



Standard Test Method for Determining Forming Limit Curves¹

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1. Scope

1.1 This method gives the procedure for constructing a forming limit curve (FLC) for a metallic sheet material by using a hemispherical deformation punch test and a uniaxial tension test to quantitatively simulate biaxial stretch and deep drawing processes.

1.2 FLCs are useful in evaluating press performance by metal fabrication strain analysis.

1.3 The method applies to metallic sheet from 0.5 mm (0.020 in.) to 3.3 mm (0.130 in.).

1.4 The values stated in SI units are to be regarded as the standard. The inch-pound equivalents are approximate.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for,²

E 6 Terminology Relating to Methods of Mechanical Testing³

E 8M Test Methods for Tension Testing of Metallic Materials [Metric]³

E 517 Test Method for Plastic Strain Ratio r for Sheet Metal³

E 646 Test Method for Tensile Strain-Hardening Exponents (n -Values) of Metallic Sheet Materials³

3. Terminology

3.1 Terminology E 6 shall apply as well as the following special terms used in this method.

3.2 *forming limit diagram (FLD)*—a graph on which the measured major (e_1) and associated minor (e_2) strain combinations are plotted to develop a forming limit curve. See Fig. 1.

3.2.1 *Discussion*—The graduated scales on the FLD shall be in percent strain, calculated from the initial gage length.

3.2.2 *Discussion*—The distance between FLD percentage increments shall be the same for both the major strain (e_1) ordinate (parallel to the vertical y axis) and minor strain (e_2) abscissa (parallel to the horizontal x axis) unless the difference is noted in the report.

3.3 *forming limit curve (FLC)*—an empirically derived curve showing the biaxial strain levels beyond which localized through-thickness thinning (necking) and subsequent failure occur during the forming of a metallic sheet. See Fig. 2.

3.3.1 *Discussion*—The curve of Fig. 2 is considered the forming limit for the material when the metal is subjected to a stamping press operation. It was obtained for a drawing quality aluminum killed steel sheet. The curve of Fig. 2 correlates with the upper curve of Fig. 1, a generic curve representing a metallic sheet material with a FLD_0 of 40 %.

3.3.2 *Discussion*—The strains are given in terms of percent major and minor strain measured after forming a series of test specimen blanks by using a grid pattern. The gage lengths before and after forming the part are measured to obtain the percent strain. The curve for negative (e_2) strains will generally follow a constant surface area relationship to the associated (e_1) strain.

3.3.3 *Discussion*—The range of possible major strain (e_1) is from 0 % to over 200 %. The range of possible minor strain (e_2) is from -40 % to over +60 %, or even greater strain levels.

3.3.4 *Discussion*—For convenience, the forming limit curve (FLC) can be plotted on a reduced range of the forming limit diagram (FLD), for example, from +20 % to +80 % major (e_1) strains and from -20 % to +30 % minor (e_2) strain. If the lowest (e_1) strain increment of the FLD is not 0 % e_1 , that value shall be noted in the report.

3.4 *grid pattern*—a pattern applied to the surface of a metal sheet to provide an array of precisely spaced gage points prior to forming the metal into a final shape by the application of a force.

¹ This method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.02 on Ductility and Flexure Testing.

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² Annual Book of ASTM Standards, Vol 01.03.

³ Annual Book of ASTM Standards, Vol 03.01.