
Maintenance & Repair - Module 1

(32 hours Course – Maintenance Management & Maintenance of Mechanical Drives)



With technical assistance from:
GERMAN DEVELOPMENT SERVICE

ded

General Survey –“Maintenance & Repair”- Module 1 Course

TARGET PARTICIPANTS

min 18 years old, at least High School graduates, experienced workers, supervisors or leadsman

LENGTH OF COURSE

32 hours / 4 days

OBJECTIVES

At the end of the course, the participants should be able to:

- know different “Maintenance Strategies” and “Condition Monitoring” Tools
- know the importance of “Preventive Maintenance Schedule”, “Maintenance Log” and “Repair History Log”.
- know the principles and how to install and maintain different mechanical drives: Belt Drives, Chain Drives, and Enclosed Gear Drives.
- know the classification and the most common shaft couplings
- align shafts for the installation of couplings using different methods.
- know the hazards during maintaining mechanical drives and know how to work safe.
- calculate speeds for belt drives, chain drives and gear drives.

COURSE OUTLINE

THEORY (50 %)	HANDS-ON TRAINING (50 %)	METHOD
<ul style="list-style-type: none"> • Maintenance Strategies • Condition Monitoring Tools • Preventive Maintenance Schedule • Maintenance Log and History files • Typical mechanical drives and their accessories • Maintaining different kinds of drives • Types of check: lubrication, temperature, and vibration. • Alignment methods of mechanical drives • Applied Mathematics 	<ul style="list-style-type: none"> • Work out the advantages/disadvantages of Maintenance Strategies • Align a typical disk coupling using the coupling alignment trainer • Install at least two complete mechanical drives on a base plate (electric motor, reducer, chain drive and electric motor, reducer, belt drive) • Make use of different couplings • Align all shafts and make a test run • Exercises in Mathematics 	<ul style="list-style-type: none"> • Lectures/Discussion • Practical Sessions • Teaching Video

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August 2000

Dear Reader,

I would like to comment this handout, because otherwise you might get a little confused while studying it.

The most important thing to know is, that this handout is developed for a **non-formal** Training Center. The participating government officials and the involved companies were not interested in long-term courses. So, I had to respect the wish of my project partners for a course with this length and was limited on the most important subjects.

One or two of the modules are still under construction. Sorry for this.

DED – Development Worker

1. MAINTENANCE MANAGEMENT

A goal of maintenance **is to eliminate or to avoid** unnecessary or unplanned downtime due to failure. The objective of Maintenance Management (MM) is to ensure the reliability and safety of plant equipment. Knowing that all equipment components will wear, appropriate management must be applied to avoid unplanned failure.

Maintenance can influence the entire plant operation, from product quality to on-time delivery, to safety records and to the impact of environmental pollutions. Poor maintenance procedures can cost a company millions of Pesos in repairs and poor quality and lost production, whereas good maintenance practices can cut production costs immensely.

Still the advantages of MM are underestimated. Why is this so? Here are some samples on how we handle other common situations in life:

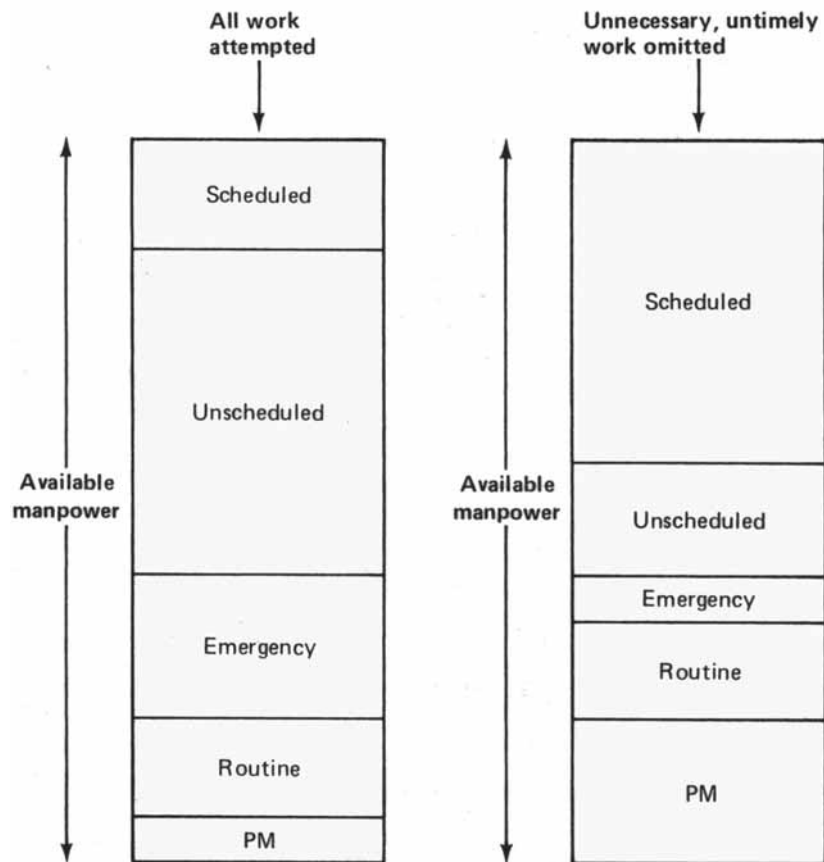
- *We go to the doctor only when we are sick*
- *Our car goes into the shop only for repairs*
- *In our home, we call electricians, plumbers, etc. only when there is a problem*
- *The focus of technical education is on dismantling/reassembling equipment*
- *In the workplace, the best "fixer" gets the promotion*

This “**bad habits**” has integrated itself into the maintenance workplace also. It is unlikely that these "habits" can be changed overnight. Moving from the approach of "**Fixing**" as the principal activity of maintenance to the approach of “**Wear Management**” - which is proactive - takes time, and a good engineering.

1.1 Types of Maintenance Strategies

Maintenance Strategy	Explanation
Run to failure Corrective Maintenance or Breakdown Maintenance	No routine maintenance tasks are performed on the equipment and then only after the equipment has suffered a failure. Repair or replace upon failure. (Reactive Maintenance)
Preventive Maintenance	Any maintenance activity for which a pre-determined job procedure has been documented, for which all labor, materials, tools, and equipment required to carry out the task have been estimated, and their availability assured before start of the task. Repair or replace on time or cycles.
Predictive Maintenance	An equipment maintenance strategy based on measuring the condition of equipment in order to assess whether it will fail during some future period, and then taking appropriate action to avoid the consequences of that failure. Employ condition monitoring to detect early stage failures. Replacement or repair is scheduled on-condition.
Planned Overhauling	The scheduled, comprehensive examination and restoration of e.g. machines, devices to an acceptable condition
Condition Monitoring Redesign and condition-control (proactive)	The use of specialist equipment to measure the condition of equipment. Vibration Analysis, Lubrication Analysis and Thermography are all examples of Condition Monitoring techniques. Changes in hardware, loading or procedures. Condition monitoring detects the presence of root causes of failure.
Redundancy	Deploy active shared-load or stand-by redundant systems

1.2 Shift from an overbalanced “Unscheduled Work” more to “Scheduled Work”



1.3 Example of a simple Preventive Maintenance Schedule

	Time (weeks)								
	1	2	3	4	5	6	7	8	9
Pump-1	AF	AF	AF	AF	AF	AF	AF	AF	AF
Pump-2	AG	AB	AG	AB	AG	AB	AG	AB	AG
Pump-3	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD
Gearbox-1	AB	AB	AB	ABD	AB	AB	AB	ABD	AB
Gearbox-2	A	AB	A	AB	A	AB	A	AB	A
Compressor-1	ABCF	ABCF	ABCF	ABCDF	ABCF	ABCF	ABCF	ABCDF	ABCF
Compressor-2	ABFG	ABFG	ABFG	ABFG	ABFG	ABFG	ABFG	ABFG	ABFG
E-Motor-1	AB	AB	ABC	AB	AB	ABC	AB	AB	ABC
E-Motor-2	AB	AB	AB	AB	AB	AB	AB	AB	AB
E-Motor-3	A	A	A	A	A	A	A	A	A

A = Visual Check & Lubrication Check
 B = Temperature Check
 C = Vibration Check

D = Lubrication Analysis (e.g. viscosity, content of abrasion.....)
 F = Clean
 G = Calibrate

1.4 Example of simple “Maintenance Log”

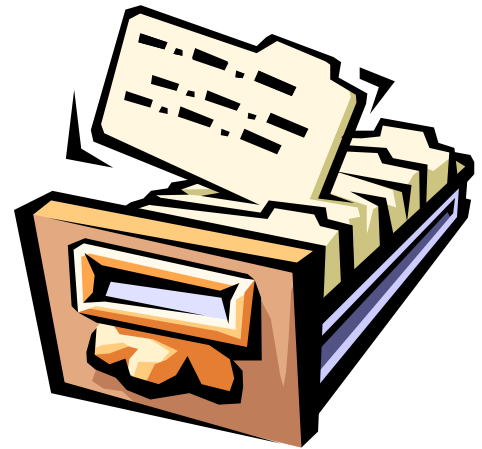
GEAR DRIVE MAINTENANCE LOG												
Location: Building 511, 1 st floor							Machine: Paper mill # 5					
Gear drive type: Reducer 1:20							Serial no.: 10245156					
Date of putting in operation: 5/20/1997							Manufacturer: Flender Germany					
Special maintenance requirements: Oil Grade 05							Auxiliary drives: <input type="checkbox"/> Belts _____ <input type="checkbox"/> Chain _____ <input checked="" type="checkbox"/> Coupling Flexible Coupling <input type="checkbox"/> Others _____					
Date	Add Oil	Change Oil	Temp. Check	Vibr. Check	Lubri Analysis	Load Check	Aux. Drive Check	Change Seal	Change Bearing	Compl. Over-haul	Initials	
1/5/00	Yes	/	86 C	/	/	46 A	Yes	/	/	/	Horst	
Belt tensioned												
1/12/00	/	/	89 C	/	Yes	48 A	Yes	/	/	/	Horst	
Change oil next week												
1/19/00	/	Yes	92 C	/	/	50 A	Yes	/	/	/	Horst	
Gear box oil Grade 05												
1/26/00	/	/	85 C	510	/	45 A	Yes	/	/	/	Horst	
O.K.												

1.5 Example of simple “Repair Report”

GEAR DRIVE REPAIR REPORT					
Location: Building 511, 1 st floor			Machine: Paper mill # 5		
Gear drive type: Reducer 1:20			Serial no.: 10245156		
Date of putting in operation: 5/20/1997			Manufacturer: Flender Germany		
Date of Repair: 5/26/2000			Auxiliary drives:		
Special maintenance requirements: Oil Grade 05			<input type="checkbox"/> Belts _____ <input type="checkbox"/> Chain _____ <input checked="" type="checkbox"/> Coupling Flexible Coupling <input type="checkbox"/> Others _____		
Part	Failure	Mark	Part	Failure	Mark
Auxiliary Drive	Chain or belt broken		Gears	Seat worn out	
	Sprocket/Pulley worn out			Broken teeth	
	Keyway problem			Worn out teeth	X
	Drive shaft bent			Others	
	Coupling damaged		Lubrication	No oil	
	Coupling rubber broken	X		Little oil	X
Others		Dirty oil			
Sealing	Lip seal defective	X	Water in oil	X	
	Housing seal defective		Breather defective		
	Others		Others		
Shaft	Seat of bearing worn out		Housing	Cracked	
	Seat of Lip seal worn out	X		Problem with bolt connection	
	Bent or broken			Problem with pin connection	
	Others			Others	
Bearings	Worn out	X	Base Plate	Loose, weak	
	Excessive damaged			Problem with bolt connection	
	Others			Problem with foundation	

EQUIPMENT FILE

To ensure a quick and smooth planning of maintenance activities as well as the actual repair job, it is advisable to maintain an equipment file for all equipment, used in the plant. The following data should be included:



- 1. Specification**
 - Type of equipment
 - Brand
 - Model
 - Date of installation
 - Serial number
 - Capacity
 - Speed
 - Load

- 2. Location**
 - Building
 - Floor

- 3. Technical Drawings**
 - Including detailed drawings

- 4. Spare Part No., and where to get them**
 - Bearing
 - Sealing
 - Lubricant
 - Drive
 - Coupling

- 5. History of Preventive Maintenance Activities** To monitor and improve Preventive Maintenance measures

- 6. History of Repair Activities** To find out the cause of break down and prevent the same failure again for the future

1.6 Condition Monitoring – 7 Tools

Lubrication Analysis	Analyzing lubricant samples at regular intervals. Lubricant analysis is in general strong in detecting failures in gearboxes, and hydraulic systems.
Vibration Analysis	Measuring vibrations of rotating machines. Vibration analysis is in general strong in detecting failures in high-speed rotating systems. Vibration analysis is especially strong in localizing the point of failure depending on the application.
Thermography	Measuring the temperature e.g. of bearings at relevant measuring points at regular intervals.
Visual Inspection	Maintenance personnel travel scheduled routes checking such things as the presence of coupling guards and the integrity of belts.
Operational-dynamics Analysis	Using various devices, employees check equipment to make sure it's meeting design specifications. A damper might be checked to make sure it's receiving a 50-percent airflow, as designed.
Electrical Monitoring.	Technicians regularly check all electrical components with voltmeters, infrared equipment, and other devices to guarantee their operational integrity.
Failure Analysis	This determines why a piece of equipment failed and how that can be prevented in the future.

Effectiveness of Lubrication-Analysis, Vibration-Analysis and Thermal-Analysis in compare:

	Predictive What is going to happen?			Failure Analysis Why did it happen?		
	Lube Analysis	Vibe Analysis	Therm Analysis	Lube Analysis	Vibe Analysis	Therm Analysis
Root Causes Control						
Lubricant contamination	excellent	poor	poor	excellent	poor	fair
Misalignment	fair	excellent	fair	fair	excellent	fair
Imbalance	fair	excellent	fair	poor	excellent	fair
Wrong lubricant	excellent	poor	poor	excellent	poor	poor
Degraded lubricant	excellent	poor	poor	excellent	poor	poor
High operating	fair	fair	excellent	fair	fair	excellent
Failure Detection						
Wear	excellent	good	fair	excellent	fair	fair
Cavitation	good	poor	fair	fair	poor	fair
Gear tooth fracture	poor	excellent	poor	fair	fair	poor
Structural resonance	poor	excellent	poor	poor	excellent	poor
Fatigue	excellent	good	good	fair	fair	excellent

1.6.1 Lubrication Analysis

Fluid condition management, when properly implemented, delivers the following productivity and profitability improvements:

- Minimized downtime
- Extended machine life
- Reduced labor costs
- Reduced fluid consumption and disposition costs.

What should be analyzed after taking a sample from a machine?

- **Chemical Properties**
Because of the oxidation of the lubricant, the durable molecules break into smaller pieces, which changes the properties of the lubricant. The test includes e.g. the viscosity, the decrease of additives, the flashpoint.
- **Fluid Contaminants**
If the lubricant carries other fluids, most likely water. These fluids are not so good at minimizing friction, so they are considered contaminants.
- **Solid Contaminants**
Mechanical action within machines creates mechanical stress that sometimes exceeds the elastic limits of the metal. Microscopic pieces of metal break off the component surface. The oil carries those pieces away so more stress can break off more pieces.

1.6.2 Vibration Analysis

The vibration analysis is a condition-monitoring tool, which is capable of measuring vibration caused by rotational and structural problems like imbalance, misalignment, looseness etc. It is also capable of measuring vibration in higher frequencies caused by rolling bearing problems. The results are usually compared with previous data to ensure that there is for each measuring point a history.

Companies, which use Vibration monitoring, have many advantage:

- Less Downtime
- Less Spare Parts Inventory
- Less Overhaul-Overkill
- Longer Production Runs
- Better Quality

Using vibration analysis, companies will have a list of "invisible" anomalies. This list will show problems long before failure, which will allow repairs to be scheduled during off hours. Problems with bearings are detected long before they fail so that other associated mechanical components are unaffected. No shafts are broken so the repairs are done in a fraction of the time. During repairs, other machines that have impending problems detected with vibration monitoring can be corrected. The parts have been ordered in advance as needed.

Especially for important equipment like Turbines, Engines, Fans, Conveyors, Pumps, Gear Boxes, etc. is advisable to monitor continuously using transducers, which are connected with a data-storage system.

1.6.3 Thermography

Regular measuring of temperature at machines is like an early warning system. The results are usually compared with previous data to ensure that there is for each measuring point a history. There are contact and non-contact thermo tools available.

- An accurate contact tool comes often with a temperature range from $-200\text{ }^{\circ}\text{C}$ up to $1300\text{ }^{\circ}\text{C}$. The accuracy is $\pm 0.5\text{ }^{\circ}\text{C}$.
- Non-contact measuring tools are normally laser tools. This method is safe and fast in use, even in critical application like hot surfaces or moving parts.

Similar to the vibration analysis, especially for important equipment like Turbines, Engines, Fans, Conveyors, Pumps, Gear Boxes, etc. is advisable to monitor continuously using transducers, which are connected with a data-storage system.

2. MECHANICAL DRIVES - BELT DRIVES

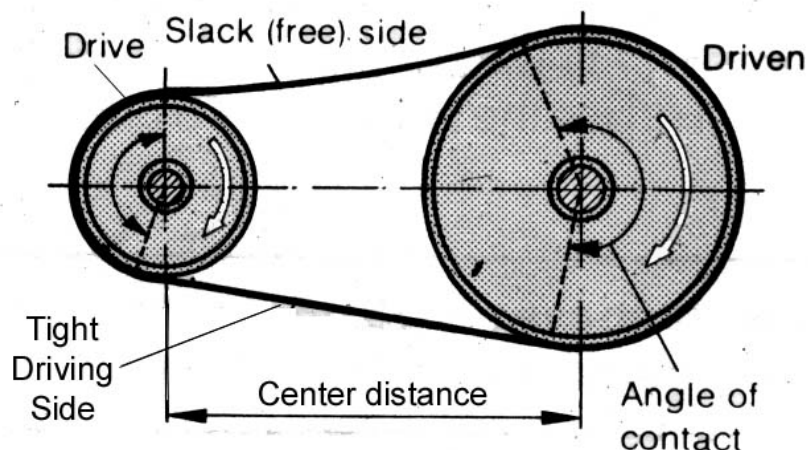
In general, we can say that belt drives transfer the turning moment between two shafts. This is possible because of the contact force between the belt and the belt wheels. The required contact force is generated, by the belt **pre-tension**, which is applied during the installation of a belt drive.

Advantages of belt drives:

- Can operate at much higher speeds than chain drives
- Elastically load transmission (quiet operation)
- Cheaper than chain drives
- Easier and cheaper to maintain than chain drives
- Lower own weight compared to chain drives (less centrifugal forces)
- Wide horsepower range (for heavy loads multiple belt drives possible - up to 12 belts)

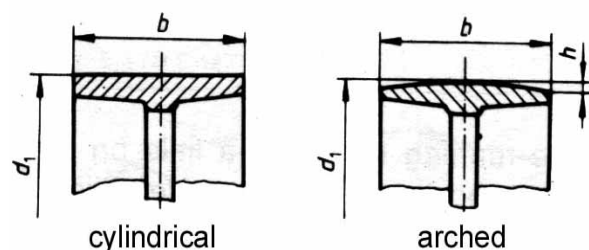
Disadvantages of belt drives:

- Limited shaft distances
- High loads for the bearings
- Due the slip effect lower speed at the driven wheel



2.1 Flat Belt Drives

This type of belt requires great care during installation. Sometimes the belts are even cut to length and spliced direct on the jobsite. Only experienced workers should do this job. The common materials are leather, nylon or a combination of both. To bring the two ends of the belt together there are different techniques from gluing, sewing and fixing with fasteners.

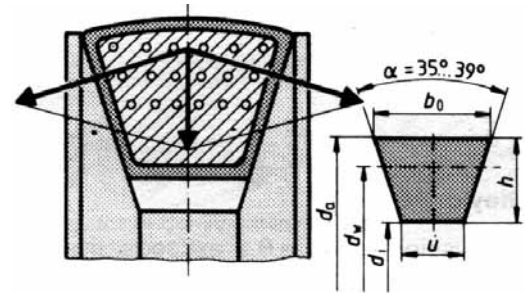


Types of pulleys for flat belt drives

2.2 V-Belt Drives

V-Belts are endlessly produced belts with a trapezoidal cross-section. The most common material combination in use is a rubber body with nylon fibers or tire cord inside to increase the tensile strength. V-belt drives can work with transmission ratios up to 10:1.

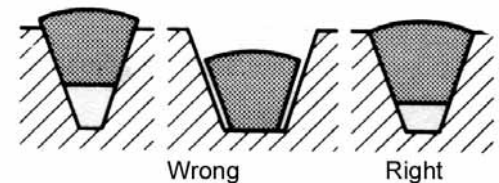
V-belt pulleys are constructed single or multi-grooved. Be carefull and use the right belt-form for the given pulley groove.



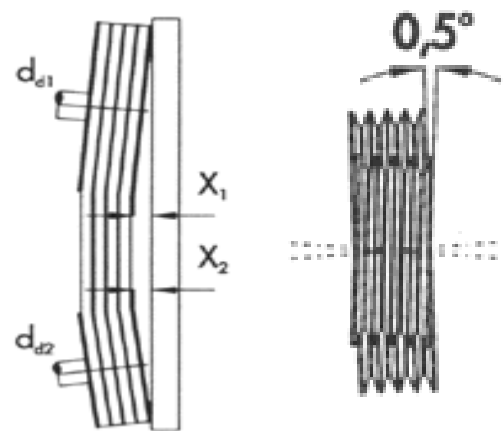
V-belt direction of force and trapezoid dimensioning

2.2.1 Installation of V-belt drive

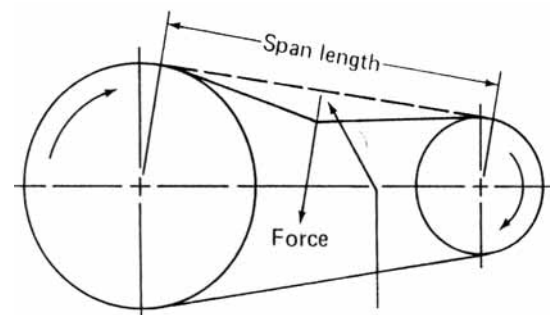
- Check if the V-belt will fit to the pulley. Only a fitting belt can transform the full transmission load.



- Align the two pulleys carefully using a straightedge. Misaligned drives can damage the bearing and the belt itself. Especially when installing multiple belt drives it is extremely important to align properly, because otherwise not all of the belts will carry the same load. The vertical misalignment should not exceed 0.5 degree.

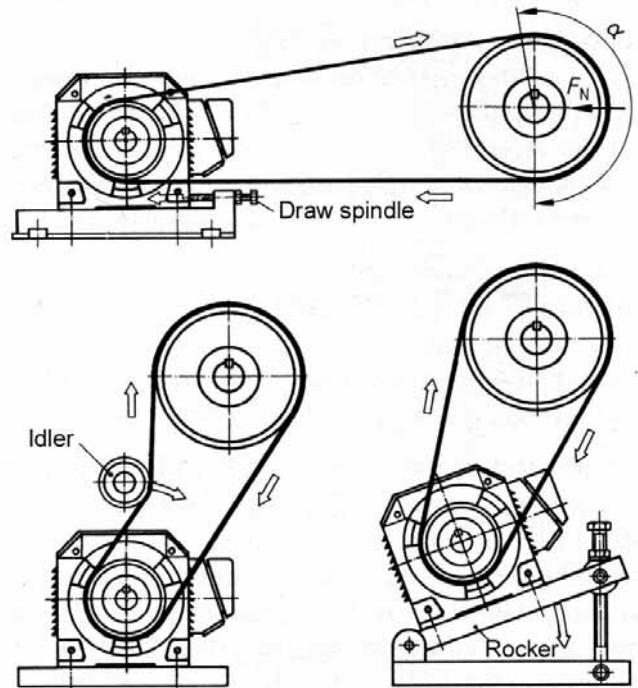


- Adjusting the V-belt tension is also very important for the working life of the whole drive including the bearings. Consult the belt manufacturer to find the recommended tension for the belt. Some manufacturers offer some tension test devices



Deflection 1.5 mm for each 10 cm of span

- The most common techniques to tension belts are the use of elongated holes with adjustment spindles and the use of rockers.
- For machines with nonadjustable centers, the best way to take up the slack is to install a tensioner.



2.2.2 Maintenance Principles for V-Belt Drives

There are two generally accepted maintenance principles for installing new belts or any multiple-belt drive.

Principle No. 1: Always replace all the belts.

Older belts naturally become stretched or worn from use. If old and new belts are mixed, the new belts will be tighter, will carry more than their share of the load, will probably fail before their time and may also contribute to uneven pulley wear.

Principle No. 2: Always use a matched set of belts from one manufacturer.

If unmatched belts and brands are mixed, the belts may have different dimensional and performance characteristics, and they could work against each other, resulting in unusual strain and short service life.

Principle No. 3: Always adjust belts after a short run-in period

The newer generations of belts are made of thermally active polyester tensile cords with a higher elongation resistance. Even for this new type of belts, it is recommended to re-adjust the tension of the belts after a short run-in period.

V-Belt Drive Troubleshoot:

Problem	Cause	Cure
Belt slips	<ul style="list-style-type: none"> • Drive under-tensioned • Drive overloaded • Worn pulleys • Shock loads 	<ul style="list-style-type: none"> • Re-tension properly • Redesign with larger pulleys or more belts • Replace Pulleys • Drive under-tensioned or under-loaded. Check drive design
Belts wears rapidly	<ul style="list-style-type: none"> • Pulleys worn • Overloaded drive • Belt hitting guard/frame • Dirt and grit entering drive 	<ul style="list-style-type: none"> • Replace or re-machine • Redesign with larger pulleys or more belts • Provide more clearance • Provide closed guards
Belt mis-matched	<ul style="list-style-type: none"> • Mixed old and new belts • Belts not of same make • Worn or improperly machined pulleys 	<ul style="list-style-type: none"> • Replace with new set • Replace with new set • Belt will ride at different positions in the grooves. Replace Pulleys.
Belt brakes	<ul style="list-style-type: none"> • Improper belt installation • Insufficient tension • Shock loads 	<ul style="list-style-type: none"> • Belt squeezed over pulley. Install new belts properly • Belts whipped on start-up or under shock • Drive under-tensioned or under-loaded. Check drive design
Belt jumps grooves	<ul style="list-style-type: none"> • Drive misaligned • Tensioner not located properly • Excessive whip and vibration 	<ul style="list-style-type: none"> • Check and realign • Redesign tensioner position • Shorten center distance or add tensioner
Belts crack	<ul style="list-style-type: none"> • Belt slipping • Excessive heat • Pulley or tensioner too small • Chemical attack 	<ul style="list-style-type: none"> • Increase tension • Provide adequate ventilation. Check slippage • Increase diameter • Provide adequate protection
Belt vibration	<ul style="list-style-type: none"> • Pulleys not balanced • Weak base construction • Resonant condition 	<ul style="list-style-type: none"> • Provide dynamically balanced pulleys • Redesign with additional supports or bearings • Until there is an improvement try to change center distance; increase or decrease number of belts or add tensioner

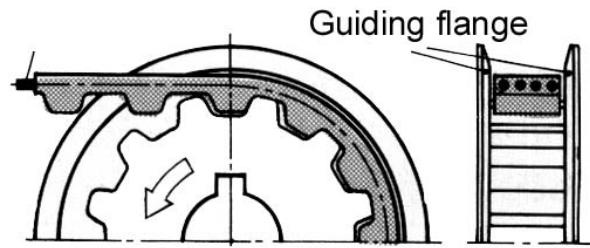
2.3 Positive-Drive Belts (also Synchronous Belt or Toothed Belt)

Positive-belt drives are widely in use in all parts of industry. One advantage of this belt type is the constant speed for driven wheel and drive wheel, because of the teeth, which do not allow any slip.

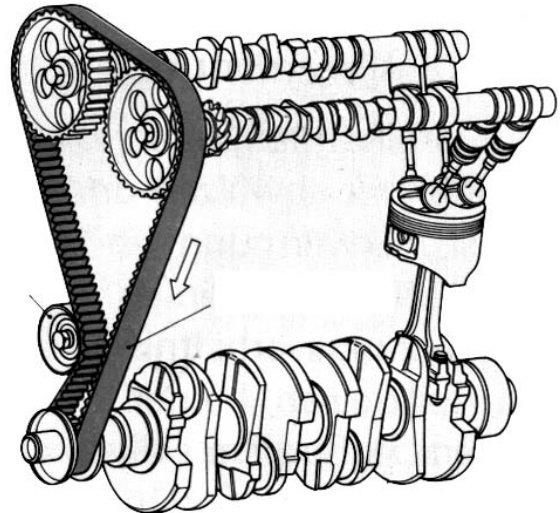
To install positive-drive belts, follow the same general procedure as for V-belts. It is normal for this type of belts to ride towards one side of the pulley when operating. Most of the pulleys will come with two flanges. If there is only one flange, then install the flanged side to the side where the belt moves.

Positive-belts do not rely heavily on tension to operate. Unlike V-belts and flat belts, all they need is to fit properly on the pulley, tooth to tooth. If available, follow the instructions of the belt manufacturer to tension the belt. This will extend the life expectancy. Tensioners should be used whenever it is absolute necessary to prevent a jump over of some teeth of the belt.

The material of “Synchronous Belts” is normally a polyurethane body for abrasion and chemical resistance, and for stretching resistance aramid fiber tensile cords. The tensile cords also provide excellent flex fatigue life and high resistance to shock and alternating loads. Nylon facing gives strength and durability to the belt teeth.



Toothed belt drive (synchronous belt drive)



Toothed belt with idler for driving camshafts

3. CHAIN DRIVES

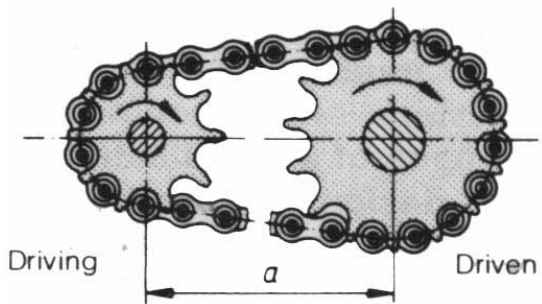
In general, chain drives transfer slip-free power between two shafts over a distance which cannot be bridged with gears. The transmission forces are carried by the chain-links gripping in the teeth of the sprocket wheels.

Advantages of chain drives:

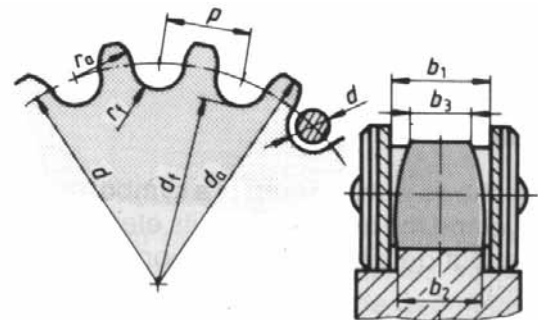
- Usable in a wide range of drive applications
- Moderate to heavy loads
- Can be used in critical areas where moisture, heat and oil is present

Disadvantages of chain drives:

- Only for lower speeds (except high performance precision roller chain drives)
- Relatively high maintenance costs
- With moderate or high speeds permanent lubrication necessary



Simple chain drive

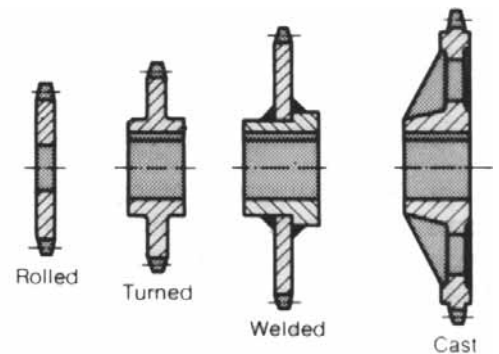


Main dimensions of sprocket wheel

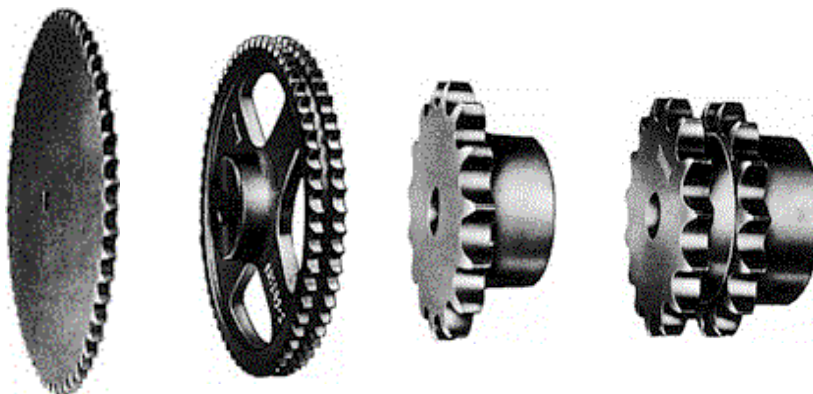
3.1 The Sprocket

Sprockets are available on the market in a big variety. They are normally made out of the following materials: Low Carbon Steel, High Carbon and Cast Iron.

The borehole comes often with standard sizes. It must be machined to the required size.



Manufacturing method



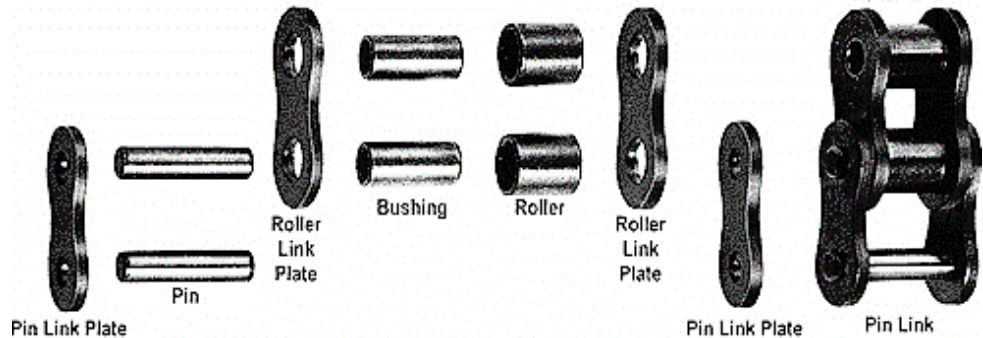
Sprocket Teeth:

Chain drives are also used for high-speed power transmission. To meet this requirement, the **sprocket tooth tips** are strengthened by means of high frequency hardening.

Hardening of tooth tips is required in the following cases:

- The number of teeth is 24 or less and the sprocket is used at higher speeds
- Small sprockets and speed ratios over 1:4
- Use with heavy loads at low speed
- Use under abrasive conditions

3.2 The Chain



3.2.1 Roller chain layout

Speed Ratio and Chain Lap

The speed ratio of Chain drives can range up to 7:1 under normal conditions. However, a speed ratio of 10:1 is possible if the required speed is very slow. Chain lap on the small sprocket must be at least 120°.

Distance between Shafts

Optimum distance between sprockets is 30 to 50 times the pitch of the chain except when there is a pulsating load. In such cases, the distance can be up to 20 times the pitch of the chain.

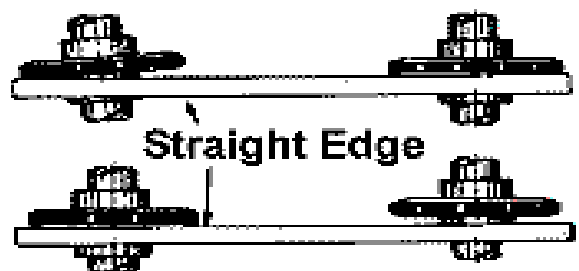
Layout

When arranging the roller chain drive, the centerline of both sprockets should be as close to horizontal as possible, though the angle of installation can be up to 60°. If installation is close to vertical, the chain tends to slip off the sprockets easily with slight chain elongation, In this case, an idler or guide stopper is recommended.

3.2.2 Roller chain Installation

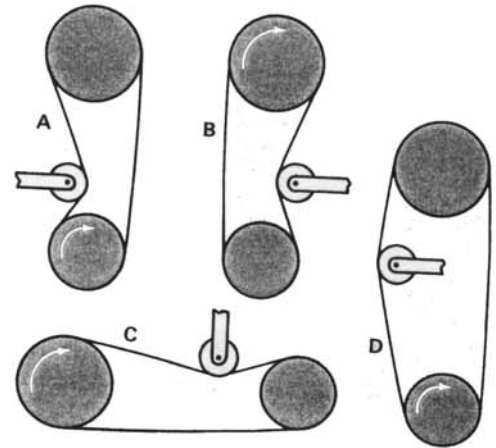
Aligning Shafts:

For efficient operation, both the driving and driven shafts must be level and they must be parallel with each other. To align the sprockets use a straightedge. Misaligned drives can damage the bearing after a short time.



Chain Tension:

Generally, roller chain is used with adequate slack. If the chain is tightened excessively, chain damage or rapid use of lubricant may result. If the chain is too loose, damage due to vibration or chain winding, may result. Adequate slack is to be adjusted to 2 % up to 4% of the chain span. For example, if the span is 800mm, slack should be $800\text{mm} \times 0.04 = 32\text{mm}$. The chain will elongate slightly from the beginning of initial driving from 0.05% to 0.1% of the full length. As this causes extra slack, adjustment of slack is required. An idler can be used to take up the slack or the shaft can be adjusted. After this adjustment, chain elongation should be minimal. If you place the idler outside the chain loop (picture A, B, C) install it nearer to the small drive sprocket. If you place it inside the chain loop, (picture D) mount it nearer to the large sprocket.



3.2.3 Roller chain Lubrication

Proper lubrication of roller chain is essential for good performance and full chain life. Care should be taken to strictly follow the lubrication schedule and recommendations. If this is not done, the service life of the chain will be shortened and maximum power transmission will not be delivered, no matter how high performing the chain or sprocket is.

Since wear between pins and bushings cause chain elongation, lubrication must be maintained on all contact surfaces. Proper lubrication forms an oil film which:

- Reduces abrasion and chain wear
- Reduces chain friction and noise
- Functions as a coolant when the chain is run at high speeds
- Functions as a cushion against impact

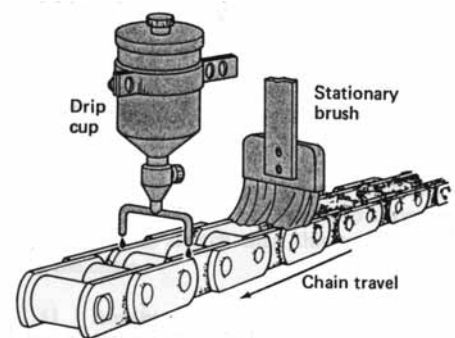
Only high-grade oil of suitable viscosity should be used. The proper type of oil to be used depends on the chain specifications, working conditions and lubrication system.

Oils to avoid:

Heavy oil, Low-grade oil, Impure oil or grease, Used oil

Types of lubrication application:

- Manual Application - Oil is applied with an oil filler or brush on the slack side of the chain.
- Oil Bath Lubrication - The chain is installed in a leak free casing.
- Lubrication By Rotating Disc - Oil can be splashed on the chain using a rotating disc installed in a leak-free casing. For this method, speed along the circumference of the disc should be over 200 m/min. If the width of the chain is over 125 mm, use a rotating disc on both sides
- Lubrication Using a Pump - The chain is contained in a leak free case and a pump is used to circulate and cool the oil



3.2.4 Chain Maintenance

Chain is usually replaced when the chain does not engage properly with the sprocket due to damage of its parts or elongation. To help prevent premature wear or damage, the following points should be checked. Observe the chain and sprockets for these items:

- Abnormal Noise
- Chain rising on the sprocket
- Stiff bending of chain
- Whether the chain contacts the case
- Damage on the sprocket teeth surfaces and side surfaces of teeth and engaging area
- Bending of chain and rotation of roller
- Vibration of the chain
- Chain winding around the sprocket
- Amount and condition of lubrication
- Abrasive stretch of the chain
- Appearance of chain, check for dirt, corrosion, damage on the outside surface of the roller, contact marks, etc

Lubrication

While the chain is driving, check if the lubricating oil moves toward the link plates, and if the chain or rotating disc is immersed in the lubricating oil of the oil bath. When the chain is stopped, check for dirt or abrasive particles produced by improper lubrication. When the chain is removed, the connecting link pin and the edge of the inside of the bushing should be checked. If there is any damage, or a red or reddish brown color can be noticed, lubrication is improper or insufficient. Regardless of the lubricating system used, roller chain should be washed periodically with petroleum or gasoline.

Sprocket

Chain and sprocket engagement can be checked by observing the roller and tooth surfaces. The installation should also be checked. The normal area where wear will occur is slightly above the bottom of the lowest point between the sprocket teeth.

Chain Elongation

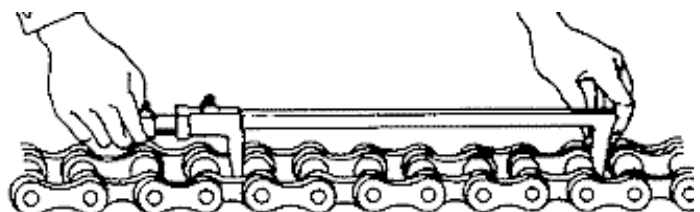
Chain stretch is calculated as the total amount of elongation caused by wear. Chain life can be estimated by measuring chain elongation.

Measuring Chain Elongation:

- The chain should be measured by stretching it slightly
- Measure the distance, using a vernier caliper. Note: When measuring, use at least 6 to 10 links to help keep any measuring error to a minimum. When measurement cannot be done with a vernier caliper, it is possible, though less accurate, to use a tape measure. If a tape measure is used, the measured length should be as long as possible.

Maximum Allowable Chain Elongation

Number of teeth on driving sprocket	Chain Elongation
60 and under	1.5 %
61 to 80	1.2 %
81 to 100	1.0 %
100 and over	0.8 %



Replacement of Chain

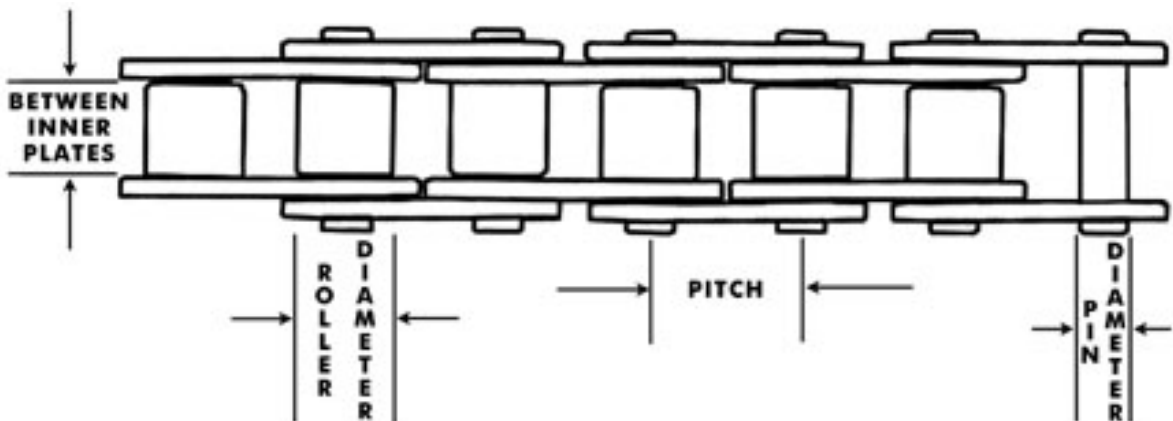
There are two relatively simple methods for cutting Roller Chain. One way is to use bench vise and punch, and the other is to use a chain breaker:

Using a bench vise and punch:

- For riveted type Roller Chain, first grind down one end of the pin to be removed. For split pin type, be sure to take out the pin.
- Put the chain into the vise and tighten the vise to secure the chain.
- Hit the head of the pin with a punch or hammer. Be sure to hit the pins alternately so that they can be removed at the same time.

Note: For riveted types, be sure to grind off the riveted part of the pin. If the pin is taken out without grinding, it will take more time and may damage the chain

3.2.5 Chain Dimension



Chain No.	Pitch	Roller Diameter	Distance between Inner Plates	Pin Diameter
#25	¼	0.130"	1/8	0.091"
#35	3/8	0.200"	3/16	0.141"
#40	½	0.312"	5/16	0.156"
#41	½	0.306"	¼	0.141"
#50	5/8	0.400"	3/8	0.200"
#60	¾	0.468"	½	0.234"
#80	1	0.625"	5/8	0.312"
#100	1 ¼	0.750"	¾	0.375"
#120	1 ½	0.875"	1	0.437"
#140	1 ¾	1.000"	1	0.500"
#160	2	1.112"	1 ¼	0.562"

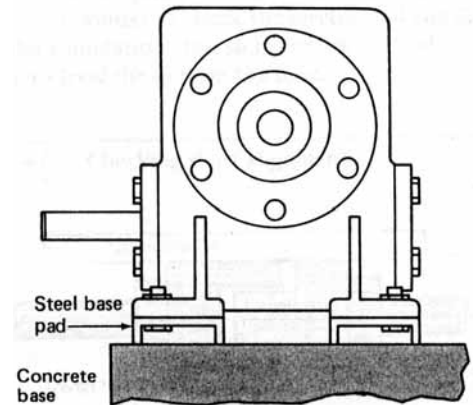
4. MECHANICAL DRIVES – ENCLOSED GEAR DRIVES MAINTENANCE

This chapter will only handle the gear drive related maintenance topics. The “Maintenance & Repair Module 2” will give more detailed information about gear drives in general.

4.1 Gear-Drive Installation

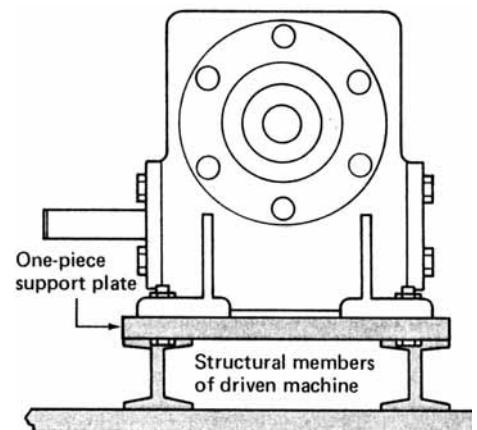
4.1.1 Floor Mounting

The foundation should be always completely solid. It is not advisable to mount a drive direct on the floor. Steel base pads or the newer generation of hard rubber-nylon pads must be used to contact the drive to the floor.



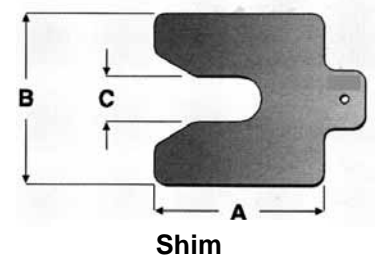
4.1.2 Structural Mounting

Enclosed gear drives are often mounted on the framework of the machine on which they drive. A support plate is used to hold the unit. The plate should be thick enough to support the weight of the drive and to stabilize the whole structure.



4.1.3 Leveling and Fixing the Gear Drive

Lift the gear drive over the mounting bolts or stud bolts and set it carefully down. Install, but do not tighten the fasteners. Use a spirit level to check the levelness of the drive and foundation. Use shims under the feet of the drive to level the unit on the base. Then tighten down all the bolts that hold it in place. Tighten the fasteners crosswise like when you mount a wheel on a car.



4.1.4 Installing the Accessories

Clean the input and output shafts of the gear drive and inspect the key seats in the shaft. Remove burr from the key seat corners. When installing auxiliary drives like belt drive, chain drive or straight coupling, think about the additional loads for the bearings if one of them will be misaligned. Cover all the moving parts with an appropriate casing. Make sure that the oil fill plug and the oil drain plug is accessible and not blocked by a part of the accessories.

4.1.5 Lubricate before Test-Run

Improper or inadequate lubrication is a leading cause of early gear drive failure. In addition, to the gearing, the bearings must be properly lubricated before the test-run.

Most gear drive housings have a small vent called “breather”. This prevents the buildup of pressure or the formation of a vacuum inside the housing and assists the flow of lubricants within the drive. Be sure the breather is in good working condition.

Some gear drives are delivered already with the proper lubrication. Do not rely on that. Check the supply of lubrication and if necessary add some oil or grease. If you install the drive in a very hot or very cold operation environment, check with the manufacturer for special lubrication instructions.

4.1.6 Test Running (no-load test)

Make one final check to see that all the components in the drive package are securely tightened down on the base or foundation. Be sure that you have supplied the gear drive and other parts with the correct amount of the proper lubricant, as recommended by the manufacturers.

Do not connect the system to load. The purpose of no-load test is to see that all drive package components operate properly. It allows you to identify any faulty parts and repair or replace them before they can damage the equipment that is to be driven by the system. Make sure you alert all personnel concerned that you are about to test the drive. Start the motor and listen to unusual sounds.

If there are some strange sounds, stop the drive and disconnect the electric energy line (or lock the switch). After opening the top of the housing, check the gears and the movement of the bearings. Check the lubrication. Check the alignment of the shaft. After location and correction of the difficulty, replace the housing cover and start the drive again.

4.1.7 Run-In

After an acceptable no-load test, slowly apply about 50 % of the operation load. Listen carefully for unusual noises or signs of trouble, as you did when test-running the drive. If possible, allow the drive to operate under this half load for 8 to 10 hours. Check the hold-down bolts. Inspect also the other system components, particular belts, chains and couplings. If everything is o.k, increase the load to full operating level. Check the bearing temperature for excessive heat and watch for signs of abnormal oil leakage.

4.1.8 Condition Monitoring

Include the gear-drive in your condition-monitoring program. Develop a log chart for the drive system. Following the maintenance log, check regular oil level, temperature of bearings, vibration and take oil samples for lubrication analysis. Auxiliary drives should be also included in the maintenance program for the drive.

4.1.9 Storage

If an enclosed gear drive is to be stored in the plant for a longer period before being installed, special treatment is needed:

- Fill the drive completely with oil. Place a tag on the housing stating that the oil must be lowered to operating level before use.
- Keep the external shafts coated with a light film of oil or grease.
- Protect the shafts with clean oil soaked rags.
- Put also some oil on the visible seals to prevent drying out

4.2 Troubleshooting for Enclosed Gear Drives

Symptom	Possible Causes									Potential Solutions									
	Overloads	Lubricant problem	Bearing misaligned	Excessive overhung loads	Shaft misalignment	Insufficient thermal HP capacity	Faulty bearing	Faulty seals	Faulty breather	Check load vs. nameplate HP	Check type and quantity of lubricant	Inspect and replace bearings as needed	Reduce overhung load	Provide more cooling	Replace drive with larger unit	Check breather for functioning	Check and replace seals as needed	Clean up seal contact area on shaft	Check and align shafts
Excessive gear wear	•	•								•	•				•				
Bent or broken shaft	•			•	•					•			•		•				•
High temperature	•	•				•				•	•		•	•					
Bearing noise and failure	•	•	•	•			•					•	•						•
Oil leakage								•	•							•	•	•	
Broken gear teeth	•		•		•					•		•							

5. SHAFT COUPLINGS

Almost every mechanical drive used in industrial plants has a coupling. The main purposes of couplings are:

- To transmit power from a motor or engine to a machine (pump, gear box, fan, etc.)
- To compensate misalignments
- To compensate axial elongation of shafts

Shaft couplings range in size from extremely small ones (servo mechanism) to huge ones (electrical power plant generator).

5.1 Classification of Couplings

Practically we distinguish the following two types of couplings:

- Rigid Couplings
- Flexible Couplings
- Elastic Couplings

5.1.1 Rigid Couplings

Rigid couplings have the function to connect two shafts so that they are joined as made out of one piece. Exactly aligned shafts are required for this coupling type.

Split Coupling:

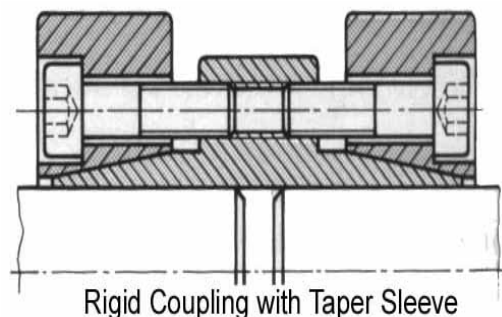
Transfer turning moment by frictional connection. The coupling is slotted and therefore after screwing up pressed against the shafts. The feather keys fix the location.

Uses: For small turning moments and low speeds



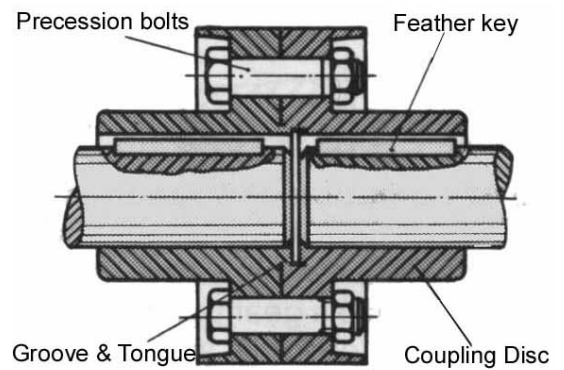
Shaft Coupling with tapered sleeves

Two exactly aligned shafts are connected by screwing up two conical rings on a tapered sleeve. Through the conical rings and sleeves there are so much friction between the sleeve and the shafts, that it is not necessary to use feather keys.



Disc Coupling:

The two half's are joined by precision bolts and transfer the turning moment by frictional connection and interlocking. Exact running of the shafts are guaranteed through groove and tongue connections.

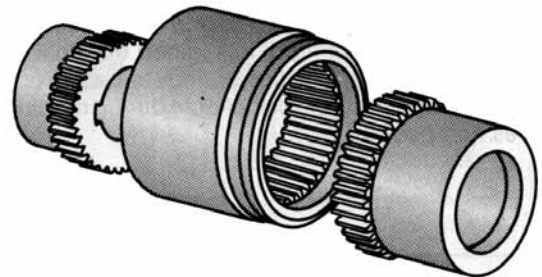


5.1.2 Flexible Couplings

These type of couplings transfer the turning moment through positive locking. They offer sufficient flexibility for small changes in length and displacement of shafts.

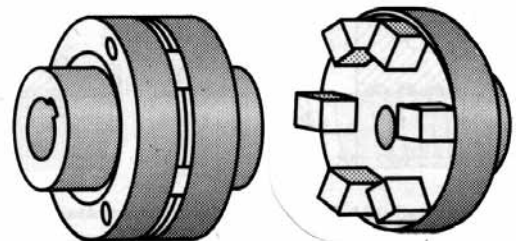
Curved Teeth Coupling

To lock or unlock the coupling the toothed coupling muff is moveable designed. This can also compensate the elongation of the shafts. Used for high torques.



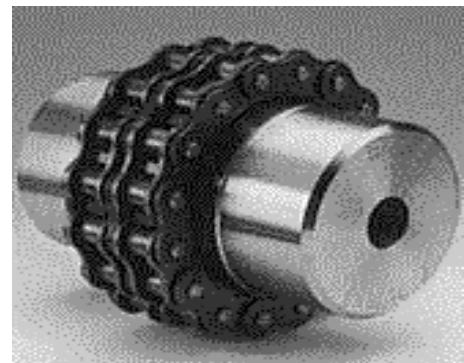
Claw Coupling

They transfer the turning moment with interlocking claws. Easy to install. Flexible enough to compensate some misalignment and some elongation of the shafts.



Roller Chain Coupling

The Roller Chain Coupling is a safe, compact and powerful flexible coupling, able to handle loads from 0.1 - 11,000 kW. The sprocket teeth are specially shaped and hardened, and torque is evenly apportioned



5.1.3 Elastic Couplings

These type of couplings transfer the turning moment through elastic elements. Bumps and vibrations are softened. The start of the driven machine is a little bit delayed because of the deformation of the rubber element, which is an advantage for the bearings. Elastic couplings offer sufficient play for small changes in length and displacement of shafts.

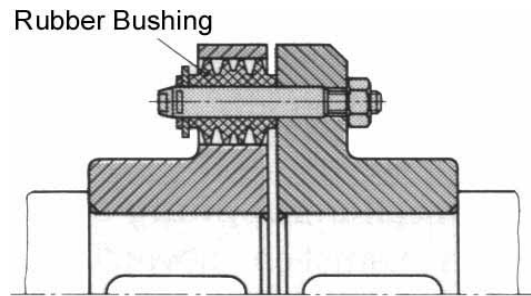
Claw Coupling with rubber elements

They transfer the turning moment with interlocking claws. Easy to install. Between the claws there is a rubber element inserted.



Disc Coupling with rubber bush

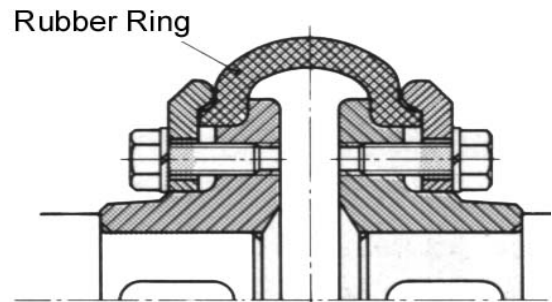
Both coupling discs are joined with precise machined alignment pins. One half of the coupling comes with holes in which are the rubber elements inserted.



Elastic Coupling with Rubber-Bush

Rubber Ring Coupling

Both coupling discs are joined by a firmly clamped rubber ring. This rubber ring is strengthened by fiber layers similar to an automotive tire.



Elastic Coupling with Rubber Ring

5.2 Proper Coupling Selection

To make a good selection of coupling for the given application it is necessary to know some basics.

- **Horsepower** -- Almost every coupling is sized based on the horsepower to be transmitted. The exceptions would be chain and rigid designs, which are selected based on the shaft diameters to be coupled.
- **Type of Drive** -- If the power source is a reciprocating engine, there can be problems with torsional vibration in a continuous steady form, which can be transmitted directly into the driven machine. The elastomeric design coupling can help to dampen this vibration.
- **Type of Driven Equipment** -- Driven machines are classified according to their load characteristics, and a service factor is assigned based on those characteristics. Multiplication of the service factor by the input horsepower gives you the design horsepower upon which most couplings are sized.
- **Coupling Operating Speed** -- Most selections are based on the HP at a certain RPM. As always, as the speed goes down the torque goes up. The other thing to check is that the maximum speed of the selected coupling is not exceeded.
- **Shaft Sizes** – The selected coupling must fit to the bore required. In many instances, it is necessary to go to a larger coupling than design would indicate in order to get the bore size you need.
- **Space Limitations** – The coupling's length and diameter must fit within the necessary confines.
- **Environment** -- If the environmental temperature it is over 77 degrees C or below -34 degrees C it can change the operating characteristics of an elastomeric coupling or effect the lubrication of a mechanically flexible coupling. If the environment is wet or oily, it limits the types of couplings you can consider. There are many environmental related things, which can affect the service life of a coupling.

6. SHAFT ALIGNMENT (COUPLING ALIGNMENT)

What is the Objective of accurate alignment?

The objective of shaft alignment is to increase the operating lifespan of rotating machinery. To achieve this goal, machinery components that are most likely to fail must operate within their design limits. Since the components that are most likely to fail are the bearings, seals, coupling, and shafts, accurately aligned machinery will achieve the following results:

- Reduce excessive axial and radial forces on the bearings to insure longer bearing life and rotor stability under dynamic operating conditions
- Minimize the amount of shaft bending from the point of power transmission in the coupling to the coupling-end-bearing
- Minimize the amount of wear in the coupling components
- Reduce mechanical seal failure
- Maintain proper internal rotor clearances
- Lower vibration levels in machine casings, bearing housings, and rotors

What are the Symptoms of misalignment?

Misalignment is not easy to detect on machinery that is running. Misalignment will be only obvious through secondary effects of the following symptoms:

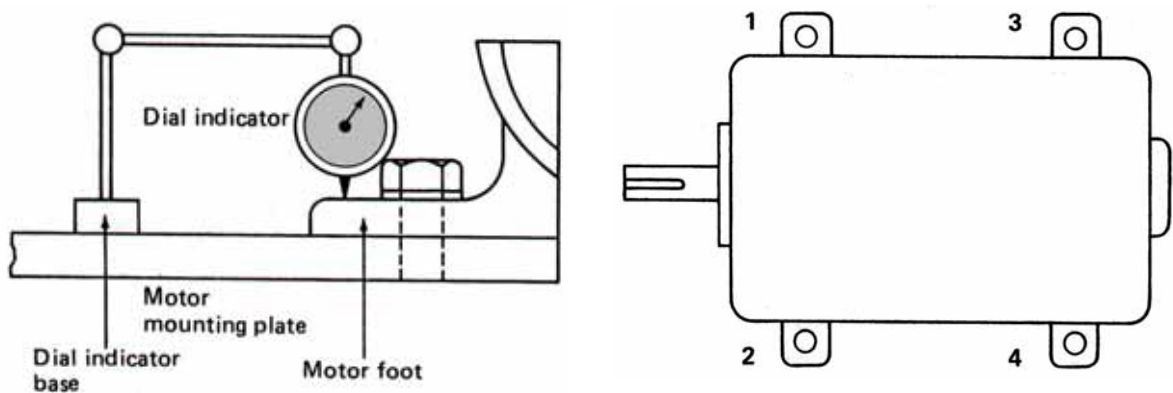
- Premature bearing, seal, shaft, or coupling failures
- Excessive vibration
- High casing temperatures at or near the bearings or high oil temperatures
- Excessive amount of oil leakage at the bearing seals
- Loose foundation bolts
- Loose or broken coupling bolts
- Some flexible coupling designs run hot under misalignment conditions. If it is an elastomeric type, look for rubber powder inside the coupling
- Unusually high number of coupling failures or they wear quickly
- The shafts are breaking (or cracking) at or close to the inboard bearings or coupling hubs

6.1 What to Align?

- Mounting Foot Leveling
- Alignment of Coupling Faces – Angular (coupling faces parallel)
- Alignment of Coupling Contour – Horizontal (bring them to same height)
- Alignment of Coupling Contours – Parallel (align them sideways)
- Adjusting the Gap between Coupling Half's (not all couplings!)

6.1.1 Mounting Foot Leveling

In the figure below you can see a plan view of a typical electric motor. This method is designed for rather bigger motors. Take the following steps to level the electro motor feet:

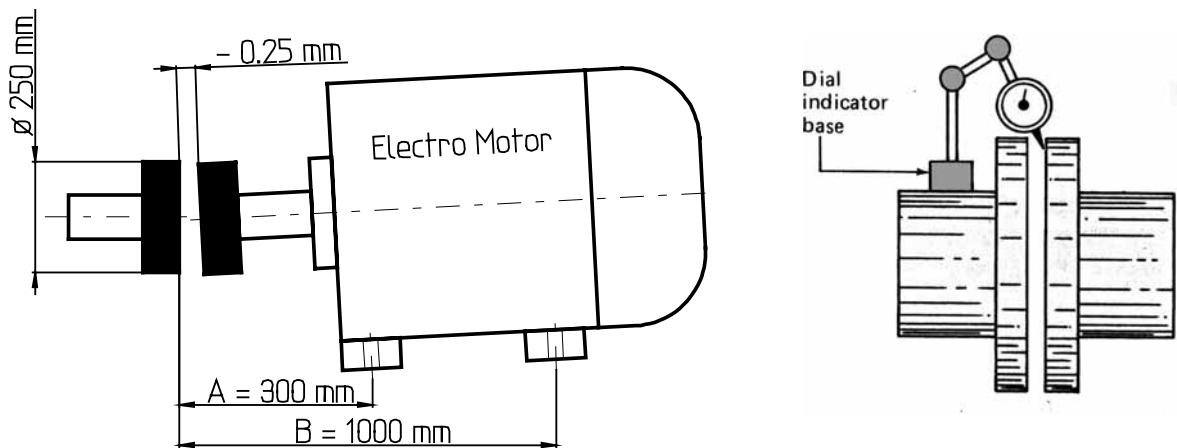


1. Tighten all four motor bolts.
2. Place the dial indicator on a clean surface of the motor mounting plate
3. Clean the indicator contact area on the motor foot (make use of a file)
4. Start with No.1, and place the point of the dial indicator on the cleaned surface
5. Set the dial indicator at zero.
6. Loosen the bolt holding down foot No. 1 and also the bolt of the next closed foot (No. 2)
7. Read the dial indicator to determine the amount of spring that has occurred.
8. Insert shims under foot No. 1 to take up the amount of spring.
9. Next, tighten all four motor bolts again. Move the dial indicator to foot No. 2. Repeat the procedure of loosening the bolts, reading the amount of spring, shimming, and re-tightening the bolts.
10. Move on to feet No. 3 and No. 4, following the same methods. If the dial indicator shows that no spring has occurred, then you need not add any shims under that particular foot. After you have removed all of the spring from the motor feet, the bolts will be relieved of excessive tension, and coupling alignment will be easier to accomplish.

6.1.2 Alignment of Coupling Faces – Angular (coupling faces parallel)

There are two common methods on how to determine the misalignment of the coupling faces.

- The dial gauge method
- The feeler gauge method



The Dial Gauge Method

Some computation is necessary to determine the shim thickness required to align couplings in an angular plane. Mount the dial indicator on one of the coupling half's and place the point of the indicator on the inside face of the other half. Turn the coupling half with the dial indicator 360 degree around and measure the misalignment.

In the example the angular misalignment on the top is **-0.25 mm**.

The diameter "D" of the coupling is **250 mm**.

The distance "A", from the inside of the driven half to the centerline of the motors closer motor feet is **300 mm**.

The distance "B", from the inside of the driven half to the centerline of the motors farther motor feet is **1000 mm**.

To compute the required shim thickness under the motors **closer** and motor **farther** feet to correct the **-0.25 mm** angular misalignment, use the following formulas:

Shim (S) needed under closer feet:

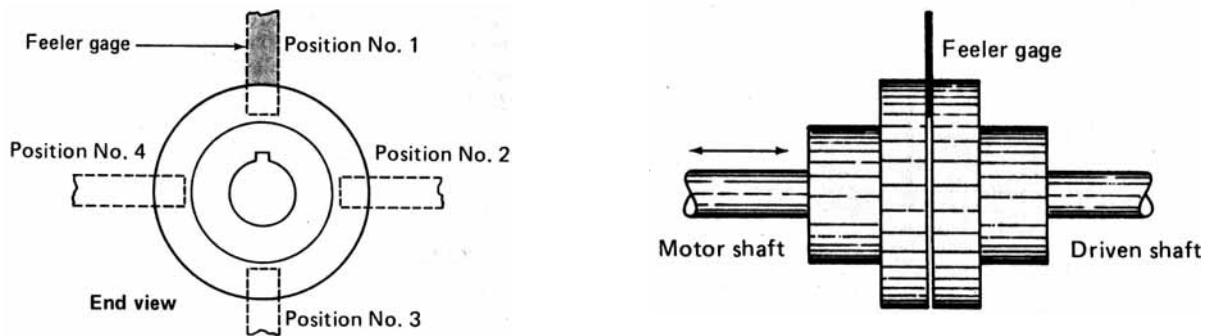
$$\begin{aligned}
 S &= \text{Indicator reading} \times A/D \\
 S &= -0.25 \text{ mm} \times 300 \text{ mm}/250 \text{ mm} \\
 S &= \mathbf{-0.3 \text{ mm}}
 \end{aligned}$$

Shim (S) needed under farther feet:

$$\begin{aligned}
 S &= \text{Indicator reading} \times B/D \\
 S &= -0.25 \text{ mm} \times 1000 \text{ mm}/250 \text{ mm} \\
 S &= \mathbf{-1 \text{ mm}}
 \end{aligned}$$

The Feeler Gauge Method

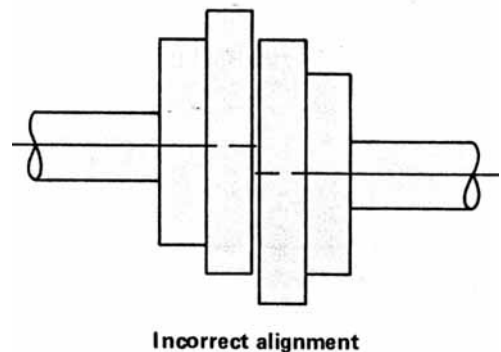
Move the (not fully fastened) motor near the already fixed driven unit, until the gap is just a little larger than the specified gap. Simply insert the feeler gauge between the coupling half's at several positions as shown on the picture below. If the gauge cannot enter at some positions, the shafts are out of angular alignment. To correct this condition, place shims under the motor feet. Always try to align the shaft as accurately as you can.



6.1.3 Alignment of Coupling Contour – Horizontal (bring them to same height)

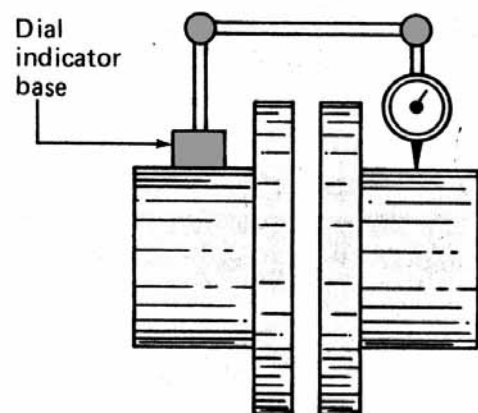
There are two common methods on how to determine the misalignment in height:

- The dial gauge method
- The straight edge method



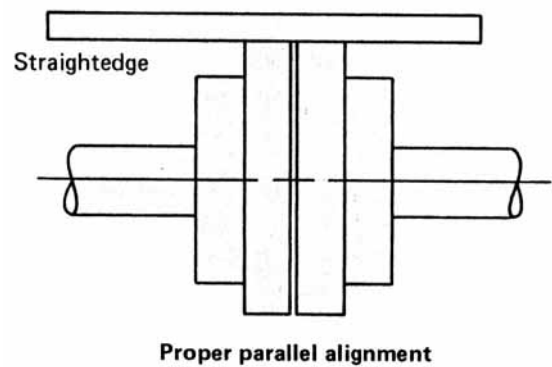
Dial Gauge Method –Horizontal Alignment

If the coupling installation requires more precise alignment of the shafts, then use precision instruments for the job. Mount the dial indicator on one of the coupling half's and place the point of the indicator in contact with the top of the other half. Manually turn the half on which the dial indicator is mounted to take four readings at points around the other coupling half. Use shims to raise the lower unit.



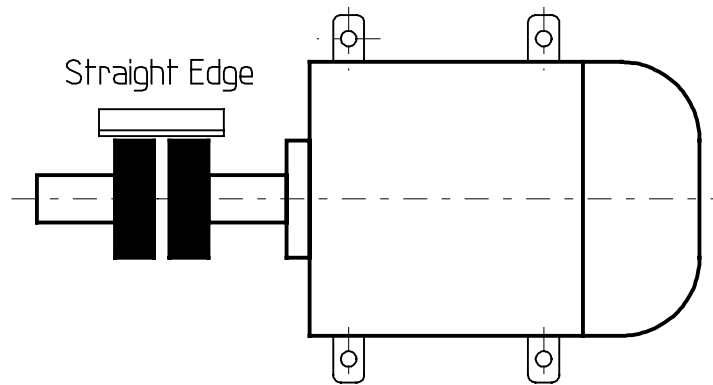
Straight Edge Method

In addition to checking the angular alignment of the shafts, it is necessary to make sure that they are horizontal aligned. To check this, place a straightedge across the tops of the coupling half. Adjust the height of the motor shaft as needed to bring the shafts into alignment.



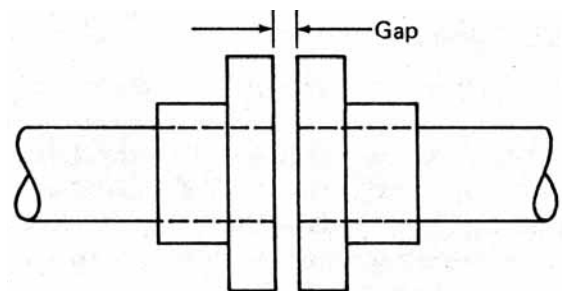
6.1.4 Alignment of Coupling Contours – Parallel (align them sideways)

In addition to checking the horizontal alignment of the shafts, it is necessary to make sure that they are sideways aligned. To check this, place a straightedge sideways of the coupling half. Adjust the motor.

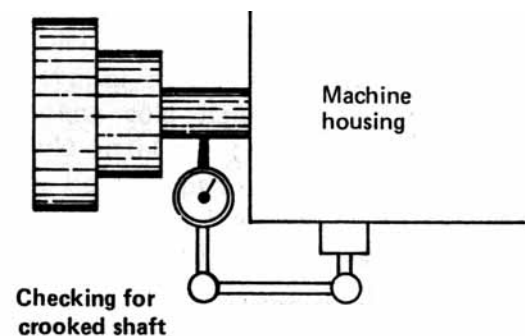


6.1.5 Adjusting the gap between the Coupling Half's

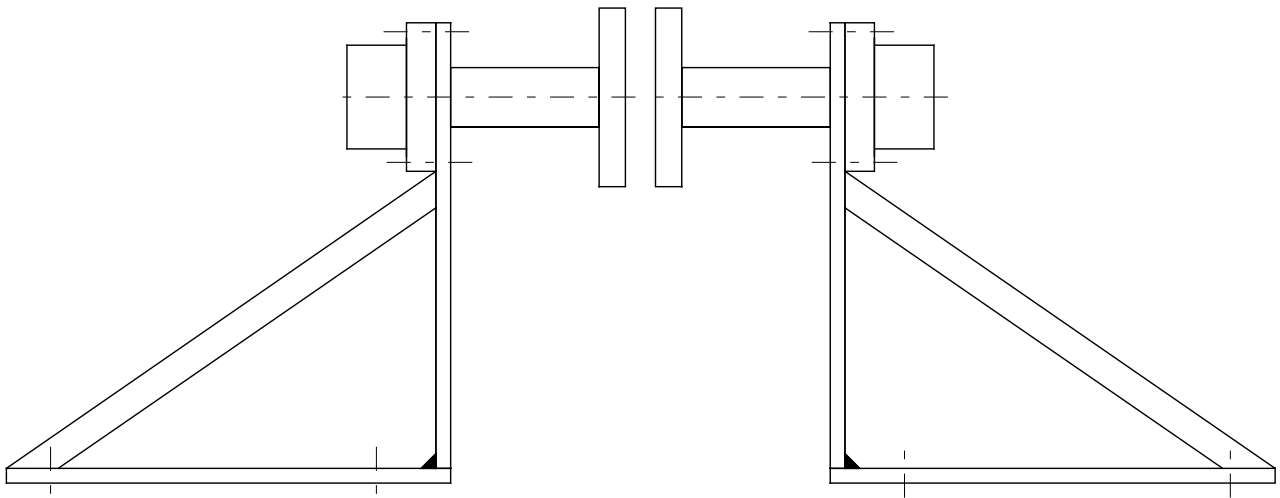
The gap between the faces of the two coupling half's is essential for the proper operation of the whole drive unit. The amount of gap required for the specific type of coupling is usually provided by the manufacturer.



Sometimes it is necessary to check also the shaft against crook. The picture besides shows how to handle this method.



Exercise - Steps of Coupling Alignment



Case: Pump was removed for repair

1. Put motor and pump in place
2. Fix both of them (not too tight)
3. Check parallelism of coupling using either feeler gauge method or dial gauge method
4. Calculate the necessary shim sizes, using the calculation method
5. Remove or add shims at motor or pump
6. Check one by one all motor feet for leveling (clearance)
7. If necessary correct leveling of motor feet
8. Proceed with horizontal alignment of coupling
9. Remove or add shims at motor or pump
10. Adjust the gap of coupling
11. Radial (sideward) alignment of coupling, using the straight edge method
12. Tight all bolts
13. Final check of all alignments, using the dial gauge

7. Safety Precautions for the Maintenance of Mechanical Drives

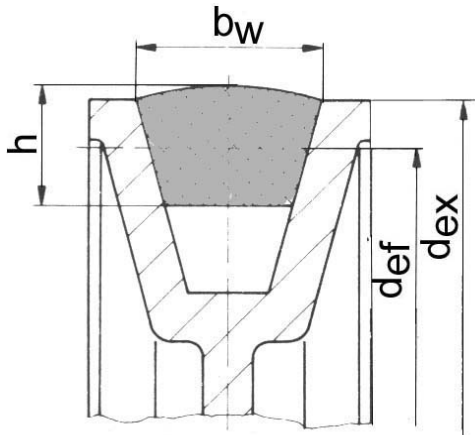
Maintaining drives, like discussed in the chapters before (chain drive, belt drive, gear drive etc.), is under disregard of safety rules a dangerous procedure.

Comply with the following to avoid serious personal injury:

- Use always care to prevent injury
- Wear the personal protective equipment like protective clothing, safety goggles, safety shoes and when necessary safety gloves.
- Guards must be provided to cover the moving parts of mechanical drives
- Before starting to work on a mechanical drive, **STOP** the machine and **LOCK-OUT** the power. Let your fellow workers know that you are – or will be – working on it.
- Never strain yourself by lifting or shifting mechanical parts that are too heavy. Use proper lifting devices for handling heavy parts.
- Before starting a test-run clean up the workplace and remove all tools, containers, etc.
- Clean up all grease, solvent and lubricant spills. Wipe the area incl. the mechanical drive with couplings and the protection cover dry and clean.
- Before you start up the drive, make sure that all fasteners are tight and all guards are in place. Inform all the workers near the mechanical drive that you start the test-run.
- Stay at the beginning of the test-run near the power switch. In case of any unusual sound or vibration, switch off the drive immediately.

8. CALCULATION OF SPEED FOR V-BELT DRIVE AND GEAR DRIVE

8.1 Single V-Belt Drive



- h = belt height
- b_w = upper belt width
- d_{ex} = external diameter
- d_{ef} = effective diameter
- n = revolution per minute (rpm)

Calculation of V-belt drives is done on the basis of the effective diameter of the pulley.

$$\text{effective diameter} = \text{external diameter} - 2 \times \text{belt height} / 2$$

$$d_{ef} = d_{ex} - 2 \times h / 2$$

Since we have a driving pulley and a driven pulley we have to give them different formula abbreviations. Driving pulley = d_{ef1} and driven pulley = d_{ef2}

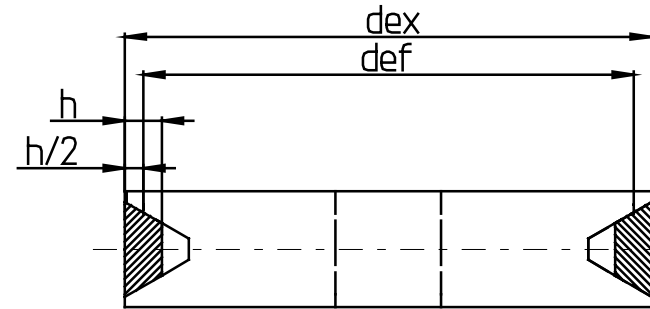
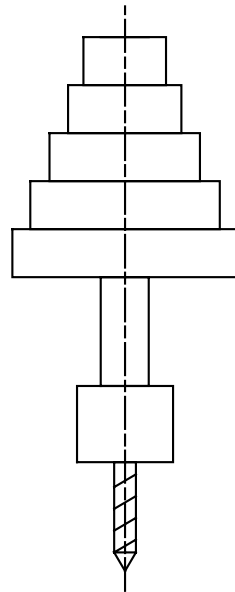
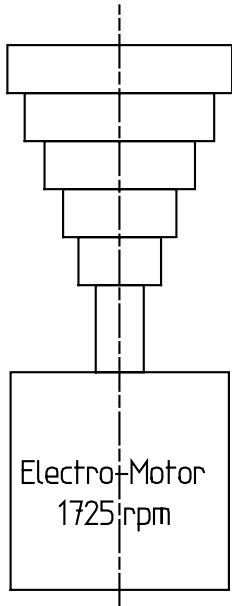
$$\begin{aligned} \text{driving } d \times n &= \text{driven } d \times n \\ d_{ef1} \times n_1 &= d_{ef2} \times n_2 \end{aligned}$$

$$n_1 = \frac{d_{ef2} \times n_2}{d_{ef1}}$$

The transmission ration (i) is the ratio between the the input and output speeds.

$$i = \frac{n_1}{n_2} = \frac{d_{ef1}}{d_{ef2}}$$

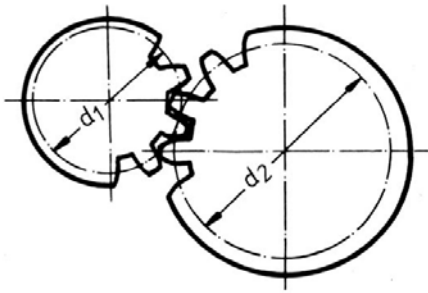
Exercise in in Spindle Speed Calculation – Workshop Drill Press CDC



$$\text{Spindle Speed} = \frac{\text{Motor Speed} \times \text{Pulley Diameter}_{ef1}}{\text{Pulley Diameter}_{ef2}}$$

Transmission Step	Drive Side		Driven Side		Spindle Speed
	Outside \varnothing of pulley (d_{ex})	Effective \varnothing of pulley (d_{ef}) $d_{ef} = d_{ex} - 2 \times h/2$	Outside \varnothing of pulley (d_{ex})	Effective \varnothing of pulley (d_{ef}) $d_{ef} = d_{ex} - 2 \times h/2$	
1					
2					
3					
4					
5					

8.2 Simple Gear Drive



- d** = pitch diameter
- n** = revolution per minute (rpm)
- z** = number of teeth
- i** = transmission ratio

Since we have a driving gear and a driven gear we have to give them different formulary abbreviations.

Driving gear = **d₁** and driven gear = **d₂**

Driving gear = **n₁** and driven gear = **n₂**

Driving gear = **z₁** and driven gear = **z₂**

Claculation of speed using the pitch diameters

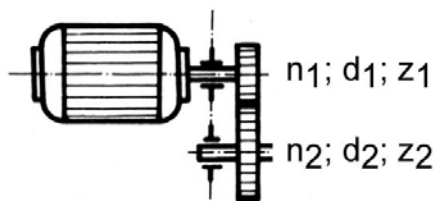
$$d_1 \times n_1 = d_2 \times n_2$$

$$n_2 = \frac{d_1 \times n_1}{d_2}$$

Claculation of speed using the number of teeth

$$z_1 \times n_1 = z_2 \times n_2$$

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



Ratio (i) calculation:

$$i = \frac{\text{driving r.p.m.}}{\text{driven r.p.m.}} = \frac{n_1}{n_2} = \frac{d_2}{d_1} = \frac{z_2}{z_1}$$

Exercises in calculating simple Gear Drives

Calculation of electric hand drill

In a hand drill, the motor rpm of 3600 1/min is transmitted to the drill spindle via two gears with 8 teeth and 32 teeth. Calculate the rpm of the drill spindle.

Find:

Given:

Solution:

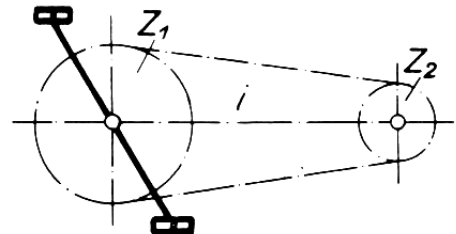
Calculation of ratio of bicycle drive

Calculate the transmission ratio between the pedal wheel with 48 teeth and a pinion with 15 teeth.

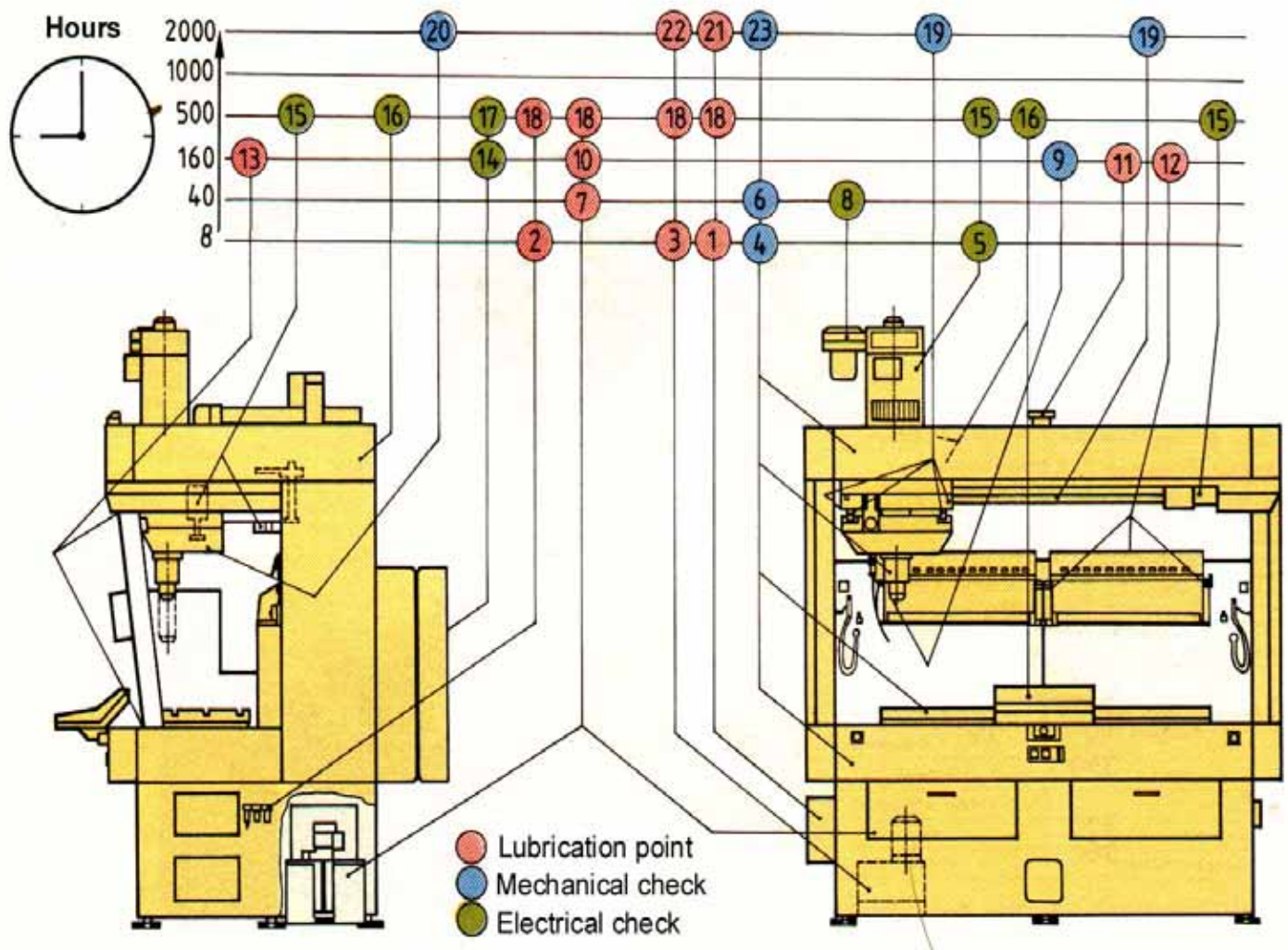
Find: Ratio i

Given:

Solution:



EXAMPLE OF A DETAILED MAINTENANCE CHART FOR A MILLING MACHINE



CLEANING MACHINE FOR MAINTENANCE DEPARTMENT



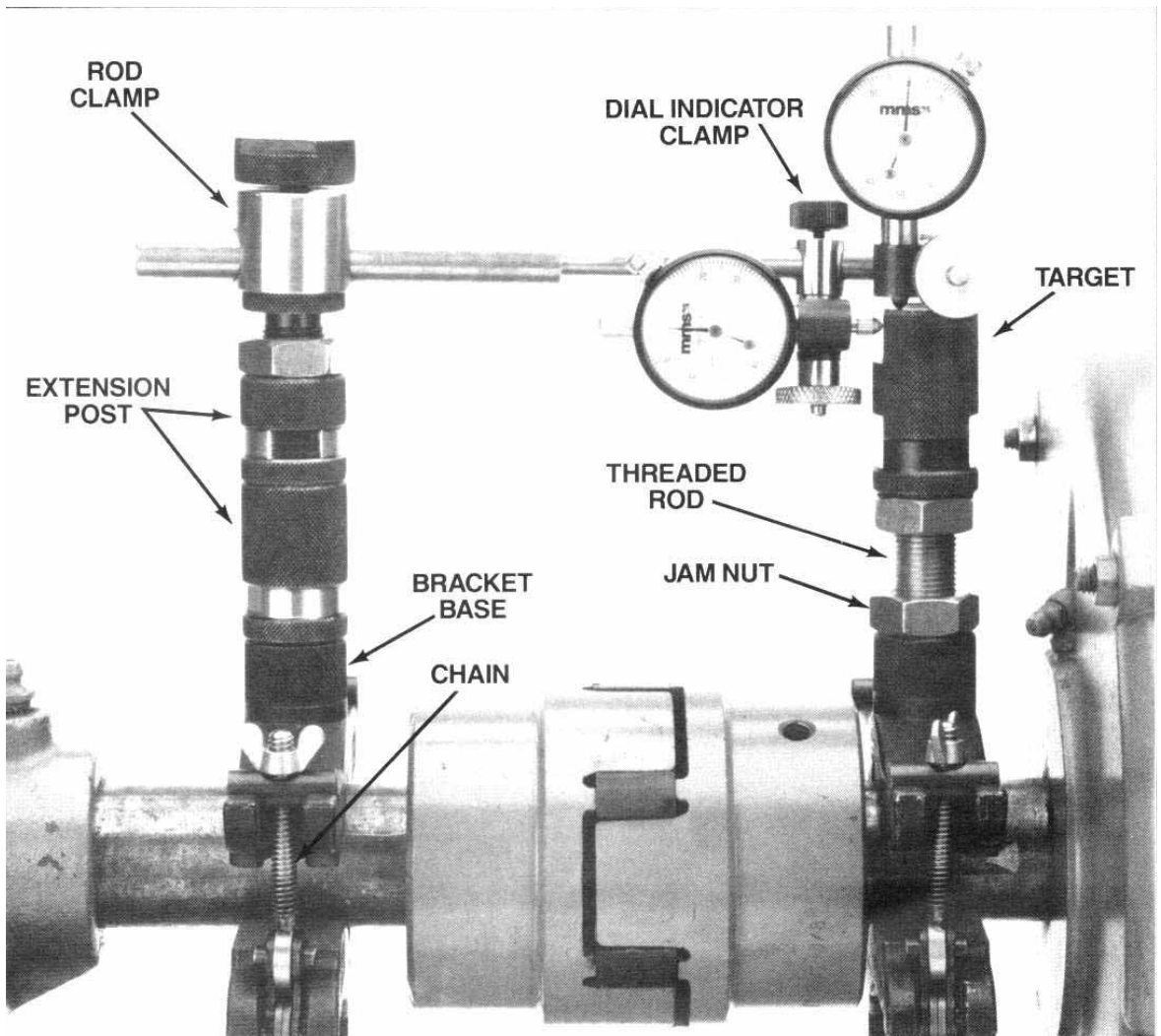
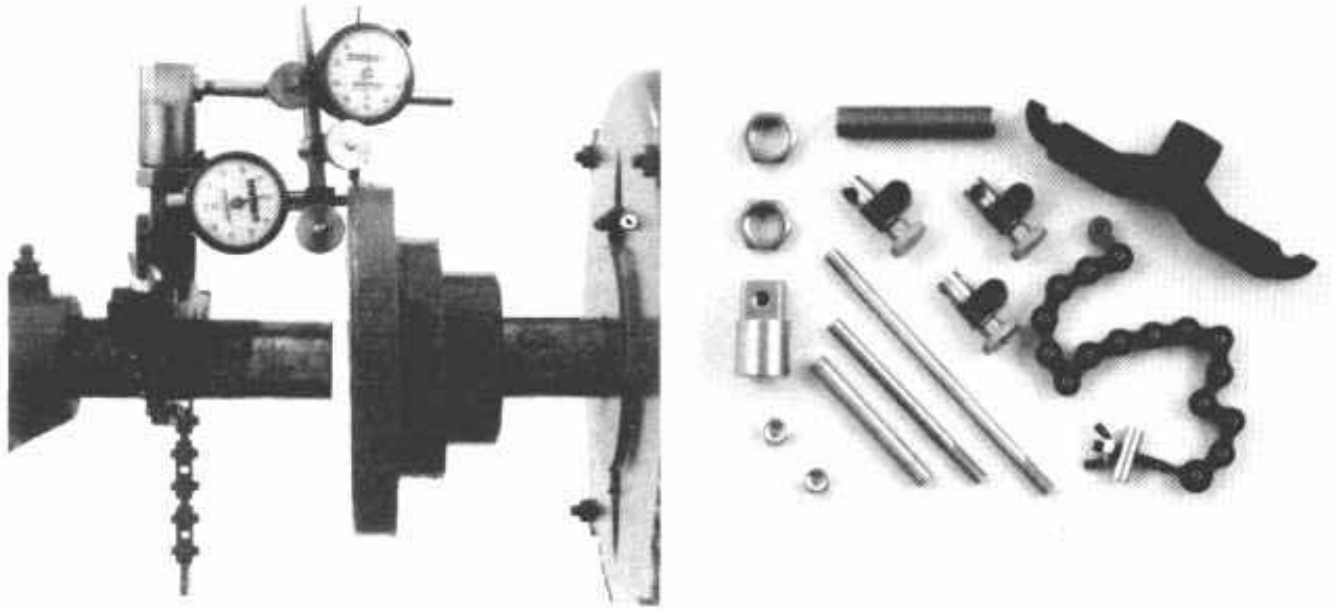
MAINTENANCE SYSTEM - IMPLEMENTATION KEY STEPS:

1. Number the equipment.
 2. Create a file for each equipment
 3. Gather data on the equipment (manuals).
 4. Develop Preventive Maintenance task and daily routines.
 5. Review existing maintenance service.
 6. Implement a work order system.
 7. Implement an inventory system for spare parts and consumables.
 8. Develop a purchasing system that meets the needs of the maintenance department.
 9. Train the management team on the process and its specific elements.
 10. Communicate to the entire maintenance team the pending changes and their involvement in the process.
 11. Train specific individuals such as the planner and inventory clerk.
 12. Use the complete system on a small scale to test the process.
 13. Modify the process as required.
 14. Document the process.
 15. Perform a skill's assessment of the work force.
 16. Establish a training program to correct skills deficiencies.
 17. Report final results to the Plant Manager.
 18. Establish a follow up audit in 6-12 months.
-

LASER BASED SHAFT ALIGNMENT TOOL



MANUAL SHAFT ALIGNMENT TOOLS

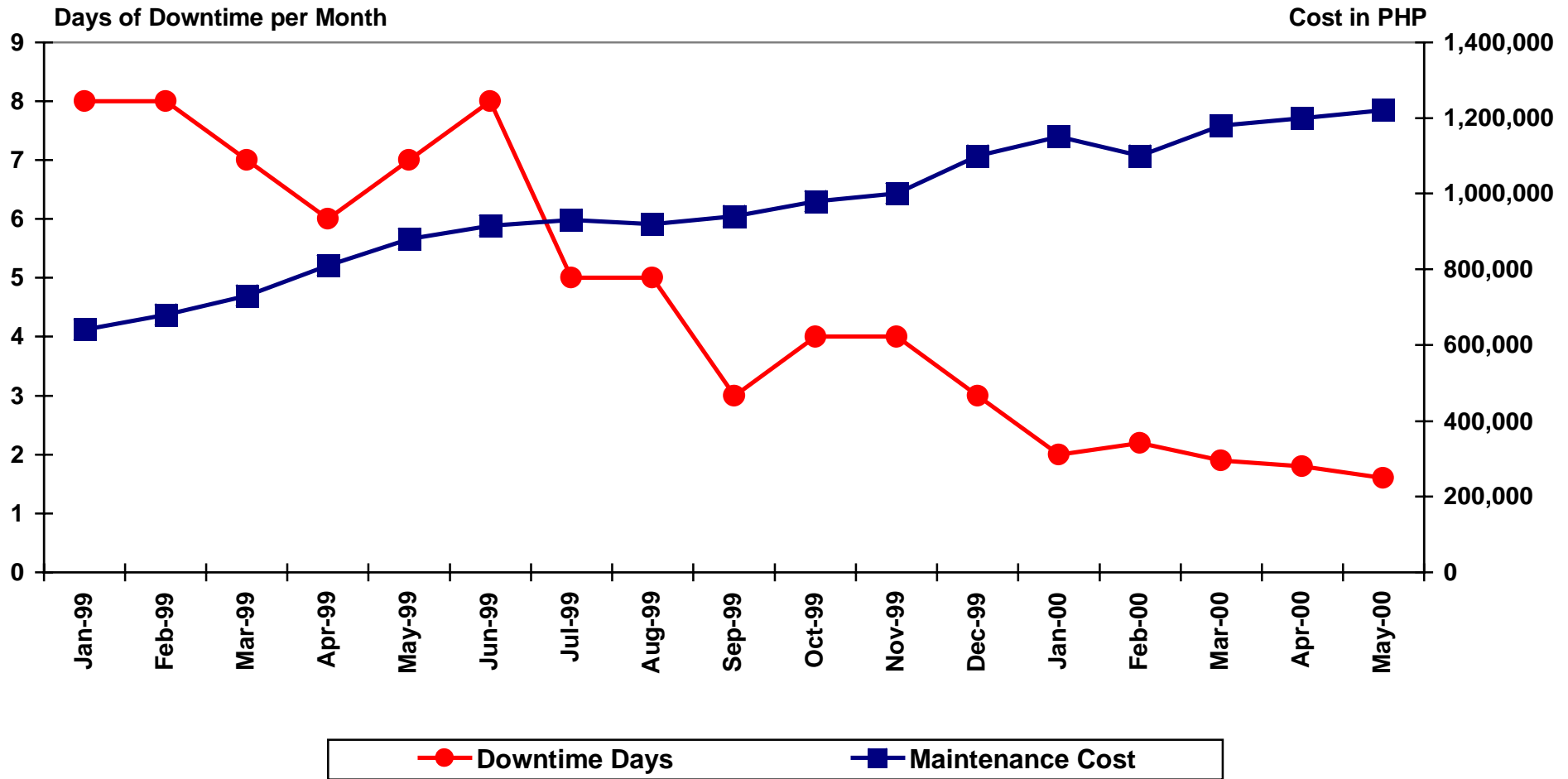


Maintenance Strategies – Output of Discussion Batch #41

Strategies	Advantages	Disadvantages	Use
Run to failure	<ul style="list-style-type: none"> • Cheap because small overhead cost 	<ul style="list-style-type: none"> • Unplanned Downtime • Higher repair cost 	<ul style="list-style-type: none"> • Simple & cheap machinery • Low value products
Preventive Maintenance	<ul style="list-style-type: none"> • Scheduled work • Less Downtime • Less repair cost 	<ul style="list-style-type: none"> • Higher overhead cost • Long preparation time 	<ul style="list-style-type: none"> • Complicated & expensive machinery • Bigger industrial plants • High value products
Predictive Maintenance	<ul style="list-style-type: none"> • Less downtime • Make use of lifetime span for equipment • Less repair cost 	<ul style="list-style-type: none"> • High overhead cost • High equipment cost • Training cost for manpower • High salary for trained people 	<ul style="list-style-type: none"> • Critical equipment • Expensive equipment • High value products • Bigger industrial plant
Planned Overhauling	<ul style="list-style-type: none"> • Less downtime during running period • Reconditioning of complete machine • Planning and scheduling in advance • Good preparation 	<ul style="list-style-type: none"> • Loose of production time • More manpower through sub-contractual works • More workload to the planners 	<ul style="list-style-type: none"> • Seasonal machinery • When low production or storage is full • Expensive critical equipment
Redundancy	<ul style="list-style-type: none"> • Less Downtime • Time to repair broken equipment • Less manpower 	<ul style="list-style-type: none"> • Higher cost because of double equipment • Higher cost for installation • Spare machinery damage during storage for long period 	<ul style="list-style-type: none"> • Very critical products or processes • Bigger industrial plants • Expensive and critical equipment

Minimizing Downtime at any Price?

Days of Downtime per Month vs Total Maintenance Cost



GLOSSARY

Unplanned Maintenance - any maintenance activity for which a pre-determined job procedure has not been documented, or for which all labor, materials, tools, and equipment required to carry out the task have been not been estimated, and their availability assured before commencement of the task.

Unscheduled Maintenance - any maintenance work that has not been included on an approved Maintenance Schedule prior to its commencement.

Predictive Maintenance - an equipment maintenance strategy based on measuring the condition of equipment in order to assess whether it will fail during some future period, and then taking appropriate action to avoid the consequences of that failure. The condition of equipment could be monitored using Condition Monitoring, Statistical Process Control techniques, by monitoring equipment performance, or through the use of the Human Senses. The terms Condition Based Maintenance, On-Condition Maintenance and Predictive Maintenance can be used interchangeably.

Vibration Analysis - the process of monitoring the condition of equipment, and the diagnosis of faults in equipment through the measurement and analysis of vibration within that equipment. Typically conducted through hand-held or permanently positioned accelerometers placed on key measurement points on the equipment. Commonly used on most large items of rotating equipment, such as turbines, centrifugal pumps, motors, gearboxes etc.

Work Order - The prime document used by the maintenance function to manage maintenance tasks. It may include such information as a description of the work required, the task priority, the job procedure to be followed, the parts, materials, tools and equipment required to complete the job, the labor hours, costs and materials consumed in completing the task, as well as key information on failure causes, what work was performed etc.

Work Request - The prime document raised by user departments requesting the initiation of a maintenance task. This is usually converted to a work order after the work request has been authorised for completion.

Tribology - the process of monitoring the condition of equipment through the analysis of properties of its lubricating and other oils. Typically conducted through the measurement of particulates in the oil, or the measurement of the chemical composition of the oil (Spectrographic Oil Analysis). Commonly used for monitoring the condition of large gearboxes, engines and transformers, amongst other applications

Thermography - the process of monitoring the condition of equipment through the measurement and analysis of heat. Typically conducted through the use of infra-red cameras and associated software. Commonly used for monitoring the condition of high voltage insulators and electrical connections, as well as for monitoring the condition of refractory in furnaces and boilers, amongst other applications. Shutdown - that period of time when equipment is out of service. Shutdown Maintenance - Maintenance that can only be performed while equipment is shutdown

Run-to-Failure - No Scheduled Maintenance - an Equipment Maintenance Strategy, where no routine maintenance tasks are performed on the equipment. The only maintenance performed on the

equipment is Corrective Maintenance, and then only after the equipment has suffered a failure. Also described as a No Scheduled Maintenance strategy.

Repair - any activity which returns the capability of an asset that has failed to a level of performance equal to, or greater than, that specified by its Functions, but not greater than its original maximum capability. An activity which increases the maximum capability of an asset is a modification.

Purchase Requisition - The prime document raised by user departments authorising the purchase of specific materials, parts, supplies, equipment or services from external suppliers.

Purchase Order - The prime document raised by an organisation, and issued to an external supplier, ordering specific materials, parts, supplies, equipment or services.

Maintenance Policy - a statement of principle used to guide Maintenance Management decision making.

Maintenance Schedule - a list of planned maintenance tasks to be performed during a given time period, together with the expected start times and durations of each of these tasks. Schedules can apply to different time periods (eg. Daily Schedule, Weekly Schedule etc.)

Maintenance Strategy - a long-term plan, covering all aspects of maintenance management which sets the direction for maintenance management, and contains firm action plans for achieving a desired future state for the maintenance function.

Failure - an item of equipment has suffered a failure when it is no longer capable of fulfilling one or more of its intended functions. Note that an item does not need to be completely unable to function to have suffered a failure. For example, a pump that is still operating, but is not capable of pumping the required flow rate, has failed. In Reliability Centered Maintenance terminology, a failure is often called a Functional Failure. Would you classify a planned equipment shutdown as a failure? Would you classify a routine equipment shutdown at shift change as a failure? Under this definition, the answer in the first case would be yes, but in the second case would be no. The justification for the inclusion of planned shutdowns as failures is that a failure, as defined, causes a disruption to the desired steady-state nature of the production process, and therefore should, ideally, be avoided.

Maintenance & Repair Module 1 – Course

Introductory Questions to the Trainees

The Trainer should ask these questions to get an overview about the knowledge and the work of the participants. He will be able to understand the structure of the company in terms of maintenance.

1. Profession and experience of trainees?
2. Did you attend trainings like this before?
3. Why does a company need maintenance personnel?
Because each machine can fail and break down. If all machines would be perfect, there would be no need for maintenance personnel.
4. What kind of machinery needs maintenance?
All rotating machines like: Pumps, Gear-boxes, Exhaust fan, Compressor, Dryer, and Mixer. But also Pipelines, Pressure valves, boilers
5. What kind of maintenance jobs do you perform?
Repair, Overhauling, Preventive Maintenance
6. How is your daily work balanced (scheduled or unscheduled)?
Scheduled work should predominate the unskilled work.
7. How is your maintenance department organized?
Manager, Planner, Supervisor
8. How is a maintenance order processed?
Verbally or through, job order form. Is there a given time to finish the job?
9. What kind of maintenance strategy do you follow in your company?
Important to give later some proposals how to improve.
10. Do you follow a maintenance schedule for the routine jobs?
Important to give later some proposals how to improve.
11. Do you fill up a maintenance log for each machine?
Important to give later some proposals how to improve.
12. Do you fill up a maintenance history log for each repair?
Important to give later some proposals how to improve.
13. What kind of condition monitoring tools do you use?
The 7 tools

MAINTENANCE & REPAIR MODULE 1 – FINAL KNOWLEDGE TEST

1. Which of the following statements about Maintenance is the most important one?

- a. Maintenance of industrial equipment is cheap.
- b. Maintenance should eliminate or reduce downtime.
- c. There is no need for skilled personnel in maintenance.
- d. Maintenance is not so important.

2. Name at least 3 different Maintenance Strategies.

3. What information does the Maintenance Log show?

- a. The cost of equipment.
- b. The order numbers of spare parts.
- c. The history of Condition Monitoring
- d. The preventive Maintenance Schedule.

4. What information does the Maintenance History show?

- a. The date of last oil check.
- b. The order numbers of spare parts.
- c. The length of belt drive.
- d. The history of all repair activities.

5. Which of the following statements about tensioning V-belts is true?

- a. Too little tension can damage bearing.
- b. Apply enough tension to prevent slipping.
- c. Only the trained experts from the manufacturer should tension belts.
- d. To little tension will change the center of pulley distance.

6. When do V-belts transmit power most efficiently?

- a. When the V-Belt sides contact the groove sides.
- b. When the top of the belt is higher than the pulley.
- c. When the bottom of the belt rests on the groove bottom.
- d. When the belt sides contact the bottom and the groove sides.

7. After a run-in period the belt should be

8. The most common cause of chain-drive failure is improper or inadequate

9. A chain begins to ride higher and higher on the sprocket teeth when it becomes worn and

.....

10. Which is the right lubrication method for very slow chain drives?

- a. Splash
- b. Manual
- c. Permanent
- d. Drip oiler

11. After how many hours of operation should you inspect a new chain drive?

- a. 24 hr
- b. 72 hr
- c. 120 hr
- d. 168 hr

12. Name at least one advantage and one disadvantage of chain drives

_____	_____
_____	_____

13. Name the 3 classifications of couplings

_____	_____

14. What is not important for the coupling selection?

- a. The horsepower to be transmitted
- b. The operation speed
- c. The environmental temperature, which will affect the coupling
- d. The type and size of ball bearing used in the electric motor

15. If a gear drive is noisy during no-load testing, what should you do?

- a. Inspect the gear teeth
- b. Check the oil reservoir
- c. Inspect the shaft and the bearings
- d. No. a., b., and c.

16. Name 3 methods to align couplings

_____	_____

17. Name 2 couplings, which allow longitude expansion of the shaft

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