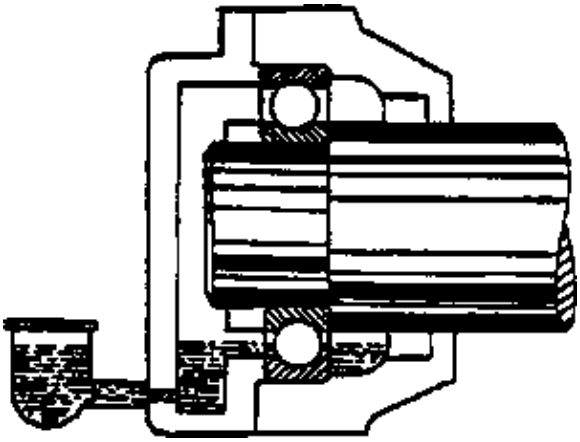


Big bearing

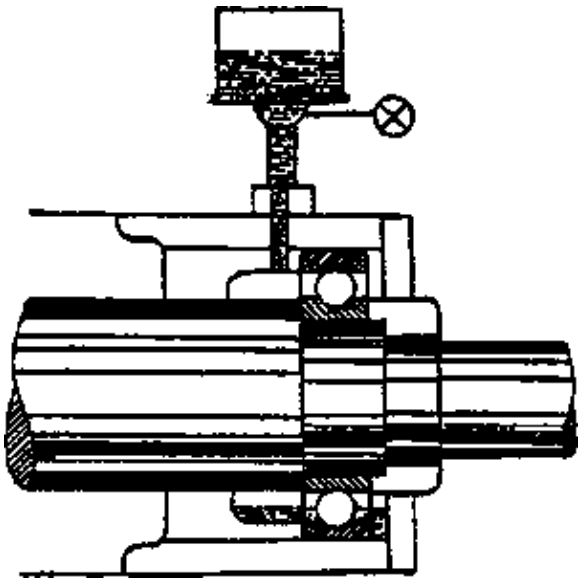


Small bearing

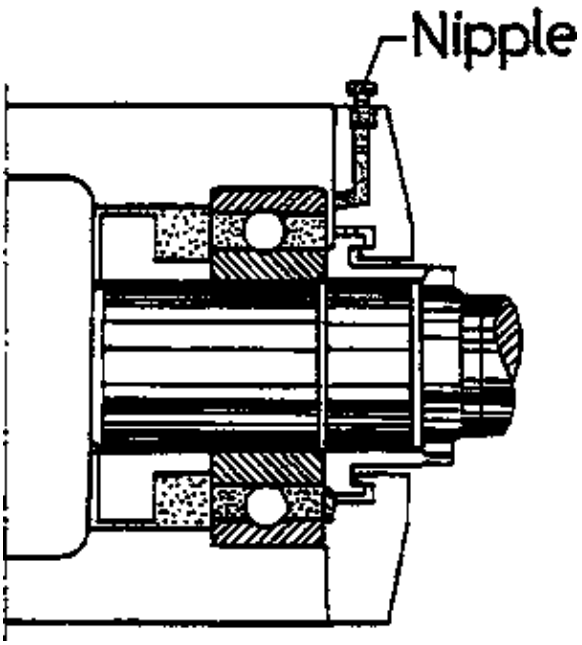
LUBRICATION METHOD



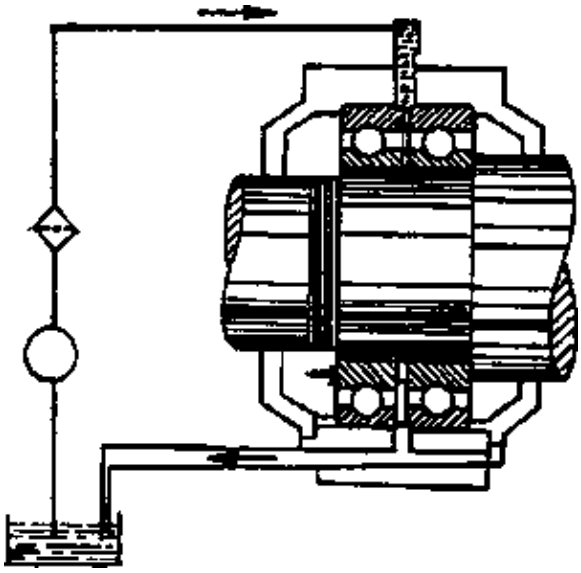
Splash lubrication



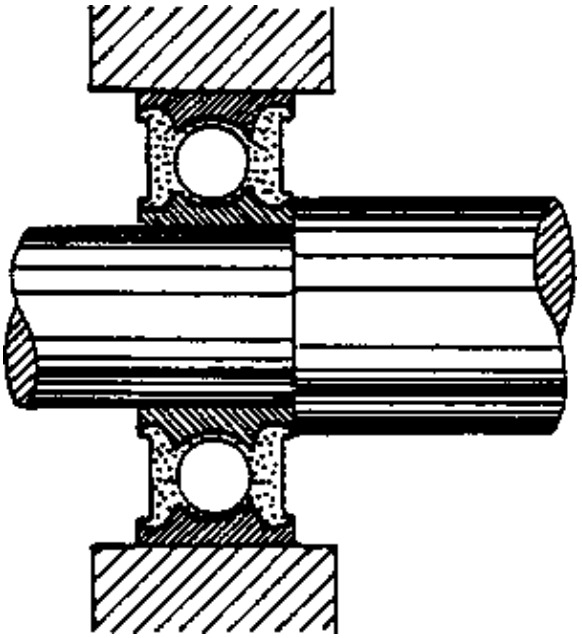
Drip feed lubrication



Grease lubrication

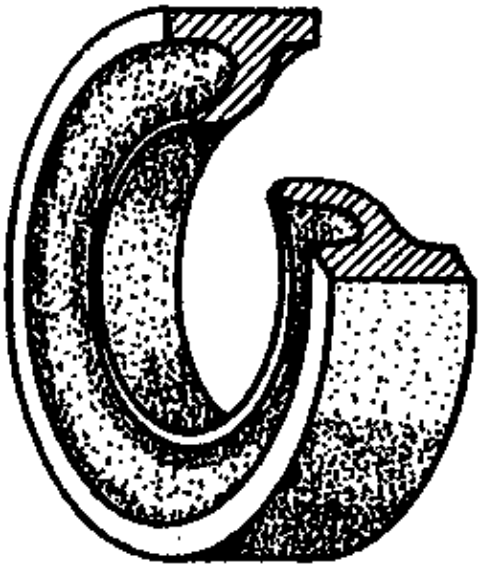


Pressure oil –lubrication

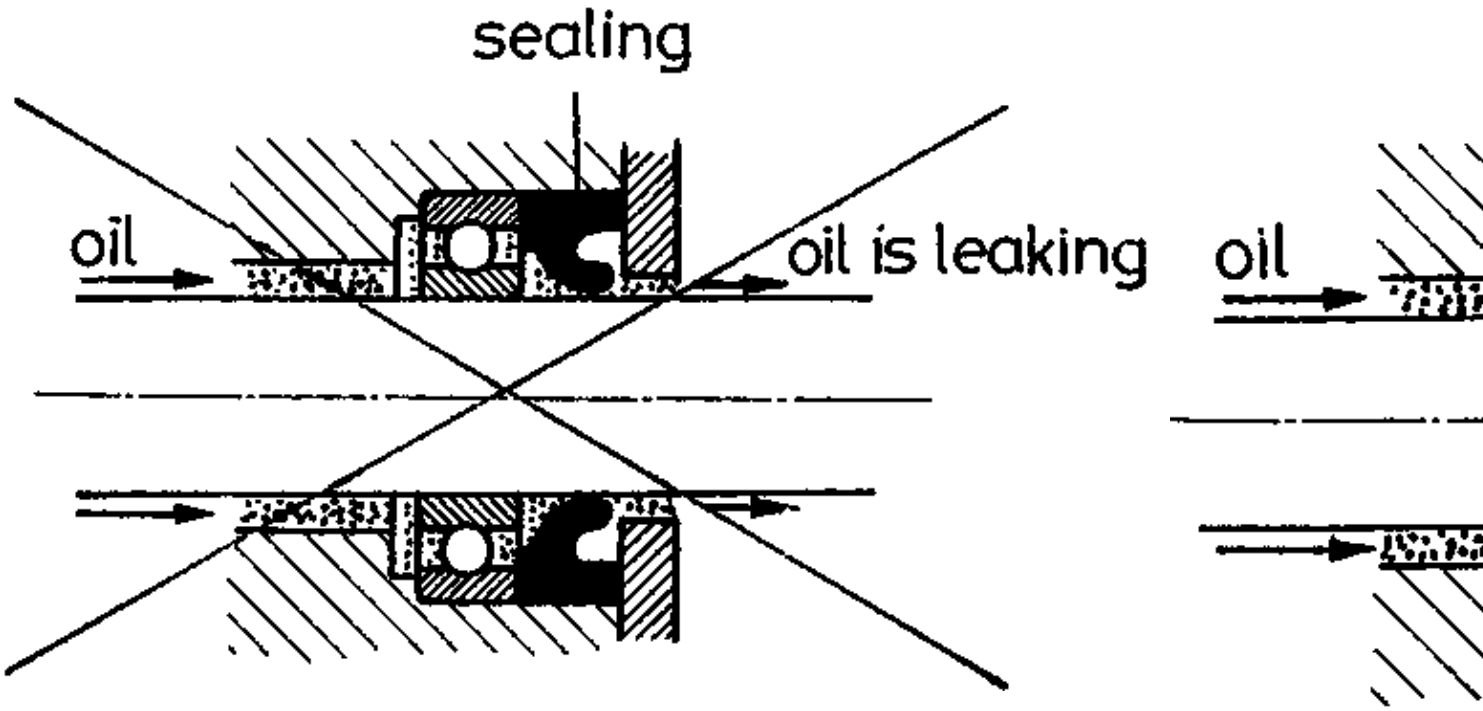


Grease filling for lifetime

SEAL ASSEMBLY



Feature of seal



8. Gear Box

Objectives

The student should be able to:

1. Indicate torque transmission paths and directions of gear trains.

2. Tell lubricating methods of gear trains.

3. Tell various types of forces acting upon bearings of gear trains and also various types of fits of those bearings.

4. Tell steps of operation and tools/equipment used in dismantling gear trains.

5. Dismantle gear train assemblies.

6. Name various parts of gear train assemblies, their materials and sizes.

7. Inspect conditions of those dismantled gear train assemblies.

8. Tell functions of various parts of gear train assemblies.

9. Measure and specify dimensions of shafts and bores.

10. Specify required surface finish of shafts

11. Tell steps of operation and tools/equipment used in reassembling gear trains.

12. Reassemble gear train assemblies.

13. Measure and calculate various dimensions of a gear.

14. Interprete specifications given on a name plate of a gear box.

15. Determine various datum of a gear box from a given table.

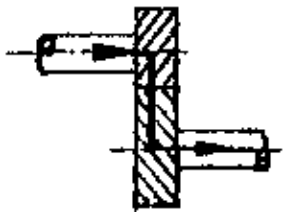
16. Calculate spindle speeds and gear ratios of a gear box.

17. Calculate power and torque of a gear box.

1. Torque transmission and direction of load

Indicate torque transmission paths (by thick lines) and their directions (by arrows) of the gear box, on both, pictures.

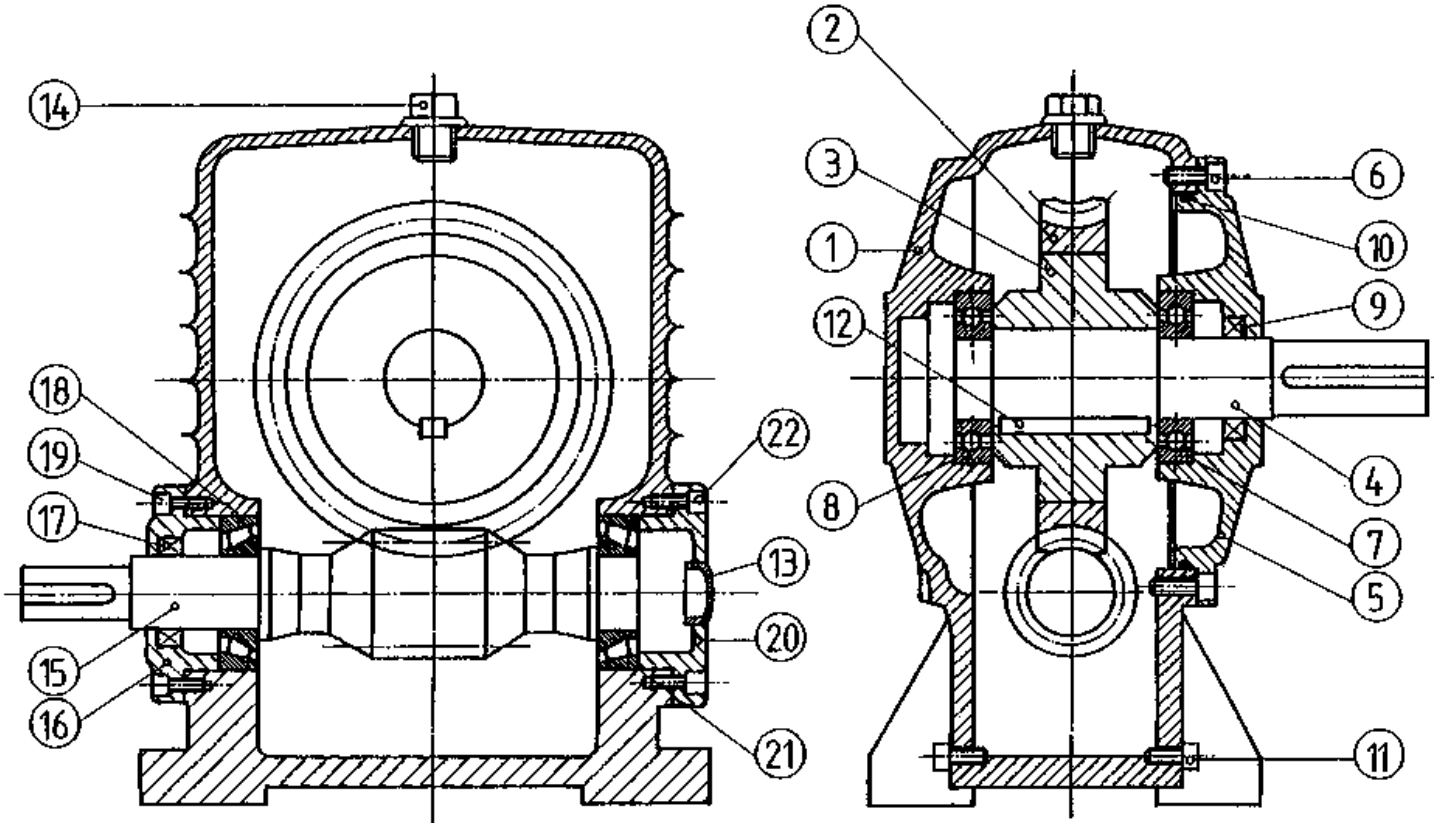
Example:



Note:

Tail of the arrow is ⊗

Head of the arrow is ⊙



From the pictures in page 1; please answer the following question

1.1 Lubrication system

The lubrication of this gear box is of:– gravity/pump/immerse/manual–type

2. Type, load and fit of bearing

Please complete the table

Bearing No.	Types of bearing	Load is stationary at...	Load is distributed over...	Interference fit at...	Transition fit at...
7					
8					
18					
21					

3–10. Disassembling the gear box

3. Shaft 4/Shaft 15 must be removed first because worm gear and thread are going to jam.

Wait! Allow the instructor to have a good check before attempting next.

4. Write down part numbers and required tools/equipment to be used in dismantling assemblies attached to the gear.

Sequence of Operations	Part No.	

		Tools/equipment used
1	14	
2		
3		
4		
5		
6		
7		
8		
9		
10		

5. Shaft 15 can be removed from the housing by way of the cover plate−16 or 20/or 16 and 20

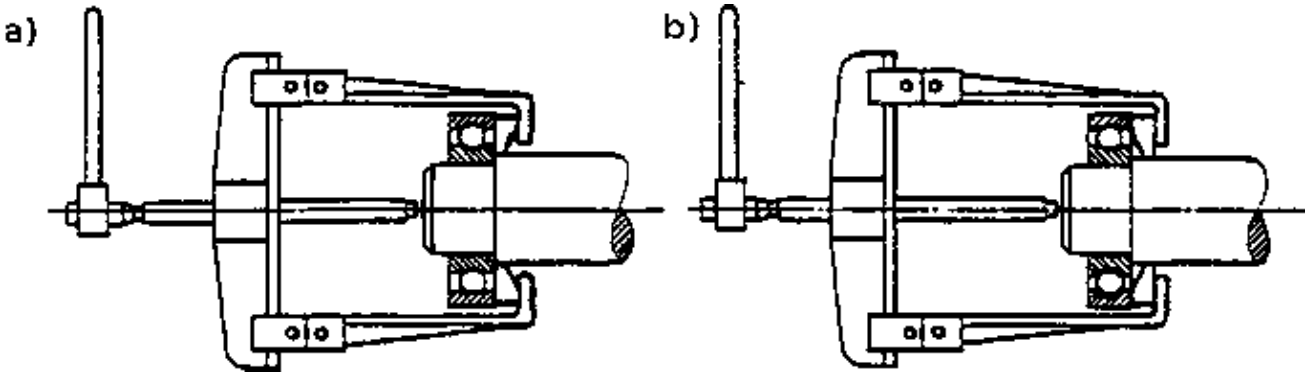
6. Write down the steps in removing components assembled to the shaft 15 after it has been removed from the housing.

Sequence	Part No.	Tools/equipment
1		
2		

7. Write down the steps for removing components assembled to the shaft 4 after it has been removed from the housing.

Sequence	Part No.	Tools/equipment
1		
2		
3		

8. Which picture shows a correct bearing dismounting,?



Wait! Allow the instructor to have a check before attempting next

Direction:

9. You should check and prepare tools/equipment as listed in the tool box.

10. Dismantle components of the gear box in correct sequence; place the dismantled components in separate sets in good orders on the equipment tray

Note: Do not separate the following parts: 2 and 3, 9 & 10 and 5, 16 and 17, 13 and 20. Great care must be exercised while working. Consult your instructor any time if you may have problem.

11. Identifying the part of a gear box

After you have completed the task, write down details of components into the table on page 4.

Quantity	Name of part	Material	Part No.	Standard size	Condition	
					Good	Poor
1	Housing	Cast iron	1	____		
			2	____		
			3	____		
			4	____		
			5	____		
			6			
			7			
			8			
			9	____		
			10	____		
			11			
			12			
			13	____		
			14	____		
			15	____		
			16	____		
			17	____		
			18			
			19			
			20	____		
			21			
			22			

Note: Count the number of teeth of both, the worm wheel and the worm thread and note them also.

12. Function of the parts

Match the functions in a, b, c, d to related components given on the right, based on the gear box shown on page 1.

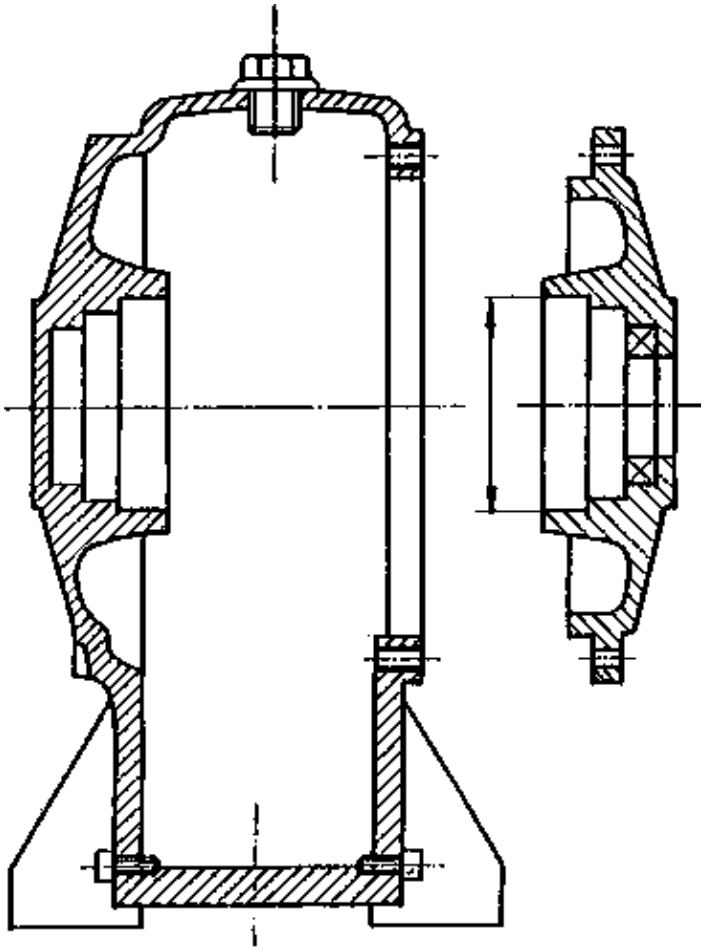
(A single component may have more than one function)

Functions	Components (part No.)
a. To transmit torque	1. Housing (1)
b. To resist load	2. Worm wheel (2)
c. To hold components	3. Worm hub (3)
d. To prevent oil leakage	4. Output shaft (4)
	5. Cover plate (5)
	6. Socket screw (6)
	7, Ball bearing (7)
	8. Seal (9)
	9. O−ring (10)
	10. Key (12)
	11. Input shaft (15)
	12. Cover plate (16)
	13. Tapered roller bearing (18)

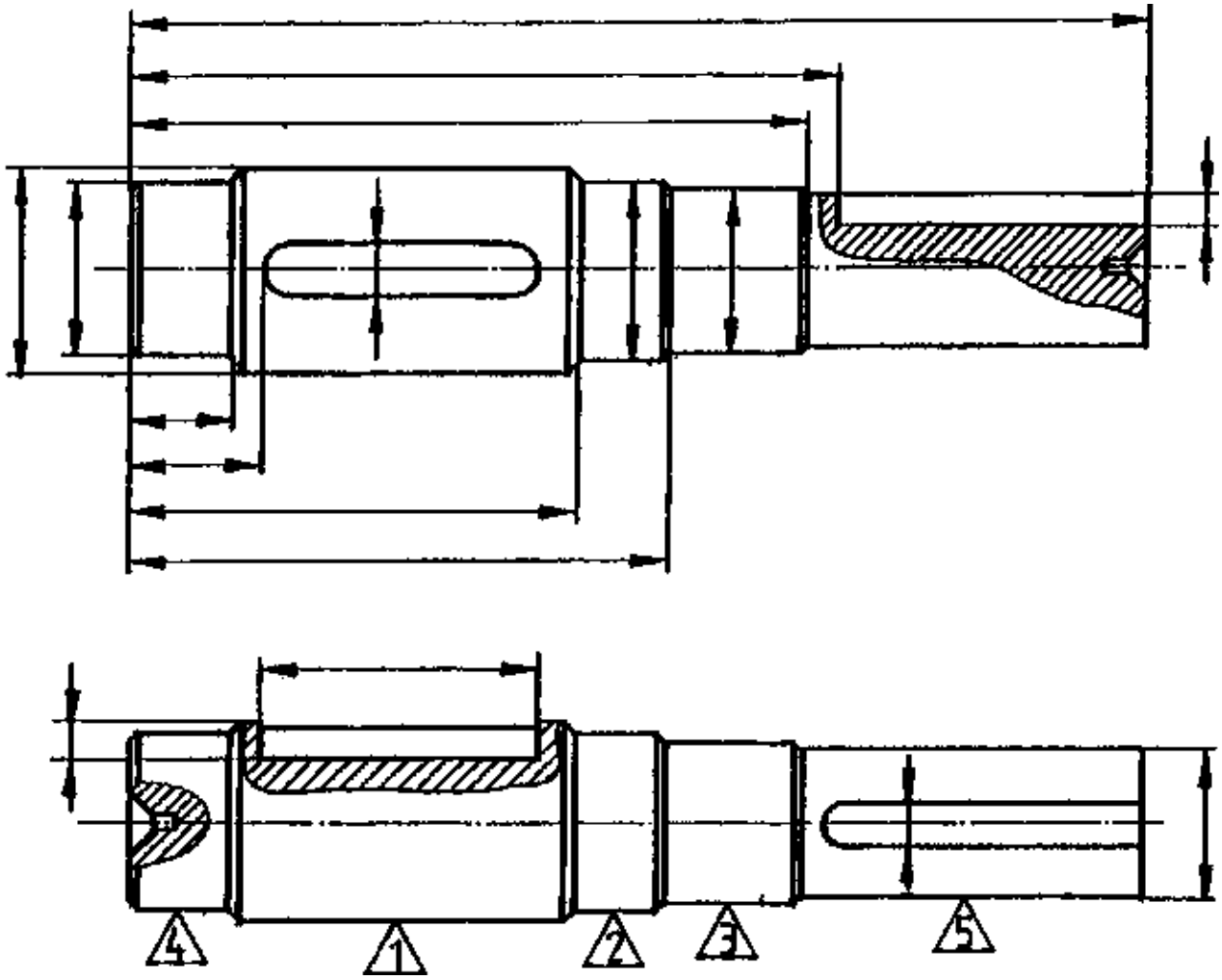
13. Measuring dimensions of shafts and bores

Measure and write down dimensions of shafts and bores with necessary symbols of required fits.

Transition fit	Bore H8	Shaft h6



Interference fit	Bore M7	Shaft m5



Make a tick for required surface finishes into the appropriate					
Surface finish	1	2	3	4	5
?					
??					
???					

14–16. Assembling the gear box

14. You are required to complete this exercise before attempting reassemble the gear box.

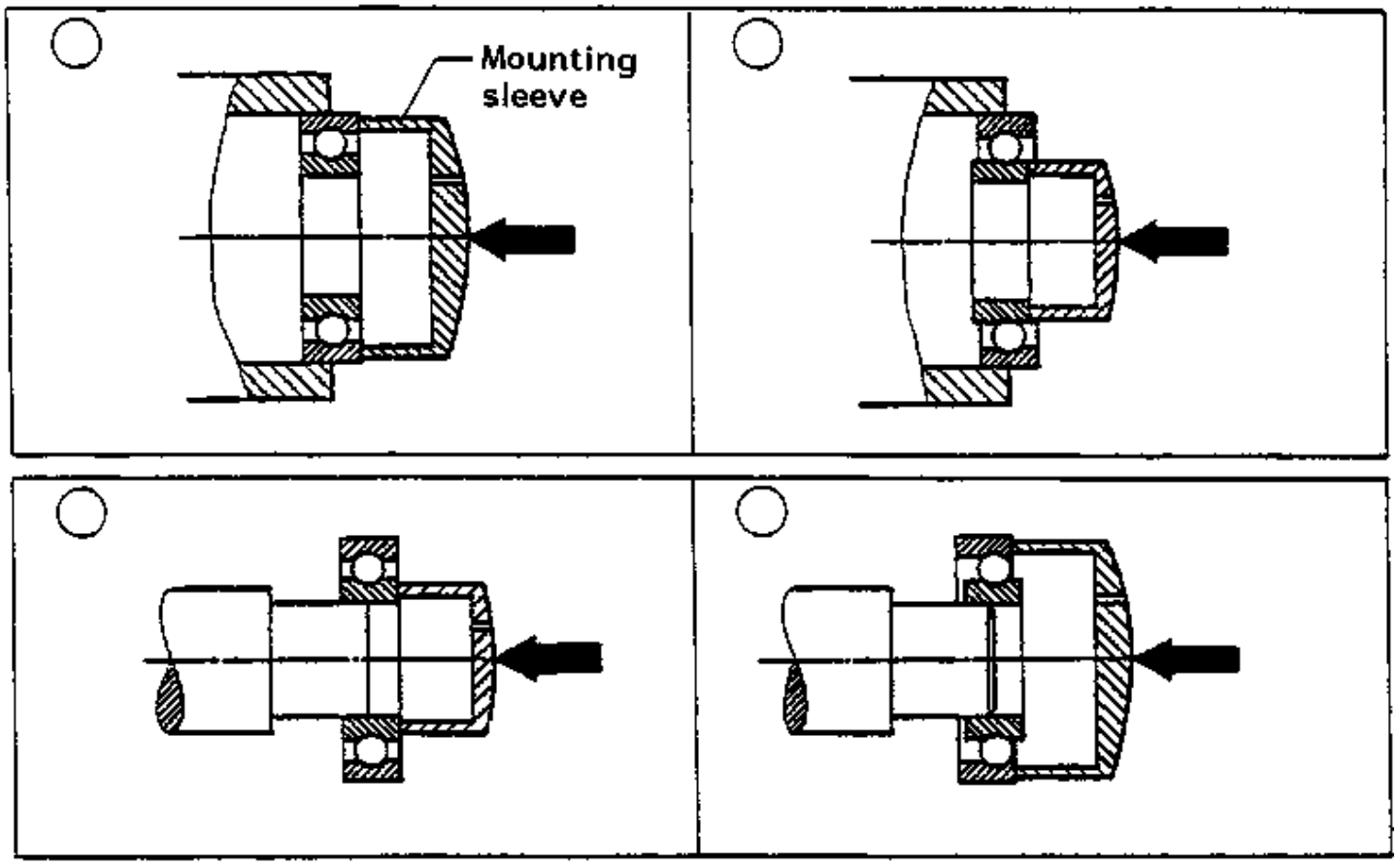
14.1 In reassembling the gear box – the output shaft/the input shaft – must be mounted firstly into the housing.

14.2 Write down the sequence of operations in reassembling the gear box, onto the table below – (See the picture, page 1)

Sequence of operation	Part No.	Mounted to part No	Tools/equipment
1	12	4	Plastic head hammer
2			
3			

4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

15. Which picture: shows correct bearing mounting



Wait! Allow the instructor to have a look before doing next

16. You are required to reassemble the gear box. Obey the following instructions

- Smear components to be reassembled with oil
- Report any damaged component to the instructor before mounting, particularly bearings

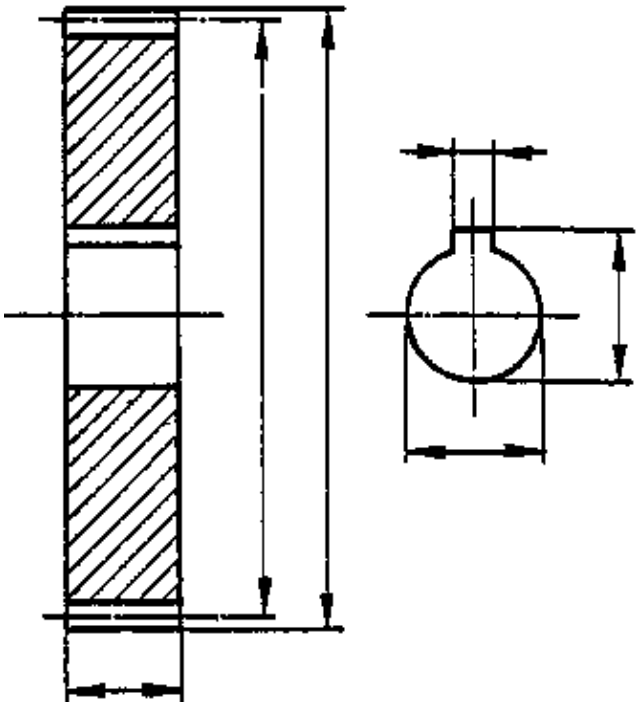
and seals.
– Use mounting sleeves to drive bearings

After you have completed the gear box reassemble, please continue the next exercise.

17. Dimension of a gear

You are required to determine various sizes and tolerances of the spur gears below, by using the standard fits as already shown on page 6.

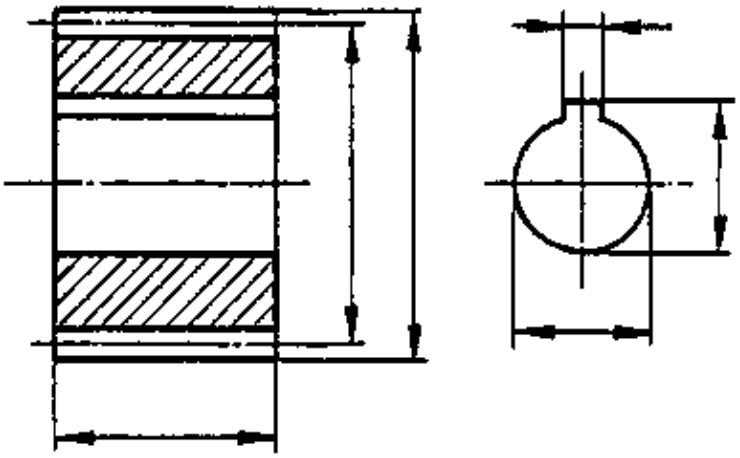
17.1



Number of gear teeth (z)	=	
Module (m)	=	
Depth of gear teeth(h)	=	

Formulae
d = m.z
$h = \frac{13}{6}m$
da = d + 2m

17.2



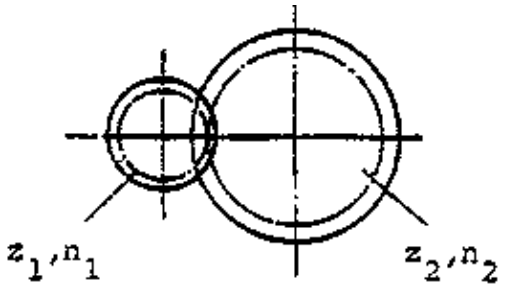
Number of gear teeth (z)	=	
Module (m)	=	
Depth of gear teeth(h)	=	

17.3 Centre distance of a gear train set(a) = _____

18. RMP and gear ratio calculations

18.1 Single gear drive

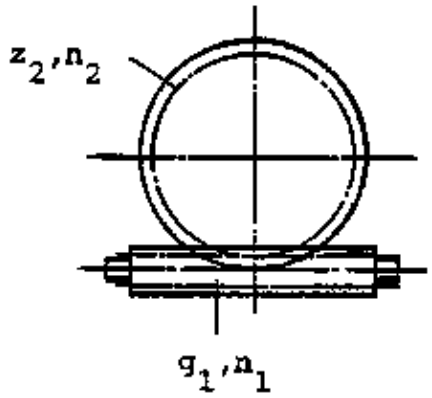
18.1.1 Spur gear



i = Gear ratio
n1 = RMP of driving gear
n2. = RMP of follower gear
z1 = number of teeth of driving gear
z2 = number of teeth of follower gear

$$i = \frac{n_1}{n_2} = \frac{z_2}{z_1}$$

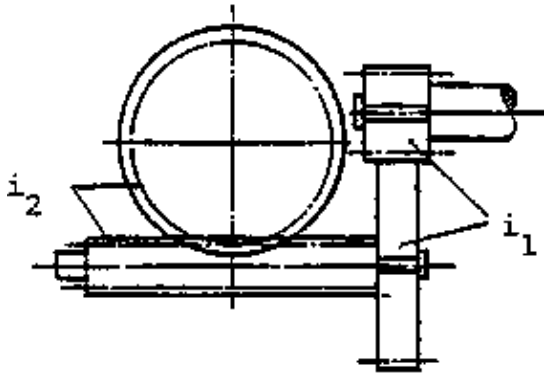
18.1.2 Worm gear



g = number of pitches

$$i = \frac{n_1}{n_2} = \frac{z_2}{g_1}$$

18.2 Multiple gear drive

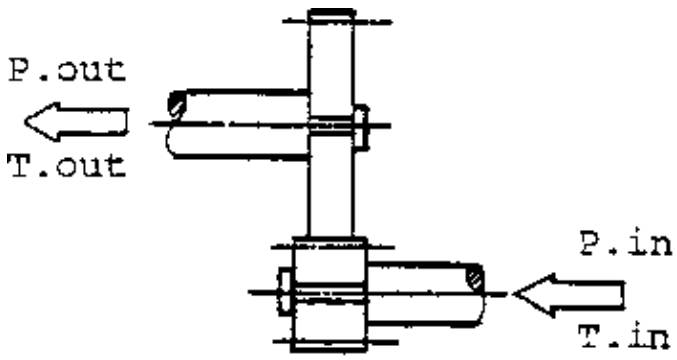


i1 = ratio of gear drive 1
i2 = ratio of gear drive 2
i3 =.....
in = ratio of gear drive n
i = joint ratio of all gear drives

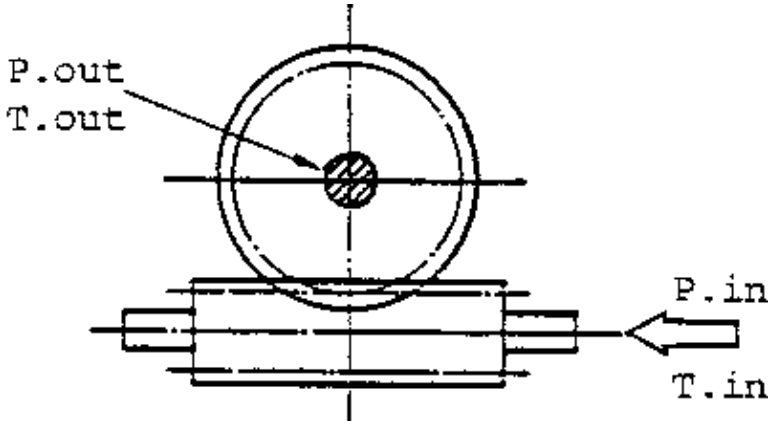
i = i1 i2..... in

19. Power, torque and efficiency of a gear box

19.1 Single gear drive



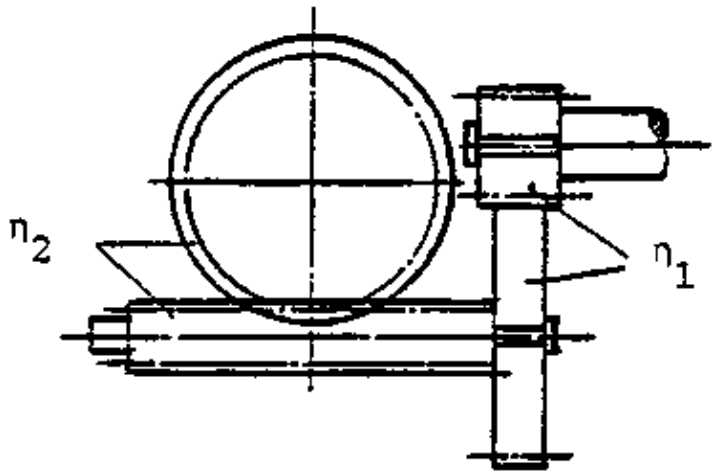
P = power
T = torque
n = efficiency



$$p = \frac{2\pi nT}{60{,}000}$$

$$n = \frac{P.out}{P.in}$$

19.2 Multiple gear drive

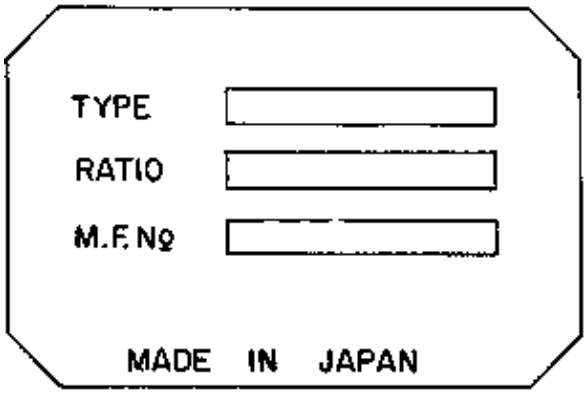


n_1 = efficiency of gear drive 1
n_2 = efficiency of gear drive 2
n_3 = efficiency of gear drive 3
n_n = efficiency of gear drive n
n = joint efficiency of all gear drive;

$$n_{(...)} = n_1 \cdot n_2 \cdot n_3 \cdot .... \cdot n_n$$

20–21. Name plate

20. Read the name plate of the gear box and fill in the missing datas in the table below.



Note: The name plate is of JIS standard which is different from DIN.

PA 18 means

1: 10 means

M 40607 means

Bellpony means

Wait! Have the instructor check before doing next

21. Based on the name plate and the table of page 13, if the required output speed is 120 min^{-1}, what will be the followings?

21.1 The input speed = _____ min^{-1}

21.2 Input power = _____ kw

21.3 Output torque = _____ kg–m

or = _____N–m

(1 kg = 9.81 N)

Selection table

PR.PA.PO.PF types

Type	Input Speed (rpm)	Ratio	1/10	1/15	1/20	1/25	1/30	1/40	1/50	1/60
12	1800	Input (KW)	0.82	0.63	0.48	0.35	0.41	0.31	0.24	0.20
		Output Torque (kg–m)	3.59	3.99	3.94	3.33	4.50	4.50	3.73	3.59
	1500	Input (KW)	0.74	0.56	0.43	0.31	0.37	0.29	0.22	0.18
		Output Torque (kg–m)	3.87	4.22	4.21	3.52	4.78	4.80	4.03	3.70
	1200	Input (KW)	0.65	0.50	0.37	0.28	0.33	0.25	0.19	0.16
		Output Torque (kg–m)	4.23	4.58	4.43	3.85	5.2	5.14	4.28	4.01
	1000	Input (KW)	0.58	0.45	0.33	0.25	0.30	0.23	0.18	0.15
		Output Torque (kg–m)	4.44	4.94	4.76	4.05	5.46	5.49	4.63	4.32
	800	Input (KW)	0.53	0.39	0.29	0.22	0.27	0.20	0.16	0.13

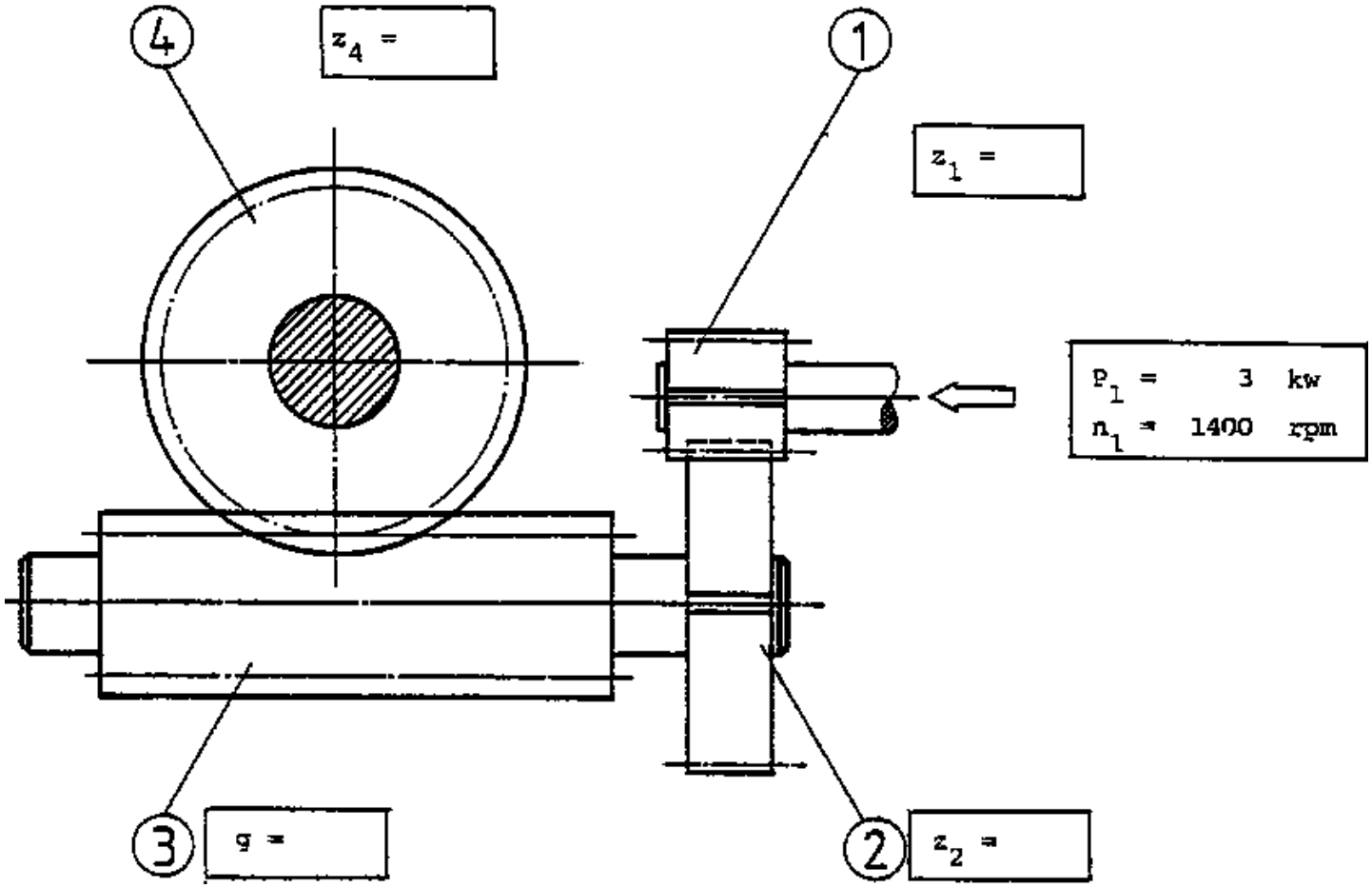
		Output Torque (kg−m)	5.00	5.23	5.16	4.40	6.07	5.85	4.89	4.54
	600	Input (KW)	0.43	0.32	0.25	0.19	0.22	0.17	0.13	0.11
		Output Torque (kg−m)	5.35	5.7	5.74	4.79	6.44	6.32	5.23	4.85
15	1800	input (KW)	1.31	1.00	0.72	0.54	0.66	0.48	0.37	0.32
		Output Torque (kg−m)	5.78	6.33	5.82	5.14	7.33	6.55	5.73	5.75
	1500	Input (KW)	1.17	0.90	0.64	0.48	0.58	0.42	0.34	0.29
		Output Torque (kg−m)	6.15	6.83	6.19	5.43	7.73	6.92	6.31	6.06
	1200	Input (KW)	1.04	0.79	0.56	0.43	0.53	0.39	0.30	0.25
		Output Torque (kg−m)	6.78	7.36	6.64	5.90	8.46	7.61	6.58	6.43
	1000	Input. (KW)	0.93	0.71	0.51	0.39	0.47	0.35	0.27	0.23
		Output Torque (kg−m)	7.23	7.88	7.14	6.32	8.84	8.00	7.05	6.88
	800	Input (KW)	0.82	0.62	0.44	0.34	0.42	0.31	0.24	0.21
		Output Torque (kg−m)	7.86	8.49	7.57	6.72	9.67	8.58	7.51	7.50
	600	Input (KW)	0.67	0.51	0.39	0.29	0.36	0.26	0.20	0.18
		Output Torque (kg−m)	8.54	9.04	8.56	7.42	10.50	9.35	8.07	7.90
18	1800	Input (KW)	2.76	2.08	1.54	1.21	1.36	1.01	0.79	0.77
		Output Torque (kg−m)	12.28	13.37	12.87	12.34	15.33	14.66	13.87	14.14
	1500	Input (KW)	2.47	1.90	1.39	1.08	1.21	0.90	0.73	0.70
		Output Torque (kg−m)	13.10	14.46	13.84	13.13	16.25	15.48	15.09	15.11
	1200	Input (KW)	2.20	1.66	1.21	0.97	1.08	0.80	0.64	0.61
		Output Torque (kg−m)	14.46	15.65	14.85	14.39	17.77	16.88	16.01	16.00
	1000	Input (KW)	1.96	1.50	1.10	0.85	0.99	0.73	0.59	0.57
		Output Torque (kg−m)	15.33	16.74	15.96	15.05	19.02	17.90	17.19	17.20
	800	Input (KW)	1.71	1.30	0.95	0.75	0.87	0.64	0.52	0.49
		Output Torque (kg−m)	1.6.58	17.88	16.92	16.23	20.38	19.19	18.32	18.04
	600	Input (KW)	1.43	1.08	0.83	0.63	0.73	0.55	0.42	0.42
		Output Torque (kg−m)	18.21	19.40	19.14	17.80	22.07	20.93	19.37	19.46
22	1800	Input (KW)	3.80	2.95.	2.06	1.68	1.89	1.35	1.10	0.90

		Output Torque (kg−m)	17.0	19.0	17.1	17.0	21.8	19.5	19.1	17.1
	1500	Input (KW)	3.41	2.65	1.88	1.49	1.70	1.23	1.02	0.83
		Output Torque (kg−m)	18.2	20.3	18.4	17.9	23.00	20.6	20.7	18.3
	1200	Input (KW)	3.07	2.30	1.65	1.32	1.43	1.12	0.88	0.73
		Output Torque (kg−m)	20.3	21.9	19.9	19.6	24.8	22.9	21.8	19.5
	1000	Input (KW)	2.75	2.08	1.47	1.20	1.37	0.98	0.80	0.66
		Output Torque (kg−m)	21.7	23.4	21.1	21.0	26.9	23.8	23.3	20.7
	800	Input (KW)	2.42	1.83	1.31	1.03	1.21	0.88	0.71	0.58
		Output Torque (kg−m)	23.5	25.4	23.0	22.2	28.9	25.6	24.8	21.9
	600	Input (KW)	2.03	1.52	1.11	0.88	1.02	0.74	0.59	0.51
		Output Torque (kg−m)	26.0	27.5	25.3	24.5	31.3	27.6	26.6	23.8
25	1800	Input (KW)	6.91	5.29	3.89	3.03	3.39	2.48	1.95	1.61
		Output Torque (kg−m)	31.3	34.6	33.5	31.9	39.9	38.1	35.9	34.3
	1500	Input (KW)	6.24	4.70	3.53	2.69	3.01	2.24	1.78	1.46
		Output Torque (kg−m)	33.5	36.5	36.0	33.6	41.9	40.4	38.7	36.7
	1200	Input (KW)	5.58	4.17	3.06	2.37	2.67	2.02	1.54	1.26
		Output Torque (kg−m)	37.1	39.9	38.7	36.5	45.1	44.9	40.9	38.8
	1000	Input (KW)	4.98	3.79	2.75	2.14	2.43	1.78	1.39	1.16
		Output Torque (kg−m)	39.5	43.2	41.3	39.1	48.7	46.6	43.4	41.7
	800	Input (KW)	4.31	3.28	2.43	1.85	2.14	1.57	1.23	1.00
		Output Torque (kg−m)	42.5	46.2	45.0	41.5	52.6	50.2	46.7	43.8
	600	Input (KW)	3.65	2.78	2.05	1.57	1.81	1 32	1 03	0.85
		Output Torque (kg−m)	47.2	51.1	49.5	46.0	57.4	54.1	50.0	47.2
30	1800	Input (KW)	10.76	3.32	5.92	4.93	5.23	3.76	3.10	2.55
		Output Torque (kg−m)	48.9	55.0	50.4	53.1	62.8	56.8	59.6	54.8
	1500	Input (KW)	9.88	7.38	5.35	4.36	4.70	3.45	2.83	2.32
		Output Torque (kg−m)	53.5	57.9	54.0	55.6	66.4	61.0	63.7	58.7
	1200	Input (KW)	8.77	6.58	4.72	3.81	4.17	3.06	2.46	2.03

		Output Torque (kg–m)	58.9	63.7	58.7	60.2	72.2	66.1	68.1	62.1
	1000	Input (KW)	7.68	5.93	4.20	3.47	3.79	2.82	2.19	1.80
		Output Torque (kg–m)	61.3	68.1	61.6	65.1	76.9	70.7	71.6	65.4
	800	Input (KW)	6.82	5.13	3.69	2.99	3.37	2.45	1.94	1.59
		Output Torque (kg–m)	67.6	73.0	66.7	69.1	83.9	75.2	77.3	69.5
	600	Input (KW)	5.67	4.38	3.17	2.51	2.79	2.06	1.61	1.34
		Output Torque (kg–m)	74.2	81.5	74.8	76.0	90.0	81.3	82.5	74.9
35	1800	Input (KW)	15.00	11.78	8.49	6.73	7.31	537	4.21	3.42
		Output Torque (kg–m)	68.8	79.0	74.8	72.9	90.2	86.0	82.0	76.5
	1500	Input (KW)	13.91	10.43	7.82	5.98	6.56	4.88	3.80	3.11
		Output Torque (kg–m)	76.2	83 2	82.0	77.0	95.4	92.2	87.0	820
	1200 1000	Input (KW)	12.23	0.17	6.78	5.19	5.81	430	3.36	2.71
		Output Torque (kg–m)	83.2	90.5	87.5	82.5	103	99.0	93.0	36.7
		Input (KW)	10.89	8.36	0.05	4.66	5.22	3.88	2.08	2.41
		Output Torque (kg–m)	88.1	97.8	93.1	88.1	109	106	98.0	91.4
	800	Input (KW)	9.59	7.22	5.28	1.12	4.07	3.35	2.63	2.12
		Output Torque (kg–m)	96.4	104	100	95.8	120	112	106	97.0
	600	Input (KW)	8.03	6.15	4.47	3.45	3.86	2.82	2.20	1.78
		Output Torque (kg–m)	106	117	111	104	129	122	114	104

22. Calculation exercises

Based on the information on pages 4 and 9, determine the valves for z_1. z_2, z_3, and z_4 and write it down onto the appropriate blocks



22.1 Demonstrate your calculations for various valves onto the left column and write the obtained results onto the right column.	
	i_1 = –
	i_2 =
	$i_{(...)}$ =
	n_2 =
	n_3 =
	n_4 =
Demonstrate your calculations on the left column and write down the obtained results on the right column.	

	T_1 =
	T_2 =
	T_3 =
	T_4 =
	P_4 =

22.2 Suppose, the efficiencies of the gear trains $n_2^1 = 0.98$, $n_4^3 = 0.88$, determine the followings:

	T_1 =
	T_2 =
	T_3 =
	T_4 =
	P_2 =
	P_3 =
	P_4 =

Tools and equipment

Number	Tools
1	Puller plate
1	Small puller
1	Plastic hammer
1	Hexagon socket screw wrench No. 6
1	Hexagon socket screw wrench No. 9
1	Pliers
1	Ring spanner No. 16–17
1	Wrench No. 8 – 9
1	Wrench No. 5/8 " – 3/4 "
1	Small flat standard screw driver
1	Middle flat standard screw driver
1	Large flat standard screw driver
2	Sleeve
1	Support, Pipe

1	Cylindrical guide
1	Puller support (Brass)
1	Gear Tooth gauge (MP)
1 pair	Wood for support jaws vice

Note: The presses, vice and vernier are prepared by the teacher.