Influence of Glass-cloth Size on Liquid Metal Distribution in the Sump of Slab DC Casting

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ABSTRACT

Temperature measurements in actual DC casting and water model experiments have been performed to investigate the influence of glass-cloth size on liquid metal temperature distribution and fluid flow in the sump of slab DC casting.

Measured temperature distributions in actual casting are strongly varied with the glass-cloth size. High temperature region in the sump is extended by using large glass-cloth.

The results of water model experiments show that the critical glass-cloth size on fluid flow pattern exist. Large glass-cloth improves the uniformity of fluid flow.

Keywords: *DC casting, glass-cloth, liquid metal distribution, water model*

1. INTRODUCTION

Direct Chill (DC) casting process is widely used in aluminum sheets plants. Formation of casting macro/micro structure during solidification of DC casting process is deeply influenced by not only direct chill cooling but also fluid flow in aluminum molten metal sump. Therefore, the distribution and the flow pattern of liquid metal in the sump are important factors in solidification and affect qualities of the resulting ingot. Liquid metal proceeds through some stages which are nozzle, float (or pin) and glass-cloth (or diffuser bag) . The stages make the flow pattern very complex and difficult to predict accurately by mathematical modeling[1][2][3].

In this study, temperature measurements in actual DC casting and water model experiments[4][5] have been performed to investigate the influence of glass-cloth size on liquid metal temperature distribution and fluid flow in the sump of DC casting.

2. EXPERIMENTAL

2.1 Temperature measurements in actual casting

99.96% high purity aluminum was cast into slab under the conditions shown in table1. Two different dimensions of glass-cloth were tested. The glass-cloth woven by glass-fiber had about 1x1mm hole in every 3mm intervals. Float distributor which has two horizontal outlets in the direction of narrow side was used.

Fig.1 shows the thermocouple positions. The thermocouples were inserted into molten metal at the same speed as the casting speed in steady-state.

2.2 Water model experiments

The dimensions of water model apparatus were 600mm thickness, 2100mm width and 1700mm depth. Water was circulated by a pump through a tundish, nozzle, float, glass-cloth, and main tank. The glass-cloth was the same as that of used in temperature measurement in actual casting. As a tracer, black ink was injected at the nozzle to visualize flow patterns. Three video cameras were used to record the 3-dimensional advancing front of the dye. Four different dimensions of glass-cloth and two flow rates were tested.

Table1 Experimental conditions for casting

Alloy	99.96% aluminum
Ingot size	400×1180mm
Metal temperature	712 ～ 719 °C
Casting speed	40mm/min
Water flux	800*l*/min
Metal level	80mm
Glass-cloth size	① 250×700mm ② 350×950mm

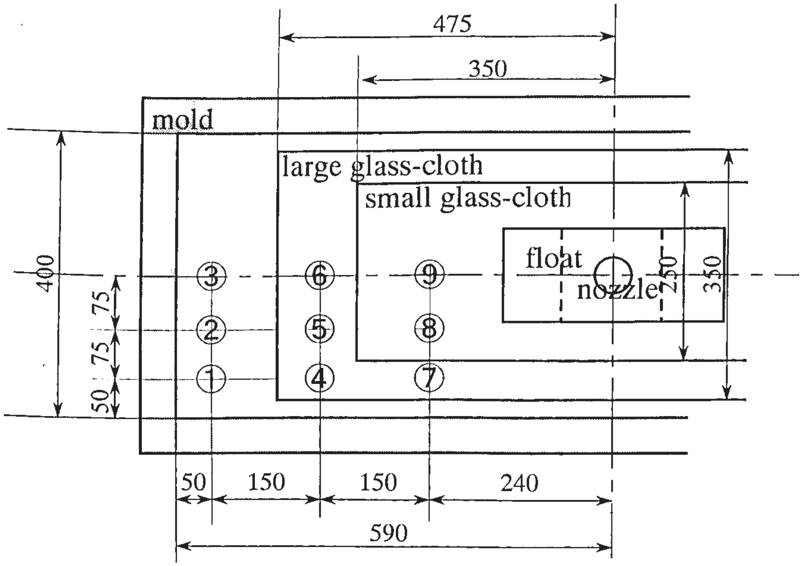


Fig.1 Thermocouple positions

3. RESULTS

3.1 Temperature measurements in actual casting

Fig.2 and 3 show isotherm plots (3-6-9 and 4-5-6 sections) in liquid metal sump, derived from measured temperature.

High temperature regions are extended downward with the expansion of glass-cloth area, which is clearly observed in 4-5-6 sections. Therefore, the isotherms are more closely spaced in the neighborhood of the solidification front in case of using large glass-cloth. In 3-6-9 sections, the isotherms are almost parallel to glass-cloth in both conditions, except 675 °C isotherm with small glass-cloth. The isotherm develops in the direction of the narrow side only in the case of small glass-cloth.

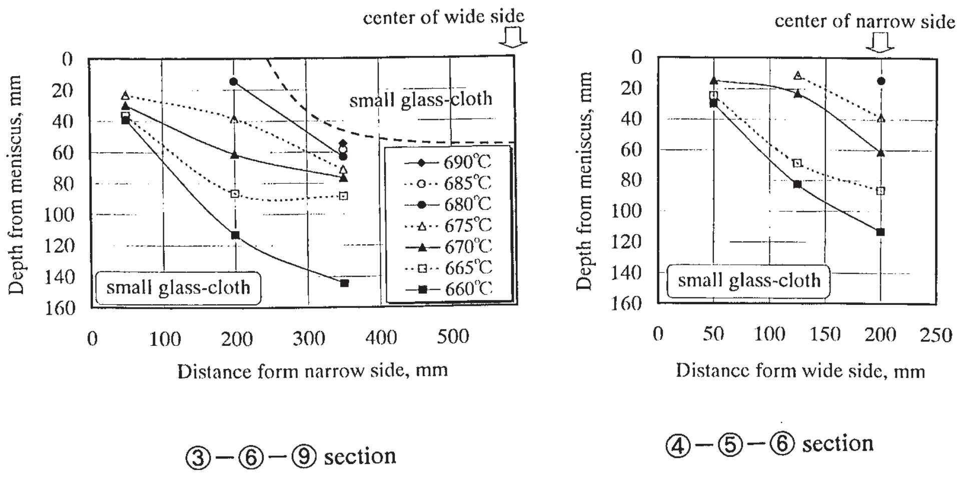


Fig.2 Temperature distributions in the sump with small glass-cloth

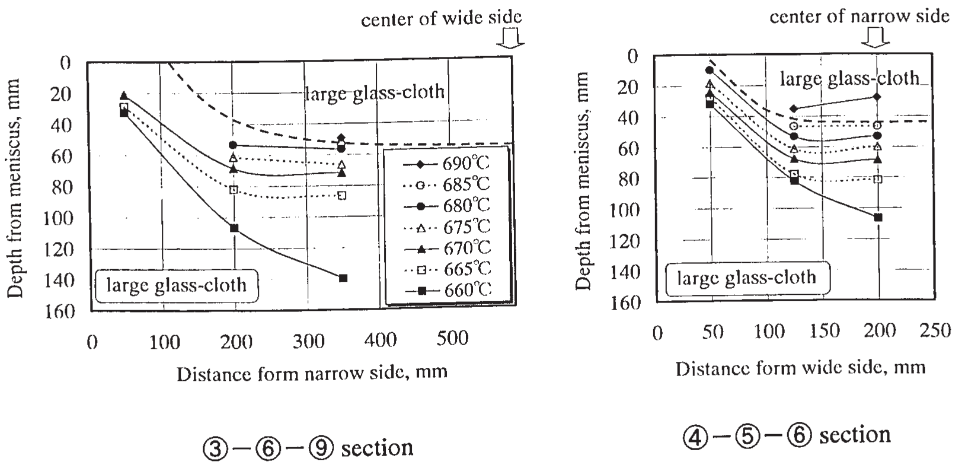


Fig.3 Temperature distributions in the sump with large glass-cloth

3.2 Water model experiments

Fig.4 and 5 show characteristics of flow patterns with two different size cloths (small-cloth and large-cloth), at flow rates of 56.7*l*/min and 100.8*l*/min (which correspond to 45, 80mm/min casting speed respectively). The solid lines in the figure indicate the advancing front of the tracer at each diffusion time.

The characteristics of the flow patterns are influenced by both the cloth size and flow rate. In case of small-cloth, strong flows out of cloth are observed in particular directions (Fig.4-a,e). The strong flows are exaggerated by larger flow rate (Fig.5-a,c). On the other hand, only calm down flow is recognized outside the large-cloth, and the increase in flow rate causes the small liquid flow to narrow side.

The liquid flow inside glass-cloth is turbulent regardless of the glass-cloth size and flow rate. This agrees with the results of temperature distributions in the sump (Fig.2,3) that high and uniform temperature regions exist inside the glass-cloth.

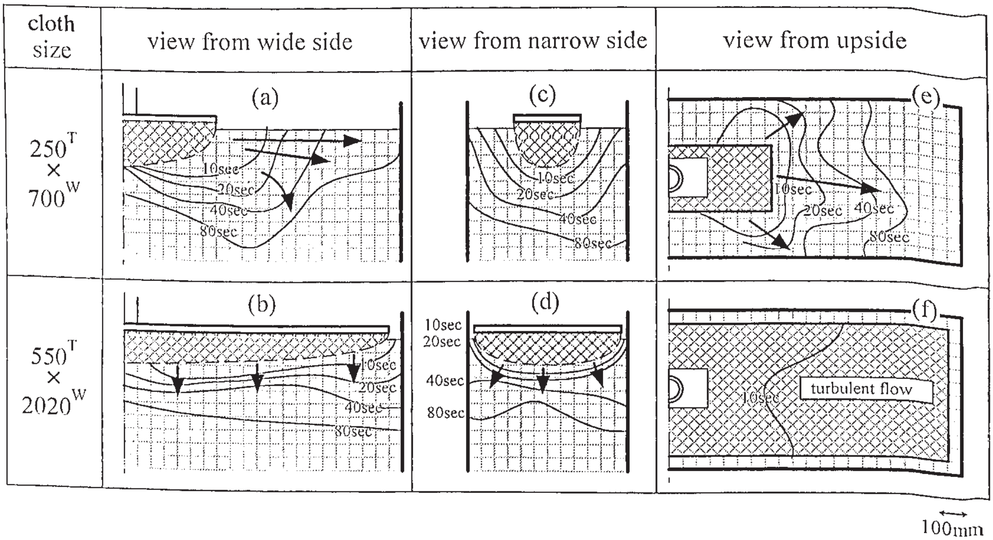


Fig.4 Characteristics of flow patterns at flow rate of 56.7*l*/min(45mm/min casting speed)

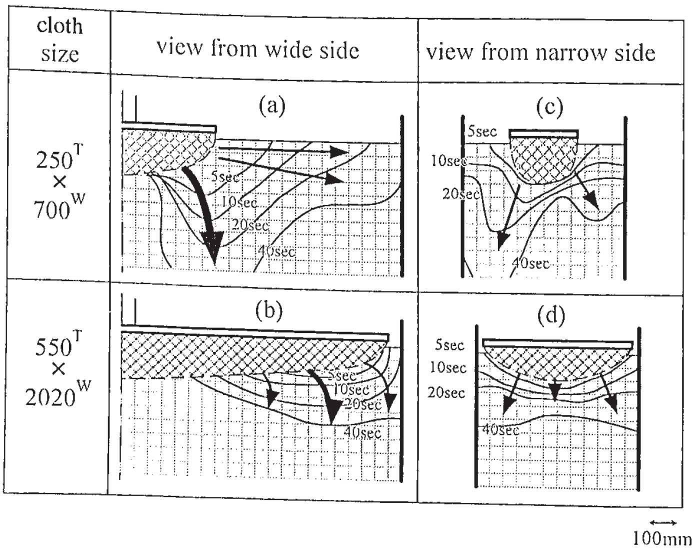


Fig.5 Characteristics of flow patterns at flow rate of 100.8*l*/min(80mm/min casting speed)

4. DISCUSSION

4.1 Definition of flow unevenness and mean residence time

Concentrated flow which makes partial high temperature region in molten metal sump brings about many kind of troubles which are the uneven thickness of solidified shell, the crack of ingot and break out. Accordingly it is to be desired that distribution of spouting flow rate is even outside the glass-cloth.

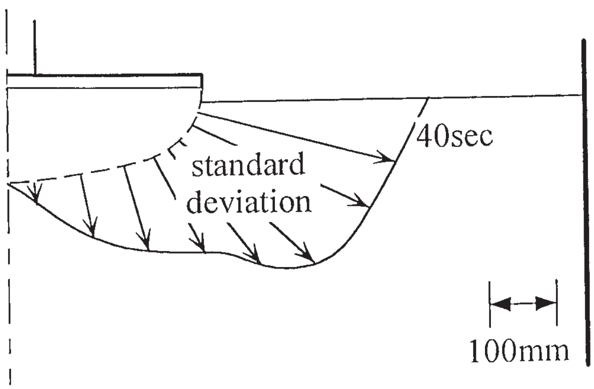
To quantify and standardize the distributions of flow, we have defined the parameters of flow unevenness and mean residence time. The flow unevenness is defined by standard deviation of moved distance from glass-cloth within 40sec. (Fig.6). The mean residence time is an average of water passage time through a pool inside the glass-cloth (= glass-cloth volume / flow rate), because the distribution of spouting flow rate is influenced by a size of glass-cloth and a flow rate.

4.2 Tendency of flow unevenness

Fig.7 shows the influence of mean residence time on flow unevenness. The flow unevenness decreases with mean residence time. It is found that the flow unevenness critically changed around 20sec. of mean residence time.

As the mean residence time in the experiments of actual castings are more than 20sec. (28sec. in small glass-cloth, 53sec. in large glass-cloth, respectively), the fluid flow outside glass-cloth thought to be calm and tolerably uniform in both conditions. In accordance with this, there is no notable disorder of the isotherms in the sump in both cases. Thus, the change of measured temperature distribution by glass-cloth size is considered to be caused not by the change of liquid flow outside glass-cloth but mainly by the change of volume inside glass-cloth.

Although the critical mean residence time in actual casting condition has to be quantitatively investigated in future experiments, it is clarified that fluid flow can be controlled by considering the value of mean residence time.



unevenness(mm/min): standard deviation of moved distance from glass-cloth within 40sec.

Fig.6 Definition of flow unevenness

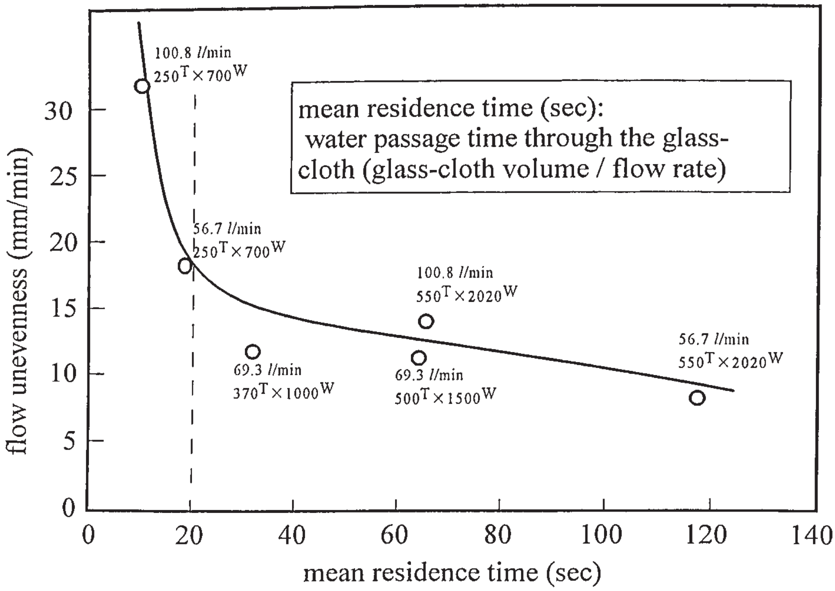


Fig.7 Influence of mean residence time on flow unevenness

5. CONCLUSION

(1)Temperature distributions are changed by the glass-cloth size. This is thought to be caused not by the change of liquid flow outside glass-cloth but mainly by the change of volume inside glass-cloth.

(2)Critical glass-cloth size on fluid flow pattern exist. Large glass-cloth improves the uniformity of fluid flow.

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