भारतीय मानक

Indian Standard

IS 13417 : 2024

इस्पात का ऊष्मा उपचार — रीति संहिता

(पहला पुनरीक्षण)

Heat Treatment of Steel — Code of Practice

(First Revision)

ICS 77.040.90

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Metallography and Heat-Treatment Sectional Committee, MTD 22

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Metallography and Heat-Treatment Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard was first published in 1992. While reviewing this standard, in the light of experience gained during these years, the Committee decided to revise it to bring in line with the present manufacturing and trade practices being followed in the country in this field.

In this revision following modifications have been made:

a) Clause on stress relieving annealing has been modified;
b) Clause on nitriding has been modified; and
c) Clause on visual inspection has been modified.

The composition of the Committee responsible for the formulation of this standard is given in Annex A.

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.

Indian Standard

HEAT TREATMENT OF STEEL — CODE OF PRACTICE

(First Revision)

1 SCOPE

This standard describes the heat treating procedures, temperature schedules, equipment requirement and other details relating to the heat treatment of plain carbon and low alloy steels.

2 REFERENCES

The standards given below 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 agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards:

IS No.	*Title*
IS 1956	Glossary of terms relating to iron and steel:
(Part 1) : 1976	General metallurgy, heat treatment and testing (*first revision*)
(Part 2) : 2018	Steel making (*second revision*)
(Part 3) : 2019	Long products (including bars, rods, sections and wires) (*second revision*)
(Part 4) : 2013	Flat products (*second revision*)
(Part 6) : 1976	Forging (including drop forging) (*first revision*)
(Part 7) : 1976	Wrought iron (*first revision*)
(Part 8) : 1976	Steel tubes and pipes (*first revision*)
IS 4432 : 1988	Specification for case hardening steels (*first revision*)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 1956 (relevant parts) shall apply.

4 TYPES OF HEAT TREATMENT

4.1 The various types of heat treatments generally applied to carbon and low alloy steels are as follows:

a) Normalising;
b) Annealing;
c) Hardening;
d) Tempering;
e) Special heat treatment;
f) Case hardening; and
g) Surface hardening.

4.1.1 *Normalising*

Normalising of steel is carried out to refine grain size, ensure structural homogeneity, modify residual stresses, enhance machinability etc. Normalising is accomplished by heating carbon steel to about 50 °C above the upper critical line of the iron-iron carbide diagram that is; above Ac_3 for hypoeutectoid steels and Ac_1 for hypereutectoid steels, followed by cooling in still or agitated air.

Generally the heating rate in normalising is not critical. However special precaution should be taken to minimize distortions caused by thermal stresses in parts/components having large variations in section size. The holding time at the austenizing temperature should be sufficient to ensure homogenization and for dissolution of carbides, if present. As a general guideline, an hour per 25 mm of part thickness may be used to calculate the soaking period.

The cooling rate is of significant importance as it influences the amount of pearlite, its size and spacing of the pearlite lamellae. Higher cooling rate may be employed to increase the strength and hardness of the parts. After the steels are cooled down evenly to black heat below A_1, they may be water or oil quenched to decrease the total cooling time.

4.1.2 *Annealing*

Annealing denotes the heating of steel above a suitable temperature holding for appropriate time, followed by cooling at a suitable rate. Steels may be annealed to achieve softness, produce desired microstructure, enhance ductility, relieve internal stresses, improve machinability, etc. Generally annealing is a preparatory heat treatment that is applied to castings, forgings and rolled stock, although in some cases, for instance heavy castings, it is used as a final treatment.

4.1.2.1 *Full annealing*

a) Full annealing consists in heating steels 30 degrees to 50 degrees above the critical point Ac_3 in case of hypereutectoid and between Ac_1 and Ac_m for hypereutectoid steels holding for suitable time and slowly cooling usually in a furnace. Unless otherwise specified annealing in case of carbon steels implies to full annealing;

b) Heating the steel too high a temperature above Ac_3 shall be avoided to prevent austenite grain growth which is detrimental to mechanical properties;

c) The heating time and the holding time at the annealing temperature shall depend upon the type of furnace used, the arrangement of work pieces inside the furnace, the height of the charge and the kind of materials being annealed; and

d) The cooling rate from the annealing temperature shall be slow enough to allow austenite decomposition at lower degrees of super cooling to prevent the formation of ferrite-cementite dispersions of high hardness. The cooling rates for alloy steels should be lower than those of carbon steel.

   The slow cooling may be accomplished by cooling the charge within the furnace and by having the heating facilities completely switched or gradually reduced.

4.1.2.2 *Stress relieving*

Slow and uniform heating to and, if necessary, holding at a temperature depending on the application but below the transformation temperature, followed by slow and uniform cooling to remove internal stresses only. Also called stabilizing treatment.

4.1.2.3 *Isothermal annealing*

a) Isothermal annealing is mostly applicable to alloy steels which necessitate very slow cooling, for reducing the overall time required for heat treatment as compared to conventional full annealing. In this process, the steel is heated as in ordinary annealing and then rapidly cooled to a temperature lower than A_1. The steel is held isothermally at this temperature for sufficient time to complete austenite decomposition and is subsequently cooled rapidly in air; and

b) From a practical standpoint, it is not suitable to carry out this heat treatment in a conventional batch furnace of large heat capacity owing to difficulties in rapid lowering of temperature. Usually two muffle furnaces or a continuous furnace with different temperature zones is made use of this treatment.

4.1.2.4 *Spheroidizing*

a) Spheroidizing of steel is carried out to impart the softest condition and improve the machinability substantially through the development of a finely dispersed structure of globular carbides or granular instead of a lamellar pearlite obtainable from conventional full annealing;

b) The extremely good ductility of spheroidizing microstructures is important for low and medium carbon steels that are to be cold formed. Also, the low hardness achieved through spheroidizing improves the machinability of high carbon steels that undergo extensive machining; and

c) Spheroidizing may be accomplished by any of the following methods:

   1) Substantially long holding at a temperature below Ac_1;

   2) Alternate heating and cooling in the temperature range, that is, just above Ac_1 and just below Ar_1; and

   3) Heating slightly above the Ac_1 temperature, and then either cooling extremely slowly in the furnace or holding at a temperature just below Ar_1.

Proper temperature control is necessary for the success of the spheroidizing process as overheating would cause the formation of lamellar pearlite instead of granular/globular pearlite. The cooling rate should be very slow to enable austenite decomposition into the ferrite-carbide aggregate and coalescence of carbides.

4.1.2.5 *Homogenization* (*diffusion annealing*)

a) Homogenization annealing is applied to alloy steel ingots and large castings to reduce dendritic and inter crystalling segregation which result in loss of ductility and toughness of alloy steels;

b) Steel for this treatment is heated to a high temperature (1 100 °C to 1 200 °C) to ensure the completion of diffusion processes necessary for composition equalisation. The holding time for homogenization is dependent upon the steel composition and the mass of the charge and is kept minimal for minimising oxidation and scaling that occur at such high temperature; and

c) Homogenization results in a coarse grain size which is eliminated during subsequent working of the ingot. However, in case of foundry castings, annealing or normalizing is subsequently resorted to refine the grain and improve properties.

4.1.2.6 *Process annealing*

a) Process annealing is an in-process subcritical annealing treatment, usually applied to cold worked steel products to restore ductility and make them amenable for subsequent working;

b) The treatment involves heating steel to a temperature slightly below A_1, soaking for an appropriate time, followed by cooling in air. Process annealing temperatures well below Ac_1 are generally used for softening a material prior to cold sawing and cold shearing; and

c) The treatment is also extensively used in the wire industry for producing ‘annealed in-process’ wire or for the production of soft wire suitable for severe upsetting and to permit the drawing of low carbon and medium carbon steel wire rods to smaller sizes.

4.1.3 *Hardening*

4.1.3.1 Hardening of steel involves heating to a temperature from 30 °C to 50 °C above Ac_3 (for hypoeutectoid steels) and above point Ac_1, (for hypereutectoid steels) holding until the completion of phase transformation, followed by cooling at a rate greater than the critical cooling rate.

4.1.3.2 *Heating rate*

The heating rate up to the austenizing temperature depends upon the steel chemistry, initial microstructure, shape and size of the work and the type of heating facility used. The rate should be less for steels with higher carbon and alloy content as well as for large components of intricate shapes.

4.1.3.3 *Heating temperature and time*

When the specified heating temperature is reached, the work should be held at this temperature for sufficient time to ensure temperature, equalization throughout the section and completion of necessary phase transformation. In general, plain carbon and low alloy steels containing easily dissolvable carbides may require very small holding time.

Higher heating temperatures should be avoided as it results in coarse grained structure and larger percentage of retained austenite upon quenching. In addition, it may also result in surface oxidation and decarburization. Steel for hardening shall be protective against oxidation and decarburization by heating to protective gaseous media, molten salts or vacuum.

4.1.3.4 *Quenching*

Quenching involves rapid cooling of the steel from the austenizing temperature by immersion in water, oil, molten salts, brine or polymer solution to develop a suitable as quenched microstructure.

Selection of proper quenching media shall be done in accordance with the specific steel chemistry, section size, etc, so that distortion, warpage and quench cracking in workpieces are avoided. The effectiveness of the quenching may be improved by suitable agitation.

4.1.4 *Tempering*

4.1.4.1 Tempering consists in heating previously hardened steel to a temperature below the transformation range (Ac_1), holding and subsequent cooling at a specified rate with the objective of increasing ductility and toughness. Tempering also helps in relieving quenching stresses and ensures dimensional stability.

4.1.4.2 Tempering is performed in either a muffle furnace, salt, molten metal or oil baths, etc. Steel components that have been heated or quenched in salts baths must be freed from any adhering salt before tempering in muffle or convection furnace by rinsing in warm water. The process shall be accomplished by soaking entire parts/components at a specific temperature for a time period sufficient to ensure completion of the tempering mechanism or by selective heating of certain areas of the part to achieve localized toughness or plasticity.

4.1.4.3 The principal variable in temperature, namely, temperating, time of holding and the cooling rate shall be properly adjusted to achieve the desired mechanical properties.

4.1.5 *Special Heat Treatment*

4.1.5.1 *Martempering*

Martempering or more appropriately termed 'marquenching' is an elevated temperature quenching procedure aimed at reducing cracking, distortion and residual stresses in steels. Martempering involves, quenching steel from the austenitizing temperature, into a hot liquid maintained or just below the Ms temperature holding in the quenching medium to ensure temperature equalisation throughout the workpiece, followed by air cooling to room temperature. Martempered parts however exhibit brittleness owing to the essentially martensitic microstrure and hence necessitate tempering for restoring toughness. Martempering is generally applicable to alloy steels, but some carbon steels that are conventionally water quenched can be martempered in sections not thicker than 5 mm using vigorous agitation in the martempering bath. Low-alloy steels that are suitable for martempering can be martempered in thicker sections up to 19 mm.

4.1.5.2 *Austempering*

Austempering of steel consists in isothermal transformation of the austenite at a temperature lower than that of pearlite formation and above that of martensite formation, resulting in the formation of a bainitic microstructure. Austempering is usually substituted for conventional quenching and tempering to obtain increased ductility and notch toughness at a given hardness and to also reduce cracking and distortion. The steels that are suitable for austempering are:

a) Plain carbon steels 0.5 percent C to 1.00 percent C and not less than 0.6 percent Mn;

b) High carbon steels, having more than 0.9 percent C and Mn slightly lower than 0.60 percent;

c) Carbon steels containing less than 0.50 percent C, but higher Mn in the range of 1.00 percent to 1.65 percent; and

d) Certain low alloy steels.

4.1.5.3 *Patenting*

Patenting is a heat treatment process that is applied to high carbon steel wire rods and 'in process' wires to develop a fine sorbitic structure that is amenable to large area reductions in cold drawing to high strength levels.

The heat treatment can be performed in a 'continuous' or 'batch manner by austenizing steel 30 °C to 50 °C above Ac_3, soaking for appropriate time, followed by isothermal quenching in lead or molten salt baths maintained in between 450 °C to 550 °C depending upon the steel composition.

4.1.6 *Case Hardening*

4.1.6.1 *Carburizing*

Carburizing of steel consists of increasing the surface carbon content so that upon heat treatment, a hard layer of martensite is produced. This is mainly applicable for low carbon steel having low hardenability, thus facilitating the production of a hard external surface with a tough core. Depending upon the physical state of the carburizing media, the process is known as pack carburizing, liquid carburizing and gas carburizing. Steel grades suitable for carburizing are covered by IS 4432, which also gives the details of carburizing, hardening and tempering treatment of these steels.

4.1.6.2 *Carbonitriding*

a) Carbonitriding is carried out by addition of ammonia to the gas carburizing atmosphere so as to simultaneously saturate the surface of steel with both carbon and nitrogen. The treatment is generally carried out by heating the steel at 850 °C to 870 °C and holding for 2 h to 10 h depending upon the depth of case desired. Carbonitriding is followed by quenching directly from the furnace or after reheating. These hardened parts are tempered at 160 °C to 189 °C so as to obtain case hardness of 60 Rc to 62 Rc;

b) Carbonitriding is generally applied to components of complex shapes, for example gears which are prone to warping, However compared to carburizing, this treatment has limited usage because case depths attainable are restricted to a maximum of 1 mm; and

c) The main advantages of carbonitriding over gas carburizing are:

1) Lower heat treatment temperature;
2) Higher hardenability of the case, enabling oil quenching with lesser tendency of warpage and cracking; and
3) Higher wear and corrosion resistance of case.

4.1.6.3 *Nitriding*

A process of surface hardening by introducing, nitrogen into the surface in a suitable steel by heating and holding it at appropriate temperature (500 °C to 600 °C) in contact with cracked ammonia or other suitable nitrogenous medium. Nitriding is normally applied as a final heat treatment and best results are obtained on the steel which has been quenched and tempered before this treatment.

4.1.6.4 *Cyaniding*

a) Cyaniding is performed by heating steel in a bath of molten alkali- cyanides, mixed with chlorides and carbonates to saturate the surface with carbon and nitrogen simultaneously. Generally the salt bath contains about 30 percent NaCN, 40 percent Na_2CO_3 and 30 percent NaCl. However for specific applications, higher cyanide content may be employed to achieve desired results. This treatment is followed by hardening and tempering to achieve a case hardness of 60 Rc ± 2 Rc; and
b) The case depth may by controlled by suitable selection of bath temperature, composition and holding time. As a guideline, treatment temperature in the range of 820 °C to 860 °C produces a thin case (0.15 mm to 0.35 mm) in 30 min to 90 min holding time. For greater case depth (0.5 mm to 2.0 mm), cyaniding is to be performed at 930 °C to 960 °C for longer holding times varying from 1.5 h to 6 h.

4.1.7 *Surface Hardening*

4.1.7.1 *Induction hardening*

a) In induction hardening, localized heating of the surface to its austenitizing temperature is accomplished by eddy current induced by an alternating magnetic field which surrounds the steel. The depth of hardened layer decreases with increasing current frequency. Generally induction hardening is carried out at frequencies of 1 000 Hz or more. In addition to frequency, the depth of penetration of the current increases with temperature, particularly pronounced at temperatures above the Curie print (768 °C), accompanied by a reduction in the heating rate. Following austenitization, parts are quenched in water, oil or air depending upon the grade of steel and then subjected to low tempering at 160 °C to 200 °C;
b) Induction hardening is generally applicable to steels having carbon content in the range of 0.30 percent to 0.50 percent where surface hardness values in the range of 50 Rc to 60 Rc can be obtained. Induction hardening shall be applied to steels which have been hardened and tempered or normalised. Fully annealed steels are not preferred for this treatment because the shorter heating-up times in induction hardening are not sufficient for carbide dissolution, thereby resulting in lower and inconsistent hardness values, and
c) This treatment is generally used for crank shafts, cam shafts, gears, automobile components, etc.

4.1.7.2 *Flame hardening*

a) This treatment is similar to induction hardening but employs high temperature flame to austenitize the surface of steel. The temperature flame is obtained by combustion of a mixture of fuel gas such as acetylene or propane with oxygen or air. Flame heads are used for burning the mixture and are of slit-type (having a single orifice in the form of a slit) or of multiple orifice type; and
b) In flame hardening, there is a risk of oxidation and overheating of the steel. Strict control on heating time, fuel and oxygen consumption is necessary. With this type of surface hardening, a hardened layer of 2 mm to 4 mm thickness with 50 Rc to 55 Rc hardness can be obtained. This technique is generally used for large work such as mill rolls, heavy shafts, large gears and dies, machine ways, etc.

4.1.7.3 'Laser surface hardening' and 'electron-beam heat treating' can also be employed for austenitizing the steel for surface hardening.

5 HEAT TREATING EQUIPMENT

5.1 Heating Media

Air, fluidized bed, molten salt baths, vacuum and protective atmosphere furnaces arc suitable for heat treatment of steels. Proper selection of heating media and necessary tools and fixtures should be done so as to avoid damage to the parts being heat treated.

5.1.1 *Air-Chamber Furnaces*

Air-chamber furnaces in which electrical resistance heating is employed may be used for heat treatment of those products which have demonstrated by test to be substantially free from high temperature oxidation after heat treatment in be fitted with air circulation system so as to ensure temperature uniformity and prevent localized overheating. The use of such furnaces may be restricted to low temperature heat treatments, such as tempering, stress-relief annealing, etc, as well as conventional annealing and normalizing.

5.1.2 *Salt Baths*

Salt bath furnaces can be used for a variety of heat treatments, such as normalizing, hardening, tempering, austempering, martempering, chemical heat treatments, etc. Salt bath furnaces facilitate rapid heating rates and better thermal control. These furnaces may be externally heated by gas or oil or by means of electrical resistance or internally heated by immersed or submerged electrodes. Salt baths shall be maintained in good condition by regular regeneration since during usage, the iron build up in the bath gets oxidized and has a tendency to cause decarburization of the steel charge. The bath may be checked time-to-time for iron build up, carburizing or decarburizing character as advised by the salt manufacturer. The salts used in the salt baths shall be of a type and grade which will not react with the steel charge. The steel charge should be free from moisture, oil and dirt before heating in the bath. The salt on the heat treated stock should be removed soon after removal from the bath as the salts, being mostly hygroscopic are liable to cause corrosion. Heating in salt baths should be avoided for parts with small holes/openings, intricate joints from which it is difficult to completely remove salts.

5.1.3 *Protective Atmospheres*

Atmosphere control may be employed to avoid of the surfaces of steel stock subjected to elevated temperature and particularly when the heat treatment is a final operation. In addition, controlled atmospheres are also employed to provide the source of elements in some heat treating processes or bring about surface cleaning of parts being treated. Commonly used atmospheres for heal treating are gaseous mixtures containing carbon monoxide, carbon dioxide, methane, nitrogen, hydrogen and argon. The proper selection of the type of atmosphere and the specific amounts of the gaseous components depend upon the characteristics of the charge and the degree of surface protection desired.

5.1.4 *Vacuum Furnaces*

Heat treatment in vacuum furnaces consists in foreword processing of stock in enclosures that arc evacuated to partial pressure levels below torr 10^{-2}. During heat treatment, vacuum is used throughout or for a part of the entire. Generally after the charge has been heated and austenitized under vacuum, cooling is carried out to room temperature using nitrogen or argon atmosphere. Vacuum furnaces are increasingly employed for annealing, hardening and tempering, stress relieving, austempering, etc, although vacuum furnaces are normally of the batch-type, continuous furnaces with multiple zone may also be used.

5.1.5 *Temperature Uniformity*

The design and construction of batch furnaces and baths shall be such that during the heating up and soaking period, the air and metal temperature at any point in the working or austenitizing zone shall not exceed 10 °C of the heating temperature for the specific steel being heat treated. After the stock reaches the temperature the design of furnaces or baths with their temperature controlling equipment shall be such that the temperature of the heating media and metal at all points in the soaking zone are maintained within maximum of ± 5 °C of the furnace control set temperature. For continuous furnaces the soaking zone is that part of the working zone in which the metal temperature is within the required austenitizing range. The design and construction of continuous furnaces shall be such that during the heating-up and soaking period, the metal temperature at any point in the working and soaking zone shall not exceed more than 10 °C.

NOTE — The uniformity norms may be decided by user and manufacturer as a part of stringent process controls based on pyrometry guidelines.

5.2 Pyrometric Equipment

A sufficient number of suitable temperature control devices, properly arranged should be provided on all heat treating equipment to assure adequate control of temperature in all working and soaking zones. The devices shall be so located as to avoid exposure to excessive dust, vibration and temperature outside the range of 0 °C to 100 °C.

5.2.1 *Temperature Measuring and Recording Equipment*

Automatic controlling and recording instruments shall be used. Instruments shall be of the potentiometer type. Temperature sensing elements should be located in, or as close as possible to the working zone. The exact location of temperature sensing elements shall be in such a place as to give accurate measurement of the working or austenitizing or both zone temperatures.

5.2.2 *Accuracy*

Temperature readings should be adjusted to within ± 5 °C of true temperature by applying corrections established by calibrating equipment. If correction greater than ± 5 °C are indicated the source of error should be determined and adjustments to the measuring equipment shall be made so that the reading represent a true temperature within ± 5 °C or less.

5.2.3 Temperature of every furnace should be checked atleast once a month, both at the bottom of the furnace and along the height. After replacing heating elements or after major repairs such a relining, the furnace must undergo a compulsory scheduled inspection. On the basis of this inspection data, working area where stock shall be placed for heat treatment is to be established.

5.2.4 In case of salt baths, periodic checking of the bath temperature and working of the temperature regulator shall be carried out atleast once during a shift by an inspection thermocouple. The results of such inspection should be systematically documented for facilitating calibration and remedial action.

NOTE — Pyrometer equipment sensitivity, instrumentation class, number of pyrometer and its construction shall be appropriate to the heat treatment carried out and stringent norms may be followed as per customer specific requirements.

5.3 Quenching Equipment

Suitable equipment for water, polymer solution or oil as well as gas quenching shall be provided. Care to be taken to maintain water quenching tank temperature in the range of 20 °C to 40 °C. Shop should have sufficient ventilation and facilities for protection against hazards.

5.3.1 *Quenching Baths*

Means shall be provided for circulation of the quenching media and for heating or cooling, as necessary. Tanks shall be of adequate size for the workload involved in order to ensure that satisfactory quenching rates are attainable.

5.3.1.1 All water-baths employed in quenching parts which have been heated in salt-bath furnaces shall be provided with a drain and inflow of fresh water to prevent a concentration of dissolved salts in the tanks.

5.3.1.2 Conventional and fast quenching oils can be employed to achieve specific properties. The gravity, flash point, fire points, viscosity, etc, for oil quenching media should be checked.

5.3.1.3 The quenching media needs to be periodically checked minimum once in 6 months for moisture, flash point, peak cooling rate.

5.3.2 *Location of Quenching Equipment*

Quenching equipment should be located in such manner and handling facilities should be so arranged and equipped, as to permit rapid transfer of the load from the heating medium to the quenching medium.

5.4 Rinsing Equipment

Rinse tanks or sprays or any other suitable processing should be employed for removing salt residues or film from the surfaces of materials which have been immersed in molten salt baths or quenched in polymer solution. Separate rinse tanks or sprays may not be necessary if it has been demonstrated that the quench bath, under maximum load condition, is capable of removing salt residues without becoming so contaminated that its efficiency is impaired.

6 RECOMMENDATION PROCEDURE AND OPERATIONS

6.1 Heat Treating Operations

Heat-treating operations shall be performed on the whole of a part or piece of material. Never on a portion only and shall be applied in a manner that will produce the utmost uniformity.

6.2 Charging of Furnaces and Baths

Material being heat treated shall be supported in such manner as to permit free access of the heating or quenching media in order to facilitate heating and cooling the material to a uniform temperature in a minimum time interval. Furnaces shall not be charged during unstable temperature conditions following upward or downward furnace setting. The time required for attaining stability following such change depends upon furnace construction and condition, as well as the degree of change of furnace setting during heat treating operations.

6.3 Cleaning of Materials

Surface of material should be substantially free from oils, grease dust and other foreign matter which could harm material being heat-treated. All parts particularly when they are heat treated in the molten salt baths should be dried since moisture reacts with the hot salts violently.

7 INSPECTION AND TESTING OF HEAT-TREATED MATERIAL

7.1 Inspection and testing of the finished heat treated steel constitutes the most important aspect of quality control. This aims at establishing whether the processed material conforms to applicable specifications and standards.

7.2 Inspection for small sized parts shall be carried out on the basis of 'complete screening' or by 'sampling inspection' as agreed upon by the manufacturer and the customer. Large components shall be subjected to piece-by-piece inspection. A number of similar articles manufactured from the same steel and subjected simultaneously to the same heat treatment shall be considered as a 'batch'. The number of parts for 'sampling inspection' shall depend upon the size of individual parts, quantity of batch heat treated and the importance of the components under consideration. As a general guideline, 5 percent to 10 percent of the components shall be evaluated.

7.2.1 *Visual Inspection*

Visual inspection is non-destructive test (aided/non aided) to check any abnormality, surface defects, scaling, warpage, cracks. The person conducting visual test may be suitably qualified with suitable vision (corrected/normal).

7.2.2 *Mechanical Testing*

Heat treated parts may be subjected to various mechanical tests, such as hardness, tensile strength, yield strength, percentage elongation, reduction in area and impact strength. Hardness measurements are to be routinely performed to as a heat treatment process check. Parts and configurations which do not permit measurement of hardness must be, during heat treatment, accompanied by test specimens from the same stock. The number of such test specimens should be atleast two. In case higher hardness values are observed in quench and tempered parts, the manufacturer may resort to further tempering treatment to achieve desired properties. Evaluation of other mechanical properties, such as tensile strength, yield strength, percentage elongation, impact strength shall be carried out in accordance with relevant IS specifications.

7.2.3 *Metallography Microstructure Evaluation*

The process of preparing the sample for microstructure through sectioning, polishing and suitable etching. The study of the phases, constitution and structure of metals and alloys with the aid of a microscope. This is a vital tool as an effective validation, verification and process control tool during heat treatment.

Microscopic examination may be carried out from time-to-time by the heat treater as a valuable tool to monitor the quality of incoming steel stock, for in-process quality control and for customer inspection. Inspection of incoming steel stock is necessary prior to machining and subsequent heat treatment for detecting excessive decarburization or segregation, surface defects such as cracks and qualifying an alloy's hardenability according to grain size. The quality of pilot and production batches can be corroborated on the basis of actual microstructures attained. The metallographic investigations may be documented for internal records or as proof to customers that the required microstructure or case depth has been achieved.

7.2.4 *Test Report*

If desired by the customer, the heat treater shall supply a test certificate incorporating the results of all tests carried out on the heat treated material.

ANNEX A

(*Foreword*)

COMMITTEE COMPOSITION

Metallography and Heat-Treatment Sectional Committee, MTD 22

Organization	*Representative(s)*
Defence Metallurgical Research Laboratory, Ministry of Defence, Hyderabad	DR AMIT BHATTACHARJEE (***Chairperson***)
Bharat Forge Limited, Pune	SHRI SURESH ARANGI SHRI SAGAR BAPAT (*Alternate*)
Bharat Heavy Electrical Limited, New Delhi	SHRI VEMANA UDAY KUMAR SHRI VARUN PANWAR (*Alternate*)
Defence Metallurgical Research Laboratory, Ministry of Defence, Hyderabad	SHRI CHANDAN MONDAL SHRI VIVEK KUMAR CHANDRAVANSHI (*Alternate*)
Directorate General of Quality Assurance, Ministry of Defence, Ichapur	SHRI P. SUNDHARAJAN DR JANA BHATTACHARAYA ROY (*Alternate*)
Directorate General of Quality Assurance, Ministry of Defence, Tiruchirapalli	SHRI D. C. KAR
Durgapur Steel Plant, Sail Durgapur	SHRI R. S. TIWARI
Hindalco Industries Limited, Mumbai	SHRI PANKAJ WANJARI SHRI MANU SAXENA (*Alternate*)
Hindustan Aeronautics Limited, Bengaluru	SHRI S. SIVARAMKRISHNAN SHRI D. K. DE (*Alternate*)
Indian Institute of Technology Bombay, Mumbai	PROF NITYANANDA PRABHU PROF K. NARASIMHAN (*Alternate*)
Indian Institute of Technology Kanpur, Kanpur	DR ANISH UPADHYAY DR KRISHAN BISWAS (*Alternate*)
Indian Institute of Technology Roorkee, Roorkee	SHRI SAI RAMUDU MEKA SHRI VARUN BAHETI (*Alternate*)
Institute of Indian Foundrymen, New Delhi	SHRI A. K. ANAND
JSW Steel Limited, Raigad	SHRI GOUTAM MUKHERJEE SHRI ARVIND KUMAR DHAKER (*Alternate* I) SHRI KRISHNA RAMAVATH (*Alternate* II)
Mishra Dhatu Nigam Limited, Hyderabad	SHRI A. PANI KISHORE DR RATHIRAM NAIK (*Alternate*)
Mukand Limited, Thane	SHRI DOMINIC SAVIO
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