



Standard Test Methods for Quasi-Static Physical Testing of Injection Molded Fiber Reinforced Thermoplastics 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. These methods provide a way of obtaining physical response properties for static tension, and thermal expansion. The test data permits a design analyst to characterize the physical behavior in a material model in finite element analysis. The scope is restricted to the characterization of injection molded fiber reinforced thermoplastic materials. The methods appear as follows:

- **Test Method A – Tensile Properties.** Tensile testing is the method to evaluate the anisotropic tensile properties of test specimens cut from an injection molded thermoplastic plaque at 0°, 45°, and 90° to the flow direction. Unless otherwise specified, ISO 527-1 and ISO 527-2 must be followed.
- **Test Method B – Thermal Expansion Properties.** Thermal expansion testing is the method to evaluate the coefficient of thermal expansion of test specimens cut from an injection molded thermoplastic plaque at 0° and 90° to the flow direction, as the sample is heated. Unless otherwise specified, ISO 11359-1 and ISO 11359-2 must be followed.

1.2 Applicability. The data obtained is to be used for finite element analysis of injection molded non-impact and impact modified short fiber reinforced thermoplastic parts. The fiber reinforced thermoplastic must have fibers of length smaller than 3 mm. The methods are intended for rigid, low failure strain materials. Typical applications include intake manifolds, oil pans, front covers, and thermostat housings.

1.3 Remarks. The effects of fiber orientation and large thermal transitions are captured using these test methods so that simulations can accurately reflect these behaviors. Finite element analysis using material models defined using the test data from the test methods described herein is used to simulate and predict the mechanical deformation and failure of injection molded fiber reinforced thermoplastic parts.

General Motors showed that a structural analysis which uses the anisotropic material model predicts well the thermal deformation and failure characteristics of injection molded fiber reinforced thermoplastic parts. This included rubber modified and non-rubber modified materials. The requirements for this analysis are:

- a. Predicting the fiber orientation.
- b. Fitting the mechanical and thermal properties to an anisotropic material model.

This standard requires that both the tensile testing and the thermal expansion testing be done, from one (1) lot of resin and a unique set of molding conditions. A complete set of data over the full temperature range is required to create an accurate anisotropic material model.

2 References

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

2.1 External Standards/Specifications.

ISO 291	ISO 527-2	ISO 8256	ISO 11359-2
ISO 294-1	ISO 1110	ISO 11359	ISO 15512
ISO 527-1	ISO 2818	ISO 11359-1	ISO/IEC 17025

2.2 GM Standards/Specifications.

GMW15702

2.3 Additional References.

- Abaqus – Software for Finite Element Analysis and computer aided engineering.
- Digimat – Software developed by e-Xstream engineering for Finite Element Analysis of composites, available at www.e-xstream.com.
- Mold Part Number 31197 available at Master Precision Products, Inc. - www.masterprecision.com.

3 Resources

3.1 Facilities. A suitable test laboratory with temperature and humidity control where needed. The laboratory should be ISO/IEC 17025 certified.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

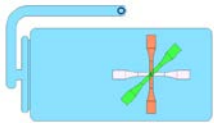
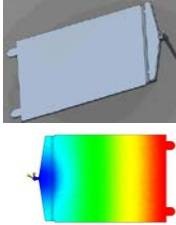
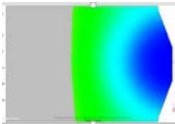
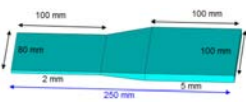
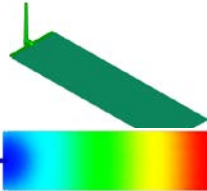
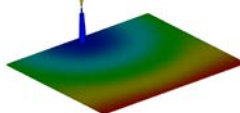
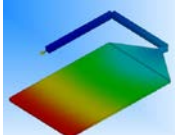
3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Injection Molding Machine.

3.2.1.1 Mold. The mold shall generate plaques that are 3 mm in thickness, 101 mm in width, and 204 mm in length. The plaque must be gated with an edge gate across the entire width of the mold. Reference the tool manufactured by Master Precision Mold, blueprint number 31197.

3.2.1.2 Alternative Molds. Other molds have been assessed acceptable based on the evolution of the flow pattern and/or fiber orientation throughout the cross section, see the list in Figure 1. Other acceptable plaques may be included in the next revision of this standard upon request. Plaques longer than the ones described in Figure 1 are acceptable. As highlighted in 1.3, the goal is to create a material model. It is not to compare data obtained from these different plaques.

PLAQUE:	Original (GM R&D)	A	B	C
W x L (inches)	4 x 8	4 x 10	7.87 x 9.84	6 x 8
W x L (mm)	101 x 204	102 x 254	200 x 250	152 x 203
T (inches)		1/8		1/8
T (mm)	3.2	3.175	3	3.175
Gating	Full width edge gate	Fan gate	Full width edge gate	Fan gate
W = Width L = Flow Length T = Thickness				
PLAQUE:	D	E	F	G
W x L (inches)	3.15 x 9.84	4 x 14	12.2 x 10.6	4.72 x 7.09
W x L (mm)	80 x 250	102 x 356	310 x 270	120 x 180
T (inches)		1/8		
T (mm)	2	3.175	2	3.2
Gating	Full width edge gate	Full width edge gate	Point gate	Fan gate
W = Width L = Flow Length T = Thickness				

Note: R&D = Research and Development

Figure 1: List of Approved Plaques

3.2.2 Tensile Testing Machine. See ISO 527-1. An example of a specimen being tested with an axial and transverse extensometer mounted is shown in Figure 2.



Figure 2: Tensile Specimen with an Axial and Transverse Extensometer Mounted

3.2.3 Specimen Cutting System. See ISO 2818. An example of a cutting system is shown in Figure 3. In this case, a specimen template is used to drive a router.



Figure 3: Example Cutting System

3.2.4 Vacuum Oven. The purpose of the vacuum oven is to dry plaques or test specimens in a vacuum condition with desiccant. An example oven is shown in Figure 4. This vacuum oven should not have to be used if the plaques and samples are properly sealed in moisture barrier containers for a limited time. Note that damaged seal bags no longer seal.

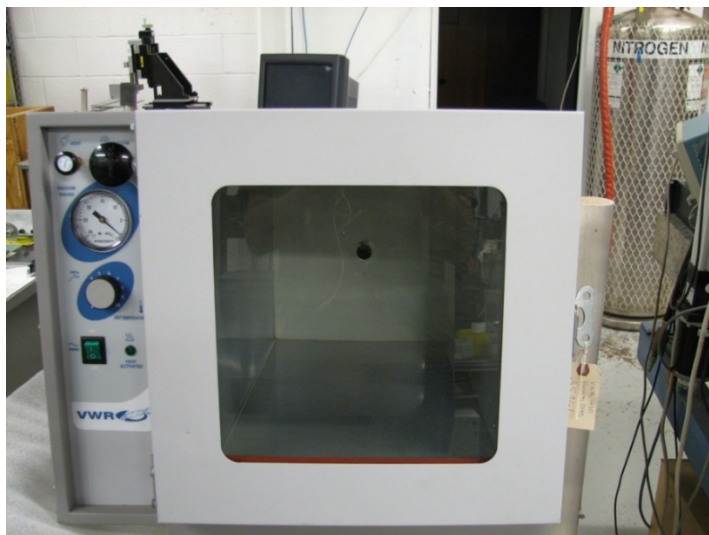


Figure 4: Example Vacuum Oven

3.2.5 Thermo-Mechanical Analyzer (TMA) Instrument. See ISO 11359-2, and Figure 5.



Figure 5: Example TMA Apparatus

3.3 Test Vehicle/Test Piece. Not applicable.

3.4 Test Time. One (1) month all inclusive.

3.5 Test Required Information. Refer to 5.3.

3.6 Personnel/Skills. A technician that is familiar with physical testing of injection molded plastics.

4 Procedure

4.1 Preparation.

4.1.1 Preparation Method A – Tensile Properties.

4.1.1.1 Conditioning of Pellets or Granules. See ISO 294-1.

4.1.1.2 Tools. See description of acceptable plaques in 3.2.1.1 and 3.2.1.2

4.1.1.3 Procedure for Injection Molding of Plaques. See ISO 294-1. The molding conditions are recommended to be such that the injection time, as defined in ISO 294-1 is 2.5 ± 0.5 s. The slow fill time is to ensure high orientation. Faster fill time is acceptable if necessary to ensure proper filling. The plaques shall be injection molded using the mold temperature and mold pressure recommended by the material supplier for test plaques.

4.1.1.4 Machining of Test Plaque. The test specimens shall be machined from the plaques in accordance with ISO 2818. All surfaces of the specimens should be free from visible flaws, scratches, or other imperfections. The test specimens are the ISO 527-2, Type 1BA small specimens described in ISO 527-2, Annex A, of overall length ≥ 75 mm, and overall width of 10 mm at the ends.

4.1.1.5 Location of Test Specimens in the Plaque. The test specimens shall be machined at 0° , 45° , and 90° to the flow direction. Note that the tensile data from the 45° specimen is key for fitting a failure criteria. Only one (1) specimen shall be obtained per plaque.

For all plaques except for Plaque D, the center of each specimen is positioned 75 mm from the end of the plaque, and in the center of the width, see Figure 6. For Plaque D, the center of each specimen is positioned 45 mm from the end of the plaque.

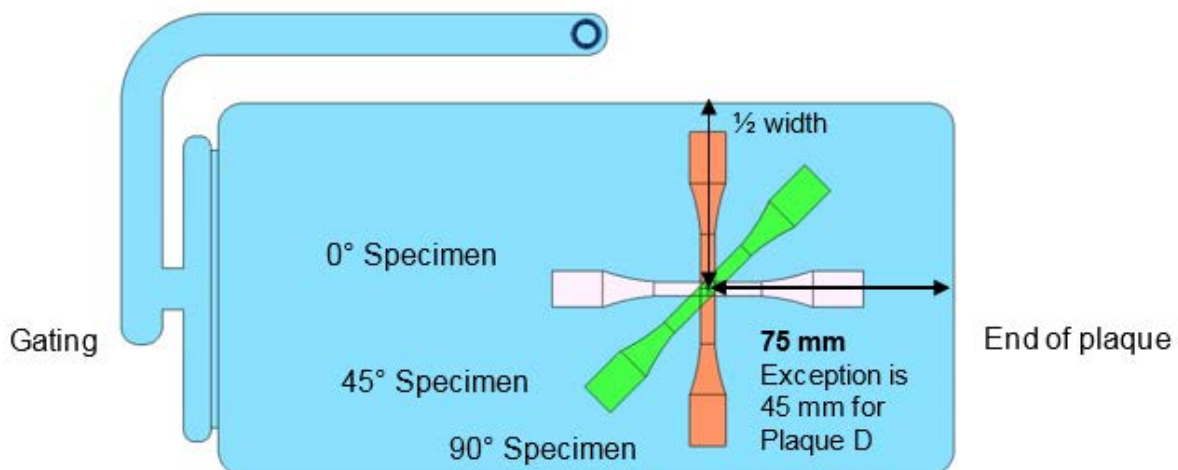


Figure 6: Schematic Diagram of Plaque Showing Location for Specimen Extraction

4.1.1.6 Storage of Plaques after Removal from the Mold. The plaques shall be sealed in containers that are impermeable to water vapor within 60 minutes of molding, and for a minimum of 24 h.

4.1.1.7 Cutting and Storage of Test Specimen. Cutting of the specimens shall be done 30 minutes after removing the seal. Within 30 minutes of being cut, the specimens shall be tested, or sealed again so that they remain in the dry condition. The total time between opening the bag and testing should not exceed 60 minutes.

4.1.1.8 Drying. If the specimens have not been sealed and kept dry as molded (DAM), they may be dried in a vacuum oven (suggested 80°C , 10 h to 15 h) with dry desiccant. It is imperative to verify adequate drying to a DAM condition. Samples shall be tested for moisture content during the drying, and must reach a constant weight with a maximum moisture content of 0.2% maximum when tested per ISO 15512 (Method B). The dried specimens shall be tested, or sealed in containers that are impermeable to water vapor, within 30 minutes of leaving the oven.