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Fluid Flow in Tundish Due to Different Type Arrangement of Weir and Dam

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Abstract: Tundish is an important metallurgical reactor in the continuous casting process. In order to control the fluid flow in tundish and thus take full advantage of the residence time available for the removal of inclusions from molten steel, the effect of weir and dam on the fluid flow has been studied in a water model based on the characteristic number Froude and Reynold number similarity criteria. The residence time distribution curves of the flow were measured by SG800. The optimum arrangement of dam and weir and the nonstationary flow in tundish were discussed. The results show that the combination of weir and dam is benefit for the flow pattern in tundish, weir can prevent the upper recirculating flow, dam can cut off the bottom flow and turn to upwards, it is advantageous to separate the nonmetallic inclusions. Furthermore, it is important to exceed the critical depth of bath during exchange ladles, not only for the inclusion floatation but also for avoiding tundish slag drainage earlier.

Key words: tundish; fluid flow; weir and dam; water model

1 Introduction

The requirements regarding the improvement of the quality of steel and performances achieved in the ladle metallurgy lead us not to consider the tundish as a simple steel container but as a real metallurgical reactor capable of appreciably diminishing the impurities of steel. In order to improve the cleaness of steel, a tundish as an intermediate vessel is used in the continuous casting process. The fluid flow phenomena in tundish have a strong influence not only on the uniform of composition and temperature of bath, but also on the separation of nonmetallic inclusions [1–5]. The fluid flow in tundish is required to provide enough time for nonmetallic inclusions to float out to the slag cover. Desirable fluid flow patterns by the use of flow control devices as dam and weir can be obtained [6]. In this paper, the effect of dam and weir on the fluid flow in tundish and the optimum arrangement of dam and weir were studied.

Another problem of tundish metallurgy is that nonmetallic inclusions are difficult to be floatated out from the metal during exchange of the ladle of two heats. So the nonstationary flow in tundish was also discussed in this paper.

2 Water Model Experiment

Considering that the fluid flow pattern in tundish is dominated by inertia, gravity and viscosity, the *Re* number and *Fr* number have been used in this experiment as similarity criteria. Therefore, a 1/3 scale model of the tundish was constructed using a transparent plexiglass. Water is used as a liquid media similar to the molten steel, thereby both the Froude and Reynold numbers as similarity criteria are invariant at any given volumetric throughout. The water model of tundish is shown in **figure 1**.

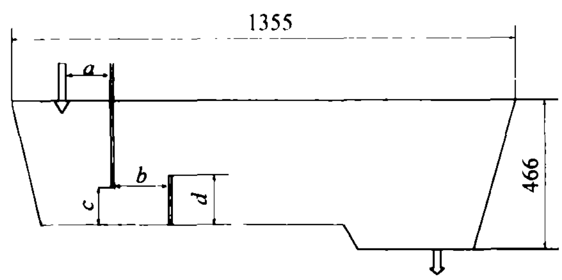

Figure1 The structure of dam and weir in tundish.

In order to study the effect of the combination of dam and weir in tundish on the fluid flow, the residence time distribution (RTD) was measured by using a water experimental system SG800. By calculating the RTD-curve, the mean residence time (t_{mean}), dead volume fraction (φ) and the minimum residence time (t_{min}) were obtained. The expected flow pattern means that t_{mean} and t_{min} are increased. The experiment conditions are listed in **table 1**.

Table 1 Experiment conditions

Volume flow rate, Q / $m^3 \cdot h^{-1}$	1.4	1.6	1.8	2.0
Depth of water, h / m	0.15	0.20	0.25	0.30
Number of weir	no	only weir	weir+dam	

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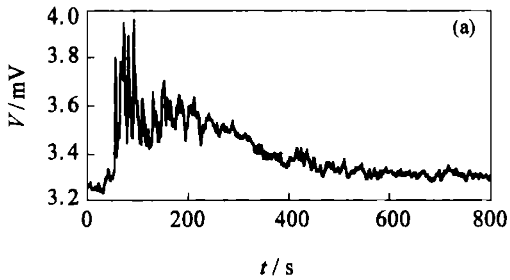
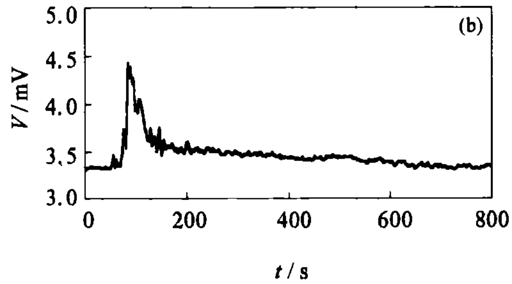
3 Experiment Results

3.1 Effect of the existence of dam and weir on the flow pattern in tundish

In order to study the effect of the structure of weir and dam on the flow pattern in tundish, some experiments were done, and the results are shown in **figure 2**. The calculation results are listed in **table 2**.





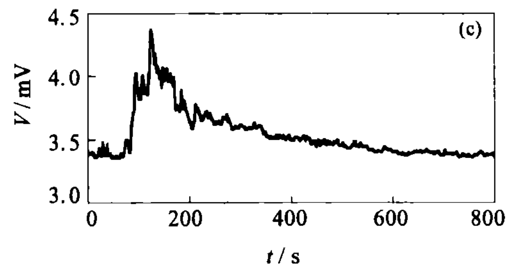


Figure 2 The residence time distribution curve varies with or without weir and dam (Q=1.6 m³ / h), (a) no wire and dam; (b) only weir (a=900 mm, c =80 mm);(c) weir+dam (a=450 mm, b=250 mm, c=80 mm, d=80 mm).

Table 2 The minimum and mean residence time varies with structure of weir and dam

parameters	no weir and dam	only weir	weir + dam
t_{min} / s	51	53	72
t_{mean} / s	211.8	233.6	268.4
t / s	302.2	302.2	302.2
φ / %	29.9	22.7	11.2

Note: t—theoretical residence time, so as the follows.

Figure 2 and table 2 shows that the minimum and mean residence time becomes longer, and dead volume becomes less, according to using the structure of weir + dam in tundish. This is because that the weir can prevent the upper recirculating flow, reducing the slag entrained. The dam can cut off the bottom flow, forming a upward flow. It is advantageous to separate the non-metallic inclusions. Only weir is also better than no weir and dam, but the effect is not obviously. The reason is that the weir does not cut off the bottom flow, the minimum residence time is not obviously increased, but the mean residence time is also increased and dead volume is decreased. So the structure of weir + dam is benefit for the flow pattern in tundish.

3.2 Effect of weir location on the flow pattern in tundish

To study the effect of location of weir on the flow pattern in tundish, some experiments were done. **Table 3** shows the minimum, mean residence time and dead volume varies with the relative location of weir. When the location of weir is far away from the inlet stream,

Table 3 Effect of location of weir on the flow pattern in tundish (Q= 1.6 m³/h, h=300 mm)

a / mm	t_{min} / s	t_{mean} / s	t / s	φ / %
300	49	212.2	302.2	29.8
450	44	204.7	302.2	32.3
600	42	185.0	302.2	38.8
750	48	222.8	302.2	26.3
900	53	233.6	302.2	22.7

t_{min} and t_{mean} are a little increased, but it is not advantageous for reducing the slag entrained and cutting off bottom flow. So only one weir in tundish is not obviously improving the flow pattern.

3.3 Effect of the combination of weir and dam on the flow pattern in tundish

The experimental results show that the combination of weir and dam is benefit to the flow pattern in tundish. In order to get optimum structure of weir and dam, many experiments were done. **Table 4** shows the effect of the location of dam on the flow pattern in tundish. **Table 5** shows the effect of the variation of casting speed on the flow pattern in tundish.

Table 4 Effect of the dam location on the flow pattern in tundish (Q= 1.6 m³/h, a= 150 mm, b=80 mm, d=80 mm)

parameters	c / mm		
	150	250	350
t_{min} / s	72	78	77
t_{mean} / s	268.4	279.9	266.5
t / s	302.2	302.2	302.2
φ / %	11.2	7.4	11.2

Table 5 Effect of the casting speed on the flow pattern in tundish (a = 150 mm, b = 80 mm, c = 80 mm, d = 150 mm)

Q / m³·h⁻¹	t_{mean} / s	t_{min} / s	t / s
1.6	72	268.4	302.2
1.8	70	257.1	282.9
2.0	65	241.6	251.6

Table 4 shows that t_{min} and t_{mean} varies with the location of dam, the distance from 150 mm increased to 250 mm, t_{min} and t_{mean} all obviously increased. But the distance varied from 250 mm to 350 mm, t_{min} decreased a little, and t_{mean} decreased markedly. So the distance from weir to dam is very important for the flow pattern in tundish. The optimum position of dam not only increase the t_{min}, but also increass the t_{mean}. The flow path becomes longer, the chance of the inclusion separation is increased.

Table 5 shows the effect of casting speed on the flow pattern in tundish. When the casting speed increased, t_{min} became shorter and t_{mean} also decreased, so the separation of inclusions is difficult. Thus it is necessary to optimum the structure of tundish, especially at high casting speed.

3.4 Effect of liquid bath depth on the flow pattern in tundish

Another problem of tundish metallurgy is that non-metallic inclusions are difficult to be floatated out during exchange ladles of two heats, because the depth of bath is lower than that of normal conditions. So it is necessary to study the fluid flow in tundish on nonstationary state. **Table 6** shows the effect of the liquid bath depth on the flow pattern in tundish. When the depth of liquid steel becomes shallower, t_{min} and t_{mean} becomes lesser.

Table 6 Effect of the liquid bath depth on the flow pattern in tundish (only weir: a = 900 mm, c = 80 mm, Q = 1.6 m³/h)

Bath depth/mm	t_{min} / s	t_{mean} / s	t / s	φ / %
300*	53	233.6	302.2	22.7
250	34	193.6	253.1	23.5
200	30	152.8	194.2	23.1
150	28	113.9	139.5	18.4

Note: * normal condition.

4 Conclusions

(1) The combination of weir and dam is benefit for the flow pattern in tundish, weir can prevent the upper recirculating flow, dam can cut off the bottom flow and turn to upwards, it is advantageous to separate the non-metallic inclusions.

(2) The optimum arrangement of weir and dam are as follow: a = 150 mm, b = 250 mm, c = 80 mm, d = 80 mm.

(3) It is important to exceed the critical depth of bath during exchange ladles, not only for the inclusion floatation but also for avoiding tundish slag drainage earlier.

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