SURFACE VEHICLE RECOMMENDED PRACTICE

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Methods of Measuring Case Depth

RATIONALE

The current useage of this specifcation is stable; no technical improvements need to be made at this time.

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***Foreword*—**This Document has not changed other than to put it into the new SAE Technical Standards Board Format. References were added as Section 2. Definitions were changed to Section 3. All other section numbers have changed accordingly.

***1. Scope*—**Case hardening may be defined as a process for hardening a ferrous material in such a manner that the surface layer, known as the case, is substantially harder than the remaining material, known as the core. The process embraces carburizing, nitriding, carbonitriding, cyaniding, induction, and flame hardening. In every instance, chemical composition, mechanical properties, or both are affected by such practice.

This testing procedure describes various methods for measuring the depth to which change has been made in either chemical composition or mechanical properties. Each procedure has its own area of application established through proved practice, and no single method is advocated for all purposes.

Methods employed for determining the depth of case are either chemical, mechanical, or visual, and the specimens or parts may be subjected to the described test either in the soft or hardened condition. The measured case depth may then be reported as either effective or total case depth on hardened specimens, and as total case depth on unhardened specimens.

It should be recognized that the relationship between case depths as determined by the different methods can vary extensively. Factors affecting this relationship include case characteristics, parent steel composition, quenching conditions, and others. It is not possible to predict, in some instances for example, effective case depth by chemical or visual means. It is important, therefore, that the method of case depth determination be carefully selected on the basis of specific requirements, consistent with economy.

2. References

2.1 Applicable Publication—The following publication forms a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

2.1.1 ASM INTERNATIONAL PUBLICATION—Available from: ATTN: MSC/Book Order, ASM International, PO Box 473, Novelty, OH 44072-9901.

"The Application of M_s Points to Case Depth Measurement," by E. S. Rowland and S. R. Lyle, ASM Transactions, Vol. 37 (1946) pp. 26–47.

3. Definitions

3.1 Effective Case Depth—The perpendicular distance from the surface of a hardened case to the furthest point where a specified level of hardness is maintained. The hardness criterion is 50 HRC normally, but see Table 1 under 5.1.

Effective case depth should always be determined on the part itself, or on samples or specimens having a heat-treated condition representative of the part under consideration.

3.2 Total Case Depth—The distance (measured perpendicularly) from the surface of the hardened or unhardened case to a point where differences in chemical or physical properties of the case and core no longer can be distinguished.

4. Chemical Methods

4.1 General—This method is generally applicable only to carburized cases, but may be used for 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 on carburized cases.

4.2 Procedure for Carburized Cases—Test specimens shall normally be of the same grade of steel as parts being carburized. Test specimens 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.

Test specimens shall be carburized with parts or in a manner representative of the procedure to be used for parts in question. 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 should be tempered at approximately 600 to 650 °C (1100 to 1200 °F) and straightened to 0.04 mm (0.0015 in) max total indicator reading (TIR) before machining is attempted. The time at temperature should be minimized to avoid excessive carbon diffusion.

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 0.05 and 0.25 mm (0.002 and 0.010 in) depending upon the accuracy desired and expected depth of case.

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% higher than that of the established carbon content of the core.

Specialized electron microprobe analyses on carefully prepared cross-sections represent an alternate procedure with potentially greater accuracy and speed, and is recommended when equipment is available.

5. Mechanical Methods

5.1 General—This method is considered to be one of the most useful and accurate of the case depth measuring methods. It can be effectively used on all types of hardened cases, and is the preferred method for determination of effective case depth. The use of this method requires the obtaining and recording of hardness values at known intervals through the case. For determination of effective case depth, the 50 HRC criterion is generally used. The sample or part is considered to be through hardened when the hardness level does not drop below the effective case depth hardness value. In some instances involving flame and induction hardened cases, it is desirable to use a lower hardness criterion. Suggested hardness levels are tabulated in Table 1 for various nominal carbon levels.

TABLE 1—CARBON CONTENT

Carbon Content	Effective Case Depth Hardness
0.28–0.32% C	35 HRC
0.33–0.42% C	40 HRC
0.43–0.52% C	45 HRC
0.53% and over	50 HRC

A plot of hardness versus depth from the surface will facilitate this reading. Figures 1, 2, 3, and 4 illustrate the recommended procedures.

Hardness testers which produce small, shallow impressions should be used for all of the following procedures, in order that the hardness values obtained will be representative of the surface or area being tested. Those testers which are used to produce Diamond Pyramid or Knoop Hardness Numbers are recommended, although testers using heavier loads, such as the Rockwell superficial, A or C scales, can be used in some instances on flame and induction hardened cases.

Considerable care should be exercised during preparation of samples for case depth determination by any of the mechanical methods, to insure against grinding or cutting burn. The use of an etchant for burn detection is recommended as a general precaution, because of the serious error which can be introduced by its presence.

FIGURE 1—SPECIMEN FOR TAPER GRIND PROCEDURE

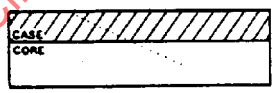

FIGURE 2—SPECIMEN FOR CROSS SECTION PROCEDURE

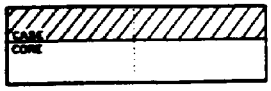

FIGURE 3—SPECIMEN FOR ALTERNATE CROSS SECTION PROCEDURE

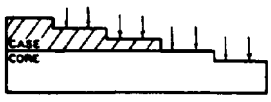

FIGURE 4—SPECIMEN FOR STEP GRIND PROCEDURE

5.2 Hardness Traverse Procedure—Cut specimens perpendicular to hardened surface at critical location being careful to avoid any cutting or grinding practice which would affect the original hardness.

Grind and polish specimen. Surface finish of the area to be traversed shall be polished finely enough so the hardness impressions are unaffected—that is, the lighter the indentor load, the finer the polish necessary.

The procedure illustrated by Figure 2 is recommended for the measurement of light and medium cases. The alternate procedure illustrated in Figure 3 is recommended for medium and heavier cases.

The hardness traverse should be started far enough below the surface to ensure proper support from the metal between the center of the impression and the surface. Subsequent impressions are spaced far enough apart so as not to distort hardness values. The distance from the surface of the case to the center of the impression is measured on a calibrated optical instrument, micrometer stage, or other suitable means.

5.3 Taper Grind Procedure—This procedure, illustrated by Figure 1, is recommended for measurement of light and medium cases.

A shallow taper is ground through the case, and hardness measurements are made along the surface thus prepared. The angle is chosen so that readings, spaced equal distances apart, will represent the hardness at the desired increments below the surface of the case.

Unless special anvils are used, a parallel section should be prepared so that readings are taken at right angles to the surface. Care should be exercised in grinding to prevent tempering or rehardening.

5.4 Step Grind Procedure—This procedure illustrated by Figure 4 is recommended for measurement of medium and heavy cases.

It is essentially the same as the taper grind section method with the exception that hardness readings are made on steps which are known distances below the surface.

A variation in this procedure is the step grind method where two predetermined depths are ground to insure that the effective case depth is within specified limits.

6. Visual Methods

6.1 General—This method employs any visual procedure with or without the aid of magnification for reading the depth of case produced by any of the various processes. Samples may be prepared by combinations of fracturing, cutting, grinding, and polishing methods. Etching with a suitable reagent is normally required to produce a contrast between the case and core. Nital (concentrated nitric acid in alcohol) of various strengths is frequently used for this purpose.

6.2 Macroscopic—Magnification methods for determination of case depth measurement are recommended for routine process control, primarily because of the short time required for determinations, and the minimum of specialized equipment and trained personnel needed. They have the added advantage of being applicable to the measurement of all types of cases. However, the accuracy can be improved by correlation with other methods more in keeping with engineering specifications for the parts being processed. These methods are applied normally to hardened specimens, and while a variety of etchants may be employed with equal success, the following procedures are typical and widely used.

6.2.1 FRACTURE—Prepare product or sample by fracturing. Examine at a magnification not to exceed 20 diameters with no further preparation.

6.2.2 FRACTURE AND ETCH—Water quench product or samples directly from the carburizing temperature. Fracture and etch in 20% nitric acid in water for a time established to develop maximum contrast. Rinse in water and read while wet.

6.2.3 FRACTURE OR CUT, AND ROUGH GRIND—Prepare specimen by either fracturing, or cutting and rough grinding. Etch in 10% 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 diameters (Brinell glass) and read all the darkened area for approximate total case depth.

6.2.4 FRACTURE OR CUT, AND POLISH OR GRIND—Prepare specimen by fracturing or cutting. Polish or grind through No. 000 or finer metallographic emery paper or both. Etch in 5% nital for approximately 1 min. Rinse in two clean alcohol or water rinses. Examine at magnification not to exceed 20 diameters (Brinell glass) and read all of the darkened zone. After correlation, effective case depth can be determined by reading from external surface of specimen to a selected line of the darkened zone.

6.3 Microscopic—Microscopic methods are generally for laboratory determination and require a complete metallographic polish and an etch suitable for the material and the process. The examination is made most commonly at 100 diameters.

6.3.1 CARBURIZED CASES—The microscopic method may be used for laboratory determinations of total case and effective case depths in the hardened condition. When the specimen is annealed properly, the total case depth and the depth of the various zones—hypereutectoid, eutectoid, and hypoeutectoid—also can be determined quite precisely.[1]

a. Hardened Condition
   1. Fracture or cut specimen at right angles to the surface.
   2. Prepare specimen for microscope and etch in 2 to 5% nital (concentrated nitric acid in alcohol).
   3. For effective case depth, read from surface to metallographic structures which have been shown to be equivalent to 50 HRC.
   4. For total case depth, read to the line of demarcation between the case and core. In alloy steels quenched from a high temperature, the line of demarcation is not sharp. Read all the darkened zone that indicates a difference in carbon from the uniform core structure.

b. Annealed Condition
   1. For specimens previously hardened or not cooled under controlled conditions.
   2. The specimen to be annealed may be protected by copper plate or any suitable means for preventing loss of carbon.
   3. Pack in a small thin-wall container with a suitable material such as charcoal.
   4. Place container in furnace at 40 to 80 °C (75 to 150 °F) above the upper critical temperature (Ac3) for the core. (Generally an annealing temperature of 870 to 925 °C (1600 to 1700 °F) is satisfactory.)
   5. Leave in furnace long enough for specimen to reach furnace temperature, but not for an excessive time at temperature, as carbon diffusion will increase total case depth.

c. Cooling Rates
   1. Carbon Steels—A satisfactory cooling rate is obtained by cooling the container in mica, lime, or other insulating material at a rate which will reduce the temperature to 430 °C (800 °F) in 2-1/2 to 3 h. Cool as desired below 430 °C (800 °F).

1. For certain applications involving moderate to high hardenability alloy steels in the 0.4 to 0.8% carbon range, the M_S method of case depth determination to specific carbon level has been found to be effective. In this method, the specimen is austenitized at the time and temperature sufficient to more than take into solution the alloy and carbon at the desired level of measurement. It is then quenched into salt at the M_S temperature of the carbon level desired, held just long enough to temper the martensite at all lower carbon levels and water quenched. Subsequent polishing and etching disclose a sharp line of demarcation between tempered and untempered martensite, which can be read with a Brinell glass to a precision of 0.05 mm (0.002 in). Additional information on this technique can be obtained by reference to "The Application of M_S Points to Case Depth Measurement," by E. S. Rowland and S. R. Lyle, ASM Transactions, Vol. 37 (1946) pp. 26–47.