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1. Injection molding machine

As for the injection molding machine, several types such as plunger type, plunger preplasticating type, screw preplasticating type and in-line screw type, etc. have been developed so far, but presently the in-line screw type injection molding machine as shown in Figure 1・ 1-1 has become the main type.

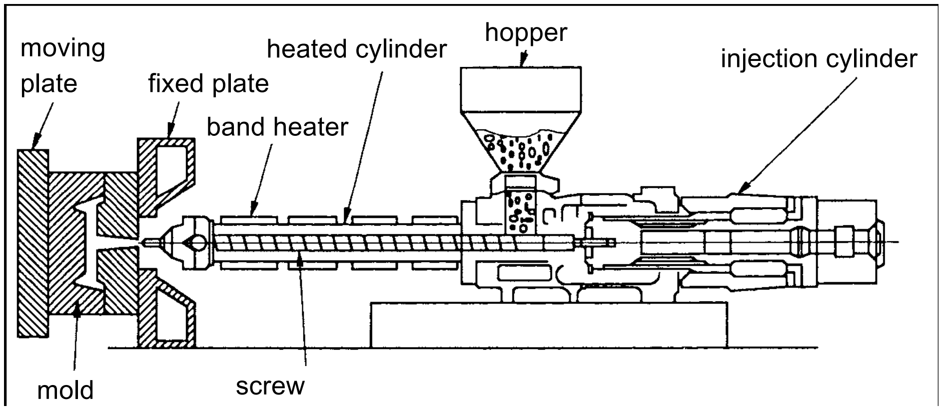


Figure 1・1－1 Theory of the in-line screw type injection molding machine

The injection molding machine consists of the injection unit and the clamping unit, and their features are described below.

1・1 Injection unit

1）Injection capacity

The proper injection capacity is found from the relationship of the molding machine capacity for the weight of 1 shot as shown in Figure 1・1-2. It is necessary to select the molding machine that satisfies the capacity of the shaded area. This figure is the summary of the actual molding results in the past, but basically, it is based on the following idea.

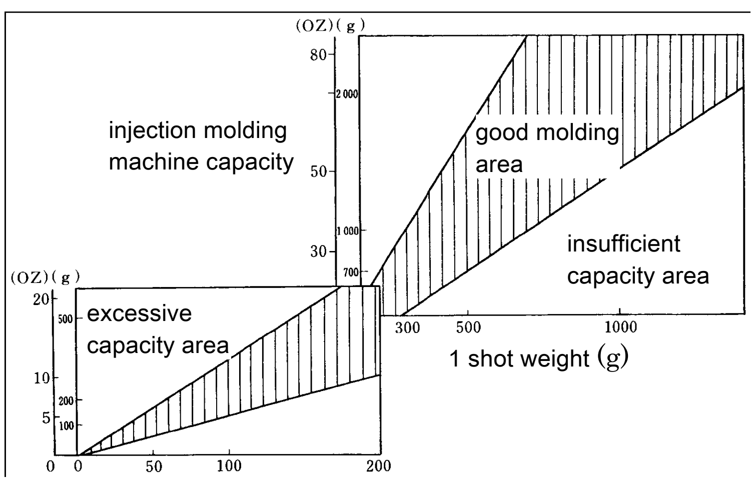


Fig. 1・1-2 Selection of molding machine from the injection capacity

At the side where the capacity is small, plasticizing time and injection time become long, and it is used at the narrow capacity of the molding machine. That is, the filling shortage is caused due to the extension of molding cycle and slow filling rate.

On the other hand, at the side where the capacity is large, dwell time of the resin inside the cylinder becomes long, and the resin thermally decomposes. The capacity range in the figure is indicated rather widely, but when it is easy to be thermally decomposed with materials containing lots of pigments and additives, it is better to conduct the molding at shot weight of 70 ~ 80% of the injection capacity.

2) Barrel

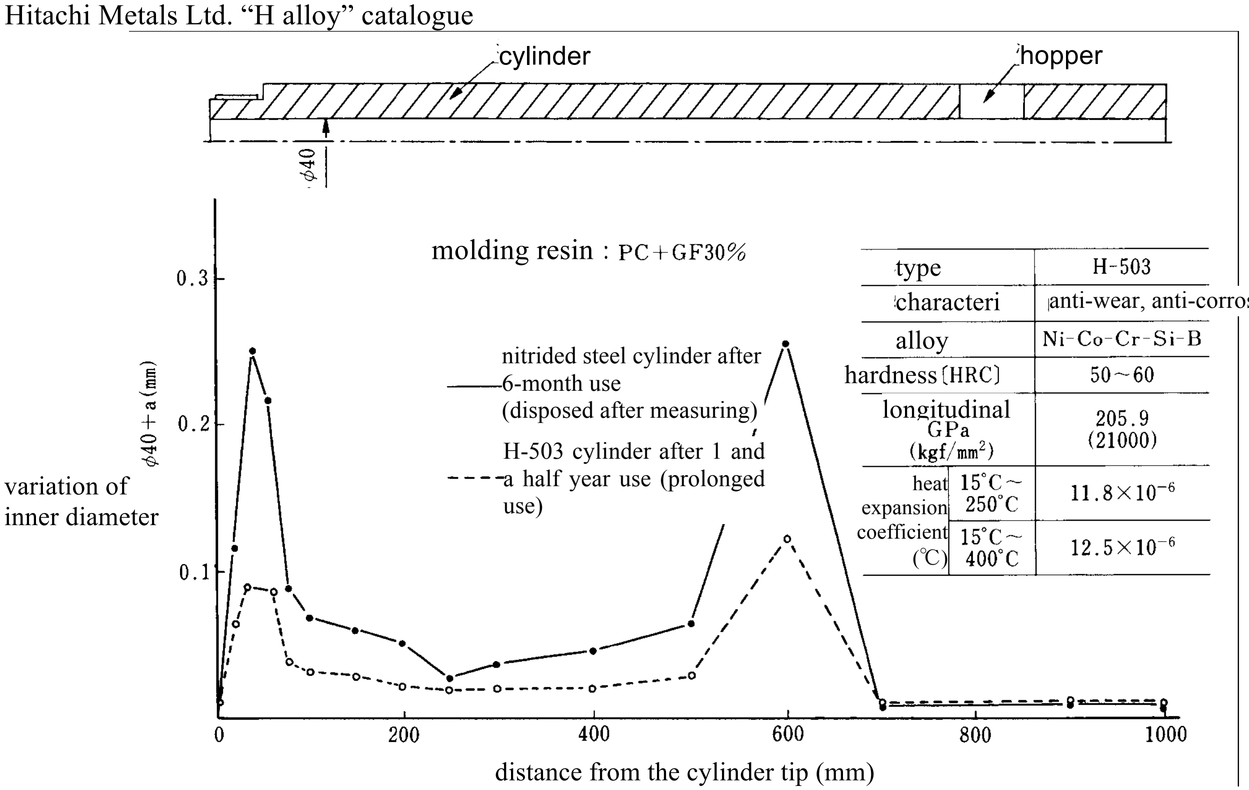
Generally, using the material (for example, nitride steel etc.) for the molding of Iupilon / NOVAREX is good. However, concerning the molding of glass fiber reinforced grade (Iupilon GS etc.) and optical grade (Iupilon H-400 etc.), it is good to consider the following for the barrel material.

As for glass fiber reinforced PC, it is good to use the bimetal (double-structure cylinder covered the inside with another metal and centrifugal casting) to prevent the barrel abrasion. For example, the H alloy (Hitachi Metals Ltd.), N alloy (Japan Steel Works Ltd.), K alloy (Kobe Steel Ltd.) etc. are well known.

Figure 1・1-3 indicates the abrasion data when molding glass fiber (30%) PC in case of using the H alloy barrel. The abrasion of the metering section vicinity where the feed section and the backflow prevention ring contact with is improved [1].

In addition, the bimetal cylinder such as H alloy is also effective in suppressing the generation of the burn of Iupilon / NOVAREX although the burn mark and black specks due to thermal decomposition become problems in the transparent use.

[1] Hitachi Metals Ltd. "H alloy" catalogue



type		H-503
characteri		anti-wear, anti-corrosion
alloy		Ni-Co-Cr-Si-B
hardness (HRC)		50~60
longitudinal GPa (kgf/mm^2)		205.9 (21000)
heat expansion coefficient (℃)	15°C~250°C	11.8×10^{-6}
	15°C~400°C	12.5×10^{-6}

Fig. 1・1-3 Barrel material and abrasion data when using GF (30%) PC

3) Screw

The 3-stage type screw of the single flight is usually used.

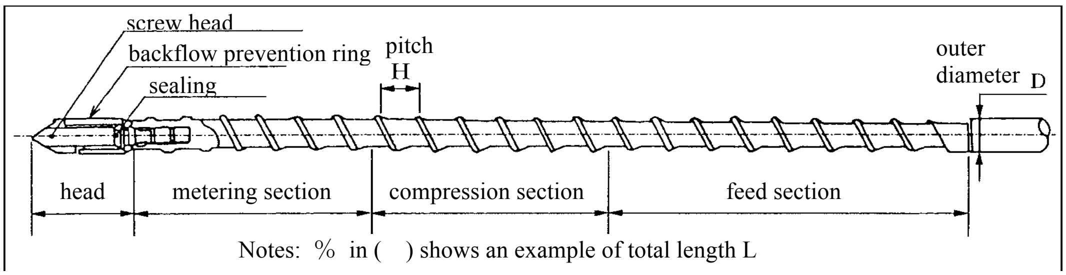
The screw design consists of the basic design based on the premises of smooth conveyance of pellet, plasticization for melting, dearation and compression, and measurement with a little unevenness.

Supply (feed section): Stroke is designed long for conveying and melting the pellet, and increasing plasticization quantity.

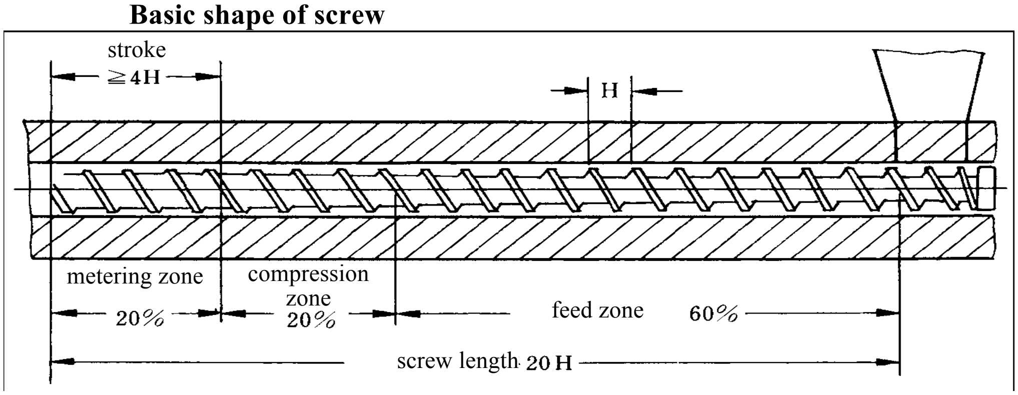
Compression (compression section): Return the air and water involved in the feed section to the hopper side and deaerate. In addition, a sufficiently melting mechanism is required. Because PC is a high viscosity material, the rapid compression type is unsuitable and moderating compression type with gradually increasing outside diameter is recommended.

Measurement (metering section): In order to suppress the measurement unevenness, the measurement stroke is designed long, 4D ~ 5D or more.

The screw design of PC is indicated in Fig. 1・ 1-4. [2]



Basic shape of screw



Screw diameter (mm)	Screw depth Feed section (mm)	Metering section (mm)	Compression ratio
30	5. 6	1. 8	2. 0 : 1
60	6. 6	3. 0	2. 2 : 1
90	9. 5	4. 0	2. 4 : 1
120	12. 0	4. 8	2. 5 : 1
120	Max. 14. 0	Max. 5. 6	Max. 3. 0 : 1

Screw pitch

H = 1.0D Screw diameter more than 80mm

H = 0.9D Screw diameter less than 80mm

Fig. 1・1-4 Design of screw for PC

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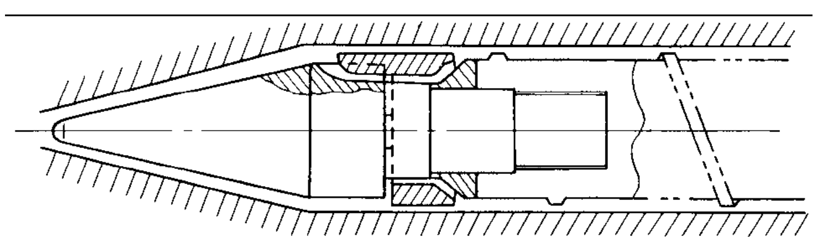
2) Jonathan M. Newcome:SPE Tech Pap Reg Tech Conf. PIONEER VALLEY SEC ('77 june 8/9) 45 – 78

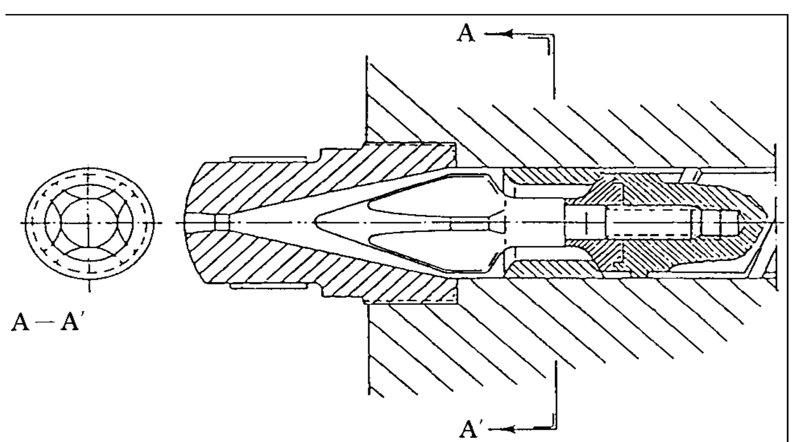
In the same figure, L/D is 20, the ratio of Feed (F) / Compression (C) / Metering (M) is divided into 60/20/20, pitch H is almost equal to screw diameter D, and compression ratio C.R. of the screw is 2.0:1~2.5:1.
The screw that its surface is covered with thick film hard Cr coating is good. When the glass fiber reinforced material is used, there is a problem of abrasion, but constantly preparing spare screw and regularly exchanging after recoating are recommended.
The screw that processed nitriding treatment is hard to be worn due to its high hardness. On the other hand, for transparent product and colored product (except the black) avoiding the burn, because it is easy to cause the burn in PC molding, it had better use the screw that processed with (Ni+Cr), (Co+Cr), TiC treatment at the surface though it is a little expensive.
Recently, the example which uses dulmage, sub flight, pin screw mounted at the screw head with the purpose to improve the melting and mixing and the dispersibility is observed with the precondition of not giving excessive shearing force to PC and the design without PC stagnation.

4) Backflow prevention valve, check ring

The screw head is equipped with the backflow prevention valve to maintain the effective injection pressure by preventing a part of measured resin from backflow through the ditch of the screw at the time of injection. The structure of this valve is indicated in Fig. 1・1-5. It can be understood that it is easy for resin stagnation with this valve structure.
Therefore, the design of the flow path without dead space by taking enough R so as not to provide the corner as much as possible is expected. In addition, as for high viscosity material such as PC, because torque is big, the fatigue failure occurs in the screw of small aperture when receiving the load by repeated rotation, the use of screw of wide aperture is recommended.



Back flow ring type equipped with nail



cross-section drawing

Fig. 1・1-5 Design of Shut Off Valve

As for compound reinforced PC such as glass fiber reinforced material etc. the backflow prevention ring sometimes cracks when the load becomes large compared with the non-reinforced material. When molding without being aware of this, the uneven dimension and the deviation from tolerance in the molding of a precise part occur due to the unstable measurement. It is necessary to note that such a trouble easily occurs in case of overload and insufficient purge.

5） Nozzle

A nozzle with the structure without PC stagnation is desirable as possible. Therefore, it is necessary to avoid using the needle shut off nozzle and torpedo nozzle due to resin stagnation. The open nozzle is the best for use.
The open nozzle is easy to cause drooling, stringiness, and it is difficult to prevent them but using a long-extended nozzle and adjusting independently the temperature at two separate places of the tip and the bottom, are effective.

6） Heater

Since PC is molded at high temperature, the heater with heat capacity can be heated to about 370℃ is used, and a band heater is usually used.
When disassembling to clean the nozzle and cylinder head and when the heater is stuck with drooling resin, the heater is disconnected. It is necessary to note that it is easy to cause the burn when continuing molding without being aware of heater disconnection.

1･2 Clamping unit

As for the molding of Iupilon / NOVAREX, either the hydraulic type or the toggle type is available.
Since the average value of the mold internal pressure in the molding of Iupilon / NOVAREX is 350-500kg/cm2, the clamping force F can be calculated by the following equation.

$$F\,(\text{ton}) = (0.35 \sim 0.50) \times S$$

where S: projected area as indicated in Fig. 1･2-1. However, it is necessary to note that when the arrangement of molding is eccentric from the center of mold (center of die plate), the clamping force, which is higher than the above formula is required.

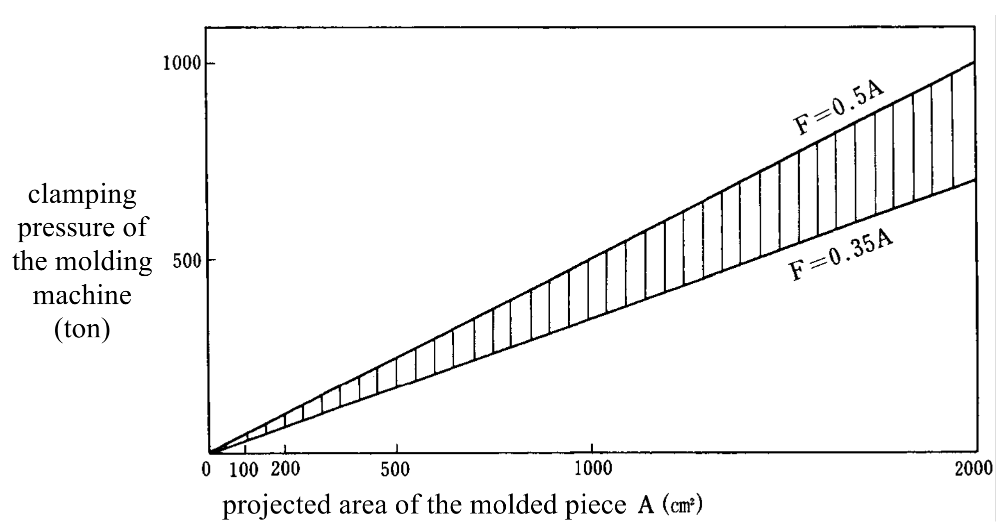


Fig. **1･2-1 Selection of molding machine from clamping pressure**

1・3 Multistep program control

The improvement of poor appearance of the moldings, the reduction of size unevenness between the molding shots, and the measures against sink marks, warpage and flash can be achieved by controlling the injection rate, holding pressure, screw rotation speed and back pressure with multistep program control at the time of injection. The effect of multistep program control in PC and its control system are indicated in Fig. 1・3-1. The outline is introduced below. [3)]

Table 1・3-1 Effect of multistep control (in case of PC)

Molding conditions	Effect
Injection rate	Prevention of jetting mark at gate part, prevention of flow mark of sharp corner, prevention of core falling and prevention of flash
Holding pressure	Reduction of molding stress and prevention of sink mark
Screw rotation speed	Stability of measurement
Back pressure	Stability of measurement

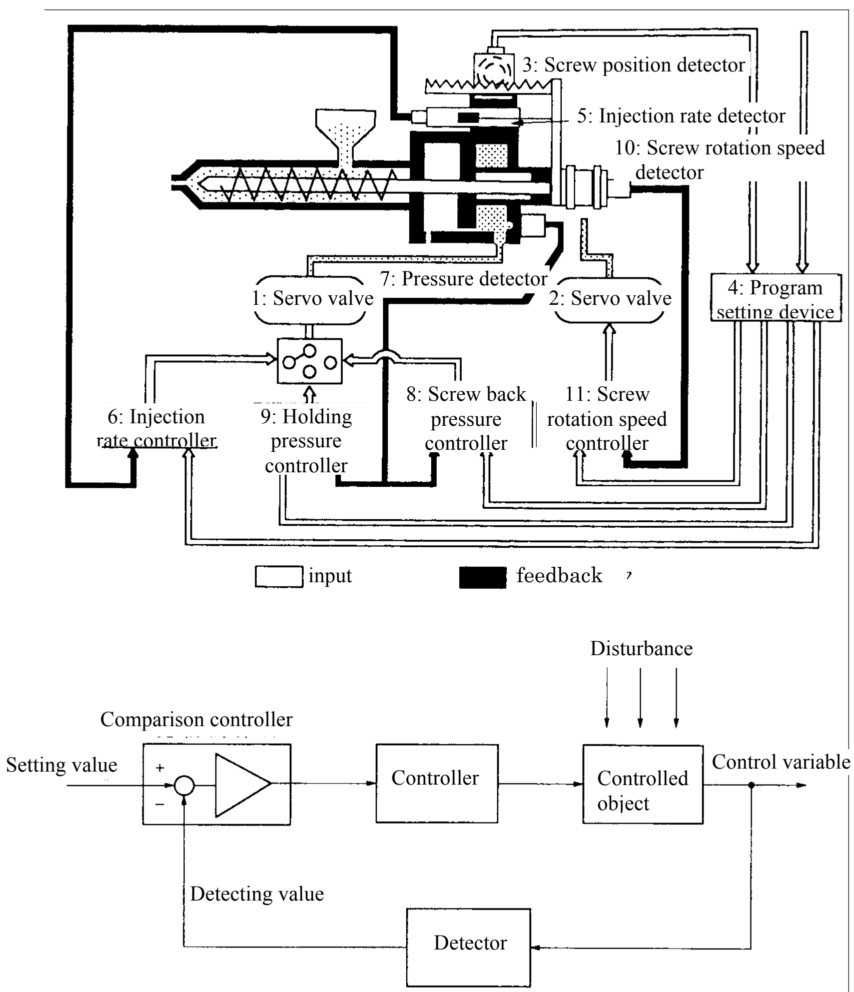


Fig. 1・3-1 Outline of multistep program control system

〈**Control of the injection rate**〉

Since the poor appearance is resulted from the change of rate of the flow front, the measures can be done by controlling the injection rate. The relationship between the flow rate and the defective phenomena is summarized in Table 1･3-2. It can be understood that the injection rate should be set to an appropriate range because there is a problem even if the flow rate is too fast or too slow.

Table 1･3-2 Flow rate and defective phenomena

Defective phenomena results from too slow flow rate of resin	Defective phenomena results from too fast flow rate of resin
Flow mark	Jetting mark
Transcription defect of mold surface	Gas burn
Weld line	Sink mark due to trouble of air purge
Short shot	

Fig. 1 3-2 indicates an example of a measure to avoid the area of various defective phenomena by controlling the injection rate with multistep program control.
It is understood that the setting range of the injection rate to have a product of good quality is narrow (shaded part) in case of general molding.

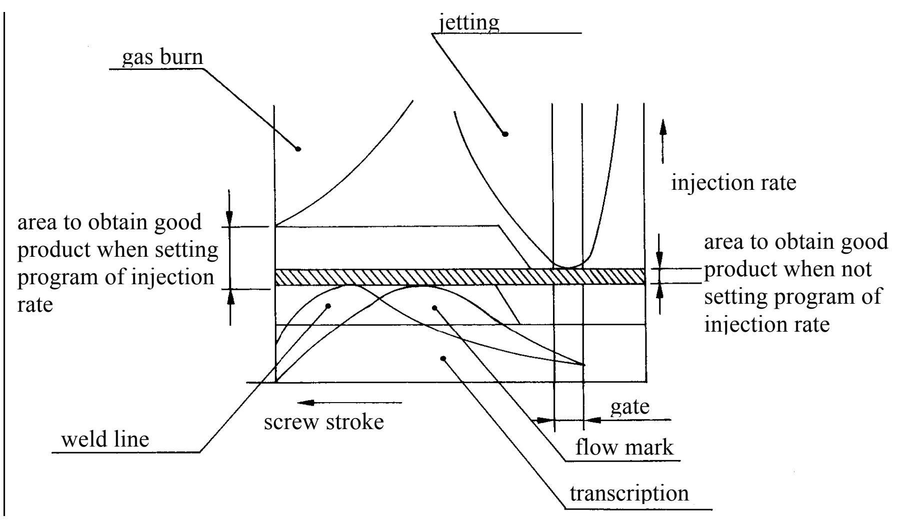


Fig. 1･3-2 Defective area of injection rate

〈**Control of the holding pressure**〉
The defective phenomena such as sink marks, warpage and flash are related to the holding pressure.
The measure against these phenomena becomes possible by controlling the holding pressure.
The relationship between the defective phenomena such as sink marks, warpage and flash and the holding pressure is summarized in Table 1･3-3. Figure 1･3-3 indicates the pattern of the holding pressure program which was obtained to avoid the defective phenomenon area.

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3) Sumitomo Heavy Industries, Ltd. Plastic Machinery, lecture textbook of injection molding “Molding B Course Practical Application”

Table **1.3-3 Holding pressure and defective phenomena**

Defective phenomena results from too low holding pressure	Defective phenomena results from too high holding pressure
Short shot Sink mark Underdimension Shrinkage strain	Flash Overdimension Crack Mold release defect Residual stress

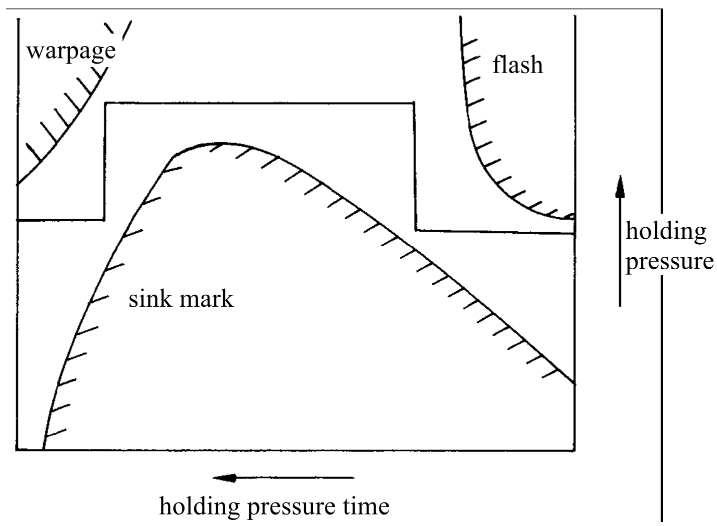


Fig. 1･3-3 Holding pressure pattern to avoid defective area

〈Control of screw back pressure and screw rotation speed〉

The stability of measurement (plasticization) is related to screw back pressure and screw rotation speed.
It is possible to improve the accuracy of uneven repeated measurement by controlling these factors.
Fig. 1･3-4 indicates the result of comparing the effects of the multistep program control of screw back pressure and screw rotation speed about the measurement position or mold release resistance[4].
From this figure, it is thought that the unevenness of the measurement position, mold release resistance was decreased by the multistep program control.

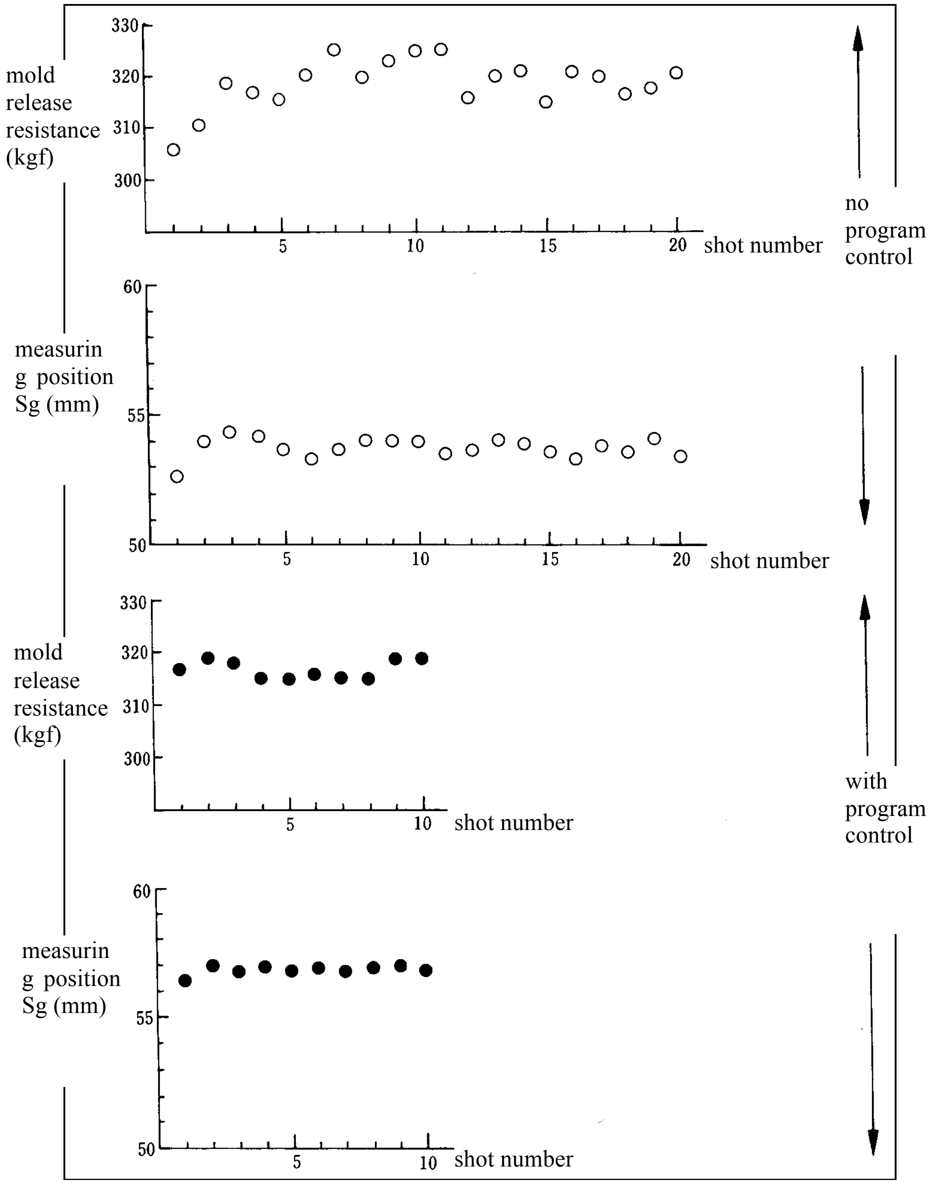


Fig. 1･3-4 Stabilization by the program control of plasticization process
(Material : S-2000)

1･4 Defective Moldings, Causes, and Remedies

Defects to be encountered in molding of Iupilon / NOVAREX are almost similar to those of other plastic materials. The defective causes and remedies of general grade and glass fiber reinforced grade are summarized in Tables 1･4-1 and 1･4-2, respectively.

The effect that the mold temperature of glass fiber reinforced grade has on the appearance is indicated in Fig. 1･4-1.

Table 1･4-3 shows the problems and remedies in an accurate molding.

Table 1･4-1 Defective causes and remedies of general grade

Defective molding	Cause	Remedy
Silver streaks (uniformly distributed in the direction of injection)	Moisture in the pellets	Dry the pellets thoroughly at 120℃. Do not allow the pellets to cool in the hopper. Perform free injection and observe the state of bubbling of the melt.
Silver streaks (irregularly distributed and often shaped like a comet locally)	Overheating of the resin (i) Overheated spots in the cylinder or nozzle (ii) Stagnation of the resin in the cylinder or nozzle	(i) Lower the temperature of the overheated spots (ii) Clean the stagnant part or replace the stagnant part with a part free from stagnation
Brown discoloration	(iii) Over heating of the resin or too long dwell time (iv) Inadequate rotation speed of screws	(iii) Check the stagnant part and the joining part of the cylinder and nozzle (iv) Set the rotation speed of screw at 45—60rpm.
Cloudy black specks and bubbles	Air trapped in the pellets	Raise the back pressure in a screw type Molding machine
Local discoloration	Insufficient venting of the mold and heat Generated by adiabatic compression of the air	Cut a 0. 01mm～0. 03mm deep vent in the parting face of the mold
Voids and black specks and silver streaks around the voids Stains	Adiabatic compression of the air entrapped in the resin in the mold. (i) Contamination by foreign matters or other resin. (ii) Contamination by eroded material of the molding machine. (iii) Fats or oils in contact with the melt.	Change the position of the gate to obtain a uniform flow of the resin in every direction. Correct the eccentricity and non-uniform thickness of the core. Lower the injection rate (i) Pay enough attention to storage of the resin and feeding to the hopper. Clean the hopper, cylinder and nozzle. (ii) Inspect the sliding surface of the measuring unit, plunger sleeve, screws, non-return valve, and nozzle. (iii) Inspect the injection unit and the mold and prevent oil leakage.

Defective molding	Cause	Remedy
Dark brown or black specks or particles	Peeling of a layer of decomposed resin formed on the internal surface of the cylinder.	Clean the internal surface of the cylinder. Keep the temperature of the cylinder at 160—180℃ when the operation is stopped.
Cloudy surface	Due to the use of a mold release agent.	Polish the mold. Reduce the amount of a mold release agent.

Sink marks on the surface Or bubble inside	Shrinkage occurring during freezing is not sufficiently compensated by the holding pressure	(i) Prolong the application of the holding pressure (ii) Prevent heat loss from the nozzle. (iii) Enlarge the gate. (iv) Make the wall of the molded piece as thin as possible. (v) Attach the gate to the part with the largest wall thickness. (vi) Prolong the cooling time when sink marks are formed after release from the mold. (vii) Increase the feed cushion of pellets.
Mold flash	(i) Insufficient mold clamping force or too high injection pressure. (ii) Wearing off of the mold.	(i) Increase the mold clamping force or reduce the injection pressure and holding pressure. Inspect the mold. (ii) Renew the mold.
Difficult molt release or Deformation during molt release	(i) Larger mold release force required (ii) Vacuum created between the mold and the molded piece. (iii) Mold release force not working on the part where the molded piece is adhered closely to the mold. (iv) Molded piece not sufficiently cooled during mold release	(i) Lower the holding pressure. Provide a sufficient draft and polish the mold. (ii) Attach a device to break the vacuum in the mold. (iii) Increase the number of ejector pins. (iv) Lower the mold temperature and speed up cooling. (v) Prolong the cooling time.
Short shot	(i) Too low cylinder temperature, too fast freezing of the passageway, too low mold temperature (ii) Too small wall thickness (iii) Irregular filling of cavities.	(i) Raise the cylinder temperature, enlarge the passageway, raise the mold temperature and the injection rate, and improve the air vent of the mold (ii) Increase the wall thickness. (iii) Change the passageway to obtain simultaneous filling.
Ripple near edges	(i) Too low resin temperature (ii) Low injection rate	(i) Raise the resin temperature, particularly the nozzle temperature (ii) Perform high speed injection.
Jet flow, cloudiness near the gate	Caused by the cooled resin or the resin cooled by colliding with the mold being carried forward again by other resin melt	Enlarge the gate. Lower the injection rate. Change the position of the gate. Raise the nozzle temperature.

Table 1·4-2 Defective causes and remedies of glass fiber reinforced grade

FLow marks	Inadewuate flow of the melt (i) Rapid change in the cross section of the molded piece. (ii) Inadewuate flow of the resin melt around sharp corners.	(i) Desin the molded piece such that the cross section changes not stepwise but smoothly. (ii) Round the sharp corners.
Weld marks	Cooling of the resin occuring brfore merging.	Raise the resin and mold temperature and perform high speed injection. Enlarge the gate
Ripple near the gate	Cooling of the resin before the holding pressure working.	Enlarge the gate
Peeling of a surface layer from the molded piece (especially when bent)	Contamination by foreign matters and other resins.	Perform purge sufficiently.
Breakage of molded pieces	(i) Moisture in the pellets (Defects due to moisture are often unnoticeable) (ii) Too low nozzle temperature. (iii) Resin cooled between the nozzle and the sprue bushing. (iv) Generation of internal stresses due to low mold temperature, too high injection pressure and holding pressure, and extremely non-uniform distribution of the wall thickness. (v) Contamination by foreign matters.	(i) Dry the pellets at 120℃. Perform purge and examine the degree of resin bubbling. (ii) Raise the nozzle temperature and remove cold slug. Detach the nozzle from the mold after injection. (iii) Remove such cooled resin every time it is formed. Use a shut off nozzle. (iv) Keep the mold temperature at 70 – 120℃.Lower the injection pressure and holding pressure and avoid excessive pressure after complete filling. Make the wall thickness distribution uniform. (v) cylinder and nozzle and cleaning.

Defective molding	Cause	Remedy
Defect of surface gloss	(i) Low mold temperature (ii) Low holding pressure (iii) Low injection rate.	(i) Raise the mold temperature (at 110 －120℃ if possible) (ii) Raise the holding pressure. (iii) Perform high speed injection.
Defect of mold release	(i) Improper taper (ii) Inadequate position of ejector pins (iii) too high mold temperature. (iv) Short cooling time. (v) Too high holding pressure.	(i) Provide a proper taper in the range of 1／100－1／50 (ii) Make adequate position of ejector pins. (iii) Lower the mold temperature. (iv) Prolong the cooling time. (v) Lower the holding pressure.
Local burn	(i) Stagnation of the resin in the molding machine (ii) Overheating of the resin due to adiabatic compression of the air in the mold.	(i) Examine the molding machine. Dismantle and perform cleaning. (ii) Install the vent hole in the mold.
Hue non-uniform	(i) Specks of the resin and floating of glass fiber. (ii) Too severe hue limit.	(i) Make the molding conditions proper. (ii) Widen the tolerance level of hue.
Defect of strength of the weld part	(i) Apply the mold release agent too much. (ii) Inadequate position of the gate and distribution of the thickness.	(i) Decrease the applied amount of the mold release agent. (ii) Change the position of gate and re-examine the distribution of the thickness.

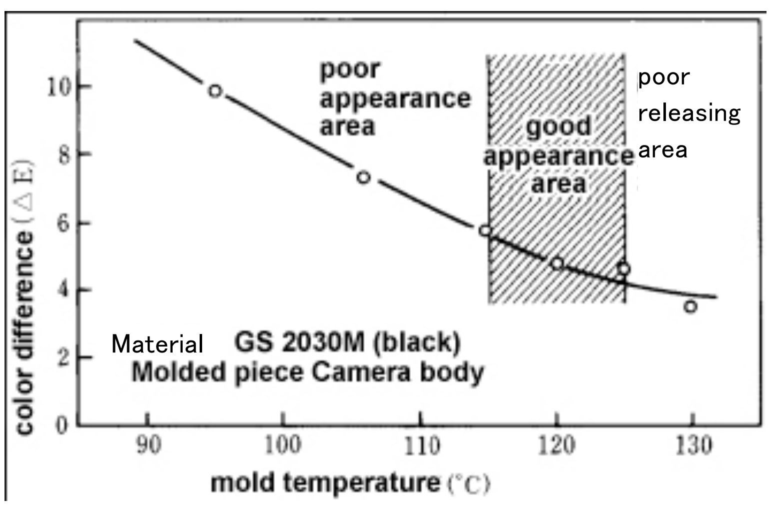


Fig. 1･4-1 Relation between the mold temperature and the appearance of glass fiber reinforced grade

Color difference: the color difference with glass reinforced PC (black) was obtained by considering the non-reinforced PC (black) as a controlled material.

Table 1·4-3 Defective causes and remedies in an accurate molding

Defective molding	Cause	Remedy
Deformation under load	Insufficient elastic modulus	A Examination of kind and content of reinforced material. C Combination with metal (insert, outsert)
	Insufficient shape rigidity	B Application of low bubble molding. C Rib reinforcement
Change of dimension according to environment conditions	Large thermal expansion coefficient.	A Combination of reinforced material.
	Anisotropy of thermal expansion coefficient.	A Addition of non-oriented reinforced material.
	Moisture absorption	A Combination of reinforced material.
	Change of dimension by heat (shrinkage by heat)	A Combination of reinforced material. C Raise the mold temperature. C Annealing treatment
Change of dimension over time	Excessive molding strain	C Uniform distribution of thickness C Molding by low holding pressure and high mold temperature
	Creep deformation	A Combination of reinforced material. B Design creep within the limit.
Estimated error of molding shrinkage factor	Anisotropy of molding shrinkage	A Use the low warpage grade (in case of reinforced grade)
	Form, position and size of gate Thickness, thickness distribution Shape effect (roundness, straightness etc)	C Fulfillment of molding shrinkage data
	Error by the mold	D Improvement of processing accuracy D Consider the influence of mold structure
Non-uniform dimension of mold process	Non-uniform material	A Control the viscosity, filling material, pellet size etc.
	Performance of the mold device	B Improve the performance of injection molding machine, mold etc. and maintainance management.
	Non-uniform molding conditions	C Control the holding pressure, resin temperature and mold temperature.
	Measuring error	C Control the dimension measurement
	Durability of the mold	D Consider the mold strength D Mold material
Warpage	Anisotropy of molding shrinkage	A Use the low warpage grade (in case of reinforced grade)
	Non-uniform pressure in the same cavity.	A Use the low viscosity material. B Use the injection compression molding machine. C Low holding pressure, high speed filling C Examine the number and position of the gate.

Defective molding	Cause	Remedy
Warpage	Non-uniform cooling	C Examine the distribution of thickness C Balance of the mold temperature D Examine the mold heating and the cooling ditch
Sink marks	Due to the failure of holding pressure	A Use the low viscosity material. B Use the high pressure molding machine and the injection compression molding machine. C Examine the position and size of the gate. C Make the wall of the molded piece as thin as possible. C Adjust the resin temperature, mold temperature and holding pressure etc.
	(prevention of sink marks by bubble generation)	A Use the low bubble grade Sink marks prevention grade C Lower the mold temperature.
Defect of mold release	Improper taper Adhesion to mold surface Imbalance of ejector power	A Use the mold release grade. C Increase a sufficient draft, shape of molded pieces C low holding pressure, low mold temperature C Use the spray mold release agent. (pay attention to defects of the appearance, crack of molded pieces) D Pay attention to mold polish direction D State of mold surface (coating, polishing degree) D System and position of ejector
Defect of gas unfilling Surface cloudiness Mold corrosion Defect of dimension Defect of mold release	Too much gas generation	A Consider the pyrolysis, additive, filling material etc. A Insufficiency of preliminary drying of materials B Use the vent injection molding machine C Too high molding temperature Too long molding cycle
	Insufficient gas venting	B Cavity vacuuming C Lower the injection temperature C Install the air vent.

A Measures regarding the materials
B Measures regarding the molding machine, auxiliary equipment etc.
C Measures regarding the product design, molding conditions etc.
D Measures regarding the mold design

2. Molding operation

2･1 Preliminary drying of materials ・ Dryer

Since Iupilon / NOVAREX have an ester bond in the main chain, the hydrolysis occurs when heated with the moisture. As a result, the physical properties, particularly the molecular weight and the impact strength are reduced. Also, the preliminary drying before molding is necessary because the generation of silver streak and void at the appearance occur. The moisture content in the pellets should be assumed to be 0.015~0.020% at the preliminary drying of Iupilon / NOVAREX. The results of the molding at various moisture content are shown in Table 2･1-1. These results indicate that the degradation of the impact strength in addition to the generation of defective appearance is very large. Therefore, it is important to use the dried pellets that the moisture content is lower than the above mentioned limit to have a good performance of Iupilon / NOVAREX.

Table 2･1-1 Effect of the moisture content at the time of injection molding

S-2000 (Molecular weight 2.5×104)

Moisture content (%)	Molecular weight of molded pieces	Falling ball impact destruction rate (%)			Appearance of molded pieces
		Ductile failure	Brittle failure	Total destruction rate	
0. 014	2. 5×104	0	0	0	Good
0. 047	2. 4	30	0	30	Good
0. 061	2. 4	50	0	50	Good
0. 067	2. 4	90	0	90	A few silver streak
0. 200	2. 2	20	80	100	Silver streak, bubble

(Note) Weight of falling ball impact test 2.13kg. The head makes the heavy bob of 10mmR fall from the height of 10 m

The drying conditions of Iupilon / NOVAREX are indicated in Table 2･1-2

Table 2･1-2 Drying conditions of Iupilon / NOVAREX

	Drying conditions		Notes
	Temperature	Time required	
Multi-tray hot air circulation dryer	120℃	4－5hr or more	Many examples of use. Pay attention to the ambient moisture Thickness less than 30mm is preferable.
Hopper dryer	120℃	3－4hr or more	Many examples of use Pay attention to the ambient moisture and short circuit pass When the input is small, the moisture distribution is bad.
Dehumidifying Hopper Dryer	120℃	2－3hr or more	It is often used for the molding of optical disk substrate and optical lens etc.

(Note) Please note that the grade of the polymer-alloy type sometimes differs in the drying conditions.

In order to dry the pellets of Iupilon / NOVAREX until the moisture content is lower than the above mentioned limit、it is necessary to note the kind of the dryer, its performance and environment (temperature and moisture).

Fig. 2･1-1 is the example which shows the dry curve by the difference of the environment with the multi-tray hot air circulation dryer. The dry efficiency is decreased under high temperature, high humidity and it requires long time until the moisture content is lower than the limit.

Also, Fig. 2･1-2 shows the results obtained by the hopper dryer in the same way.
The dehumidification hopper dryer that is not affected by the environment and the dry efficiency is good. However, it is necessary to pay attention to the time degradation of the dehumidifier performance and consider the short pass phenomenon of the pellets when determining the drying capacity.

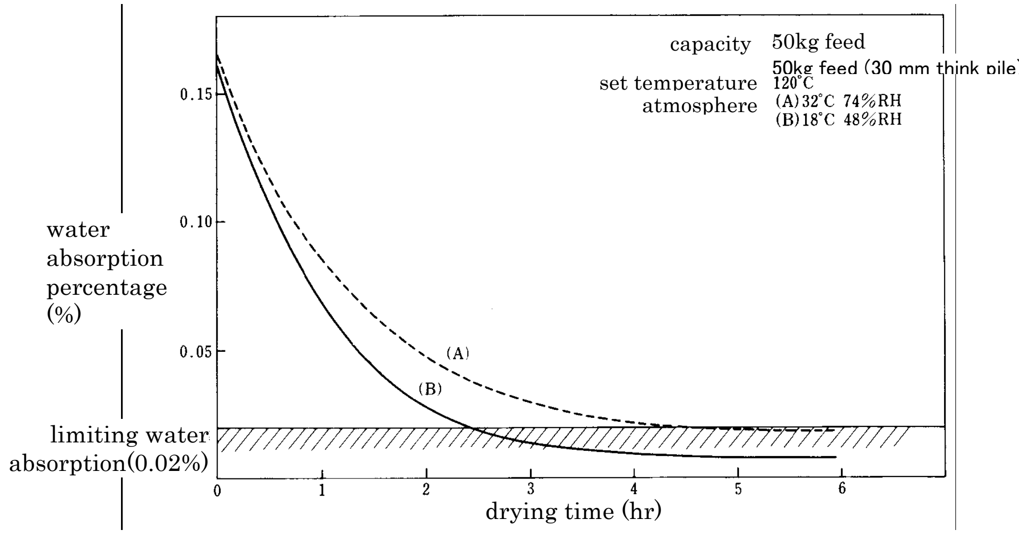


Fig. 2･1-1 Multi-tray hot air circulation dryer

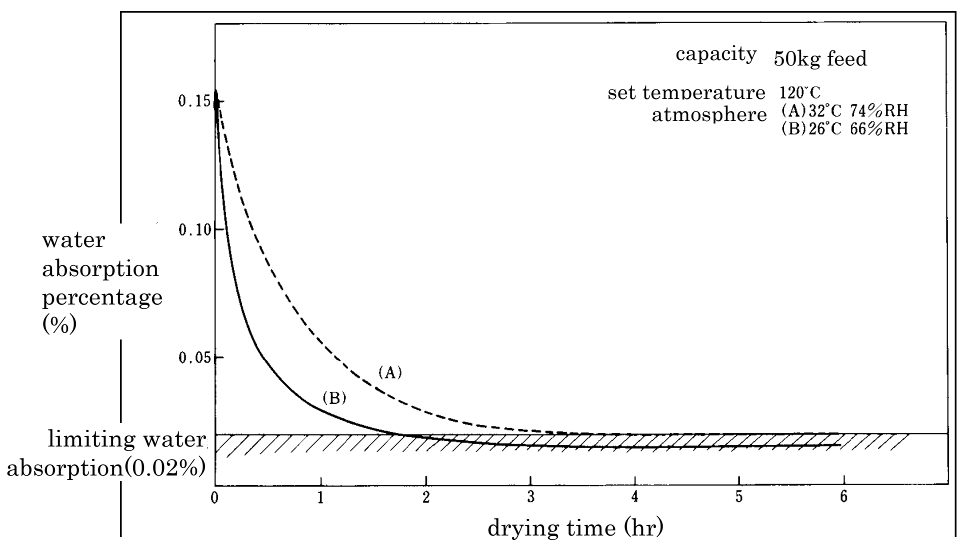


Fig. 2･1-2 Drying conditions by the hopper dryer

Prevention of moisture absorption in the hopper

It is necessary to pay attention to the moisture re-absorption in the molding machine hopper in addition to the preliminary drying of the pellets as described in Section 2･1. Moreover, it is also necessary to consider preventing the moisture re-absorption by shortening the installation of the hopper dryer, hopper insulation and dwell time of the pellets as much as possible.

2･2 Molding conditions

1） Cylinder temperature

The resin temperature is often higher than the setting temperature of the cylinder by 10 - 20 °C.
It is good to measure the characteristic of the injection molding machine to use in advance.
The general molding temperature of Iupilon / NOVAREX is in the range of 260 ~ 320°C, but it is better to set it as low as possible for deep colored products.
As for the setting of the cylinder temperature, it is common to set the temperature gradient such that the hopper side is higher by 10 - 20 °C. When the rotation torque of the screw becomes overload by the high viscosity grade and so on, the temperature on the hopper side may be set high oppositely. .
In addition, the selection of the molding temperature should be made in consideration of the molding cycle time, namely the dwell time of the resin in the cylinder.
The molding machine with the injection capacity by corresponding to the weight of the molded pieces and molding conditions is selected, and the dwell time is shortened as much as possible to avoid the thermal degradation of the resin.
It is necessary to note that the temperature of the nozzle has a slight affect on the cold flow of the molded pieces and the leakage of the resin (drooling).

2） Injection pressure, holding pressure

The injection pressure and holding pressure are set as low as possible if the sink marks and voids do not occur in the molded pieces. However, in case of the resin with high melt viscosity such as Iupilon / NOVAREX, the inside of the mold can not be filled from the pressure loss with the flow process of the resin if the pressure is not raised to some degree. As soon as the cavity is filled, the injection pressure is reduced to the level that does not cause sink marks. In addition, the pressure is raised to reduce the mold shrinkage of the resin, but from the point of strain and mold release characteristic which remain in the molded pieces, the pressure should be set as low as possible.

3） Injection rate

As indicated in Fig. 2･2-1, since the flow length increases when the injection rate increases, the fast filling is carried out for thin-walled molded pieces. However, when the fast filling is carried out, defects such as flow marks and flash are produced.
Since the recent injection molding machine is equipped with the multistep control of the injection rate (program injection), both the filling and appearance can be controlled by changing the rate according to the shape and gate of molded pieces.
The basic rate program is as follows.

(a) Make high speed at the passage of the sprue and runner part.
(b) Make low speed at the initial filling of the gate part and product part, and at the time of filling completion.
(c) Make low speed when passing over the thin type core and pin part.

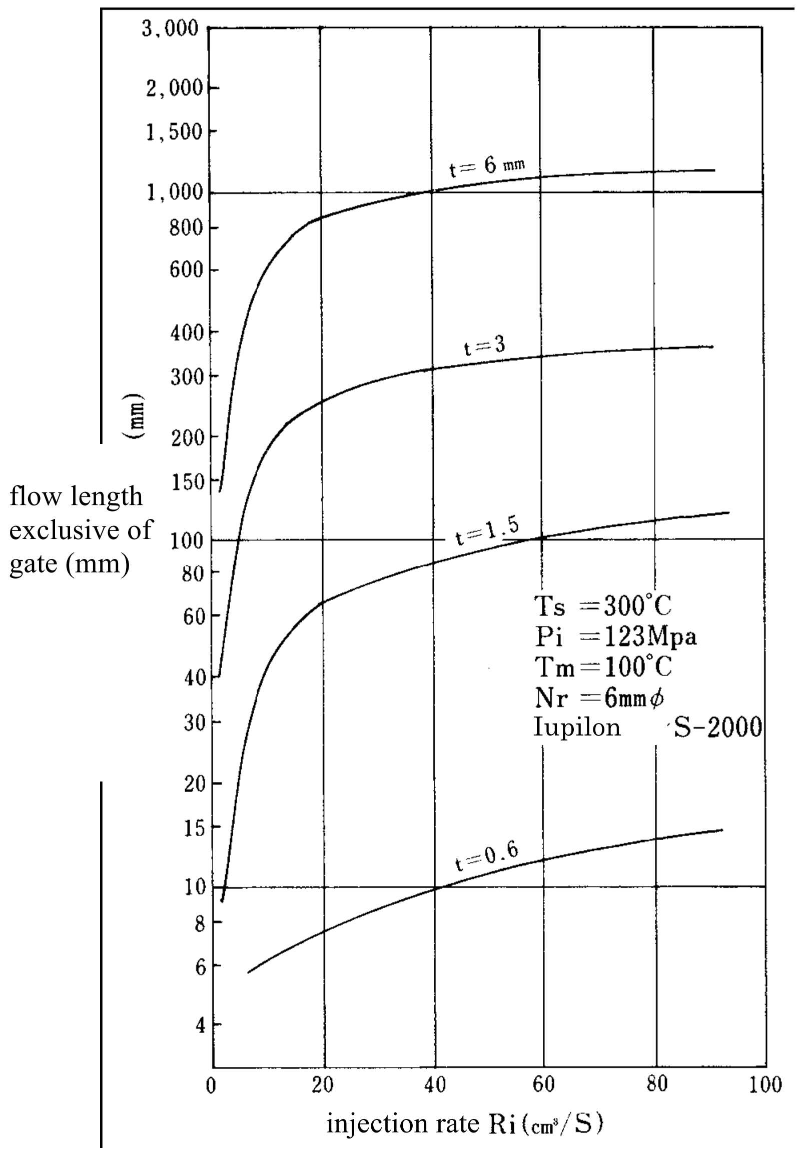


Fig. 2・2-1 Injection rate vs Flow length

4） Rotation speed of screw and Back pressure

It is necessary to increase the rotation speed of screw to shorten the plasticizing time but it becomes the cause of air entry, generation of the resin burning, bubble and silver streaks resulting from the deaeration insufficiency, and easy to cause the thermal degradation by adiabatic exothermic heat.

The back pressure is about 5 - 10 % of the injection pressure to improve the deaeration effect on the hopper side. Since the back pressure has an affect on the leakage (drooling) of the resin from the nozzle, the consideration of setting temperature is also necessary.

5） Mold temperature

The mold temperature is one of the important conditions in the molding of Iupilon / NOVAREX.

When the mold temperature is too low, the filling becomes bad, and in addition to the defective appearance such as flow marks etc., the molding strain is easy to be generated. On the other hand, when the mold temperature is too high, the resin is easy to stick to the mold surface and defect of the mold release and deformation of the molded pieces after the mold release easily occur. The standard mold temperature is 70 ~ 120℃.

2・3 Other cautions

1) The mold release agent is selected and used according to the usage of the molded piece and the presence of the secondary processing.
The mold release agents of silicone derivatives are usually used, but in case of printing and hot stamp, painting etc.as secondary processing, and cloudiness in the vicinity of the gate just after the application, it is better to use the paintable type or unused.

2) It is necessary to pay attention to the shape, removing fat and washing in case of inserts (refer to "Iupilon Technology Report", PCR304 for detail). Sharp corners should be avoided in inserts (Fig. 2・3-1).

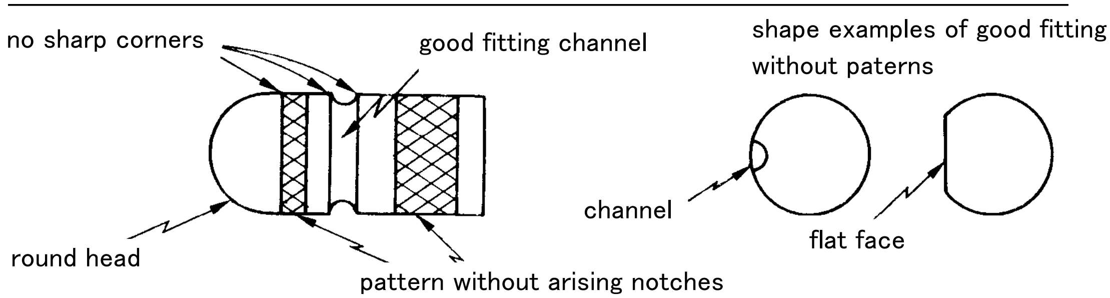


Fig. 2・3-1 Shape of a blind insert

The thickness of the molded pieces around the insert is necessary to be 0.5 times the diameter of the insert even in the worst case because it has an affect on the strain around the insert. In addition, if the insert is a metal in large size, preheating is necessary.
In case a large number of inserts are to be used, the dwell time of the resin in the cylinder is prolonged because it takes long time for the mold installation and as a result, the thermal degradation of the resin may take place. Carrying out the insert after the molding is better.

2・4 Product quality control

Strictly speaking, the molding operation is not over when the material feeding is converted into molded pieces, but it is necessary to check whether the pieces exhibit enough strength in actual use. From this point of view, it is very important to select proper molding conditions.
The evaluation is not easy although molding conditions are modified and selected while judging their performance in actual use. The requested characteristics of the molded pieces are based on the basis of the customer's specification, and it is impossible to conduct everything in the molding process.
The management is thoroughly executed in the early stage when producing a new molded piece, and it is necessary to focus on the point and to conduct day-by-day management afterwards.
The item that should be managed in the molding process is to prevent the reduction of strength of molded piece due to 1. the degradation and decomposition of the resin, 2. molding strain.
This is explained as follows.

1) Degradation, Decomposition of the resin

Measurement of the molecular weight is used as a means to examine the degradation and decomposition of Iupilon / NOVAREX.
It is necessary to note that the measurement of the molecular weight is difficult in a special grade, and can not be judged only by it in some cases.
Since the measurement of the molecular weight is time consuming, it is better to conduct it at the stage of selecting the molding conditions at the beginning and to keep the correlation with other simple test method, and then manage it
For example, it is also good to bend a sprue and a runner and examine the condition of breakage or conduct an impact test sensitive to the reduction in the molecular weight due to the decomposition of the resin (falling ball impact test etc. to add the impact in the molded piece with the hammer).

2）Molding strain

A method often used for determination of the molding strain (residual stress) is to immerse Iupilon / NOVAREX in specific solvents to observe the presence of cracks generated. As for Iupilon / NOVAREX general grade, it is inspected by using the combined solvent of MIBK (methyl isobutyl ketone) and methanol.
This method is suitable for stress detection by the following reasons.
(a) In case of crack generation, a relatively big crack is generated and is easy to determine.
(b) The detected stress can be changed by changing the mixed composition.

Table 2･4-1 is summarized based on current practical results. However, because the detection method of residual stress by solvent is a method of large unevenness actually, the result should be considered as a rough standard and an evaluation standard in correspondence with practical test must be decided. Also, the correspondent mixed composition of the conventional carbon tertrachloride / butanol system was described

Table 2･4-1

Mixed composition（volume ratio）		Detected stress MPa（kg／cm2）	Evaluation
MIBK／Methanol	CCl_4／Butanol		
1／1 （MIBK＝50%）	1／0 （CCl_4＝100%）	3．9 （40）	Too severe for checking stress of normal molded piece Suitable for searching molding conditions for stress reduction and annealing conditions.
1／2 （33%）	1／1 （50%）	8．3 （85）	Molded piece is suitable for stress check in a simple substance.
1／3 （25%）	1／3 （25%）	13 （130）	Suitable for the check of assembly articles and insert articles loaded by joint stress and external force.
1／7 （12．5%）	1／7 （12．5%）	17 （170）	When the crack is generated at this level, there is a possibility that the crack is generated in actual use, too.
0／1 （0%）	0／1 （0%）	21 （210）	

・ After the sample is immersed in the mixed solvent of MIBK (methyl isobutyl ketone) and methanol for one minute, take it out, conduct water washing and observe the crack.

2･5 Material replacement, Interruption of Operation, and Cleaning by Dismantling

1） Material replacement

Polyamide, polyacetal etc. should not be replaced directly with Iupilon / NOVAREX and the reverse is also similar. It is because these resin materials decompose when replacing directly to the molding temperature range of Iupilon / NOVAREX, and also promote the decomposition of Iupilon / NOVAREX. In such a case, polyethylene and polystyrene must be used between the two.
However, it is necessary to note the case when a transparent resin such as polystyrene is mixed with Iupilon / NOVAREX because the end point of the replacement can not be clearly discernible.
Recently, to make the replacement of color, material easy, various replacement materials (cylinder washing material) are available in the market. A proper replacement material can be selected according to the molding temperature range of the material before replacement, the material of the replacement purpose.

2） **Interruption of Operation, and Cleaning by Dismantling**

The resin is gradually decomposed and formed a carbonized layer on the internal surface of the heating cylinder and around the backflow prevention ring of the screw over a long period of operation. This carbonized layer does not peel off during the normal molding operation. However, when the temperature of the heating cylinder goes down during interruption of the operation, the carbonized layer peels off due to shrinkage, contaminates the molded pieces and becomes black specks when the molding operation is resumed. Therefore, it is better to keep the heating cylinder at 150～180℃ during interruption of the operation for a short time. When the operation is stopped for a long time, it is good to replace Iupilon / NOVAREX with other resins of lower molding temperature range and lower the temperature. Polyethylene and polystyrene are good as replacing resins.
Since the carbonized layer on the internal surface of the heating cylinder and around the backflow prevention ring of the screw gradually becomes thick and begins to contaminate the molded pieces when the decomposition progresses, the heating cylinder and the screw should be dismantled and cleaned regularly. Especially, since the contamination of foreign matters, black specks are not good for transparent molded pieces, it is necessary to dismantle and clean once every several months.
When various resins are molded with the same molding machine, it is necessary to dismantle and clean the cylinder and the screw regularly.
The dismantling procedure is done by replacing with polyethylene and polystyrene after the resin in the cylinder is emptied as much as possible. After dismantling, remove the remaining melted resin quickly, and then remove the carbonized layer with the spatula and brush made of cupper or burn with the burner. If Iupilon / NOVAREX remains and it is impossible to take it out, an effective method is to wash with a solvent such as methylene chloride etc. In this case, pay attention to the work environment (ventilation, fire).

3. Product design and Mold design

3・1 Product design

When using Iupilon / NOVAREX, the contents shown in Table 3・1-1 are considered as problems in practical use. As shown in Table 3・1-2, it is necessary to investigate and examine sufficiently so as not to cause these problems. In addition, the calculating formula shown in Table 3・1-3 is useful for the standard of lightening, decision of the product thickness, and the selection of molding machine, etc.

Table 3・1-1 Defective phenomena observed in PC molded piece

Classification	Contents
Strength	Crack and deterioration of impact strength due to degradation at the time of molding Breaking due to excessive load stress Deterioration of strength due to concentration of stress Crack of insert and screw tightening part Solvent crack due to oil, plasticizer etc. Deterioration due to hot water and alkali.
Dimension	Defect of dimensional due to error of estimation of mold shrinkage factor Deformation due to excessive stress and warpage at the time of molding. Deformation due to creep deformation and thermal expansion.
Appearance	Silver streaks, sink marks, flow marks, specks, weld line, hue non-uniform, Uneven brightness of embossing, uneven brightness of weld part, floating of glass fiber

Table 3・1-2 Points to be checked at the time of PC molding

Classification	Items
General	Reason of PC molding, commercialization schedule, weight and material, production quantity, price in the past
Required performance	Lifetime, strength, dimension accuracy, rigidity, flammability, electrical property
Use environment	Temperature, chemical atmosphere (oil, solvent, hot water), kind of contacted substance (PVC, packing), outdoor use or not.
Tightening method	Inserting, screw tightening, bonding, caulking.
Appearance	Hue, existence of embossing, existence of coating

Table 3・1－3　Points to be checked at the time of PC molding

Classification	Items
Weight (in case of constant shape)	W : weight of PC product, W0: weight of metal product $W = \rho_2/\rho_1 * t_2/t_1 * Wo$ ρ1t1 : density and thickness of metal, ρ2t2 : density and thickness of PC
Necessary thickness to give the same loss	t : thickness of PC, t0 : thickness of metal $t = to * \sqrt[3]{E_2/E_1}$ E1 : bending elastic modulus of PC, E2 : bending elastic modulus of metal
Thickness and Flow Length	t : thickness L=30～40×t2 L : maximum flow length
Required mold clamping force of molding machine	P : mold clamping force P (ton) =0・35～0・50×S　s : projected area
Capacity of molding machine	Q : Capacity (g) Q=1・4～3・3W　w : Weight of molding piece (g)

Next, in order to maximize the good performance of Iupilon / NOVAREX, it is necessary to pay sufficient attention to the shape design. The key points are as follows:

(1) The thickness is uniform and no sudden change of the thickness.
(2) An acute angle is absent.
(3) Provide a proper taper.
(4) Undercuts are absent.

As for the main items, the standard and cautions in the molding are described in order as follows.

1) Thickness

The thickness of the molded piece should be decided in consideration of the required performance of the product and moldability of the material.

The relationship between the thickness and the flow length for Iupilon / NOVAREX is shown in Fig. 3・1−1.

In case where the thickness is extremely thin, defect of unfilling, when it is extremely thick, defects such as sink marks, bubbles, deformation etc. and impact strength deterioration occur (thickness 4 ～ 5 mm or more). In addition, the sudden change of the thickness obstructs the flow of resin causes flow marks, notch effect at the corner, and weakening of strength.

Examples of the design to have the uniform thickness are shown in Fig. 3・1−2。

The distribution standard of thickness is shown in Fig. 3・1-3.

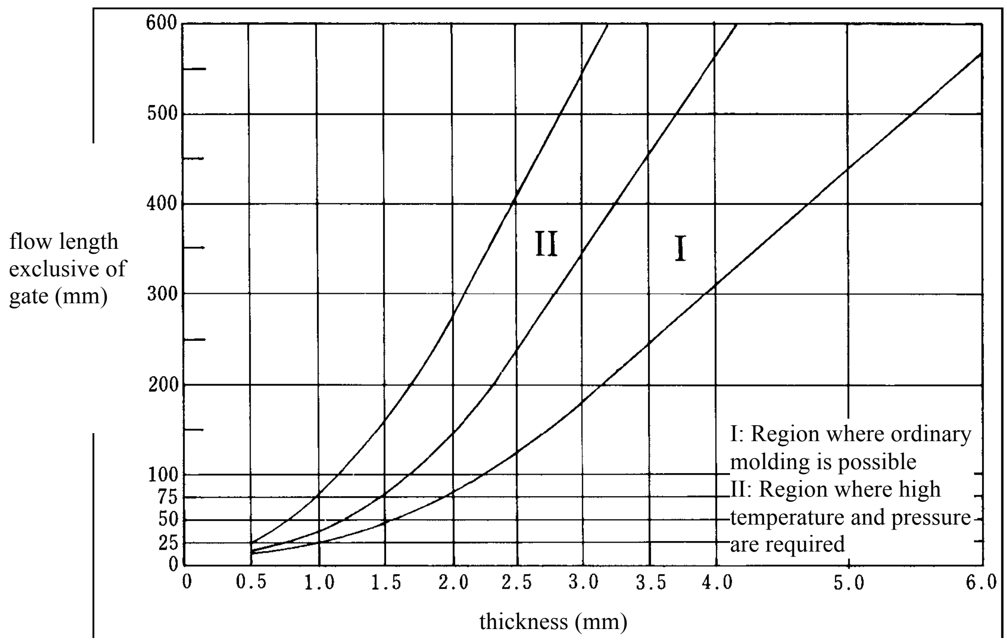


Fig. 3･1-1 The relationship between the wall thickness and the flow length for Iupilon / NOVAREX

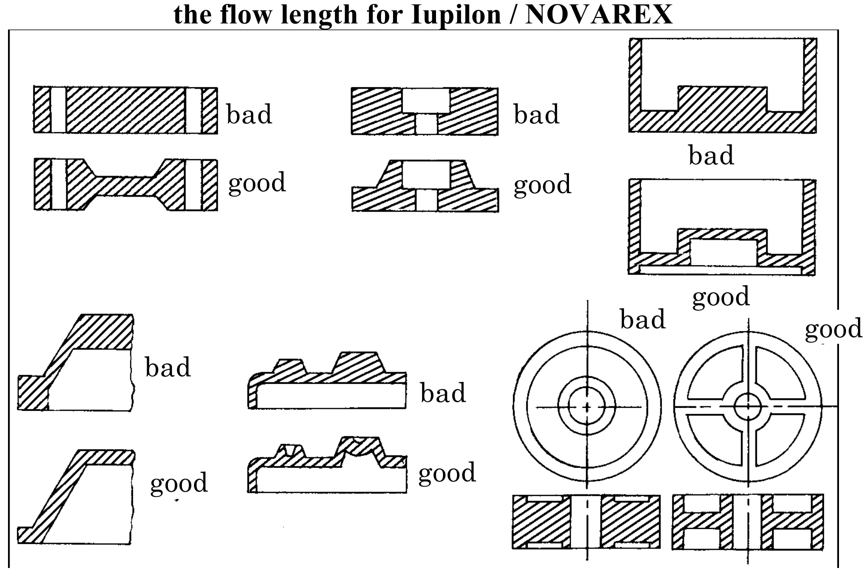


Fig. 3･1-2 Distribution of the thickness

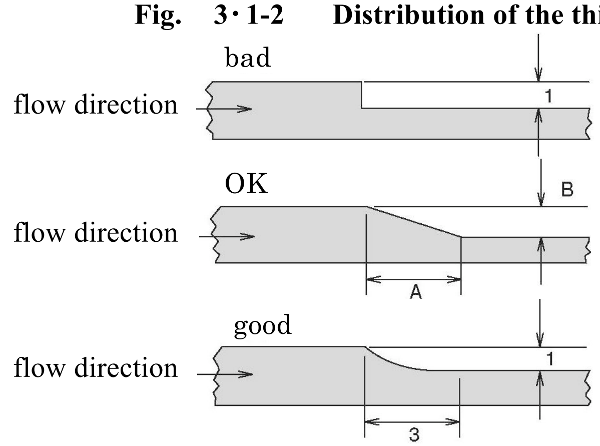


Fig. 3･1-3 Change of the thickness

2） Corner R

The range of 0.5 ~ 1.0mmR is suitable for the corner . Since an excessive stress occurs at the corner of the molded piece due to the concentration of stress, be sure to provide R at the corner.

The relationship between the notch R and the impact value for Iupilon / NOVAREX is shown in Fig. 3･1-4. The brittle fracture is shown when the notch R is below 0.1R. The relationship between the corner R and the stress concentration factor is shown in Fig. 3･1-5. When the corner R is small, the stress concentration factor becomes large, and as a result, it is easy to cause cracks, residue stress becomes large and defects such as flow marks easily occur.

On the other hand, if the corner R is too large, defects such as sink marks, bubbles, and deformation etc. occur. Therefore, the ratio of the corner R and the thickness (R/T, R'/T), as shown in Fig. 3･1-6 must be noted for the design of the corner.

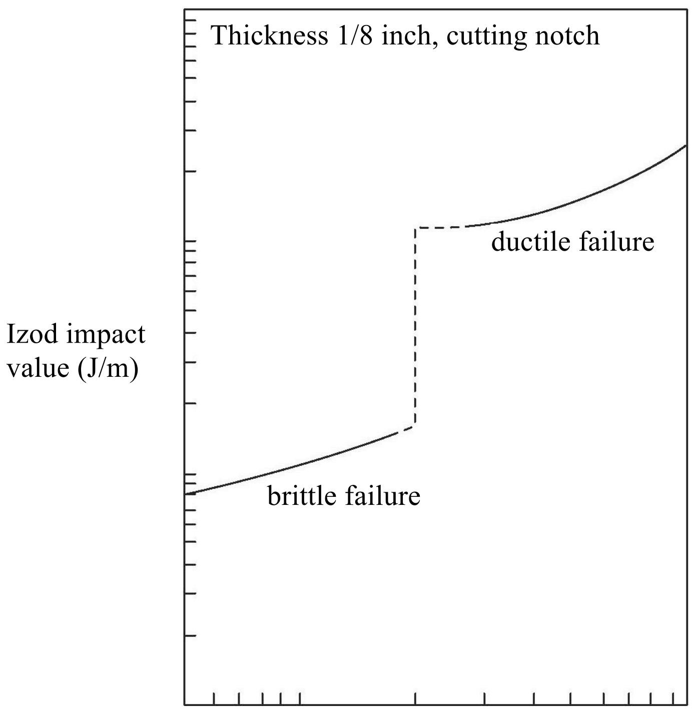


Fig. 3･1-4 The relationship between the notch R and

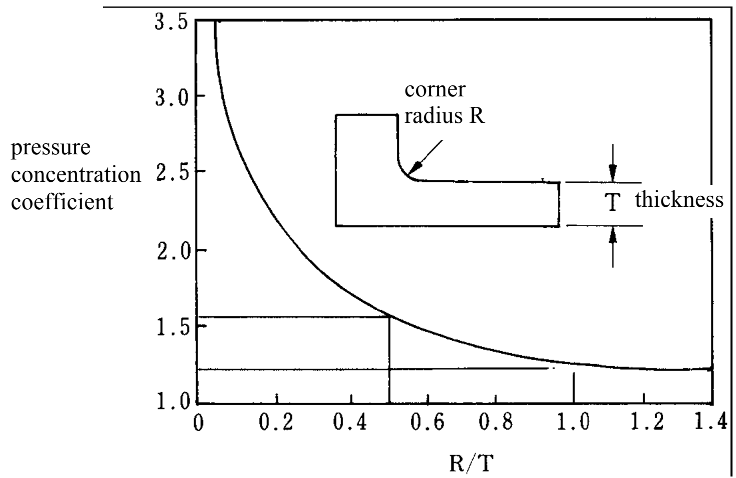


Fig. 3･1-5 The relationship between the corner R and stress concentration factor

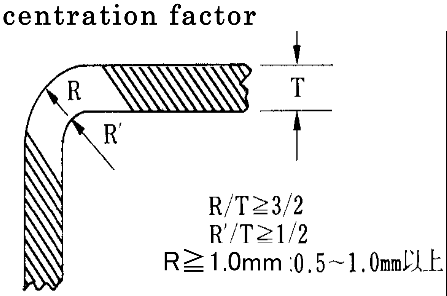


Fig. 3･1-6 Design of the corner R

3） Weld line

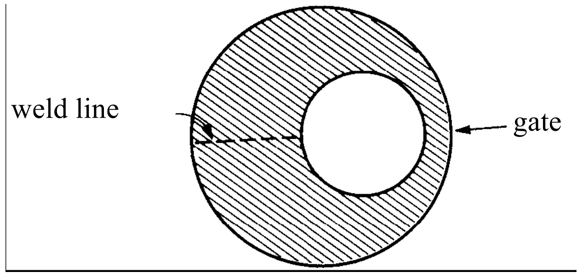
In addition to the deterioration of strength, various defective phenomena at the weld part are observed as shown in Table 3･1-4. The reinforcement measures at the weld part such as the gate type, gate position, rib reinforcement etc. as shown in Fig. 3･1-7 are effective.

Table 3･1-4 Defective phenomena observed at the weld part

Phenomena	Practical failure	Notes
Deterioration of strength	Deterioration of tensile elongation and impact strength	Mainly observed in glass fiber reinforced grade, polymer alloy grade
Generation of crack	Generate in the vicinity of insert, screw boss	
Defect of	Irregular color, Uneven	Mainly observed in deep colored-substance

appearance	brightness of embossing	and polymer alloy grade
Defect of dimension	Sink marks, roundness defect	Many defects in glass fiber reinforced grade

A. Take the gate in the direction where the deposited area of the weld becomes large



B. Reinforce the rib in the vicinity of the generated hole of the weld line.

C. Select the position of gate as the weld line does not generate in the vicinity of the insert metal fitting

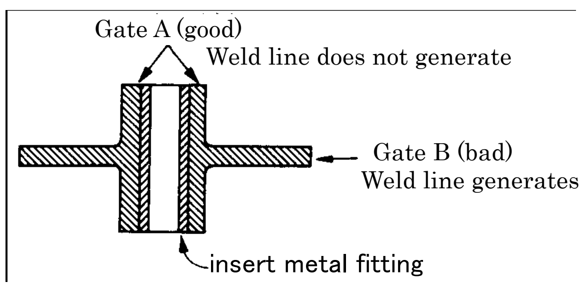


Fig. 3・1-7 Examples of design of the weld part

4） Shape of Rib

It is good to think that the design of a rib is almost the same as other plastic materials. Namely, the measure to prevent the generation of sink marks on the rib opposite side, and the notch effect at the corner part etc. is necessary. The design standard of a rib is shown in Fig. 3・1-8. Do not forget to provide R above 0.5 ~ 1.0mmR at the base corner of the rib.

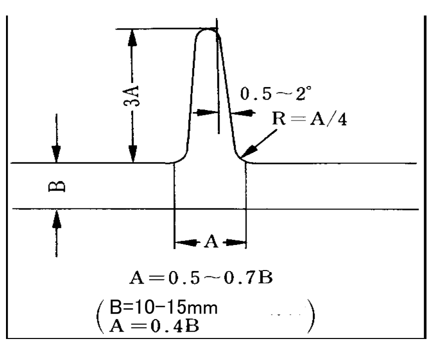


Fig. 3・1-8 Design of a rib

5) Tapering

In general, the standard of a taper is in the range of 1/100 ~ 1/50 (0.5 ~ 1.0°).
An example of the molded piece with a deep rib is shown in Fig. 3・1-9.

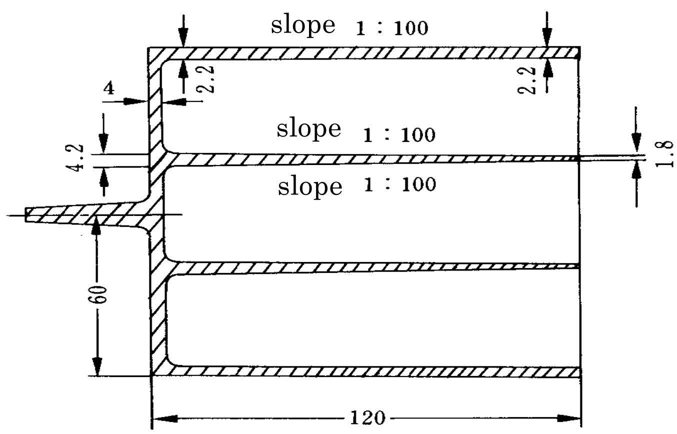


Fig. 3・1-9 Example of taper

6) Undercut

There is no problem when missing an undercut by using the side core, but when pulling out an undercut by force with a normal mold, it is difficult to take a deep undercut because of the high mechanical strength and elasticity modulus of Iupilon / NOVAREX.
The mold release possible undercut △R in case of a cylindrical piece as shown in Fig. 3・1−10 can be calculated by the following equation.

$$\triangle R = 0.02 r_i \frac{L + 0.38}{L}$$

where $$L = \frac{1 + (r_i / r_o)^2}{1 - (r_i / r_o)^2}$$

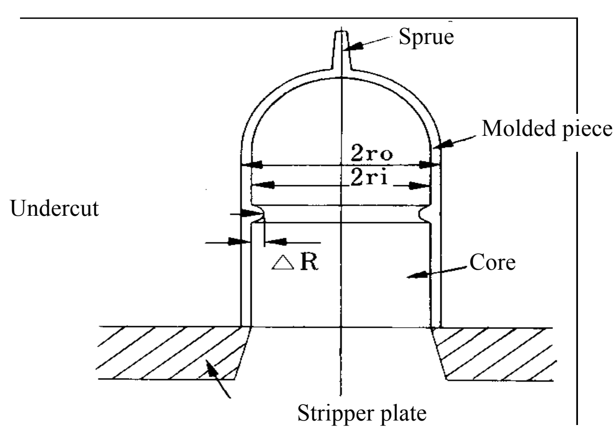
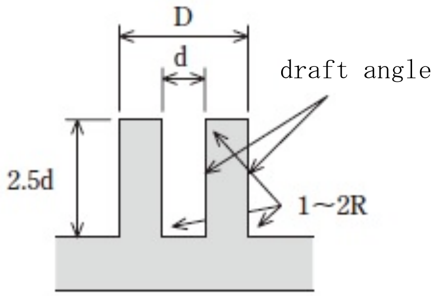


Fig. **3・1-10 Peripheral undercut △R on the cylindrical piece**

7) Boss

The design standard of a boss is shown in Fig. 3・1-11.

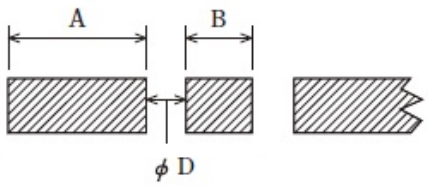


D=3d (d＜5mm)
D=2d (d＞10mm)

Fig. **3・1-11 Boss**

8) Hole

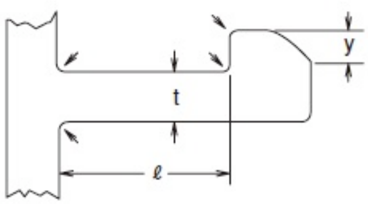
It is necessary to note that when the edge and the hole of the molded piece come close, it results in the weakening of mechanical strength. Refer to Fig. 3・1-12 for the design of the hole.



A≧2D
B≧D

Fig. **3・1-12 Hole**

9) Snap fit



$$\varepsilon = \frac{3y.t}{21^2} \leqq 0.06\sim0.08$$

However, the load is generated only in an instant at the time of assembly, and it becomes 0 afterwards.
Take a proper R.

Fig. 3・1-13 Snap fit

10) Press fit

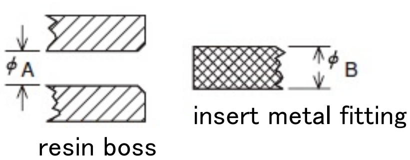


Fig. 3・1-14 Press fit

① Metal insert

Hot compression B−A≦0.2~0.3

Cold compression $\frac{B-A}{B} * 100 \leqq 0.6\%$

② Resin insert (PC-PC)

Cold compression $\frac{B-A}{B} * 100 \leqq 1.5\%$

③ As for the resin with elasticity modulus lower than that of PC, it is good to add α to the above.

3・2 Mold Design

Since the productivity and quality of the molded piece are greatly influenced by the mold design, the mold design is extremely important issue.

The basic concept of the mold design is as follows.

(1) The filling of the resin can be easily done,

(2) The mold release can be easily done.

(3) Pay attention to the control of the mold temperature.

(reduction of non-uniform dimension including the shape, appearance of the product and stabilization of quality)

Each item of the mold design is explained in order as follows.

1) Sprue

Basically, the sprue should be shaped as thin and short as possible.

The points which should be noted are the mold release characteristic and air bubble of the base. As for the mold release, the draft should be 3-5^0 as shown in Fig. 3・2－1. As for the air bubble of the base, it is important to design the diameter of the base to the suitable thickness. When the air bubble occurs at the base in the direct sprue, it results in the cutting of the sprue, defect of the product at the time of mold releasing. The diameter for not causing the air bubble at the base is as follows:

The diameter of the sprue base ≦ (2. 5−3. 0) ×thickness of the base

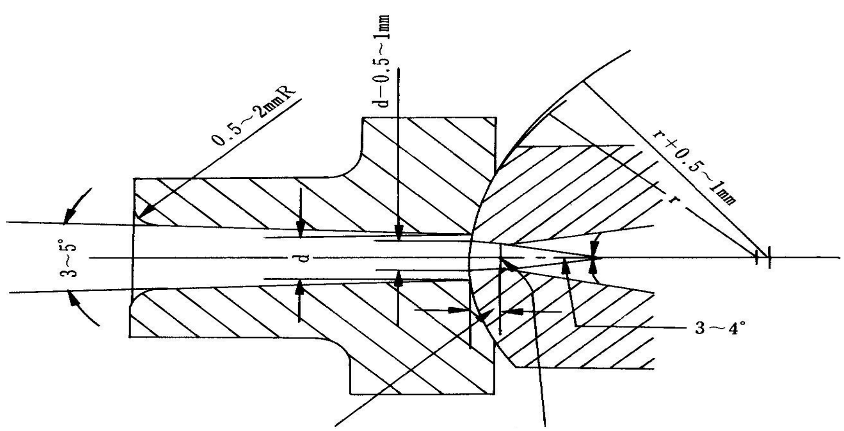


Fig. 3・2－1 Shapes of the nozzle and the sprue bushing

The pressure loss of the sprue part can be calculated by the following equation.
It is preferable to reduce the pressure loss as much as possible.

$$\Delta Ps = \frac{8uq}{\pi (d_m/2)^4} l$$

where, △ps : pressure loss of the sprue part

u : viscosity of the resin

q : volume flow of the resin

l : sprue length

dm : average diameter of the sprue

$$dm = \left[\frac{1}{3(d_2 - d_1)} \left(\frac{1}{d_2^3} - \frac{1}{d_1^3} \right) \right]^{-(1/4)}$$

d_1 : diameter of the sprue tip

d_2 : diameter of the sprue base

2) Runner

The circular, hemi circular and trapezoidal cross section shapes of the runner as shown in Fig. 3・2-2 are acceptable.

Concerning the thickness of the runner, it should be decided in consideration of the pressure loss for the lower limit and the economic efficiency for the upper limit

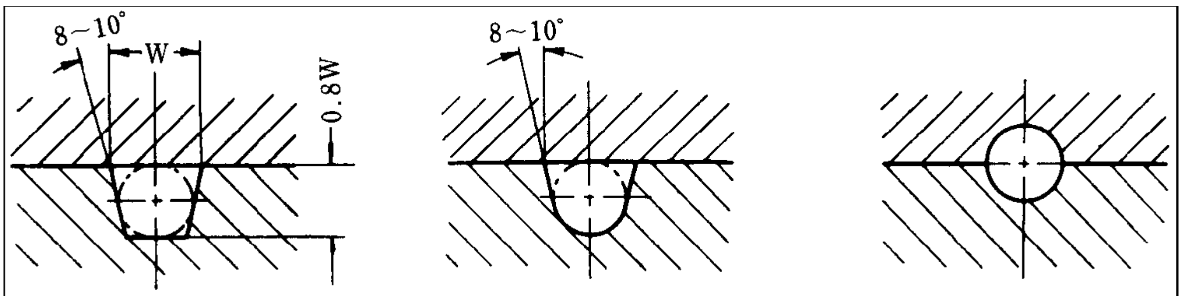


Fig. 3・2－2 Cross sections of runners

The following empirical relationship between the length and thickness of the runner is the common practice.

Length	＞200mm	φ 10
	100－200mm	φ 8
	＜100mm	φ 6

In the case of a multi-cavity mold, it is preferable to balance the runner length to each cavity, and all the cavities should be filled simultaneously as shown in Fig. 3・2-3 and 3・2-4. Also, when it is difficult to balance the runner length, it is preferable to balance the gate for simultaneous filling as shown in Fig. 3・2-5.

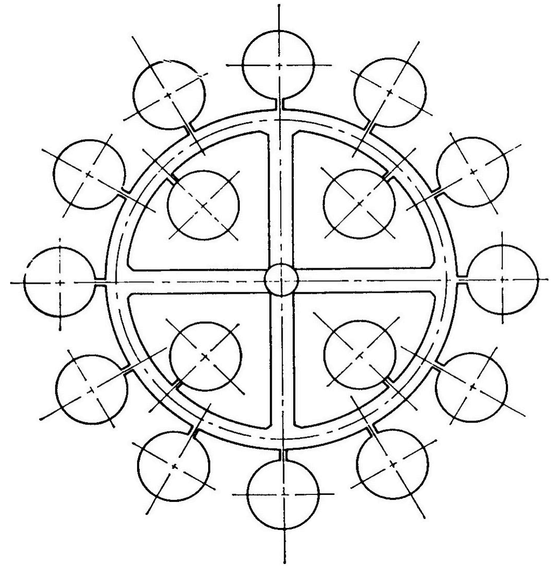


Fig. 3・2－3 Circular arrangement of cavities

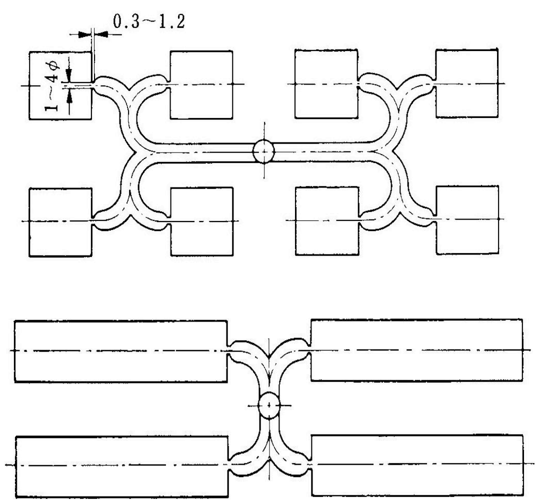


Fig. 3・2－4 Parallel arrangement of cavities

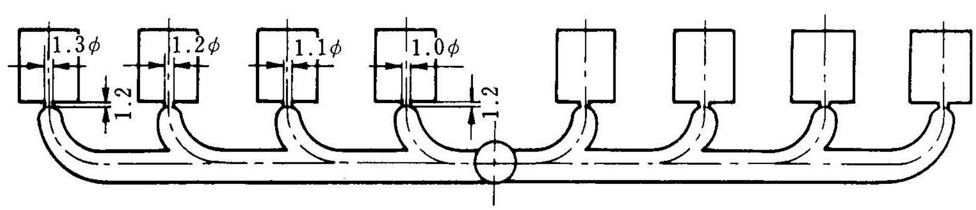


Fig. 3・2－5 Linear arrangement of cavities

The pressure loss of the runner part can be calculated by the following equation.
It is preferable to reduce the pressure loss as much as possible.

$$\triangle P_\gamma = \frac{8uq}{\pi (d_\gamma / 2)^4} l_\gamma$$

$\triangle P_\gamma$: pressure loss of the runner part

u : viscosity of the resin

q : volume flow of the resin

l_γ : runner length

d_γ : hydraulic depth of the runner part 4 (S／l)

S : cross section area of the runner part

l : circumferential length cut of the runner part

3） Gate

The direct gate, side gate, pinpoint gate, submarine gate and tab gate can be applicable to the gate shapes. The side gate and pinpoint gate are commonly used as the gate shapes of Iupilon / NOVAREX molded piece.

When the thickness of the side gate is thin, defective appearance such as unfilling, jetting marks occurs. From the market results, it is often designed the gate thickness equivalent to 50－70% of that of the molded piece thickness. The gate width is 1.5 - 2.0 times the thickness and the gate land length about 2mm is applicable.

The pressure loss of the rectangular cross section at the gate can be calculated by the following equation.

$$\triangle P = \frac{12Luq}{W h^3}$$

$\triangle p$: pressure loss at the gate

u : viscosity

q : volume flow of the resin

W : gate width

h : gate thickness

L : gate land length

As for the pin gate shape, it is important to determine the most suitable diameter of the gate by considering from the viewpoint of crack and deformation of the product at the time of cutting and gate breakage for the maximum dimension, while taking defective problems such as jetting and unfilling for the minimum dimension into consideration. The typical pinpoint gate shape is shown in Fig. 3・2－6. Also, Fig. 3・2－7 shows the relationship between the pin gate diameter and the thickness of the base based on the market results It is recommended to design in reference to Fig. 3.2-7. Generally, the average value of the pin gate diameter ranges from 1.0 to 2.0mm.

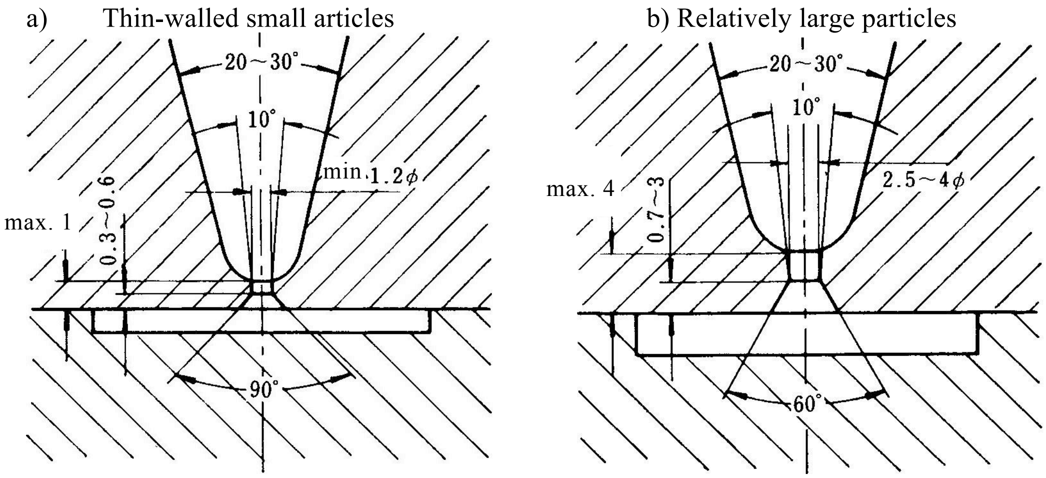


Fig. 3・2－6 Shape and dimension of pinpoint gate

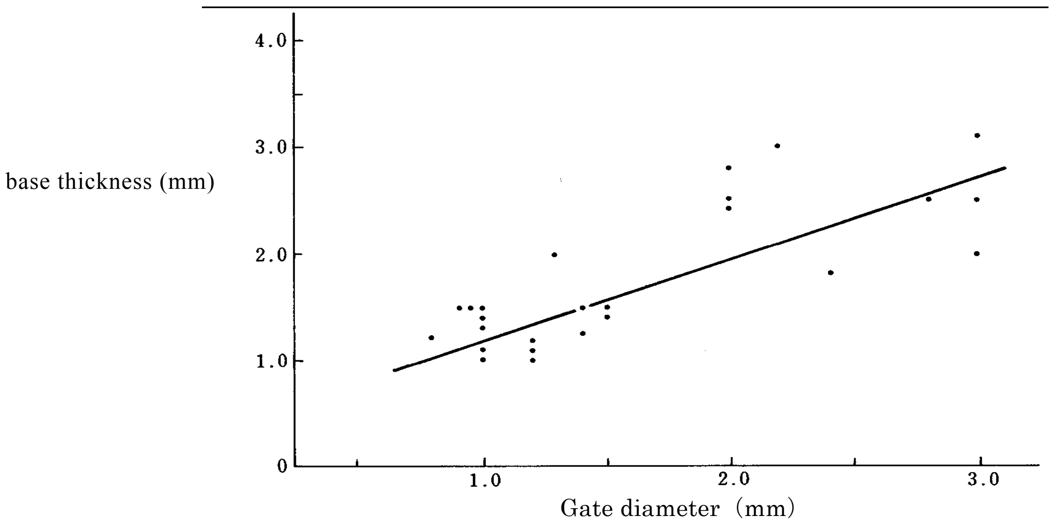


Fig. 3・2－7 Actual relationship between the pin gate diameter and the thickness of the base

The pressure loss at the gate of the circular section can be calculated by the following equation.

$$\triangle P = \frac{8uq}{\pi R^4} l$$

where, △p : pressure loss of the gate

u : viscosity of the resin

q : volume flow of the resin

R : gate radius

l : gate land length

Notes and the design standards of the shape of the direct sprue gate are similar to the items described at the section of sprue. Fig. 3・2-8 shows the examples of standard direct blue gate.

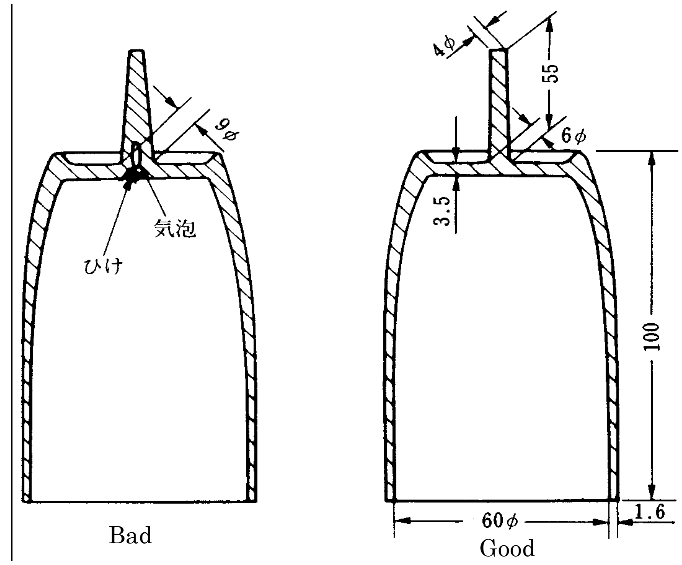


Fig. 3・2－8　Examples of direct sprue design

It is good to determine the gate diameter of the submarine gate in a similar way of the pin gate. The standard shape of the submarine gate is shown in Fig. 3・2-9.

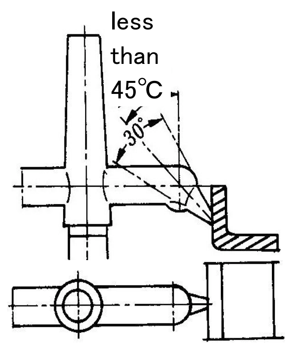


Fig. 3・2－9　Example of submarine gate design

The tab gate is effective for reduction of defects such as flow marks etc. but the pressure loss increases. Since this type of gate has both merits and demerits, it is recommended to use it properly.

4) Position of Gate

The standards to determine the position and the number of gates are as follows.

(1) Consider the thickness of the molded piece and the flowability of the resin (l/t).

(2) Arrange to allow the resin flow from the thick inside of the molded piece toward the thin inside.

The flowability data (bar-flow flow length) of Iupilon standard grade are shown in Fig. 3・2－10 and 3・2－11.

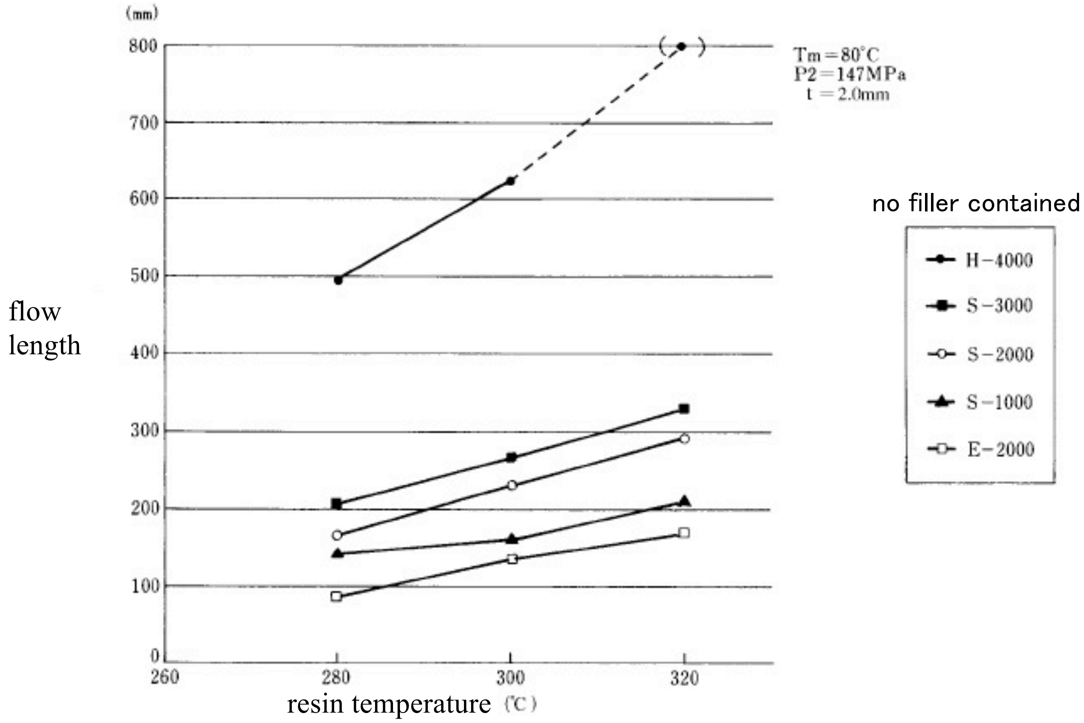


Fig. 3・2－10　Bar-flow flow length vs resin temperature

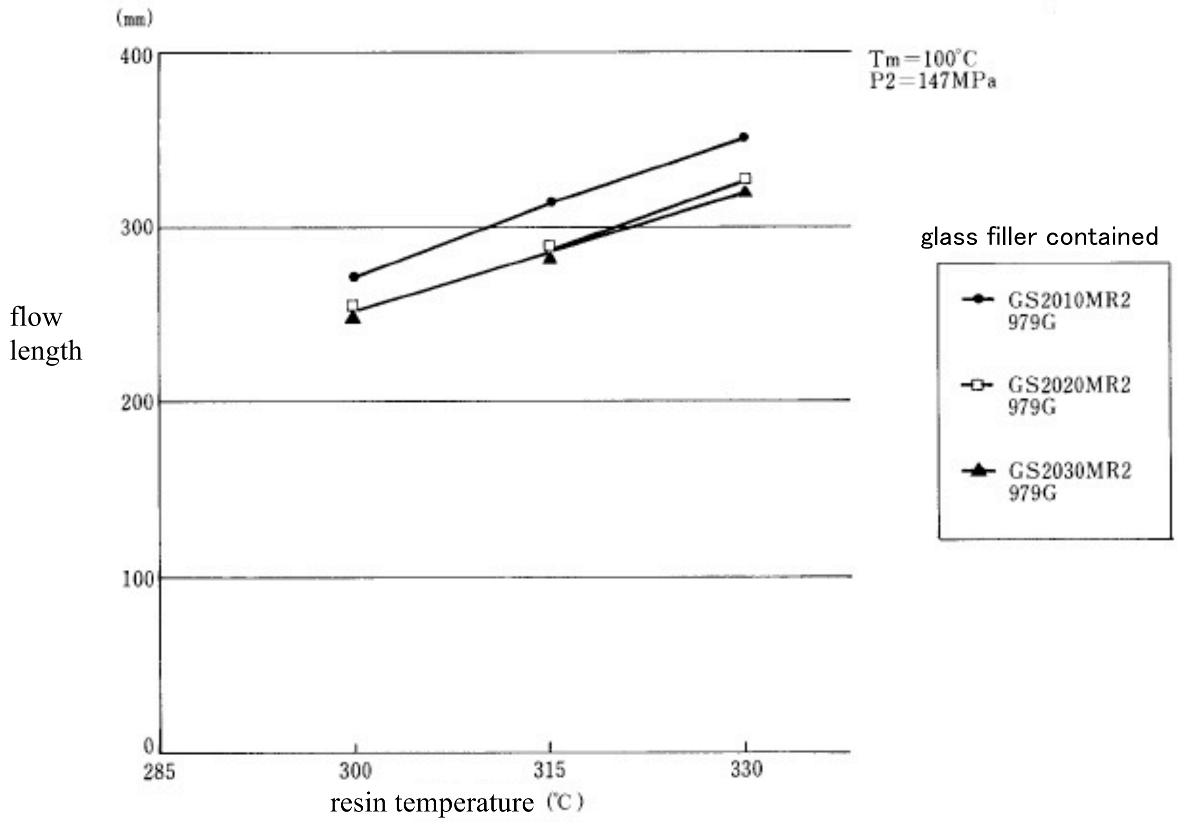


Fig. 3・2－11　Bar-flow flow length vs resin temperature

5） Taper

Because the mold shrinkage percentage of Iupilon is small and its adhesion with the metal is good, a proper taper should be provided. Generally, the taper standard is in the range of 1／100－1／50（0.5－1．0^0）.

6） Corner R

When the corner R is small, the crack occurs due to the concentration of stress and residue stress becomes large to cause defects such as flow marks etc. It is necessary to provide the range of 0.5 ~ 1.0mmR or more for the corner.

7） Mold Material

The mold steel materials include carbon steel, prehardened steel, hardened steel etc. as shown in Table 3･2-1. Especially, there is no restriction of the mold material and the material is used according to the purpose. For example, as for the mold to use the material containing glass fiber for molding, hardening steel such as SKD－61, SKS－3 etc. is used for abrasion resistance.

Table 3・2－1　Mold steel material

Classification	Hardness HRC	Material	Chemical composition	Examples of use
Pre hardened steel	13	HIT81	S55C	・general purpose resin, large-scale, general merchandise
	28	HIT82	SCM440	
	15－20	ZX10	Copper alloy	・high cycle production (TV housing, tape recorder and radio housing, washing machine cover)
	33	HPM2 HPM38 ASL30F	SCM improved (free cutting) SUS420J2 (improved) SUS420(improved)	・non-transparent product molding, die plate , holder (miscellaneous goods, toys, TV cabinet, tape recorder and radio) ・fire retardant agent additive resin, general transparent product, rubber (home appliances, medical equipment, tableware) ・anticorrosion goods (cassette, floppy case)
	35－40	PSL	SUS630 improved	・PVC, foaming resin, rubber (telephone, connecting, pipe, various reels)
	40	HPM1 HPM50 FDAC	AISIP21 improved AISIP21 improved SDK61 improved	・ABS reinforced resin, general processing, die plate (various home appliances, car inner panel miscellaneous goods) ・emphasis on made-up desk (mirror surface・embossing・electric discharging process) (dust cover, various transparent cases, OA equipment) ・engineering plastic, slide core
Hardened steel	50－55	HPM38 HPM38S	SUS420J2 improved SUS420J2 improved	・ Made-up anticorrosion mirror surface (video disk, cassette case, medical equipment, lighter parts) ・Made-up anticorrosion, hyper mirror surface (optical disk, aspheric lens)
	55－60	HPM31	SKD 11 improved	・abrasion resistant, precision engineering plastic (various gears, connectors, VTR cassette)
	60－68	HPM40	Powder high speed	・high abrasion resistant super engineering

	60－68	HPM40	steel	plastic (connectors, IC mold, gear)
Aging treatment steel	40－45	YHD50FM	High hardness non magnetic steel	・magnetic molding (plastic magnet)
	52－57	YAG	Super strength steel	・high toughness, tight mirror surface (various optical lens, thin-wall product molding core pin)

8） Mold heating and cooling

The design of heating and cooling of the mold is important in the molding of Iupilon / NOVAREX.

In the case of Iupilon / NOVAREX, it is preferable to set the mold temperature to 80℃ or more in order to reduce the molding strain, to improve the good appearance and the dimensional accuracy. The method of circulating oil or pressurized water for heating and cooling is the most suitable. When the core is heated locally, the method of using the chiller for cooling or thermo pipe for a core pin is recommended.

Since the space heater and cartridge heater are effective in the heating but ineffective in the cooling, it is preferable to use an auxiliary heat source of heating.

9） Ejection method

It is necessary to pay attention to the ejection method because the mold release resistance from the cavity is big in the case of Iupilon / NOVAREX.

When the ejection method is not suitable, defects such as cracks, deformation of the molded piece occur. Generally, the circular pin and angular pin are good for the direct ejection, the stripper plate and sleeve ejection methods are suitable for a deep product.

10） Air vent

When gas accumulates in the rib, the blind boss and the last filling part at the time of molding, defects such as resin burning, mold corrosion etc. due to the unfilling and the adiabatic compression occur. Especially, such a defect easily occurs when filling at high speed. Therefore, the air vent should be provided at these places. Especially, it is necessary to install air vent enough when molding the material such as compound reinforced grade with a lot of gas generation.

It is good to design the air vent clearance in the range of 1／100－3／100mm.

An example of the air vent design was shown in Fig. 3・2－12.

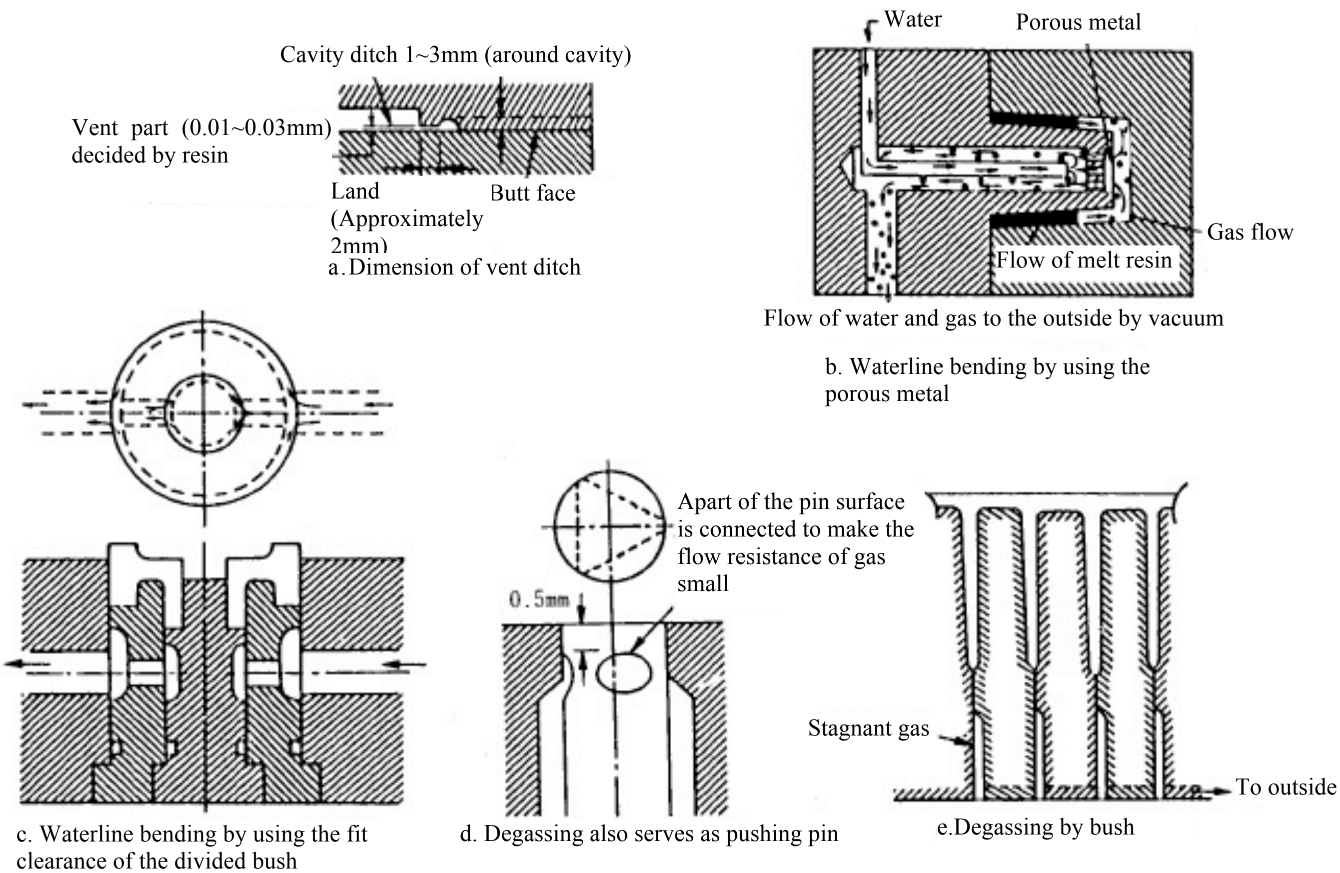


Fig. 3・2－12 Examples of air vent design

4. Mold shrinkage and dimensional accuracy

Mold shrinkage of Iupilon / NOVAREX varies depending on grade, molding conditions and shapes of molded piece as shown in Table 4－1. Mold shrinkage percentage of various grades of Iupilon / NOVAREX varies in the range of 0. 05－0. 70% as shown in Table 4－2.

Mold shrinkage after molding is stable for 24－48 hours as shown in Table 4－3.

As for the mold shrinkage anisotropy of the general grade, it is constant without depending on the flow direction of the resin and the right angle direction with it and has little anisotropy as shown in Table 4－4.

As for the glass fiber reinforced grade, a big difference in the mold shrinkage percentage in the flow direction of the resin and the right angle direction with it is recognized and the anisotropy is also observed. The relationship between the holding pressure and mold shrinkage percentage at the time of molding is shown in Fig. 4－2. The mold shrinkage percentage becomes low when increasing the holding pressure.

Dimensional accuracy is affected by the material, the molded piece shape, the design and the fabrication precision of the mold, and the molding conditions.

The dimensional tolerance of Polycarbonate which is published in SPI is shown in Table 4-5.

The example of the unevenness and the dimension tolerance of the molded piece with the shape are shown in Table 4－6 and Fig. 4－3.

The number of gates and roundness of the cylindrical molded piece, the number of gates and mold shrinkage percentage, and the measurement example of dimensional accuracy are shown in Fig. 4－4, －5, －6 and Table 4－7.

The following can be said from these results.

(1)The dimensional accuracy becomes low when the shape error is included.

(2)The dimension not decided by the mold, for example, the accuracy of the height dimension is low.

(3)The accuracy of the material containing the glass fiber is lower than that of the unreinforced material.

Table 4－1　Behaviour of mold shrinkage

	Items	Comments
Material	Melt viscosity	The holding pressure works well for the material with lower viscosity, the mold shrinkage percentage becomes low.
	Combination of filling agent and mold shrinkage percentage	When combining the filling agent, the mold shrinkage percentage becomes low.
	Anisotropy of mold shrinkage percentage	When combining the fibrous filling agent, the anisotropy occurs. As for the direction that the fiber oriented, the mold shrinkage percentage becomes low.
Design	Thickness	Because the pressure loss at the side where wall thickness is thin, the mold shrinkage percentage becomes high. The mold shrinkage percentage becomes high at the side where wall thickness is thick due to slow cooling effect. There is the intermediate thickness that the mold shrinkage percentage becomes minimized
	Gate	When the gate diameter is large, the mold shrinkage percentage becomes low. As for the material that there is anisotropy in the mold shrinkage percentage, the mold shrinkage percentage depends on the gate position and the number.
	Shape	The shape accuracy depends on the shape of the molded piece (roundness, cylindrical, straightness etc.)
Molding conditions	Holding pressure	When the holding pressure is high, the mold shrinkage percentage becomes low.
	Mold temperature	When the resin temperature is high, the mold shrinkage percentage becomes low.

Table 4－2　Mold shrinkage percentage of various grades of Iupilon / NOVAREX

Grade	Mold shrinkage percentage、%			
	Shape A		Shape B	
	／／	⊥	Inner diameter	Outer diameter
S2000	0．5—0．7		0．49	0．56
IJS2010	0．5—0．7			
IJS2020	0．5—0．7			
IJS2030	0．5—0．7			
GS2010M	0．3	0．5		
GS2020M	0．1	0．4		
GS2030M	0．05	0．3	0．15	0．23
LGS2230M	0．08	0．31	0．16	0．24

LGS2230MA	0. 20	0. 36	0. 24	0. 34
LCF2410	0. 09	0. 24	0. 13	0. 21
LCF2415	0. 07	0. 31	0. 07	0. 14
LCF2410A	0. 22	0. 32	0. 27	0. 33

Shape A : t3. 2× ϕ 100mm circular plate (／／) : parallel to the gate

Shape B : (OD) 58× (ID) 54× (H) 25mm (⊥) : vertical to the gate

Cylindrical molded piece Gate : pin gate／3 points／ϕ 1.5mm

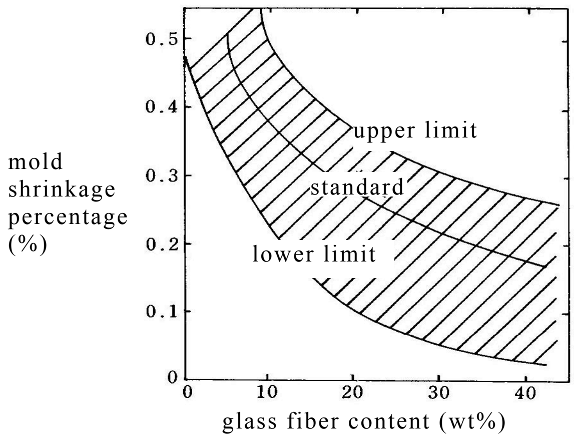


Fig. 4－1 Influence of glass fiber content to mold shrinkage percentage

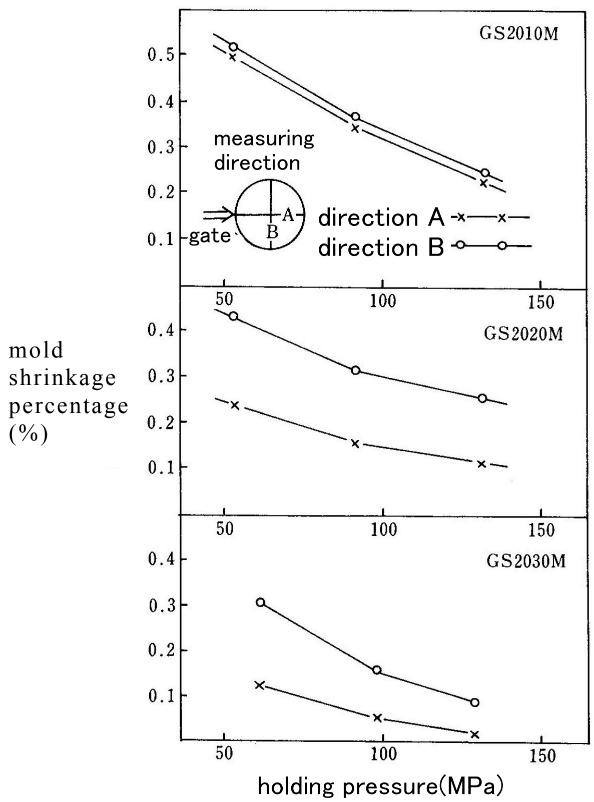


Fig. 4－2 Mold shrinkage percentage vs Holding pressure

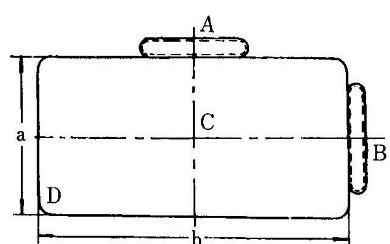
Table 4－3　Mold shrinkage of Iupilon / NOVZREX

Molding conditions			Mold shrinkage (cm／cm)		
Cylinder temperature (℃)	Injection rate	Injection pressure MPa (kg／cm2)	After 5 days	After 10 days	After 30 days
270	2	137 (1400)		0. 0076	
〃	8	〃 (〃)	0. 0076	0. 0079	0. 0076
290	2	82 (840)	0. 0082	0. 0084	0. 0082
〃	8	〃 (〃)	0. 0072	0. 0076	0. 0076
〃	2	137 (1400)	0. 0060	0. 0062	0. 0059
〃	8	〃 (〃)	0. 0065	0. 0065	0. 0068
310	2	82 (840)	0. 0066	0. 0067	0. 0065
〃	8	〃 (〃)	0. 0065	0. 0066	0. 0068
〃	2	137 (1400)	0. 0059	0. 0061	0. 0059
〃	8	〃 (〃)	0. 0057	0. 0057	0. 0057

Table 4－4　Mold shrinkage of polycarbonate

Position of gate	a		b	
	Length mm	Shrinkage %	Length mm	Shrinkage %
A	86. 31	0. 79	184. 60	0. 75
B	86. 32	0. 78	184. 61	0. 75
C	86. 30	0. 80	184. 61	0. 75
D	86. 30	0. 80	184. 56	0. 77

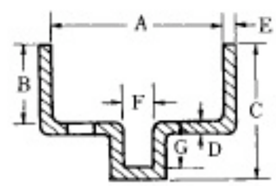
Note）Test mold for measuring shrinkage



a＝87mm b＝186mm　Thickness＝2.5mm

Table 4－5　PC dimensional tolerance (from SPI information)

	Dimension (mm)	Tolerance (mm): ±0. 05　±0. 10　±0. 15　±0. 20　±0. 25	
A inside diameter (Note 1) B Depth (Note 2) C Height (Note 2)	20 40 60 80 100 120 140	General, precise	
	152.4－304.8 (add the tolerance at right to every 25.4mm)	General±	Precise±
		0. 076	0. 038
D bottom thickness (Note 2)		0. 076	0. 051
E side thickness (Note 3)		0. 076	0. 051
F pore diameter (Note 1)	0. 00－　3. 18 3. 18－　6. 35	0. 051 0. 051	0. 025 0. 038
	6. 35－12. 70 12. 70－	0. 076 0. 076	0. 051 0. 051
G pore depth (Note 4)	0. 00－　6. 35 6. 35－12. 70 12. 70－25. 40	0. 051 0. 076 0. 102	0. 051 0. 051 0. 076



（Note） The tolerance based on the premise of 3.2mm thickness.

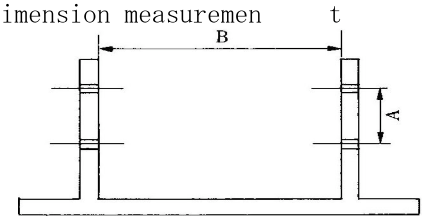
（1） This tolerance is not the accuracy including the aging characteristic of the material.
（2） Take the parting-line into consideration.
（3） As for the shape of the parting, it is necessary to make the thickness become uniform as much as possible.(Though it is impossible to make the thickness become uniform completely for this shape)
（4） Note that the ratio of the hole depth to the diameter is not to become the span that the core pin is damaged.

Table 4－6 Unevenness and dimensional tolerance of the sample.

	Drawing dimension	Molded piece dimension
A 1)	29 ±0. 1	28. 911±0. 03
	35 ±0. 1	35. 017 ±0. 27
	75 ±0. 1	74. 951±0. 17
	155 ±0. 3	154. 868±0. 13
	175 ±0. 3	174. 727 ±0. 14
	272 ±0. 3	271. 667 ±0. 23
	280 ±0. 3	279. 920±0. 14
B 1)	54	56. 871±0. 05
	74. 5±0. 5	74. 961±0. 27
	93 ±0. 3	93. 365±0. 40
	126	125. 984 ±0. 28
	274	274. 759±0. 41
	278 ±0. 3	278. 323 ±0. 24
	286	286. 260±0. 34

(Material：GS2030MR2)

Note) 1) Position of dimension measurement



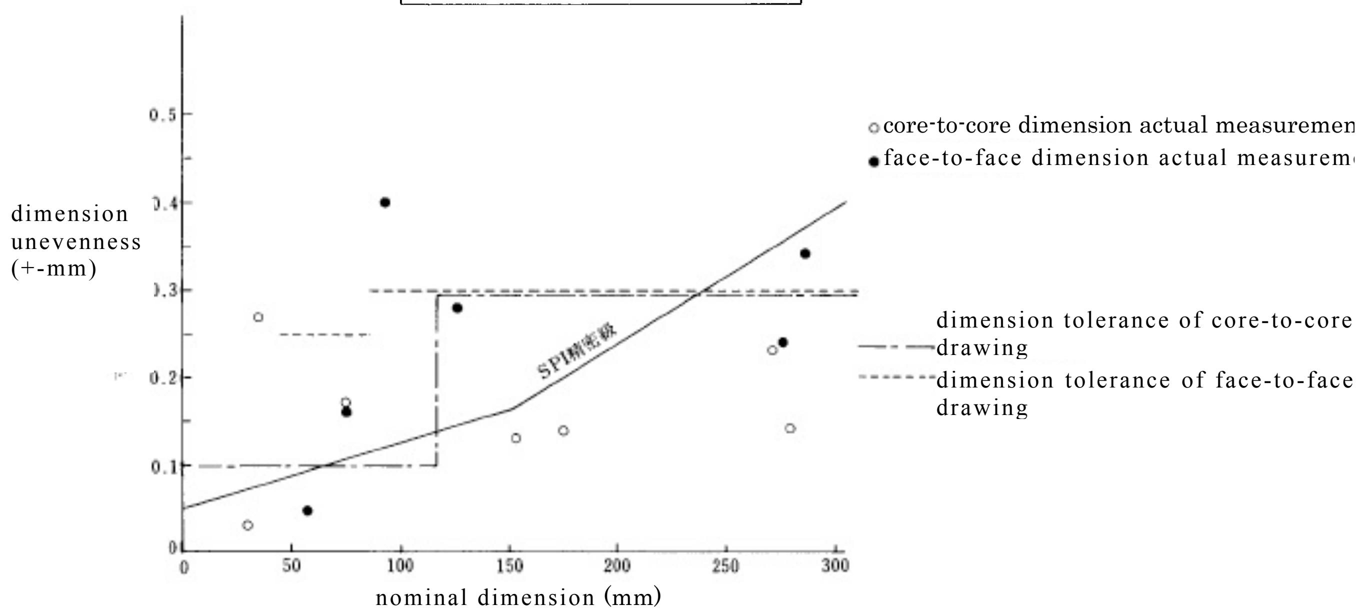


Fig. 4－3 Nominal dimension vs Dimension unevenness

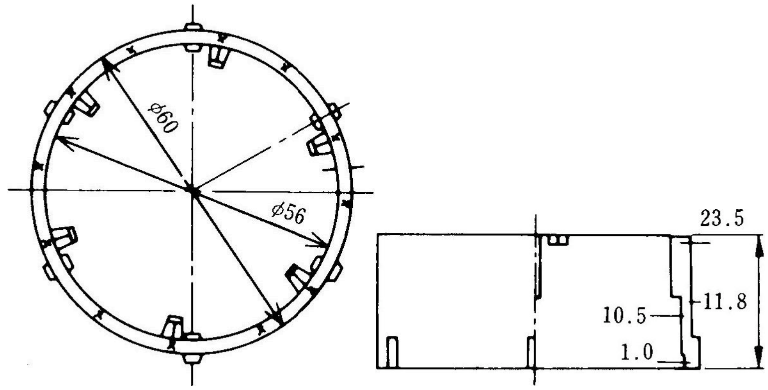


Fig. 4－4　Shape of molded piece and Position of dimension measurement

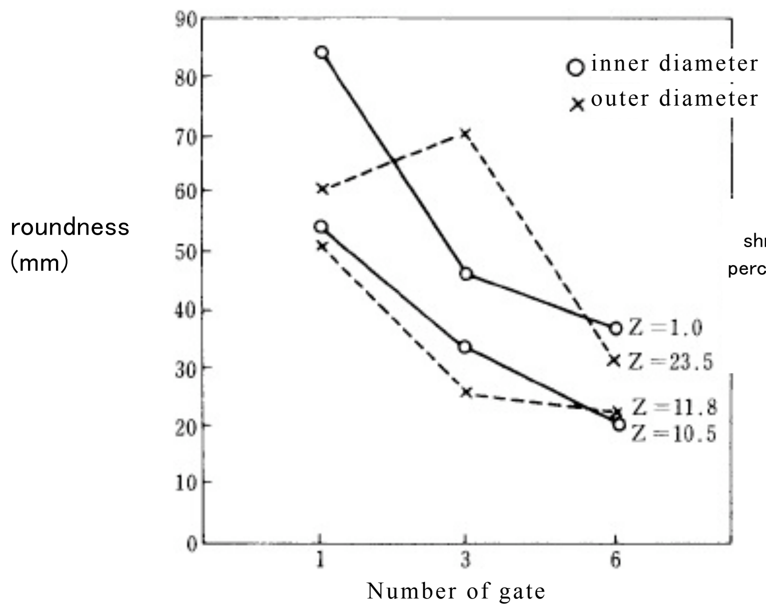


Fig. 4－5　Number of gate vs circularity
(Relation to position of direction of height)

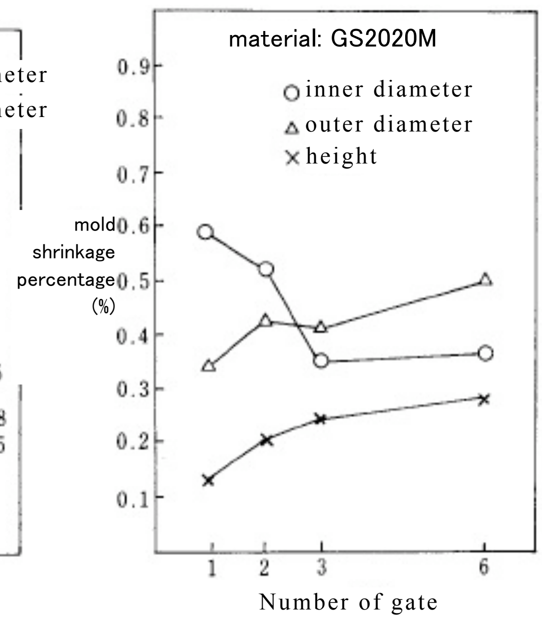


Fig. 4－6 Number of gate vs mold shrinkage percentage

Table　4－7　Example of measuring dimension accuracy of Iupilon

Shape error / Position / Material	Including the shape error			Not including the shape error		
	OD	ID	Height	OD	ID	Height
S2000	±17	±16	±25	±9	±9	±12
S3000	±16	±18	±21	±7	±9	±12
GS2020M	±36	±29	±39	±8	±9	±27

Molding machine : 〈 Sumitomo Neomat 〉 N350／120（〈 with Cycap〉）

Molded piece : cylindrical molded piece　（OD 60mmϕ， ID 56mmϕ， Height 25mm）

Molding conditions : The resin temperature, injection rate, injection pressure, and mold temperature etc. were changed according to the experimental design.

Data： show by the value of 3α.

The outer diameter, inner diameter, height etc. were measured with 3D dimension measurement machine for several points and their data analysis was done.

“Including the shape error” is when analyzing by each measuring value, and “Not including the shape error” is when analyzing by the average value.

5．CAE

CAE(Computer Aided Engineering) has been widely introduced to the design of the injection-molded piece as an assistive technology of the product and the mold design.

The advantages are as follows.

（1） The prototype test period can be shortened because the computer can be used for case study.

(2) A reasonable and economical design can be done because the extra design from the safety viewpoint is not needed.

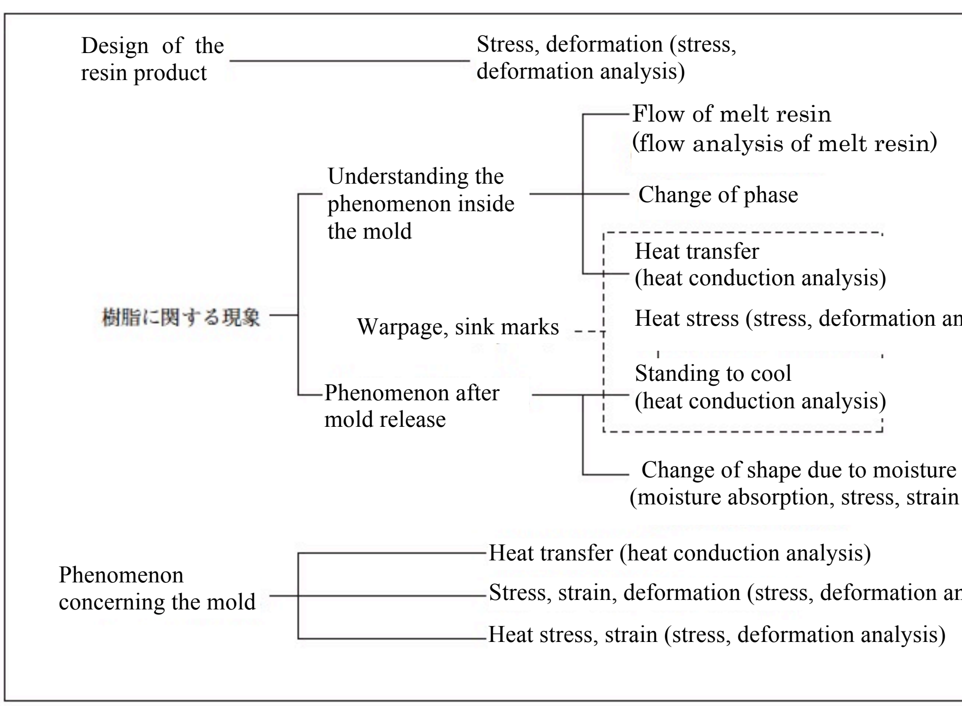
(3) The product quality can be improved because the system design including materials, shape of molded piece, mold and molding conditions etc is possible.

(4) Compared with empirical molding data, the analytical data by CAE has the generality and is possible for effective utilization.

Especially, it can be used by an unskilled worker of the molding.

As for the application scope of CAE, as shown in Table 5-1, stress of the resin product (structural analysis), deformation analysis, flow behavior of the resin inside the mold (flow analysis), supposition of the weld line, conduction of heat inside the mold (thermal analysis), and estimation of temperature distribution of the resin at the time of the last filling are conducted.

Table 5－1　CAE Application



The data base of each resin and each grade is necessary when analyzing, and it is divided into the solid state properties and melted state properties. As for the solid state properties, the values of mechanical physical properties of normal Iupilon are used as shown in Table 5－2.

Table 5－2 Values of mechanical physical properties of Iupilon
(Young modulus, shear modulus, Poisson's ratio, coefficient of linear thermal expansion)

			Iupilon S2000	GS2015M	GS2020M	GS2025M	GS2030M
Young modulus E[1] (Kg／cm2)			23. 0×103	39. 8×103	46. 9×103	59. 0×103	80. 8×103
Shear modulus G[2] (Kg／cm2)			7. 97×103	14. 6×103	17. 2×103	21. 8×103	29. 9×103
Poisson ratio ν[3]			0. 38	0. 365	0. 36	0. 355	0. 355
linear coefficient of expansion α[4] ($\times 10^{-5}$ cm／cm℃)	a (1. 6t)	(／／)	5. 72	2. 84	2. 41	2. 15	1. 78
		(⊥)	6. 36	5. 41	5. 35	5. 05	4. 80
	b (3. 2t)	(／／)	6. 57	3. 08	2. 62	2. 45	2. 26
		(⊥)	7. 07	6. 35	6. 17	6. 00	5. 86

Notes) 1) modulus of elasticity, E.
2) shear modulus, G＝E／2（1＋ν）.
3) Poisson's ratio, ν.
4) coefficient of linear thermal expansion, α

As for the melted state properties, viscosity data are shown in Fig. 5-1 ~ 5-5, specific heat data in Fig. 5-6, coefficient of heat conductivity in Fig. 5-7, and P－ν－T data in Fig. 5-8.

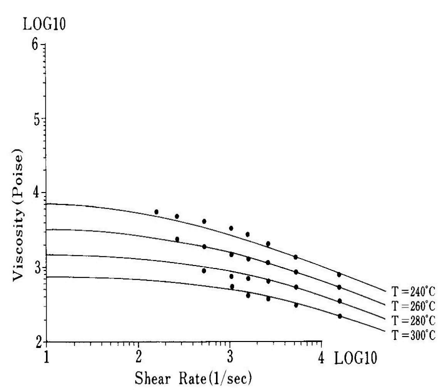


Fig. 5－1 Viscosity curve （Iupilon H－4000）

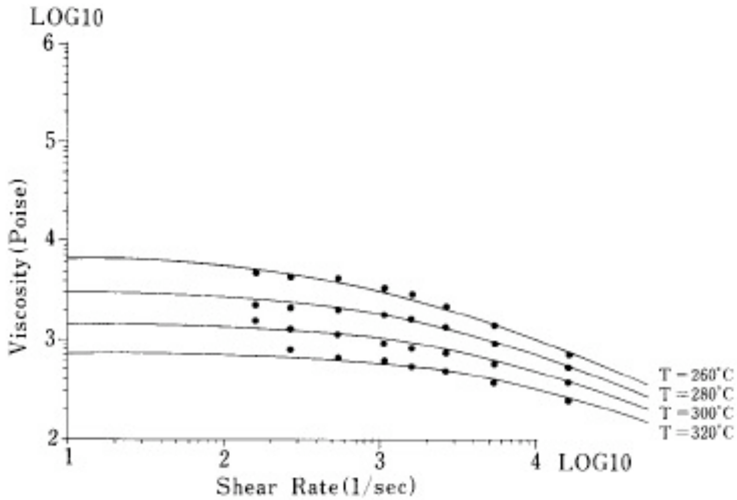


Fig. 5－2　Viscosity curve　(Iupilon H－3000)

Iupilon S3000 flow analysis data

(Single－point polymer specific heat)		2．2858E＋03	J／Kg．deg－C
(Single－point polymer thermal conductivity)		2．6000E－01	W／m－K
(Constant polymer density)	(solid density)：	1．2000E＋03	kg／m3
	(melt density)：	1．0500E＋03	kg／m3
(Freeze Temperature)		144 ℃	
(No Flow Temperature)		170 ℃	

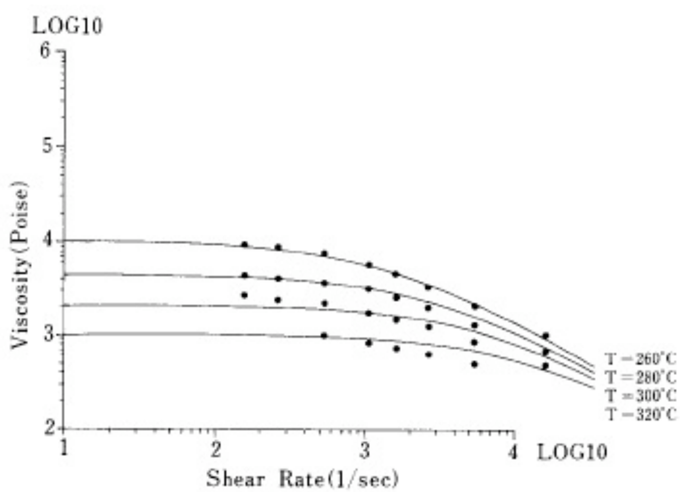


Fig. 5－3　Viscosity curve (Iupilon S3000)

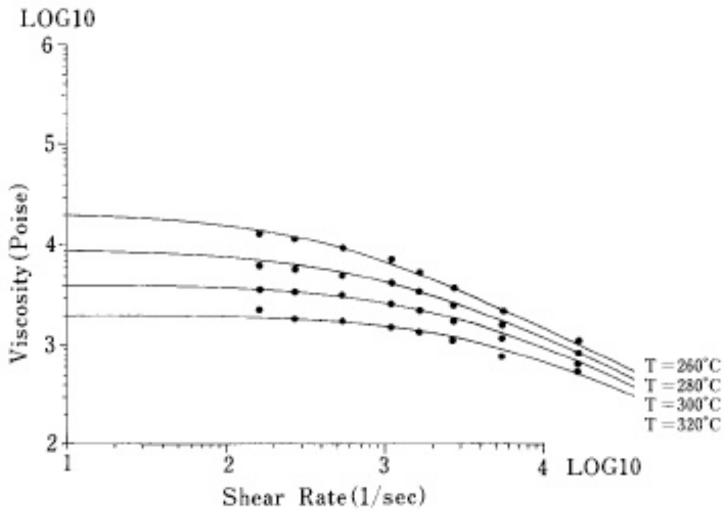


Fig. 5－24　Viscosity curve（Iupilon S2000）

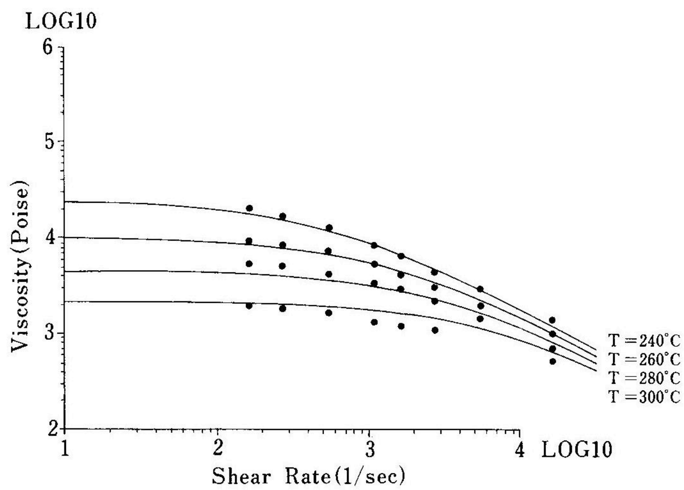


Fig. 5－5　Viscosity curve（Iupilon SI000）

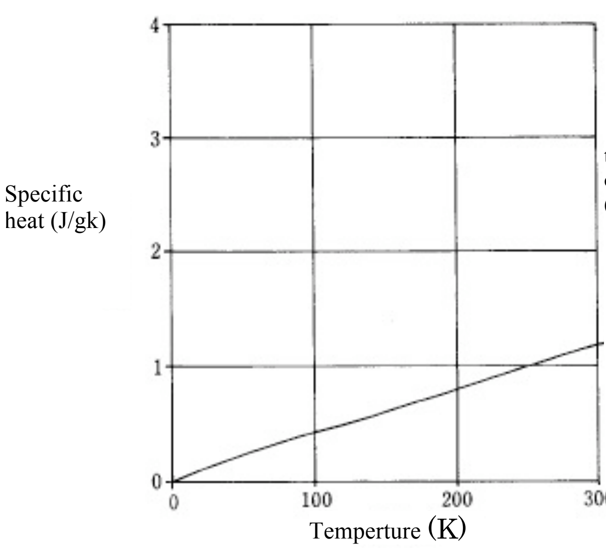


Fig. 5－6　specific heat data

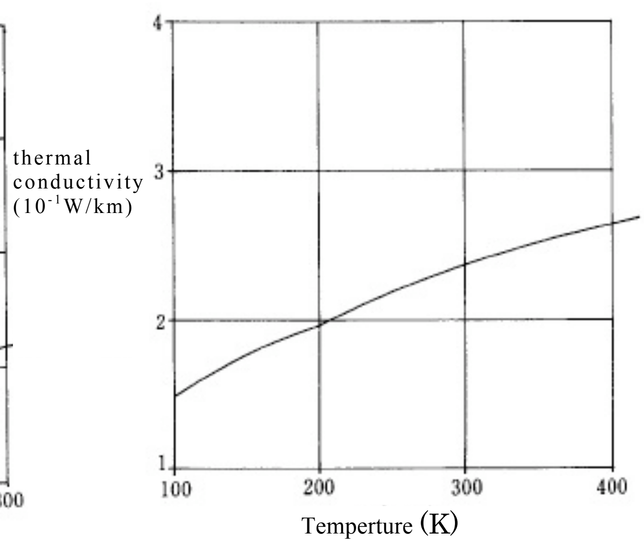


Fig. 5－7　thermal conductivity data

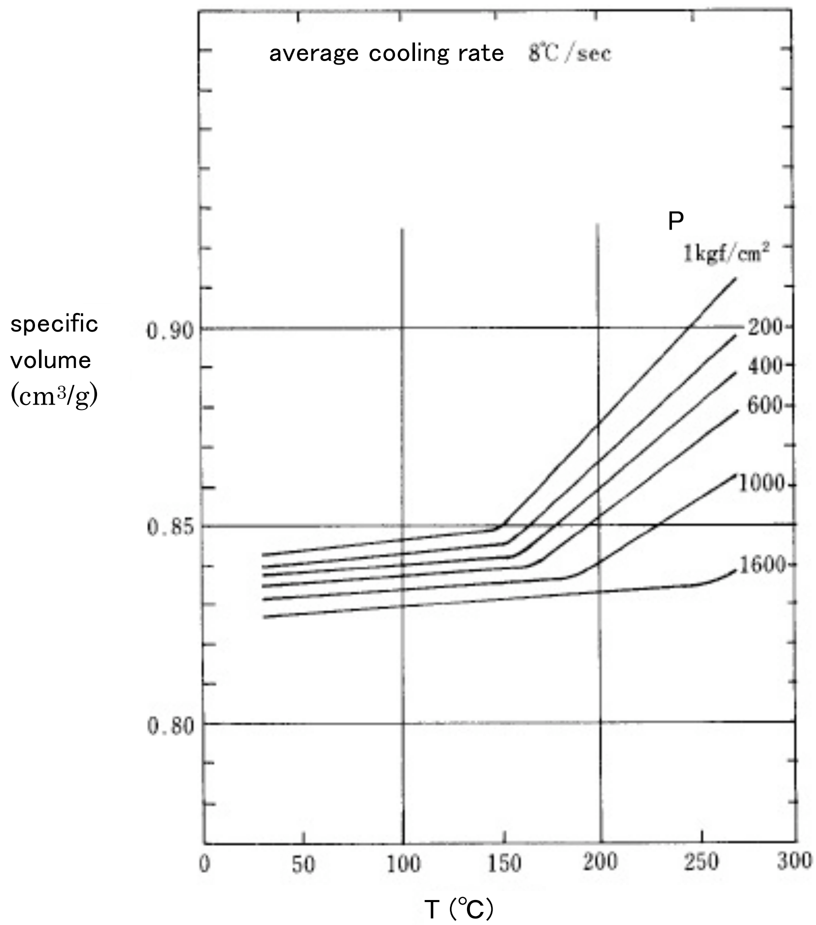


Fig. 5－8　P－ν－T data

6. Hot runner molding

The hot runner molding of Iupilon/NOVAREX is used for the purpose of reducing cost by the reduction of the cold runner, improving the flowability by the reduction of pressure loss of the cold runner part.

As for the hot runner system, the heating method, different types of the gate seal method are variously developed.

The advantage and disadvantage by the difference of the heating method are as follows.

(1) The internal heating method becomes adiabatic when the heater position is away from the cavity.

(2) As for the external heating method, insulating the cavity from heat is necessary though the flow path is simple.

The advantage and disadvantage by the difference of the gate seal method are as follows.

(1) As for the open gate method, the structure control is simple, sac back is indispensable and there is a limit to the gate.

(2) The mechanical seal method has small pressure loss. The gate sealing is perfect and there is neither drooling nor stringiness, but on the other hand, the structure is complicated, and there is a limit between pitches of the gate in the case of multipoint gate.

(3) As for the thermal seal method, there is a limit to the gate diameter, and it is hard to keep the gate balance in the case of multipoint gate.

The points to keep in mind when selecting the hot runner system are as follows.

1) There is no stay of the resin.

2) The structure must be simple as possible.

3) Neither drooling nor stringiness, and the adjustment must be easy.

4) There be an adiabatic-efficiency at the gate part.

5) The color replacement must be easy.

6) As for the valve gate method, there is no resin stay in the sliding part of the pin, and the pin is not eccentric.

7) The maintenance must be easy.

8) The gate diameter is large, and the pressure loss is small.

7. Reuse of Iupilon / NOVAREX

As for the regrind material use of Iupilon/NOVAREX, the method of use by mixing 20-30% of the regrind material with new material is recommended. The results of measuring the physical properties of 100% and 30% regrind materials by using Iupilon S3000R are shown in Table 7－1, 7－2. In the 100% regrind material, after repeated use of this material, the reduction of molecular weight, the increase of discoloration degree and the reduction of overall light transmittance are observed. On the other hand, there are few changes of these physical property values in the 30% regrind material.

test items / unit / reuse frequency	molecular weight	total light transmittance	haze value	YI value	tensile yield strength	tensile failure strength	tensile failure elongation	Izod impact value
	×10⁴	%	%		MPa(kg/cm²)	MPa(kg/cm²)	%	J/m(kg·cm/cm)
0	2.3	88.8	1.7	—	62.6(638)	68.2(695)	120	858(87.5)
1	2.3	87.2	2.1	2.5	61.8(630)	63.8(651)	112	784(79.9)
2	2.2	86.2	2.1	5.2	61.8(630)	66.1(674)	113	782(79.7)
3	2.2	85.8	2.3	8.1	61.9(631)	61.8(630)	104	828(84.4)
4	2.2	84.2	2.6	10.9	61.8(630)	60.8(620)	95	782(79.7)
5	2.2	82.7	3.0	14.6	61.9(631)	63.3(645)	109	862(87.9)
6	2.1	81.5	4.1	18.2	61.7(629)	65.3(666)	113	715(72.9)
7	2.1	80.4	3.8	19.3	61.6(628)	64.2(655)	110	870(88.7)
8	2.1	79.1	4.3	26.0	61.7(629)	60.6(618)	98	870(88.7)
9	2.1	78.3	4.2	28.9	61.7(629)	62.4(636)	104	786(80.1)
10	2.1	77.4	5.1	30.9	61.6(628)	62.0(632)	102	844(86.1)

Notes) 1) thickness 3.2mm with 0.25R notch

Table 7-1 Physical properties of Iupilon S-3000R (100% of the regrind material)

test items / unit / reuse frequency	molecular weight	total light transmittance	haze value	YI value	tensile yield strength	tensile failure strength	tensile failure elongation	Izod impact value
	$\times10^4$	%	%		MPa(kg/cm^2)	MPa(kg/cm^2)	%	J/m(kg·cm/cm)
0回	2.3	88.8	1.7	—	62.6(638)	68.2(695)	120	858(87.5)
1回	2.2	88.2	1.2	1.2	61.9(631)	69.2(706)	120	861(87.8)
2回	2.2	87.9	2.0	1.7	61.9(631)	72.6(740)	127	856(87.3)
3回	2.2	88.0	1.2	2.0	62.3(635)	68.6(700)	121	854(87.1)
4回	2.2	88.0	1.3	1.9	62.2(634)	66.2(675)	123	856(87.3)
5回	2.2	88.0	1.0	1.9	62.1(633)	71.4(728)	129	900(91.8)
6回	2.2	88.2	1.0	2.5	62.2(634)	67.9(692)	119	870(88.7)
7回	2.2	88.0	1.5	2.0	62.2(634)	70.9(723)	124	863(88.0)
8回	2.2	88.0	2.0	2.5	61.8(630)	71.4(728)	129	856(87.3)
9回	2.2	88.0	1.0	1.8	61.7(629)	67.6(689)	121	858(87.5)
10回	2.2	88.0	1.4	1.8	61.3(625)	70.9(723)	128	868(88.5)

Notes) 1) thickness 3.2mm with 0.25R notch

Table 7-2 Physical properties of Iupilon S-3000R (30% of the regrind material)

The relationship between the reuse frequency and strength of Iupilon GS2010M (containing glass fiber) is shown in Table 7-3. In the case of glass fiber reinforced PC, the strength falls because the glass fiber crushes by repeated use of the material as shown in this table. The 30% regrind material mixture has less strength fall than the 100% regrind material.

The various factors to affect to the performance deterioration due to the regrind material use of PC are summarized in Table 7-4. It should be noted that the reuse causes the performance deterioration due to the contamination of foreign substances besides the degradation of the material.
The general notes for the use of the regrind material are given as follows.

(1) Because the mixture ratio of the regrind material changes according to the heat stability of the material itself (presence of the additive and the filling agent or not) and molding conditions (controlled state of the regrind material, mold temperature and dwell time) etc., the mixture ratio should be decided to correspond to each material and molding condition.

(2) The regrind material should be used without any contamination of foreign substances (other resin, dust, mold release agent, oil, insert metal fitting) etc. When the regrind material is used with the adherence of the mold release agent that had been used at the time of molding by the transparent material, the molded piece may become bleached.

(3) The use of the regrind material at the molded piece which is extremely affected by the contamination of glasses lens, optical lens, optical disk substrate should be avoided. (Refer to Table 7-5).
It is better to use the regrind material for other application that the contamination does not become a problem.

(4) When the crushed regrind material is used, the measurement at the time of plasticizing becomes uneven when the screw diameter is small, and the dimension of the precise molded piece may vary widely from the tolerance.
In this case, the management of the grain diameter of the crushed material or the measure of the re-pelletizing etc. is necessary.

(5) As for the molded piece that inserts metal fitting, it is better to adopt the method that inserts it after the molding as much as possible.

Table 7－3 Reuse test results of glass fiber reinforced PC

Classification	Reuse frequency	Average fiber length （〃m）	Bending strength MPa（kgf／cm2）	Bending elastic modulus GPa（kgf／cm2）
Virgin material	－	241	112（1，220）	3．53（36，000）
100% reuse	1	187	111（1，130）	3．30（33，700）
	2	154	105（1，070）	3．10（31，600）
	3	146	102（1，040）	3．03（30，900）
	4	140	109（1，110）	2．96（30，200）
30% reuse	1		116（1，180）	3．38（34，506）
	2		116（1，180）	3．40（34，700）
	3		116（1，180）	3．40（34，700）
	4		116（1，180）	3．40（34，700）

Material : Iupilon GS2010M（10% glass fiber）

Table 7－4　Various factors to affect to the performance deterioration of the regrind material

Factors	Contents
Heat deterioration of material and crushing of filling material	Heat stabilizer Kind and amount of colorant, kind and shape of filling material
Deterioration due to processing conditions	Preliminary drying (temperature, time） Molding temperature Molding cycle Capacity of molding machine
Contamination of foreign substances	Contamination of mold release agent（adhesion of blowing mold release agent used in the previous molding） Adhesion of oil（molding oil etc.） Contamination of black specks（carbide） Contamination of metal powder（insert metal fitting atc.） Contamination of different resin Other contamination

Table　7－5 Analysis results of contamination

Contamination size（μm）	0．5－0．5	1－2	2－5	5－10	10－21
New material	12，000	200	50	0	0
20%regrind material	522，320	5，290	680	100	0
30%regrind material	858，710	8，790	1，220	90	10
50%regrind material	1，406，230	16，680	2，000	200	10

Notes)　Measuring method: Laser light scattering method HIAC/ROYCO 4000 Model Particle counter

Material: Iupilon H-3000R

8. Annealing treatment of Iupilon / NOVAREX

8・1 Annealing treatment

Generally, the residual stresses exist in the injection molded piece due to some causes. Especially, the residual stresses are empirically known to be large at the vicinity of the gate, the edge part of the molded piece, and the part where there is a big change of the thickness of the product etc.
When there are residual stresses in the molded piece, if oil, grease, printer's ink, paints, and thinner, etc. come in contact with it, the crack will occur.
Therefore, in order to remove residual stresses in the molded piece, the so-called annealing treatment is carried out by heating at the temperature which is about 20℃ lower than the glass transition temperature of PC（Tg≒145℃）, then maintaining at this temperature in a given time and after that conducting the cooling operation to room temperature.
Iupilon / NOVAREX is annealed at 120－125℃ for 1-2 hours. It is good to carry out the annealing in a short time for the simple shape and when the thickness of the product is thin, but for a complicated shape or if the thickness of the product is thick, annealing for 2-3 hours is required in consideration of safety.
The results of the relationship between the annealing treatment time and the residual stress by using a tensile test piece of 3.2mm thickness and a bend test piece of 6.4 mm thickness are shown in Fig. 8・1-1.

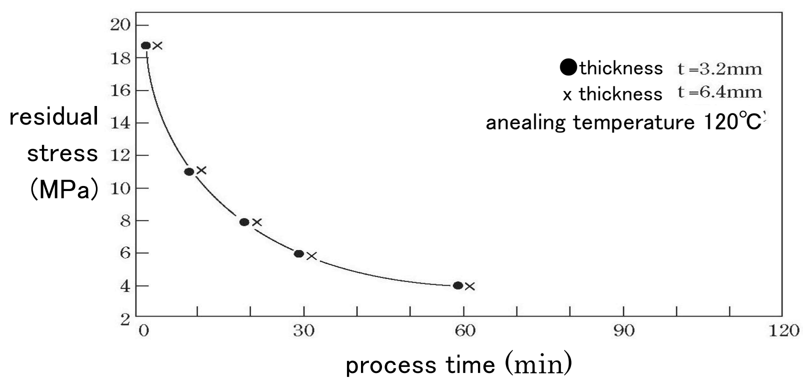


Fig. 8・1－1 Annealing treatment time vs residual stress

Fig. 8・1-1 shows that the residual stress decreases with the annealing treatment time regardless of the thickness of the sample.

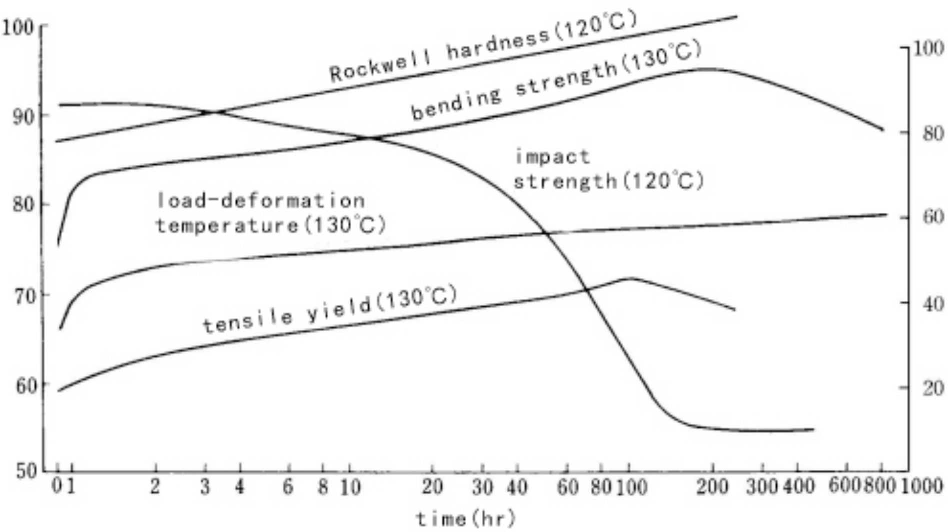


Fig. 8・1－2　Change of physical properties by heat treatment of Iupilon / NOVAREX

The crack concentrates on the vicinity of the gate and the edge part before annealing, and on the whole, a lot of residual stresses at the surface coat are observed. However, with the test piece of the simple shape like this test, the stress relief advances to the extent that the crack is slightly observed if the annealing is treated for 30 minutes.
As for the detection method of residual stress, refer to Section 2・4-2 of the molding strain.
The hot air circulation-type oven is usually used as the heating method for annealing treatment.
Water and oil, etc. can be used as heat carriers for other resin, but they are not proper for Iupilon / NOVAREX because they cause the hydrolysis and solvent crack.

When annealing Iupilon / NOVAREX, the following changes are observed.
(1) Elongating the annealing causes the decrease of impact strength （Refer to Fig. 8・1－2）.
(2) Change in dimension due to heat shrinkage (heat shrinkage percentage 0.1－0.15% at120℃).
(3) Cost increase

From the above results it had better avoid the annealing treatment as much as possible.

The main purpose of the annealing is to remove residual stress in the molded piece、but in the case of Iupilon / NOVAREX, except the necessity to conduct the annealing treatment due to unavoidable circumstances, the product design and molding conditions should be considered to reduce residual stress.

Recently, the method of applying the far-infrared radiation is known to be effective for the annealing treatment. According to this method, about 1/3 - 1/2 of the annealing treatment time can be shortened in comparison with conventional method. The summary is introduced in next section.
（Please contact us for more information）

8・2　Annealing effect of using both hot air / far infrared radiation systems

The following effects were confirmed by measuring the residual stress after annealing the molded piece, surface temperature, and inner temperature of the molded piece.

(1) When using both the heating systems of hot air, far infrared radiation together, the annealing treatment time can be shortened 3-4 times in comparison with the case of using only the hot air heating system.

(2) In the case of using only the far infrared radiation heating system, the heating rate can be rapidly quickened by raising the heater temperature but
it could lead to the excessive heating of the heated piece.

(3) In the case of using both the heating systems of hot air, far infrared radiation together, when the current does not applied to the far infrared radiation heater and it is heated by the same temperature by hot air, the molded piece temperature raises at the speed almost similar to the time of applying current.

(6) Because the annealing treatment time depends strongly on the heating temperature of the molded piece, if 5 minutes have passed after the molded piece temperature reached 120 °C, the annealing is completed.

(7)

Table 8・2－1　Change in Izod impact strength after annealing
Test material：Iupilon S3000（t＝3．2 impact bar　0．25R with notch）

Far infrared radiation annealing			Oven annealing		
Treated time (min)	IZOD Strength 0／m)	Brittle failure n＝5	Treated time (hrs)	IZOD Strength 0／m)	Brittle failure n＝5
0	821	0／5	0	821	0／5
1	870	0／5	1	811	0／5
3	835	0／5	3	665	1／5
5	830	0／5	5	532	2／5
10	830	0／5	10	262	4／5

Annealing conditions：Far infrared radiation annealing　Panel temperature 180℃
Hot air temperature 140℃
Oven annealing 120℃

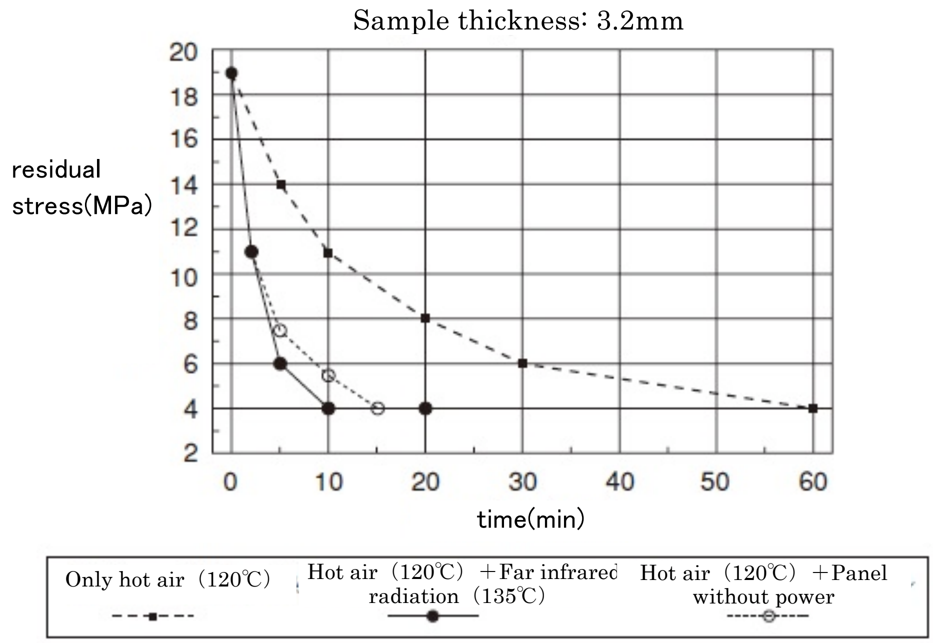


Fig. 8・2－1　Residual stress decreasing curve of flat plate

Mitsubishi Gas Chemical Company, Inc., our parent company is the patent-holding company of this technology.

(Registration number: 20 77432　Registered on August 9,　1996)

International System of Units（abbreviated SI）

Main Unit Conversion Table

Force	N	dyn	kgf		
	1	1×10^{5}	1．01972×10^{-1}		
	1×10^{-5}	1	1．01972×10^{-6}		
	9．80665	9．80665×10^{5}	1		

Pressure	Pa	kgf /cm^2	atm	mmHg・Torr	
	1	1．01972×10^{-5}	9．86923×10^{-6}	7．50062×10^{-3}	
	9．80665×10^{4}	1	9．67841×10^{-1}	7．35559×10^{2}	
	1．01325×10^{5}	1．03323	1	7．60000×10^{2}	
	1．33322×10^{2}	1．35951×10^{-3}	1．31579×10^{-3}	1	

Stress	Pa or N／m^2	kgf /mm^2	kgf /cm^2		
	1	1．01972×10^{-7}	1．01972×10^{-5}		
	9．80665×10^{6}	1	1×10^{2}		
	9．80665×10^{4}	1×10^{-2}	1		

Energy・Work・Heat	J	kW・h	kgf・m	kcal	
	1	2．77778×10^{-7}	1．01972×10^{-1}	2．38889×10^{-4}	
	3．600×10^{6}	1	3．67098×10^{5}	8．6000×10^{2}	
	9．80665	2．72407×10^{-6}	1	2．34270×10^{-3}	
	4．18605×10^{3}	1．16279×10^{-3}	4．26858×10^{2}	1	

Power	W	kgf・m／S	PS	kcal／h	
	1	1．01972×10^{-1}	1．35962×10^{-3}	8．5985×10^{-1}	
	9．80665	1	1．33333×10^{-2}	8．43371	
	7．355×10^{2}	7．5×10	1	6．32529×10^{2}	
	1．16279	1．18572×10^{-1}	1．58095×10^{-3}	1	

Viscosity（viscous modulus）	Pa・S	cP	P		
	1	1×10^{3}	1×10		
	1×10^{-3}	1	1×10^{-2}		
	1×10^{-1}	1×10^{2}	1		

Kinetic viscosity（kinematic viscosity	m^2／S	cSt	St		
	1	1×10^{6}	1×10^{4}		
	1×10^{-6}	1	1×10^{-2}		
	1×10^{-4}	1×10^{2}	1		

coefficient)					

Heat conductivity	W／（m・K）	kcal／(h・m・℃)			
	1 1．16279	8．6000×10^{-1} 1			

Specific heat	J／（kg・K）	kcal／（kg・℃） cal／（g・℃）			
	1 4．18605×10^{3}	2．38889×10^{-4} 1			

CAUTION

● Data described in this catalog are typical examples of the measurement by our company's test method.

● The use application described in this catalog does not guarantee the application result to the said usage of this product.

● Please consider the industrial property and use conditions etc. related to the usage and application described in this catalog in your company.

● Please refer to the used material, technical information of the grade and product safety data sheet (MSDS) in the handling of this product (transportation, storage, molding, disposal etc.).
Especially, please confirm safety sufficiently when using the food container wrapping, medical parts, safety tool, toys for the infant etc.

● The chemicals (carbon black, titanium oxide, zinc oxide) that should notify in applicable laws and regulations, Item 2 of the Article 57 of the Occupational Health and Safety Law, Item 2 of the enforcement order 18, name in attached table 9 etc. may be contained in case of each grade colored article of this product. Please contact for the details.

● Because some items of the MEP products correspond to specified articles of the controlled target products under the Export Trade Control Ordinance, please contact us for the details.
Please conform to the applicable laws and regulations of the Foreign Exchange and Foreign Trade Control Law etc. when conducting the export and sale of the MEP product and the product that included the MEP product.

● The deterioration of some articles in this product may occur due to the residual fumigant which is used for the fumigation treatment of the wooden pallet.
Please refrain from carrying out the fumigation treatment by loading the corresponding product on the wooden pallet or loading on the wooden pallet that the fumigation was treated.

● There is a possibility that harmful gas and fume are generated by the heat decomposition of the resin at the time of molding and cleaning the tack.
Please install the ventilator for the local or the whole ventilation.

● When the product which added fluorocarbon resin is heated above 250℃, the poisonous gas may be generated due to the decomposition of fluorocarbon resin. Therefore, the ventilation of work environment should be done sufficiently. Also, please do not burn this product when dispose it but carry out the landfill instead.

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