

Injection Molding and Recent Molding Materials

Introduction

Due to recent labor force shortage, the integral molding of sealing materials has been considered in Japan too.

And the molding of sealing materials by LIM molding which is not yet so common domestically has been conceivable as an enterprise-scale business.

In the business of rubber molding of sealing materials, the mainstream is the Calendar molding with vulcanization and LIM molding of liquid resin.

Recently ThreeBond has started to sell Hy-molding (Hybrid molding) system which the injection molding of

thermoplastic resin is combined with LIM molding using liquid silicone as thermal-curing resin.

This issue of our technical news provides thermoplastic resins, an overview of injection moldings, and LIM molding of liquid resin, all of which are related to Hy-molding.

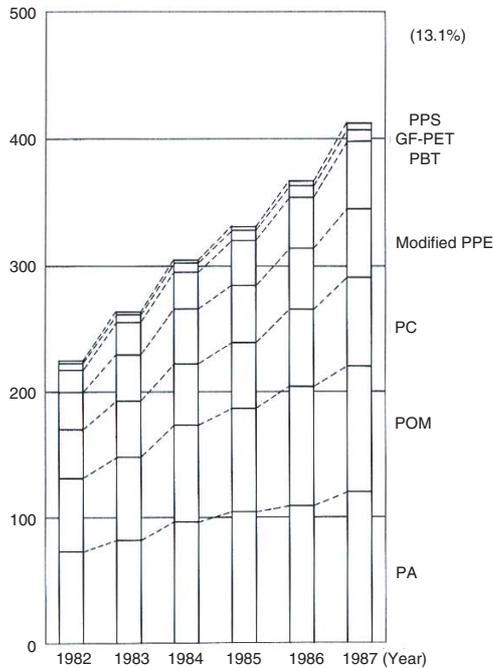
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1. Positioning of Plastic Material

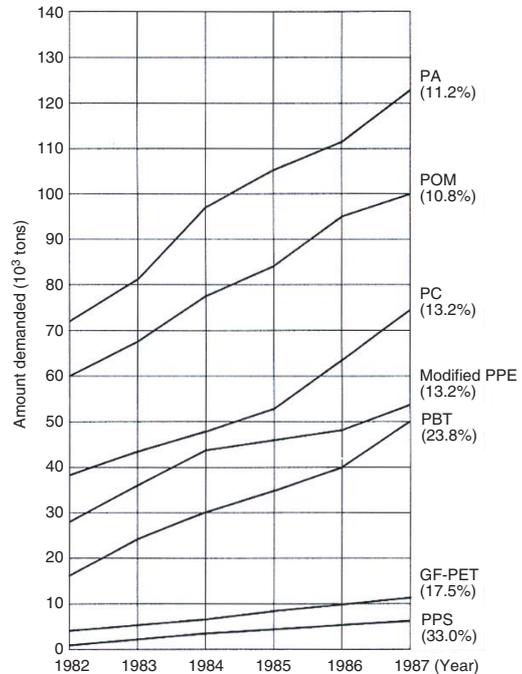
Since the advent of bakelite invented early in this century a lot of plastic materials have been invented and applied to practical uses. In these days the domestic production

volume exceeds 10 million tons per year. This figure is almost the same as the one of the production volume of steel.



Source: CMC "Naigai kagakuin shiryou"
The value in parentheses are average annual growth rate.
The value in 1987 is estimated partly.

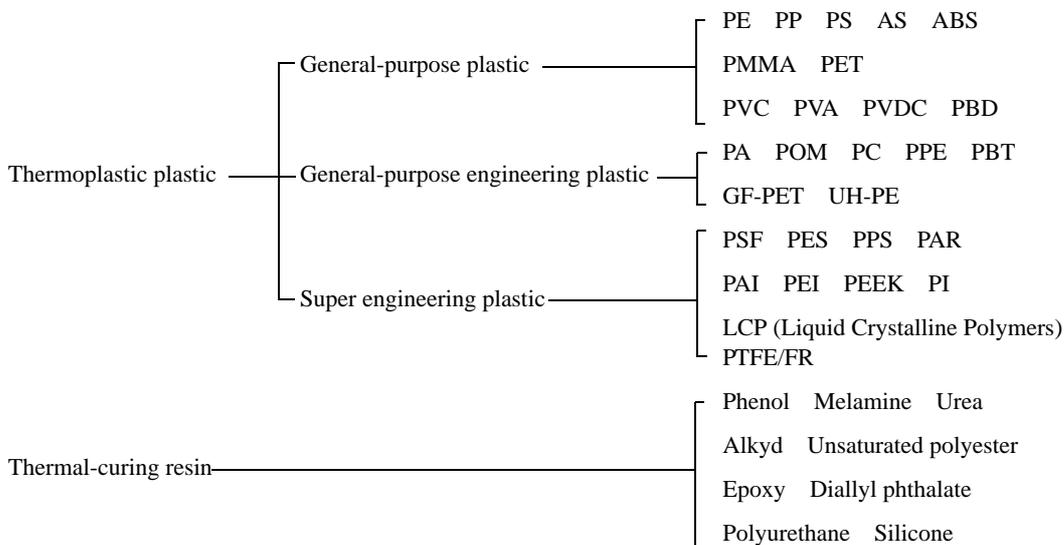
Figure 1. Demand trends of general-purpose engineering plastic in Japan (1982 - 1987 No.1)



Source: CMC "Naigai kagakuin shiryou"
The value in parentheses are average annual growth rate.
The value in 1987 is estimated partly.

Figure 2. Demand trends of general-purpose engineering plastic in Japan (1982 - 1987 No.2)

A chart that classifies commonly available materials is shown below.



The resin which has properties with over 100 °C heat resistance, over 500kgf/cm² mechanical strength and over 2400kgf/cm² bending modulus is called engineering plastic, and the resin material which has over 150 °C heat resistant temperature and can be used for a long time is particularly called super engineering plastic. As to engineering plastic, Du pont developed and commercialized polyacetal homopolymer which was believed to be the plastic material replacing metal materials in 1960, and used nylon resin, which was

conventionally for fiber products, for injection molding. Then, other companies developed polyacetal copolymer, polycarbonate modified polyphenylene ether and polybutylene terephthalate. Due to its relatively low-cost (the price is below 1000 yen/kg) and the improvement of injection molding techniques, the demand for engineering plastic has increased smoothly and is now attaining to 7% of total production volume of all plastic materials.

1-1. Recent Plastic Materials

In automobile-related companies the weight saving of cars in order to improve fuel efficiency is common, and for that purpose the use of plastic parts is expanded. Also in other industries the use of plastic parts is getting more accelerated with the demands such as weight saving of products, labor force shortage, simplified assembling, design effects and processability.

In these days both low-costed commodity plastic and level-upped demand characteristics of plastic parts have

been particularly required, and plastic materials with new quality grade are actively being developed.

This is called ABC of plastic materials.

- (A) Alloy: Development of Polymer Alloy
- (B) Blend: Development by Resin Blend
- (C) Composite: Improvement of Material Properties by Composite

1-2. Requested Items for Plastic Performance Improvement

- a Requirements of the conflicting properties which are included in conventional plastics, such as low-cost vs heat resistance and easy formability, high impact strength vs high rigidity
- b Enabling special features (antistaticity and photosensitivity) and addressing user needs
- c Improvement of properties in low molecular weight compounds such as flame retardant or plasticizer
- d Improvement of long-term storage stability against high durability and weather resistance
- e Improvement of plastic properties for heat resistance and high rigidity, and refinement of properties by mixing reinforcing agents (glass fiber, inorganic filler, carbon fiber, metal powder, or metal filler)

which are mixed with in order to improve flame resistance, self-extinguishing and formability.

1-3. Representative Examples of Polymer Alloy and Resin Blend

Modified PPE/PS	Heat Resistance, mechanical strength, formability, price improving	(GE, Asahi Kasei)
Modified PPE/PA	Improvement of chemical resistance in PPE	(GE, Asahi Kasei, Mitsubishi Plastics)
STPA/Modified polyolefin	Improvement of impact resistance in nylon	(Mitsubishi Plastics, Sumitomo Chemical)
PA/Modified ABS	Improvement of dimensional stability in nylon	(Mitsubishi Monsanto Chemical)
PA/DAR/Elastomer	Improvement of dimensional stability of nylon	(UNITIKA)
PC/PS.ABS	Heat resistance, formability, price improving	(Mitsubishi Kasei, Teijin, Mitsubishi Gas Chemical)
PC/Polyester	Chemical resistance, improvement of stress crack resistance	(GE, Mitsubishi Kasei, Teijin, Mitsubishi Gas Chemical)
PET/PBT	Low repulsion re-grade in PBT	(Celanese, Polyplastics, Mitsubishi Kasei)
STPBT/PBT/MBS/PC	Improvement of impact resistance in PBT	(GE, Mitsubishi Kasei, Toray)
PET/Polyolefin	Improvement of formability in GF-PET	(Du Pont, Teijin, Mitsubishi Kasei, TOYOBO, Mitsubishi Petrochemical)
POM/Thermoplastic polyurethane	Improvement of impact resistance in POM	(Polyplastics, Du Pont, Mitsubishi Gas Chemical)
Transparent PAR/PET	Improvement of transparency in PAR	(UNITIKA)

1-4. Representative Examples of Super Engineering Plastics

LCP (Liquid Crystalline Polymers)	Characterized in high rigidity / High strength, dimension stability, easy formability
PAR (Polyarate)	Excellent in flame retardance, impact resistance, weather resistance and less hygroscopicity
PSF (Polysulphone system)	Excellent in heat resistance, mechanical strength, flame retardance, hygienic safety (hydrolyzability), creep resistant characteristics
PEEK (Polyketone system)	Excellent in heat resistance (240 °C), flame retardance, radiation resistance
PEK	
PAEK	

1-5. Hy-molding and plastic materials

Secondary resin compounds in Hy-molding is thermal-curing resin. Since it is cured rapidly by remaining heat of primary resin and mold temperature heat, and then it is made into sealing components, following characteristics may appear depending on the kinds of resin.

- 1) Resin with low deflection temperature: ABS PS AS PE
Effect of silicone works slowly for mold temperature can not be set to high.
- 2) Effect of plasticizer PVC system
Silicone will not be cured due to the effect of plasticizer compounded with PVC series resin.
- 3) Easy in Hy-molding of glass-reinforced resin
Secondary resin can be easily cured due to the

improvement of strength at releasing and heat resistance.

- 4) Since the resin with relatively high melting temperature holds also high remaining heat, releasing of primary resin needs much attention although secondary resin silicon will be cured rapidly.

Hy-molding can accommodate most plastics by making molds after considering the measures for mold release in designing phase and sealing structures.

When it is difficult to perform Hy-molding system D forming, system O should be used, that forms secondary sealing components separately after forming primary sealing components, so that integrated molding can be proceeded.

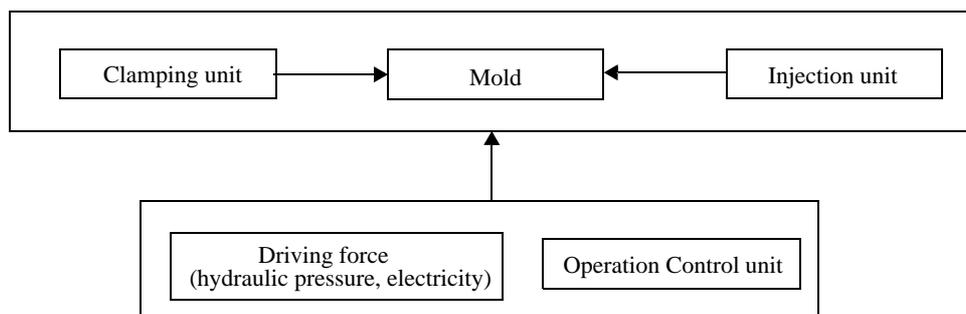
2. Overview of Injection Molding Machines and injection molding

Injection molding is a processing method that differs from other molding processed in that it can produce molded parts with good dimensional accuracy in a short time. A typical workflow of molding process is as follows:

- 1) Melting resin materials Heat resin and lower its viscosity
- 2) Molding Pressure-inject molten resin into a mold and form it
- 3) Cooling Solidify in a mold by removing heat

Solidify in a mold by removing heat

The machine, which can make the process described above work and proceed in due order and eventually produce molded parts, is the injection molding machine. It is composed of mold clamping unit which attaches, opens and closes molds, and picks out molded parts; injection unit which feeds molded parts, melts resin by heat and injects resin with pressure; operation control unit which coordinates all the works; and driving forces (hydraulic pressure or other) of each operation.

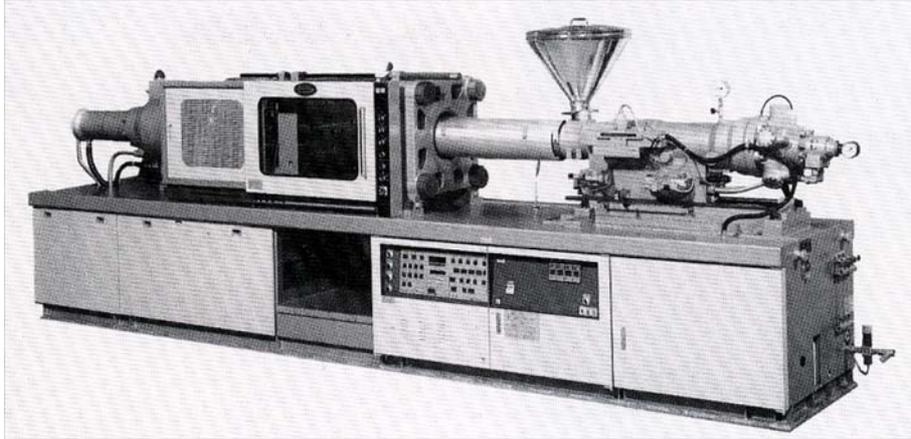


2-1. Classifying of molding machines

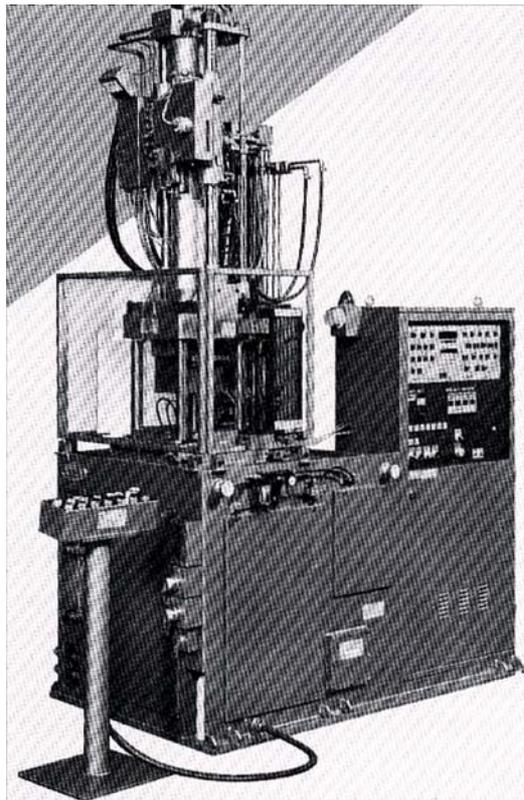
« Classification based on the allocation of injection unit and clamping unit »

Horizontal injection machine

Vertical injection machine



Picture 1. Injection machine



Picture 2. Vertical injection machine

« Classification based on clamping unit »

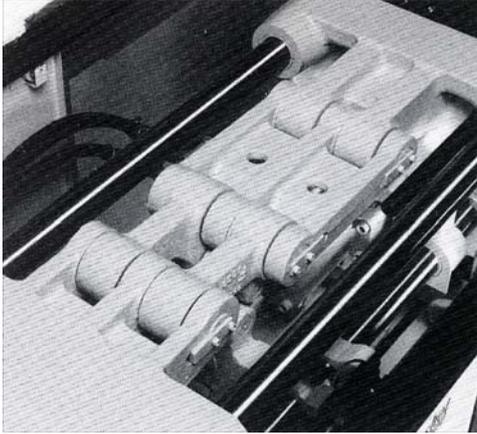
Toggle type

Direct-hydraulic clamping type

Other

2-2. Toggle type

This is the method to utilize opening and closing operations of adapter plate and generating of clamping force. Both single toggle type mechanism and double toggle type mechanism are used in molding machines.



Picture 3

The most outstanding characteristic of toggle type that clamping force can work stably. Since a toggle link is clamped at the location where it exceeds its dead point and is fully elongated, a tie bar is elongated by injection pressure and the restoring force of the tie bar caused by its elasticity works even if mold opens only a little. Thus, clamping force increases automatically and prevents mold's opening.

2-3. Direct-hydraulic clamping type

This is the clamping type in which hydraulic cylinder controls directly opening and closing operations of adapter plate and generating clamping force. The working mechanism is simple and the operability at low pressure clamping which works as protection of a mold is excellent.

In direct-hydraulic clamping type, booster ram system or auxiliary cylinder system is utilized in order to speed up opening and closing mold.

As to other types, in these days some manufacturing companies speed up opening and closing mold by adapting a crank-cam system, which is utilized for opening and closing operation of press machine. Also, there are a wedge type (cuneiform) and a composite type as well.

Table 1. Toggle type and direct-hydraulic type

	direct-hydraulic type	Toggle type
Clamping force	No more clamping force generated than clamping cylinder's ram area and hydraulic generating force.	By restoring force of the elongated tie bar caused by injection pressure, clamping force corresponding to the injection pressure will be generated.
Opening and closing speed of mold	Boosting time of clamping force is required. Good operability due to hydraulic control.	High speed opening and closing, and slowing down at termination, which is characterized toggle system.
Die thickness adjustment	Setting the location of pressure switching is enough.	Adjusting of the location of toggle links is required.
Maintenance	Much hydraulic oil level of hydraulic cylinder	Maintaining the toggle link part is required (abrasion of link pin) Less hydraulic oil level.
Durability	Sealing of hydraulic oil	Maintaining parallelism of adapter plates is mandatory.
Displaying clamping force	Managed by hydraulic gauges	Managed by elongation of the tie bar

2-4. Mold and attaching mold

A mold is attached to the machine typically by using threaded holes in the adapter plate of molding machine. In these days, in order to shorten the set-up time for mold change work, some manufacturers announce various types of mold change system.

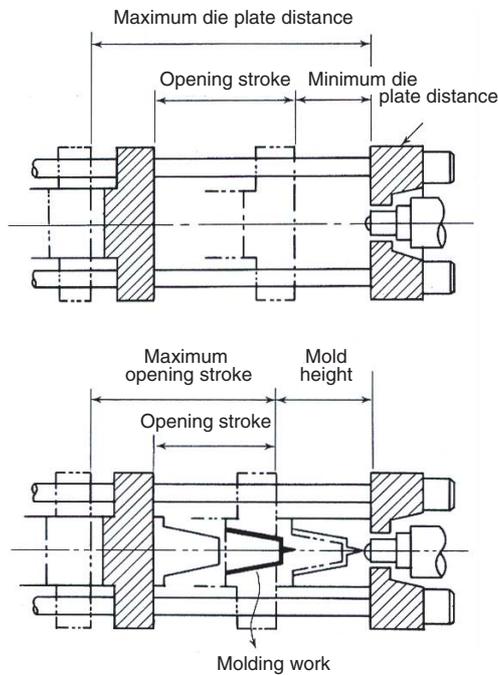


Figure 3

Relation between the size of adapter plates and the size of mold is shown in tie bar distance, dellite, and minimum mold height.

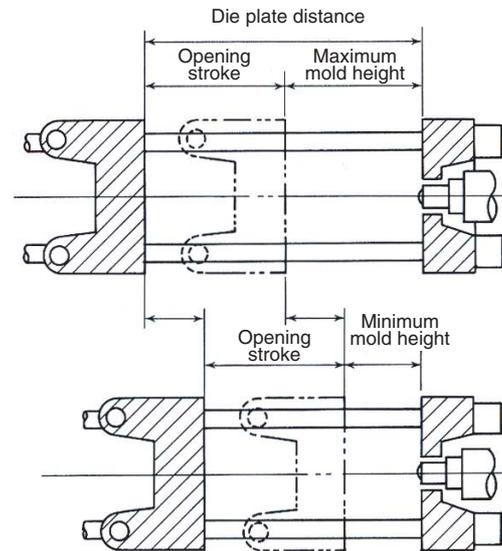


Figure 4

2-5. Recent way of attaching mold

- 1) This is the system to clamp a mold by utilizing hydraulic or air pressure to attach it to the molding machine after installing the attachment to the adapter plate and standardizing the mold outside dimension. (Some manufacturer announce the inserting-changing system for large molding machines. The insertion is made from its side.)
- 2) This is the system to replace the blocks corresponding to the inserting portion that is a mold product after attaching a standard mold base to the mold machine.

Shortening setup time by attaching a mold to the adapter plate will be more common with diversifying of molding operations.

Also, by regarding a mold as a part of molding machine, some molding machine manufacturers work on mold making, and special precision molding and vacuum molding method are also introduced.

NISSEI PLASTIC INDUSTRIAL CO., LTD.	FP System
Sumitomo Heavy Industries, Ltd.	Cassette style system
SHINKO SELBIC CO., LTD.	Command system
Other	Cassette system Capsule molding

2-6. Molding Conditions

In injection molding process, injection machine, mold, and molding conditions are most important elements. It is required to consider the following items in order to design molds and configure molding conditions.

« Items to configure design conditions »

Cavities layout

Number of cavities

Gate and runner structure

Layout of temperature control plumbing

« Items to configure mold conditions »

Temperature condition (cylinder or mold temperature)

Plasticization condition (screw rotation speed, back pressure)

Injection condition (pressure, speed, time)

Cooling condition (time, mold temperature, mold releasing)

(A) Selection of molding machine

Since number of cavities, project area, and runner length are presumed by mold structure, and approximate filling pressure is presumed by product materials, the following items should be considered to select the molding machine.

- Relation between minimum fluid flow pressure and clamping force (necessary clamping pressure)
- Plasticizing capacity of molding machine from resin materials
- Injection capacity of molding machine

- Relation between mold attachment area and dellite

(B) Molding condition

Optimum molding conditions are fluid important, and it means that resin should be filled into a mold at a temperature and pressure as low as possible. The basics to configure molding conditions is to find the optimum temperature condition because temperature conditions are associated with all other configuration items.

Temperature conditions are particularly affected by cylinder temperature and mold temperature, and the fluid flow characteristic of filled resin is changed by runner and gate structure of structure.

Depending on types of resin, resins are classified to highly temperature dependent ones and highly pressure dependent ones by fluid flow characteristics.

And it is well known that even highly pressure dependent resins become excellent in fluid flow characteristics rapidly as temperature rises.

In order to have stable fluid flow characteristic it is important to grasp temperature range of the resin.

Depending on temperature thermoplastic resin may cause thermal decomposition to deteriorate its physical properties. Even in lower temperature, long staying in cylinders may cause relatively decomposition. In thermal decomposition of resin, if the resin goes through gate and runner portion at high speed, shearing force occurs not only in cylinders but also in the resin, heat is generated and thermal decomposition occurs partially.

As the standard to configure temperature conditions, it is important that we should know the temperature when the resins go through the nozzle part of molding machine.

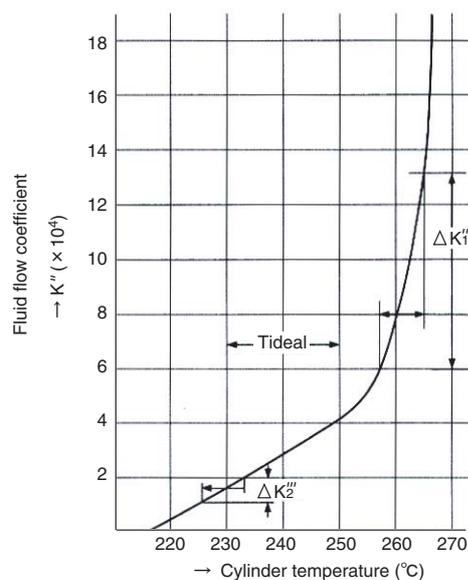


Figure 5

(C) Effect of pressure

Some of factors dominating dimensional accuracy are viscosity of resin (temperature characteristics), injection pressure, and injection rate. These factors are related to one another, and optimum condition will be determined by synergistic effect of three factors. Particularly as to pressure affection, because operational stability in hydraulic circuit of molding system is the problem, it is desired to make hydraulic driving force stable, and the condition setting is required that no pressure changes per shot have occurred.

Recent molding machines have high injection pressure and many of them are high injection rate, and their

controlling systems are also being improved. But most important point is still to find out the pressure setting on understanding quality characteristic of products.

(D) Effect of injection rate

Effect of injection rate means how fast and uniformly molten resin can be filled into mold. Essentially, high injection rate is preferred. In fast-filling into mold, to grasp a timing of switching from filling pressure to holding pressure and gate sealing time is difficult. And appearance and quality characteristics of molded products are affected (burned by resin, flush, jetting, flowmark). Thus, injection speed must be set accordingly.

2-7. Cause of failure in molding conditions

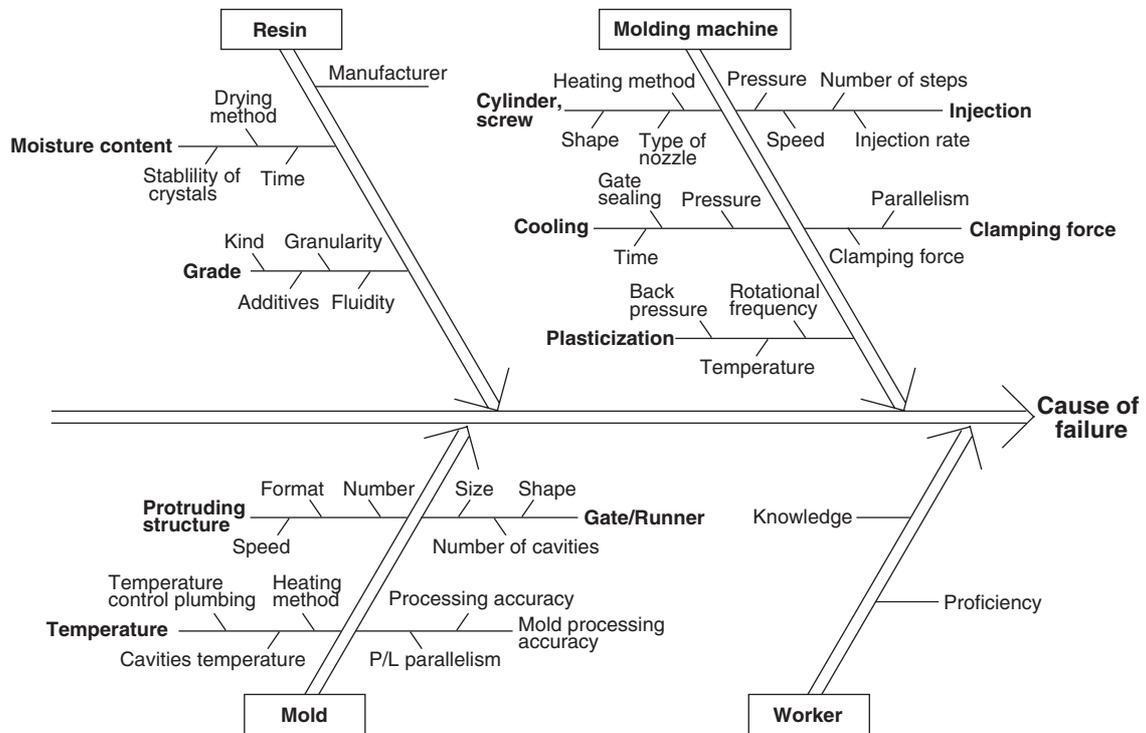


Figure 6. Characteristic of molding failure diagram

3. Applications to Hy-molding and LIM molding

ThreeBond's Hy-molding is composed of primary molding (to mold thermoplastic resins) and secondary molding (thermal-curing LIM molding). In LIM molding two-part liquid resin will be mixed in a cylinder, heated and cured into rubber material.

Since it is in liquid state at room temperature, it has low viscosity and low pressure injection is possible. And thermal management is rather easy because the temperature in the cylinder is managed at room temperature.

In conventional LIM (RIM) molding, the injection has been a pressing molding, and burring from parting surfaces has been regarded as inevitable.

In Hy-molding system, removing burrs from parting surfaces enables molding with dwell pressure by devising mold structure, and it enables molded products to be taken out as well as molding without burrs.

LIM molding can be done with a simple injection machine by utilizing ThreeBond's Hy-molded silicone resin. Hy-molding O system can mold a mold on air driven injection machine and small clamping unit, and sealing materials on a metal surface or plastic surface.

LIM molding will be utilized in various fields and commercialized from now on.

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