

**Properties of Low Carbon Sheet Steel
and Their Relationship to Formability**

- 1. Scope**—Problems associated with the evaluation of formability or deep drawability of sheet metals are complex and may be difficult to solve due to the number of variables involved. As long ago as 1940, the AISI Technical Committee on Sheet Steel reviewed this problem. More recently, Volume 1 of the Ninth Edition of the ASM Metals Handbook contains sections on "Low Carbon Steel Sheet and Strip" and "Formability of Steel Sheet" that provide suggestions to help evaluate parts and select materials. The purpose of this information report is to summarize the sheet metal characteristics that are commonly used when attempting to predict the formability of sheet metal.
- 2. References**
 - 2.1 Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.
 - 2.1.1 SAE PUBLICATIONS**—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J126 JUN81—Selecting and Specifying Hot and Cold Rolled Steel Sheet and Strip
SAE J810—Classification of Common Imperfections in Sheet Steel
SAE J863 DEC81—Methods of Determining Plastic Deformation in Sheet Metal Stamping
SAE J1392—Steel, High Strength, Hot Rolled Sheet and Strip, Cold Rolled Sheet, and Coated Sheet
 - 2.1.2 ASTM PUBLICATIONS**—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 370—Mechanical Testing of Steel Products
ASTM E 8—Tension Testing of Metallic Materials
ASTM E 8—Methods of Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 517—Standard Test Method for Plastic Strain Ratio r for Sheet Metal
ASTM E 643—Standard Method for Conducting Ball Punch Deformation Test for Metallic Sheet Material
ASTM E 646—Tensile Strain Hardening Exponents (n values) of Metallic Sheet Materials

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

QUESTIONS REGARDING THIS DOCUMENT: (724) 772-8512 FAX: (724) 776-0243
TO PLACE A DOCUMENT ORDER: (724) 776-4970 FAX: (724) 776-0790
SAE WEB ADDRESS <http://www.sae.org>

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

Volume 1 of the Ninth Edition of the ASM Metals Handbooks

3. Traditional Tests of Formability—The Rockwell Hardness and the Ball Punch Deformation Test (sometimes referred to as the Olsen or Erichsen Cup Test) have historically been the primary mechanical tests made by the fabricator to indicate formability. These tests are easily and quickly made, and require a minimum quantity of material. Unfortunately, they are not exact measures of formability, and can be used only as a guide in determining if trouble in a press operation is due to the sheet metal.

3.1 Ball Punch Deformation Test—This test consists of forcing a ball-type punch against the surface of a securely clamped sheet specimen until the metal fails. A deeper cup indicates better ductility. Details for conducting this test can be found in ASTM E643, "Standard Method for Conducting Ball Punch Deformation Test for Metallic Sheet Material." The test can also be used to predict surface coarsening after forming.

For example, with material exhibiting an ASTM grain size of 8 or finer, the outer surface of the cup will be smooth, however, with a grain size of 7 or larger there will probably be moderate to heavy surface coarsening. In addition, directionality problems within the sheet, and any tendency for brittle fracture, may be detected by examination of the fracture line.

3.2 Rockwell Hardness Test—Indentation hardness is one of the common controls in sheet steel production. However, it is not an exact indicator of formability and should not be used to establish rigid inspection limits. Details for conducting the test are given in ASTM E18 "Methods of Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials." As explained in E18, there are minimum sheet thickness limits for various hardness scales. Normally, the hardness of a low carbon steel is reported as an HRB value; but for thin sheets, such as less than 0.040 in (1 mm), the test should be made using the F scale. The HRB value can then be obtained from a conversion table and included in parentheses. Surfaces of the sheet to be tested may be prepared by lightly pre-polishing with 180 grit paper to provide a smooth flat surface. Results are more repeatable with this type of surface preparation than when the as-rolled surface is used. For comparison purposes, any change in the as-received surface should be noted.

4. Tension Test—Data from tension tests can give a more complete measurement of formability, ASTM A370, "Mechanical Testing of Steel Products," and E8, "Tension Testing of Metallic Materials," describe testing procedures.

NOTE—Any taper in the width of the bar between the gage marks could affect the total elongation adversely.

4.1 Yield Strength—The measured strength depends on both the steel and the conditions under which the prepared specimen is loaded. This term is applicable to those materials having an engineering stress-strain diagram in the transition from elastic to plastic strain which is a smooth curve as well as to those which exhibit an upper yield point or sharp knee. The upper yield point may be reported as well as the lower yield point. If only a single yield point value is reported it should be indicated whether it is the lower or upper yield point. In reporting yield strength, the method by which it was determined should be stated (0.2% offset method, 0.5% extension underload method, half of the pointer or from a stress-strain diagram). See ASTM E8 for a description of these methods.

In forming sheet metal, the upper yield point has to be overcome before any deformation occurs in the flat blank. Experience has indicated that when the upper yield point is high in relation to the lower yield and approaches the ultimate strength, the material will have a greater tendency to split than material which has an upper yield point only slightly higher than the lower yield point. A low yield strength is preferred when formability is the major consideration.

4.2 Tensile Strength—The strength at the highest load reached during the tension test is the tensile strength. It is calculated in psi or MPa units using the specimen cross sectional area measured before testing.

- 4.3 Elastic Ratio**—The yield strength divided by the tensile strength expressed as a decimal value is the elastic ratio. Steels with low elastic ratios have a greater capacity for being formed due to the greater separation between the yield load and the ultimate load during which forming can take place.
- 4.4 Total Elongation**—The total elongation is the percent increase of a gage length on the tension test specimen. For low carbon sheet steel, a 2 in (50 mm) gage length and a 0.5 in (13 mm) gage width is normally used. Steels with a higher percent elongation will stretch further before failure. This elongation is a direct measure of ductility and represents an important consideration in evaluating formability. Caution must be used, however, in comparing elongation values since they depend on specimen preparation and testing procedure. Total elongation also may vary with sample orientation in relation to the sheet rolling direction.
- 4.5 Uniform Elongation**—The amount of deformation that can occur before any measurable localized necking of the tension specimen starts, is known as uniform elongation. This is designated as e_u and will usually vary between 20 and 28% for low carbon steel.
- 4.6 Yield Point Elongation**—The yield point elongation indicates the intensity of stretcher strains that can develop in certain low carbon steels in lightly formed areas. It is caused by interstitial elements such as carbon and nitrogen, or in the case of certain high strength steels, a very fine grain size. The tendency to strain can be minimized by temper rolling at the producing mill. However, in grades subject to aging, the effect of temper rolling is only temporary and it is necessary for the user to properly roller level the sheet immediately before forming a shape. Sheet steels are available that will not exhibit yield point elongation.
- 4.7 Typical Mechanical Properties**—Table 1 lists typical mechanical properties of hot rolled and cold rolled sheet steel. Metallic coated products generally exhibit higher yield strength and hardness and lower elongation due to the type of processing associated with the coating operations. The properties listed are intended for information only, and the values are not to be used as criteria for acceptance or rejection. Mechanical properties are not normally used in specifications unless special structural properties are required in the part. Due to the range of properties possible, the expected distribution can overlap among the various qualities. The ranges are broader for hot rolled sheets than for cold rolled. Also, rimmed steels may exhibit a broader range of properties than killed steels, due to the segregation of carbon, phosphorous, and sulfur that occurs during solidification in the steel making process.