



Standard Tensile Test Methods for Metallic Materials for Use in Finite Element Analysis

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This standard provides requirements for test methods and reporting of results for uniaxial tensile properties of metallic materials pertaining to material modeling in finite element analysis.

1.2 Applicability. This standard applies to all metallic materials that will be included in finite element analysis with the exception of metallic foil.

1.3 Remarks. International standards governing tensile testing provide requirements for testing of a single specimen. This standard provides additional details on how to test a collection of specimens for the purpose of calibrating mathematical material models in finite element analysis codes.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM B557/557M	ASTM E8/E8M	ISO 7500-1	ISO/IEC 17025
ASTM E83	ISO 6892-1	ISO 26203-2	

2.2 GM Standards/Specifications.

GMW3335

2.3 Additional References.

- General Motors Supply Power website (<https://gmsupplypower.covisint.com/web/portal/home>)

3 Resources

3.1 Facilities. All testing, as specified in this document, shall be performed in laboratories that are accredited to ISO/IEC 17025. Lab accreditation documentation shall be provided upon request. Choice of the test lab shall be approved by General Motors Materials Engineering.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label. Calibration in accordance to ISO 7500-1 is required.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Quasi-static Testing. Follow requirements in ASTM E8/E8M, ASTM B557/557M, ISO 6892-1 and GMW3335 for specimen dimensions and uniaxial tensile testing machine specifications. Sheet-type specimens, as defined in ASTM E8 shall be used for thicknesses up to 4 mm; otherwise, round specimens per ASTM E8 or ASTM B557 shall be used. Strain shall be measured with an extensometer per ASTM E83, Class B2 or better, laser extensometer or high-speed digital image correlation method (DIC) per 3.2.3. Strain measurement by the DIC method is preferred.

3.2.2 Intermediate Strain Rate Testing (Strain Rate in the Range 0.1/s to 500/s). Follow requirements in ISO 26203-2 for specimen dimensions, uniaxial tensile testing machine specifications and force measurement. ASTM

E8 small size round bar specimen is acceptable for fastener materials testing only. Strain shall be measured with an optical extensometer, laser extensometer or DIC. Strain measurement by the DIC method is preferred.

3.2.3 Digital Image Correlation Equipment. When a DIC system is used for specimen surface deformation and strain measurement, a stereo DIC system is required. The system shall consist of two cameras, a tripod or a similar mounting structure to support the cameras in the required location, a data acquisition box for image capture and data logging, and an image capture and data processing software. Additional lighting may be needed to provide enough contrast for image capture and to prevent motion blur that can occur with a shorter exposure time during testing at rates 50/s and higher.

Cameras used for quasi-static testing shall have a minimum framing rate of 20 images/s with the lens size of 35 mm or 70 mm.

Cameras used for high strain rate testing (strain rate between 0.1/s and 500/s) shall have a minimum framing rate of 20 000 images/s or a framing rate that can produce at least 30 images at the nominal strain rate of 500/s without the loss of resolution (i.e., the entire gauge length of the specimen must stay captured in the image from the beginning to the end of the test). At least 10 images are required in the linear region of the stress-strain curves for modulus determination.

Image capture, and the post-processing of the image data to compute deformation and strain, shall be performed with the same commercially available software according to the instructions provided by the software supplier. The DIC system shall be calibrated before each test session (or any repositioning of the test/optical equipment) according to the instructions provided by the DIC software supplier.

If the DIC system has capability for variable image sampling rate, the number of images generated by the variable sampling rate shall be 1000 to 2000 for strain rates < 0.1/s and 200 to 1000 for strain rates 0.1/s to 500/s. For DIC systems using a constant image sampling rate, the recommended sampling rate for each nominal strain rate is given in Table 1.

Table 1: Recommended DIC Sampling Rates

Target Strain Rate	Suggested DIC frames per second
0.002/s	10
0.1/s	500
1.0/s	1500
100/s	20 000
500/s	20 000

3.3 Test Vehicle/Test Piece. Parts to be characterized, if needed, shall contain sufficient volume of material to provide test specimens per ASTM E8/E8M, ASTM B557/B557M or ISO 6892-1 standards.

3.4 Test Time. The total coordination and test time are dependent on the type of testing and the number of specimens tested and are expected not to exceed 15 days for quasi-static testing or 30 days for intermediate strain rate testing.

3.5 Test Required Information. For specimens cut from production parts the following shall be provided: part name and number, alloy, heat treatment, location in part, part production or pre-production phase and, if applicable, manufacturing line.

3.6 Personnel/Skills. Test personnel shall be fully trained in the execution of test procedures described in test methods cited in Section 2. Additionally, test personnel shall be fully trained on the DIC methodology and the specific DIC software used during testing.

4 Procedure

4.1 Preparation. Specimen preparation shall be conducted as specified in GMW3335 and ASTM E8. In particular, specimens shall be free of defects such as scores, grooves, burrs, wrinkles, die marks, effects of overheating, etc. and must have all oils, lubes, or dry films removed prior to measurement. Galvanized specimens may have the zinc coating removed. Milling is the preferred method for preparation, care must be

taken such that minimal cold work is imparted to the edges of the reduced section. For quasi-static tests at unbaked condition, the specimens shall be cut in 0°, 45° and 90° orientation with respect to the rolling/extrusion direction of the material. For paint baking tests, as described in 4.1.1, and intermediate speed tests, as described in 4.3.2, the specimens shall be cut in 0° orientation with respect to the rolling/extrusion direction of the material.

4.1.1 Paint Baking. Many materials exhibit hardening during paint baking. Test specimens utilized to assess the extent of bake hardening effect shall be processed as follows before testing. This excludes specimens from parts that have already been paint baked. For the materials for which the bake hardening effect is known to be negligible General Motors Materials Engineering may grant the waiver from this requirement.

4.1.1.1 Pre-straining. Three sets of specimens shall be pre-strained at a quasi-static strain rate, per 3.2.1 and Table 2, to 2%, 5% and 10% engineering strain. A fourth set of specimens shall be prepared without pre-straining.

If during pre-straining the stress begins to decrease while the strain is still increasing (i.e., a stress-strain curve becomes horizontal) the specimen shall be discarded and a new set of specimens shall be pre-strained at a lower maximum strain, 0.5% to 1% before the drop in stress. The lower maximum strain shall be reported.

4.1.1.2 Baking. Aluminum specimens shall be baked in an oven at 185 °C for 20 minutes. Steel specimens shall be treated in an oil bath as follows.

- The oil bath shall be heated to 170 °C and allowed to stabilize for 5 minutes.
- The four sets of specimens from 4.1.1.1 shall be submerged in the oil and held for 20 minutes after the oil restabilizes to 170 °C.
- The specimens shall be removed, cooled to ambient temperature on an absorbent surface and degreased.

Recommended oil for the bath is Xiameter 100 CST Silicone.

4.1.2 DIC Specimens. Specimens tested with the DIC method shall have a high-contrast pattern applied to the surface facing the cameras. It is recommended to apply a thin, uniform layer of flat white paint on the specimen gauge area. Black paint dots shall then be applied on the top of the white paint layer such that no single black dot exceeds 25% of the pixel subset size to be used for DIC post-processing. Paint chosen shall adhere to the specimen until the completion of the test without affecting the specimen properties.

4.2 Conditions.

4.2.1 Environmental Conditions. Environmental test conditions as specified in ASTM E8/E8M, ASTM B557/B557M or ISO 6892-1 shall be applied.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions.

4.3.1 Number of Test Specimens Five specimens shall be tested for each orientation, strain rate, pre-strain level and bake condition. Additional specimens shall be prepared in case a retest is needed. Test requirements are summarized in Table 2.

Table 2: Tensile Test Requirements Summary

Test Type	Quasi-static Tension						Intermediate Strain Rate Tension			
Test specimen type	ASTM E8/ASTM B557 ^{Note 1}						ISO 26203-2 ^{Note 2}			
Test strain rate	0.002/s						0.1/s	1/s	100/s	500/s
Specimen orientation (for sheet and extrusion only)	0°		45°	90°	0°	0°	0°	0°	0°	0°
Pre-strain for bake hardening	0%	2%	5%	10%						
Number of repetitions	5	5	5	5	5	5	5	5	5	5

Note 1: ASTM E8 for sheet specimens < 4mm thick; round specimens per ASTM E8 or ASTM B557 otherwise.

Note 2: ASTM E8 small size round bar specimen is acceptable for fastener materials testing only.