



Test Methods for Foam Materials for Use in Finite Element Analysis Modeling

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 flexible cellular materials and non-woven fibrous materials, as such pertains to material modeling requirements for use in finite element analysis (FEA). Test methods covered in this document are summarized in Table 1.

Table 1: Test Methods Included in this Standard

Test Method	Requirements
Uniaxial Compression	Appendix A
Uniaxial Tension	Appendix B
Shear	Appendix C

1.2 Applicability. This standard applies to all thermoplastic, elastomeric and silicone flexible cellular materials, and non-woven fibrous materials that will be used in FEA.

1.3 Remarks. This standard provides additional details on how to test a collection of specimens for the purpose of calibrating mathematical material models in FEA codes.

2 References

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

2.1 External Standards/Specifications.

ASTM D618	ASTM D7078	ISO 3386-1	ISO/IEC 17025
ASTM D1621	ISO 845	ISO 7500-1	
ASTM D1622	ISO 1798	ISO 8256	

2.2 GM Standards/Specifications.

None

2.3 Additional References. None.

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. Follow the requirements in Appendix A for uniaxial compression, Appendix B for uniaxial tension and Appendix C for shear tests.

3.2.1 Digital Image Correlation (DIC) Equipment. A DIC system may be required for specimen surface deformation and strain measurement. A typical DIC system consists of two (2) cameras, a tripod or a similar mounting structure to support the cameras in the required location, a data acquisition system (DAS) 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.

Cameras used for high strain rate testing (strain rate between 0.1/s and 100/s) shall be capable of recording images at speeds specified in Table 2.

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 the capability of the variable image sampling rate, then the number of images generated by the variable sampling rate shall be 1000-2000 for strain rates below 0.1/s and 100-1000 for strain rates 0.1-100/s. For DIC systems using a constant image sampling rate, the recommended sampling rate for each nominal strain rate is given in Table 2.

Table 2: Recommended DIC Sampling Rates

Target Strain Rate	Number of DIC Captured Images per second (s)
0.01/s	10-20
0.1/s	50-100
1.0/s	100-200
10/s	1000-2000
50/s	5000-10000
100/s	10000-20000

3.2.2 Test Chamber for Elevated and Low Temperatures. The test chamber must conform to the following requirements:

Air must circulate through the chamber at a velocity of 1 m/s to 2 m/s at the location of the specimen and grips. Air circulation promotes the uniformity of temperature field inside the chamber and minimizes fogging at cold temperatures. The chamber must be capable of maintaining the temperature within $\pm 2^\circ\text{C}$ of the specified test temperature and must have a range of operating temperatures including -40°C to $+90^\circ\text{C}$. Humidity operating range of the chamber should be 25% relative humidity (RH) to 60% RH with control accuracy of $\pm 3\%$ RH of set value (if requested for humidity-controlled testing).

The chamber internal size must allow for housing of the specimen and test hardware and permit freedom to mount and remove specimens from the chamber. The chamber shall contain access points for routing a thermocouple and other wiring and a window to allow the use of optical measurement devices.

At cold temperatures, the chamber and the cooling medium shall prevent the moisture build-up on the specimen and test hardware and minimize the fogging inside the chamber.

3.3 Test Vehicle/Test Piece. Parts to be characterized, if needed, shall contain sufficient volume of material to provide standard test specimens specified in Appendices A thru C.

3.4 Test Time. The total coordination and test time is dependent on the type of testing and the number of specimens tested and shall not exceed 15 d for compression testing, 15 d for tensile testing, and 5 d for shear testing.

3.5 Test Required Information. For specimens cut from production parts the following shall be provided: material and the part supplier, part name and number, location in part and the orientation at which the specimen is cut.

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.

4.1.1 Test Specimens.

4.1.1.1 Specimen Density. Density of each specimen shall be determined according to ISO 845 or ASTM D1622 and included in the test report. If the specimen contains skin resulting from the manufacturing process, the location of the skin in the specimen (e.g., bottom side only, back side only, both sides, etc.) and the skin thickness shall be recorded and included in the test report.

4.1.1.2 Specimen Geometry. For extruded materials and materials showing orientation of the cellular structure, the specimens shall be cut in 0, 45, and 90 degree orientation with respect to the extrusion direction of the material for uniaxial compression and tension tests. Follow instructions in Appendix A for uniaxial compression specimen geometry, in Appendix B for uniaxial tension specimen geometry and in Appendix C for shear specimen geometry.

4.1.1.3 DIC Specimens. Specimens tested with the DIC method shall have a high-contrast pattern applied to the surface facing the cameras (usually black-and-white or use the speckle contrast color based on specimen color). If a required contrast cannot be achieved by applying color speckles to the natural specimen color, it is recommended that the specimen is first painted with a thin, uniform, white flat paint layer across the 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.

4.1.1.4 Specimen Extraction. Test specimens shall be extracted as specified in Appendices A thru C. The surface finish of the cut surfaces shall be smooth. Processes that may alter the surfaces by heating or abrading shall be avoided.

4.2 Conditions.

4.2.1 Environmental Conditions. Specimens shall not be tested < 72 h after manufacture. Condition the specimens according to ASTM D1621 for room temperature tests (23 ± 2) °C. For tests at other temperatures, follow the requirements in ASTM D618.

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. The tests shall be performed in five (5) replicates for each specimen orientation, strain rate, and temperature condition. Additional specimens shall be prepared in case a retest is needed. For uniaxial tension, sufficient number of specimens shall be tested to provide five (5) breaks within the gauge length for each applicable condition (strain rate, temperature, orientation).

4.3.2 Test Matrix. A summary of required tests is shown in Table 3. All listed tests shall be performed at room temperature (23 ± 2) °C. Additional temperatures are dependent on the material application and shall be determined and confirmed with General Motors Materials Engineering before testing.

Table 3: Test Matrix

Test Type/ Standard	Specimen	Orientation	Test Speed/ Strain Rate
Density ISO 845 or ASTM D1622	ISO 845 or ASTM D1622		
Compression ASTM D1621	50 mm × 50 mm × 25 mm or 50 mm × 50 mm × H mm (if 10 mm < H = < 25 mm) If H = < 10 mm, stack specimens to 25 mm	0 degrees for isotropic cellular materials and non-woven fibrous materials	0.01/s 1.0/s 10.0/s 50.0/s 100/s
Tension ISO 1798	Type 1 or Type 3 for cellular materials Type 2 for non-woven fibrous materials	0, 45, 90 degrees to extrusion direction for extruded or materials showing orientation of cellular structure	0.01/s 1.0/s 10.0/s 50.0/s 100/s
Shear ASTM D7078	ASTM D7078 Double lap shear for large bead foams	Strong and weak shear (Appendix C, Figure C1) only for extruded or materials showing orientation of cellular structure	2 mm/minute (7 mm/minute for double lap shear)

4.3.3 Retest. Test specimens, test practice and test data shall be continuously inspected for irregularities. Specimens and test data shall be discarded and replaced if any of the following occurs:

- An incorrect test procedure was applied, or the test equipment malfunctioned.
- Test velocity was not maintained within 10% of the nominal velocity throughout the test.
- Fracture occurred at grips due to excessive gripping of the specimen (uniaxial tension, shear).
- Either fracture or necking occurred outside the gauge length (uniaxial tension).
- If a pre-existing crack, not indicative of the specimen/part manufacturing process, was detected in the fracture area (uniaxial tension).
- Excessive noise in stress-strain curve.
- Less than 10 points collected for the determination of modulus.
- Absence of initial linear region or multiple linear regions (uniaxial tension, shear).
- Uncharacteristic features in the curve shape due to, for example, sudden changes in strain rate.
- Test results for one (1) specimen show a large deviation (over 40%) from the average test results.

All specimens, tested and discarded, shall be listed in the test report. Reasons for discarding a test specimen shall be documented in the report.

Any replacement tests shall be reported according to 5.3.1 and Appendices A thru C. Test procedures and equipment shall be verified and recalibrated as necessary.

4.4 Responsibility. Any deviations from the requirements specified in this standard shall be reviewed and approved by General Motors Materials Engineering before testing.

5 Data

5.1 Calculations. Not applicable.

5.2 Interpretation of Results. Not applicable.

5.3 Test Documentation. The test data shall be provided in digital format according to the template. For specimens cut from parts, report all data specified in 3.5 and 5.3.1 in addition to the data specified in the template.

5.3.1 Test Report. For each specimen the report shall contain, but is not limited to, the following (using the term definitions in the appropriate standards):

- Test standard
- Picture of the test setup
- Temperature and humidity at which the test specimens were conditioned
- Specimen dimensions and, if applicable, the number of plies in a stack (for thickness < 10 mm, uniaxial compression)
- Type of test specimen used (e.g., rectangular, ISO 8256, Type 3, etc.)
- Specimen thickness (uniaxial tension, shear)
- Specimen extraction method
- Location in the larger samples/parts from which the specimens were taken (if applicable)
- The presence or absence of surface skins and whether the skin was removed for testing
- Location of the skin, if present (e.g., on the top side, front side, both sides, etc.)
- Skin thickness (if present)
- Density (apparent overall density, per ASTM D1622, for specimens with the skin; apparent core density, per ASTM D1622, for specimens without skin)
- Temperature and humidity during testing
- Method of force measurement
- Method of displacement/strain measurement
- Nominal strain rate/crosshead speed
- Specimen orientation (e.g., 0 degrees to extrusion direction, etc.), if applicable
- Gauge length (uniaxial tension, shear)
- Location of fracture (e.g., inside the gauge region, within the grip area, etc.), (uniaxial tension, shear)
- Pre-test and post-test specimen images (a group picture of all specimens tested under the same condition)
- Video of the test for any one specimen at each strain rate and at each temperature and orientation
- Observations made during test
- Plot of displacement vs. time for all specimens tested with the same method.
- Stress vs. strain for all specimens tested with the same method. Comparisons shall be made at different strain rates, temperatures and orientations (if applicable) to assess the test data variation and assure the correct trend in the data (e.g., stress increases with the increase in strain rate, stress decreases with the increase in temperature, etc.) These comparisons shall be made for each test method.

The following shall be reported, in tabular format, from the start of test until the end of unloading (uniaxial compression) or until specimen fracture (uniaxial tension, shear):

- Time (seconds (s)), force (Newtons (N)), displacement (millimeters (mm))
- Engineering axial stress (megapascals (MPa)) vs. engineering axial strain (mm/mm) (uniaxial compression and tension)
- Engineering shear stress (MPa) vs. engineering shear strain (mm/mm) (shear)

The number of reported data points for each of the properties specified in the preceding shall be 1000-2000 for strain rates below 0.1/s and 100-1000 for strain rates 0.1-100/s.