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IS 6416 (1988): Methods for Measuring Case Depth of Steel
[MTD 22: Metallography and Heat Treatment]

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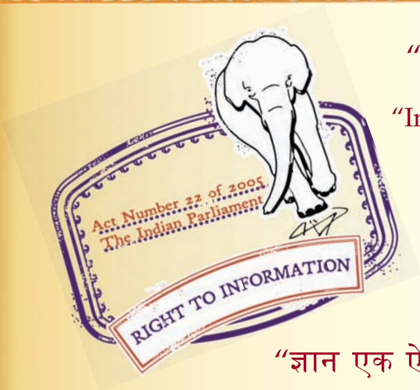

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IS 6416 : 1988
(Reaffirmed 2003)

Indian Standard

METHODS FOR MEASURING CASE DEPTH OF STEEL

(First Revision)

UDC 669·14-155·2 : 620·178·152·68

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NEW DELHI 110002

October 1989 **Price Group 2**

Metallography and Heat Treatment Sectional Committee, SMDC 27

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards on 30 September 1988, after the draft finalized by the Metallography and Heat Treatment Sectional Committee had been approved by the Structural and Metals Division Council.

This standard was first published in 1971. It has now been revised to bring it in line with the latest developments and current practices in this field. In this revision, more details about the hardness method and the macrostructure method have been given.

It is often necessary for some machine parts to have hard surface to resist wear and at the same time possess adequate toughness. These requirements as well as the improvement of fatigue life are met by treating the steel by one of the several methods described in Annex A.

This standard prescribes four methods for the measurement of case depth of steels. The hardness method is the most suitable and shall be the reference method. For measuring the total case depth of carburized cases, the chemical method being the most accurate shall also be the referee method. The macrostructure and microscopic methods may be used for routine and control purposes.

In the preparation of this standard, assistance has been derived from the following:

JIS G0557-1977 Method of measuring case depth for steel. Japanese Industrial Standards Committee.

JIS G0559-1977 Method of measuring case depth of steel hardened by flame or induction hardening process. Japanese Industrial Standards Committee.

SIS 11700-1965 Method of measuring case depth in steel. Seriges Standardizenringakommission, SIS.

DIN 50190-1979 Case hardening depth of steel. Deutscher Normanausschuss.

SAE J 423 a-1979 Methods of measuring case depth. The Society of Automotive Engineers, USA.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

METHODS FOR MEASURING CASE DEPTH OF STEEL

(First Revision)

1 SCOPE

This standard prescribes the following four methods of measuring case depth (CD) of steel hardened by carburizing, nitriding, carbonitriding, cyaniding or induction and flame hardening (applicable methods are indicated in Table 1):

a) Hardness method,

b) Chemical method,

c) Macrostructure method, and

d) Microscopic method.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
IS 228 : 1959	Methods of chemical analysis of pig iron, cast iron and plain carbon and low alloy steels (*revised*)
IS 1501 (Part 1) : 1984	Method for Vickers hardness test for metallic materials: Part 1 HV 5 to HV 100 (*second revision*)
IS 1586 : 1968	Method for Rockwell hardness test (B and C scales) for steel (*first revision*)
IS 1956 : 1976	Glossary of terms relating to iron and steel

3 TERMINOLOGY

3.1 For the purpose of this standard, the definitions given in IS 1956 : 1976 and the following shall apply.

3.2 Effective Case Depth

It is the perpendicular distance from the surface to that point of the core of the piece at which hardness is equal to the values shown below:

Type of Steel	*HV*	*HRC*	*HRA*	*Treatment*
Steel with carbon, percent				
0·28 to 0·32	350	35	68	Flame or induction hardened
0·33 to 0·42	400	40	70	
0·43 to 0·52	450	45	73	
Over 0·53	500	50	76	
Case hardening steels	550			Carburized, and hardened and tempered
Nitriding and carbonitriding	Values to be mutually agreed upon			Nitrided and carbonitrided

3.3 Total Case Depth

It is the perpendicular distance from the surface to that point at which the change in chemical composition, hardness or microstructure of the case and core no longer can be distinguished.

4 SAMPLING

The number of test pieces to be used for testing and their selection shall be as agreed to between the contracting parties.

5 HARDNESS METHOD

5.1 Principle

This method consists of cutting the specimen at right angle to the hardened case, preparing the surface suitably for testing and making a hardness traverse on the case and core of the specimen.

5.2 This method is considered to be most accurate for measuring case depths and may be used as a referee and control method applicable to either specimens or parts.

5.3 Preparation of Surface to be Examined

The test specimen shall be cut at right angle to the hardened case and polished so as to permit correct measurement of hardness impressions. Care shall be taken in cutting to avoid heating that may affect the hardened surface.

5.4 Hardness Measurement

Hardness testers that produce small shallow indentations shall be used. Testers used to produce diamond pyramid or knoop Hardness numbers are recommended. The test load will be between 0·98 and 98·1 Newtons (0·1 and 10 kgf). Rockwell A or C scales produce a comparatively deeper indentation and these can be used in case of flame or induction hardened cases.

5.4.1 For Vickers hardness and Rockwell C scale hardness test, reference may be made to IS 1501 (Part 1) : 1984 and IS 1586 : 1968, respectively.

5.4.2 A hardness transition curve shall be drawn by measuring hardness on a few number of points along the straight lines at right angles to the plane as shown in Fig. 1 and measuring the distance of respective hardness indentations from the outer edge of hardened case. This distance can be measured on a calibration optical instrument, micrometer stage or by other suitable means.

The hardness traverse should extend up to the core. The space between the measuring points on sample (l_2-l_1, l_3-l_2, l_4-l_3, etc, in Fig. 1) will not exceed 0·1 mm, in general. The space between adjacent indentations shall be not less than 2·5 times the diagonal length of indentations.

The effective case depth or the total case depth shall be determined from the hardness transition curve.

6 CHEMICAL METHOD

6.1 This method is generally applicable only to carburized cases, but may be used for nitrided, cyanided or carbonitrided cases. The procedure consists in determining the carbon content (and nitrogen when applicable) at various depths below the surface of a test specimen. This method is considered the most accurate for measuring total case depth of carburized cases.

6.2 Specimen

Test specimens shall normally be of the same grade of steel as parts being carburized. Test specimen may be actual parts, rings or bars and should be straight or otherwise suitable for accurate machining of surface layers into chips for subsequent carbon analysis.

6.2.1 Test specimens shall be carburized with parts. Care should be exercised to avoid distortion and decarburization in cooling test specimens after carburizing. In cases where parts and test specimens are quenched after carburizing, such specimens shall be tempered at approximately 600-650°C and straightened to 0·04 mm maximum total indicator reading (TIR) before machining is attempted. The time at this temperature should be minimized to avoid excessive carbon diffusion.

6.2.2 Test specimens must have clean surfaces and shall be machined dry in increments of predetermined depth. The analysis of machined chips will then accurately reveal the depth of carbon penetration. Chosen increments usually vary between 0·050 and 0·10 mm depending upon the accuracy desired and expected depth of case.

6.2.3 Chips from each increment shall be kept separate and analyzed individually for carbon content by an accepted method. Total case depth is considered to be the distance from the surface equivalent to the depth of the last increment of machining whose chips analyze to a carbon content 0·04 percent higher than that of the established carbon content of the core.

6.3 Analysis

The chemical analysis of the metal shall be carried out in accordance with IS 228 : 1959.

7 MACROSTRUCTURE METHOD

7.1 Macroscopic method of determination of case depth is recommended for routine process control, primarily because of short time required for determinations and minimum of specialized, equipments and trained personnel needed. This method is mostly applied to hardened and carburized specimens.

7.2 The test consists of determining the depth of hardened surface under low magnification on the sectional surface of test specimen. A wide variety of etchants can be used successfully to enhance the contrast between case and core. The total case depth shall be determined by measuring the distance from the surface to the point showing a different coloration. Accuracy can be improved by correlation of macrostructure observed with other methods such as hardness method.

7.3 Preparation of Surface to be Examined

The test specimens shall be cut or fractured perpendicular to the hardened surface. Following variations

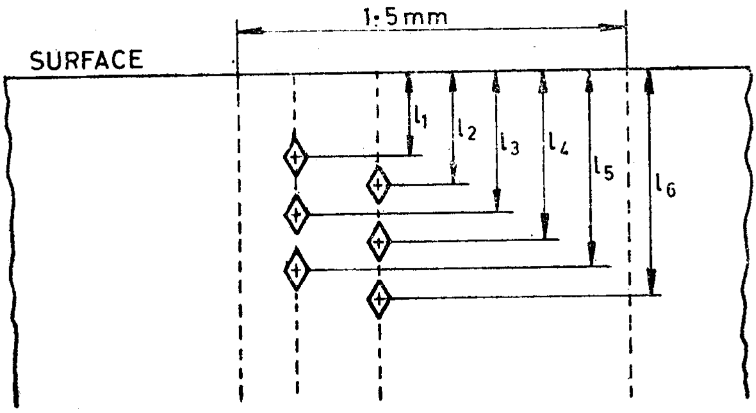

FIG. 1 ARRANGEMENT FOR HARDNESS MEASUREMENT

may be adopted depending upon the accuracy desired.

7.3.1 *Fracture*

Prepare product or sample by fracturing. Examine at a magnification not to exceed 20× with no further preparation.

7.3.2 *Fracture and Etch*

Prepare product or sample by fracturing and then etching in 20 percent nitric acid in water for a time established to develop maximum contrast. Rinse in water and read while sample is still wet.

7.3.3 *Fracture and Rough Grind*

Prepare specimen by either fracturing or cutting and rough grinding. Etch in 10 percent nital for a period of time established to provide a sharp line of demarcation between case and core. Examine at magnification not to exceed 20× and read all the darkened zone for approximate total case depth. Care shall be taken during the cutting and grinding to avoid any heating of the specimen.

7.3.4 *Fracture, Grind and Polish*

Prapare specimen by fracturing or cutting, grinding through No. 000 or fine metallography emery paper, polish and etch in 5 percent nital for approximately one minute. Rinse in water and examine at a magnification not exceeding 20× and read all the darkened zone. After correlation, effective case depth can be determined by reading from external surface of specimen to a select line of darkened zone.

8 MICROSCOPIC METHOD

8.1 The test consists in determining the depth of hardened surface under a metallurgical microscope. In the case of nitrided parts where depth is thin, this method is recommended.

8.2 Preparation of Surface to be Examined

The test specimen shall be cut perpendicular to the hardened surface and the cut face polished. Care shall be taken during cutting or polishing to avoid any heating of the specimen.

8.2.1 The test surface shall be etched in two to three percent nital or any other suitable reagent.

8.3 Magnification

The polished and etched specimen shall be examined at 100 times magnification.

8.3.1 The total case depth is the distance from the surface to the point at which the change in structure is no longer distinguishable.

9 DESIGNATION OF CASE DEPTH

9.1 The indication of case depth shall be made by the identification symbols given in Table 1.

Table 1 Identification Symbols for Case Depth

(*Clauses* 1 *and* 9.1)

Case Depth	Hardness Method	Macro-structure Method	Microscopic Method	Chemical Method
Carburized				
Total case depth	CDT HX*	CDT Ma	CDT Mi	CDT Ch
Effective case depth	CDE ( ) HX*	—	—	—
Nitrided				
Total case depth	NDT HX*	—	NDT Mi	NDT Ch
Carbonitrided				
Total case depth	CNDT HX*	—	CNDT Mi	CNDT Ch
Flame hardened				
Total depth of hardened surface	FDT HX*	FDT Ma	FDT Mi	—
Effective depth of hardened surface	FDE ( ) HX*	—	—	—
Induction hardened				
Total depth of hardened surface	IDT HX*	IDT Ma	IDT Mi	—
Effective depth of hardened surface	IDE ( ) HX*	—	—	—

( ) Values inside the bracket are indicative of the hardness value at which the effective case depth is measured (*see* **3.2**)

*Indicates type of test and load, for example:

a) HV — Vickers test
b) HV 5 — Vickers test with 5 kg load
c) HRC — Rockwell C Scale
d) HRA — Rockwell A Scale

9.2 The case depth shall be given in mm, measuring correct to one place of decimal, and be expressed in unit of 0·1 mm.

Examples

a) CDE 15 HV 1 effective case depth of 1·5 mm — measured by Vickers hardness test using 1 kg load

b) CDT 25 HV 5 total case depth of 2·5 mm — measured by Vickers hardness test using 5 kg load.

c) CDT 22 Ma total case depth of 2·2 mm — measured by macrostructure method.

d) IDE (400) 15 HV 5 induction hardened, effective case depth of 1·5 mm — measured up to 400 HV from the surface using 5 kg load.

e) FDE (40) 25 HRC flame hardened, effective case depth of 2·5 mm — measured up to 40 HRC from the surface.

f) FDT 40 HV 5 flame hardened total case depth of 4·0 mm — measured by Vickers hardness testing using 5 kg load.

g) FDT 20 Ma flame hardened, total case depth of 2·0 mm — measured by the macrostructure method.

ANNEX A

(*Foreword*)

METHODS FOR CASE HARDENING OF STEEL

Steel	*Process*
Directo hardening steels	By differential hardening treatments, namely, flame and induction hardening
Carburizing steel	By case carburizing and hardening, carbon enrichment of case being obtained by pack carburizing, gas carburizing or carburizing in cyanide bath, or carbonitriding
Nitriding steels	By a nitriding process
Carbonitriding	During carbonitriding, C and N are absorbed simultaneously in the steel. N increases the hardness of the carburized layer. The process can be carried out in salt bath or gas. The treatment temperature is normally 800-900°C but both lower and higher temperature can be employed. Carbonitriding in salt bath is the same as cyanide bath hardening. Carbonitriding means carburizing takes gas with simultaneous N pick up. Carburizing takes place by passing gases. Nitrogen in the form of ammonia is supplied direct into the furnace. The composition of the carbonitriding gases are as follows:

Gas	*Volume* (percent)
N_2	42
H_2	38
CO	20
NH_3	8

Steel	*Process*
Carbonitriding	The surface carbon content is about 0·7 percent. The nitrogen content is 2-4 percent and the effective case depth varies between 0·3 and 0·6 mm. The heat treatment is done for 2-4h depending upon the depth of the case. After treatment, the steel is hardened in the same way as after conventional gas carburizing.
Laser Glazing	The laser glazing process uses high power densities, that is, 10^6 to 10^7 W/cm and relatively short dwell times (10^{-8} to 10^{-4} s) to rapidly melt and recast the substrate of suitable material. In order to produce extremely fine grained structure with improved wear and corrosion resistance. The treatment homogeneity adhesion of overlay coating is applied by electro-chemical technique. Glazed surfaces are produced by means of rapid solidification, the surfaces are noncrystalline (amorphous) and exhibit high hardness value.

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