TOYOTA ENGINEERING STANDARD

NO. : TSM5515G

TITLE : POLYACETAL RESIN MOLDING MATERIALS

CLASS : C2

Established/Revised : Rev.11 (Jul.2005)

This standard has been revised in consequence of the following changes:
(1) quality requirements have been revised as a result of introduction of new ISO molds.
(2) standards to be referenced for test methods have been changed.
(3) misdescription has been corrected.

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POLYACETAL RESIN MOLDING MATERIALS

1. Scope

This standard covers the general properties of polyacetal resin molding materials (hereinafter referred to as "molding materials") used for automotive plastic parts. The molding materials shall meet the part performance criteria and material specifications in separate standards.

The parts made of materials provided by this standard shall conform to prohibitions and restrictions for substances of environmental concern in TSZ0001G. Exempt uses specified by EU ELV Directive shall conform to the latest version of the Directive.

2. Classification and Designation

The classification and designation of the molding materials shall conform to Table 1. For a molding material requiring special performance, the following suffixes shall be added to its material code.

C: Chemical resistance
D: High temperature light oil resistance
H: Heat-aging resistance
L: Light resistance
V: Low VOC (Volatile Organic Compound)
W: Weatherability

Example: TSM5515G-1L

- 1L — Suffix
- TSM5515G-1 — Classification

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Table 1 Classification of Molding Materials

Classification	Material code	Composition	Major application
Class 1A	TSM5515G-1A	Copolymer type of high-viscosity polyacetal resin	Suitable for parts requiring creep resistance and/or repeated fatigue resistance. Temperature condition: 105℃ max.
Class 1B	TSM5515G-1B	Copolymer type of moderate-/low-viscosity polyacetal resin	Suitable for general parts. Temperature condition: 105℃ max. When materials suffixed with D are used in light oil, the temperature shall not exceed 100℃.
Class 2A	TSM5515G-2A	Homopolymer type of high-viscosity polyacetal resin	Suitable for parts requiring mechanical strength, creep resistance and repeated fatigue resistance. Temperature condition: 80℃ max. No hot-water resistance expected.
Class 2B	TSM5515G-2B	Homopolymer type of moderate-/low-viscosity polyacetal resin	Suitable for parts requiring mechanical strength. Temperature condition: 80℃ max. No hot-water resistance or grease resistance expected.
Class 2C	TSM5515G-2C	Homopolymer type of moderate-viscosity polyacetal resin	Suitable for parts requiring mechanical strength. Temperature condition: 105℃ max. No hot-water resistance expected.

3. Quality

The quality of the molding materials can be evaluated in principle in accordance with either one of the following, depending on the Japanese or international standard to which the associated test method shall conform.

New JIS or ISO Standard → TSM0506G

Former JIS or former ASTM Standard → TSM0501G

Regardless of the applicable standard, the quality of the molding materials shall meet the property requirements specified in Table 2 or 3 and Table 4, when they are tested under the test conditions specified in Section 4 and the test results are evaluated in accordance with the criteria specified in Section 5. If no specific requirements have been established, however, TSM0506G shall apply. Note that because the molding materials covered herein are highly sensitive to strong acid, use of the materials shall be prohibited where the materials are subject to contact with strong acid.

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Table 2 Requirements for General Mechanical Properties (when measurement method complying with ISO Standard is used)

Test item		Class 1A	Class 1B	Class 2A	Class 2B	Class 2C
Density		1.37 to 1.44				
Tensile test	Tensile strength (MPa)	57 min.		60 min.		61 min.
	Strain at fracture (%)	18 min.	9 min.	20 min.		
	Modulus of elasticity (MPa)	1870 min.		2080 min.		
Charpy impact test	With notch (kJ/m²)	4.1 min.	2.7 min.	5.5 min.	3.6 min.	
Deflection temperature under load	1.8 MPa (℃)	75 min.	80 min.	88 min.		
	0.45 MPa (℃)	132 min.		142 min.		
Rockwell hardness	M Scale	66 min.		73 min.		

Table 3 Requirements for General Mechanical Properties (when measurement method complying with former JIS is used)

Test item		Class 1A	Class 1B	Class 2A	Class 2B	Class 2C
Specific gravity		1.37 to 1.44				
Tensile test	Tensile strength (MPa)	55 min.		65 min.		59 min.
	Elongation at fracture (%)	40 min.	20 min.	40 min.		20 min.
Flexural test	Flexural strength (MPa)	73 min.		85 min.		
	Flexural modulus (MPa)	1800 min.		2000 min.		
Izod impact test	With notch (J/m)	44 min.	29 min.	59 min.	39 min.	
Heat distortion temperature	1820 kPa (℃)	95 min.				
	455 kPa (℃)	140 min.		150 min.		
Rockwell hardness	M Scale	70 min.		75 min.		

Table 4 Other Property Requirements

Item			Class 1A	Class 1B	Class 2A	Class 2B	Class 2C
Water absorption (%)			0.4 max.				
Heat aging resistance (suffixed with H)	Tensile strength retention rate at yield (%)		70 min.		---		90 min.
Grease resistance (suffixed with C)	Tensile strength retention rate at yield (%)	110℃	90 min.		---	Shall not exhibit conspicuous degradation of properties that will impede use	---
		85℃	---		90 min.		
Antifreeze resistance (suffixed with C)	Tensile strength retention rate at yield (%)		90 min.		Shall not exhibit conspicuous degradation of properties that will impede use		
Weatherability (light resistance) (suffixed with W or L)			Discoloration and/or color fading shall be better than Grade 3 in Table 6.				
High temperature light oil resistance (suffixed with D)	Tensile strength retention rate at yield (%)		---	90 min.	---		
Low VOC (suffixed with V)	Quantity of evaporated formaldehyde	Method A (μg/g)	---	1.2 max.	---		
		Method B (μg/m³)		140 max.			

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4. Test Method

4.1 Testing in Accordance with ISO or New JIS

4.1.1 Test Specimen Preparation

Prepare the test specimens in accordance with Section 2 of TSM0506G, as a rule. The practical conditions for injection-molding the test specimens or those for compression-molding the flat plates to be used for punching the test specimens shall conform to ISO 9988-2. For the injection molding, in particular, mold the test specimens under the conditions best suited to MFR of the material by using a die conforming to TSM0506G. The injection molding speed, V_I, shall be determined from equation (1) given below.

$$V_I = V_S / t_I \cdot A_C \cdot n \quad \text{---------- (1)}$$

Where,
V_I: molding speed (mm/s)
A_C: cross sectional area (mm^2)
V_S: shot capacity (mm^3)
n: number of cavities in die
t_I: cross sectional area of test specimen at its principal portion (mm^2)

4.1.2 Test Specimen Conditioning

Prior to the test, condition the test samples and test specimens in accordance with Section 2.4 of TSM0506G. For the conditioning time, however, comply with ISO 9988-2, which is 16 h or longer.

4.1.3 Ambient Condition of Test

For the ambient condition of the test, conform to Section 2.4 of TSM0506G.

4.1.4 Collection of Test Data

Collect the test data in accordance with Section 2.5 of TSM0506G. Attach the test specimen molding conditions and other related data to the test results.

4.1.5 Number of Test Data (n)

The number of test data, n, required for evaluating the properties of the molding materials shall be 10 min., unless specified specifically.

4.1.6 Density Measurement Test

Carry out the measurement in accordance with Section 3.1 of TSM0506G.

4.1.7 Tensile Test

Comply with the test method specified in Section 3.2 of TSM0506G. For the tensioning speed and other conditions of the test, comply with ISO 10350-1, as a rule. The practical test conditions are shown in Table 5.

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Table 5

Item		Cross head speed	Remark
Tensile test	Yield stress (MPa)	50 mm/min	---
	Elongation after fracture (%)		When the elongation after fracture is 10% or less, use 5 mm/min.
	Modulus of elasticity (MPa)	1 mm/min	---

4.1.8 Charpy Impact Test
In accordance with Section 3.3 of TSM0506G.

4.1.9 Deflection Temperature under Load Measurement Test
In accordance with Section 3.4 of TSM0506G.

4.1.10 Hardness Test
In accordance with Section 3.8, TSM0506G. This test shall be conducted in the atmosphere of 23 ± 2℃, and measurement shall be based on M-Scale.

4.2 Testing in Accordance with Former ASTM or Former JIS
Unless otherwise specified, the test shall be conducted under the conditions specified in Section 4.2.1 to 4.2.4 inclusive.

4.2.1 Conditioning
Condition the test samples and/or specimens in accordance with Section 4, TSM0501G for not less than 24 h.

4.2.2 Atmosphere
In accordance with Section 5, TSM0501G

4.2.3 Preparation of Test Specimens
In accordance with Section 3.1, TSM0501G

4.2.4 Number of Test Specimens
In accordance with Section 6, TSM0501G

4.2.5 Specific Gravity Test
In accordance with Section 9.1, TSM0501G

4.2.6 Tensile Test
In accordance with Section 9.2, TSM0501G. This test shall be conducted in the atmosphere of 23 ± 2℃ with 10 mm/min of crosshead speed.

4.2.7 Flexural Test
In accordance with Section 9.3, TSM0501G. This test shall be conducted in the atmosphere of 23 ± 2℃ with 2.0 mm/min of crosshead speed.

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4.2.8 Izod Impact Test
In accordance with Section 9.4, TSM0501G. This test shall be conducted in the atmosphere of 23 ± 2℃.

4.2.9 Hardness Measurement Test
In accordance with Section 9.9, TSM0501G. This test shall be conducted in the atmosphere of 23 ± 2℃, and measurement shall be based on M-Scale.

4.2.10 Heat Distortion Temperature Measurement Test
In accordance with Section 9.6, TSM0501G. This test shall be conducted at 1820 kPa and 455 kPa of flexure stress.

4.3 Testing Other Mechanical Properties

4.3.1 Water Absorption Measurement Test
In accordance with Section 9.16, TSM0501G

4.3.2 Heat Aging Resistance Test (Suffixed with H)
Use the tensile test specimens shaped in accordance with Section 3.1 of TSM0501G. Condition the test specimens as follows:
(1) Condition in accordance with Section 4 of TSM0501G.
(2) Leave for 1440 h (60 days) in a Geer oven adjusted to 110 ± 2℃. Then again, condition in accordance with Section 4 of TSM0501G.
Using the test specimens conditioned in (1) and (2), conduct the tensile test in accordance with Section 9.2 of TSM0501G. Determine the tensile strength retention rate at yield from equation (2).

Tensile strength retention rate at yield S (%) = S_1/S_0 × 100 --- (2)

where,
S_0: tensile strength after conditioning (1)
S_1: tensile strength after conditioning (2)

4.3.3 Grease Resistance Test (Suffixed with C)
Use the tensile test specimens shaped in accordance with Section 3.1 of TSM0501G. Condition the specimens as follows:
(1) Condition in accordance with Section 4 of TSM0501G.
(2) Apply the same grease/oil as that for actual production use uniformly over the specimen surfaces, and leave the specimens at 110 ± 2℃ (85 ± 2℃) for 1440 h (60 days). Then, wipe the grease/oil off the specimens, and condition again in accordance with Section 4 of TSM0501G.
Using the test specimens conditioned in (1) and (2), conduct the tensile test in accordance with Section 9.2 of TSM0501G. Determine the tensile strength retention rate at yield from equation (3).

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Tensile strength retention rate at yield S (%) = S_1/S_0 × 100 --- (3)

where,
S_0: tensile strength after conditioning (1)
S_1: tensile strength after conditioning (2)

4.3.4 Antifreeze Resistance Test (Suffixed with C)

Use the tensile test specimens shaped in accordance with Section 3.1 of TSM0501G. Condition the specimens as follows:

(1) Condition in accordance with Section 4 of TSM0501G.

(2) Immerse the test specimens under the following conditions:
Dilute the same antifreeze as that for actual production use by 50% (vol) with distilled water, and immerse the specimens in the dilution of 110 ± 2℃ for 1440 h (60 days). Then, wash them with water, and again condition in accordance with Section 4 of TSM0501G. Next, using the specimens conditioned in (1) and (2), conduct the tensile test in accordance with Section 9.2 of TSM0501G. Determine the tensile strength retention rate at yield from equation (4).

Tensile strength retention rate at yield S (%) = S_1/S_0 × 100 --- (4)

where,
S_0: tensile strength after conditioning (1)
S_1: tensile strength after conditioning (2)

4.3.5 Weatherability (Light Resistance) Test

This test is performed on W- or L-suffixed materials requiring weatherability (light resistance).

(1) Test equipment
(a) For W molding materials:
Sunshine Weather-O-Meter (Section 9.20, TSM0501G)
(b) For L molding materials:
Fade-O-Meter (Section 9.20, TSM0501G)

(2) Weatherability test conditions
(a) Black panel temperature: 83 ± 3℃
(b) Exposure time: 800 h

After exposure, inspect the surface for cracks with an 50-power microscope. Also, check test specimens visually for discoloration and/or color fading, and evaluate the results in accordance with the criteria given in Table 6.

Table 6

Grade	Rating	Conditions
5	Excellent	No visible change
4	Good	Slight change
3	Fair	Small change
2	Unacceptable	Change
1		Remarkable change

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(Reference)

Table 7

Grade	Color difference (ΔE)(1)
5	0.7 or less
4	0.8 to 2.0
3	2.1 to 4.0
2	4.1 to 7.0
1	7.1 or more

Note: (1)
Acceptable color difference of interior parts after light resistance test is specified in individual parts drawings.

4.3.6 High Temperature Light Oil Resistance Test

Prepare tensile test specimens that have been configured in accordance with Section 3.1 of TSM0501G. Condition the above specimens according to the following procedures:

(1) Condition the specimens under the procedures specified in Section 4 of TSM0501G.

(2) Immerse the specimens in the high lubricity standard light oil (RF-90-A-92) made by Haltermann Co. With the container covered tightly, store it for 500 h at 100 ± 2℃. Replace the light oil with fresh quantity and store the container for further 500 h at 100 ± 2℃. Take the specimens out of the container, wipe the oil carefully off the specimens, and condition them under the procedures specified in Section 4 of TSM0501G.
After completion of the respective procedures (1) and (2), put the test specimens to the tensile test specified in Section 9.2 of TSM0501G. Determine the tensile strength retention rate at yield from equation (5) as follows:

Tensile strength retention rate at yield S (%) = S_1/S_0 × 100 ------- (5)

Where,
S_0: tensile strength after conditioning in accordance with procedure (1)
S_1: tensile strength after conditioning in accordance with procedure (2)

4.3.7 Low VOC

Carry out the test in accordance with Method A or Method B specified below.

(1) Method A (bag method)
Calculate the quantity of formaldehyde evaporated from the test piece in accordance with TSM0508G. The test piece shall be a flat piece of 60 × 60 × 2 mm in dimensions as shown in Fig. 4 in TSM0506G, Section 2.3. The temperature of resin during test piece molding shall be 190℃. Use a cutting knife for removing the molded test piece from the runner. Take care not to heat the test piece. Using equation (6), calculate the quantity of evaporated formaldehyde. In the calculation, divide the quantity of formaldehyde evaporated from one test piece by its mass that has been measured in advance. For the test result, record the quantity of evaporation per unit mass or μg/g.

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Quantity of evaporated formaldehyde(μg/g) = [Quantity of formaldehyde evaporated from test piece (μg/test piece)]/[Mass of test piece (g)] -- (6)

(2) Method B (thermal desorption method)
Calculate the quantity of formaldehyde evaporated from the test piece in accordance with TSM0509G.

5. Evaluation of the Test Result

5.1 Numerical Value of Test Result

Calculate the mean value ($\overline{X}$) and the standard deviation (s) from the data obtained from the procedures given in Section 4. The method for rounding the numerical values is defined in Section 6 of TSM0501G. The number of test specimens is 15 ($n = 15$).

5.2 Evaluation of Test Result

Judge the numerical values calculated in Section 5.1 as follows:

(1) For lower limit values specified in Tables 2 through 4
Accept : ($S_L \leqq \overline{X} - 2.00 \times s$)
Reject : ($S_L > \overline{X} - 2.00 \times s$)
S_L: lower limit value of specification

(2) For upper limit values specified in Tables 2 through 4
Accept : ($S_U \geqq \overline{X} + 2.00 \times s$)
Reject : ($S_U < \overline{X} + 2.00 \times s$)
S_U: upper limit value of specification

where, mean value of test specimens:

$$\overline{X} = T/n$$
$$T = (X_1 + X_2 + X_3 + \cdots + X_n)$$

standard deviation of test specimens:

$$s = \sqrt{(V)}$$

$$V = S/(n-1)$$
$$S = (X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + \cdots + (X_n - \overline{X})^2$$
$$= \Sigma Xi^2 - (\Sigma Xi)^2/n$$

6. Indication of Material Marking to Part

Indicate the material marking to the parts which are made of the material covered by this standard, as given in Table 8.

Table 8

Material	Material code	Marking method
Polyacetal resin	TSM5515G-1A	>POM<
	TSM5515G-1B	
	TSM5515G-2A	
	TSM5515G-2B	
	TSM5515G-2C	

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Applicable Standards

TSM0501G	Standard Test Methods for Plastic Molding Materials
TSM0506G	Standard Test Methods for Plastic Molding Materials for Compliance with ISO
TSM0508G	Volatile Substance Measurement Method under Sampling Bag Method
TSM0509G	Test Method for Measuring Volatile Substances under Heat Desorption Method
TSZ0001G	Control Method for Substances of Environmental Concern
ISO 9988-2	Plastics -- Polyoxymethylene (POM) Moulding and Extrusion Materials -- Part 2: Preparation of Test Specimens and Determination of Properties
ISO 10350-1	Plastics -- Acquisition and Presentation of Comparable Single-Point Data -- Part 1: Moulding Materials

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