Injection Molding

Reny is a generic name of the composite molding material which is mainly consisted of Nylon MXD6, developed by Mitsubishi Gas Chemical Company, leading the world.

Nylon MXD6 is a crystalline thermoplastic resin which can be attained from m-Xylylenediamine (MXDA) and adipic acid. Also, its property is a bit different from Nylon 6 and Nylon 66.

Moldability is similar to Nylon 6 and Nylon 66, but its condition need to be chosen appropriately based on the inherent property of Nylon MXD6.

These days, the molding machine and the mold technology have improved, so the moldings are sometimes done by using an advanced technology of each, but here states about a general injection molding of Reny.

1. Injection molding method

1-1 Molding machine

Reny can be molded by plunger type, screw preplasticating type, or inline screw type, but the inline screw type is most common.

Molding machine with the following specifications is preferred.

1) Check valve is on the screw head.
   If there is no check valve, resin will backflow and be a cause of sink marks and uneven dimension.
   Furthermore, check valve, screw, and cylinder should be abrasion-resistant, because Reny is mainly consisted of glass fiber reinforced grade.
2) The nozzle should be an open type with the band heater for heating, and temperature controllable.
3) If using the nozzle with bulb to prevent a drooling, spring type needle nozzle is general. Moreover, bulb type nozzle has a lot of resin retention area and become a cause of burned spot, so be careful.
   Also, latest molding machines have suck back feature that rolls back the screw forcibly, so if using this type, nozzle with bulb is unnecessary.
   Furthermore, if drooling is drastic, drying the pellet will be necessary, since the cause is a moisture of material in most of the time.

1-2 Preliminary drying of material

Reny is supplied in a special bag that prevents moisture absorption during storage and shipping.
Basically, predrying is not necessary prior to molding if the bag has just been opened.

However, Reny absorbs moisture gradually when exposed to air, so the predrying process should be applied to pellets that have been left unused at least one hour after opening the bag.

Moisture absorption of the pellet differs by the left environment condition, but one example is indicated in Figure 1.

When preliminary drying the pellet which has absorbed moisture, drying until the moisture percentage become lower than 0.3% is preferred, and the drying condition depends on the moisture absorbed state, but basically it should be done by hot-air dryer in 85℃, for about 12 hours. Drying efficiency will improve if dehumidifier is on the drying machine.

Also, be careful of the oxidization coloring when using hot-air dryer and drying in more than 90℃.

Vacuum drying is very profitable for preventing oxidization coloring and shortening drying time, and in this case, drying in 120℃ for 3 hours will be necessary.

Figure 2 indicates examples of drying time and pellet moisture percentage.

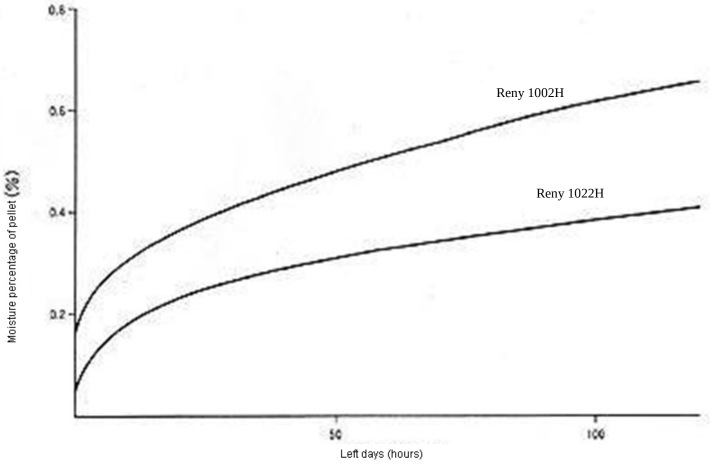


Figure 1. Relation of left time and pellet moisture percentage in 23℃, 55%RH
Pellet depth of bat:17.5mm

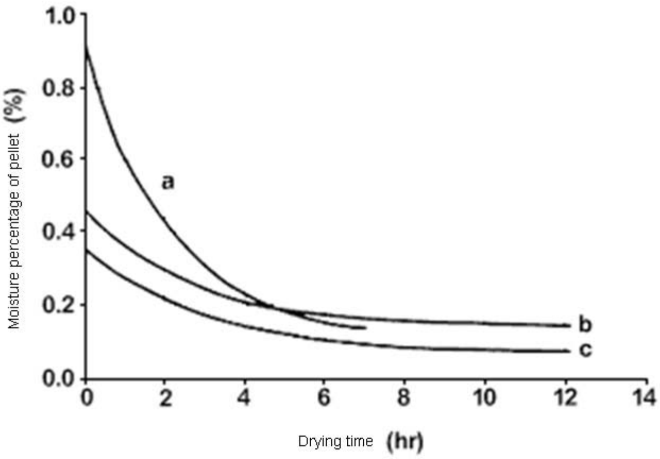


Figure 2 Pellet drying time and moisture percentage

a: Reny1002H Temperature 120℃, vacuum (300～400MPa)
Pellet depth of bat 3㎝
b: Reny1002H KP electric drying machine KRS L-5 type made by Katoriki
Temperature 85℃, pellet depth of bat 4 ㎝ outside temperature 61℃ to 10℃, relative humidity 39% to 49%
c: Reny1022H Same as condition b

1-3 Molding condition setting

(1) Resin temperature

Nylon MXD6 is a crystalline polymeric material with melting point of 243℃. Therefore, molding is possible within 245℃ to 290℃, but molding in 250℃ to 280℃ is general.

Also, from about 300℃, degradation will start, so do not make the resin temperature more than 300℃.

Normally, the resin temperature might rise by 10℃ to 20℃ from the heating cylinder preset temperature. This is because of the shear heat generation by the screw revolution, so in the actual molding, relation of preset temperature and resin temperature should be checked by measuring blank shot molten resin using the thermometer.

Also, in unreinforced grade, if resin temperature is set high, sink marks will occur, so it should be set lower.

Table 1 indicates performance shift when the material is left inside the cylinder of the molding machine. There is no big difference to the performance if only left about an hour.

Table 1. Retention time and tensile property change inside molding machine cylinder

	1022H			1501AH		
Retention time Minutes	Tensile strength retention rate %	Tensile elongation retention rate %	Tensile modulus retention rate %	Tensile strength retention rate %	Tensile elongation retention rate %	Tensile modulus retention rate %
1	100	100	100	100	100	100
30	100	100	100	100	100	100
60	99	96	99	99	94	98

Resin temperature: 280℃

(2) Injection pressure

Injection pressure should be set considering the mold construction and other molding conditions, but generally 49 to 118MPa will be enough.

Reny molding recommends relatively high resin temperature of 130℃. Reny has good flow property, so burr might occur depending on the molding condition. Avoid molding only by the primary pressure, and use secondary and tertiary pressure to prevent the burr.

(3) Mold temperature

Mold temperature is one of the most important factor of Reny molding.
Up to 150℃ is a moldable range for the mold temperature, but if molded under 90℃, the molded product will be quenched and its surface will become amorphous, just like the glass fiber embossed.
If mold temperature is set 120℃ to 150℃, the molded product will crystallize sufficiently, and become milky color, and its surface appearance will be good and glossy.
Table 2 indicates physicality of Reny typical grades molded at mold temperature of 75℃ and 130℃.
Performance tend to be good as the mold temperature rises, but there is no big difference at ordinary temperature.

Table 2. Mold temperature and physicality of Reny typical grades

Material	SI unit (engineering unit)	Reny1002H		Reny1022H		Reny1501AH	
Mold temperature	℃	75	130	75	130	75	130
Density		1.431	1.443	1.650	1.653	1.535	1.538
Tensile strength	MPa	177	178	256	228	181	183
Elongation	%	2.1	1.9	1.9	1.8	2.2	2.1
Tensile modulus	10^2・MPa	116	117	163	175	118	122
Flexural strength	MPa	228	235	330	335	255	261
Flexural modulus	10^2・MPa	108	110	164	168	113	114
Compressive strength	MPa	206	225	218	231	213	228
Compressive modulus	10^2・MPa	66	72	83	94	72	75
Izod impact strength with notch	J/m	78	76	114	124	83	77
Izod impact strength without notch	J/m	382	333	883	902	569	480
Tensile impact strength	KJ/m	103	92	198	178	124	74
Rockwell hardness	M Scale	111	112	110	111	109	110
Heat distortion temperature (1820KPa)	℃	220	222	221	226	220	221
Taber wear weight	mg	28	25	43	33	34	28
Water absorption (20℃ 24Hr)	%	0.57	0.20	0.42	0.18	0.48	0.22
Molding shrinkage 102×3.2mm	%	0.53	0.55	0.42	0.44	0.50	0.52

Table 3. Heating treatment and heat distortion temperature of low temperature molded product

Reny Grade number	Mold temperature ℃	Heating treatment condition	Heat distortion temperature ℃
1002H	50 50 130	None 130℃, an hour None	78 178 182
1022H	50 50 75 75 130	None 130℃, an hour None 130℃, an hour None	85 182 95 186 185

specimen thickness: 1/16″, fiber stress: 1820KPa
1002H: resin temperature 253℃, 1022H: resin temperature 265℃

About appearance, as mentioned above, 120℃ or hotter mold temperature is required to attain a good and glossy molded product.

However, in case of the thin molded product, glossy ones can be made at mold temperature of only 80℃ to 90℃ if molded by high injection pressure. But it is just a transcription of a mold surface happened by high injection pressure, so the gloss can be lost in few days if the crystallization is not enough. This state can be seen by putting molded product in the water soon after molding, or leaving by the hot-air drying machine of 130℃ for several minutes.

Also, if want to make it glossy at mold temperature of about 90℃, Reny2031 or Reny2620 is recommended.

Heat carrier circulation type is preferred for heating method of the mold.

Points of mold heating are,

(a) Keep the mold at predefined temperature.
(b) Keep the temperature distribution inside the mold equal.
(c) Remove the heat conducted by the resin.

and heating by the cartridge heater is simple, but has trouble in temperature controlling accuracy, so be careful.

Additionally, inserting heat insulation plate between the mold and the mold attachment plate is preferable at high temperature molding.

In the case of molding Reny, mold temperature is most important to keep the stable dimension accuracy and molded product physicality.

(4) Injection speed

Injection speed should be adjusted properly thinking about the resin flow property, appearance (burr, flow mark, sink mark, surface blur). Surface condition will be better as the injection speed get faster.

(5) Back pressure

There is no need to put a back pressure when molding Reny.
Back pressure might be put to distribute the material, prevent the air bubbles on the molded product, or rise the weighing accuracy. However, if back pressure is too high, glass fiber will be shorter, and end up with performance degradation, so be careful.

(6) Molding cycle

Molding cycle is controlled by
(a) injection time
(b) pressure keeping time
(c) cooling time
(d) intermediate time
Injection process should be kept until the gate seal finishes.
Gate sealing time will differ by the gate cross-section shape, mold temperature, and resin temperature, so injection time that molded product weight and dimension fit within a certain range, need to be found.

1-4 Cause and countermeasure of defects

Cause and countermeasure of molding defects that can be seen when molding Reny, are shown in Table 4.

Table 4. Cause and countermeasure of defects

Defect	Cause	Countermeasure
Silver streak	Moisture inside the pellet.	Dry the pellet at 85℃ for about 12 hours.
Tarnish	Resin overheat or retention time too long.	Lower resin temperature. Use the molding machine with small capacity. Check the retention fitting part of cylinder and nozzle.
Local tarnish or burn	Insufficient degassing inside the mold Heat generation by adiabatic compression of the air.	Place a vent on the mold matching surface.
GF locally embossed	Same as above.	Same as above.
Glossy face and GF embossing face are sparse	Insufficient crystallization because the mold temperature is under 100℃.	Raise mold temperature to about 130℃.
Dark or black spot, or chip mixed in	Foreign material mixed in. Detachment of decomposition resin film that gradually formed in the cylinder wall.	Take care of resin stock and hopper load. Clean up the cylinder wall.
Sink mark or air bubble inside	Shrinkage when cooling is not made up sufficiently by pressure keeping.	Increase pressure keeping time. Raise pressure keeping. Make thin as possible. Place the gate on the thick part. Take the cushion volume. Lower resin temperature.

※GF: Glass fiber

Defect	Cause	Countermeasure
Flash	Insufficient mold locking force. Injection pressure too high. Injection speed too fast. Abrasion of mold, lack of stiffness in mold material. Resin temperature too high.	Strengthen mold locking force. Decrease injection pressure and keeping pressure. Decrease injection speed. Fix or renew the mold. Lower resin temperature.
Weld mark	Cooling until the resin reaches to the joint.	High speed inject by raising the resin and mold temperature. Upsize the gate. Change the gate location and shape.
Flow mark (Jetting)	Early flew cooled resin or the part that got cooled by colliding with the mold, getting washed away again by the molten resin.	Upsize the gate. Change the gate location. Place cold slug well pool at the sprue and the runner. Take gate balance.
Demolding defect or deformation when demolding. (Soft molded product)	Strong demolding force is required. Become decompressed between the mold and the molded product. Demolding force is not acting sufficiently on cohesion point of the mold and the molded product. The molded product is not crystallized or cooled sufficiently. Resin temperature too high.	Decrease injection pressure. Add taper. Polish the mold well. Find the place where beat the decompression on the mold. Add ejector pin. Increase cooling time. Raise mold temperature to about 130℃, or lower it to 80℃ and solidify by cooling. Lower resin temperature.
Filling insufficiency	Resin temperature too low. Flow passage freezing too fast. Mold temperature too low. Too thin. Filling is uneven in each cavity. Insufficient material supply.	Raise resin temperature. Widen the flow passage. Raise mold temperature, and increase injection pressure and speed. Increase injection speed. Make it thicker. Change the flow passage, or try to fill at once by widening. Increase measurement value.
Molded product damaged or embrittled	Nozzle temperature too low. Mold temperature too low, injection pressure too high, generation of internal residual strain based on difference in thickness distribution. Notch effect. Thermolysis. Foreign material mixed in.	Raise nozzle temperature and remove cold slug well. Adjust injection pressure and pressure keeping, try to make the thickness distribution even. Make the sharp corner of the mold round. Lower temperature on the heating part. Dissolve and clean the cylinder and the nozzle.

2. Usage of recycled material

Strength change retention rate of repetitively used crushed sprue and runner which is made when molding, is indicated in Table 5 to 7. Strength degradation by using recycled material is small, so it can be used repetitively.

When using recycled material, use after sufficient drying except for the case when using by crushing it soon after molding.

Recycling condition:—

Crusher: ROTOPLEX 16/8 type crusher screen (using 8mmö) made by Itoman Engineering Company

「The meaning of "Recycled number" seen in Table 5 to 7: 」If the recycled number is 0, it is 100% virgin product.

If the recycled number is 1, 50% is material which crushed the 100% virgin molded product, and the other 50% is virgin material.

If the recycled number is 2, 50% is recycled material made of a molded product in recycled number 1, and the other 50% is virgin material.

From recycled number 3, will be repeated as above.

Table 5. Physicality of Reny1002H when recycled material is used (strength retention rate %)

	Recycled number	0	1	2	3	5
Tensile	Strength	100	98	97	97	96
	Elongation	100	97	98	95	95
	modulus	100	106	102	103	104
Flexural	Strength	100	99	98	96	97
	modulus	100	98	98	99	98
Compression	Strength	100	97	10	96	98
	modulus	100	98	101	94	100
Izod impact strength		100	83	93	92	91

Table 6. Physicality of Reny1501AH when recycled material is used (strength retention rate %)

	Recycled number	0	1	2	3	5
Tensile	strength	100	97	95	93	94
	elongation	100	101	99	96	102
	modulus	100	103	99	101	97
Flexural	strength	100	97	98	96	95
	modulus	100	97	97	98	97
Izod impact strength		100	93	93	92	97

※Recycled material usage of more than 25% is not allowed for UL standard applied product, unless permitted individually.

Table 7. Physicality of Reny1022 when recycled material is used (strength retention rate %)

	Recycled number	0	1	2	3	5
Tensile	strength	100	96	97	94	94
	elongation	100	97	97	100	100
	modulus	100	96	100	96	93
Flexural	strength	100	98	98	96	97
	modulus	100	99	99	98	98
compression	strength	100	106	106	105	103
	modulus	100	100	100	100	97
Izod impact strength		100	90	89	90	87

3. Flowability in injection molding

Flowability of molding material is important when deciding a molding condition in injection molding, and a molded product thickness and gate location in mold designing.

Flowability of the material can be known by measuring MI value by melt indexer.

However, it is difficult to evaluate the flowability of material on actual injection molding, even though these flowability can indicate flow ability between materials.

Therefore, calculating the flow distance of materials is preferred on the actual mold. Spiral mold is practically used in this test, that it is on the catalogue of each company.

But, this spiral flow also cannot evaluate the relation of molded product thickness and flowability. So in this case, relation of molded product thickness (t) and flow length (L), (L/t), need to be examined, using the bar–flow mold that can change thickness.

Flowability measured by the spiral flow mold and the bar–flow mold, which is to evaluate the flowability when injection molding Reny, is indicated below.

3-1 Flowability by the spiral flow mold

Measurement condition: —
Molding machine: SN-100N made by Niigata Engineering Co., Ltd　Intermediate time: 3S
Injection speed: 40mm/sec　Measured value: 60mm
Injection time: 7S　Screw revolution: 100rpm
Cool time: 18S　Mold: spiral flow mold, 6mmö semicircle

Figure 3 indicates temperature dependency of spiral flow of each grade Reny and commercial glass fiber reinforced engineering plastic. Also, Figure 4 indicates pressure dependency of spiral flow. Figure 5 indicates influence of pellet moisture percentage.

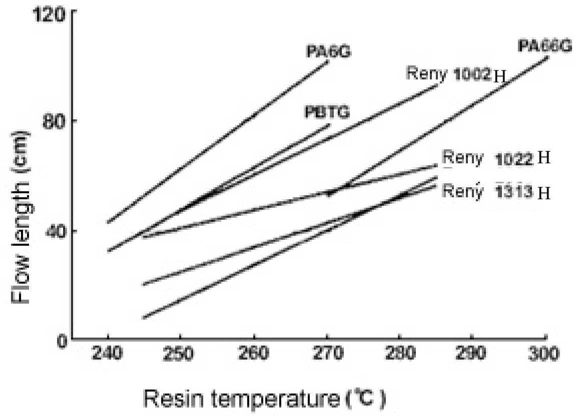


Figure 3. Temperature dependency of spiral flow (mold temperature 130 ℃, injection pressure 98MPa)

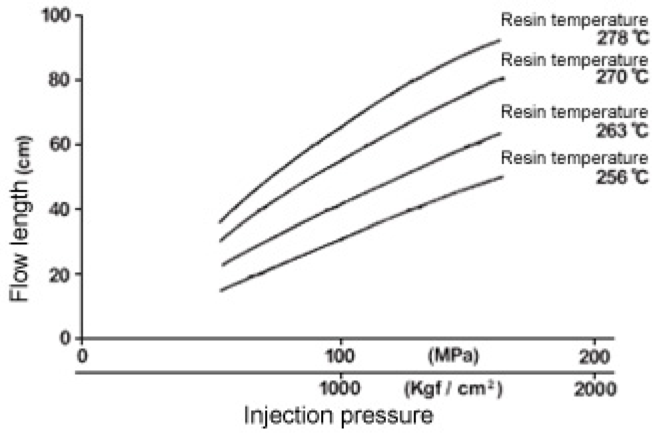


Figure 4. Pressure dependency of spiral flow of Reny1022 (mold temperature 130℃)

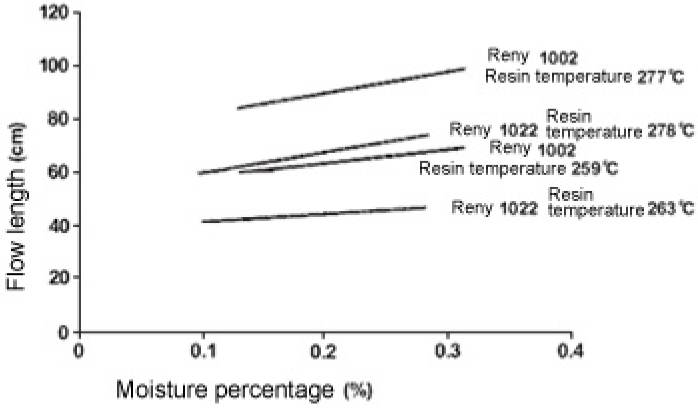
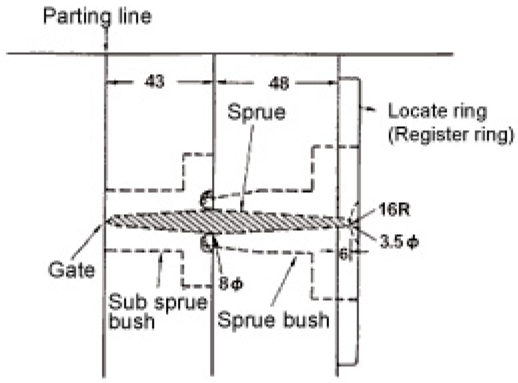


Figure 5. Influence of moisture to spiral flow of Reny1002 and Reny1022
(mold temperature 130℃, injection pressure 109MPa)

3-2 Flowability by the bar-flow mold

Measurement condition: —
Molding machine: SN-100N made by Niigata Engineering Co., Ltd, Nozzle: spring needle nozzle
Injection speed: 50mm/sec
Screw revolution: 100rpm
Injection time: 7sec
Cool time: 15sec
Intermediate time: 3sec
Measured value: 60mm
Switching point: 15mm-7mm-1sec-1sec
Back pressure: 0MPa
Mold: bar-flow mold
width 20mm, maximum length 842mm
Gate: pinpoint gate
1.5m mö × 1.5mm
1.0m mö × 1.5mm
1.5m mö × 2.0mm
thickness 1mm, 2mm, 3mm

Figure 6 indicates sprue shape, Figure 7 indicates bar-flow cavity shape.



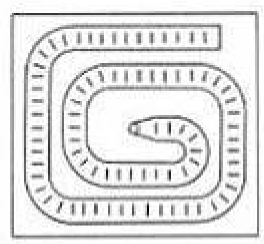


Figure 7. Bar-flow cavity

Figure 6. Sprue shape

(1) Injection pressure and flow length

Relation of injection pressure and flow length in each cavity thickness is indicated in Figure 8 to 10.
Flow length will be greatly affected by injection pressure.

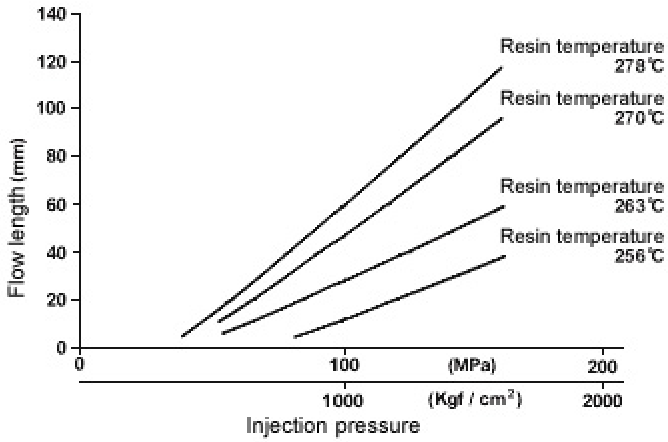


Figure 8. Pressure dependency of Reny1022 bar-flow (cavity thickness 1mm)
(gate diameter 1mmö, cavity thickness 1mm, resin temperature 130℃)

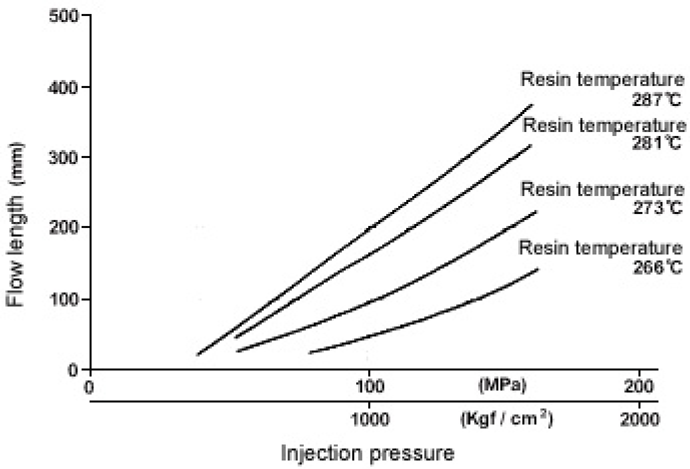


Figure 9. Pressure dependency of Reny1022 bar-flow (cavity thickness 2mm)
(gate diameter 1mm**ö**, cavity thickness 2mm, mold temperature 130℃)

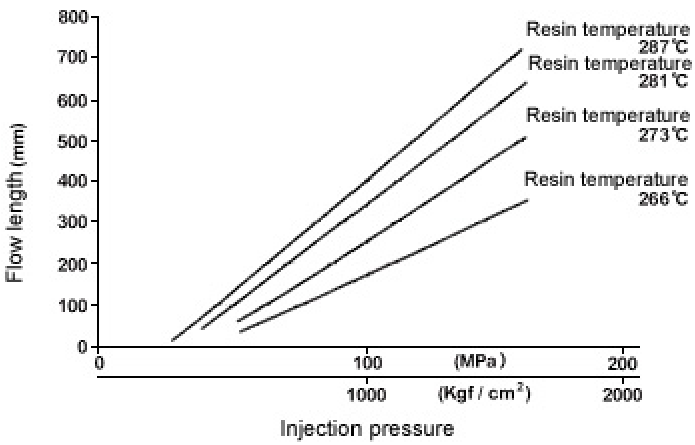


Figure 10. Pressure dependency of Reny1022 bar-flow (cavity thickness 3mm)
(gate diameter1mm**ö**, cavity thickness 3mm, mold temperature 130℃)

(2) Resin temperature and flow length

Influence of flow length to resin temperature is indicated in Figure 11, but resin temperature also gives a great influence to flow length.

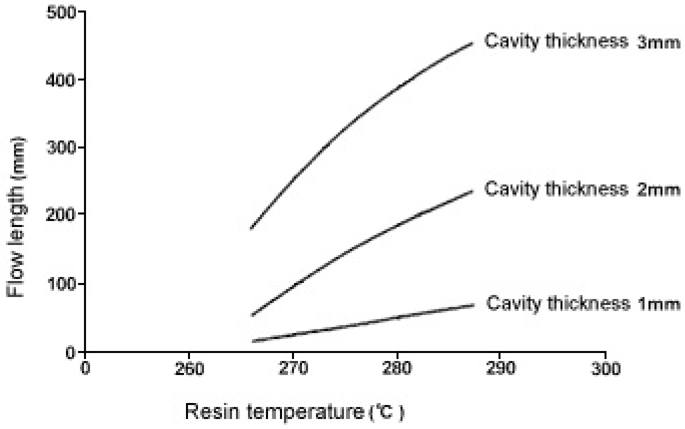


Figure 11. Resin temperature and flow length of Reny1022
(gate diameter 1mmö, injection pressure 109MPa, mold temperature 130℃)

(3) Cavity thickness and flow length

Both Figure 12 and Figure 13 indicate relation of injection pressure and resin temperature against cavity thickness of Reny1022. Flow length will increase as the cavity thickness increases.

Ratio (L/t) of flow length (L) and cavity thickness (t) is often used to express the flow property of the material. Figure 14 and 15 indicate relation of cavity thickness and L/t. From the result of Figure 14, L/t will change its value from 10 to 170, by the effect of cavity thickness increase or injection pressure. More specifically, L/t is a value that changes depending on the cavity thickness, injection pressure, and resin temperature, so cannot say that there is a universality as a value that expresses material flow property. However, this value is effective when evaluating flow property of particular material in an appropriate condition.

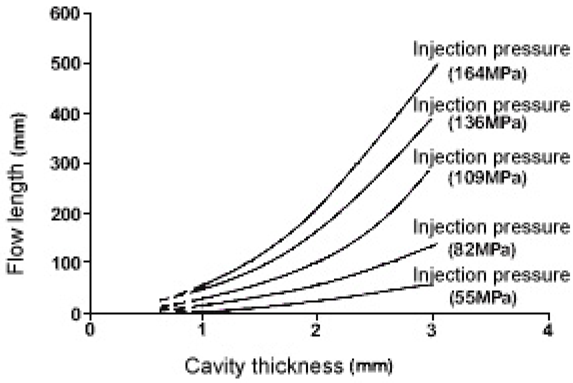


Figure 12. Cavity thickness and flow length of Reny1022 (gate diameter 1mmö, resin temperature 273℃, mold temperature 130℃)

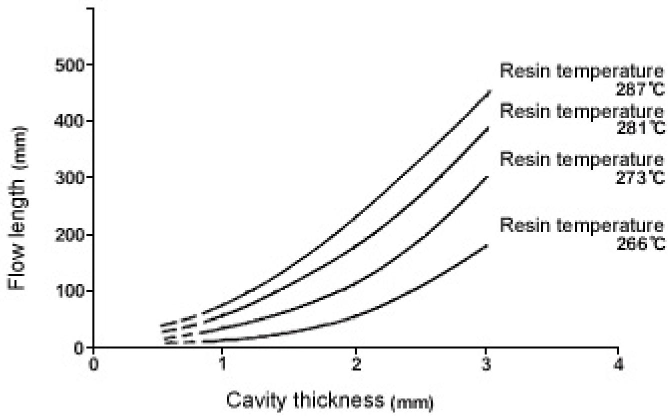


Figure 13. Cavity thickness and flow length of Reny1022 (gate diameter 1mmö, injection pressure 109MPa, mold temperature 130℃)

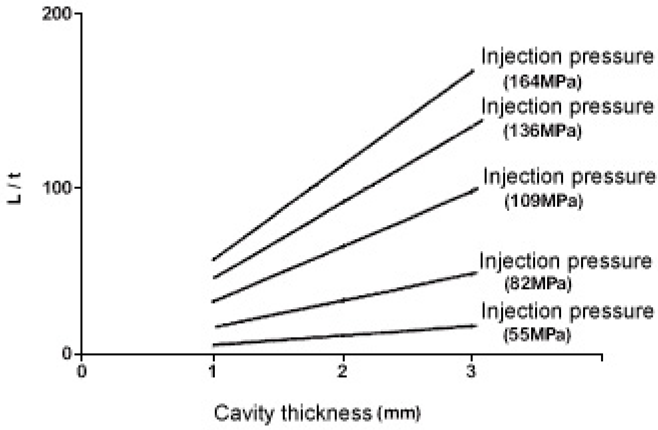


Figure 14. Cavity thickness and L/t of Reny1022 (gate diameter 1mmö, resin temperature 273℃, mold temperature 130℃)

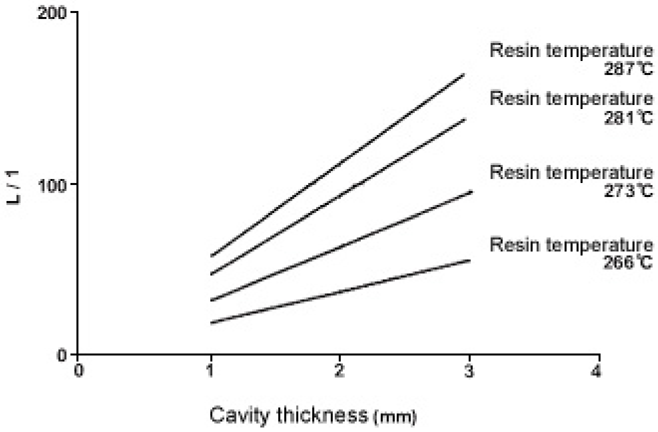


Figure 15. Cavity thickness and L/t of Reny1022 (gate diameter 1mmö, injection pressure 109MPa, mold temperature 130℃)

(4) Mold temperature and flow length

Figure 16 indicates relation of mold temperature and flow length.
Influence of mold temperature to flow length is relatively small compared to the other factors.

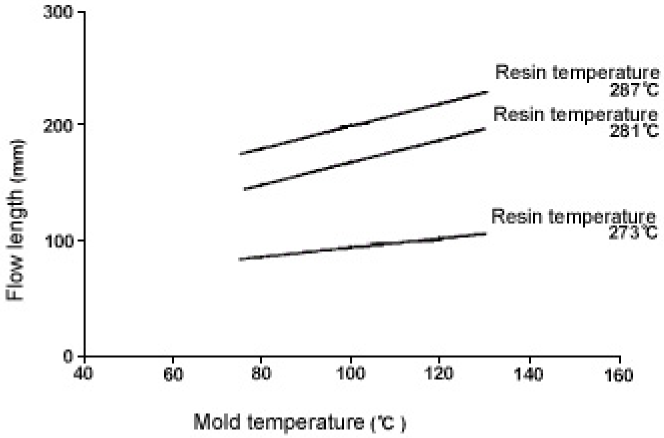


Figure 16. Mold temperature and flow length of Reny1022
(gate diameter 1mmö, injection pressure 109MPa, cavity thickness 2mm)

(5) Gate diameter and flow length

Figure 17 indicates relation of gate diameter and flow length.
As the cavity gets thicker, influence of gate diameter will be greater.

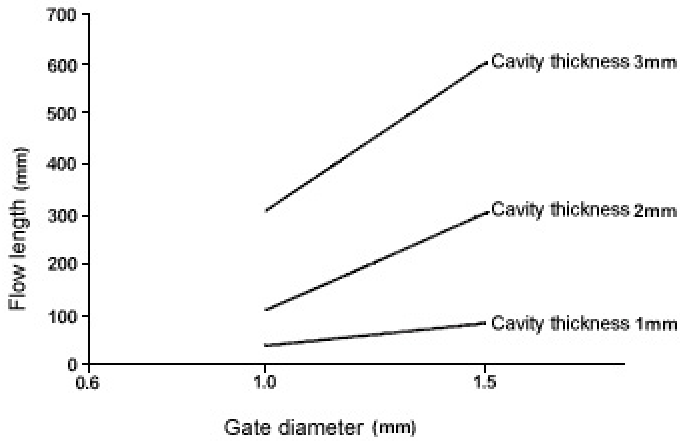


Figure 17. Mold temperature and flow length of Reny1022
(mold temperature 130℃, injection pressure 109MPa, resin temperature 273℃)