Doc: MTD 22 (26066)
July 2024

भारतीय मानक ब्यूरो

भारतीय मानक मसौदा

लौह एवं इस्पात की परिभाषित शब्दावली
भाग 1 सामान्य धातुकर्म, ताप उपचार और परीक्षण

(दूसरा पुनरीक्षण)

Draft *Indian Standard*

Glossary of Terms Relating to Iron and Steel
Part 1 General Metallurgy, Heat Treatment and Testing

(*Second Revision*)

ICS 77.080.20

FOREWORD

(*formal clause will be added later*)

This standard was originally published in 1962 and subsequently revised in 1976. This revision has been brought out to bring the standard in the latest style and format of the Indian Standards. In addition to this, references clause has been added.

This standard is published in seven parts. The other parts in the series are

Part 2 Steel making
Part 3 Long products (including bars, rods, sections and wires)
Part 4 Flat products
Part 6 Forging (including drop forging)
Part 7 Wrought iron
Part 8 Steel tubes and pipes

This standard has been prepared for the guidance of the manufacturers and the users to assist them in the uniform interpretation of the common terms used in the iron and steel industry.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Doc: MTD 22 (26066)
July 2024

Draft *Indian Standard*

GLOSSARY OF TERMS RELATING TO IRON AND STEEL

PART 1 GENERAL METALLURGY, HEAT TREATMENT AND TESTING

(*Second Revision*)

1 SCOPE

This draft standard (Part 1) covers terms commonly used in the field of general metallurgy, heat treatment and testing.

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
IS 1500 (Part 1) : 2019 /ISO 6506-1 : 2014	Metallic materials — Brinell hardness test Part 1 Test method (*fifth revision*)
IS 1586 (Part 1) : 2018 /ISO 6508-1 : 2016	Metallic materials — Rockwell hardness test Part 1 test method (*fifth revision*)
IS 1598 : 1977	Method for izod impact test of metals (*first revision*)
IS 1599 : 2019 /ISO 7438 : 2016	Metallic materials — Bend test (*fourth revision*)
IS 1608 (Part 1) : 2022 /ISO 6892-1 : 2019	Metallic materials — Tensile testing Part 1 Method of test at room temperature (*fifth revision*)
IS 1716 : 2023 /ISO 7801 : 1984	Metallic materials — Wire — Reverse bend test (*third revision*)
IS 1757 (Part 1) : 2020 /ISO 148-1:2016	Metallic materials — Charpy pendulum impact test Part 1 Test method (*fourth revision*)
IS 6885 (Parts 1) : 2020 /ISO 4545-1:2017	Metallic materials — Knoop hardness test Part 1 Test method (*second revision*)
IS 7291 : 1981	Specification for high speed tool steels (*first revision*)
IS 7598 : 1990	Classification of steels (*first revision*)
IS 14329 : 1995	Malleable iron castings — Specification

3 DEFINITIONS

3.1 Acid Process

A steel making process in which steel is refined under an acid slag in an acid refractory lined furnace or convertor.

3.2 Acid Steel

Steel made by acid process.

3.3 Ageing

A change in properties which may occur gradually with time at atmospheric temperatures (natural ageing) and more rapidly at elevated temperatures (artificial or accelerated ageing).

Artificial ageing refers to:

a) *Quench Ageing* — Ageing following quenching (*see* also **3.296**), and
b) *Strain Ageing* — Ageing induced by cold-working.

3.4 Age-Hardening

Hardening due to ageing (*see* **3.3**).

3.5 Air-Hardening

Hardening by cooling in air or gas at ambient temperature from a temperature above the transformation range.

3.6 Air-Hardening Steel (Self-Hardening Steel)

A steel which responds to air-hardening treatment.

3.7 Air Test (Pressure Test)

A test for leakage of a hollow product by subjecting it to a specified air pressure.

3.8 Allotropy (Polymorphism)

The reversible phenomenon by which certain metals may exist in more than one crystal structure. If not reversible, the phenomenon is termed ‘Polymorphism’.

3.9 Alloy

A substance having metallic properties consisting of two or more elements in which the major constituent is a metal, or of metallic and non-metallic elements which are miscible with each other when molten, and have not separated into distinct layers when solid.

3.10 Alloying Element

An element (metal or non-metal) added deliberately to a metal to modify its mechanical and/or physical properties.

3.11 Alloy Steel

A steel containing one or more alloying elements as a result of which it develops specific characteristics (for detailed definition *see* IS 7598).

3.12 Alpha Iron

The body-centred cubic form of iron which in pure iron is stable below 910°C.

3.13 Annealing

Heating to and holding at a suitable temperature, followed by cooling at a suitable rate, for inducing softness. It may also be used for the following other purposes such as:

a) Improving machinability,
b) Improving cold-working properties,
c) Obtaining a desired structure,
d) Reducing stresses, and
e) To facilitate diffusion processes.

When applicable, the more specific terms, such as full annealing, isothermal annealing or sub-critical annealing, etc, should be used.

Full Annealing — Heating to and holding at some temperature above the transformation range, followed by cooling slowly through the transformation range. The exception is in the case of austenitic steels which are quenched rapidly from the homogenizing temperature for softening the material.

Isothermal Annealing — Heating to and holding at some temperature above the transformation range, then cooling to and holding at a suitable temperature below the transformation range until the austenite-to-pearlite transformation is complete, and finally cooling in air.

Process Annealing — In the sheet and wire industries, heating a ferrous alloy to a temperature close to, but below, the lower limit of the transformation range and then cooling, in order to soften the alloy for further cold-working.

Sub-critical Annealing — Heating to and holding at some temperature below the transformation range, followed by cooling at a suitable rate.

Unitized Annealing — *See* **3.294.**

3.14 Arrest Point

The point at which an otherwise continuous cooling or heating curve of a metal or alloy shows a discontinuity or break. It occurs at a temperature at which a phase change takes place in the metal or alloy and results from the absorption or evolution of heat during heating or cooling respectively (*see* Fig. 1).

3.15 Ac Point

An arrest point on heating (*see* **3.14**).

3.16 Ar Point

An arrest point occurring on cooling (*see* **3.14**).

3.17 Ausforming

Cold-forming of metastable austenite in alloy steel and subsequent cooling in air or oil resulting in the formation of bainite, martensite, etc. This treatment is employed for improved strength.

3.18 Austempering

Isothermal sub-critical transformation of austenite at temperatures below that at which pearlite is produced and above that at which martensite is formed.

3.19 Austenite

A solid solution of carbon and/or alloying elements in gamma iron which has a face centred cubic crystal structure.

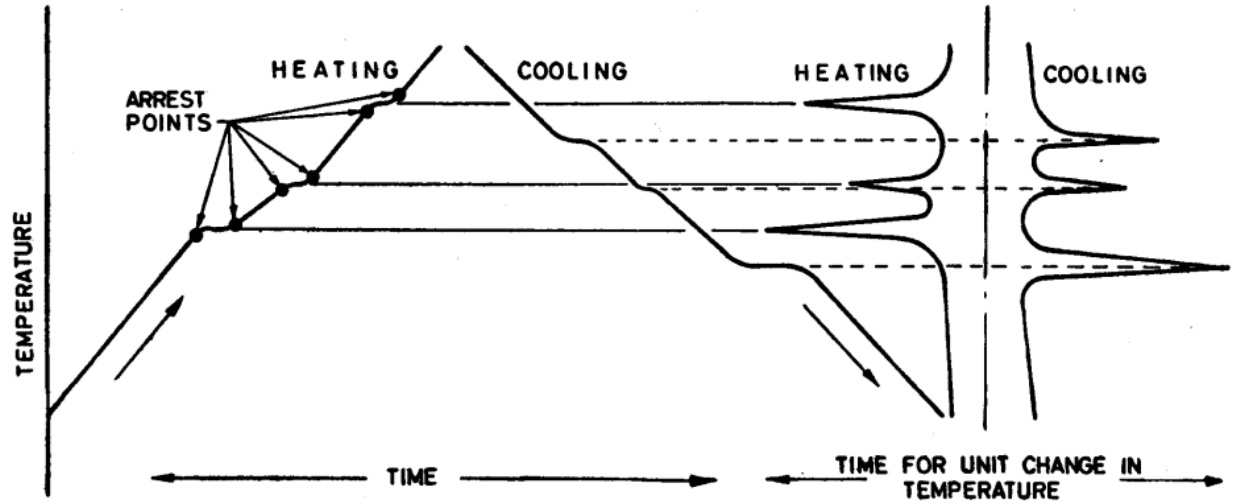


FIG. 1 HEATING AND COOLING CURVE

3.20 Austenite Grain Size or Austenitic Grain Size

The size of austenite grains developed when steel is heated above the critical (or transformation) range under specified conditions. The grain coarsening tendency of a steel is determined by measuring the austenitic grain size under standard conditions.

3.21 Austenitic Steel

A steel, generally non-magnetic, containing sufficient proportions of alloying elements (for example, nickel, chromium and/or manganese, etc) to render it predominantly austenitic at atmospheric temperatures.

3.22 Austenitising

Heating steel to a temperature above the critical range, to render the steel wholly austenitic (*see* Fig.2).

3.23 Bainite

The constituent produced when austenite transforms at a temperature below that at which pearlite is produced and above that at which martensite is formed.

3.24 Baking (Stoving)

Heating after pickling to remove hydrogen.

3.25 Banded Structure

A segregated structure of nearly parallel bands running in the direction of rolling or forging, which is revealed by etching the polished surface.

3.26 Basic Process

A steel making process in which steel is refined under a basic slag in a basic refractory lined furnace or convertor.

3.27 Basic Steel

Steel made by the basic process.

3.28 Bend Test

A test for ductility and soundness. It is carried out by bending a test piece at the middle, over a specified radius generally by a steadily applied load or by blow. Three kinds of bend tests are used in practice, namely:

a) *Single Bend Test* — wherein the test piece is bent once according to the specified angle and radius of bend (*see* IS 1599);
b) *Close Bend Test* — wherein the test piece is bent through an angle of 180° and the two arms are folded flat on each other; and
c) *Reverse Bend Test* — wherein the test piece is first bent through an angle of 90° and then the bend is opened out so that the piece reverts to its original position. In some cases the piece is bent through an angle of 180° and then brought back to its original straight condition. The bending, in both cases, is then continued counting the number of reverses, till the piece fractures. (This test is used for sheet, strip and wire.) (*see* IS 1716).

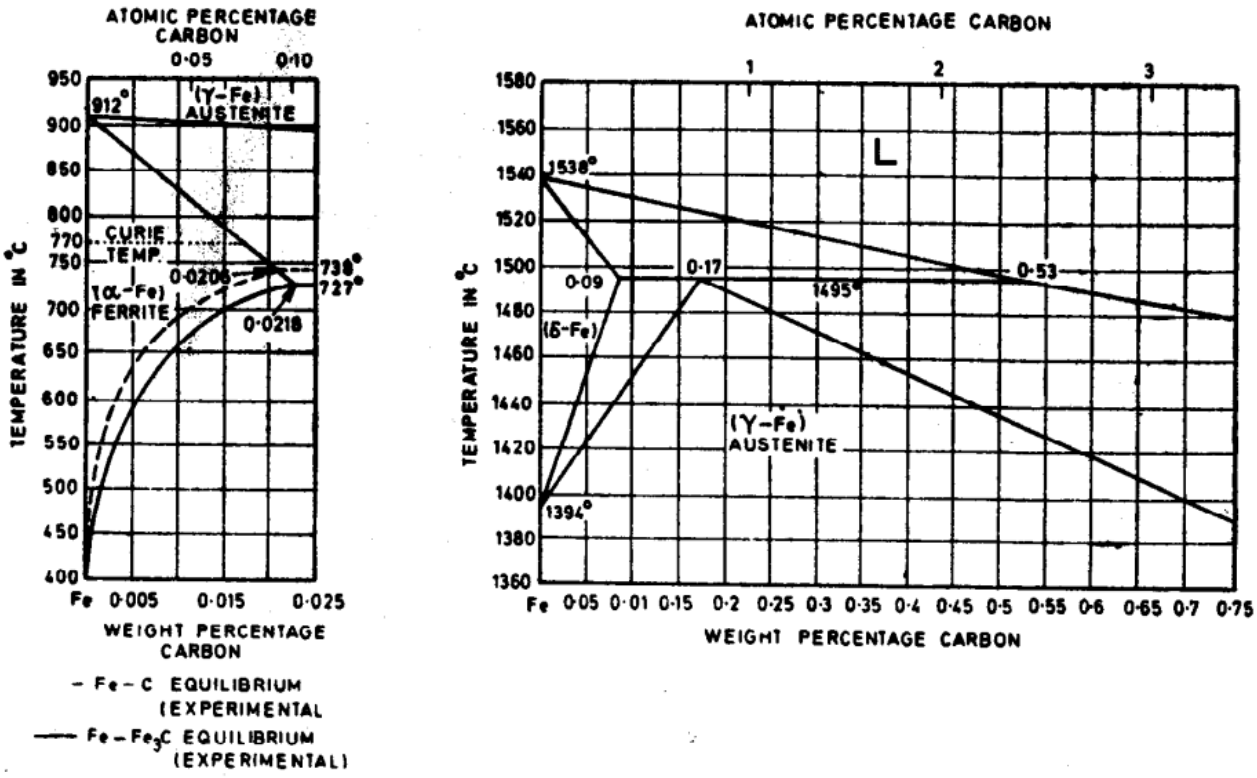


FIG. 2 IRON-CARBON EQUILIBRIUM DIAGRAM

3.29 Bessemer Process (Henry Bessemer Process)

A steel making process in which pig iron is refined in an acid refractory lined convertor by blowing air or a mixture of air, carbon dioxide and oxygen or steam through the molten metal. The basic process is known as Thomas process.

3.30 Bessemer Steel

Steel made by the Bessemer process.

3.31 Black Annealing

Annealing without any protective medium.

3.32 Blackheart Malleable Cast Iron

White cast iron rendered malleable by suitable annealing using inert atmosphere to prevent appreciable decarburization, in order that the carbide is decomposed into graphitic carbon and ferrite. The temper carbon, as it is called, is distributed in the form of nodules, unlike the flaky graphite. The fracture shows a dark grey core from which it derives its name (*see* IS 14329).

3.33 Blank Carburizing

A test applied to carburizing steels for determining the core properties.

3.34 Blank Nitriding

The thermal treatment associated with nitriding, as applied to a test piece without the nitriding medium.

3.35 Blast Furnace

A vertical shaft furnace where a large volume of air blast is used for smelting iron ore, with coke or charcoal with suitable fluxes, into pig iron.

3.36 Blasting

A process of cleaning or preparing surfaces by high speed impact of abrasive particles, such as sand, chilled iron shot, or angular steel grit (generally called sand blasting, shot blasting or grit blasting).

3.37 Blister (Pin-Head Blister)

Local separation of a layer of steel causing a protuberance on the surface, underneath which is a cavity.

3.38 Blow Holes

Cavities in iron or steel castings formed by entrapped gas bubbles during solidification.

3.39 Blue Annealing (Blueing)

Sub-critical annealing of steel, during which the surface is oxidized to a blue colour by controlled amount of air/ steam permitted into the annealing chamber.

3.40 Blue Brittleness

Brittleness occurring in steel when worked in the temperature range of approximately 200 to 400°C, or when cold after being worked within this temperature range.

3.41 Blueing

Heating in a suitable atmosphere for imparting a blue colour to bright steel (*see* also **3.39**).

3.42 Bottom Casting (Uphill Casting)

Simultaneous casting of a number of ingots by pouring the molten metal into a central refractory-lined tube or trumpet, whence it flows through refractory runners into the bottom of the moulds.

3.43 Boundary Film

A thin envelope of a constituent deposited at the grain boundaries.

3.44 Box Annealing (Close Annealing)

Annealing carried out in a closed container to minimize oxidation.

3.45 Breaking Strength

Breaking load at the time of fracture divided by the original cross-sectional area of the test piece (*see* Fig. 3).

3.46 Bright Annealing

Annealing under controlled atmosphere (neutral or reducing gas) to prevent oxidation of the surface and to preserve its brightness.

3.47 Brinell Hardness Test

An indentation carried out by pressing a hard steel ball of known diameter, under a standard load, against the surface of a material, and then measuring the diameter of indentation produced (*see* IS 1500 (Part 1)). The result of the test is expressed as Brinell hardness number (HB).

$$\text{HB} = \frac{\text{Load in kg}}{\text{Spherical area of the impression in mm}^2}$$

3.48 Brittle Fracture (Crystalline Fracture)

A fracture without any visible or appreciable plastic deformation.

3.49 Brittleness

Tendency to fracture without any visible sign of appreciable deformation.

3.50 Brittle Transition Temperature — *See* **3.424.**

3.51 Burning

Heating to such a high temperature that the properties of the material are permanently impaired by incipient fusion or oxide penetration.

3.52 Carbo-Nitriding

Surface treatment through the introduction of carbon and nitrogen simultaneously (*see* also **3.55** and **3.57**).

3.53 Carbon Steel

An unalloyed steel (*see* IS 7598).

3.54 Carburizing (Case-Carburizing)

A process of introducing carbon into the surface of a solid piece of steel by heating and holding above the transformation temperature in contact with a suitable source of carbon which may be a solid, liquid or gas.

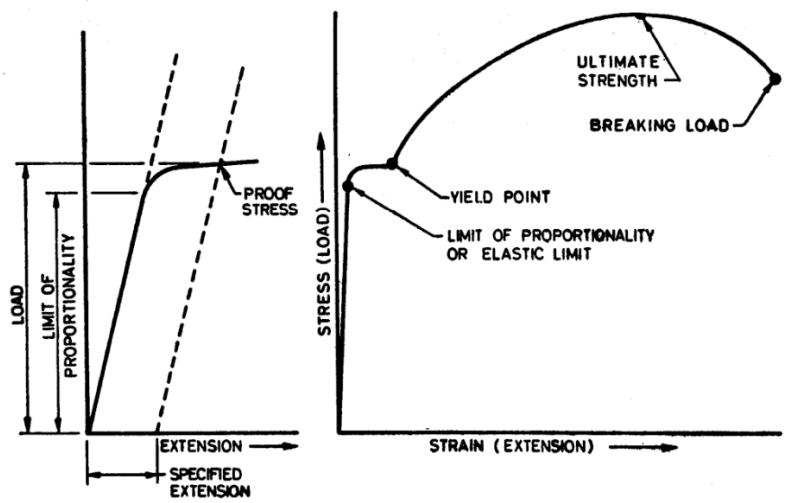


FIG. 3 STRESS-STRAIN CURVE

3.55 Case

The surface layer which has been hardened by changing the composition or by heat treatment or a combination of both.

3.56 Case-Carburizing — *See* **3.54**.

3.57 Case-Hardening

Hardening the surface by changing its composition followed by, if necessary, suitable heat treatment.

NOTE 1 — The term is usually applied to carburizing or cyaniding treatment, with or without further heat treatment for grain refinement, followed by quenching, to produce a hard case and a core of suitable properties.

NOTE 2 — Nitriding is one of the methods of case hardening.

NOTE 3 — Flame and induction hardening are not included in this definition.

3.58 Cast (Heat or Melt)

Usually the product of a single furnace charge. Sometimes the furnace contents are tapped into two or more ladles when the product of each ladle may be called a separate cast.

3.59 Casting

Pouring or teeming molten metal into moulds. This also refers to metal objects so produced.

3.60 Cast Iron

An alloy essentially of iron and carbon containing more than 2 percent carbon (usually between 2.5 and 4 percent). It also contains silicon, manganese, sulphur and phosphorus in varying amounts. The character of cast iron is controlled by the manner in which carbon is present, and the

fractured surface of cast iron exhibits characteristic colour, namely, white, mottle, or grey (*see* Fig. 4), depending on whether carbon is present wholly in combined state (as carbide) or partly in combined state or wholly in the form of graphite.

3.61 Cast Steel

The term is used for steel castings.

3.62 Caustic Cracking (Caustic Embrittlement)

Intercrystalline cracking in mild steel due to the combined effect of stress corrosion in alkaline media.

3.63 Cellular Structure (Network Structure)

A structure in which the constituent is present as a network surrounding the crystal grains. For example, cast iron has such a structure.

3.64 Cementite

A compound of iron and carbon, known chemically as iron carbide and having the approximate formula Fe_3C. It is characterized by an orthorhombic crystal structure. When it occurs as a phase in steel, the chemical composition will be altered by the presence of manganese and other carbide forming elements.

3.65 Charpy Impact Test

A pendulum type single blow impact test in which a specimen (usually notched) is supported at both ends as a simple beam and broken by a falling pendulum on the face opposite to and immediately behind the notch. The energy absorbed as determined by the subsequent rise of pendulum, is a measure of impact strength or notch toughness and is expressed in joules (*see* IS 1757(Part 1)).

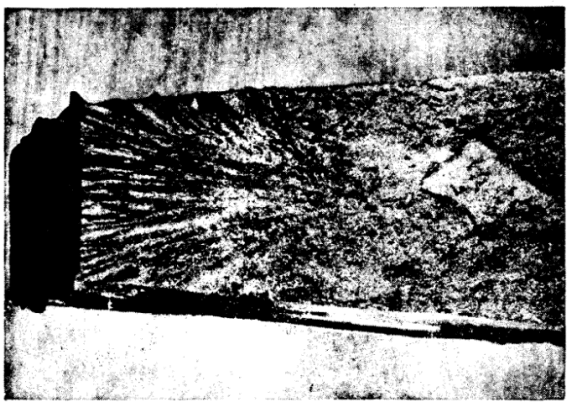


FIG.4 SURFACE OF CAST IRON FRACTURE

3.66 Chill Crystals

A thin skin of small crystals formed by rapid freezing of molten metal in contact with a cold surface (*see* Fig. 5).

3.67 Chill Cast

Cast against a mold which has heat extracting properties.

3.68 Clad Steel

A composite material obtained by firmly bounding together a carbon or alloy steel with a surface layer of another steel, metal or alloy.

3.69 Cleavage Fracture (Crystalline Fracture)

Fracture along cleavage planes. Such fractures show bright facets and are characterized by little plastic deformation.

3.70 Cleavage Plane

Planes of easy fracture related to the crystal structure. They are not necessarily related to the boundaries of the crystal and are found in both minerals and metals.

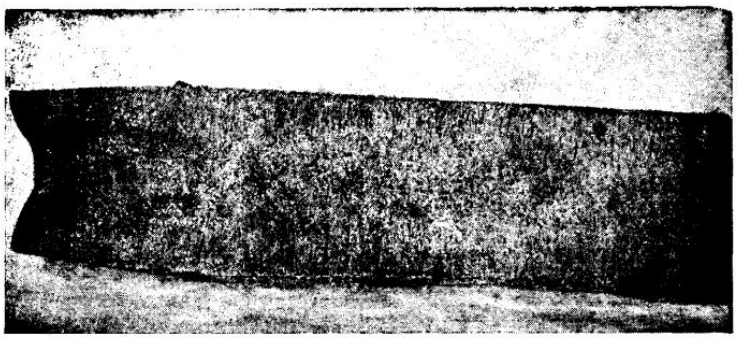


FIG. 5 INGOT SECTION SHOWING CRYSTALLINE ARRANGEMENT

3.71 Close Annealing — *See* **3.44**.

3.72 Coalescence

Formation of bigger aggregates due to the merger of smaller ones.

3.73 Cold Shortness

Lack of ductility at atmospheric temperatures.

3.74 Cold-Working

Substantial mechanical working (usually above 5 percent), for example, drawing, rolling, forging, etc, of a metal or ahoy below its normal recrystallization temperature.

3.75 Columnar Crystal

The crystals growing generally normal to the cooling surface during solidification (*see* Fig. 5).

3.76 Combined Carbon

Carbon present in chemical combination with iron or other alloying elements.

3.77 Compression Strength

Stress under compression to fracture or to produce a definite amount of deformation.

3.78 Compression Test

A test for determining the maximum compressive load for producing a specified strain or fracture in a metal.

3.79 Constitutional Diagram (Equilibrium Diagram)

A diagram showing the constituents of an alloy formed under given conditions (*see* **3.146**).

3.80 Contraction Cavity

A cavity formed in an ingot as a result of contraction during solidification. Also referred to as shrinkage cavity or pipe (*see* Fig. 6, and **3.317**).

FIG. 6 CONTRACTION CAVITY, SHRINKAGE CAVITY OR PIPE

3.81 Controlled Atmosphere (Prepared Atmosphere)

A prepared atmosphere which helps to control the effect of surface oxidation, decarburization, etc, during heating, holding and cooling of steel.

3.82 Cooling Curve

A time-temperature relationship shown graphically for determining the arrest points (*see* Fig. 1).

3.83 Cooling Stresses

Stress developed in a material during cooling as a result of temperature gradients.

3.84 Copper Bearing Steel

A carbon or low alloy steel containing a minimum of 0.2 percent copper for obtaining better atmospheric corrosion resistance.

3.85 Copper Sulphate Test (Preece Test)

A test applied for assessing the quality of galvanized coating by dipping in copper sulphate solution under standard conditions.

3.86 Core

a) The inner portion of rimming steel.
b) The softer inner portion of case-hardened or surface-hardened steel.
c) A preformed sand aggregate inserted in a mould to shape the interior or that part of a casting which cannot be shaped by a pattern.

3.87 Cored Structure

The structure arising from a composition gradient produced in a solid solution and/or progressive freezing.

3.88 Corrosion

Chemical and/or electrochemical attack on metals or alloys.

3.89 Corrosion Embrittlement

An embrittlement caused in certain alloys by exposure to corrosive environment. It results from intergranular type of corrosion attack.

3.90 Corrosion Fatigue

Fatigue accelerated by corrosive conditions.

3.91 Creep

The continuous flow of a metal or alloy when stressed below its yield point or proportional limit. It is more marked at elevated temperatures and is, therefore, important in connection with metals and alloys for service at high temperature.

3.92 Creep Curve

A graphical representation between the deformation and time in a creep test.

3.93 Creep Limit

The maximum stress which a metal or alloy can withstand without deforming faster than at a specified strain rate at a given temperature.

3.94 Creep Rate

The rate of strain during 'creep test' under specified conditions of stress, temperature and time.

3.95 Critical Cooling Rate

The slowest cooling rate from a given temperature which can give a fully martensitic structure.

3.96 Critical Grain Growth

The appreciable grain growth observed in critically strained steels when annealed under certain conditions.

3.97 Critical Point (Change Point, Critical Temperature and Transformation Point)

The temperature at which a phase or a magnetic change takes place.

3.98 Critical Range

The range of temperature within which the phase or magnetic change occurs during heating or cooling.

3.99 Critical Strain

The minimum strain required to produce critical grain growth.

3.100 Crystal Grains (Grains)

The individual crystalline regions (crystallites) which constitute in the aggregate the metal or alloy.

3.101 Crystalline Fracture — *See* **3.48** and **3.69**.

3.102 Cup and Cone Fracture

The fracture of a ductile material in tension, one half having a cup-like form while the other half has the form of a truncated cone which fits into the cup (*see* Fig. 7).

FIG. 7 CUP AND CONE FRACTURE

3.103 Cupping Test

A ductility test for sheet and strip. This test involves forming a bulge or cup by stretch-forming the blank (that is, a test piece) through a circular die with the aid of a special dome shaped punch and measuring the depth of the bulge or cup prior to fracture.

3.104 Curie Point

The temperature above which a metal or alloy ceases to be magnetic.

3.105 Cyanide Hardening (Cyaniding)

A process of surface hardening by introduction of carbon and nitrogen together, using a molten cyanide bath.

3.106 Cyaniding — *See* **3.105**.

3.107 Damping Capacity

The ability of a metal or alloy to absorb the energy of mechanical vibrations.

3.108 Dead Soft Steel

A very low carbon steel characterized by high ductility, generally supplied in the fully annealed condition.

3.109 Decalescenes

Heat absorption without rise in temperature when a steel is heated through the critical range.

3.110 Decarburization

Loss of carbon from the surface of steel usually during heating, hot-working or heat treatment (*see* Fig. 8).

FIG. 8 DECARBURIZED SURFACE LAYER OF STEEL SPECIMEN

3.111 Deep Drawing

Forming cup shaped articles or shells by using a punch to force sheet metal into a die.

3.112 Deep Drawing Steel

A high quality steel which permits deep drawing.

3.113 Deep Etch Test

Etching a suitably prepared specimen with acid to reveal defects.

3.114 Delta Iron

The allotropic form of iron which in pure iron exists between approximately 1400°C and the melting point (*see* Fig. 2). Delta iron has a crystalline structure similar to alpha iron, namely, that of the body centred cubic form.

3.115 Dendrite

A crystal with a fir-tree structure formed by the initial freezing from a nucleus of primary branches followed by the formation from these of secondary branches at intervals so that a crystal skeleton is formed.

3.116 Dendritic Structure

The fir-tree like structure exhibited within a crystal grain in most of the cast metals and alloys. The metal solidifies preferentially on the crystal axis of the first formed nucleus and later on the parallel axis of secondary and higher order nuclei.

3.117 Diamond Hardness Test

A test to determine hardness by pressing a rhombus based diamond pyramid with an angle between long opposite edges 172° and short opposite edges 130° under a standard load on to the surface of the material and measuring the longer diagonal of the indentation produced (*see* IS 6885 (Part 1)). The result of the test is expressed as knoop hardness number (KHN).

$$\text{KHN} = \frac{\text{Applied load in kgf}}{\text{Surface area of indentation}}$$

3.118 Diamond Pyramid Hardness (Vickers Pyramid Numerals)

Hardness number determined by diamond pyramid hardness test.

3.119 Diamond Pyramid Hardness Test (Vickers Hardness Test)

A test to determine hardness by pressing a square-based diamond pyramid with an angle between opposite faces of 136° under a standard load into the surface of the material, and measuring the diagonal of the indentation produced. The diamond pyramid hardness number (HV).

$$\frac{\text{F}}{\text{A}} = \frac{\text{Applied load in kilograms} - \text{force}}{\text{Pyramidal area of indentation in mm}^2}$$

3.120 Differential Heating

A method of controlled heating to obtain a desired non-uniform temperature distribution in a material.

3.121 Differential Quenching (Selective Quenching)

A method of controlled quenching that results in different parts of a material achieving different hardness.

3.122 Diffusion

A movement of atoms within a solution which may be a liquid, solid or gas. The net movement is usually in the direction from regions of high concentration towards regions of low concentration.

3.123 Dilatometry

The test is used to evaluate minute length changes *versus* temperature/time of steels and other materials to investigate phase transformation, recrystallization, precipitation, thermal expansion co-efficient, etc.

3.124 Divorced Pearlite

Pearlite heat-treated to render its cementite constituent spheroidized (also called spheroidized carbide as distinct from lamellar carbide).

3.125 Drift Test (Pin Expansion Test)

A test for plate, carried out by boring a hole of a given diameter near the edge of the plate and enlarging it by a conical tool having a specified taper until either a specified increase in diameter takes place or cracking occurs. The test is also applicable to tubes, in which the diameter is increased at one end by forcing into the bore a mandrel of specified taper (*see also* **3.157**).

3.126 Drop Test

A test carried out on a material to determine its resistance to fracture or breakage under specific conditions. The usual form of this test is to drop the finished article (such as, tyre wheel, a sealed hollow receptacle containing liquid, etc) from a predetermined height.

3.127 Ductility

Ability to undergo plastic deformation usually as a result of tension.

3.123 Damp Test

A test to detect surface defects in materials intended for cold-or hot-forging. The test is carried out by upsetting a test piece of suitable length either cold, or after heating to the forging temperature, as the case may be, till a specified reduction is obtained.

3.129 Duplex Structure

A microstructure made of two phases.

3.130 Dynamic Strength

Strength of a material when subjected to suddenly applied or changing loads.

3.131 Elastic Deformation

A reversible change in dimensions under applied stress.

3.132 Elasticity

The property of a metal or alloy which permits return to its original dimensions on removal of applied stress not exceeding its elastic limits.

3.133 Elastic Limit

The maximum stress (generally in tension) a material can withstand without suffering permanent deformation.

3.134 Electro-Galvanizing

Zinc coating by electrodeposition.

3.135 Electrolytic (Galvanic) Corrosion

Preferential corrosion of a metal having electrical contact with another metal or conductor.

3.136 Electropolishing (Electrolytic Polishing)

A process of polishing metals and alloys by an electrolytic treatment.

3.137 Electro-Tinning (Tinning)

Tin coating by electrodeposition.

3.138 Elongation

The increase in length of a tensile test piece under stress. The elongation at fracture is conventionally expressed as a percentage of the original gauge length of the standard test piece.

3.139 End Quench Hardenability Test (Jominy Test)

A test in which the test piece is heated to a suitable temperature above the transformation range and then quenched at one end. The gradation of hardness along the length is then determined. The most common form of this test is the Jominy test.

3.140 Endurance Limit (Fatigue Limit)

The maximum stress below which a material can presumably endure an infinite number of stress. If the stress is not completely reversed, the value of the mean stress, the minimum stress or the stress ratio should be stated. When the mean value of the stress is zero, the endurance limit is equal to half of the maximum range of stress.

3.141 Endurance Range (Fatigue Range)

The maximum range of stress, which the material will withstand for a specified large number of stress cycles. When the mean value is zero the fatigue range is twice the fatigue limit.

3.142 Endurance Ratio (Fatigue Ratio)

The ratio of fatigue limit to the ultimate tensile strength.

3.143 Endurance Test (Fatigue Test)

A test to determine the fatigue range (endurance range).

3.144 Energizer

Substances (for example, barium carbonate and sodium carbonate) used in carburizing mixture for accelerating the carburizing process.

3.145 Equi-axed Crystals

Crystals which have axes approximately equal in length.

3.146 Equillibrium Diagram (Phase Diagram)

A diagram showing the limits of composition and temperature within which the various phases of an alloy may be formed, or exist under equilibrium conditions (*see* Fig. 9).

3.147 Erichsen Test

A test for sheet in which the depth of impression at fracture, obtained by forcing a cone-shaped plunger with a spherical end into the test piece, is measured in millimetres and used as an index of drawability.

3.148 Etching

Treatment of prepared metal surfaces with suitable reagents for revealing the structure by preferential attack on crystal grains or the phases.

3.149 Eutectic

A mixture of two or more constituents, which has the lowest freezing and melting points.

3.150 Eutectic Point

The point in the phase diagram indicating the composition and solidification temperature of an eutectic.

3.151 Eutectic Structure

The structure corresponding to the eutectic point. In general this is lamellar and is produced by simultaneous solidification of the constituents forming the eutectic.

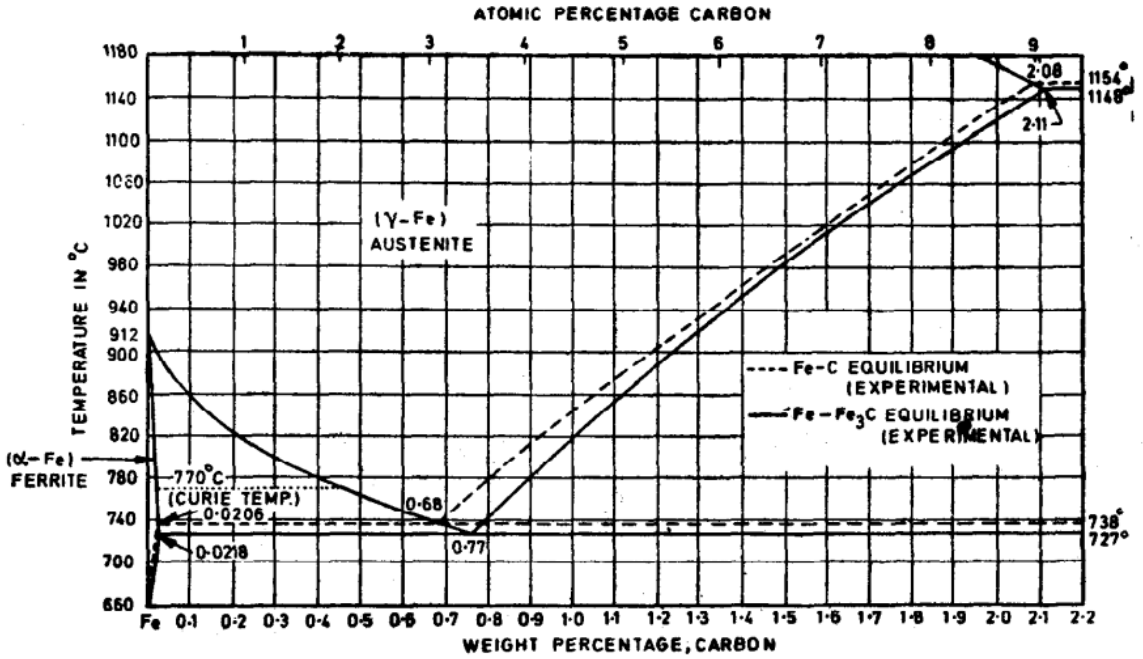


FIG. 9 EQUILIBRIUM DIAGRAM

3.152 Eutectoid

The mixture of two or more constituents formed at a constant temperature from the breakdown of a single solid solution during cooling and which transforms into a solid solution during heating.

3.153 Eutectoid Point

It is a specific point in the phase diagram indicating the temperature and phases corresponding to an eutectoid.

3.154 Eutectoid Steel

Steel of entirely eutectoid structure, that is wholly pearlitic.

3.155 Eutectoid Structure

The structure, usually lamellar, corresponding to an eutectoid.

3.156 Exfoliation (Flaking)

Spalling away in the form of thin flakes from the surface of a material. This may result due to corrosion in the case of metals or thermal shocks in the case of hard metals and refractories.

3.157 Expanding Test

A test mostly used for tubes in which one end of the sample is expanded, by means of tapered grips, to a specified diameter.

3.158 Falling Weight Test

A test applied by dropping a specified weight from a definite height on to the material to be tested. Normally applied to tyres, axles, rails, etc, when a maximum deflection without fracture is usually specified.

3.159 Fatigue

The tendency to fracture by means of a progressive crack under repeated alternating and/or cyclic stresses considerably below the tensile strength.

3.160 Fatigue Fracture

The characteristic fracture associated with fatigue failure.

3.161 Fatigue Limit — *See* **3.140.**

3.162 Fatigue Range — *See* **3.141.**

3.163 Fatigue Ratio — *See* **3.142.**

3.164 Fatigue Test — *See* **3.143.**

3.165 Flakes — *See* **3.198.**

3.166 Ferrite

The microconstituent corresponding to the crystalline form known as ‘alpha’ iron (which has a body-centred cubic lattice). Many alloying elements (for example, nickel, manganese and silicon) are soluble in alpha iron, hence the term ferrite refers also to such solid solutions.

3.167 Ferritic Steel

A steel which contains essentially ferrite (BCC structure) as the microconstituent.

3.168 Fibre

An elongated arrangement of the plastic constituents of the structure due to working and is usually revealed by etching.

3.169 Fibrous Fracture

A dull grey fracture in which considerable distortion has occurred, indicative of toughness.

3.170 Flaking — *See* **3.156**.

3.171 Flame Hardening

Rapid heating of the surface, by means of an oxy-gas flame to a temperature above the transformation range, followed by immediate quenching (usually by means of a water jet).

3.172 Flanging Test

A test for tube in which the end of the tube is turned back to form a flange at right angles to the axis of the tube.

3.173 Flattening Test

A test for tube in which a short length of the sample tube is flattened diametrically by a specified amount.

3.174 Flow Line

Pattern revealed by suitably etching the prepared surface of a wrought material revealing the directional 'flow' during working.

3.175 Fracture Toughness Test

The test is used to evaluate the resistance of the material to crack propagation under given conditions of rack size, geometry of the specimen, environment and the nature of the applied load.

3.176 Free Cementite

Cementite not associated with pearlite.

3.177 Free Cutting Steel

Steel in which special addition of such elements as sulphur, lead, etc, are made to enhance machinability.

3.178 Free Ferrite

Ferrite not associated with cementite.

3.179 Galvanizing

Process of depositing zinc on a metallic surface (*see* **3.134** and **3.215**).

3.180 Gamma Iron (or Iron)

The face-centred cubic form of iron stable between approximately 910 to 1400°C.

3.181 Gangue

Part of an ore, which has to be either removed during benefication of the ore, or slagged during smelting.

3.182 Gas Carburizing

Carburizing in a gaseous medium of suitable composition.

3.183 Gas Cyaniding

A process of surface hardening of steel by heating in a suitable gaseous atmosphere so that carbon and nitrogen are simultaneously absorbed by the steel, followed by desired rate of cooling.

3.184 Gas Welding

A group of processes, wherein welding is effected by heating with a gas flame or flames, with or without the application of pressure and with or without the addition of filler metal.

3.185 Gauge Length

a) The specified length in the tensile test piece over which elongation is measured.
b) The length under test in torsion and compression test pieces.

3.186 Ghost (Ghost Lines)

A segregated streak, usually containing a concentration of sulphide, phosphide, oxide, etc, lower in carbon than the surrounding material (*see also* **3.311**).

3.187 Grain Boundary

The boundary outlining a crystal.

3.188 Grain Growth

Increase in the size of grains associated with heating to high temperatures. Grain growth also occurs during normal subcritical annealing after critical amount of cold reduction.

3.189 Grain Refiner

A substance added to the molten metal or alloy to produce finer grains.

3.190 Grain Refining

Heating appropriately through the transformation range followed by cooling suitably from above that range, for obtaining desired refinement of grains, which may also be obtained by controlling the finishing temperature of hot-worked material or by suitable cold work followed by annealing.

3.191 Grain Size

The size of crystal constituting a material and is expressed by the number of grains or crystals per unit area.

3.192 Grain Size Control

A control exercised during steel making and finishing for obtaining a steel with the desired requirements for grain size.

3.193 Grain Size Number

A number (N) to classify the grain size on the basis of the total number of grains (n) in an area of 2.54 x 2.54 cm^2 at a magnification of 100 diameter, the relation being

$$n = 2^{N-1}$$

The grain size number and the total number of grains are shown in Fig. 10.

3.194 Graphitic Carbon

Carbon present in the form of graphite.

3.195 Graphitic Steel

Steel which contains small amount of carbon in the form of graphite.

3.196 Graphitizing

Heating and cooling in a controlled manner so as to transform the combined carbon to graphitic form (for example, free carbon) of desired size and amount.

3.197 Grinding Cracks

Cracks appearing in a network pattern and arising from excessive heat generated during grinding (*see* Fig. 11).

3.198 Hair Line Cracks (Flakes)

Internal ruptures in steel caused by stresses which probably arise from the combination of several factors, such as volume changes due to transformation, brittleness due to the presence of hydrogen and the arrangement of the microstructure, resulting from hot-working. The size of such ruptures may vary considerably but they are usually comparatively short in length when viewed on a surface cut at right angles to the plane of defect, and generally are so fine that they cannot be discerned except after etching or by magnetic crack direction.

3.198.1 *Snowflakes* — When hairline cracks are exposed by fracturing, they appear as bright crystalline areas of almost circular form, sometimes known as snowflakes.

3.199 Hardenability

The property that determines the ability of a given steel to harden right through and is assessed by measuring hardness distribution from surface to interior after quenching under specified condition (*see* **3.139**).

3.200 Hardenability Test

A test for assessing hardenability (*see* **3.139**). There are other methods also for determining the hardenability which are used for specific purposes.

3.201 Hardening

Any process which increases the hardness, for example, quenching from or above the transformation range, or cold-working.

3.202 Hardness

Resistance to indentation, abrasion, deformation, scratch, etc.

3.203 Hardness Test

A test to determine the hardness and is generally measured by the resistance of the material to deformation under standard conditions. There are various forms of this test using different instruments for measuring indentation (for example, Vickers, Rockwell, Shore, Brinell etc).

3.204 Heating Curve

A graph constructed by plotting the temperature against time when a material is being heated in a regular manner. Any ‘arrest’ in temperature indicates constitutional change (*see* **3.82**).

3.205 Heat Resisting Cast Iron

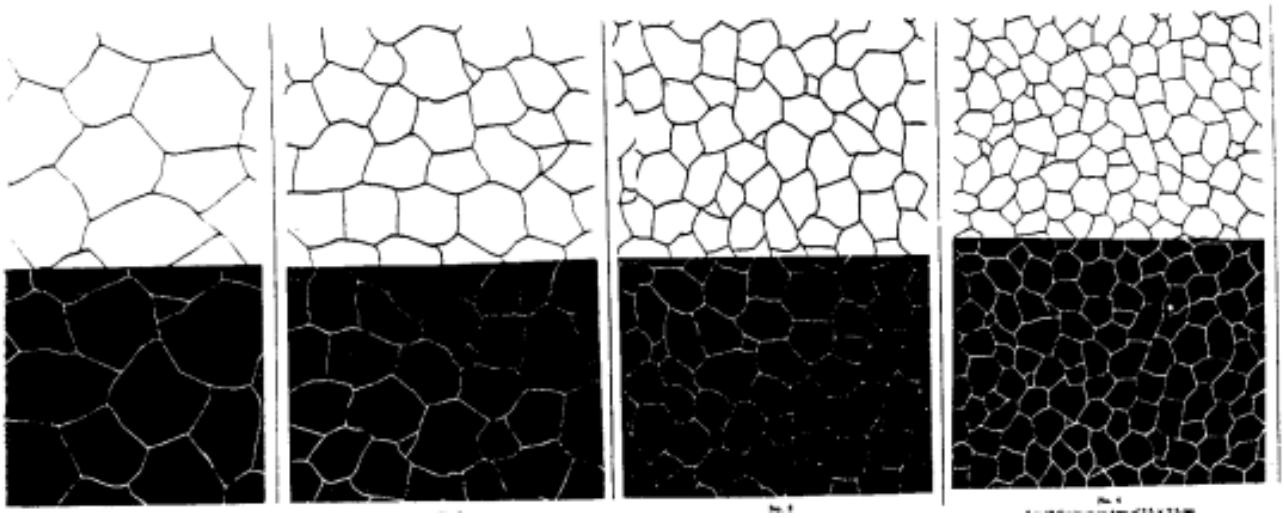
An alloy cast iron suitable for high temperature service (above 400°C).

3.206 Heat Resisting Steel

An alloy steel generally containing high percentages of chromium and/or nickel and possessing enhanced resistance to scaling coupled with good mechanical strength at high temperatures.

3.207 Heat Tinting

A process for developing colour on a specially prepared surface by heat, the object being (a) to impart a protective film, and (b) to reveal crystalline structure by affecting different constituents in a different way.

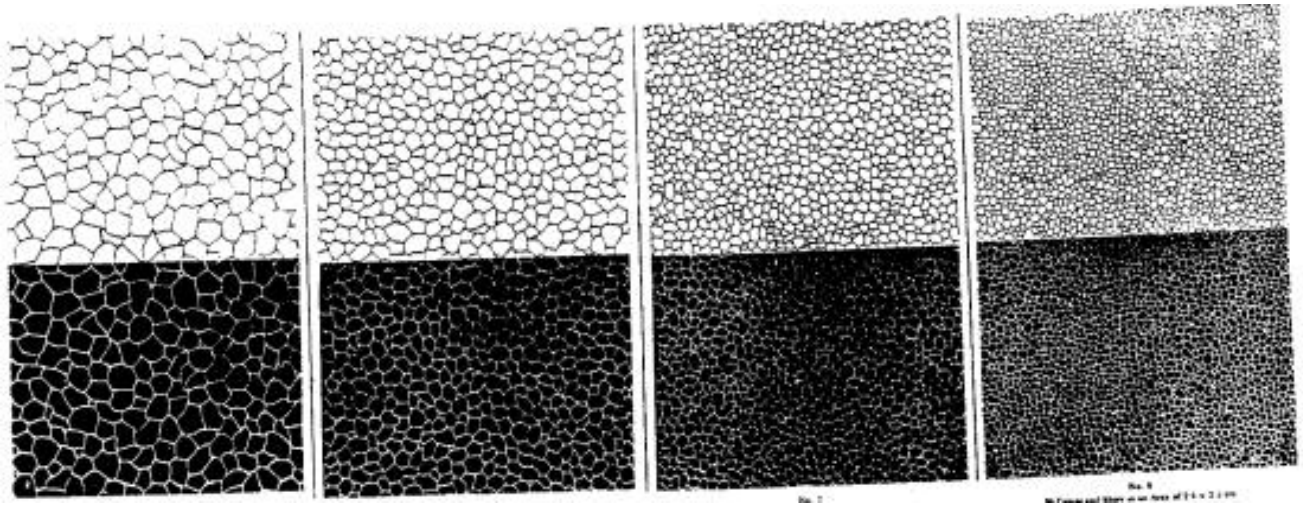


No. 1
Up to $1\frac{1}{2}$ Grains in an Area of 2.5 × 2.5 cm

No. 2
$1\frac{1}{2}$ to 3 Grains in an Area of 2.5 × 2.5 cm

No. 3
3 to 6 Grains in an Area of 2.5 × 2.5 cm

No. 4
6 to 12 Grains in an Area of 2.5 × 2.5 cm



No. 5
12 to 24 Grains in an Area of 2.5 × 2.5 cm

No. 6
24 to 48 Grains in an Area of 2.5 × 2.5 cm

No. 7
48 to 96 Grains in an Area of 2.5 × 2.5 cm

No. 8
96 Grains and More in an Area of 2.5 × 2.5 cm

FIG. 10 GRAIN SIZE CHART

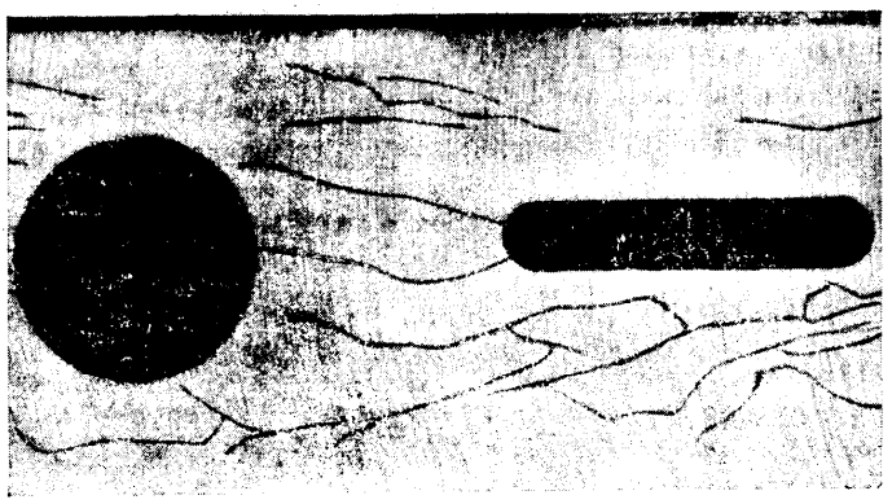


FIG. 11 GRINDING CRACKS

3.208 Heat Treatment

Combination of heating and cooling operations in a prescribed manner (with respect to time, temperature and rate of heating and cooling) to induce desired properties in metals and alloys in the solid state. The conventional heating for hot-working does not come within the scope of heat treatment.

3.209 Heterogeneity

Variation in composition in a given piece of metal or alloy.

3.210 High carbon Steel

Carbon steel containing generally more than 0.60 percent carbon.

3.211 High Speed Steel

A special variety of tool steel which, by virtue of its composition, retains its cutting hardness at a low red heat (*see* IS 7291).

3.212 Homogeneity

Uniformity of composition in the same piece of metal.

3.213 Hooke's Law

The law defining stress-strain relationship under certain condition, namely, within elastic limit the strain produced is proportional to the applied stress.

3.214 Hot-Forming

Operations, such as bending and pressing, after heating the material to appropriate temperature.

3.215 Hot Galvanizing (Hot-Dip Galvanizing)

Coating with zinc by immersion in a bath of molten zinc.

3.216 Hot-Shortness

Tendency to crack during hot-working.

3.217 Hot Tinning

Coating with tin by dipping into a bath of molten metal.

3.218 Hot-Working

The operation of plastic deformation of metals and alloys at appropriate temperatures in a manner that no strain hardening occurs during such operation.

3.219 Hydraulic Test (Hydrostatic Teat, Pressure Test)

A test for tubes or hollow products in which the test samples are subjected to a specified internal liquid pressure.

3.220 Hydrogen Embrittlement

Loss in ductility due to the absorption of hydrogen.

3.221 Hydrostatic Test — *See* **3.219**.

3.222 Hyper-Eutectoid Steel

Steel containing more than eutectoid percentage of carbon.

3.223 Hypo-Eutectoid Steel

Steel containing less than eutectoid percentage of carbon.

3.224 Impact Test (Notched Bar Impact Test)

A test to determine the behaviour of metal under suddenly applied stresses.

3.225 Inclusions (Non-metallic Inclusions)

Non-metallic materials like oxides, sulphides, silicates, refractories, etc, embedded in the metal.

3.226 Indentation Hardness

Hardness value derived by an indentation method.

3.227 Induction Hardening

Process of hardening by induction heating to the appropriate temperature and quenching in a suitable medium.

NOTE — This process is generally applied to surface hardening but may also be applied to full hardening.

3.228 Induction Heating

Process of heating by electrical induction method, that is, by induced current.

3.229 Ingot

Castings of suitable shape and size intended for subsequent hot-working.

3.230 Ingot Iron

Very low carbon steel generally made in the open hearth containing very small amounts of other elements.

3.231 Ingot Structure

Crystalline arrangement (for example chill, columnar and equi-axed crystals) in an ingot.

3.232 Inherent Grain Size

Austenite grain size developed under standard conditions (*see* **3.271**).

3.233 Inhibitor

Substance (generally organic in nature) added in pickling bath to minimize metal loss.

3.234 Intercrystalline Corrosion (Intergranular Corrosion)

Corrosion which occurs grain boundaries.

3.235 Intercrystalline Fracture

A fracture occurring along grain boundaries, for example, a creep fracture.

3.236 Intergranular Corrosion — *See* **3.234.**

3.237 Internal Stress

Stress existing within a metal as a result of transformation, temperature gradients or mechanical working.

3.238 Interrupted Quenching — *See* **3.418.**

3.239 Intra-Crystalline Fracture

Fracture taking place across the grains or crystals in a metal.

3.240 Inverse Segregation — *See* **2.360.**

3.241 Isothermal Transformation

A transformation of austenite taking place at a constant temperature.

3.242 Izod Impact Test (Notched Bar Impact Test)

A type of impact test wherein a test piece, with a standard V-shaped notch and fixed at one end, is struck by the blow of a pendulum and the energy thus absorbed in fracturing the test piece (recorded by the testing machine) is measured (*see* IS 1598).

3.243 Jenkin's Bend Test

An alternating bend test through an angle of 180° carried out with a machine having a constant radius of bend.

3.244 Jominy Test — *See* **3.139.**

3.245 Keyhole Notch

A type of notch (which takes the shape of a keyhole) used in Charpy impact test.

3.246 Knock Down Test — *See* **3.429**.

3.247 Laminations

A defect in rolled materials, characterized by a tendency to split into layers along the directions of rolling usually due to the presence of non-metallic inclusions or other discontinuity in the steel.

3.248 Lap (Overlap)

A surface defect, similar to a seam in appearance and is caused by folding over of hot steel in the form of fin, sharp corners, etc, on the rolled surface, and subsequently, rolled or forged but not welded to the surface.

3.249 Lead-Bearing Steel

A steel containing lead (about 0.20 percent) for obtaining better machinability.

3.250 Lead Patenting

A patenting process where quenching is carried out in a lead bath (*see* also **3.302**).

3.251 Ledeburite

The eutectic of iron and iron carbide system solidifying at about 1130°C. It is made up of austenite and cementite, and contains about 4.3 percent carbon.

3.252 Limit of Proportionality (Proportional Limit)

The stress (that is, load per unit area of the test piece) at which the strain (that is, elongation per unit gauge length) just ceases to be proportional to the applied stress.

3.253 Liquidus

The lines (in a two-component system) or surfaces (in a three-component system) in equilibrium diagrams representing temperatures at which solidification commences during cooling, or melting completed during heating.

3.254 Load-Extension Curve (Stress-Strain Curve)

A graphical representation showing the relationship between applied load and elongation of the test piece in a tensile test (*see* **3.100**).

3.255 Local Extension

The elongation produced in a tensile test piece where necking occurs.

3.255 Luder Lines — *See* **3.401**.

3.257 Macro-etch

Etching prepared surfaces with acid or other suitable reagent to reveal macro-structure flow lines and defects.

3.258 Macro-structure

The crystalline structure and the distribution of impurities on the macro-etched surface visible to the naked eye or under low magnification (not exceeding 10 diameters).

3.259 Magnetic Change Point or Magnetic Transformation Point (Curie Point)

The temperature at which iron loses its ferromagnetism on heating and recovers the same during cooling (temperature corresponding to this point for pure iron being about 770°C).

3.260 Magnetic Crack Detection

A method of detecting surface and sub-surface flaws. It is carried out by magnetising the surface to be examined and then covering it with very fine magnetic powder either in emulsion form or in solid form then draining off the excess oil. At discontinuities, left by cracks, there will be change in magnetic flux, as such the magnetic ‘ powder ’ aligns itself accordingly on the surface, giving well formed ‘ patterns ’ outlining the cracks.

3.261 Malleability

Capacity for undergoing deformation in all directions, usually cold deformation by hammering or squeezing.

3.262 Malleable Cast Iron (Malleable Iron)

Cast iron that is cast white and made malleable by annealing in an oxidizing or neutral medium (*see* also **3.32** and **3.438**).

3.263 Malleabilizing

The process of annealing white cast iron so as to transform combined carbon partly or wholly (depending on the type of the product desired) into graphitic carbon. In some instances, the carbon is removed partly or completely from the white iron.

3.264 Manganese Steel

A steel which contains only manganese as alloying element. Generally it refers to the austenitic variety containing 12 percent manganese.

3.265 Martempering

An isothermal treatment in which the object is quenched from a suitable austenitising temperature to a temperature slightly above the Ms point and held at that temperature for a suitable length of time for equalizing temperature and then cooled in air. The martensite thus formed is then tempered as desired (*see* Fig. 12).

3.266 Martensite

The hard microconstituent formed when a steel is cooled appropriately from above the transformation temperature, that is, cooled with a speed faster than its critical cooling rate. It is generally an interstitial super saturated solid solution of carbon in iron having a body centred tetragonal lattice and its microstructure is characterized by an acicular or needle-like pattern.

3.267 Martensite Transformation (Mf Point, Ms Point)

The transformation of austenite to martensite. It takes place very quickly over a range of temperature and is largely believed to be diffusionless. The temperature at which the transformation commences is termed as Ms point and the temperature at which the transformation is completed is termed as Mf point.

3.268 Martensite Transformation Range

The martensite transformation takes place over a range of temperatures depending on the rate of cooling. The temperature at which the transformation begins is termed as Ms point and the temperature at which the transformation finishes is termed as Mf point (*see* **3.267**).

3.269 Mass Effect

The effect of mass, that is, thickness, size and shape, in causing a variation in properties at different depths in a heat-treated material arising from difference in cooling rate of different portions.

3.270 Maximum Stress

The maximum load reached in a tensile test divided by the original cross-sectional area of the gauge length portion of the test piece. Also called as ‘ultimate tensile stress’ or ‘tensile strength’.

3.271 McQuaid-Ehn Grain Size

A measure of the size of crystal grains first suggested by McQuaid, and refers to grains developed in steel carburized at 925°C for 8 hours and then cooled in furnace resulting in a hyper-eutectoid case with cementite outlining the austenite grains.

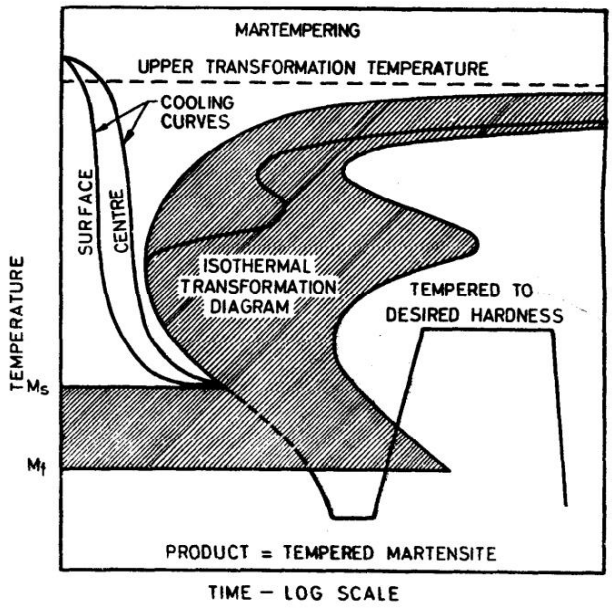


FIG. 12 SCHEMATIC TRANSFORMATION DIAGRAM FOR MARTEMPERING

3.272 Mechanical Properties

Properties which are determined by mechanical methods involving destruction or deformation or both, such as tensile test, bend test, impact test and hardness. These properties are indicative of elastic and non-elastic behaviour of metals under applied stress.

3.273 Mechanical Strength

Strength evaluated on the basis of mechanical properties.

3.274 Medium Carbon Steel

Carbon steel containing generally minimum of 0.30 percent carbon and maximum of 0.60 percent carbon.

3.275 Mesnager Notch

U-shaped notch used in some Izod impact test.

3.276 Metallography

The study of the constitution and structure of metals and alloys with the aid of a microscope.

3.277 Microstructure

The structure of metals or alloys revealed (after polishing and etching) under the microscope.

3.278 Middle Half of Gauge Length

The central half of the guage length marked on a test piece.

3.279 Mild Steel

Carbon steel containing generally less than 0.30 percent carbon.

3.280 Modulus of Elasticity (Young's Modulus)

Ratio of direct stress to strain within the elastic limit, in tension or compression.

3.281 Modulus of Rigidity

Ratio of shear stress to strain within the elastic limit, in shear.

3.282 Necking

It is the localized reduction in cross section occurring in a ductile material under tension before fracture.

3.283 Network Structure — *See* **3.63**.

3.284 Neumann Bands

Thin twin bands running parallel to certain crystallographic planes observed (after polishing and etching) in ferrite crystals deformed by impact without any prior straining. Slow straining itself or slow straining followed by impact does not reveal such bands.

3.285 Nicked Fracture Test

A test for welds in which an examination is carried out of a fracture obtained by nicking or sawing a small part of the cross section of a specimen and then breaking the same by bending.

3.286 Nitriding

A process of surface hardening by introducing, nitrogen into the surface in a suitable steel by heating and holding it at appropriate temperature in contact with cracked ammonia or other suitable nitrogenous medium.

3.287 Non-metallic Inclusion — *See* **3.225**.

3.288 Normalizing

A process of heat treatment for improving mechanical properties brought about by grain refinement and uniformity in structure. The process involves heating to and holding for a specified time at a suitable temperature above the transformation range, followed by cooling freely in air.

3.289 Notch Brittleness

Tendency of a metal to fail by brittle fracture at a notch or stress raiser by a suddenly applied load.

3.290 Notched Bar Impact Teat — *See* **3.224** and **3.242**.

3.291 Notch Sensitivity

Reduction in nominal strength, impact or static, caused by stress concentration due to a notch or any stress raiser, and is usually expressed as a ratio of the notched to the unnotched strength.

3.292 Notch Toughness

A high resistance to fracture under suddenly applied loads at a notch or other stress raiser.

3.293 Open Annealing (Black Annealing) — *See* **3.31**.

3.294 Open Coil Annealing (Unitized Annealing)

Annealing of a sheet coil in the form of a loosely wound coil with or without a metal spacer between successive laps of the coil, thus providing gap for the atmosphere to circulate around each lap of the coil. This form of annealing is generally used for decarburization annealing and/or denitriding, that is, annealing simultaneously with decarburization and denitriding to produce extra low carbon and low nitrogen steels. Generally it is carried out in Bell type furnaces, but when carried out in Bogie Hearth Furnaces the process is usually termed as 'unitized annealing '.

3.295 Open Hearth Furnace

A furnace having a dish shaped hearth in which the bath is heated by convection from the flame over the surface of the metal and by radiation from the roof. Commonly used for steel making.

3.296 Overaging

Softening which follows ageing by prolonged heating, at the ageing temperature.

3.297 Overlap — *See* **3.248**.

3.298 Overheating

Heating to such a high temperature that an undesirably coarse grained structure is produced. Severe overheating may result in the properties being permanently impaired (*see* Fig. 13).

3.299 Pack Annealing

Close annealing of packs of sheets.

3.300 Pack Rolling

Rolling two or more sheets at a time.

3.301 Passivity

The state of remaining unattacked chemically after a slight initial attack due to the formation of a protective film.

3.302 Patenting (Air Patenting)

Heating to an appropriate temperature above the transformation range and then cooling at a controlled rate in the desired medium (for example, air, lead or a salt bath) to produce structure desirable for subsequent cold-working. Usually this is applied to wire drawing.

3.303 Pearlite

The microconstituent of eutectoid composition revealing, under the microscope, alternate layers of ferrite and cementite. In the iron-carbon system this constituent contains slightly under 0.9 percent carbon.

3.304 Preece Test — *See* **3.85**.

FIG. 13 COARSE GRAIN STRUCTURE DUE TO OVERHEATING

3.305 Peritectic Change (Peritectic Reaction)

A reversible change involving the formation of a new solid phase at a constant temperature as a result of the reaction between a prior solid and a liquid phase of an alloy. During heating the change proceeds in opposite direction.

3.306 Permalloy

Nickel alloys containing 20 to 60 percent iron, used for their high magnetic permeability and electrical resistivity.

3.307 Permanent Magnet Steel

A heat-treated special steel of suitable composition possessing high coercive force and remanance and, therefore, suitable for use as permanent magnets.

3.308 Permanent Set (Plastic Deformation)

Deformation existing after the removal of the applied load (that is, the material does not revert to its original dimension after the removal of the load) (*see* **3.318**).

3.309 Phase

A completely homogeneous, physically distinct and mechanically separable portion of a metallic system.

3.310 Phase Diagram — *See* **3.146**.

3.311 Phosphide Streak

An elongated area of segregated phosphides which is revealed on etching.

3.312 Photomicrograph

A photographic reproduction of the microstructure.

3.313 Pig

Molten metal cast into suitable shapes intended for remelting.

3.314 Pig Iron

The primary product of smelting iron ore containing usually between 3 to 4.5 percent carbon along with silicon, manganese, phosphorus and sulphur in varying amounts depending upon the quality of raw materials used. Pig iron is used in the foundry or for conversion into steel.

3.315 Pin-Head Blister — *See* **3.37**.

3.316 Pin Hole Porosity

Minute holes scattered throughout the surface of a casting resulting from micro-shrinkage or gas evolution during solidification.

3.317 Pipe (Contraction Cavity, Shrinkage Cavity)

An axial cavity caused by contraction during solidification of an ingot. Also the defects arising from the axial cavity on the semifinished or finished products. It may also refer to tubular sections.

3.318 Plastic Deformation — *See* **3.308**.

3.319 Plasticity

Ability of a metal or an alloy to undergo plastic deformation without rupture.

3.320 Poisson's Ratio

The ratio of transverse strain to the longitudinal strain under tension or compression within the elastic range.

3.321 Polymorphism — *See* **3.8**.

3.322 Pot Quenching — Direct quenching from the carburizing operation.

3.323 Precipitation Hardening — Hardening caused by the precipitation of a constituent from a super saturated solid solution.

3.324 Preheating

Heating at a moderate temperature carried out as a preliminary to further heating at a higher temperature.

3.325 Prepared Atmosphere — *See* **3.81**.

3.326 Pressure Test — *See* **3.7** and **3.219**.

3.327 Primary Carbide

Carbide in excess of the eutectic composition. This term is also used for carbide in excess of eutectoid composition.

3.328 Primary Crystals

The first dendritic crystals which form in an alloy during cooling below the liquidous temperature.

3.329 Principle Stresses

Normal stresses along rectilinear co-ordinates so chosen that shearing stresses are zero.

3.330 Process Annealing

Sub-critical annealing applied in sheet and wire industry for the purpose of softening for further cold-working (*see also* **3.13**).

3.331 Proof Rend Test

A test in which a tube, supported suitably, is loaded to give a specified bending moment.

3.332 Proof Stress

A stress that will cause a specified permanent, deformation in a material, usually 0.1 percent of the gauge length.

3.333 Proportional Limit — *See* **3.252**.

3.334 Quenching — Rapid cooling.

3.335 Quenching Cracks

Cracks resulting from thermal stresses induced on rapid cooling or quenching.

3.336 Radial Test — *See* **3.425**.

3.337 Ram's Horn Test

A test for determining the suitability of wrought iron or steel for forging, and is carried out by punching a hole near the end of test bar heated to forging temperature, drifting the hole, splitting longitudinally to the adjacent end of the bar and finally doubling the parted portions backwards.

3.336 Range of Proportionality

The part of stress strain curve over which the strain is proportional to the stress.

3.339 Recalescence

Evolution of heat during cooling through the transformation range of the steel or iron, associated with gamma to alpha transformation on cooling and is revealed by brightening (reglowing) of metal surface.

3.340 Recalescence Point

The temperature at which recalescence occurs (*see also* **3.97**).

3.341 Recrystallization

The change from one crystal structure to another occurring on heating or cooling through a critical temperature. The formation of new, strain free grain structure from that of cold worked metal on heating, is also called recrystallization.

3.342 Recrystallization Temperature

The temperature at which recrystallization commences.

3.343 Red Hardness

The relatively high hardness retained by certain special steels (for example, high speed tool steels) even when heated up to a low red heat.

3.344 Reduction of Area

Percentage reduction in area of a tensile test piece after fracture. The difference between original area of the cross section and the smallest area at the point of rupture of the tensile test piece, when expressed as percentage of the original area, gives this value.

3.345 Refining

The removal, by slag or other reactions, of undesirable elements and of metallic oxides and gases from molten steel.

3.346 Refractory

A heat-resistant material usually non-metallic, used for furnace lining to withstand high temperatures.

3.347 Regenerator

Arrangement (chambers filled with a checkwork of refractory bricks) for receiving and then utilizing heat from hot spent gas from a furnace.

3.348 Residual Stress

Stresses existing within a metal in absence of or in addition to, the stresses caused by external load. These stresses could be present due to mechanical deformation, thermal expansion/contraction electro or magneto-striction or due to welding, etc.

3.349 Resilience

Property of a material to return to its original shape and after the removal of the stress that has produced elastic strain. This is measured as energy per unit volume released upon unloading.

3.350 Reverse Torsion Test

A test for wires carried out by twisting the test piece a specified number of times in one direction and then in the opposite direction.

3.351 Rivet Test

A test for rivets. It consists of two parts, namely: (a) for shank, and (b) for the head. In (a) the shank is bent cold and hammered till the two parts of the shank are in contact with each other, without showing any sign of fracture on the outside of the bend. In (b) the head is flattened hot until its diameter is $2\frac{1}{2}$ times the diameter of the shank, without showing any crack.

3.352 Rockwell Hardness Test

A hardness test for measuring the indentation hardness using an indentor in the form of a diamond cone, or a hardened steel ball. The hardness value being read directly on the dial of measuring instrument (*see* IS 1586(Part 1)).

3.353 Ruling Section

Limiting cross section of a bar which would obtain uniform mechanical properties on heat treatment. It is expressed as a diameter of a round bar. The rectangular or other sections are expressed as equivalent round sections by applying conversion factors.

3.354 Scab

Irregular shaped patches of metal on ingot surface arising from cavities in mould walls or caused by loosely adhering layers of metal.

3.355 Scale

Oxide formed on the surface of steel or iron after heating under oxidizing conditions.

3.356 Scleroscope Hardness Test (Shore Scleroscope Hardness Test)

A test in which hardness is measured by noting height of rebound of a freely falling diamond pointed tup or hammer (placed inside a graduated glass tube), from a fixed height on the smooth surface of the specimen to be tested.

3.357 S-Curve (TTT Diagram)

An isothermal transformation curve showing the time taken by austenite to transform isothermally at various temperatures between A3 and commencement of transformation (Ms). It is sometimes called 'S' curve because the curve has a shape like letter S for some steels such as plain carbon steels. It is also called 'C' curve as many curves have a shape like letter C. It is called TTT diagram because it represents time-temperature-transformation relationship (*see* Fig 14).

3.358 Seam

Long shallow groove or striation formed during rolling by the elongation of oxidized surface or subsurface blow holes. Seams may also be caused by rippled surfaces or by recurrent teeming laps.

3.359 Secondary Hardening

A phenomenon that takes place in certain types of hardened steels (for example, high speed steel), and results in greater hardness on tempering at some higher temperature, than would be obtained by tempering the same steel at lower temperature.

3.360 Segregation

A non-uniform distribution of some constituents and/or impurities, in a cast product characterized by the mode of solidification of alloys. Segregation usually persists through subsequent hot and cold-working. Generally, the concentration of low melting point constituents tend to be higher in the centre than the surface. Sometimes, the reverse of this phenomenon takes place and is known as inverse segregation.

3.361 Self-Hardening Steel — *See* **3.6**.

3.362 Shear Crack

A diagonal transgranular crack caused by shear stress.

3.363 Shearing Test

A form of shear test to determine the stress required to cut or shear the material across its section.

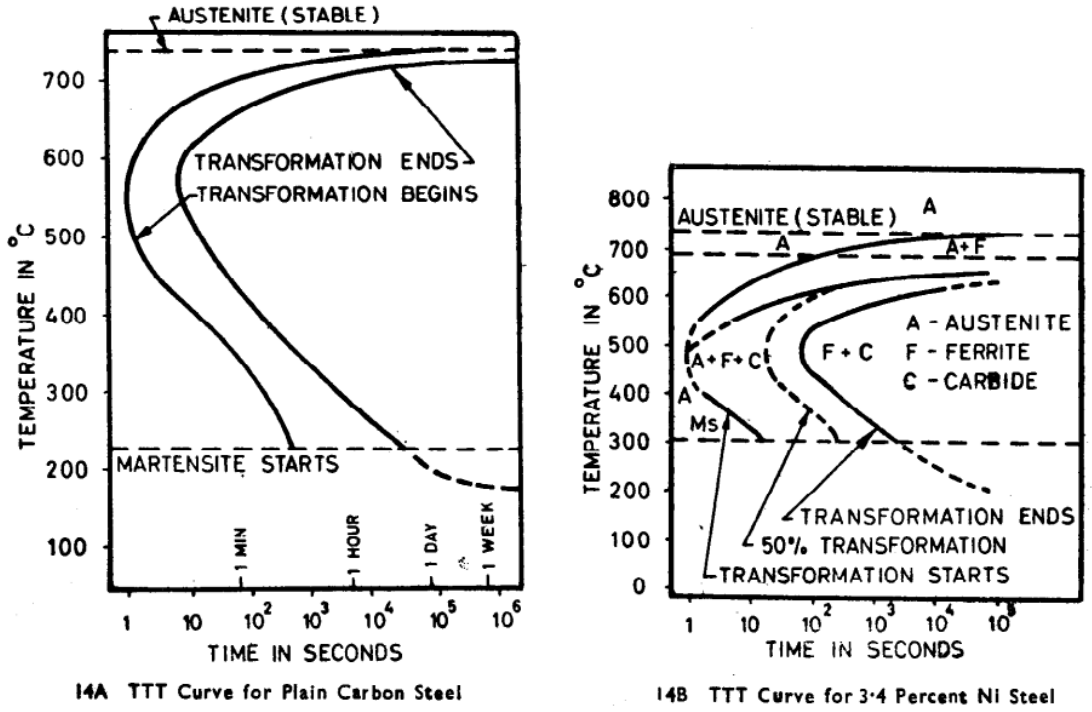
3.364 Shear Test

A test to determine the resistance to sliding of one portion over the other when a material is twisted.

3.363 Shrinkage Cavity — *See* **3.317**.

3.366 Sigma Phase

Hard and brittle non-magnetic inter-metallic phase with a tetragonal crystal structure found in many binary and ternary alloys of transition elements, for example, in chromium steels.



14A TTT Curve for Plain Carbon Steel

14B TTT Curve for 3·4 Percent Ni Steel

FIG. 14 TTT CURVE

3.367 Silky Fracture

Fracture showing very fine grains and smooth grey appearance, characteristic of tough and strong metals.

3.368 Slip

Sliding of a part of a crystal over the other along certain planes, known as slip planes. It is by such sliding movements that deformation occurs as a result of stress.

3.369 Slip Bands

Parallel lines across individual crystal observed under microscope, in a cold-worked metal.

3.370 Slug Test — *See* **3.429**.

3.371 Snarl Test

A workshop test applied to wire which is looped, pulled taut, unlooped, pulled taut again, the operation being repeated until fracture occurs.

3.372 S/N Curve (Stress Number Curve)

The curve derived from the number of cycles of stress to produce failure when plotted against the range of stress from a series of fatigue tests.

3.373 Snow Flakes — *See* **3.198.1**.

3.374 Soaking

Holding the material in a furnace after the outside has reached the desired temperature until uniformity of that temperature has been reached throughout its mass and any desired metallurgical changes have been completed.

3.375 Softening

Reducing the hardness by heat treatment, usually tempering, but at times, annealing, primarily to facilitate machining.

3.376 Solidification Range

The range of temperature over which freezing takes place.

3.377 Solid Solubility

Extent to which one constituent is soluble in another, in the solid state, to form a solid solution.

3.378 Solid Solution

Two or more constituents forming in the solid state, a single homogeneous phase.

3.379 Solidus

The lines of surfaces (depending on whether two or more constituents are involved) in thermal equilibrium diagrams indicating the temperatures of complete solidification or commencement of melting.

3.380 Sorbite

The microstructure resulting from the tempering of martensite at about 450°C. It is also used to denote fine pearlite which is not resolved at low magnification.

3.381 Spalling (Flaking) — *See* **3.156**.

3.382 Spark Test

A visual test for an approximate estimation of carbon and content of different alloying elements in steel by observing sparks produced by holding a sample against grinding wheel.

3.383 Special Steel

Steel in the production of which special care has to be taken so as to attain the desired cleanliness, surface quality and the mechanical properties.

3.384 Spectroscopy

The test used to find the composition of metals and by finding the intensities of standard spectral lines in an instrument calibrated with spectroscopic standard materials.

3.385 Spheroidite (Spheroidized Cementite)

An aggregate of iron and alloy carbides of essentially spherical shape dispersed throughout a matrix of ferrite obtained by prolonged heating just below ACI, or other methods of spheriodize annealing.

3.386 Spheroidizing

A process of heat treatment to produce globular form of carbide in steel and consists in prolonged heating of steel to a suitable temperature, within or near the transformation range. This treatment improves machinability and facilitates finishing by cold work. It is also useful where such structure is desirable for further heat treatment in processing certain materials.

3.387 Spiegeleisen

A ferro-alloy containing carbon between 4 to 6.5 percent and manganese between 15 to 30 percent.

3.388 Stabilizing

Treatment given to certain materials for such purposes as: (a) improved life under service condition, (b) better workability, (c) decreasing age-hardening characteristics at room temperature, and (d) obtaining dimensional stability. This term is also used for inhibition of weld metal decay in certain varieties of austenitic nickel chrome stainless steels by the addition of certain elements, for example, titanium, and niobium (columbium).

3.389 Stainless Steel

An alloy steel containing about 12 percent or over of chromium with or without nickel together with other elements, and is characterized by its high resistance to corrosive media.

3.390 Steads Brittleness

Brittleness arising from very large grains caused by incorrect heat treatment of material previously subjected to critical cold deformation.

3.391 Stoving — *See* **3.24**.

3.392 Strain

Deformation caused by stress and expressed as the change per unit of original dimensions in the test bar under tension or compression. Under shear, the strain is measured by the angular displacement.

3.393 Strain Age Embrittlement

Embrittlement caused by strain ageing and occurs particularly in low carbon steels.

3.394 Strain Age Hardening

Increase in hardness which occurs as a result of strain ageing.

3.395 Strain Hardening (Work Hardening)

Increase in hardness caused by cold-working.

3.396 Strauss Test

A test used to assess the corrosion resistance of stainless steels.

3.397 Stress — Load per unit area.

3.398 Stress Raiser

Factors, such as abrupt changes of section, sharp corners, sharp fillets, surface crack, etc, which cause concentration of stress at these places.

3.399 Stress Relieving (Stabilizing)

Heating to and, if necessary, holding at a sufficiently high temperature below the transformation range, followed by slow cooling to remove internal stress only. Also called stabilizing treatment (*see also* **3.388**).

3.400 Stress-Strain Curve

A curve showing the relationship between stress and strain (similar to load-extension curve).

3.401 Stretcher Strains (Luder Lines)

The roughening and somewhat furrowed appearance on the surface of low carbon sheets or strips as a result of uneven spreading in the initial stages of cold-deformation after annealing, normalizing or after hot-rolling, though being not so marked in the last two cases.

3.402 Stoving — *See* **3.24**.

3.403 Sub-zero Treatment

Treatment given to certain hardened steels by cooling to temperatures below zero (0°C) to transform any retained austenite to martensite.

3.404 Sulphur Print Test

A macrographic method of examination, for the distribution of sulphide impurities in steel, in which a sheet of bromide paper after being soaked in dilute sulphuric acid is placed upon the plain polished steel surface. The sulphides in steel react with the acid liberating sulphuretted hydrogen which in turn reacts with the silver salt in the paper, leaving a dark stain, thus indicating the distribution of sulphur and also showing flow lines in forging.

3.405 Supersonic Test — *See* **3.428**.

3.406 Tangential Test — *See* **3.425**.

3.407 Temperature/Impact Curve

The curve plotted with notch impact values against corresponding testing temperatures (*see* Fig. 15).

3.408 Temper Brittleness

Notch brittleness to which some alloy steels are susceptible as a result of tempering within certain temperature range that is, 350-600°C, or on slow cooling through this range of temperature after tempering at high temperatures.

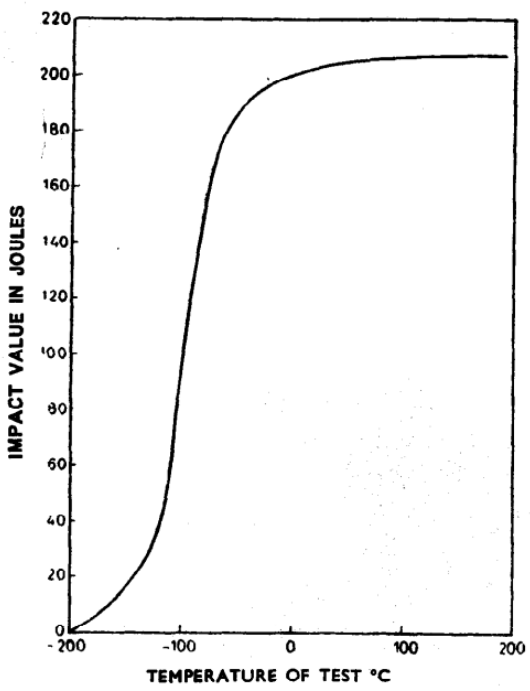


FIG. 15 A TYPICAL TEMPERATURE — IMPACT CURVE

3.409 Temper Carbon

Graphitic carbon resulting from decomposition of carbides in ferrous materials.

3.410 Temper Colour

Colour developed on the bright steel surface due to oxide film formation when steels are tempered between 200 to 350°C. Each tempering temperature produces a distinctive colour and hence the latter is indicative of temperature reached. Time factor also affects the colour, so also the steel composition. But with care low alloy and plain carbon steels give good indication of tempering temperature by the colour developed.

3.411 Tempering

Heating to elevated temperature but below transformation zone, of hardened steels and holding for specified time at temperatures followed by cooling at desired rate to develop desired mechanical properties these steels.

3.412 Tensile Strength

The maximum load reached in a tensile test divided by the original cross-sectional area of the gauge length portion of the test piece. Also termed as maximum stress or ultimate tensile stress (*see* Fig.3).

3.413 Tensile Test

A test in which a standard test piece, gripped at both ends, is subjected to tension by load, which is progressively increased till fracture takes place. This test is conducted to give the following information (*see* IS 1608 (Part 1)):

a) Limit of proportionality
b) Yield point,
c) Proof stress,
d) Ultimate tensile stress,
e) Percentage elongation, and
f) Percentage reduction of area.

3.414 Test Piece (Test Specimen)

The sample prepared in accordance with standard dimensions for the purpose of testing, for example, tensile test piece (*see* Fig. 16).

3.415 Test Sample

A portion of material selected from any bulk consignment in accordance with the method of sampling for the purpose of carrying the desired test.

3.416 Thermal Stresses

Stresses developed in a material during heating or cooling as a result of temperature gradients.

3.417 Thomas Process — *See* **3.26** and **3.29**.

3.418 Time Quenching (Interrupted Quenching)

Interrupting the quench after a predetermined time followed by air cooling. Generally this treatment is employed for reducing distortion and to self temper the hardened surface with a view to improving the toughness.

3.419 Tolerance Limit

Permissible deviation from stipulated values.

3.420 Torsion

Straining a material by twisting

3.421 Torsion Test

A test carried out by twisting a test piece about its axis until fracture occurs. When the test piece is machined of from a bar, the practice is to state the maximum stress in shear and the angle of rotation. In tests for wires, the acting length in relation to the diameter and the number of twists to be withstood, are specified.

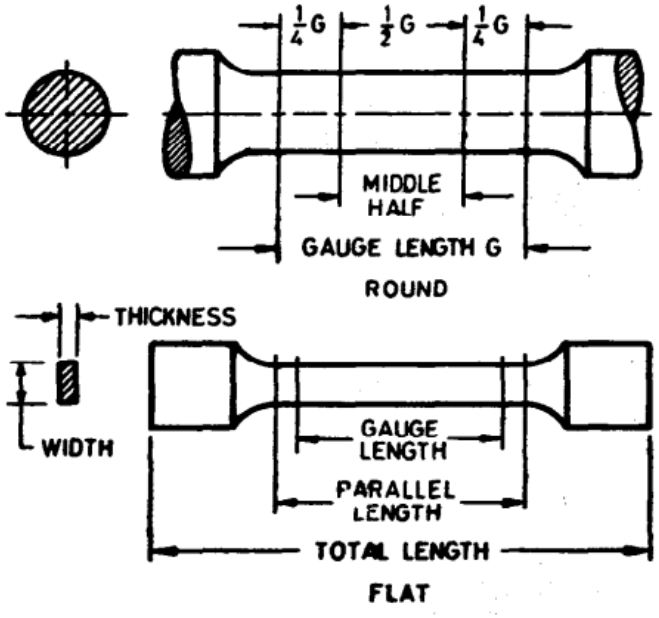


FIG. 16 TENSILE TEST PIECES

3.422 Transcrystalline Fracture

Fracture across the grains.

3.423 Transformation Range (Critical Range)

The range of temperature over which transformation, that is, change of phase takes place in the solid state during heating or cooling.

3.424 Transition Temperature (Brittle Transition Temperature)

When the notched-bar impact test is carried out on ferritic steel over a range of temperatures, including sub-zero temperatures, the fracture changes from ductile (fibrous) to brittle (crystalline) with progressive decrease in testing temperature. The temperature at which 50 percent ductile and 50 percent brittle fracture is obtained, is usually termed as the transition temperature and is 50 percent of the shelf impact value at the higher temperatures (*see also* **3.407**).

3.425 Transverse Test (Radial Test, Tangential Test)

A test for steel blooms, forgings, sheets, etc, in which the longitudinal axis of the test piece is at right angles to the direction of rolling or working. In case of forgings, a transverse test may be specified in a circumferential, tangential or radial direction. In the case of cast iron, it refers to a test used for determining the modulus of rupture of a centrally loaded beam test piece supported at the ends.

3.426 True Tensile Stress

The stress (load divided by the minimum cross-sectional area of the test piece at the time of fracture) at the time of fracture.

3.427 TTT Curve

Time-temperature-transformation curve (*see* **3.357**).

3.428 Ultrasonic Test (Supersonic Test)

A non-destructive test for detecting internal defects, such as cracks, cavities and unsoundness due to discontinuities, by the application of high frequency sound waves. The detecting instrument transmits such waves through the prepared surface of the material under test and these waves are reflected back by internal flaws.

3.429 Upending Test (Jump Test, Knock Down Test, Slug Test)

A test to detect surface defects on bars, billets, etc, intended for hot or cold-forging. The test is carried out by hammering or forging the ends of the test piece (hot or cold, as the case may be) till reduced by specified amount.

3.430 Uphill Casting — *See* **3.42.**

3.431 Vickers Hardness Test — *See* **3.119**.

3.432 V-Notch

A notch, in the form of V, made in test pieces for impact test, the standard notch angle, in the commonly used Izod impact test piece, is 45° with root radius of 0.25 mm.

3.433 Wear Test

A test for determining resistance of a sample to abrasion under given conditions, such as loading, lubrication, speed, etc.

3.434 Weathering Steels

Steels with improved resistance to atmospheric corrosion obtained by small additions of copper, phosphorous, chromium, etc. Such steels have got characteristic properties and develop a thin stable oxide film on weathering.

3.435 Weld Decay

Intercrystalline corrosion which develops in certain austenitic chromium-nickel steels, which have been heated and/or slowly cooled through the temperature range of 500 to 900°C and subjected to chemical attack by certain corrosive agent. It is so called because in a welded structure the zones adjacent to the weld which have been in this temperature range are liable to fail in this manner.

3.436 Weld Decay Test

A test for determining whether a steel is susceptible to weld decay.

3.437 White Cast Iron

Cast iron in which all the carbon is in the combined state and the fracture is white in appearance (*see also* **3.60**).

3.438 Whiteheart Malleable Cast Iron

A cast iron made by prolonged annealing of white cast iron, in an oxidizing atmosphere, in which decarburization and graphitization take place to eliminate cementite. The carbon that remains is in the form of temper carbon nodules (*see* IS 14329).

3.439 Widmannstaten Pattern or Structure

A coarse microstructure indicative of high casting temperature or overheating in solid state and results from simultaneously precipitation of ferrite along different planes in the crystals.

3.440 Work Hardening — *See* **3.395**.

3.441 Wrapping Test

A test used for wire. It is carried out by wrapping a wire, round a mandrel of specified diameter, unwrapping and repeating the process for a specified number of times.

3.442 Wrought Iron

A very low-carbon iron containing varying amounts of mechanically included slag. The chief characteristic of wrought iron is that the temperature employed in its production is too low to render it fluid and its condition is never more than pasty or semi-fumed. It is produced by many processes, for example, Puddling, Walloom Lancashire and O.H.

3.443 X-ray Metallography

The test is used to evaluate quantitatively various phases, residual stress, structures of compound and their identification, etc.

3.444 Yield Stress

The stresses at which a marked increase in strain occurs without an increase in stress during tensile tests. Low carbon steels usually exhibit this phenomenon.

3.445 Young's Modulus — *See* **3.280**.