Thin-Wall Aluminum Die-Casting Technology for Development of Notebook Computer Housing

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Silicon-based aluminum casting alloys are known to be one of the most widely used alloy systems mainly due to their superior casting characteristics and unique combination of mechanical and physical properties. However, manufacturing of thin-walled aluminum die-casting components, less than 1.0 mm in thickness, is generally known to be very difficult task to achieve aluminum casting alloys with high fluidity. Therefore, in this study, the optimal die-casting conditions for producing 297 mm×210 mm×0.7 mm thin-walled aluminum component was examined experimentally by using 2 different gating systems, tangential and split type, and vent design. Furthermore, computational solidification simulation was also conducted. The results showed that split type gating system was preferable gating design than tangential type gating system at the point of view of soundness of casting and distortion generated after solidification. It was also found that proper vent design was one of the most important factors for producing thin-wall casting components because it was important for the fulfillment of the thin-wall cavity and the minimization of the casting distortion.

KEY WORDS: Aluminum; Thin-wall die-casting; Notebook computer housing; Cold chamber die-casting machine

1. Introduction

Among the aluminum casting alloys, the Al-Si based alloy systems are one of the most widely used alloy systems because of their unique characteristics such as low density, moderately high strength, and good castability, *etc.*[1–3]. Recently, the demand for lightweight alloys in electric/electronic and automobile component housings using aluminum has been greatly increased mainly because it is lightweight having high damping capacity and dent resistance compared to plastics.

However, it is generally known that manufacturing of thin-wall aluminum component with a thickness less than 1.0 mm by using high pressure die casting process is quite difficult due to its low fluidity. This leads to the limited application of the aluminum alloy in the fields of housing of electric/electronic components such as notebook computer and cellular phone, *etc.* Therefore, in this study, die-casting process technology for the production of thin-wall aluminum components based on the investigation of the optimal die design including runners and gating system and casting conditions was investigated. Moreover, experimental examinations of gating design effects on the fabrication processing of sound thin-wall aluminum notebook housing with a thickness of less than 0.8 mm.

2. Experimental

Prior to the actual die-casting experiment, casting simulation was conducted to set up the die-casting and melt conditions. Die-casting die made out of H13 tool steel for the thin-wall notebook housing in size of 210 mm×297 mm×0.7 mm was designed and fabricated for the experiment. As shown in Fig.1, the 2 different types of gating system, tangential type and split type, were used for this investigation.

A commercial ALDC12 aluminum die-casting alloy (Al-(9.6–12)%Si-(1.5–3.5)%Cu, Table 1) was melted up to 780°C and the die was heated up to 230°C before the die casting. The major specifications of the cold chamber die-casting machine (Fig.2), used for this study are shown in Table 2. Molten aluminum alloy was injected into the die cavity under the conditions of 0.35 m/s in injection speed until the plunger traveled up to 370 mm in shot sleeve and then the injection speed was accelerated linearly to the high injection speed of 2.0, 2.5, 3.0, 3.5, 4.0 and 4.5 m/s from 370 mm to 390 mm in shot sleeve. Table 3 shows the summary of die-casting conditions for this investigation.

3. Results and Discussion

The solidification simulation was conducted for 2 different gate designs, tangential and split type prior to the die-casting experiment. The flow pattern and temperature distribution during filling of aluminum melt with the gate designs studied are shown in Fig.3. It was found that both gate designs exhibited quite uniform melt flow throughout the filling of the cavity. However, the tangential type gate design resulted in the melt temperature dropped area (circled in Fig.3(a)) at the last stage of filling while the split type gate design allowed the melt to fill the cavity above the liquidus temperature.

As mentioned, actual die-casting experiments were conducted for the notebook computer housing in size of 210 mm×297 mm×0.7 mm. Figure 4 shows the resultant castings with varied high speed injection from 2.0 to 4.5 m/s while low speed injection was fixed to 0.35 m/s. As shown, both gate designs allowed filling the casting with high speed injection of more than 3.0 m/s. However, less than 3.0 m/s of high speed injection failed to fill the thin-wall cavity. It was

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Table 1 Chemical compositions of ALDC12 alloy (in wt pct)

Alloy	Cu	Si	Mg	Zn	Fe	Mn	Ni	Sn	Al
ALDC12	1.5–3.5	9.6–12.0	0.3	1.0	0.8	0.5	0.5	0.3	Bal.

Table 2 Specification of die-casting machine

Clamping force/kN	Injection force/kN	Plunger diameter/mm
5250	490	ϕ70

Table 3 Die-casting experiment conditions

Melt Temp.	Die Temp.	High speed injection/(m/s)	Low speed injection/(m/s)
780	230	2.0, 2.5, 3.0, 3.5, 4.0, 4.5	0.35

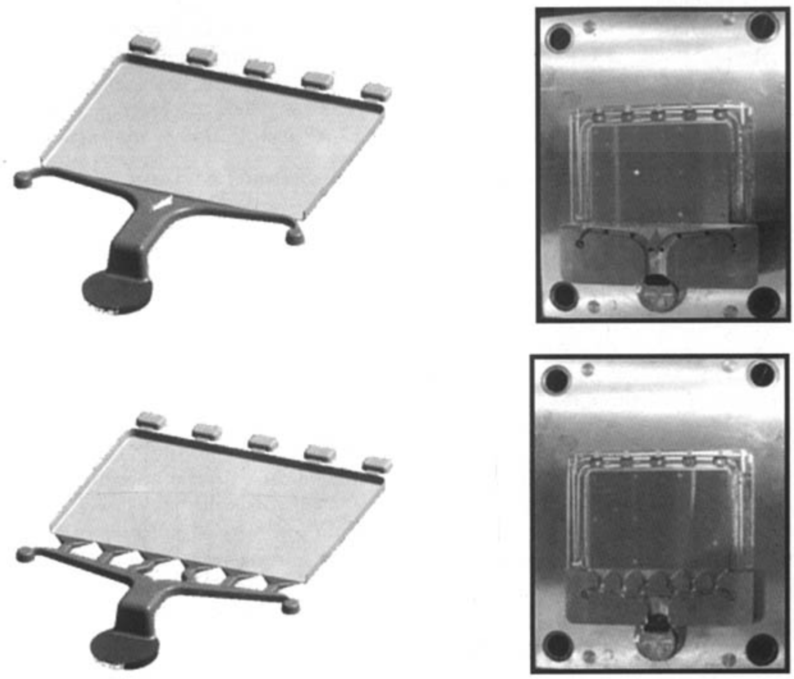

Fig.1 Schematic illustration notebook housing (210 mm×297 mm×0.8 mm) and 2 different gate designs: (a) tangential type, (b) split type

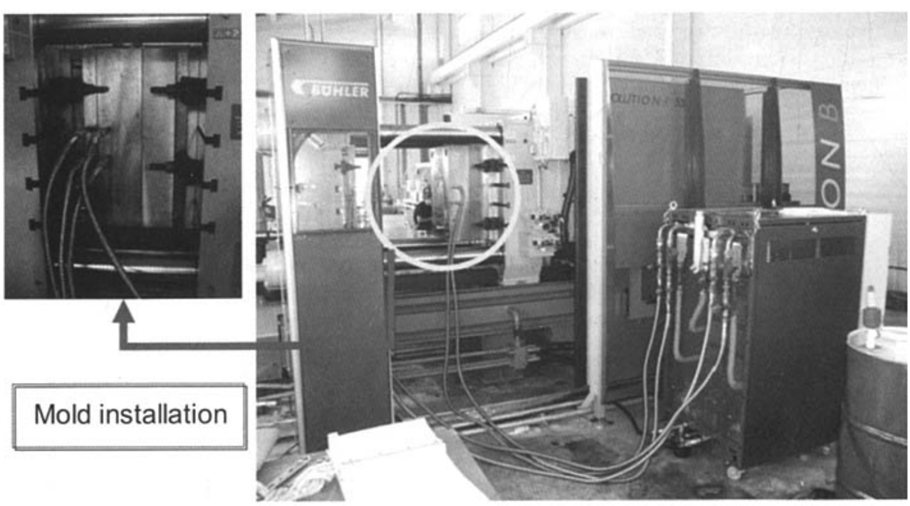

Fig.2 High speed die-casting machine

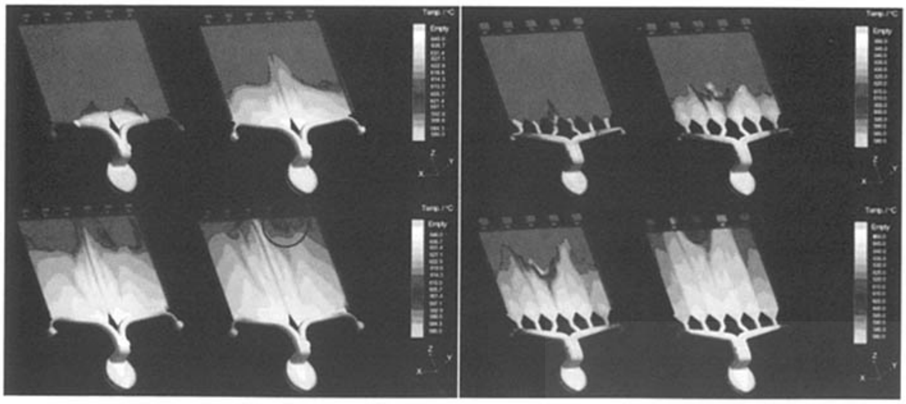

Fig.3 Simulation results of 2 different gate designs: (a) tangential type, (b) split type

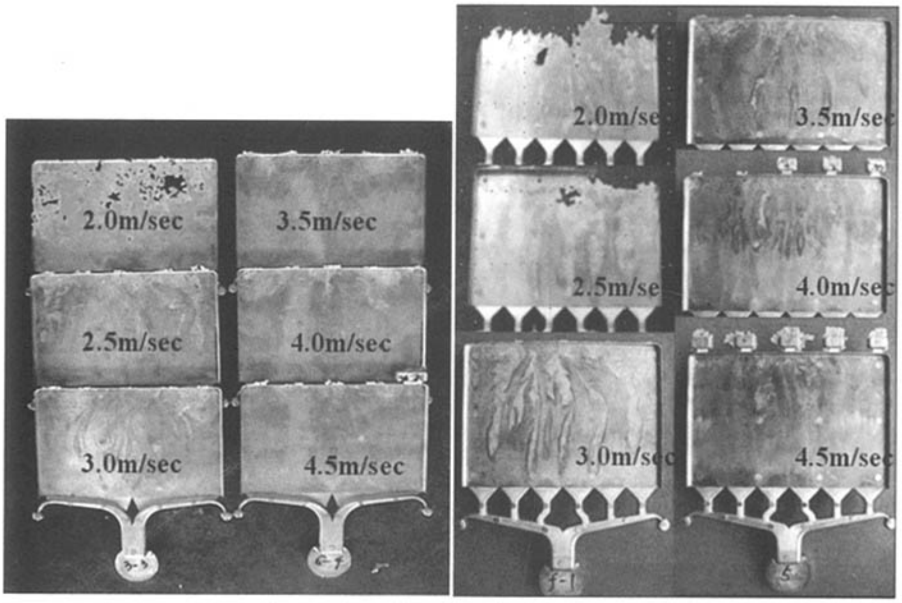

Fig.4 Die-casting results by varying the high speed injection: (a) tangential type, (b) split type

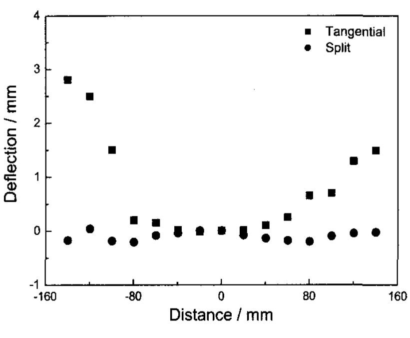

Fig.5 Distortion of tangential and split type gating system after the removal of gates

also found that the tangential type gate design was not able to fill the overflow even at the highest injection speed used for this investigation. Moreover, the tangential type gating system resulted in more distortion of the casting after the removal of the gate.

In Fig.5, the amount of distortion measured after removal of each gating system was displayed. The result clearly showed that the tangential type gating system could resulted in more severe distortion than split type. Since notebook housing fabricated in this research was only 0.7 mm in thickness, the stress build up because of the shrinkage of casting after the completion of solidification was an important factor to consider for the mass production of the notebook housing. Therefore, it was concluded that the split type gate design was better than the tangential type because of the aforementioned matters.

However, even with split type gate design there were casting defects such as flow line and misrun during die-casting. Therefore, two major modifications were introduced. One was the increase of the overflow and vent sizes. The volume of the overflow was increased about 70% (from 4400 mm^3 to 7500 mm^3) and the overflow ingate length was also increased from 13.5 mm to 30 mm in total length for the better flow of air in the die cavity. Moreover, upper part of sleeve was machined to have inclined slope as shown in Fig.6

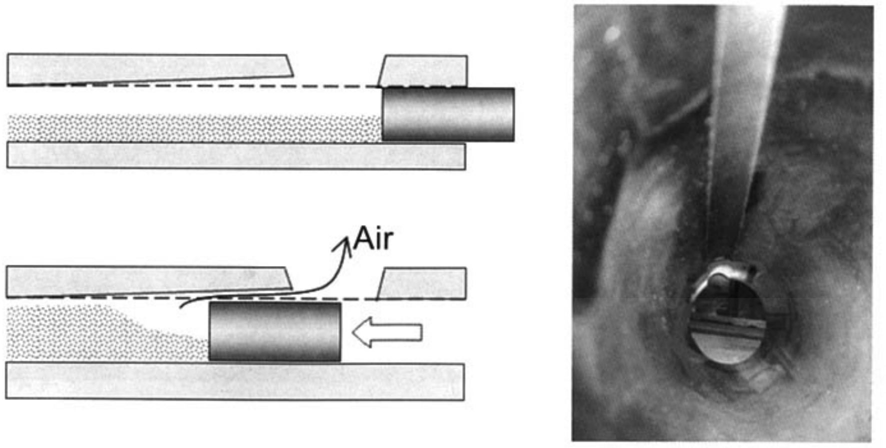

Fig.6 Schematic illustration of the inclined slope sleeve

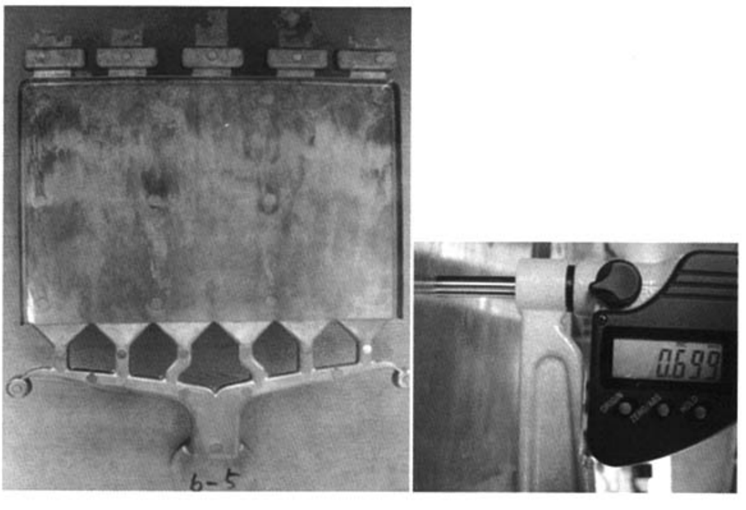

Fig.7 Thin-wall notebook housing with a thickness of 0.7 mm

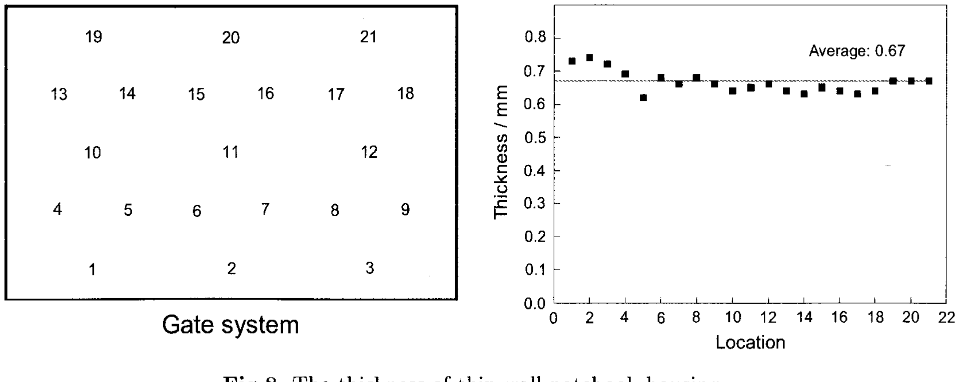

Fig.8 The thickness of thin-wall notebook housing

to minimize the turbulence and air entrapment inside of the sleeve during injection. Because the sleeve was filled with aluminum less than 30% (minimum of 40% of sleeve filling is recommended in die-casting process in field) resulting large amount of entrapped air and high turbulence during injection[4]. As the Fig.6 shows, the machined slope would help air inside of the sleeve to flow out more easily during injection so that the air entrapment in the melt would be minimized. With two modifications mentioned earlier, sound thin-wall notebook housing casting with less defect was successfully fabricated (Fig.7). There found to be less flow line, crack and misrun defects in the casting. The thickness of the casting was measured (Fig.8). In left figure, the locations of the thickness measured and are shown and the right figure shows the measured thickness of the casting. The thickness was found to be quite uniform and average thickness of 0.67 mm was obtained.

Because the casting was so thin, less than 0.7 mm, the ejection from the die after the solidification became very important. Thin-wall casting could be bent or even cracked during the ejection; therefore, the number of ejector pin and its lay out were very critical in die design. Moreover, the use of die temperature controller was also an important factor for fulfillment of die cavity for thin-wall die-casting. It was found that without the die temperature controller, the die was not heated up sufficiently even with more than 20 times of injection. When the die did not be heated up to appropriate temperature, the melt would be rapidly cooled down when it injected inside of the cold die cavity. As a result, severe casting defects including misrun and cracks were exhibited without die temperature control.

4. Conclusion

(1) Between tangential and split type gate designs, split type gating system was found to be better for thin-wall die-casting because the melt flows more uniformly inside the die cavity.

(2) As the melt reached the ingate, the high speed injection needed to be higher than 3.0 m/s, preferably 4.5 m/s, for sound thin-wall die-casting in size of notebook computer housing.

(3) The thickness was uniform throughout the casting and average thickness of 0.67 mm was obtained.

(4) For thin-wall aluminum die-casting, the location and the size of air vent and overflow were important factors for minimizing the flow line and misrun defects in the casting.

(5) Inclined slope sleeve design was helpful for air entrapped inside of sleeve to flow out during injection.

(6) Because the casting volume was quite small, it is important to control the die temperature as high as possible.

Acknowledgement

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