



Standard Test Methods for Quasi-Static Physical Testing of Injection Molded Short Fiber Reinforced Thermoplastics for Use in Finite Element Anisotropic 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 information on the molding, testing and reporting of test data from injection molded short fiber reinforced thermoplastic plaques. The results allow a design analyst to characterize the anisotropic physical behavior in a material model to be used in finite element analysis. The test methods are as follows:

- **Method A:** Tensile testing to evaluate the anisotropic tensile behavior of test specimens cut from an injection molded thermoplastic plaque at 0 degrees, 45 degrees, and 90 degrees (see 7.1) to the flow direction.
- **Method B:** Thermal expansion testing to evaluate the thermal expansion behavior of test specimens cut from an injection molded thermoplastic plaque at 0 degrees and 90 degrees to the flow direction, as the sample is heated.

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 methods are intended for rigid, low failure strain materials.

1.3 Remarks. Results from this test method are used to generate finite element analysis models to simulate and predict the thermal deformation as well as the mechanical deformation and failure of injection molded fiber reinforced thermoplastic parts.

The requirements for the anisotropic analysis are:

Measuring or predicting the fiber orientation

Fitting the mechanical and thermal properties to an anisotropic material model.

A complete set of tensile and thermal expansion data over the full temperature range is required to create an accurate Digimat (see 2.3) thermo elastic plastic (TEP) anisotropic material model. A complete set of tensile data at one temperature is required to create an accurate Digimat elastic plastic (EP) anisotropic material model.

2 References

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

2.1 External Standards/Specifications.

ISO 291	ISO 527-1A	ISO 2818	ISO 15512
ISO 294-1	ISO 527-1BA	ISO 8256	ISO/IEC 17025
ISO 527	ISO 1043-1	ISO 11359-1	
ISO 527-1, 2	ISO 1110	ISO 11359-2	

2.2 GM Standards/Specifications.

None

2.3 Additional References.

- Abaqus – Software for Finite Element Analysis and computer aided engineering.
- Component Technical Specification (CTS).
- Digimat – Software developed by e-Xstream engineering for Finite Element Analysis of composites.
- Mold Part Number 31197 available at Master Precision Products, Inc.; www.masterprecision.com.
- Subsystem Technical Specification (SSTS).
- Vehicle Technical Specification (VTS).

3 Resources

3.1 Facilities. A suitable test laboratory with temperature and humidity control where needed. The laboratory is preferably ISO/IEC 17025 certified and shall be approved by General Motors Materials Engineering.

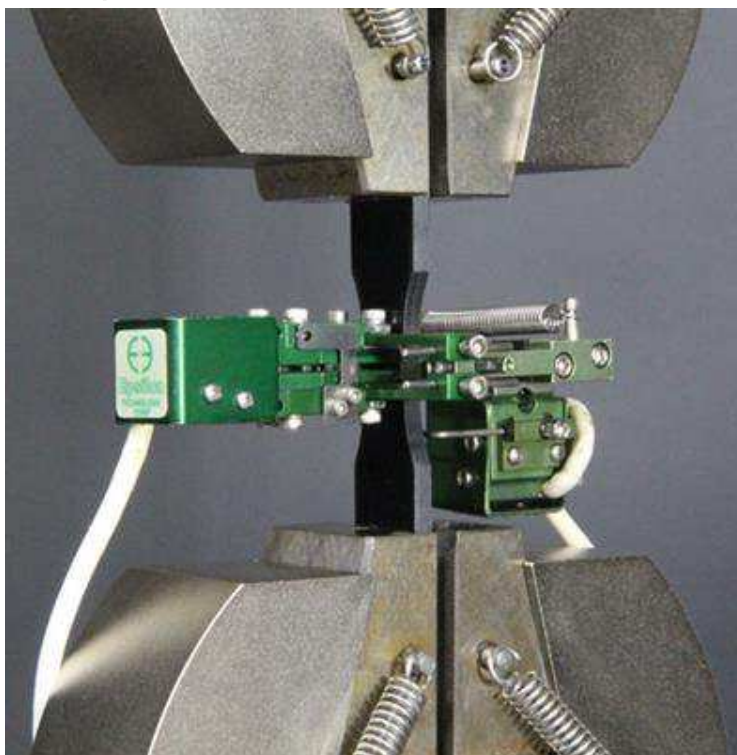
3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

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 Tensile Testing Machine and Extensometer. See ISO 527-1. An example of a specimen being tested with a contact (clip-on) axial and transverse extensometer mounted is shown Figure 1. The use of non-contact (dot tracking/video/virtual) extensometer is an alternative.

Figure 1: Tensile Specimen with an Axial and Transverse Extensometer Mounted



3.2.2 Specimen Cutting System. See ISO 2818. An example of a cutting system is shown Figure 2.

Figure 2: Vertical Milling Machine for Specimen Cutting



3.2.3 Vacuum Oven. See ISO 15512, Method B. The purpose of the vacuum oven is to dry plaques or specimens in a vacuum condition with desiccant, in the eventuality that plaques molded with hydroscopic resins were not sealed in moisture proof bags. An example oven is shown Figure 3.

Figure 3: Vacuum Oven



3.2.4 Temperature-Humidity Controlled Chamber. See ISO 1110. The purpose of this chamber is to condition plaques to standard 23 °C/50% Relative Humidity (RH) equilibrium moisture content (COND23/50) using ISO 1110 accelerated procedure. An example chamber is shown Figure 4.

Figure 4: Temperature-Humidity Controlled Chamber



3.2.5 Thermo-Mechanical Analyzer (TMA) Instrument. See ISO 11359-1. An example of a TMA Instrument with mechanical cooling option for thermal expansion measurement is shown Figure 5.

Figure 5: Thermo-mechanical Analyzer (TMA) Instrument



3.3 Test Vehicle/Test Piece. Not applicable.

3.4 Test Time. One (1) month for **Method A** and **Method B** testing.

3.5 Test Required Information. Refer to Section 5.

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

4 Procedure

4.1 Preparation.

4.1.1 Preparation of Injection Molded Plaques.

4.1.1.1 Procedure for Injection Molding. The plaques shall be injection molded per ISO 294-1, using the mold temperature, mold pressure, fill time, recommended by the material supplier for test plaques. To obtain a consistent material model, the plaques used for both the tensile and thermal expansion testing shall be molded in the same molding trial, with the same lot of resin, same molding conditions. It is recommended to mold extra plaques (30%) for troubleshooting, potential retesting, or additional testing.

Plaques with resins that absorb humidity such as polyamides shall be kept in the Dry as Molded (DAM) state with moisture content 0.2% maximum per ISO 15512, Method B and sealed in bags that are impermeable to water vapor within 60 minutes of molding. It is recommended that only few plaques be stored in each moisture proof bag for practical reasons, since opened bags no longer seal against moisture.

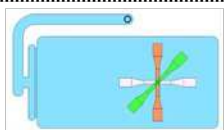
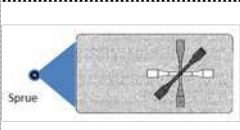
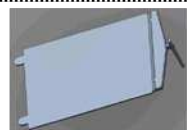
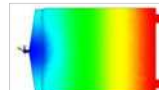
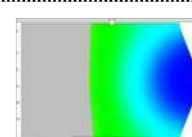
4.1.1.2 Acceptable Plaque Dimensions. The GM traditional mold generates plaques that are 101 mm in width, and ≥ 204 mm in length, and $3.20 \text{ mm} \pm 0.02 \text{ mm}$ in thickness. The mold is gated with an edge gate across the entire width of the mold. Reference Mold Part Number 31197 (see 2.3). Many plaques have been assessed acceptable, see the list of known plaques in Figure 6.

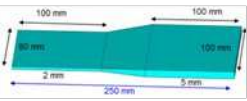
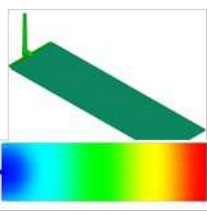
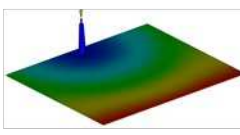
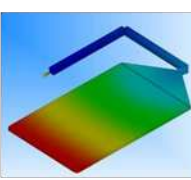
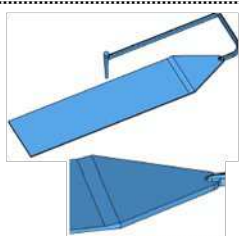
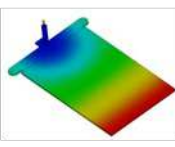
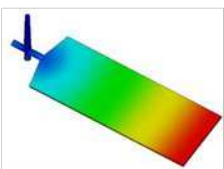
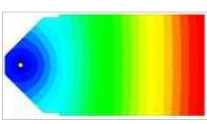
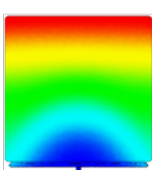
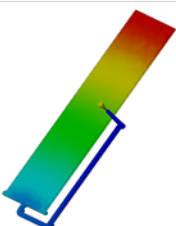
Plaques may be included by GM Materials Engineering in the next revision of this standard upon request. For approval to this standard a mold flow fill time plot and one set of tensile data in 0 degrees, 45 degrees, and 90 degrees to flow direction on any 30% to 50% glass fiber composite is requested. In general, long plaques with length > 7 in ($> 177 \text{ mm}$), width > 3 in ($> 76 \text{ mm}$), thickness 2 mm to 3.2 mm (with a tolerance on the thickness of $\pm 0.02 \text{ mm}$), gate on the short width side, should be acceptable. Other less traditional geometries that allow to capture the anisotropic material behavior might be acceptable pending review and approval by GM Materials Engineering.

As part walls are getting thinner, and because the fiber orientation microstructure is very dependent on the thickness, a general thickness closer to 2 mm is preferred. Alternatively, a general thickness closer to the main application thickness is preferred.

As outlined in 1.3, the goal is to create a TEP material model. It is not to compare data obtained from these different plaques and microstructures.

Figure 6: List of Approved Plaques

PLAQUE:	Original	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)	2.2 / 2.78	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				
PLAQUE:	H	I	J	K
W x L (inches)	4.02 x 14.02	3.15 x 4.7	4 x 10	4.13 x 5.9
W x L (mm)	102 x 356	80 x 120	102 x 254	105 x 150
T (inches)			1/8	
T (mm)	2	2	3.175	2
Gating	Fan gate	Full width edge gate	Fan gate	
W = Width L = Flow Length T = Thickness				
PLAQUE:	L	M	N	
W x L (inches)	9.84 x 9.84	4 x 12	3.94 x 14.17	
W x L (mm)	250 x 250	101.6 x 304.8	100 x 360	
T (inches)		1/8		
T (mm)	3	3.175	3	
Gating	Full width edge gate			
W = Width L = Flow Length T = Thickness				

4.1.2 Preparation of Controlled Moisture Content for Resins that Absorb Humidity.

4.1.2.1 DAM State. To keep the plaques in the DAM state, cutting the specimens shall be done shortly after opening the moisture proof bags. The DAM specimens shall then be tested or sealed again within a few hours (h). The total time, between opening the bag and testing or re-sealing in moisture proof bags, should not exceed one (1) working day at room temperature.