TECHNICAL NOTE

SUMITOMO CHEMICAL

Ultra-High Heat Resistant Engineering Plastics

SUMIKAEXCEL™ PES

Polyethersulfone

3. Injection Molding

High heat Resistant Amorphous Polymer

Version 04 / Nov. 2023

SUMITOMO CHEMICAL Co., Ltd. Advanced Polymers Division

4. Injection Molding

4-1 Injection Molding Conditions

Molding Conditions

The standard molding conditions for SUMIKAEXCEL PES and SUMIPLOY are shown below.

Table 4-1-1 Standard Molding Conditions for SUMIKAEXCEL PES

Grade		3600G 4100G		4800G		3601GL20 / 3601GL30 4101GL20 / 4101GL30 ES5340	
		Recommended	Range	Recommended	Range	Recommended	Range
Drying temperature (°C)		160-180		160-180		160-180	
Drying time (hr)		5-24		5-24		5-24	
Cylinder temperature (°C)	Rear	320	300-340	320	320-340	320	300-340
	Center	340	320-370	340	330-370	340	320-370
	Front	350	330-380	360	340-390	350	330-380
	Nozzle	350	330-380	360	340-390	350	330-380
Suitable resin temperature (°C)		350	350-360	360	350-370	350	350-360
Tool (Mold) temperature (°C)		140-180	120-180	140-180	120-180	140-180	120-180
Injection pressure (MPa)		100-200	100-200	100-200	100-200	100-200	100-200
Injection speed		Low speed	Low to medium speeds	Low speed	Low to medium speeds	Low speed	Low to medium speeds
Screw rotation (rpm)		50-100	50-100	50-100	50-100	50-100	50-100
Back pressure (MPa)		5-10	5-10	5-10	5-20	5-10	5-10
Holding pressure (MPa)		50-100	50-100	50-100	50-150	50-100	50-100

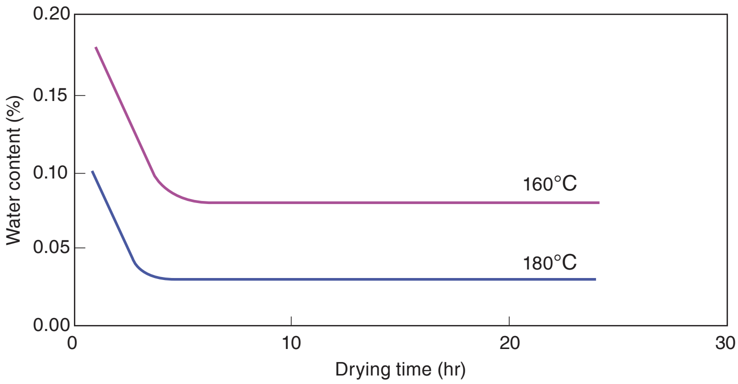
Table 4-1-2 Standard Molding Conditions for SUMIPLOY

Grade		GS5620 CS5220 / CS5530 / CS5600		E3010 FS2200		CK3400 / CK3420 CK4600	
		Recommended	Range	Recommended	Range	Recommended	Range
Drying temperature (°C)		160	160-180	160	160-180	160	160-180
Drying time (hr)		8	5-24	8	5-24	5	5-24
Cylinder temperature (°C)	Rear	320	320-340	320	300-340	380	360-400
	Center	340	330-370	340	320-370	390	370-410
	Front	360	340-390	350	330-380	390	380-420
	Nozzle	360	340-390	350	330-380	400	380-420
Suitable resin temperature (°C)		360	340-390	350	350-360	400	380-420
Tool (Mold) temperature (°C)		140-180	120-180	140-180	120-180	180	120-180
Injection pressure (MPa)		100-200	100-200	100-200	100-200	100-200	100-200
Injection speed		Low speed	Low to medium speeds	Low speed	Low to medium speeds	Low speed	Low to medium speeds
Screw rotation (rpm)		50-100	50-100	50-100	50-100	50-100	50-100
Back pressure (MPa)		5-10	5-10	5-10	5-10	5-10	5-10
Holding pressure (MPa)		100-200	50-200	50-100	50-150	100-200	50-200

Pre-drying

As SUMIKAEXCEL PES is susceptible to water absorption, it must be dried thoroughly prior to usage. PES resin should be dried at temperatures ranging from 160 to 180°C for 5 to 24 hours, using a hot air circulation oven or a dehumidifying dryer. When drying using oven trays, PES resin should be spread on the trays to a thickness of 50mm or less. In particular, for molding large sized moldings, it is recommended that PES resin is dried at a temperature of 180°C.
In addition, the use of a dehumidifying dryer is recommended for non-reinforced grades and for large sized moldings. If a hopper dryer is used, it is important to ensure that it has both adequate resin capacity and large heat capacity. If pre-drying is sufficient, then silver streaking or flashing may appear on the surface of the molding. If this kind of phenomena occurs, then further drying of the resin is necessary.
As SUMIKAEXCEL PES is not susceptible to hydrolysis, it will not deteriorate during the drying process, if dried in accordance with the abovementioned conditions.

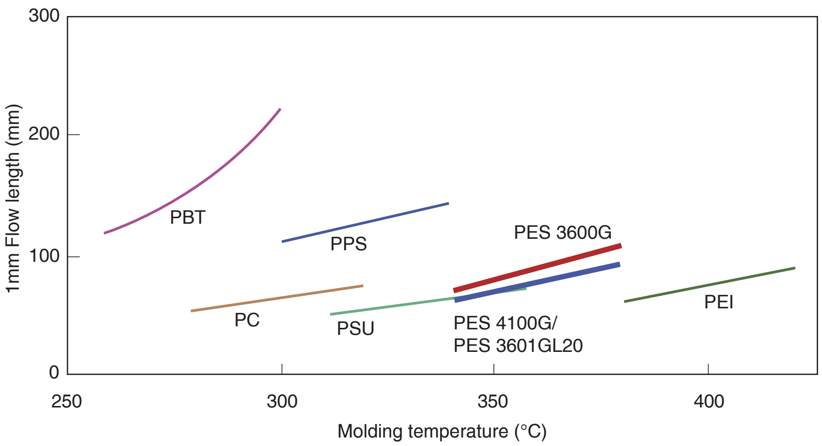
Figure 4-1-1 Drying Curve of 4100G



Resin Temperature

A resin temperature of 330 to 380°C is recommended. As SUMIKAEXCEL PES possesses high melt viscosity, the resin temperature tends to increase to a value higher than the cylinder temperature setting due to shear heat generation, and this may result in a temperature difference of more than 40°C. The resin temperature must be carefully monitored while molding operations are performed.

Figure 4-1-2 Flow length of PES (1mm)



Resin Residence Time

The length of time that it stays in the cylinder has a major impact on injection molding product quality. The residence time should be no longer than 10 minutes. The longer the residence time, the greater the possibility of thermal deterioration resulting in discoloration, black streaks, or black spots on molded parts.

Mold Temperature

The mold temperature should be set in a manner such that the surface temperature will be between 120 to 180°C. Also, ensure that the surface of the mold has a uniform temperature distribution.
If the mold temperature is excessively low, moldings may warp or crack (rupture) due to residual stresses. Residual stresses may also cause glass fibers to be visible on the surface of moldings for glass fiber grades. Moldings having low residual stresses can be obtained by using a high mold temperature. However, if the tool temperature is excessively high, deformation may occur during mold release.
With respect to the methods used for mold heating, both heaters and oil temperature control are recommended. However, for the following molds, oil temperature control should be implemented in order to ensure the most uniform mold temperature distribution: molds that have complex shapes; deep molds; and molds that have slide cores.
In particular, when molding large sized products and when using non-reinforced grades, additional precautions must be taken to ensure that proper mold temperatures are maintained.

Injection Pressure and Holding Pressure

In general, the injection molding of SUMIKAEXCEL PES requires high injection pressure of 100 to 200MPa. Over 150MPa of injection pressure is required for the molding of thin-walled products, for the molding with glass fiber reinforced grades, and for the molding of products with large flow length.
It is recommended that the holding pressure is set to 1/2 to 1/3 of the injection peak pressure, and it should be set as low as possible at the level that does not cause sink marks. The lower the holding pressures, the less residual stress there will be on the molded products.
The higher the peak pressure and holding pressure, the more difficult it is to release from the mold. Therefore, adjust the V-P switching position so that the peak pressure does not increase too much.

Injection speed

In general, SUMIKAEXCEL PES should be molded at low to medium injection speeds. However, the optimum injection speed will vary depending on the shape of the products.
As SUMIKAEXCEL PES has high melt viscosity, an excessively high injection speed will result in burning and silver streaking, due to the heat generated by shear and adiabatic air compression. However, high injection speeds are required for the molding of both thin-walled products (1mmt or less) and products with large flow length. In general, lower injection speeds result in products that have less residual stress.

Screw Rotation Speed and Back Pressure

It is recommended that screw rotation speed is between 50 to 100rpm in order to prevent increases in resin temperature due to shear heat generation.
The appropriate back pressure allows for consistent melting of resin. The recommended back pressure is 5 to 10MPa. When molding PES grades that have high molecular weights, ensure that a greater back pressure is applied. However, if back pressure is too high, problems such as resin overheating and overloading may occur.

Temporary Suspension of Molding

Whenever the molding process is suspended for a short period of time, set the cylinder temperature to 250 to 260°C, in order to prevent thermal deterioration of the resin. If the resin temperature decreases to less than 250°C, the screw surfaces and internal walls of the cylinder may be damaged and foreign objects may be caused after the molding process has resumed. When the molding process is to be suspended for a long period of time, reduce the cylinder temperature only after the inside of the cylinder has been purged with purging materials.

Purging Method

Recommended purging materials are as follows : polyethylene that has a high molecular weight of approximately MFR 0.05 ; polycarbonate ; or more preferably, the same materials containing glass fiber.

- As SUMIKAEXCEL PES requires high processing temperatures, smoke, gas emission, and resin blown-off may occur during the purging process.
- Ensure that none of the purging material is left within the cylinder.

Table 4-1-3 Recommended Purging Procedure (When Switching to SUMIKAEXCEL PES)

Item		Recommended Conditions/Procedures
Setup	Back pressure	High (Ensure that the screw retracts slowly.)
	Screw rotation speed	Set the same rotation speed as for when molding the prior resin.
Purging	1. Prior resin discharge	Discharge as much of the prior resin from the hopper and cylinder as possible.
	2. Purging material input	Input purging material while maintaining the prior resin molding temperature, and perform sufficient purging. When using a glass fiber reinforced purging material replace it with a non-reinforced purging material before replacing it with PES so that no glass fibers remain.
	3. Temperature change	Change to the PES molding temperature while continuing to input purging material.
	4. Purging material discharge and PES input	Discharge the purging material thoroughly after reaching the moldingtemperature of PES, and then input the PES.
	5. Molding	After purging with PES, it is possible to perform molding once the cylinder temperature becomes stable.

Checking of Residual Stress

SUMIKAEXCEL PES molded products may suffer from defects such as cracking or breakage during mold release, due to the effects of residual stress.
The following method can be used to check the residual stress of SUMIKAEXCEL PES molded products. This method can also be used for determining optimum molding conditions.

● Test method
1. Allow the molded products to cool to room temperature
2. Immerse the molded products in xylene for 90 seconds
3. Clean it them in cold water
4. Check the molded products carefully for cracks.
5. If there are no cracks, perform the same test in toluene. Thereafter, perform the test in the same manner, changing the solvent to ethyl acetate, then methyl ethyl ketone, in that order.
6. The kind of solvent that caused the cracks can be used to estimate the magnitude of the residual stress in the molded product. (see "Table 4-1-4")

Table 4-1-4 Residual Stress Checking Method for SUMIKAEXCEL PES (4100G)

Solvent	Residual strain	Residual stress
Cracks occurred in xylene	1.3-1.5% or more	30-40MPa or more
Cracks occurred in toluene	1.0% or more	27MPa or more
Cracks occurred in ethyl acetate	0.50% or more	14MPa or more
Cracks occurred in methyl ethyl ketone	0.35% or more	10MPa or more

4-2 Moldability

Flowability

Flowability of SUMIKAEXCEL PES improves greatly as the cylinder temperature, injection pressure, and wall thickness of molded products increase. However, mold temperature does not have a major impact. If mold release failure, glass fiber floating or weld cracking occurs, it is recommended to increase the mold temperature to 160°C or higher.

Apparent Melt Viscosity

The apparent melt viscosity of SUMIKAEXCEL PES is as follows.

Figure 4-2-1 Temperature Dependence of Apparent Melt Viscosity

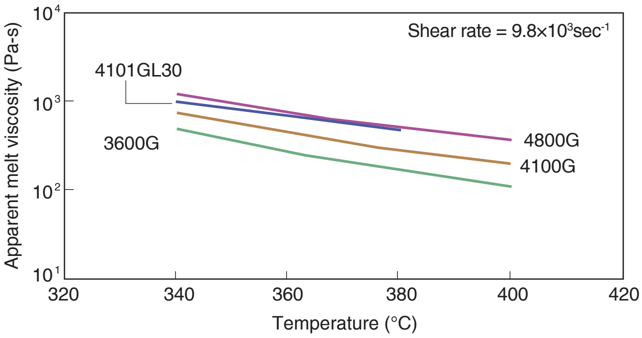
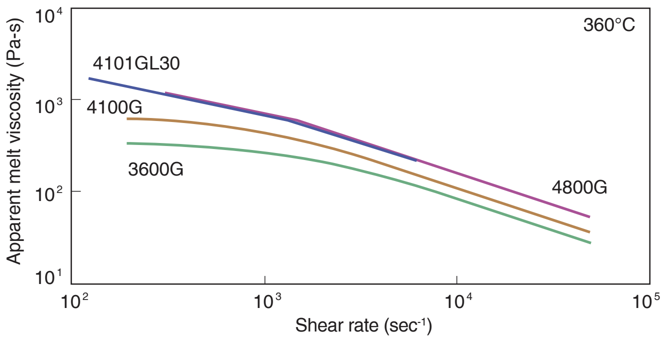


Figure 4-2-2 Shear Rate Dependence of Apparent Melt Viscosity



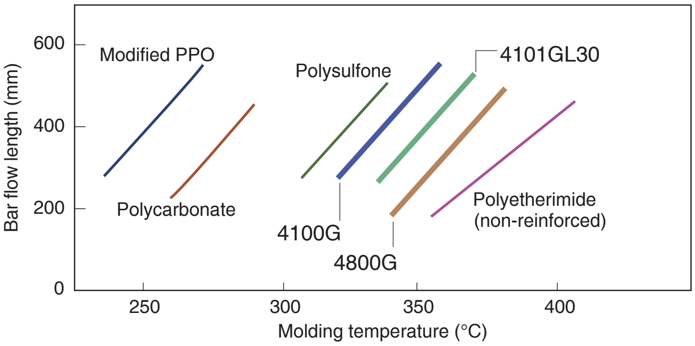
Molding of Relatively Thick-Walled Products

This section focuses on the flow characteristics at a wall thickness of 3mm.

Effect of Cylinder Temperature

When the cylinder temperature increases, the melt viscosity of the resin decreases and the flowability improves. The bar flow length improves by 30 to 60% when it is set 20°C higher.

Figure 4-2-3 Temperature Dependence of Bar Flow Length

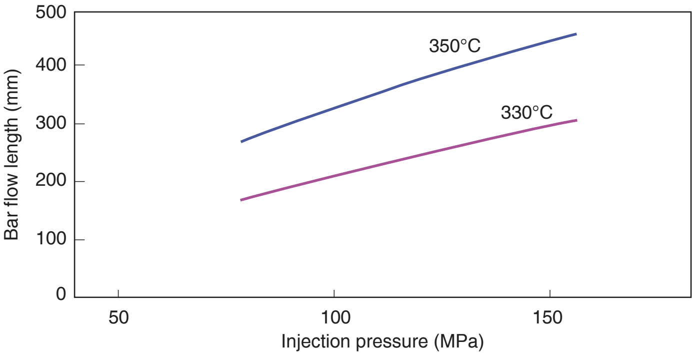


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : medium
Mold : 3mm x 8mmw
Mold temperature : 120°C

Effect of Injection Pressure

The bar flow length improves by 10 to 20% when the injection pressure is set 20 MPa higher. High-pressure molding is generally recommended, but carefully check for mold release defects and residual stress due to overpacking. Select appropriate conditions by setting the secondary pressure.

Figure 4-2-4 Dependence of Bar Flow Length on Injection Pressure (4100G)

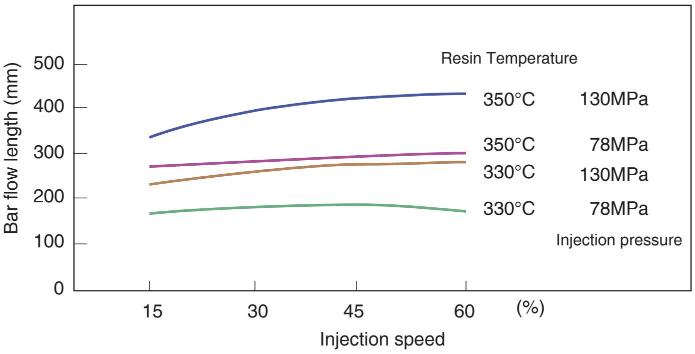


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection speed : medium to high
Resin temperature : 330°C, 350°C
Mold : 3mm x 8mmw
Mold temperature : 120°C

Effect of Injection Speed

Injection speed does not have a significant effect on the bar flow length.

Figure 4-2-5 Dependence of Bar Flow Length on Injection Speed (4100G)

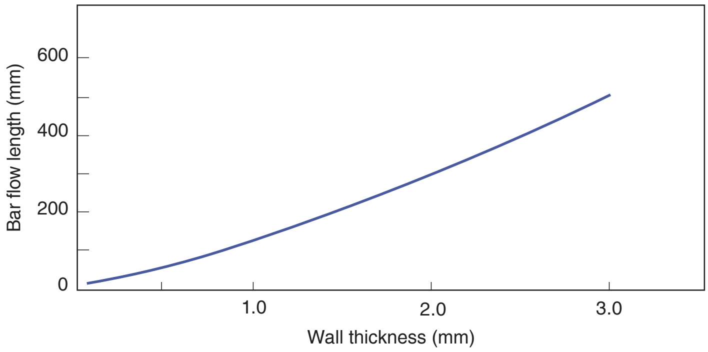


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Mold : 3mm x 8mmw
Mold temperature : 120°C

Effect of Product Wall Thickness

Flow length increases sharply with wall thickness. When the wall thickness is 1.5mm or higher, flowability can be improved 40 to 70% by increasing the wall thickness by 0.5mm.

Figure 4-2-6 Effect of Wall Thickness on Bar Flow Length (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 60%
Resin temperature : 360°C
Mold : 8mmw bar flow
Mold temperature : 120°C

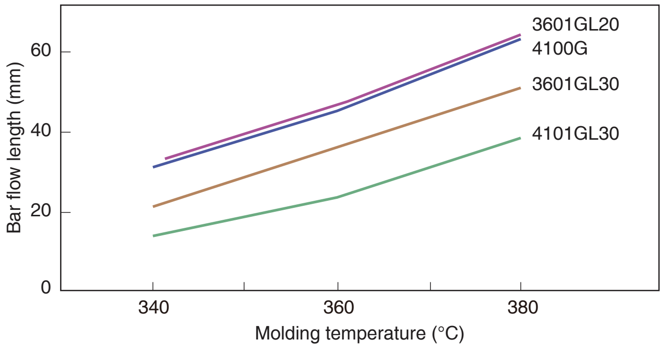
Molding of Thin-Walled Products

This section describes the flow characteristics at wall thickness of 0.1 to 0.7mm.

Effect of Cylinder Temperature

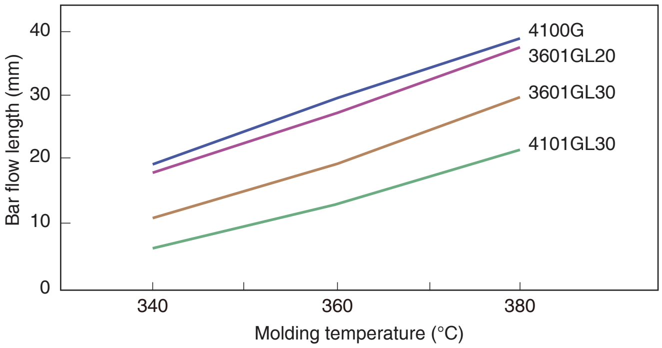
Flowability improves as the cylinder temperature increases, but this effect decreases when the wall thickness is 0.3mm or less. Considering the effects of thermal degradation, a temperature of up to about 380°C is suitable.

Figure 4-2-7 Cylinder Temperature Dependence (Thickness: 0.7mm)



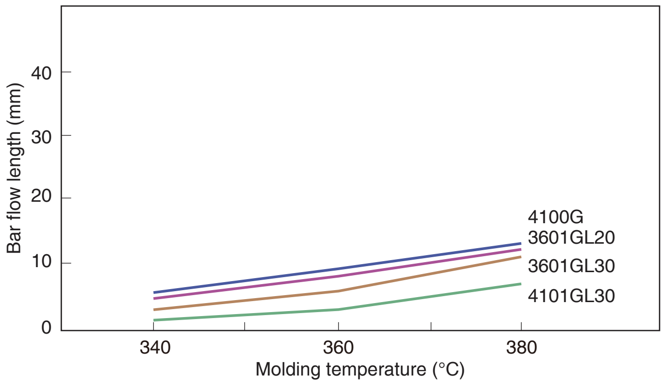
Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Mold : 0.7mmx8mmw
Mold temperature : 140°C

Figure 4-2-8 Cylinder Temperature Dependence (Thickness: 0.5mm)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Mold : 0.5mmx8mmw
Mold temperature : 140°C

Figure 4-2-9 Cylinder Temperature Dependence (Thickness: 0.3mm)

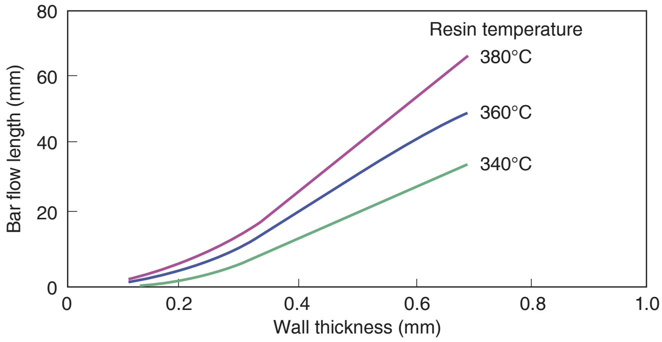


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Mold : 0.3mmx8mmw
Mold temperature : 140°C

Effect of Product Wall Thickness

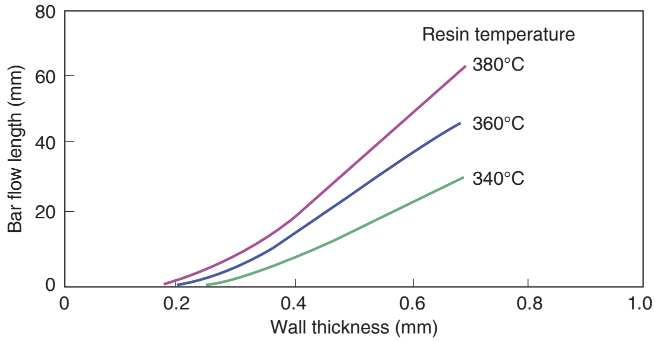
The flowability depends on the wall thickness, so please pay attention to this when designing your product.

Figure 4-2-10 Wall Thickness Dependence (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Bar flow width : 8mm
Mold temperature : 140°C

Figure 4-2-11 Wall Thickness Dependence (3601GL20)

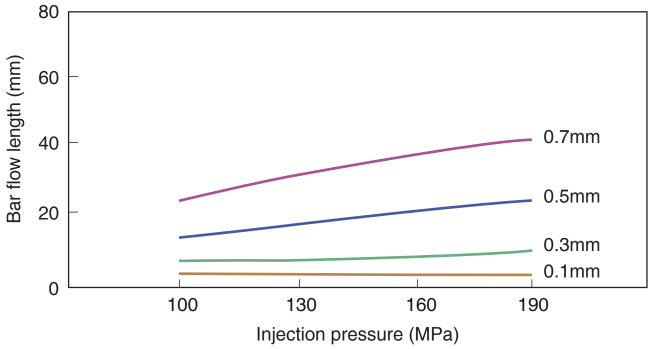


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Bar flow width : 8mm
Mold temperature : 140°C

Effect of Injection Pressure

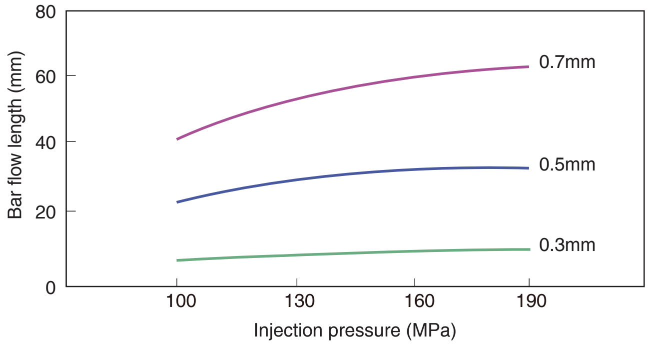
Thin-wall flowability tends to be greatly affected by injection pressure. Injection pressure of at least 100MPa is recommended. However, it is required to determine the proper injection pressure by taking product appearance and residual stress into consideration.

Figure 4-2-12 Injection Pressure Dependence (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection speed : 75%
Resin temperature : 340°C
Bar flow width : 8mm
Mold temperature : 140°C

Figure 4-2-13 Injection Pressure Dependence (3601GL20)

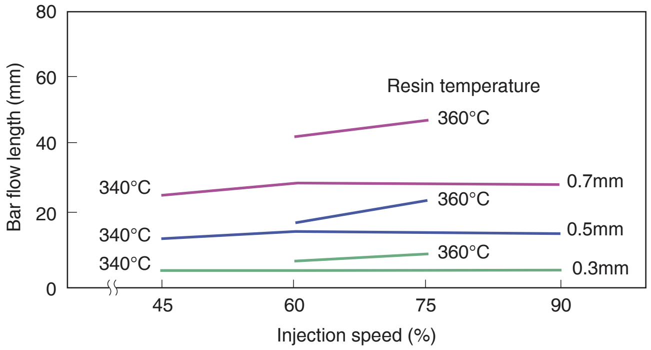


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection speed : 75%
Resin temperature : 340°C
Bar flow width : 8mm
Mold temperature : 140°C

Effect of Injection Speed

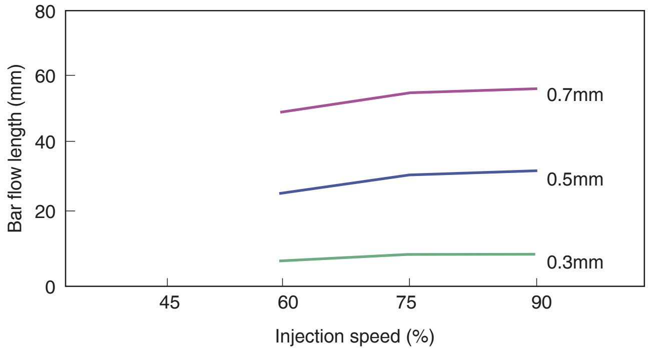
Thin-wall flowability is not affected by injection speed so much. If the injection speed is too high, it may cause defects such as burns.

Figure 4-2-14 Injection Speed Dependence (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Bar flow width : 8mm
Mold temperature : 140°C

Figure 4-2-15 Injection Speed Dependence (3601GL20)

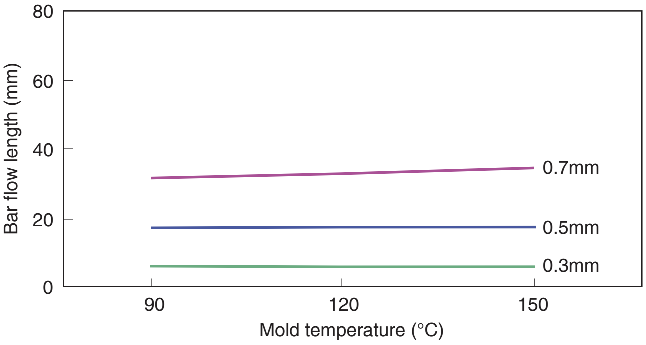


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Resin temperature : 360°C
Bar flow width : 8mm
Mold temperature : 140°C

Effect of Mold Temperature

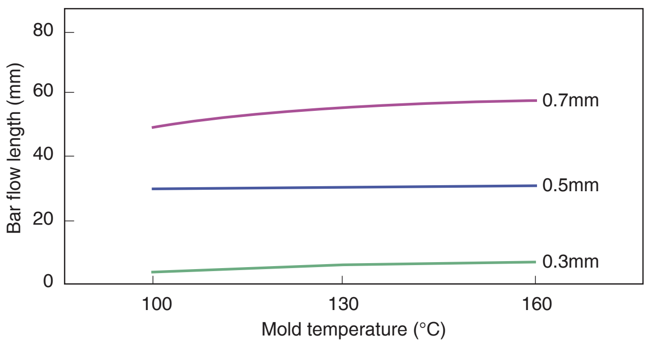
Thin-wall flowability is not affected by mold temperature so much. However, it is recommended to raise the mold temperature to at least 160°C if problems such as sticking in the mold, poor surface appearance, or low weld strength occur.

Figure 4-2-16 Mold Temperature Dependence (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Resin temperature : 340°C
Bar flow width : 8mm

Figure 4-2-17 Mold Temperature Dependence (3601GL20)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Resin temperature : 340°C
Bar flow width : 8mm

4-3 Injection Molding Machine and Mold Design

Selection of Injection Molding Machine

SUMIKAEXCEL PES can be molded using standard in-line type injection molding machines and plunger (preplasticating) type injection molding machines.

Screw and Cylinder

- Since the filler reinforced grades of SUMIKAEXCEL PES are filled with glass fiber, etc., it is recommended to use wear-resistant materials for screws and cylinders.
- A standard full flight type screw is good for SUMIKAEXCEL PES. Sub-flight screws and high mixing screws are not recommended because the residence time in the cylinder may become longer, or the resin temperature may rise above 400°C due to shear heating.

- A typical screw design suitable for SUMIKAEXCEL PES is as follows.
  - L/D (screw length [L]/screw diameter [D]) : approx. 20
  - Compression ratio : around 2 to 2.2
  - Ratio of each zone :
    Feed zone : around 55%
    Compression zone : around 25%
    Metering zone : around 20%
- Screw heads for in-line type injection molding machines are recommended to be equipped with backflow prevention mechanism.

Nozzle

- For the material of the nozzle, the same as those in "Screw and Cylinder" can be used.
- Use of the open type nozzle is suitable. Shut-off nozzles are not preferable because they have a lot of dead space and resin tends to retain in it.
- For the nozzle heater, it is recommended to use an independent temperature controller with PID control.

Injection Unit and Its Control System

- Due to the high melt viscosity of SUMIKAEXCEL PES, it is recommended that injection molding machines with a maximum injection pressure of 200MPa or higher be used.
- Screw rotation torque during metering tends to be large also due to high melt viscosity, so it is recommended that injection molding machines with high power plasticizing units be used.

Injection Capacity

- It is recommended to select a molding machine whose shot size is about 1/3 to 3/4 of its maximum injection capacity. If the shot size is too small, the residence time of resin in the high temperature cylinder will be longer, and various molding defects are more likely to occur.

Mold Design

As PES has high melt viscosity and low mold shrinkage, the following factors must be taken into account when designing molds.

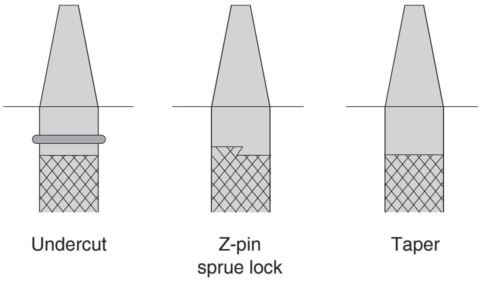
Mold Materials

- Molds used for making prototypes and for small production lots can be composed of carbon alloy steel for machine structural use (S55C). However, these molds should be hardened by quenching if they are to incorporate sliding core parts.
- When mass production and high dimensional precision are required, it is recommended that steels having greater rigidity be used, such as chrome molybdenum steels (SCM435 and SCM440) or alloy tool steels (SKD11 and SKD61).
- Before using a material other than the above, carefully consider whether there are any problems. (Cu alloys, etc., are not recommended as mold materials.)

Sprue

- The length of the sprue should be designed as short as possible, and it is recommended that the taper angle be enlarged (up to 5°).
- A sprue lock should be installed in order to secure better sprue release, as shown in Figure 4-3-1.

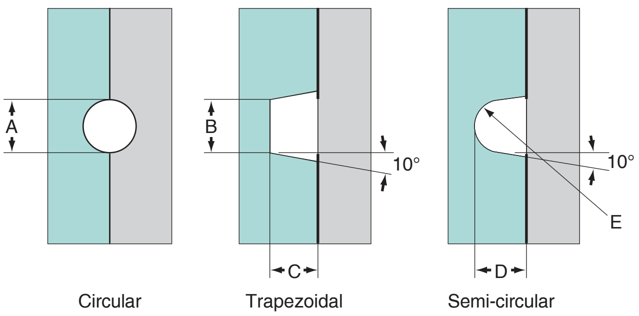
Figure 4-3-1 Sprue Diagram



Runner

- Runners are preferred as thick and short as possible. The thickness and length should be determined with consideration of resin flowability.
- Runners should have a circular or trapezoidal cross-sectional shape.
- Considering the gate balance is also important.

Figure 4-3-2 Runner Cross-Sectional Diagram



Examples of Runner Cross-sectional Sizes (mm)

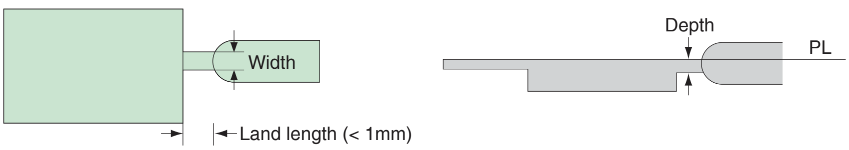
A	B	C	D	E
>4	>3	>3	>4	D/2

Gate system

Side gate

- For rectangular gates, it is most efficient to use deep lands with short lengths. The appropriate land length is 1mm or less, and the land gate depth should be about 70% of the wall thickness of the molded products.

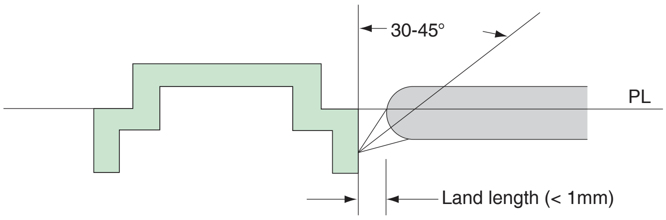
Figure 4-3-3 Side Gate Diagram



Pinpoint/Submarine Gate

- The gate diameter should be between 0.8 to 1.2mm, with land lengths of 1mm or less. If flow length are long, it is preferable to have multi gates rather than to enlarg the gate diameter.

Figure 4-3-4 Pinpoint/Submarine Gate Diagram

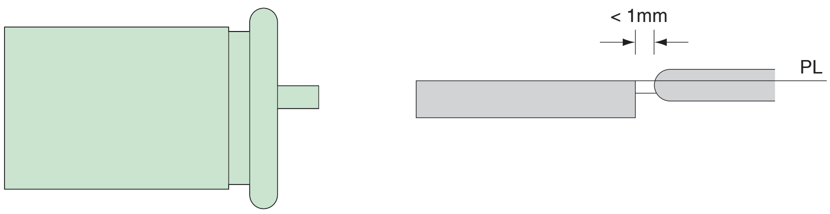


(Example of submarine gate)

Film gate

- The preferred gate depth should be equivalent to "the wall thickness of the moldeding products x 0.5". The land length should be 1mm or less.

Figure 4-3-5 Film Gate Diagram



Draft Angle

- As PES has low mold shrinkage, draft angle should be in the range of at least 1° (1/60) to 2° (1/30). For deeper cavities, a larger draft angle would be recommended.
- As thin-walled products tend to be overfilled, a larger draft angle is recommended.
- Larger draft angles are also recommended for glass fiber reinforced grades.
- If adequate draft angles cannot be utilized due to the shape of the molded products, it may be necessary to install slide cores or devise some good ejection methods.

Air Venting (Gas Drainage)

- The recommended depth for air vents ranges from 0.01 to 0.05mm. SUMIKAEXCEL PES has high melt viscosity, so flash defects will not easily occur even when 0.05mm air vents have been installed.
- Air vents must be installed for the molding of thin-walled products.

4-4 Use of Recycled PES

When mixing recycled PES (re-pelletized or regrind) with virgin pellets, it is necessary to adjust the mixing ratio according to the grade and application. Table 4-4-1 shows the recommended mixing ratios of recycled PES for each grade.

Table 4-4-1 Recommended Mixing Ratios of Recycled PES

Grade	Ratio of recycled PES (%)
4100G / 4800G	30 or less
3601GL20 / 4101GL20	20 or less
3601GL30 / 4101GL30	10 or less

Non-reinforced grades may darken the color of the molded products and become brittle if too much recycled PES are used. For glass fiber reinforced grades, the amount of recycled PES that can be added is limited to smaller quantities because the glass fibers shorten during re-pelletizing or regrinding, which result in a loss of mechanical strength. Table 4-4-2 shows the impacts on mechanical properties when recycled PES is used for SUMIKAEXCEL PES.

Table 4-4-2 Impacts of Using Recycled PES against SUMIKAEXCEL PES on Tensile Properties

Grade		4100G / 4800G				3601GL20 / 4101GL20	
Ratio of recycled PES (%)		30		100		30	100
Property		Tensile strength (MPa)	Mode of break	Tensile strength (MPa)	Mode of break	Tensile strength (MPa)	Tensile strength (MPa)
Number of recycling times	Virgin	86	Ductile	86	Ductile	126	126
	1	87	Ductile	87	Ductile	126	121
	2	89	Ductile	87	Ductile	125	116
	3	88	Ductile	87	Ductile	126	109
	4	88	Ductile	88	Ductile	124	102
	5	89	Ductile	87	Ductile	122	98

TECHNICAL NOTE

Ultra-High Heat Resistant Engineering Plastics

SUMIKAEXCEL™ PES

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