

Shrinkage

Contraction of Plastics Molded Part

The shrinkage of plastics signifies the volume contraction of polymers during the cooling step of the processing of polymers. This contraction is partly due to the difference of **density of polymers** from the melt state and the cooled, rigid state.

Most of the plastic molded part shrinkage occurs in the mold while cooling. A small amount of shrinkage occurs after ejection as the part continues to cool and after that the part may continue to shrink very slightly until the temperature and moisture content stabilize. In higher shrink materials such as **acetal** and **nylon**, the post-mold shrinkage can be significant.

If the regions of the part shrink unequally (called as warpage) stresses are created within the part which, depending on part stiffness, may cause the part to deform or change shape and hence leading to cracks in parts during long term use.

The shrinkage of molded plastic parts can be as much as 20% by volume, when measured at the processing temperature and the ambient temperature.

This volume contraction of polymers often leads to warped parts and dimension differences between manufactured parts and the mold (the die if we consider extrusion as the processing technique).

Shrinkage is a rate, so it is expressed in **percent, %**.

View All Commercially Available Shrinkage Polymer Grades in Omnexus Plastics Database

Check out more on shrinkage:

- » **Shrinkage Values of Several Plastics**
- » **Significance of Shrinkage in Applications**
- » **How to Calculate Shrinkage of Polymers?**
- » **Causes of Variation in Molded Parts or Shrinkage**

Applications include:

The amount of shrinkage needs to be accurately predicted. It is an important property to consider while designing plastic parts with:

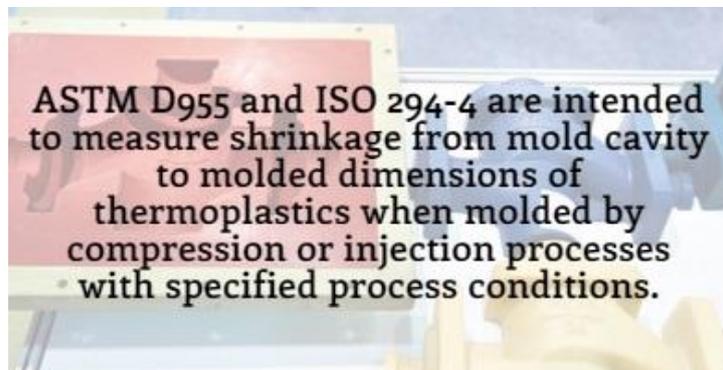
- Optimized dimensional stability.
- High tolerances to ensure finished and assembled products function properly

For example, critical dimensioning is important for a part that supports internal **electrical components** to make sure product's operation. If a plastic part carrying a circuit board changes size with age can cause one or more circuits on the board to crack, causing intermittent or complete failure.

Methods Used to Determine Shrinkage of Plastic Part

A standard method to measure “mold shrinkage”, i.e. contraction compared to the injection molding tool, is the **ASTM D955**. Other international standard methods related to plastic shrinkage are: **ISO 294-4** (for **thermoplastics**) and **ISO 2577** (for **thermosets**).

- ASTM D955 - Standard Test Method of Measuring Shrinkage from Mold Dimensions of Thermoplastics. This standard covers the measurement of specimen shrinkage for injection and compression molding.
- ISO 294-4 - Plastics — Injection Molding of Test Specimens of Thermoplastic Materials — Determination of Molding Shrinkage
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- ISO 2577 - Plastics — Thermosetting molding materials — Determination of shrinkage



(ofcourse there exist several other testing methods as well, but they are not discussed here).

Causes of Variation in Molded Parts or Shrinkage

The shrinkage rate is strongly depending on the polymer composition & material properties (PVT, thermal properties...), itself but also on the processing conditions (temperature, pressure, flow rate etc.) applied and part design & geometry (Wall thickness, gate location, mold constraints).

Let's discuss several factors in detail...

Polymer Composition

Semi-crystalline polymers (e.g. **Polybutylene terephthalate** or **Polypropylene**) always show a higher shrinkage than amorphous polymers (e.g. **PS, PC, PVC, ABS, PMMA**). This is because semi-crystalline polymers when cooled down, they see part of their macromolecular chains re-arranged to form crystallite that is a well-organized structure, leading to less space needed for the same number of atoms.

However, a slow rate of crystallization or a low degree of total crystallization has the effect of reducing shrinkage and thereby reducing warpage in semi-crystalline polymers.

It is also important to note that the presence of side chains in molecular structure inhibits the ability of molecule to fit into a developing crystal structure. Hence, these high degrees of chain entanglements in highly branched polymers also inhibit rapid crystallization.

Nucleated resin grades show higher amounts of shrinkage. This is same of copolymers and homopolymers as well.

Molecular Weight

Degree of shrinkage is also influenced by molecular weight. HMW resins show a higher viscosity on filling and a higher pressure drop in the tool cavity during filling. Higher packaging pressure must be used to compensate for the cavity pressure drop or else the lower pressure melt will result in higher shrinkage in the final part.

Fillers and Fibers

Fillers and fibers are generally added in plastics to modify properties such as **stiffness**, creep resistance etc. Filler systems and fiber reinforcements in composites result in different shrinkage from the virgin polymer. Most fillers and fibers have relatively low **coefficient of thermal expansion**, hence when part is cooled down during processing, these additives tend to shrink significantly. The reduction on shrink is approx. proportional to their concentration.

Fiber-filled materials such as polymers filled with long glass fibers shrink less along the direction in which fibers align (typically the **flow direction**) compared to the shrinkage in the **transverse direction**.

Recycled fiber-reinforced polymers exhibit different mold-shrinkage characteristics than those of virgin resin.

Pigments

Pigments, in general, lead to increase in shrinkage. They promote shrinkage by acting as a nucleating agent. The use of pigments tends to increase the cross-flow shrinkage in semi-crystalline polymers.

Presence of **pigments in polymers** can affect the crystallization and hence the mold shrinkage.

- Organic pigments provide crystalline nuclei from which crystals grow. Earlier initiation of crystallization and more rapid crystallization result in high amount of crystallinity in pigments resin as compared to neat polymer.
- Inorganic pigments cause the same type of shrinkage change to a less degree.

Time and Stress – Dimensional Stability

In plastics, the rate of dimensional change is determined by the stress level and the temperature at which the part is held under stress. At increasing times, the part under load will deform in response to the applied load.

Loss of fluids such as plasticizers loss due to migration or boil-off with time also causes shrinkage and increases brittleness.

Further excessive shrinkage beyond the acceptable level can be caused by:

- Low injection pressure
- Short pack-hold time or cooling time
- High melt temperature
- High mold temperature
- Low holding pressure

Shrinkage Values (%) of Various Plastics

Polymer Name	Min Value (%)	Max Value (%)
ABS - Acrylonitrile Butadiene Styrene	0.70	1.60
ABS Flame Retardant	0.30	0.80
ABS High Heat	0.40	0.90
ABS High Impact	0.40	0.90
ABS/PC Blend - Acrylonitrile Butadiene Styrene/Polycarbonate Blend	0.50	0.70
ABS/PC Blend 20% Glass Fiber	0.20	0.30
ABS/PC Flame Retardant	0.30	0.60
Amorphous TPI Blend, Ultra-high heat, Chemical Resistant (High Flow)	0.80	1.00
Amorphous TPI Blend, Ultra-high heat, Chemical Resistant (Standard Flow)	0.80	1.00
Amorphous TPI, High Heat, High Flow, Transparent, Lead-Free Solderable (High Flow)	1.00	1.20
Amorphous TPI, High Heat, High Flow, Transparent, Lead-Free Solderable (Standard Flow)	1.00	1.20
Amorphous TPI, Moderate Heat, Transparent	0.50	0.70

Amorphous TPI, Moderate Heat, Transparent (Food Contact Approved)	0.50	0.70
Amorphous TPI, Moderate Heat, Transparent (Mold Release grade)	0.50	0.70
Amorphous TPI, Moderate Heat, Transparent (Powder form)	0.50	0.70
ASA - Acrylonitrile Styrene Acrylate	0.40	0.70
ASA/PC Blend - Acrylonitrile Styrene Acrylate/Polycarbonate Blend	0.30	0.70
ASA/PC Flame Retardant	0.40	0.80
ASA/PVC Blend - Acrylonitrile Styrene Acrylate/Polyvinyl Chloride Blend	0.30	0.70
CA - Cellulose Acetate	0.30	1.00
CAB - Cellulose Acetate Butyrate	0.20	0.90
Cellulose Diacetate-Pearlescent Films	1.00	1.50
Cellulose Diacetate-Matt Film	1.00	1.50
CP - Cellulose Propionate	0.10	0.90
CPVC - Chlorinated Polyvinyl Chloride	0.30	0.70
ETFE - Ethylene Tetrafluoroethylene	3.00	4.00
EVA - Ethylene Vinyl Acetate	0.40	3.50
FEP - Fluorinated Ethylene Propylene	3.00	6.00
HDPE - High Density Polyethylene	1.50	4.00
HIPS - High Impact Polystyrene	0.20	0.80
HIPS Flame Retardant V0	0.30	0.60
LCP - Liquid Crystal Polymer	0.10	0.60
LCP Carbon Fiber-reinforced	0.10	0.50
LCP Glass Fiber-reinforced	0.10	0.40

LCP Mineral-filled	0.10	0.50
LDPE - Low Density Polyethylene	2.00	4.00
LLDPE - Linear Low Density Polyethylene	2.00	2.50
MABS - Transparent Acrylonitrile Butadiene Styrene	0.40	0.70
PA 11 - (Polyamide 11) 30% Glass fiber reinforced	0.50	0.50
PA 11, Conductive	0.70	2.00
PA 11, Flexible	1.40	1.80
PA 11, Rigid	0.70	2.00
PA 12 (Polyamide 12), Conductive	0.70	2.00
PA 12, Fiber-reinforced	0.70	2.00
PA 12, Flexible	0.70	2.00
PA 12, Glass Filled	0.70	2.00
PA 12, Rigid	0.70	2.00
PA 46 - Polyamide 46	1.50	2.00
PA 46, 30% Glass Fiber	0.30	1.30
PA 6 - Polyamide 6	0.50	1.50
PA 6-10 - Polyamide 6-10	1.00	1.30
PA 66 - Polyamide 6-6	0.70	3.00
PA 66, 30% Glass Fiber	0.50	0.50
PA 66, 30% Mineral filled	0.60	1.00
PA 66, Impact Modified, 15-30% Glass Fiber	0.20	0.60
PA 66, Impact Modified	1.20	3.00
PAI - Polyamide-Imide	0.60	1.00

PAI, 30% Glass Fiber	0.10	0.30
PAI, Low Friction	0.10	0.50
PAN - Polyacrylonitrile	0.20	0.50
PAR - Polyarylate	0.90	1.20
PARA (Polyarylamide), 30-60% glass fiber	0.10	0.40
PBT - Polybutylene Terephthalate	0.50	2.20
PBT, 30% Glass Fiber	0.20	1.00
PC (Polycarbonate) 20-40% Glass Fiber	0.10	0.50
PC (Polycarbonate) 20-40% Glass Fiber Flame Retardant	0.10	0.50
PC - Polycarbonate, high heat	0.70	1.00
PC/PBT Blend - Polycarbonate/Polybutylene Terephthalate Blend	0.60	1.10
PCTFE - Polymonochlorotrifluoroethylene	0.50	1.50
PE - Polyethylene 30% Glass Fiber	0.20	0.60
PEEK - Polyetheretherketone	1.20	1.50
PEEK 30% Carbon Fiber-reinforced	0.00	0.50
PEEK 30% Glass Fiber-reinforced	0.40	0.80
PEI - Polyetherimide	0.70	0.80
PEI, 30% Glass Fiber-reinforced	0.20	0.40
PEI, Mineral Filled	0.50	0.70
PEKK (Polyetherketoneketone), Low Cristallinity Grade	0.004	0.005
PESU - Polyethersulfone	0.60	0.70
PESU 10-30% glass fiber	0.20	0.30
PET - Polyethylene Terephthalate	0.20	3.00

PET, 30% Glass Fiber-reinforced	0.20	1.00
PET, 30/35% Glass Fiber-reinforced, Impact Modified	0.20	0.90
PETG - Polyethylene Terephthalate Glycol	0.20	1.00
PE-UHMW - Polyethylene -Ultra High Molecular Weight	4.00	4.00
PFA - Perfluoroalkoxy	3.00	5.00
PHB - Polyhydroxybutyrate	1.20	1.60
PI - Polyimide	0.20	1.20
PLA,injection molding	0.30	0.50
PMMA - Polymethylmethacrylate/Acrylic	0.20	0.80
PMMA (Acrylic) High Heat	0.20	0.80
PMMA (Acrylic) Impact Modified	0.20	0.80
PMP - Polymethylpentene	1.60	2.10
PMP 30% Glass Fiber-reinforced	0.30	1.20
PMP Mineral Filled	1.40	1.70
Polyamide 66 (Nylon 66)/Carbon Fiber, Long, 30 % Filler by Weight	0.30	0.30
Polyamide 66 (Nylon 66)/Carbon Fiber, Long, 40 % Filler by Weight	0.30	0.30
Polyamide 66 (Nylon 66)/Glass Fiber, Long, 40 % Filler by Weight	0.30	0.30
Polyamide 66 (Nylon 66)/Glass Fiber, Long, 50 % Filler by Weight	0.30	0.30
Polyamide 66 (Nylon 66)/Glass Fiber, Long, 60 % Filler by Weight	0.30	0.30
PP Homopolymer, Long Glass Fiber, 30% Filler by Weight	0.40	0.40

PP Homopolymer, Long Glass Fiber, 40% Filler by Weight	0.30	0.30
PP Homopolymer, Long Glass Fiber, 50% Filler by Weight	0.30	0.30
POM - Polyoxymethylene (Acetal)	1.80	2.50
POM (Acetal) Impact Modified	1.00	2.50
POM (Acetal) Low Friction	1.80	3.00
POM (Acetal) Mineral Filled	1.50	2.00
PP - Polypropylene 10-20% Glass Fiber	0.30	1.00
PP, 10-40% Mineral Filled	0.60	1.40
PP, 10-40% Talc Filled	0.90	1.40
PP, 30-40% Glass Fiber-reinforced	0.01	1.00
PP (Polypropylene) Copolymer	2.00	3.00
PP (Polypropylene) Homopolymer	1.00	3.00
PP, Impact Modified	2.00	3.00
PPA - Polyphthalamide	1.50	2.20
PPA – 30% Mineral	1.00	1.20
PPA, 33% Glass Fiber-reinforced	0.50	0.70
PPA, 33% Glass Fiber-reinforced – High Flow	0.74	0.76
PPA, 45% Glass Fiber-reinforced	0.10	0.30
PPE - Polyphenylene Ether	0.50	0.80
PPE, 30% Glass Fiber-reinforced	0.10	0.40
PPE, Flame Retardant	0.60	1.00
PPE, Impact Modified	0.60	1.00
PPE, Mineral Filled	0.30	0.70

PPS - Polyphenylene Sulfide	0.60	1.40
PPS, 20-30% Glass Fiber-reinforced	0.20	0.50
PPS, 40% Glass Fiber-reinforced	0.20	0.50
PPS, Conductive	0.30	1.00
PPS, Glass fiber & Mineral-filled	0.30	0.70
PPSU - Polyphenylene Sulfone	0.70	0.70
PS (Polystyrene) 30% glass fiber	0.20	0.20
PS (Polystyrene) Crystal	0.10	0.70
PS, High Heat	0.20	0.70
PSU - Polysulfone	0.70	0.70
PSU, 30% Glass fiber-reinforced	0.10	0.60
PSU Mineral Filled	0.40	0.50
PTFE - Polytetrafluoroethylene	3.00	6.00
PTFE, 25% Glass Fiber-reinforced	1.80	2.00
PVC (Polyvinyl Chloride), 20% Glass Fiber-reinforced	0.10	0.20
PVC, Plasticized	0.20	4.00
PVC, Plasticized Filled	0.80	5.00
PVC Rigid	0.10	0.60
PVDC - Polyvinylidene Chloride	0.50	2.50
PVDF - Polyvinylidene Fluoride	2.00	4.00
SAN - Styrene Acrylonitrile	0.30	0.70
SAN, 20% Glass Fiber-reinforced	0.10	0.30
SMA - Styrene Maleic Anhydride	0.40	0.80
SMA, 20% Glass Fiber-reinforced	0.20	0.30
SMA, Flame Retardant V0	0.50	0.50

TPS, Injection General Purpose	0.60	1.50
TPS, Water Resistant	0.60	0.90
XLPE - Crosslinked Polyethylene	0.70	5.00