A Study on the Manufacturing of Large Size Hollow Shape Parts for Prototype-Car using Rapid Prototyping Technology and Vacuum Molding

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ABSTRACT

Rapid Prototyping(RP) techniques have revolutionized traditional manufacturing methods. These techniques allow the user to fabricate a part directly from a conceptual model before investing in production tooling and help develop new models with significant short time. This paper suggests the new process to manufacture large size hollow shape parts for prototype-car using Rapid Prototyping technology and Vacuum Molding with the reduction of delivery time. In addition, this paper introduces the dividing and combining method to make large size RP master model in spite of the limit of the build chamber dimensions of commercialized RP systems and post-processing method to achieve sufficient surface quality.

1. INTRODUCTION

In the development stage of new cars, prototype-cars manufactured for an aim to inspect a shape of design, performance, and stability generally adopt the same process of manufacturing parts as mass production in order to get the reliability of test results, but the modified manufacture methods which are different from mass production are used considering urgency of manufactured parts and quantity in case of manufacturing cars having unique specifications like RHD(Right Hand Drive) cars, shapes of parts, and needs for the early stage-test of functions due to the urgent change of design. In this case, it is necessary for parts manufactured by the changed manufacture process to have mechanical function for the whole external appearance and the performance of assembly such as dimensional accuracy and a reliable result.

This paper suggests the new process to rapidly manufacture half molds for vacuum molding using a master model of a large size hollow shape part for prototype-car made by Rapid Prototyping machine, SLS(Selective Laser Sintering)[1][2][3] , and to adhere two parts made by vacuum molding. In addition, this paper introduces the dividing and combining method to make large size RP master model despite of the limit of the build chamber dimensions of commercialized RP systems and post-processing method to achieve sufficient surface quality.

2. MAIN PROCESS

The general method to make hollow shape parts for prototype-car is blow molding. There are two blow moldings which are Resin-based blow molding[4] and ZAS(Zinc Alloy for Stamping) blow molding. ZAS blow molding is used in large size mass production due to the requirement of the same size of mold equipment and specification. Fig. 1 shows the comparison between suggested method and conventional method for manufacturing of large size hollow shape parts using ZAS blow mold.

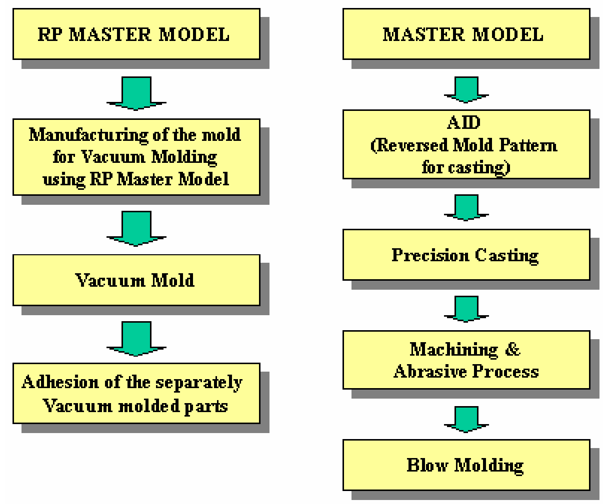


Fig. 1 Comparison between suggested method (a) and conventional method for manufacturing of large size hollow shape parts using ZAS blow mold(b)

2.1 Manufacture of Mater Model

2.1.1 Special features of molding parts

A part manufactured in this paper is a Heater to Air Ventilation Duct Connector to control temperature and humidity of the inside car using heat and energy from an engine. It is installed inside an instrument panel and has a shape to avoid interference with electric wires and outer parts controlling equipment of sound and temperature. Fig. 2 shows a feature of heater to air ventilation duct connector

2.1.2 Parting and molding of master model

The part to mold is modeled by CATIA. The part is 1200mm long. So, it is impossible to mold the whole part at one time due to the chamber size of SLS machine, Sinterstation 2000. Therefore the method to divide the modeled shape into seven parts and adhere them is applied as shown in Fig. 3.

Fig. 2 Feature of heater to air ventilation duct connector

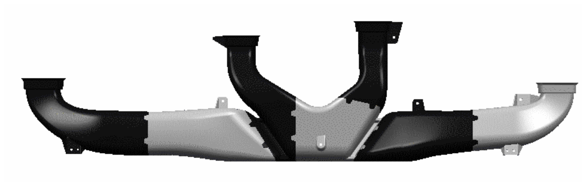


Fig. 3 Feature of divided CATIA data

The ladder-shaped structure at each divided parts is adopted to get an exact position and keep the adhesion strength during the process of adhering a master model. After the two mold inverted from the master model are manufactured, the process of removing the master model from the mold should be performed to make the complete mold for vacuum molding. The thickness of the master model is about 2mm because the method to crush the master model in the mold is used. The complete molded parts are adhered along the ladder-shaped structure. If the surface of this area is rough, it is difficult to adhere 7 parts. In case there are rough surfaces, post-processing is required for adhesion. Fig. 4 shows the process of adhering those parts.

Fig. 4 Adhesion of separately built SLS subparts

2.1.3 Post-process of combined SLS master model

There are two methods to improve the surface roughness of parts made by RP machine. One is to control building orientation and laser scan path and the other is to post-process built parts. The improvement of the surface roughness using building orientation and laser scan path has limitations and increases building time. Therefore this paper uses the method of post-processing parts.

There are two post-processing methods that are abrasion and coating. It depends on mechanical strength. It is difficult to use an abrasive method because the master models manufactured by SLS process have sufficient mechanical strength. This paper adopts a coating method to improve the surface roughness using resin. The used coating method has three steps. Three steps are demonstrated as follows;

First, undercoat is sprayed on the master model to improve the surface roughness in short time. Undercoat uses urethane material, PUTTY(P000-C4125). After spraying, hardened undercoat material needs to sandpaper.

Second, fine air bubbles exist due to property of spraying PUTTY and it is not easy to remove all the fine air bubbles. Rapidly dried RED PUTTY is covered on the area of air bubbles using brush and needs to sandpaper.

Third, the surface of the master model is coated with SANDING SEALER to get sufficient surface roughness for tooling. Table 1 shows materials used to enhance the surface roughness

Table 1 Materials used to enhance the surface roughness

	Materials
First step	PUTTY(P000-C4125)
Second step	RED PUTTY(051144-05972)
Third step	SANDING SEALER

2.2 Manufacture of Mold

2.2.1 Selection of parting line and works

The selection of parting line is an initial process of manufacturing mold and an important work for the whole mold structure, cost, delivery time, and qualities of molded parts. In this paper, the parting line is determined by the following rules.

First, additional combining structures designed to assemble surrounding parts is included in the parting line.

Second, a space between a sheet and a vacuum mold in order to absorb the sheet into the vacuum mold using suction pressure generated from the pump of vacuum molding machine should be sealed up. In case of having air-leakage shape, it is necessary to have a dam for protecting air-leakage in outer area of a product.

Third, trivial undercut is negligible in selection of parting line.

2.2.2 Manufacturing process of half mold

A work of accumulating heat-resisting resin is carried out above a master model fixed on a base plate after work of parting line. The heat-resisting resin plays a role in preventing the damage of the mold surface at high temperature of about 150°C. Then frames for reinforcement are built and outer frames are installed to prevent the damage of the mold under strong suction pressure generated from the process of vacuum molding in Fig. 5. Resin is accumulated to support the strength of mold between the reinforcement frame and the outer frame. Fig. 6 shows a completely built mold structure and a feature.

In order to make the second half mold, the work is carried out on base plate without separating the master model from already finished first half mold. The work process to manufacture the second half mold is equal to the process of the first half mold. When the manufacture of the second half mold is completed, two molds are separated and the master model stuck to the second half mold is crushed.

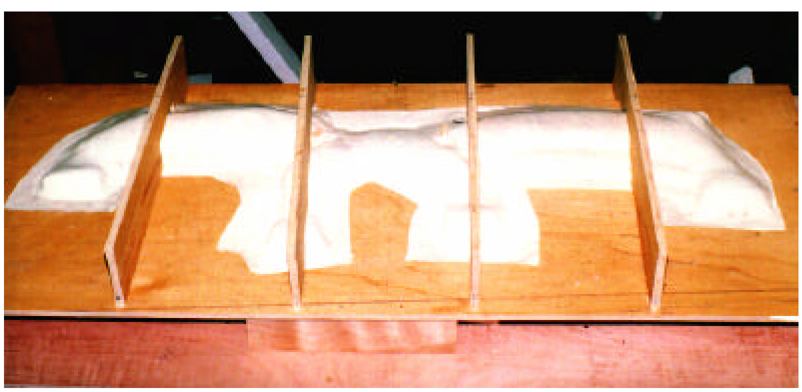
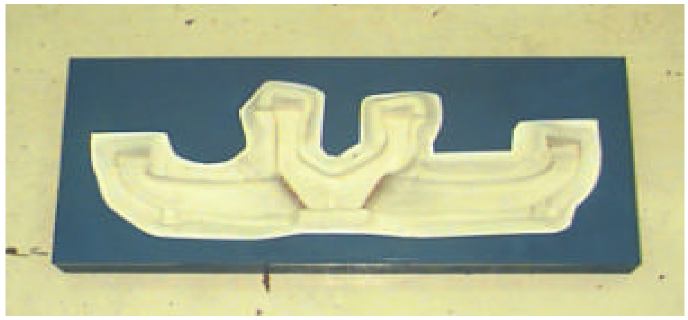
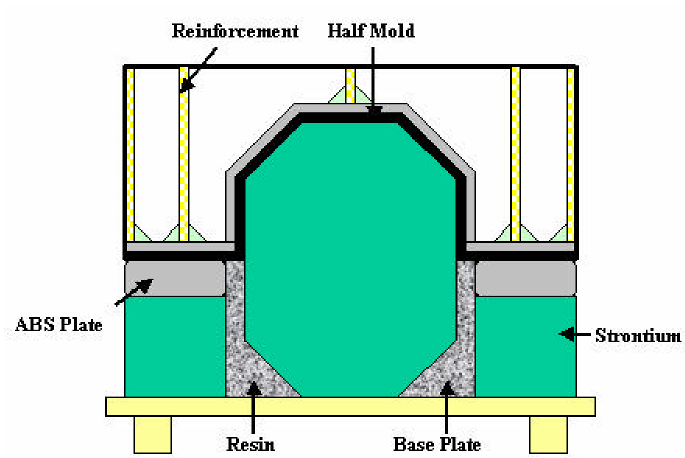


Fig. 5 Feature of mold reinforcement structure



(a)



(b)

Fig. 6 Schematic diagram of half mold for vacuum molding(a) and feature of the first half mold.(b)

2.3 Process and condition of vacuum molding

The first step for vacuum molding is that the mold is loaded into the vacuum mold machine. The contact surface between the mold and the vacuum mold machine should be completely airtight when the mold should be loaded into the vacuum molding. After loading the mold, a sheet for vacuum molding is set up into the clamp. Then the sheet is heated to get enough flexibility. Table 2 shows the operating conditions applied to this paper. ABS sheets are used for the suggested process.

Table 2 Operating conditions of vacuum molding with respect to materials

	ABS	PP
Standard Condition (Thickness : t, Temperature : °C)	2.5t/23°C	2.5t/23°C
Shrinkage	8/1000	16/1000
Heating Temperature (°C)	250	300
Heating Time (sec)	155	180
Transfer Time (sec)	4 ~ 5	4 ~ 5
Mold Uploading Velocity (mm/sec)	100	100
Cooling (with fan) Time (sec)	80	150

The heated sheet is then transferred to molding area. After sheet transferred to molding area is fixed on clamp, the elevator uploads and the surface of mold lifts up the surface of sheet. Then the pumps loaded into vacuum mold machine inhale the air between the mold and the sheet. The sheet is cooled using a fan after inhaling the air. The completely cooled sheet is separated from the mold. Fig. 7 shows the whole process of vacuum molding.

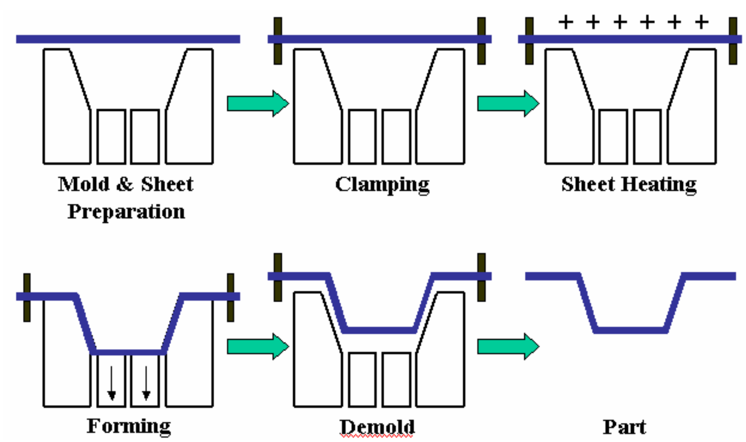


Fig. 7 Schematic diagram of vacuum molding

The sheet is then cut along the boundary of product-shape area and surrounding area is removed. The first half part and the second half part molded from vacuum molding are adhered together along the parting line. Finally, a complete part is obtained. Fig. 8 shows the feature of manufactured part from vacuum molding.

Fig. 8 Photo of manufactured part

3. EXPERIMENTAL RESULTS

3.1 Measuring error

Fig. 9 shows the main dimensional sections to get measuring error of manufactured parts between the design dimensions and the molded part dimensions. Table 3 shows the design dimensions and the average value of sampling dimensions of vacuum molded parts. SLS parts were manufactured considering shrinkage 0.8% of vacuum molded parts.

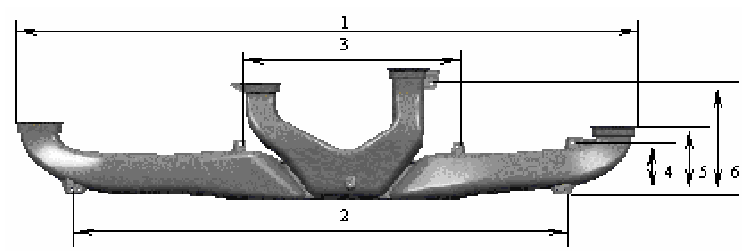


Fig. 9 Sample dimensions of a model

Table 3 Design Dimension and Molded Part Dimension

	Design Dimension (mm)	Molded Part Dimension (mm)	Shrinkage (mm)
1	1298.16	1297.68	-0.48
2	1033.88	1033.52	-0.36
3	452.99	452.78	-0.21
4	110.80	110.68	-0.12
5	159.40	159.25	-0.15
6	265.32	265.08	-0.24

4. CONCLUSIONS

This paper suggests the new process to manufacture large size hollow shape parts for prototype-car using Rapid Prototyping technology and Vacuum Molding. In addition, this paper introduces the dividing and combining method to make large size RP master model despite the limit of the build chamber dimensions of commercialized RP systems and post-processing method to achieve sufficient surface quality. In order to know if the suggested process is used in industrial fields, the suggested process is compared with the existing process, ZAS blow molding. From experiment results, the suggested vacuum molding process shows that products have sufficient quality considering that the tolerance of large size blow molding is 1 mm approximately.

REFERENCES

1. F. Prioleau, "Selective Laser Sintering – The Process and Its Materials," Proceedings of the ANTEC '93, Vol. 3, pp. 3231-3234, 1993.
2. T.S. JANG, "Development and Technology of Prototype-Car using Rapid Prototyping," PKATEC Workshop and RP Exhibition", pp. 34-38, 1998.
3. P.F. Jacobs, "Streolithography Accuracy, QuickCast^{TM} & Rapid Tooling," ICALEO, p. 194, 1995.
4. H.J. YANG, B.J. HWANG, S.H. LEE, "A Study on Manufacturing Resin-based Blow Mold using SLS Parts and Forming Prototype-Car Parts," Journal of the Korean Society of Precision Engineering, Vol. 17, pp. 124-131, 2000.