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The Development of an Automatic Molten Metal Supplier for an Aluminum Thermal Furnace

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Abstract

The objective of this development project is to localize an automatic molten metal supplier that has been distributed by WESTOMAT, Germany, throughout the world. To achieve this purpose, an energy-saving pressurized dosing furnace and molten metal differential pressure control system that is able to automatically supply a determined quantity of aluminum molten metal were developed. The localized equipment was installed in a site. Also, the results of the test operation of this equipment can be summarized as follows:

It was able to improve the productivity because there were small decreases in supplying speeds and small losses in wastes compared to the existing mechanical molten metal supplier. Also, it was able to minimize the cost in maintenances due to the direct application of high temperature molten metals to molds. In addition, there were small energy losses due to the use of high thermal insulators compared to the existing reverberating furnace and able to prolong the life-time of furnaces and produce good quality nonferrous metals because it represented small carbon refractories and alumina in applied molten metals. Furthermore, it demonstrated no particular differences by objectively comparing it with the product by WESTOMAT.

Key Words : nonferrous metals(비철금속), automatic supplier of molten metals(자동 용탕 공급 장치), application of the molten metals in a mold(금형 주입), maintenance(유지 보수), mechanical contact(기계적 접촉)

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1. Introduction

For a die casting process using nonferrous metals like aluminum or magnesium, in general, the molten metals in a furnace is to be warmed by transferring it into a thermal furnace nearby the die casting machine using a ladle. The thermal furnace is prepared to process the die casting process through settling stored molten metals and stabilizing its temperature and supplies the molten metals using a robot arm that is operated as a chain system for transferring molten metals from the thermal furnace to molds(1~3). Regarding the problem occurred in the operation of a mechanical transferring system and the trouble for workers in a site, it usually concerned in a low efficiency in production due to frequent faults and inferior in quality caused by the decrease in the temperature of molten metals due to the movement of molten metals. In addition, there exists certain losses in the production cost due to the loss of molten metals because it is difficult to supply a quantified amount of molten metals. Thus, it is necessary to solve the problem that may occur in the existing mechanical transferring system. For solving the problem, a development of a new system that automatically supplies the molten metals instead of using the conventional mechanical system is required(1~3). In the precedent case of this automatic molten metal supplier, the company of WESTOMAT in Germany developed and distributed it throughout the world successfully by joining the company of DIDIER that represents a specialty in refractories(4,5). The final goal of the localization development of the automatic molten metal supplier in this study is to guarantee more excellent performance and lower product price than that of the system produced by WESTOMAT and to distribute it in domestic markets. For achieving this goal, it is necessary to develop an energy saving type of pressurized dosing furnace and a differential pressure control system for molten metals that automatically supplies a quantified amount of molten aluminum(4,5).

2. Main subjects

2.1 Development of a pressurized dosing furnace

Selection of refractory materials and calculation of heat capacity are to be performed to manufacture a pressurized dosing furnace. Here, the materials that consider the first calculation of thermal capacity and condition of surface temperature are also selected to perform these processes and then a computer simulation is to be carried out to achieve the test for its appropriateness(1,5,7~9).

The reason that presents the dim and obscure data produced in the first calculation of thermal capacity and surface temperature is asked to limit the open of the data from the sponsor of this study. In the results of the computer simulation for the first selection, the application conditions of the refractories are acceptable because aluminum is melted at a low temperature region, 660℃. However, as the melted aluminum reaches to the temperature of 800℃ the viscosity and tension will be decreased. Then, it will easily penetrate the internal structure of the refractories. In addition, because it shows a very strong reduction level it may occur certain damages in refractories due to the reduction of the chemicals of sodium silicate and alkali components included in refractories. It can be considered that the penetration of aluminum is expected due to the pores of refractories, and there are

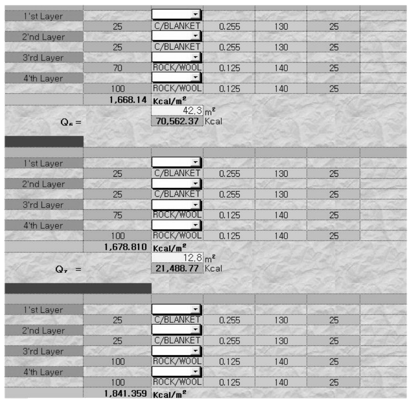

Fig. 1 First computer simulation

some structural spalls because the thermal expansion increased by six times at 800℃ with respect to that of the original layer due to the increase in the composition of metal Si and Al_2O_3 caused by the generation of deteriorated layers and structural spalling due to the melted aluminum. In addition, it can be seen that there are some damages due to the generation of spalls in deteriorated layers caused by the mechanical shock in a removing process of the surface of refractories. For minimizing the problem presented in the first selection, the secondary materials were selected as follows and then a conditional test for its appropriateness was applied[1,5,7,9].

Fig. 2 shows the dim and obscure data as same as Fig. 1 due to the know-how of the sponsor. In the results of the second conditional test, the performance of its thermal insulation decreased and that generated some impurities due to the reaction between the component of SiO_2 and the molten aluminum because it used dense refractories. In addition, if the content of SiO_2 approaches more than 20%, and the temperature of molten aluminum exceeds 700℃, some impurities will be generated and then the molten aluminum does penetrate to the inside of refractories. The deterioration of refractories represents a decrease in efficiency and a loss in energy. Also, a type of corundum will be formed at the wall of the furnace due to the reaction between the castable and the molten aluminum[4,8,10].

If the corundum is formed at the wall of the furnace, the internal space will be decreased and that causes energy losses due to the decrease in its efficiency. Finally, it will supply low quality molten aluminum. It can be seen that the molten aluminum that does penetrate to the joint section of refractory bricks changes the lining profile and that leads to decrease the entire thermal insulation in the furnace[9~11]. The localization product presented in this study was produced as an energy saving pressurized dosing furnace for preparing the penetration of molten metals using a type of low cement refractories and through an effective construction of backup materials based on a computer simulation and manufacturing experience[13~16]. As a result, the atmospheric temperature inside the furnace showed a low level of about 100℃~200℃ compared to that of the conventional furnace and decreased the content of hydrogen in molten metals because it represented a low oxidized loss in refractories and SiO_2 in molten metals[2].

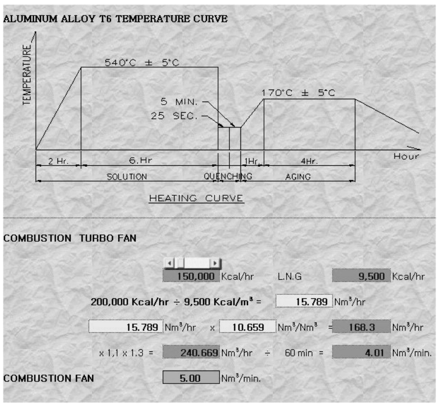

Fig. 2 Second computer simulation

2.2 Development of a pressurized control system

A pressurized control system is influenced by the air pressure supplied to the inside of the furnace in which it is necessary to determine a pressure level by considering various factors because the molten metals are to be supplied through a rising tube. The applied pressure can be determined according to the amount of molten metals filled in the furnace, the level of differences in the pressure, and the amount of supplied molten metals[1~3]. The product developed in this study was configured by considering these factors as shown in Fig. 3 and Table 2. Then, a pressurized control system was developed by following the operation presented in Fig. 4[1~3].

The mentioned major steps can be summarized as follows; Step 4 controls a pressure detection sensor[1~3] in which the detection range was determined by the minimum of $250mmH_2O$ and the maximum of $1,500mmH_2O$. Here, the solenoid valve for the first pressure is to be pressurized until the pressure switch is detected, and the solenoid valve for the second pressure can be pressurized as a proportional control method in order to discharge its quantified amount after applying the first pressure. The sensor unit can be applied as a way that connects the

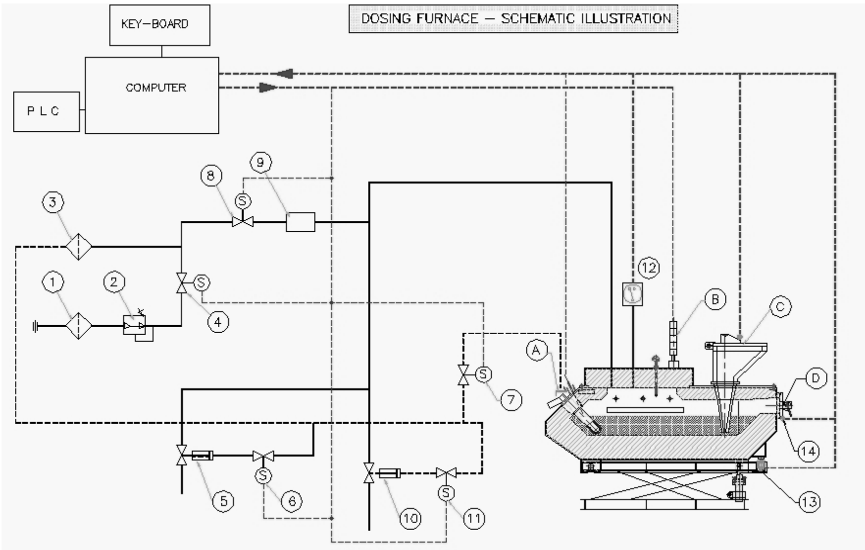

Fig. 3 Layout of the pressurized control system

Table 2 Configuration of the pressurized control system

NO	Item
A	Rising tube and sensor
B	Indicator of the cumulation level of molten metals
C	Casting hole of molten metals
D	Cleaning unit of the inside of the furnace
1	Pressured air tank and filter unit
2	Pannel of the pressurized control system
3	Oil system of the pressured air
4	Sol v/v for the first pressurizing
5	First air vent valve
6	Second air vent valve
7	Pressurized control system
8	Sol v/v for the second pressurizing
10	Pressured vent hole for the first pressurizing
11	Pressured vent hole for the second pressurizing
12	Pressurized vent of the dosing furnace
13	Weight detection load cell

Step 1	Initial Model
Step 2	Calculation of the amount of molten metals using a load cell
Step 3	Presentation of the preparation level of molten metals and its application
Step 4	Determination of the pressure of the inside of the furnace using a pressure sensor
Step 5	Applying the first pressure using a sol v/v for the first pressure
Step 6	Applying a detection sensor according to the application of the first pressure
Step 7	Applying the second pressure using sol v/vs for the first and second pressure
Step 8	Applying the second pressure to the molten metals using sol v/vs for the second pressure
Step 9	Application of molten metals
Step 10	Release the second pressure using the second vent sol v/v

Fig. 4 Operation steps in the pressurized control system

molten aluminum and sensor electrically as they are raised according to the applied pressure[1,2]. Step 5 and Step 8 operate the pressure proportion control valve where two pressurized air valves, which control an automatic molten metal supplier, were installed for the safety[1~3]. The connection of the pressurized air was carried out by using two 2/2 valves in series where the valves are located at a stop position and will be closed according to the increase in the pressure inside the furnace. The internal discharge in the furnace can be performed using 2/2 piston control valves in parallel where the valves are located at a stop position and will be open by the power of the spring in the valve. Step 10 controls the air vent valve unit in which the emergency air vent valve can be controlled by on/off as a manual operation, and a commercial air vent valve is used to release the applied pressure.

3. Experiment and results of the site application

The product developed in this study was installed at the S company located at J City in Gyeongnam and was applied to a test working for producing a large vehicle wheel as shown in Fig. 5.

In the results of the test working, there were some problems as follows. First, as shown in Table 3, there was a certain difference between the target and the actual amount of molten metals[2,4].

Second, as illustrated in Fig. 6, there were some difficulties for avoiding the dangerous fugitive molten metals to a safety zone as workers carried out their die casting works due to the fugitive molten metals from the die casting mold.

The results of the solutions for these two problems can be determined as follows.

From the first problem, because the product developed in this study was fabricated by copying the appearance of the product manufactured by the WESTOMAT, Germany, it was difficult to control the applied pressure as a

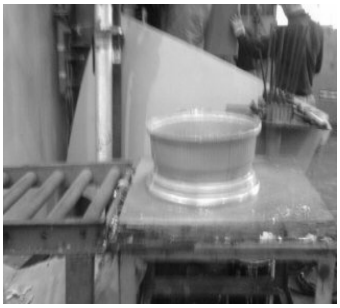

Fig. 5 Large vehicle wheel

Table 3 Configured and discharged quantity in molten metals

No	Target (kg)	Appl. (kg)	Temp. of molten metals	Target pressure	Load Cell
1	52	70.00	670	0.09	2060
2	52	51.35	670	0.09	2024
3	52	51.58	670	0.0925	2011
4	52	52.01	670	0.095	1984
5	52	50.77	670	0.09625	1970
6	52	50.96	670	0.0975	1955
7	52	51.36	670	0.102	1925

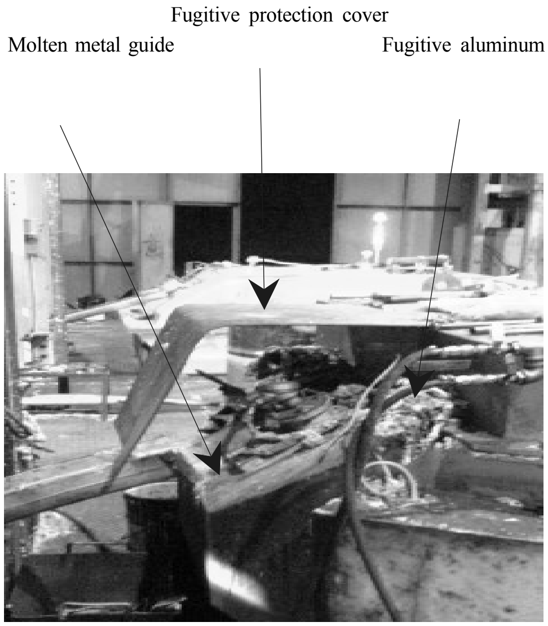

Fig. 6 First session of the fugitive aluminum in a dosing furnace

proportional manner. This problem was solved by minimizing the error occurred in the calculation of the volume of the internal furnace through fabricating the internal shaft furnace as a shape of rectangle. As shown in Table 4, the results represented that it was possible to obtain the constant pressurizing and application of molten metals even though the molten metals showed a lack of uniformity.

From the second problem, it was solved by the mold company that installed and operated their products[1~3]. The detailed way for solving this problem is not mentioned in this study because it has no direct relations to this study. Table 5 shows the results of the comparison between the WESTOMAT and the localized product developed in this study. However, the more specific quantified data cannot be open due to the demand of the sponsor[4,5].

Table 4 Pressurizing and discharging of molten metals after modifying the equipment

No	Temp (℃)	Pressurizing (kgf/cm^2)	Discharging (g)	Power meter (kw)	Capacity (kg)	Hydro-gen content (cc)
1	720	0.9	30,000	22,110	1,200	3.0
2	719	1.0	30,100	22,115	1,170	3.5
3	720	1.2	30,500	22,111	1,140	4.0
4	721	0.9	30,000	22,112	1,110	2.5
5	718	0.9	30,030	22,112	1,080	3.0
6	720	1.0	30,100	22,112	1,050	2.0
7	719	1.1	30,500	22,113	1,020	3.0
8	720	0.9	30,000	22,113	990	3.0
9	720	0.8	29,900	22,114	960	2.0
10	719	1.0	30,000	22,115	930	3.5

4. Conclusion

In the results of the application of the automatic non-ferrous molten metal supply system developed in this study to an actual site, the advantage and future direction can be summarized as follows:

(1) It shows a high productivity compared to the conventional system with a mechanical transferring system because it represents almost no losses in application speed and its amount.
(2) Because it directly applies the high temperature molten metals into the mold, it does not require specific maintenance and minimizes the load of the maintenance for the system because it has no mechanical contacts.
(3) It represents almost no losses in energy because it uses high quality thermal insulation materials compared to the existing reverberating furnace.

Table 5 Comparison between the WESTOMAT and the localized product

Item	WESTOMAT	Localized Product
Problems in the maintenance of refractories	Difficulties in the maintenance due to the joint structure of upper and lower plates	Totally separate the upper and lower plates for maintaining refractories easily
Problems in the cost of expendables	A filling tube, which is an expandable, is used to apply molten metals.	The molten metals can be directly applied instead of using the filling tube.
Problems in the quality of molten metals and energy losses	Due to the external treatment of gas the quality of molten metals is low and shows a lot of energy loss for compensating its temperature.	A gas treatment device is installed at the lower part and directly processes the gas. Then, it increases the quality of molten metals and is able to compensate the temperature. Also, it leads to minimize the energy loss.
Problems in the flowing of molten metals	A certain unstable due to the use of a hydraulic jack	It shows a relatively stable by changing the jack into a hydraulic cylinder.

(4) It is possible to extend the service life of the furnace because the system shows a small oxidation in refractories in molten metals and aluminum oxide and that leads to produce quality nonferrous metals.
(5) In the results of the comparison between the WESTOMAT and the localized product developed in this study, it can be seen that it represents almost same performance as that of the WESTOMAT.

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