# Sandwich Injection Molding utilizing Waste Plastics

Tsutomu Nagaoka(IPEJ)

Plastics Machinery Department,
Machinery Company, Kobe Steel, Ltd.

## Introduction

Currently many people are concerned about environmental problems, recycling and saving resources, which are taken up as the big social problems.

Especially in recycling, the package and container recycling law was completely executed in April 2000, followed by the execution of the home appliance (televisions, refrigerators and washing machines) recycling law and the construction material recycling law in April 2001. Thereafter the industries of automobiles, OA equipment, business machines, game machines and so on are planning voluntary or legal regulation on their products. Thus the achievements of 3R (reduce, reuse and recycle) aimed at the realization of environmentally recycling society has become an important task imposed to us in the 21st century.

It has been said that recycling efficiency of plastic materials is low because they have a variety of functions and types, are produced in a large quantity, and difficult to classify.

Under these circumstances, in order to improve recycling ratio of plastics, unification of plastic material types to be used, reduction of the number of plastic material types, design technique for easy disassembly and classified collection are being implemented, and the material recycling instead of the chemical or thermal recycling is taking a favorable turn.

Further more in order to commercialize the plastic material recycling, sandwich and special molding for the purpose of utilization, cost reduction and functional improvement of recycled materials are attracting public attention.

In this paper, application examples of “MMP sandwich injection molding” technique (hereafter referred to as “MMP-SW” technique) developed by our company are introduced to identify the problems and tasks of this technology to be solved in the near future.

## 1. Outline of "MMP-SW"

The development of this technique was started in order to realize the material recycling of waste plastics at low cost about ten years ago, and the commercialization of recycled bumpers for Honda Motor Co., Ltd. was achieved in 1996. The development concept and the machine outline are shown in Table 1 and Figure 1 respectively.

The purpose of the development was commercialization of thin-walled and large-sized molding because the products were to be used as automotive parts.

The "MMP-SM" technique, capable of providing thin-walled and large-sized products, enables to use an existing machine and a mold to achieve cost reduction in material recycling. Furthermore, by transferring the sandwich molding function from the machine side to the mold side, a conventional machine can be commonly used as a sandwich molding machine without introducing a special purpose machine.

Recently, in order to further increase added value, a combination with special molding or other molding techniques is performed as described later.

## 2. Typical application

### (1) Molding wall thickness and core filling ratio

The "MMP-SW" technique enables the fabrication of thin-walled product molding instead of conventional thick-walled molding by transferring the sandwich molding function to the die side and simplifying the structure as shown in Figure 1.

Figure 2 shows relations between product wall thickness and core filling ratio based on test results.

Recently it became possible to mold about 0.8 mm pin gate product such as the casing for note type PC using PC/ABS. The "MMP-SW," having a nickname (given by us) "Kintaro candy molding," can deal with any injection molded product having any wall thickness.

### (2) Set core ratio and actual core thickness of product

Core filling ratio is called a core ratio because molding conditions are decided by amounts of skin injection and core injection in the sandwich molding and its ratio is important. The measurement of the core ratio on actual products is difficult.

Table 2 shows the actually measured core thickness of products molded by an 850-ton injection molding machine using a mold of a refrigerator vegetable case (design wall thickness 1.8 mm) as a typical example of thin-walled products as shown in Photo 1.

The actual core ratio almost coincides with the set core ratio (However, samples were taken from the representing portions because core filling condition varies depending on the place.)

The reason for the difference of skin layer thickness between the stationary platen side and movable platen side is considered to be due to the difference of the gate position and the mold temperature.

### (3) Test example of OA equipment[1), 2)]

The OA equipment includes copy machines, facsimile machines, PCs, telephones and so on.

Table 3 and Figure 3 show an application example in a copy machine of CANON INC. In this example, the sandwich molding firstly obtained the UL94-5V certification to successfully expand business opportunities. In this molding, it became possible to contribute to product cost reduction by using flakes, as core materials, made by washing and crushing casings of recycled copy machines.

### (4) Example of automobile

Commercialization of recycled bumper is the first application example in automobiles as afore-mentioned.

In this example, impact strength of bumpers which was lowered during long term use was improved by adding approximately 5% of HDPE as shown in Fig. 4[3)]. In addition, this application example realized the recycling cost reduction by utilizing bumpers as core materials without removing the coating film.

### (5) Application examples of daily necessaries and house components (bath components)

Application examples of daily necessaries and bath components relate to the package and container recycling law and the construction material recycling law respectively. Especially the bath components have used thermoset resin (unsaturated polyester such as SMC and BMC) in a large quantity, and thermal recycling has been mainly performed to utilize the waste materials for land reclaiming and cement additives.

Photo 2 shows an example of material recycling in which the materials made by crushing collected bath components (SMC) and mixing them with thermoplastic materials were used as the core materials to produce "bath components" from "bath components.[4)]

The product shown in Photo 2 is composed of HIPS in the skin layer and similar materials in the core as main material. The molded product was exhibited in the 45th

CONEX 2000 to be fortunately awarded the yellow ribbon prize.

Table 4 shows comparison of properties in case of using FRP as core materials. This is an application example of PP, which proved that the strength can be maintained even if approximately 30% of crushed FRP is used.

### (6) Application example of game machines

Typical products for game machines include pachinko and pachi-thro panels. We have realized commercialization of recycling of pachinko panels (plastic frames) having complicated shape as shown in Photos 3 and 4 in joint research with Sanyo Bussan Co., one of the biggest companies in this field.

In this molding, recycling and shrinkage prevention were realized by combining the sandwich molding and gas-assist molding as clearly shown in Photo 3.

Usage ratio of plastics in game machines are increasing year by year, and application of this process to products other than plastic outer frames (Photo 4) are now studied.

The game machines are designated as the Class 1 specified product in "Resources Effective Use Promotion Law" to be executed in April 2002. The industrial field is going to establish voluntary system to realize the recycling.

## 3. Other application

The "MMP" molding technique, provided with a core injection unit and an injection unit for an existing injection molding machine, can be applied to special molding (dichromatic and double-layer) other than the sandwich molding by installing an attachment, and adopted by automotive exterior and interior materials.

Although it is difficult to describe in detail in this paper due to a patent problem, the application range of the MMP molding is expected to expand because it enables us to realize special material sandwich molding.

## Conclusion

Examples of plastic material recycling by the "MMP-SW" technique were introduced in this paper. However, the material recycling of waste plastics has just reached the first stage, and the fact is that those waste materials are incinerated or disposed of in reclaimed lands (although partly commercialized as cement baking or blast furnace reduction materials).

Pervasion of the plastic material recycling leads to the reduction of global environment load and the reduction and prevention of carbon dioxide or dioxin emission. It is necessary to promote classified refuse collection, develop separating technology and develop low price compatibility agent to realize those reduction.

It is essential to establish cooperative system between research institutions, colleges and the government in addition to private companies to develop this technology.

It is also necessary to reform consciousness of consumers in cooperation with the government and through the media from the viewpoint of collection and utilization promotion.

We will continue to conduct research and development of this technology aiming pervasion and market expansion in order to contribute to the improvement of social and global environment.

## References

1) CANON INC., Environment Report in 2000

2) Tsutomu Nagaoka, Mold Processing, 12, [6] (2000)

3) Takeuchi, J. et al, Automotive Technology, 51, [5] (1997)

4) Tsutomu Nagaoka, Reinforced Plastics, 47, [7] (2001)

Table 1 Development concept of "MMP-SW" technique

| Item | Conventional system | MMP-SW technique | Purpose and effect | Remarks |
|---|---|---|---|---|
| Molding machine | Newly manufactured | Existing machine usable | Equipment investment reduction | Either vertical or horizontal possible. No restriction of manufacturer. |
| | Special purpose machine | Commonly used -co-injection molding -injection molding | Running cost reduction (Operating ratio improvement) | Commonly used for general, sandwich and special (dichromatic or double-layer) molding |
| Mold | Modification required | No modification required | Equipment investment reduction | |
| Product wall thickness | Thick wall (6 - 10 mm) | Thin wall possible (1.5 - 4.0 mm) | Application expansion(electric appliance and automobiles) | |
| Core material ratio | 5 - 15% | About 30% or more | Material cost reduction (Recycling ratio improvement) | Patent: Adoption of self-cleaning method |
| Equipment structure | Complicated | Simplification | Easy molding work | |
| Development initiative | Mainly by machinery manufacturer | Mainly user | | |

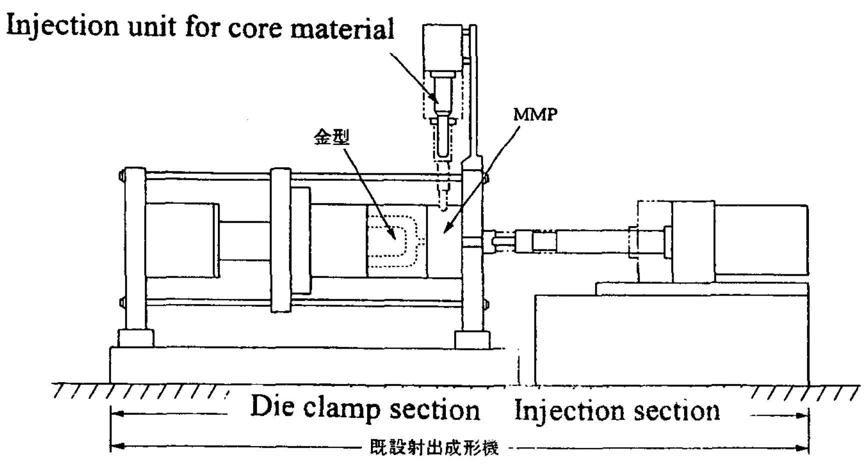


Figure 1 Modification of existing machine for co-injection molding

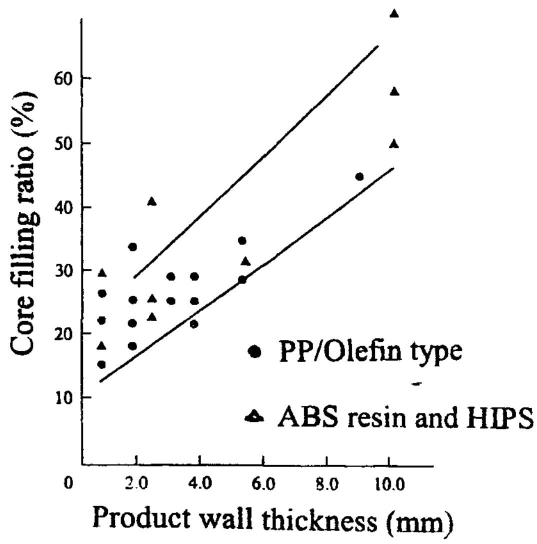


Figure 2 Relation between product wall thickness and core filling ratio

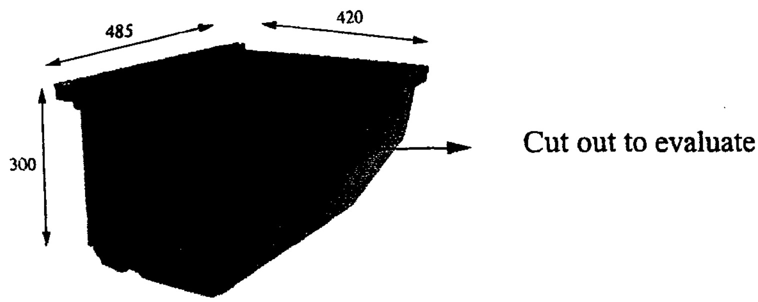


Photo1 Molded product outline(vegetable case)

Table 2 Set core ratio and actual core thickness
(Design thickness of die 1.8 mm)

| Item | | Unit | Actual measurements | | | |
|---|---|---|---|---|---|---|
| Set core ratio | | % | 10.0 | 20.0 | 30.0 | 40.0 |
| Thickness | Skin (Stationary side) | mm | 0.818 | 0.909 | 0.682 | 0.818 |
| | Core | mm | 0.182 | 0.363 | 0.636 | 0.818 |
| | Skin (Movable side) | mm | 0.727 | 0.545 | 0.455 | 0.409 |
| | Wall thickness | mm | 1.727 | 1.817 | 1.773 | 2.042 |
| Actually measured core ratio | | % | 10.5 | 20.0 | 35.9 | 40.0 |

Note) The set core ratio is calculated by the following formula:
Set core ratio = (Set amount of core injection)/{(Set amount of skin injection) + (Set amount of core injection)}

Table 3 Comparison of properties in OA equipment

| Item | Tensile strength (kgf/mm$^2$) | Elongation (%) | Tensile impact strength (kg cm/cm$^2$) | Flame retardancy 5VB |
|---|---|---|---|---|
| Sandwich | 5.94 | 148 | 143.9 | □ |
| Recycling 100% | 5.61 | 61 | 112.1 | □ |
| Virgin 100% | 6.11 | 142 | 154.2 | □ |

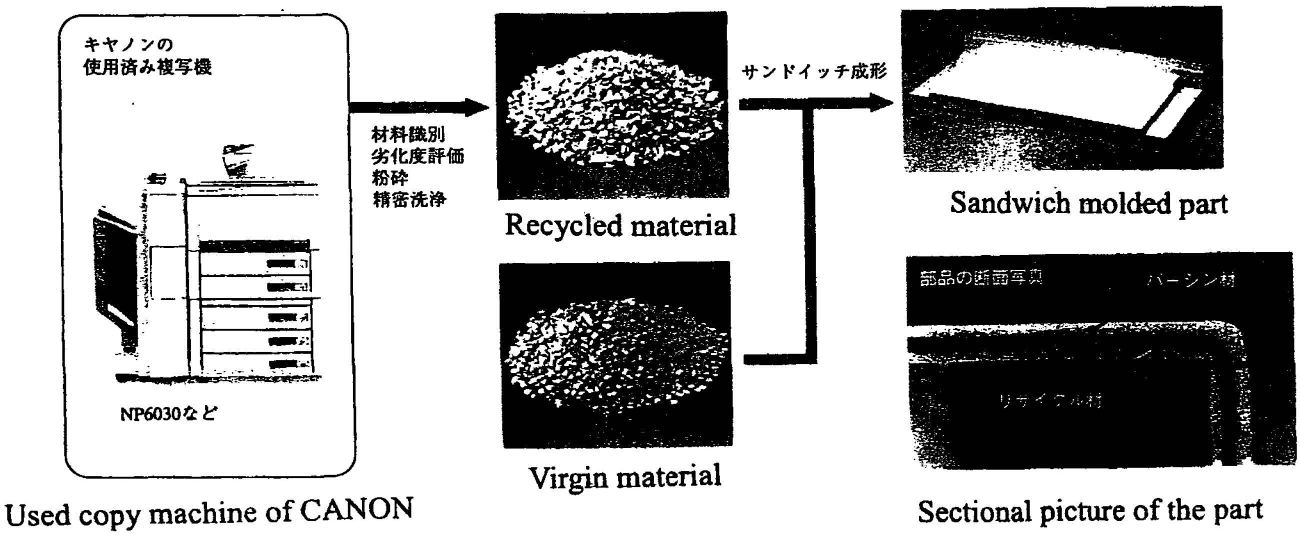


Figure. 3 Plastic recycling system

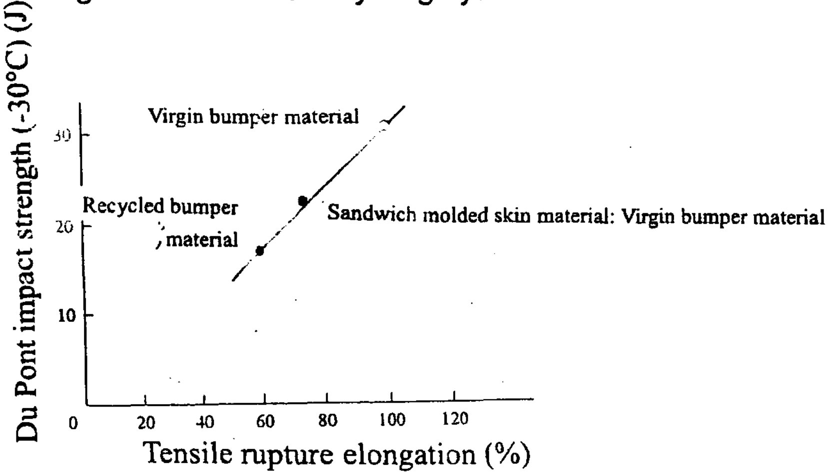


Fig. 4 Relation between tensile rupture elongation and Du Pont impact strength

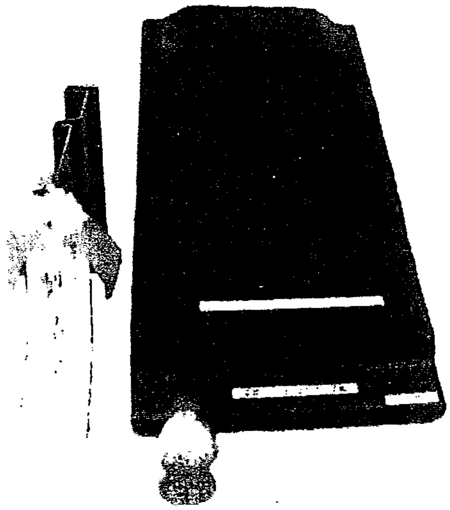

Photo 2 Mirror cabinet (crushed SMC used)

Table 4 Comparison of properties in case of using crushed FRP as core material

| Item | Unit | Only PP | Sandwich molded product |
|---|---|---|---|
| Tensile strength | MPa | 28 | 24 - 25 |
| Tensile rupture strength | MPa | 20 | 22 - 24 |
| Tensile rupture elongation | % | 50 | 10 - 14 |
| Tensile modulus of elasticity | MPa | 1,650 | 1,450 - 1,490 |
| Bending strength | MPa | 33 | 32 |
| Bending modulus of elasticity | MPa | 1,430 | 1,410 - 1,500 |
| Izot impact strength | $kJ/mm^2$ | 12.4 | 4.4 - 6.2 |

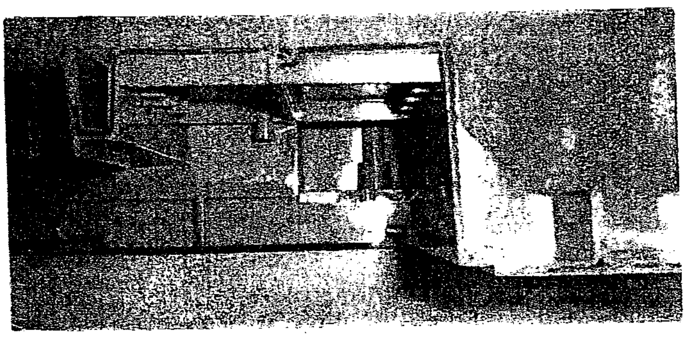

Photo 3 Sectional photo of outer frame
(Recycled material looks black)

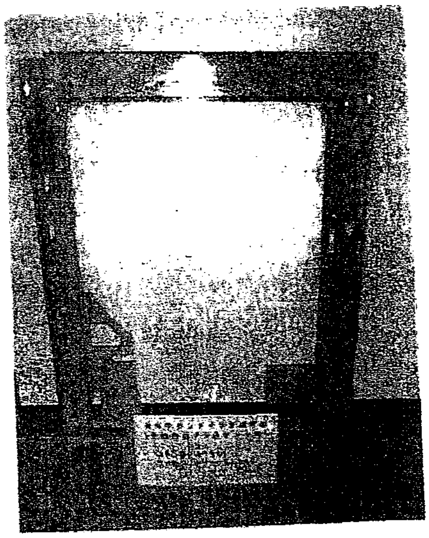

Photo 4 Game machine (outer frame)