Lecture 35

The Lecture Contains:

Objectives

Structure-property relation

Property of the phases

What are the final finishing operations?

Surface hardening

Steel types and hardening methods

Objectives:

The final finishing operations are performed to produce a product for a given application, which ranges from structural to space applications. In this connection it is important to note the role of steelmaking to produce steels of desired chemistry and cleanliness. Impurities like sulphur and phosphrous are detrimental to most of the steel grades for all finishing operations. In aluminum killed steels, alumina inclusions must be suitably modified prior to deformation processing. Other types of inclusions must be suitably distributed within the matrix. The objectives of these operations are to generate the mechanical properties in the steel product required for a given application. The important properties are:

Strength : Measure of the resistance of material to permanent deformation

Ductility : Measure of the degree of plastic deformation

Hardness : Resistance to localized deformation

Creep : Resistance to time dependent deformation under load

Fatigue: Resistance of a material against fluctuating stresses.

Fracture toughness: Resistance to brittle failure

The above properties depend strongly on the number , size and size distribution of phases and the impurities.

Structure –property relation

Properties at materials depend strongly on structure of metals we will be concerned with steel.

Pure iron is highly ductile. Addition carbon increases strength. Fe- C system can alloy with several elements to promote either the formation of carbides (such as Ti, Zr, V, Nb, W, Mo, Cr etc.) or nitrides (such as Al, Ti etc)or to stabilize austenite (such as Ni, Mn etc.) or to stabilize ferrite(such as Cr, W, Mo, V, Si etc.)

Steel is a polycrystalline material and its microstructure consists of grains (also called phases or crystals) oriented in different directions, and grain boundary. A polycrystalline cube 10mm on edge, with grains 0.001 mm in diameter, would contain 10^{12} crystals with a grain boundary area of several square meters. Grain boundaries are important.

Grain boundary is the region of misfit between the grains. Due to different atomic configurations, it acts as sinks as sinks for impurity atoms which tend to segregate to interfaces

The equilibrium diagram of Fe-C system shows the following phases:

- α ferrite: interstitial solution of carbon in bcc iron. Maximum solid solubility of carbon is 0.02% at $723°\mathrm{C}$ and decreases to $0.008\ \%$ at $0°\mathrm{C}$.
- Austenite: FCC crystal structure and solid solubility of carbon is 2.08% at $1148°\mathrm{C}$ and decreases to 0.8% at $723°\mathrm{C}$.
- Cementitie $(\mathrm{Fe_3C})$: An intermetallic compound, hard and brittle in nature. It is stable at room temperature. It has 6.67 % carbon.

The above phases are obtained when steel from the austenitic region is cooled very slowly. However, several other phases can be obtained by varying cooling rates. In the table given on the next page the different phases are summarised which can be obtained during phases transformation of steel

Property of the phases *

Phase	Structure	Nature
Spheroidite	Small $\mathrm{Fe_3C}$ spheres in $\alpha - \mathrm{matrix}$	Soft and ductile
Coarse pearlite	Alternative thick layers of ferrite and cementite	Harder & stronger then pheroedite
Fine pearlite	Alter native this layers of ferrite and cementite	Harder and strength than coarse pearlite
Bainite	Very fine and elongated particles of $\mathrm{Fe_3C}$ in $\alpha -$ ferrite matrix	Hardness and strength is greater than fine pearlite.
Marten site	Body centered tetragonal single phase	Stronger & hander than

	needle shape.	bainite.
Tempered marten site	Very small $\mathrm{Fe_3C}$ sphere like particles in $\alpha - \mathrm{ferrite\ matrix}$	Stranger and harder but ductility is greater than marten site

Mechanical properties i.e. strength and plasticity depend on type, number, size and size distribution of phases. For example fine grain size has better properties at room temperature. Coarse grain size improves creep properties.

Failure of metals consists of crack initiation and its growth. Crack can propagate either within the grain or at the grain boundary. Inter-granular failure is always brittle and usually proceeds with particles of the brittle phase being separated out at the boundaries of the grain.

What are the final finishing operations?

1. surface hardening
2. Heat treatment
3. Deformation processing

In this lecture we will deal salient features of surface hardening. The next lectures deal with other methods.

Surface hardening

Surface hardening methods are used to harden the surface. The different methods are:

1. Thermo chemical surface hardening
2. Thermal surface hardening
3. Coating

In thermo-chemical surface hardening composition of steel surface is altered and then steel is heat treated with or without quenching.

Austenitic type of steels are hardened by carburizing, carbonitriding or cyaniding treatment. In all these methods non-metallic elements C either singly or in combination with nitrogen are diffused into the austenitic phase.

In ferrite type of steels both nitriding and nitro- carburizing treatments are performed. Carbon or Carbon + nitrogen are diffused in the ferrite phase.

In thermal surface hardening, heat alone is used to alter the microstructure without altering the composition. Steel can be heated either by induction of laser or by electron beam or by flame.

Induction heating involves heating the component by induced eddy current to a temperature at which austenite forms rapidly. Metal surface is heated by using special inductors using an alternating current of frequencies between 50 hertz to 1000 hertz. Depending on the required depth of hardening. Steel is then quenched for martensite transformation.

In flame hardening, a high intercity flame is used to heat the metal as austenitic temperature and then following by quenching.

Steel types and hardening methods

Law carbon steels	Alloy steel	Tool steels	Staislen steels
Carburizing Cyaniding Ferrite Nitro carburizing Carbonitriding	Nitriding or ion nitriding	Titanium carbide gas nitriding ton nit riding Salt nit riding	Gas nitriding titanium carbide ton nitriding

References:

W.D. Calliste r: Material Science and Engineering
For more details, see the references given at the end of 37 lecture