Cooling Behavior by Water Spray and Air-Blow on Green Sand with High-Temperature

Yasuhiro Maeda [1*], Shingo Yoshida [2], Yuuka Ito [2,3], Takashi Hanai [3], Hiroyasu Makino [3]
1. Dept. of Mechanical Engineering, Daido University, 10-3 Takiharu-cho, Minami-ku, Nagoya 457-8530, Japan
2. Graduate Student, Dept. of Mechanical Engineering, Daido University
3. SINTOKOGIO Ltd., 3-1 Honohara Toyokawa 442-8502, Japan
*Corresponding address: e-mail: y-maeda@daido-it.ac.jp

Abstract: The sand cooling process before the mulling of green sand is fundamental to obtaining the green molding sand with proper conditioning and performance characteristics. In a previous study [1], the water-spay cooling behavior of the high-temperature green sand that exceeds 100℃ by water spray is investigated under static conditions. It is clarified that in the early stage of watering cooling, the evaporation cooling of water mainly occurred by watering. Further, in the later stage of watering cooling, the temperature is decreased under heat transfer behavior the same as air (natural) cooling.

In the present study, both the water spray cooling and air-blow cooling behavior of the high-temperature molding sand with a high temperature that exceeds 100℃, which is mulling, is investigated by the experiment and the numerical analysis. It clarifies the effect of watering on the temperature drop of the hot sand in the early stage of sand cooling. Then the air-blow cooling phenomenon is also clarified in the later stage of cooling. Further, two types of cooling behavior are explained by two equations introduced by the heat transfer and the modified evaporation of water.

Keywords: Green Sand, Hot Sand, Watering, Air-blow, Heat transfer

1 Introduction

The temperature of return sand becomes higher because of the change of the component of green molding sand and the speedup of the molding line [1-3]. The sand cooling process before the mulling of green sand is very important to make the comfortable green sand mold and to obtain comfortable quality molding sand. The green sand before the mulling process requires suitable properties of temperature and moisture content.

In a previous study [4], the high-temperature molding sand that exceeds 100℃ is investigated under static conditions, then the water spray cooling behavior of the molding sand is investigated. It is clarified the cooling phenomenon of molding sand with high temperatures that exceed 100℃.

In the present study, both cooling behavior by water spray and air-blow on the high-temperature molding sand is investigated by the experiment and the calculation. The effect of the addition of air-blow to water spray on colling behavior is analyzed. The temperature of green molding sand is estimated by using the theoretical equations using a heat transfer and an evaporation equation.

2 Experimental procedure

The green molding sand consists of synthetic sand (mullite beads) with 10% sodium bentonite, and water. The properties of molding sand are controlled 40% of the compact ability (CB) index using Sympson-type mulling machine. The molding sands of 500g are pre-heated to the initial temperature of 120, 100, and 80℃ in the heater.

The experimental conditions are detailed in Table 1. In the experiment, the molding sand, which undergoes mulling and air-blowing, is cooled naturally by atmospheric air, with variations in watering amount and air-blow speed. Then, the temperature and moisture content of the molding sand are measured during cooling at 30s of intervals.

3 Result and discussion

The comparison of the cooling behavior varying with the air-blow speed in the case of the initial temperature of 100℃ and the watering amount of 10g is shown in Fig.1. From the figure, the air-blow affects the early stage of temperature drop of molding sand. The temperature gradient slope of molding sand after cooling is nearly the same. These two points show a similar temperature drop even if the initial temperature of casting sand is changed.

Table 1 Experimental conditions

Green molding sand	Sand 90%+Bentonite10%+Water
Sand	Ceramic Sand (Mullite beads)
Bentonite	Na-Type (Volclay)
Compactability	40%
Initial Temp.	80, 100, 120 ℃
Weight of sample	500 g
Cooling type	Air-blow, Air-blow + Water spray
Watering amount	0, 10, 20 30 g
Air-blow speed	0, 0.8, 1.6 m/s.

From the previous study in the case of static conditions, the cooling behavior is analyzed in two mechanisms. In the early stage of watering cooling, the evaporation cooling of water mainly occurs by watering. Later stage of watering cooling, the temperature is decreased in accordance with heat transfer behavior the same as air (natural) cooling. The tendency of cooling behavior obtained in the case of present conditions such as the air-blow and the air-blow + Water spray cooling is the same with the previous ones.

Modifying the theoretical analysis model proposed in the previous study [4], two equations to estimate the cooled molding sand temperature are obtained in the present study. Equation (1) is the water evaporation equation for the early stage of water spray cooling.

$$T_{s2} = T_{s1} + \frac{L_s}{\beta_s \times C_s}\Delta w - \left(T_{s1} - T_1\right)\frac{1-e^{-H(1-\varphi')t_0}}{1-\varphi' e^{-H(1-\varphi')t_0}} \tag{1}$$

Equation (2) is the heat transfer cooling equation for the later stage of cooling.

$$T_{s2} = T_{s1} - \left(T_{s1} - T_1\right)\frac{1-e^{-H(1-\varphi')t_0}}{1-\varphi' e^{-H(1-\varphi')t_0}} \tag{2}$$

Where, T: temperature [K], t: time [s], L: latent heat of vaporization [J/kg], C: specific heat [J/kgK], w: moisture content [kg/dry.kg], α: heat transfer coefficient [W/m^{2}K], β: rate of wet sand, A: surface area [m^2], m: Mass [kg], subscript: a: air, s: sand, sw: wet sand, sd: dray sand.

Fig.2 shows the comparison of water spray cooling behavior between experiments and calculations. From Fig.2, it is possible to infer the behavior close to the gradient of temperature decrease of the experiment by setting the specific heat correction coefficient to β_s=0.25 and the heat transfer coefficient correction coefficient to β_c=0.60. The temperature of molding sand is dropped by the evaporation of water in the early stage, and then it is decreased by heat transfer behavior in the later stage.

4 Conclusion

It is clear the cooling behavior of both the watering and air-blow on the green molding sand with high temperatures that exceed 100℃. The air-blow affects the initial stage of temperature decrease of molding sand. Two types of cooling behavior are explained by two equations introduced by the heat transfer and the evaporation of water using two correction coefficients.

References

[1] Japan Foundry Engineering Society: Report of Technical Session “Trend of Sand Mold Technics”, No. 164 of JFS Meeting, Kyoto (2014), pp.1-37.

[2] Japan Foundry Engineering Society: Research Report No.90, (2002), pp.71-81.

[3] Japan Foundry Engineering Society: Research Report No.117, (2015), pp.12-40.

[4] Y. Maeda and H. Makino: “Basic Investigation into Water Cooling of the Green Molding Sand with High Temperature”, International Journal of Metalcasting, 11(2017), pp27-32.

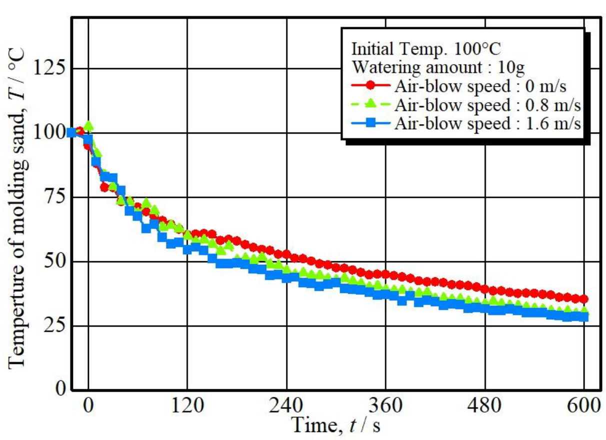

Fig.1 Comparison of the cooling behavior varying with the air-blow speed in the case of the initial temperature of 100℃ and the watering amount of 10g.

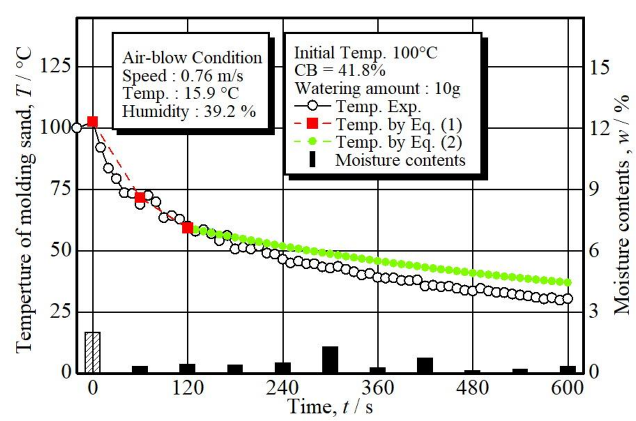

Fig.2 Comparison of cooling behavior between experiments and calculation in the case of initial temp. of 100℃, watering amount of 10g and air-blow speed of 0.8m/s.