Ferrous Materials

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Ferrous Materials

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1. General

Educational material for courses on metallography divides naturally into the following subjects: Fundamentals of general metallography; ferrous materials; nonferrous materials and their alloys; materials testing; corrosion and corrosion prevention.

This series of projection films can be used for the theoretical and practical education and training in metal fabrication. It can also be used for further and refresher training in the metal−fabricating field. To aid instructors in preparations for lessons and avoid misinterpretation of the contents of projection films, all of the films are accompanied by detailed explanations. Ease of comprehensibility called for the liberal use of colors in the design of projection films on methodological principles.

All crystallographic relationships (lattices, unit cells, structural faults, etc.) were marked in <u>blue</u>, whereas transitions to higher temperatures accompanied by state changes were marked in <u>red</u>.

Cooling curves of thermal analysis and heating curves of thermal treatment were plotted against a <u>blue</u> background, whereas constitutional diagrams and those relating to strength properties were plotted against <u>yellow</u> and <u>green</u> backgrounds, respectively.

Projection films nos. 5 and 9 are photomicrographs taped in their respective fields with the use of Prena adhesive tape.

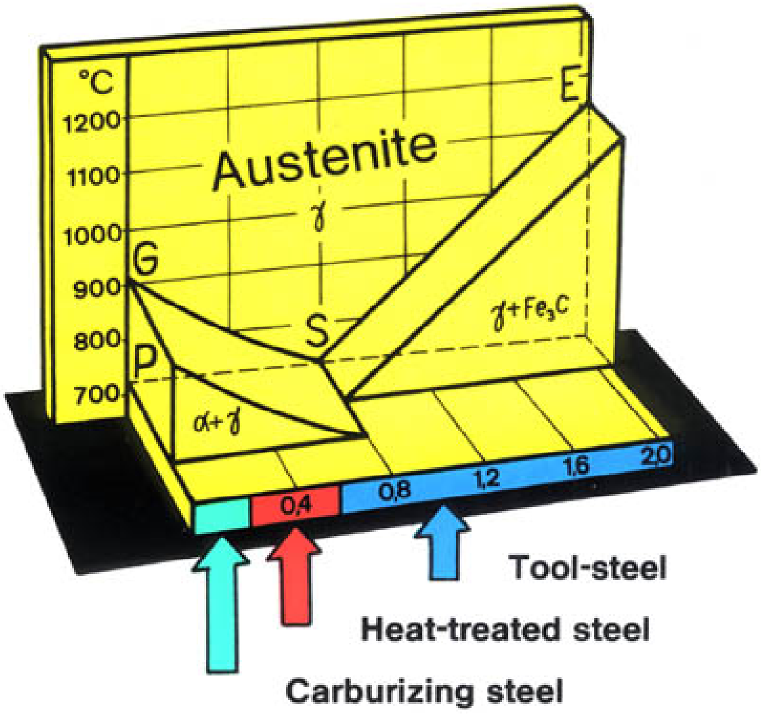
To enable instructors to plot their own diagrams, films no's. 18, 19, and 20 were provided with cm grids. The films and booklet are contained in plastic folders. This series of projection films is supplied complete with a frame to take up films.

2. List of projection films

Film no.	Film title
1	Classification of steels
2	Properties of unalloyed steels
3	Austenite – Pearlite
4	Martensite
5	Structure in hardened steel
6	Stress–relief heat treatment
7	Normalizing heat treatment
8	Soft annealing heat treatment
9	Change in structure
10	Hardening
11	Procedure of hardening
12	Surface hardening
13	Hardness survey
14	Hardening and tempering diagram
15	Weld
16	Selection of high–alloy steels
17	Readily castable ferrous materials
18	Film with cm grid
19	Film with cm grid
20	Film with cm grid

3. Explanations of projection films

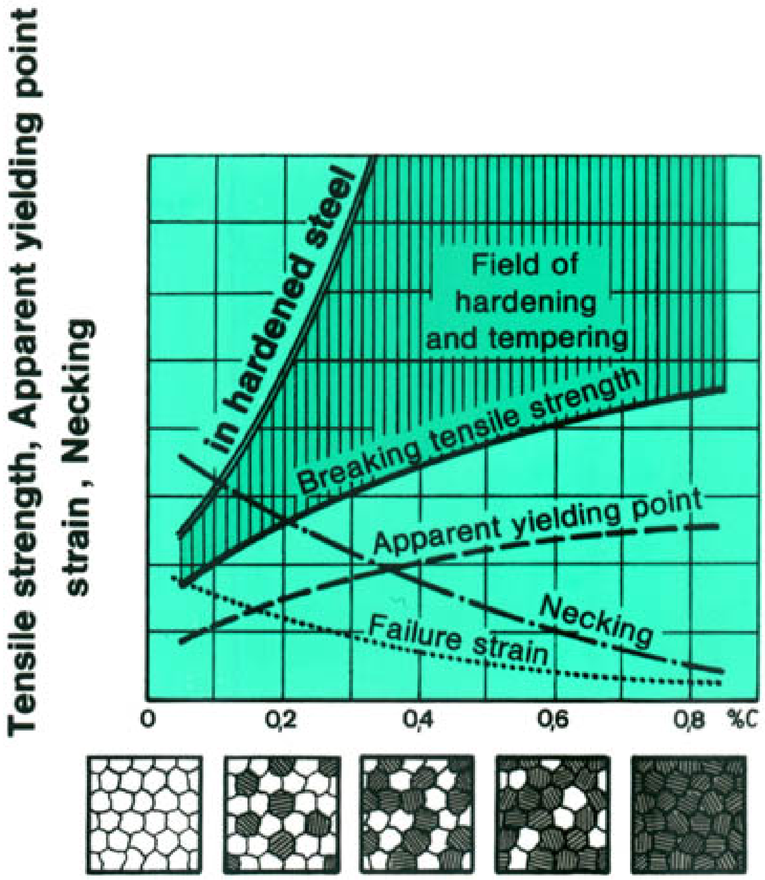
Classification of steels



Film no. 1: Classification of steels

This film serves to explain the properties of heat−treated, case−hardening, and tool steels. Instructors should describe the relationship between the properties of steels and the iron−carbon diagram and discuss the dependence of grades of steel upon carbon contents and structural constitutions. Also, it is recommended to make additional use of films nos. 21 (iron−carbon diagram no. 1), 22 (iron−carbon diagram no. 2), and 23 (steel corner) of the series of projection films on fundamentals of general metallography, in order to take the element of formality from the classification of steels.

Properties of unalloyed steels



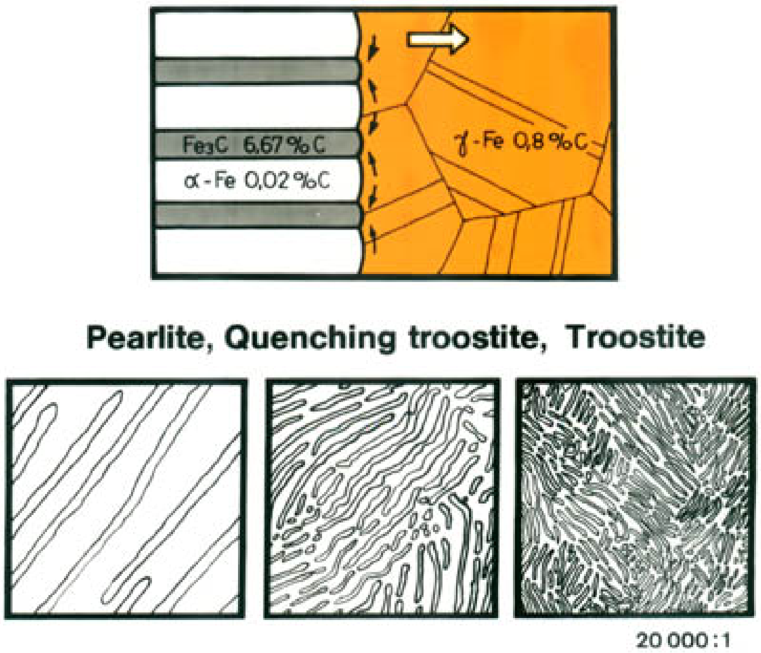
Film no. 2: Properties of unalloyed steels

The tensile strength, yield strength, elongation, and reduction of area are given in a diagram as a function of the carbon content. Also shown are schematic micrographs of steels having different carbon contents. Since steels whose carbon content is less than 0.8 percent show mixtures of ferrite and pearlite (with different proportions of these structural constituents), there can be. noted a relation between structural composition and steel working and fabricating behavior.

For example, the ultimate tensile stress increases as the proportion of pearlite increases.

It is essential to discuss changes in steel properties due to heat treatment. In the diagram, this dependence is expressed by indicating the as–hardened tensile strength. Be sure to include the said films nos. 21 and 23 in the discussion of film no. 2 showing the properties of unalloyed steels.

Austenite – Pearlite



Film no. 3: Austenite − Pearlite

This film shows the schema of austenite−pearlite transformation and micrographic representations of pearlite, sorbite, and troostite drawn from electron micrographs. The effect of the rate of cooling upon− the austenite−pearlite transformation can be explained in connection with the said film no. 23 (steel corner).

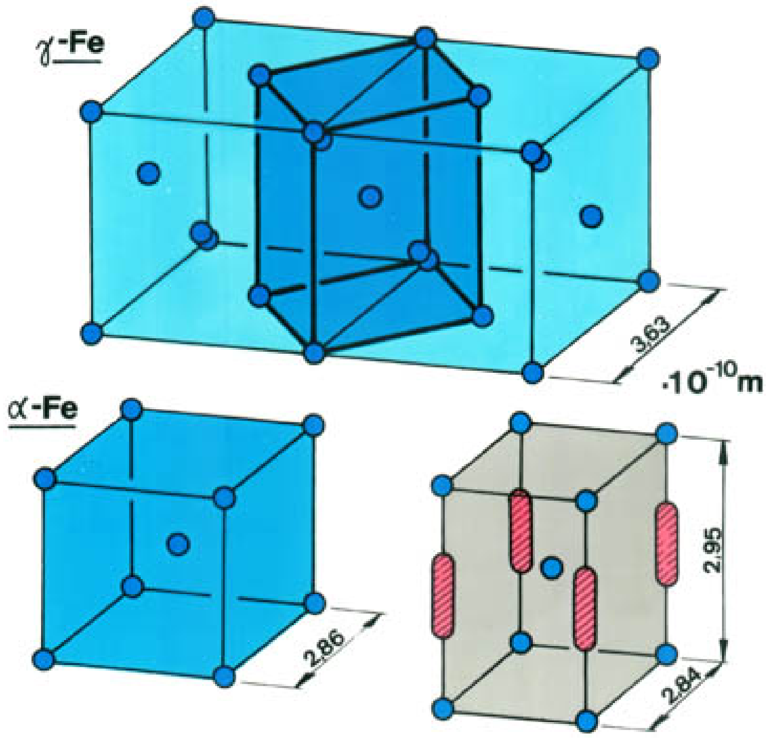
Characteristic features include the diffusion of carbon from austenite to secondary cementite and the self−diffusion of iron atoms during transformation of face−centered cubic unit cells into body−centered cubic unit cells.

After having explained the mechanism of transformation (with the lower part of the film being covered), the individual structures corresponding to the different rates of cooling can be dealt with one by one. For this, it is necessary to consider the scale of 20,000: 1 (electron microscope).

The term sorbite (finely lamellar pearlite whose structure is still within the limits of resolution of the optical microscope) should be used only to describe that structure which is formed on cooling from the austenite region. The same comments hold true with regard to the term troostite (extremely finely lamellar pearlite).

Such terms as tempering sorbite, osmondite, quenching sorbite, tempering troostite, and quenching troostite should no longer be used as they are now obsolete.

Martensite

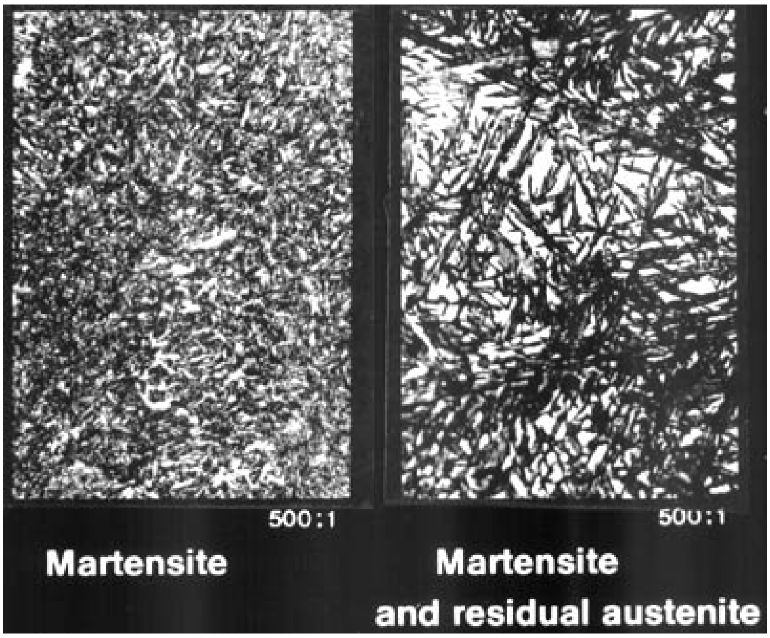


Film no. 4: Martensite

Rapid supercooling results in gamma–iron solid solutions being transformed into alpha–iron solid solutions by what is known as lattice flip–over. Rapid cooling provides against processes of diffusion taking place. Carbon will remain imbedded in the alpha–iron solid solution. There is formed a tetragonally distorted unit cell of extreme hardness.

This film shows Bain's principle of transformation. The possible location of carbon atoms is drawn in red and hatched. The film can be partially covered as shown in the sketch.

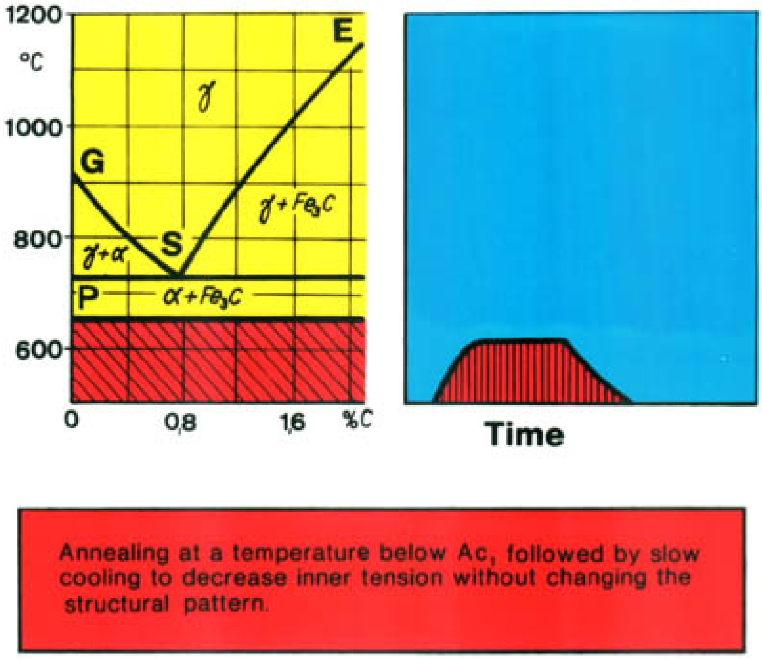
Structure in hardened steel



Film no. 5: Structure in hardened steel

To show structures in hardened steels, use is made of micrographs (x 500) of martensite and martensite containing residual austenite (etched using 3 % alcoholic nitric acid). Residual austenite is formed when steel having more than 0.6 % of carbon is cooled from excessive temperatures or at too rapid a rate. If residual austenite is present, then the desired hardness will not be obtained.

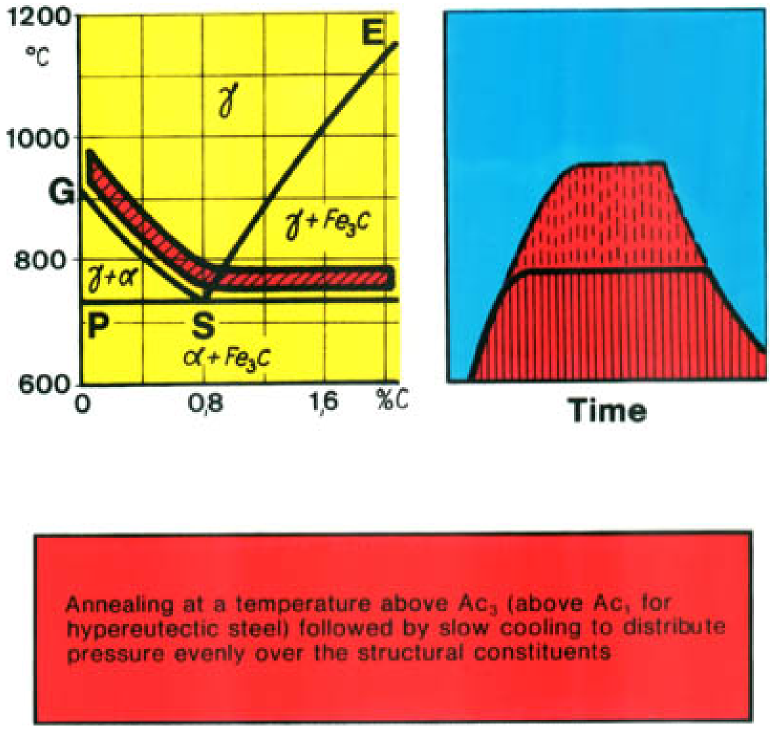
Stress–relief heat treatment



Film no. 6: Stress–relief heat treatment

This film shows the steel corner of the iron–carbon diagram with annealing field, the time–temperature curve, and a definition of the annealing process. It is used in connection with a discussion of stress–relief annealing. It is essential to again refer to the location and significance of line A_{c1}. Be sure to discuss the subject step by step; for this, it is necessary to partially cover the film.

Normalizing heat treatment



Film no. 7: Normalizing heat treatment

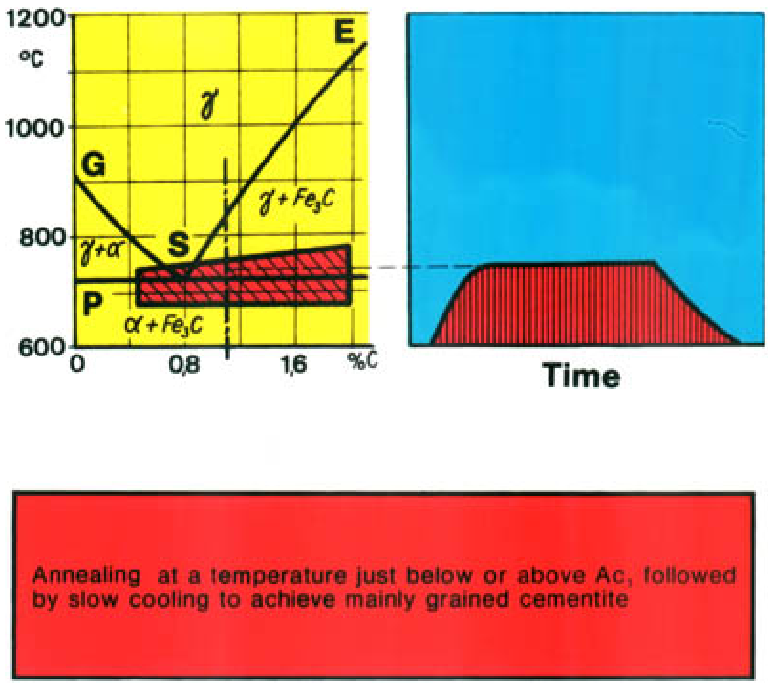
Normalizing is used to refine the coarse and irregular structures of castings, forgings, and rolled pieces. Using this film, it is possible to determine the annealing temperatures required for different grades of steel. In the diagram, the annealing field is drawn in red and hatched. When plotting a temperature–time curve it is necessary to consider that higher normalizing temperatures are required for lower–carbon steels. It is for this reason that the process of annealing is marked, in this diagram, by a series of dashes.

A definition of the annealing process is given in the lower half of this film.

The subject of normalizing neat treatment should be discussed in steps and in connection with film no. 9 showing structural changes.

It is essential to again refer to the location and significance of lines A_{c1} and A_{C3}, respectively.

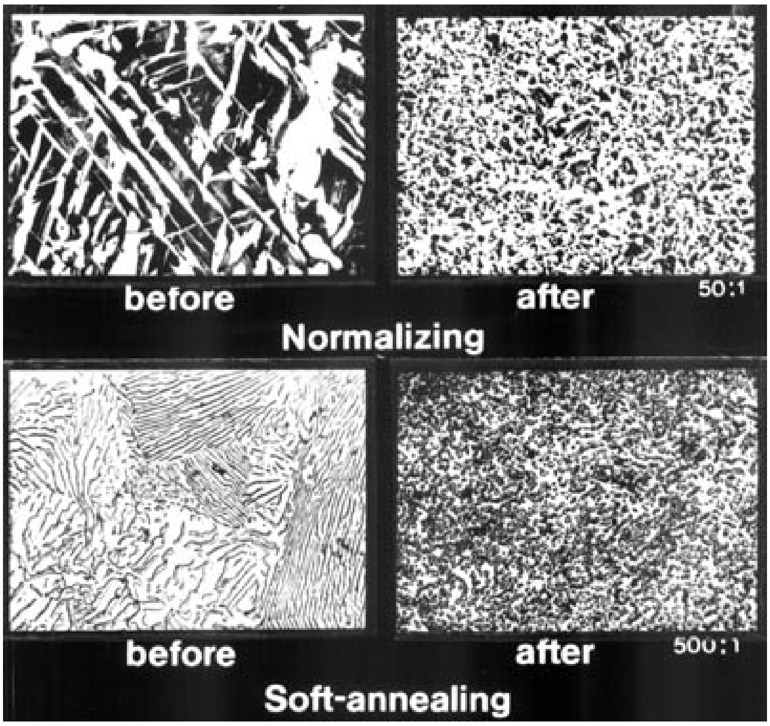
Soft annealing heat treatment



Film no. 8: Soft annealing heat treatment

Soft annealing provides for a major improvement of both machinability and cold–formability inasmuch as cementite tends to take on the smallest surface for a given volume (granular cementite). Using film no. 8 in connection with film no. 9 showing structural changes, it is possible to discuss the steel corner of the iron–carbon diagram with annealing field, plot a temperature–time curve of soft annealing as a function of the carbon contents of steels, and work out a definition of soft annealing heat treatment.

Change in structure



Film no. 9: Change in structure

This film is used in connection with films nos. 7 and 8 showing normalizing and soft annealing heat treatment, respectively.

This film shows the

- as−cast structure of cast steel prior to normalizing heat treatment (x 50), with ferrite and pearlite being shown in a Widmannstätten arrangement;

- as−normalized structure of cast steel (x 50);

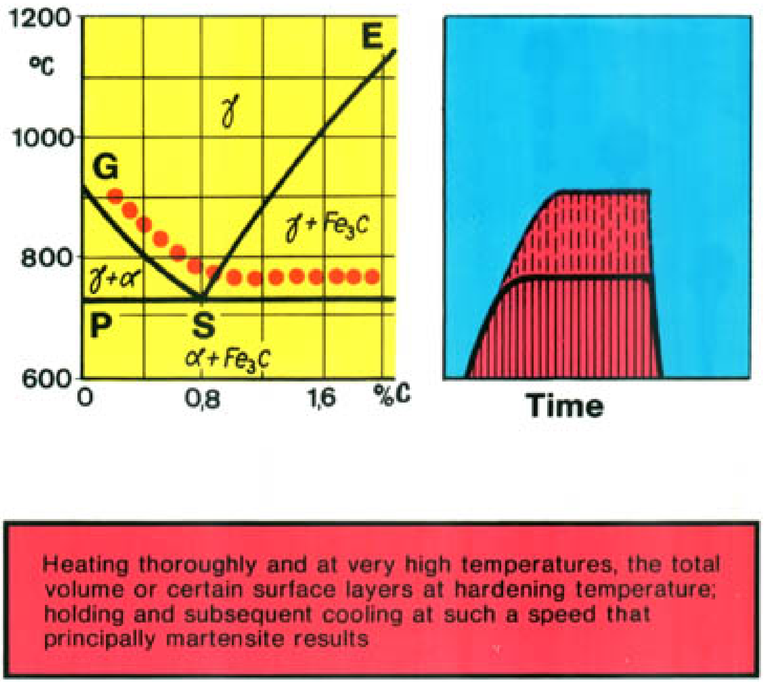
- structure of C 100 W1 prior to soft annealing heat treatment (x 500); pearlite can be seen here, with cementite being arranged in lamellar form; and

- as−soft−annealed structure of C 100 W1 (x 500); globular cementite can be seen to be finely divided in ferrite.

All structures were etched using 3 % alcoholic nitric acid.

By partially covering the film being projected, it is possible to show individual micrographs and compare them with each other. It is essential to show students that the structural constitution of a material can be changed both intentionally and unintentionally. This allows instructors to discuss changes in material properties as a function of the structure of a material. Conversely, the structure of a cast material can be concluded from certain properties thereof.

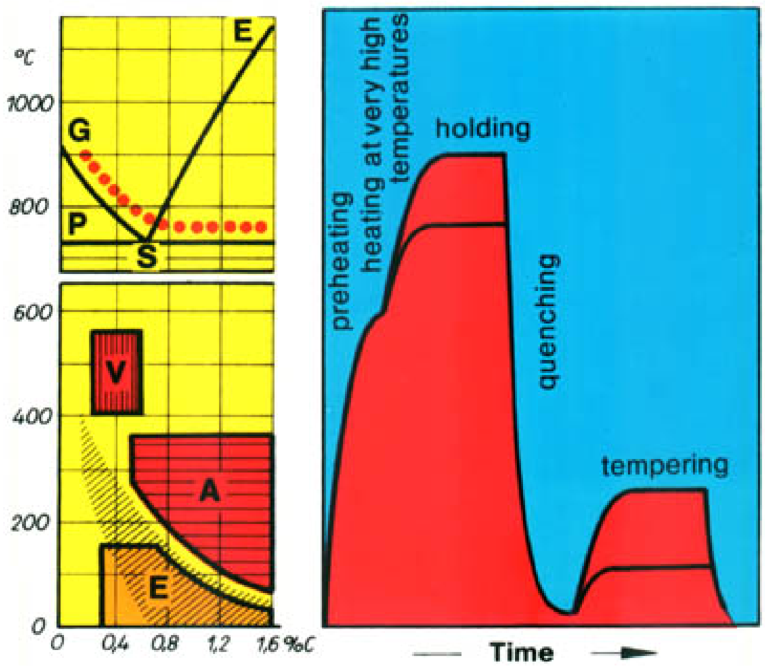
Hardening



Film no. 10: Hardening

This film can be used to discuss steel hardening problems. When explaining the steel corner of the iron–carbon diagram, with the line of hardening temperatures being dotted red, it should be pointed out that sub–pearlitic steels have to be heated as far as the austenite region. In the case of super–pearlitic steels, however, quenching from the region extending up to A_{c1} will be sufficient. Higher hardening temperatures would not only result in the formation of residual austenite but involve a major risk of cracking as well. Film no. 10 also shows the temperature–time diagram in addition to giving a definition of hardening.

Procedure of hardening



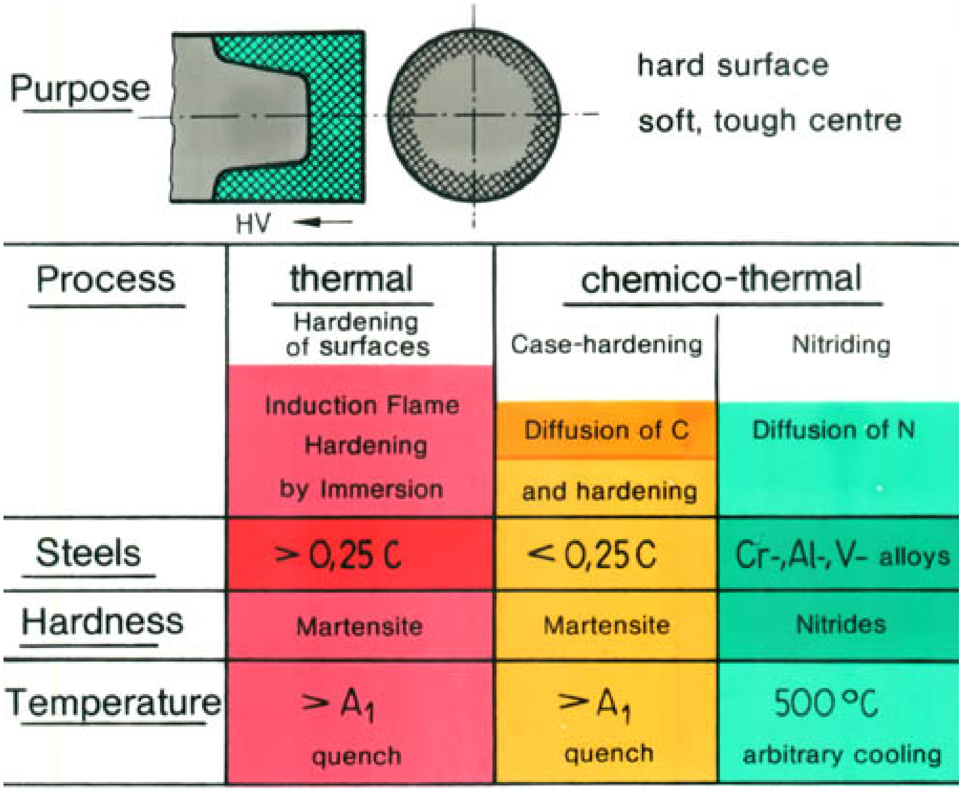
Film no. 11: Procedure of hardening

This film, together with film no. 10, is used to explain the individual procedural steps of hardening. Heating the work to high temperatures is followed by rapid quenching to harden the structure. Re–tempering allows higher quality properties to be obtained. This is illustrated by the temperature–time diagram of hardening. In the steel corner of the iron–carbon diagram, the red dotted line shows the hardening temperatures and the fields for tempering treatments.

The dark–yellow field (E) relates to low–temperature tempering, whereas the red fields (A and V) relate to medium–temperature and high–temperature tempering, respectively.

Combined hardening and high–temperature tempering is generally referred to as refining by heat treatment (V). When discussing the contents of the film it is appropriate to take the proper treatment temperatures from the relevant standards and work out a technology for a particular work. The iron–carbon diagram is here serving as a clue only, in order to explain the effect of heat treatment and the transformations effected.

Surface hardening



Film no. 12: Surface hardening

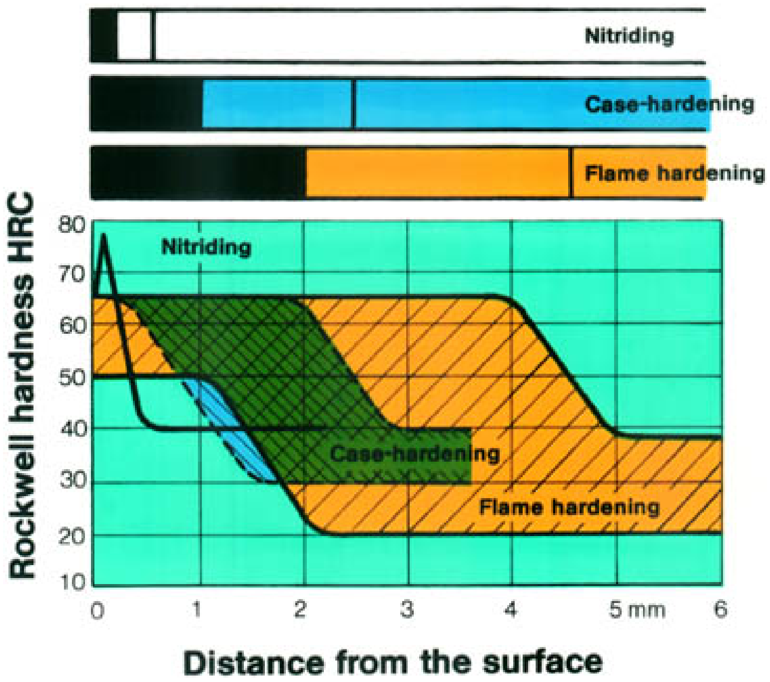
This film is used to illustrate the purpose of superficial hardening and provides useful information about parameters of individual hardening methods.

The upper representation shows a hardened shaft. The hardness traverse across the diameter is shown on the left of the cross section.

Surface and case hardening are based on martensite formation. When discussing the contents of this film it is essential to point out that in surface hardening the carbon content required for martensite formation is already contained in the steels and the surface hardness is obtained by local heating. With case hardening, on the other hand, the minimum carbon content is achieved through diffusion into the surface.

In the case of nitriding, strength–improving elements are nitrogen compounds such as iron, chromium, aluminum, and vanadium nitrides. The hardness of nitrides exceeds that of the martensite. The extremely hard and wear–resisting surface is, however, very thin.

Hardness survey

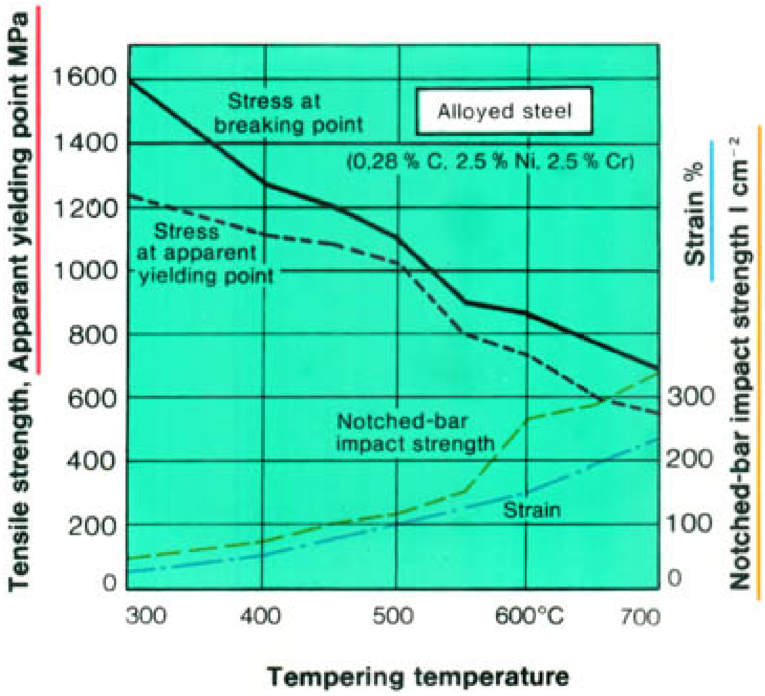


Film no. 13: Hardness survey

This film includes a diagram showing the thickness of the hardened surface layer obtained using the individual methods of hardening. When discussing the contents of this film it is necessary to point out differences in hardness level as a function of the hardening procedure and distance from the surface. In the upper part of the film, black fields indicate the depths of hardened layers (which can be obtained in general hardening), while the vertical lines indicate the maximum values.

Films nos. 12 and 13 should be dealt with together, since different steels and methods are used for hardening. The green region in the diagram applies to both case and flame surface hardening.

Hardening and tempering diagram

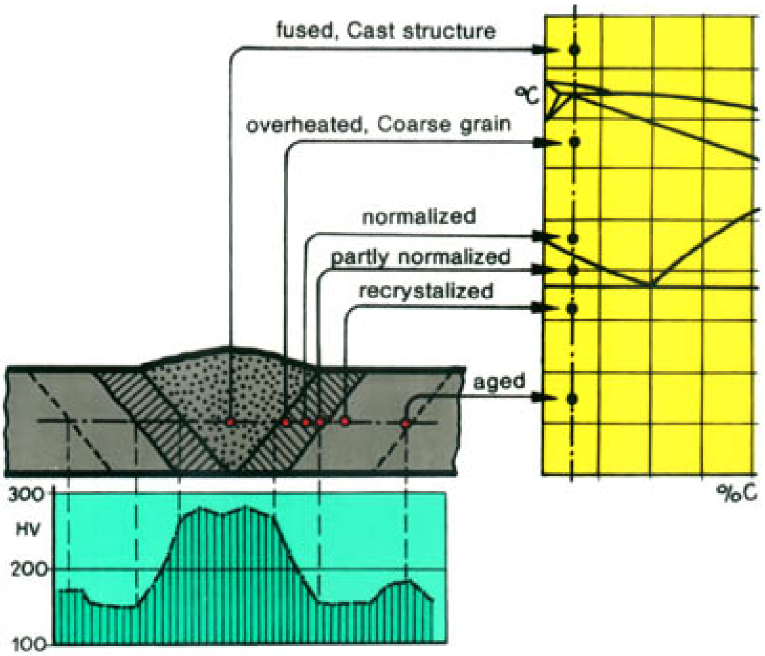


Film no. 14: Hardening and tempering diagram

Quenching and subsequent tempering is a method of improving a steel's strength and impact or toughness properties. The quenching and tempering diagram in this film shows the tensile strength, the yield strength, the proof strength, and the impact strength of an alloy steel containing 0.28 percent of carbon, 2.5 percent of nickel, and 2.5 percent of chromium.

The tempering temperatures required to achieve certain quality properties can be taken from the quenching and tempering diagram. For example, if the material containing 0.28 percent of carbon, 2.5 percent of nickel, and 2.5 percent of chromium is required to have a strength in the range of from 100 to 120 kgf/mm^2, then it is necessary that a tempering temperature of about 500 °C be chosen. Be sure to discuss film no. 14 in connection with film no. 1 that is concerned with the classification of steels.

Weld

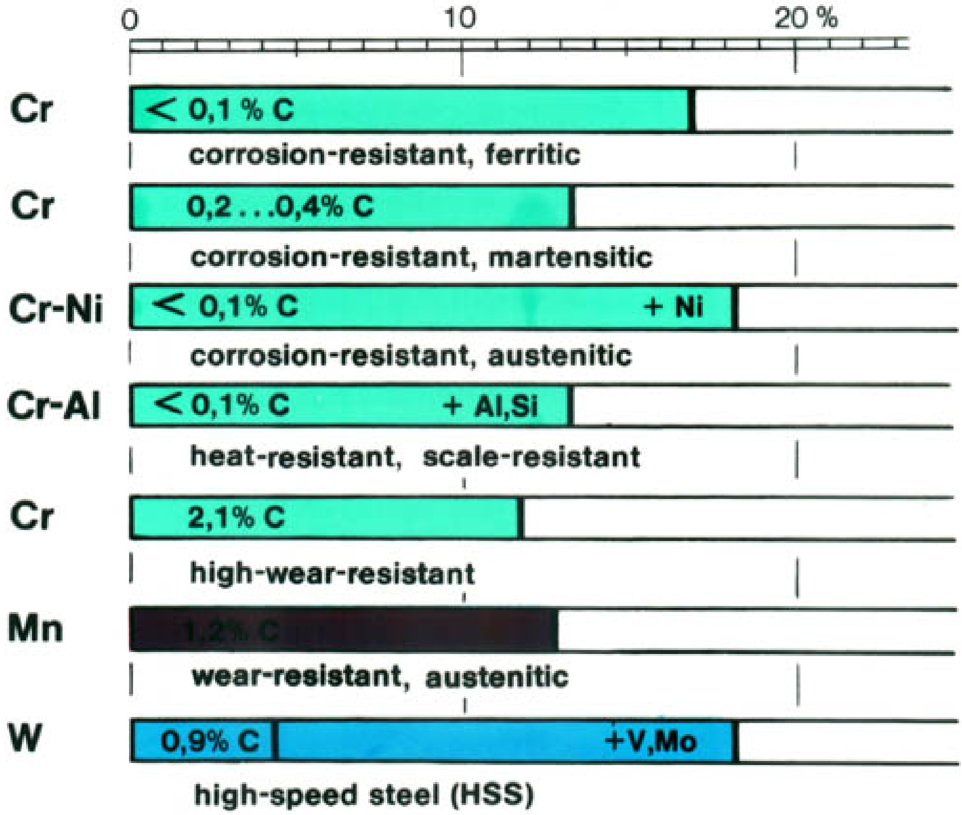


Film no. 15: Weld

For a graphic depiction of theoretical relationships, the buildup of a weld was included in this series of films as a practical example. Certain regions of the schematic cross section are used and related to parts of the iron–carbon diagram. The structure and hardness of a material can be inferred from micrographs.

The diagram showing the hardness traverse across the weld region need be discussed qualitatively only. The heat treating processes dealt with previously should be touched upon, too.

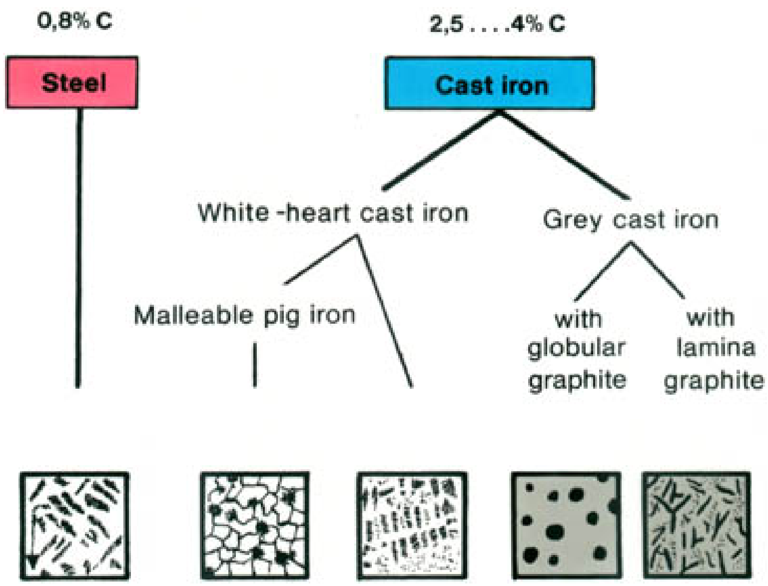
Selection of high–alloy steels



Film no. 16: Selection of high–alloy steels

This film presents a selection of high–alloy steels, allowing the alloying elements and the most important properties to be easily explained to students. In the case of high–alloy steels, the proportion of alloying elements usually exceeds the 5 percent limit. The alloy element content is included in the designations. Only the principal alloy elements and contents were marked in color, with green, lilac, and blue being used for chromium, manganese, and tungsten, respectively.

Readily castable ferrous materials



Film no. 17: Readily castable ferrous materials

The term castable ferrous materials is used to describe those ferrous materials of which the carbon content exceeds the limit of solubility in the gamma–iron solid solution. High–carbon ferrous materials have excellent casting characteristics. In this film, a distinction is made between cast steel, malleable pig iron, white cast iron, spheroidal graphite cast iron, and flake graphite cast iron. The structures and properties can be derived from micrographs.

Classification of cast ferrous materials

Structual scheme

It is important that students should be able to identify the names of particular cast materials with the special characteristics thereof. Aiding students in acquiring this ability are schematized micrographs of cast ferrous materials.