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Optimum Design of Slot Shape for Preventing the Misrun of an Aluminum Motor Rotor in Die Casting

Sung-Mo Lee, Won-Jae Lee and Byung-Youn Moon
Hyundai Heavy Industries Co., Ltd., Korea

ABSTRACT

The optimum design for slot shape of aluminum motor rotor with diameter of 450mm was performed to prevent the misrun in die casting process. In order to do it, the effects of the variables including slot width and slot length on the misrun of the aluminum motor rotor with various core length in die casting process were evaluated using numerical analysis. The critical solidification modulus and slot width for preventing the misrun of the aluminum motor rotor increase with an increase in core length. Based on the results, the design criteria of slot shape for preventing the misrun of aluminum motor rotor with various core length were established.

Key words: Motor rotor, die casting, solidification modulus, misrun

INTRODUCTION

The misrun can be easily introduced in the die casting process of the large motor rotor with long and slender core requiring the long filling time. In order to prevent the misrun, the slot shape of a motor rotor should be designed considering the filling and solidification characteristic as well as the electomagnetic performance. Up to now various criteria have been proposed to predict the defects of castings. However most criteria focused on the shrinkage defect of the gravity casting [1-4] and there are few the studies about the misrun in die casting process.

The purpose of this study is to establish design criteria of the slot shape for preventing the misrun in die casting of aluminum motor rotor. In order to do it, the effects of the core length, slot width and slot length on the misrun of the aluminum motor rotor were evaluated using numerical analysis. Based on the results, the optimum design conditions of slot shape were proposed.

NUMERICAL ANALYSIS

Figure 1 shows the configuration of motor rotor with diameter of 450mm and core with a large number of slot. Fig. 2 and 3 show 3D CAD model and numerical analysis model used for this study, respectively. As show in Fig. 2 and 3, the simplified model with one slot was used for numerical analysis in order to reduce the computing time. Variables used for numerical analysis are core length, slot width and slot length as shown in Fig. 4 and Table 1. Table 2 and 3 give material and initial temperature of each part in die casting process of aluminum motor rotor and heat transfer coefficient at each boundary surface of aluminum motor rotor, respectively.

(a)

(b)

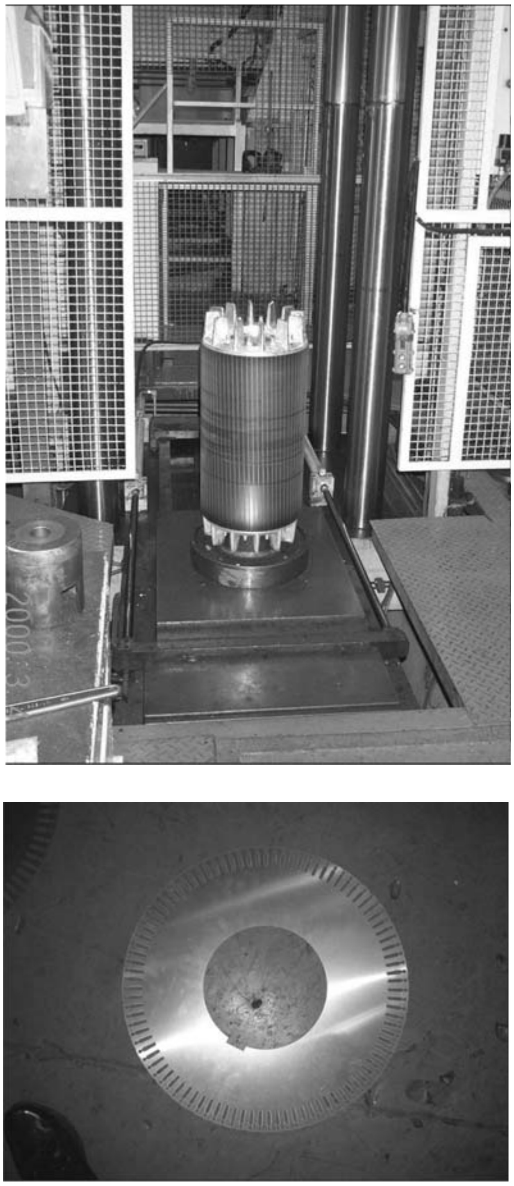


Fig. 1 : Motor rotor and core with diameter of 450mm
(a) motor rotor (b) core

RESULTS & DISCUSSION

Fig. 5 shows the change of filling state in die casting process of aluminum motor rotor with core length of 700mm, slot width of 9mm and slot length of 25.5mm obtained by numerical analysis. As shown in Fig. 5 (d), in the filling state of 100%, the cavity is perfectly filled with the melted aluminum from lower end ring to upper end ring without misrun. However, when slot width of 9mm and slot length of 25.5mm are changed into 7.6mm and 18mm respectively. The misrun was found at the middle of the slot as shown in Fig. 6. In addition, the upper end ring wasn't filled perfectly. This result agrees well with the actual motor rotor with misun as shown in Fig. 7.

From the above results, it can be easily understand that the misrun in die casting of aluminum motor rotor strongly depends on the slot width and slot length. Therefore, in this study, solidification modulus (M) as given in equation (1) was selected as the design factor controlling misrun in die casting. The solidification modulus was widely used for determinning the size of riser in the gravity casting.

$$M = \frac{Area}{Circumference} \qquad (1)$$

Table 1
Variables used for numerical analysis

Core length [mm]	Slot length [mm]	Slot width [mm]
600	10 ~ 62	6 ~ 10
700	12 ~ 60	6.8 ~ 10
860	12 ~ 60	7.7 ~ 12

Table 2
Material and initial temperature of parts

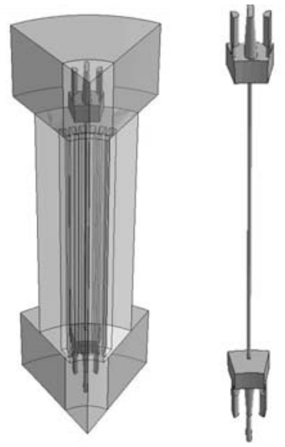
Part	Material	Temperature [^oC]
Mold	SKD61	200
Core	SM25C	25
Casting	Pure Al	705

Table 3
Heat transfer coefficient used for numerical analysis [5]

Interface	Air / all Cast /	mold
HTC [$cal/cm^2 sec^oC$]	0.001	0.1

Table 4
Critical values of solidification modulus and slot width for aluminum motor rotor with diameter of 450mm

Core length [mm]	Critical solidification modulus [mm]	Critical slot width [mm]
600	2.8	6.8
700	3.1	7
860	3.3	8



(a) casting (b) mold

Fig. 2 : 3D CAD model

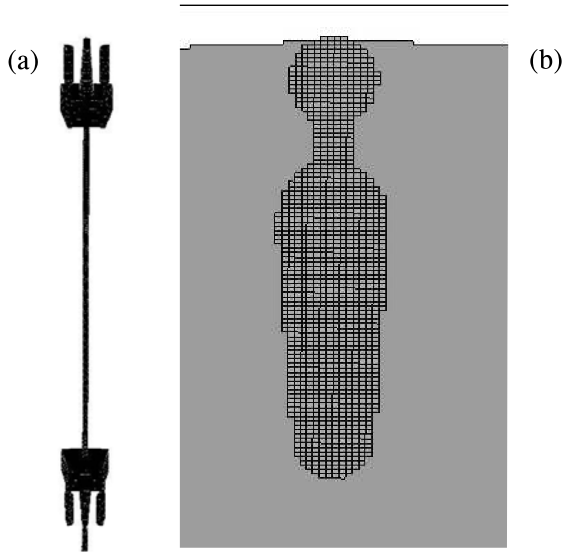


Fig. 3 : Numerical analysis model (a) casting (b) section of slot

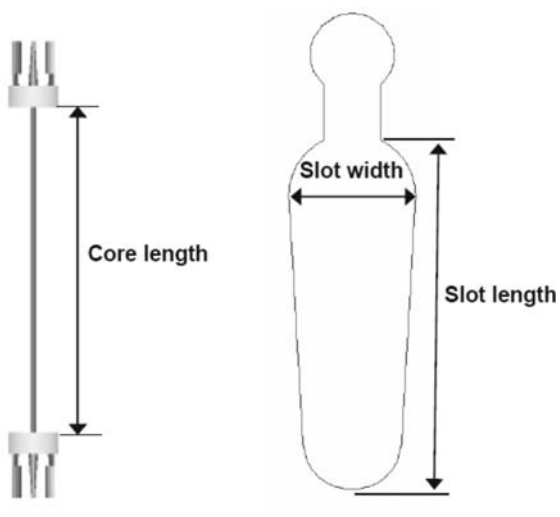


Fig. 4 : Variables used for numerical analysis

(a)

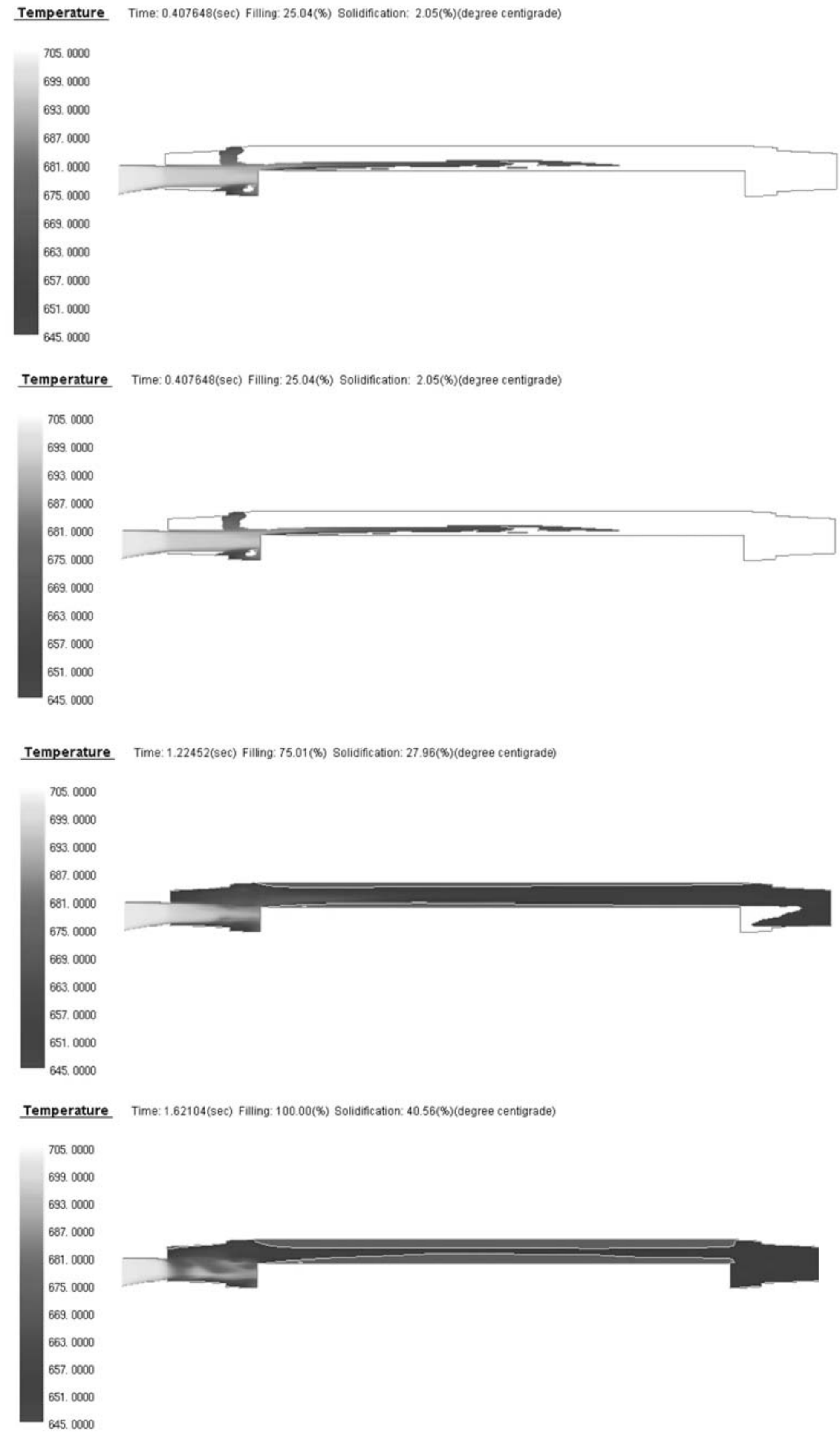
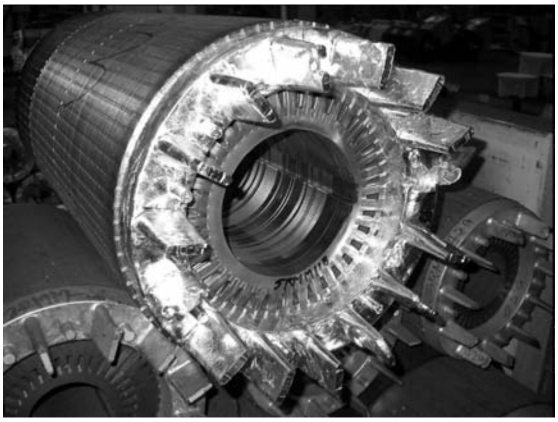


Fig. 5 : Filling sequence without misrun (a) filling : 25% (b) filling : 50% (c) filling : 75% (d) filling : 100% (Core length 700mm, slot width 9mm, slot length 25.5mm)

Fig. 6 : Numerical analysis result with misrun (Core length 700mm, slot width 7.6mm, slot length 18.8mm)

Fig. 8 (a) - (c) show the die casting limit diagram when the core length is 600mm, 700mm and 860mm, respcetively. X axis is slot width, and Y axis is slot length. As shown in Fig. 8 (a), when the modulus and the slot width is larger than 2.8mm and 6.8mm respectively, it is possible to fill the cavity without misrun in die casting of aluminum motor rotor with core length of 600mm. In this case, the critical solidification modulus for preventing the misrun is 2.8mm. The critical values of solidification modulus increase with an increase in

(a)



(b)

Fig. 7 : Actual motor rotor with misun (a) motor rotor (b) detail of "A"

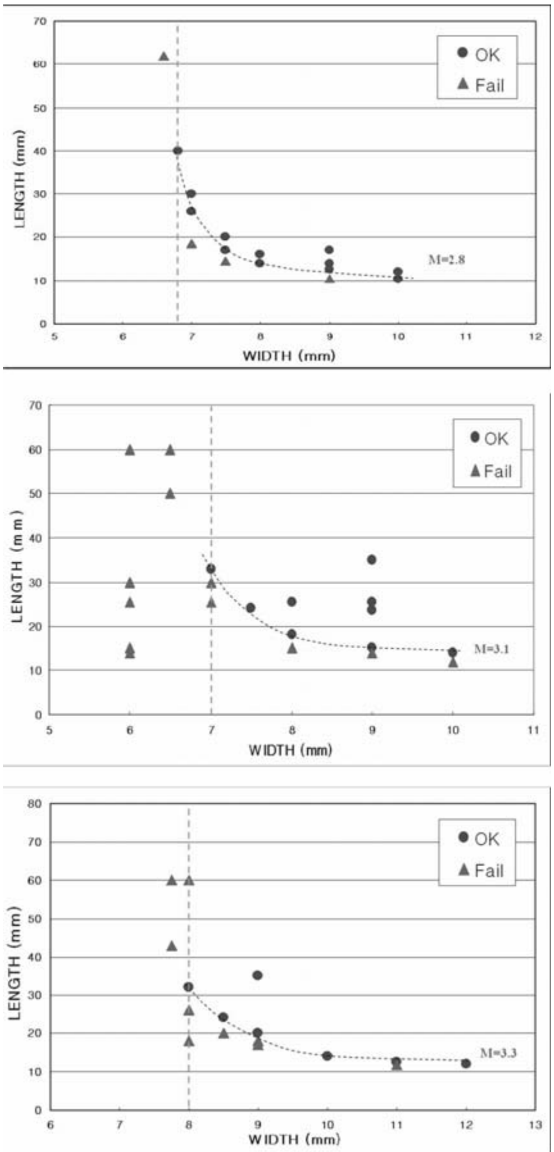


Fig. 8 : Die casting limit diagram (a) core length : 600mm (b) core length : 700mm (c) core length : 860mm

the core length as shown in Fig. 8. In addition, the minimum value of slot width for preventing the misrun increases with an increase in the core length. The critical values of solidification modulus and slot width obtained from this study are given in Table 4.

Base on the results, it can be concluded that the larger values of solidification modulus and slot width are required in order to prevent the misrun in die casting of aluminum motor rotor with an increase in the core length. This is because the filling time and solidification rate increase with an increase in the core length.

CONCLUSIONS

The comprehensive numerical analyses were performed to establish the design criteria for preventing the misrun in die casting of aluminum motor rotor with the diameter of 450mm. The results were as follows.

1. Numerical analysis procedure was established to evaluate the misrun in die casting process of aluminum motor rotor and verified by comparing with the location of misrun found at the actual rotor.
2. The effects of the core length, slot length and slot width on the misrun of aluminum motor rotor in die casting were evaluated. From the results, it was concluded that the misrun of die casting could be easily predicted by solidification modulus and slot width.
3. The critical values of solidification modulus and slot width for preventing the misrun increase with an increase in core length. Based on the results, according to the core length of the aluminum motor rotor, the critical solidification modulus and slot width for preventing the misrun were established.

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