Microwave Drying Chamber

Drying the complex shaped molds in short time
(Molds with holes or cylindrical shape)

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1. INTRODUCTION

In molding of investment casting mold, in general, wax model tree is coated with slurry containing the refractory zircon flower, followed by high alumina sanding with the particle size of 0.3-0.7mm (approx. 0.01”-0.03”) for primary and second layer, and 0.7-1.5 mm (approx. 0.03”-0.06”) for third and the following layers.

After the slurry coating and sanding, the tree is dried over 2-6 hours per layer in a drying chamber where temperature and humidity are kept in constant condition. This process is repeated about 6-8 times. In this case, a complicated shape with cylindrical or holes take much longer drying time compared with the other ordinary shapes.

When drying the molds in microwave mold drying Chamber, which was reported earlier, it will shorten the drying time considerably compared to the natural drying method 1, 2. Even with the microwave drying Chamber, complex shaped molds were consuming extra 30 minutes compared with the other ordinary shapes. To address this challenge, we have newly developed microwave drying Chamber with unique combined proprietary technologies that is capable of drying the molds in complex shapes in considerably shorter time.

This presentation will describe technical details of time reduction in mold drying process, mold temperature control with microwave drying system and how this technology can be practically applied and contributed for investment casters.

2. ATTEMPT (OR EXPERIMENT) OF MOLD DRYING METHOD AND TIME REDUCTION

2.1 Present - Natural drying method

When drying the molds in complex shapes with cylindrical or holes will consume much longer time than the ones in relatively simple shape. Refer Figure 1. , Figure 2. The reasons are as follows;

(1) Due to the complex shape, in other words, high humidity is stagnant in the air hole of cylindrical mold, and the air in the inner surface of the tree is hard to move to the outer surface.

(2) Small humidity difference between the humidity near the surface of the mold and humidity of the cylinder air hole. Since they are small difference and moisture is difficult to spread out.

![Fig. 1.Cylniderical shaped tree](image1)

![Fig. 2. Tree with holes](image2)

![Fig. 1-1. Section of cylindrical shaped tree](image3)

![Fig. 2-1. Section of tree with holes](image4)
2.2 Drying time reduction attempt

In order to shorten the drying time for the molds in complex shapes there have been several attempts to be made. Except for a method of using a quick drying slurry and drying in extreme low humidity atmosphere, the following three methods are popular.

(1) Industrial Fan
In order to remove the humid air that has stagnated near the mold surface, industrial pressure ventilation fans are installed to position along the transport route of the hanger conveyor, devotes to force the dry air in the tree surface; this is a method to accelerate drying. In a dry room, where an industrial fan can be set up is limited, and the result of drying time reduction is also limited.

(2) Dehumidifying dry room
This is a method of supplying dry air near the mold surface to facilitate drying. Increasing the dehumidification capability will relatively lower the humidity of the drying room then the moisture can be easily out of the air hole of mold. However, to dehumidify the air in the drying room to the desired level, it must be cooled by freezer to the condensation of moisture in the air. It is technically possible, however the desirable humidity is determined by comparing the benefits of reduced drying time and running energy cost due to extremely high electricity usage. This percentage varies depending on climate of the region where the plant is located, and it is desirable at 45 to 55% humidity in general.

(3) Dedicated mold drying chamber
With this method, multiple trees are put into a dedicated mold drying chamber, and the air in the chamber is stirred by industrial fan to speed up the drying process.

None of the above three methods are capable of supplying dry air deeply in the inner surface of the hole or cylindrical shapes. Therefore, earnestly, it must be dried over time in the drying room for mass production where the room must be kept to a constant temperature and humidity level.

3. DRYING MECHANISM AND DRYING METHOD

3.1 Currently the following two drying methods are recognized as practical use.

(1) Natural drying method to dry in the drying room, where the room is kept to constant temperature and humidity.
Water content will come out to the mold surface while diffusing in the difference of osmotic pressure that is utilizing the difference in moisture content between the core part of the mold and the surface area. Water content is adsorbed on dry air and surrounding the moisture around the mold is removed. (Including the use of quick-drying slurry or drying in extreme dry air)

(2) Microwave mold drying method
Microwave irradiation is applied into the inside of molds to encourage water content to come out from the core part to the mold surface utilizing the difference in osmotic pressure.

3.2 Qualitative Study on movement of high humidity air in the case while the mold is being dried.

When considering qualitatively mold drying mechanism it will be as follows; Water content is diffused due to the difference in moisture content of the inside mold and moved to the surface where the humidity is low. The speed of diffusion is further activated by microwave and drying speed changes. Figure 3.1, Figure 3.2 are graphical charts to macroscopically visualize the progress per unit time to show how the humidity difference will be affected on the drying time between the
humidity near the mold surface and humidity of the mold air hole. It can be seen that the more you lower the humidity obviously it is advantageous for drying.

In consideration we must perform factor analysis of the moving mechanism of moisture content in the mold depending on materials of construction, shape, density, and also considering the boundary conditions of air humidity near the mold surface we must conduct numerical calculation to predict the drying time, but this itself alone has so much volume to study one theme, and we shall leave them for the researchers.

![Graph 1](image1.png)

![Graph 2](image2.png)

**Fig. 3.1** humidity atmosphere = 45%

**Figure 3.2** humidity atmosphere = 55%

### 4. REMOVING THE HIGH HUMIDITY AIR NEAR THE MOLD SURFACE USING MICROWAVE

Even we activated water molecules by microwave radiation and made them easier to appear on the mold surface, if the humidity atmosphere in the mold surface vicinity is high, it is difficult to diffuse them into the surrounding air. We suggest the following combined method to shorten the drying time.

1. In order for the water contents came out from the inside of the mold should not be stagnant in microwave Chamber, we must quickly remove high humidity air around the mold.
2. Supply dry air near the mold surface and let the high humidity air to be easily adsorbed.
3. Forcibly discharged the high humidity air that adsorbed moisture to the outside of the Chamber.
4. Forcibly remove the high humidity air from within the surface of the concave surface of the hole shape, such as a cup or a cylindrical shape.
5. MICROWAVE DRYING CHAMBER TO DRY THE COMPLEX MOLDS IN SHORT TIME

5.1 How to use microwave drying Chamber

The permittivity of the wax is small enough, not even comparable to that of the raw mold therefore the effect of the microwave is low. However, the temperature dependence of wax is greater. It is necessary to optimize the microwave irradiation so as not raising the temperature and keep the steady state temperature of the wax in contact with the mold surface. Fig 4.1 shows wax samples to investigate the temperature dependence of the wax. Figure 4.2 The results of the measurement. In the molding process, the drying result (effect) with microwave varies depending on the thickness of the raw mold as follows;

(1) Thin layers, 1st layer to 3rd layer: the thickness from the first, second and third layers will be approx. 1-2mm (approx. 0.04”- 0.08”) thin and the effect of microwave applied to the internal part must be limited.
(2) 3rd - 4th layer: the thickness of the mold becomes 3-4mm (approx. 0.12”- 0.16”), the moisture is less likely to be out and it takes a long time to dry. Drying effect of microwave increases.
(3) 4th to 8th layers: the mold becomes even thicker as5-10mm (approx. 0.2”- 0.39”). Microwave acts toward the moisture effectively to significantly shorten the drying time.

![Fig 4.1 Wax and raw mold used for test (measurement).](image1)

![Fig 4.2 Temperature dependence of the linear thermal expansion coefficient of wax](image2)

5.2 High quality microwave drying Chamber

Illustration of microwave drying Chamber

(1) Compact Chamber : 0.85kw×6 units, 1.5kw (2.5kw) × 2 units
   The two simultaneous drying allows 5-20kg (approx. 11-44lb)/ tree. See Fig 5.1 suitable for HMLV(High Mix Low Volume) production.

(2) Medium-sized Chamber: 1.5kw × 3 units
   Drying 5-40kg (approx. 11-88lb)/tree the molds with difficult part to dry the inside of the tree such as cylindrical, hole shape. Fig 5.2 Reference.- Pictures of the Chambers for Kawasaki Heavy Industries
(3) Large Chamber (2.5kw × 8 units) shown in Figure 5.3
   It is suitable for the mass production of the same shape, 30-80kg (approx. 60-176lb)/tree.

(4) Chamber for high quality precision investment castings: 1.5kw × 4 units - 1.5kw × 10 units
   It is suitable for drying the slender shaped mold of high quality precision castings, 10-50Kg (approx. 110 lb)/tree. It can be controlled by dispersing the temperature of every part the mold surface, and it is capable to finely control the temperature of the mold surface.

6. SUMMARY

It has been 3 years since we developed the microwave mold drying Chamber and the system. Meanwhile, we answered to many quality requirements for various types of trees, molds and drying conditions along with the improvements and upgrades of the prototype microwave Chambers in terms of both software and hardware. As a result, it was highly appreciated and being used by several leading manufactures in Japan. We will continue to improve and will contribute to the future development of the investment casting industry and the community.
References
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