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Fluidity of Aluminum Piston Alloy with Different Amount of Pouring Temperature

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Abstract: One of the principal attributes of the aluminum-silicon alloys is their excellent fluidity, or the ability to fill a mold cavity. Fluidity is a complex characteristic that is influenced by surface tension, viscosity, alloy freezing range, melt, cleanliness, superheat, and solidification conditions. Chemical modifiers are generally considered to be detrimental to fluidity despite the fact that all the chemical modifiers commonly in use decrease surface tension. This investigation has been carried out to study the influence of pouring temperature of aluminum piston alloy on casting fluidity and microstructure defects. A strip type of fluidity testing mould was used in this study, and optical microscope to find microstructure defects. The results showed that higher the pouring temperature greater the casting fluidity. Otherwise, the overheating caused porosity, solidification shrinkage, and dross formation into the microstructure of the alloys melted at temperature higher than 760 C°.

Keywords: aluminum alloys, casting, fluidity.

Introduction

Due to their unique properties, such as low density, high thermal conductivity, simple net-shape fabrication techniques (casting and forging), ease of machinability, high reliability, and excellent recycling characteristics, aluminum alloys are the preferred material for pistons in both gasoline and diesel engines. Due to their excellent castability, where silicon plays a significant role, especially having high thermal characteristics that increase fluidity, Al-Si casting alloys are frequently utilized to create engine parts. [1-3]. Otherwise, casting characteristics of AI-Si alloys requires careful melting, degasifying, and pouring. Failure to exercise adequate control during the melting and casting processes is one of the most important problems [4, 5]. Pouring molten metal into the mold and then filling it are two crucial processes in the casting process. It has been noticed in foundry practice that some alloys fill the mould cavity completely and reproduce its intricacies in the finished casting better than others do when filling moulds of sophisticated design, particularly those that involve thin portions. Therefore, testing for mould filling capacity is crucial since it not only aids in choosing the right alloy composition for a certain application, but also helps with quality control and reduces casting rejections. Mistune castings or the absence of surface characteristics may be caused by inadequate fluidity [6, 7]. The characteristics of mould and metal jointly are involved in determining fluidity and pouring temperature is one of the factors related to metal. The aluminum-silicon alloys containing 8.5 to 13% Si are widely used to produce automotive parts. Generally, the higher the silicon content, up to the eutectic composition (12.6% Si), the greater the fluidity and, consequently, the easier an alloy is to cast [2]. The previous research found that pure Si would have been expected to have over 21 times the fluidity of pure aluminum as a result of its higher latent heat. However its greater rate of heat loss, seen to be nearly 5 times faster as a result of its higher freezing temperature, reduces this significantly. The low density of silicon also reduces the effect somewhat further [8]. G. Timelli et. Al [9] investigated investigate the fluidity of four different high pressure die cast Al–Si and Al–Si–Cu alloys at pouring temperature range of 580–760 °C. They found that fluidity linearly increases at increasing temperatures. At the other study, Chennakesava Reddy et. Al [6] found out that influence of pouring temperature on fluidity of Al-Si-Mg cast alloys is positive, where higher the pouring and mould pre-heat temperature greater the casting fluidity, as pouring temperature range is between 650 and 850 °C, and the mould preheated before pouring to 400 °C. They also found that silicon content in the alloy raises the surface tension resulting resistance to tearing of liquid layers and iron content favors the streamline flow of metal in the channels. The aim of the present study is to investigate the strip fluidity of Al-Si piston alloy with different pouring temperature used for gravity die casting, the strip fluidity test measures the ability of alloy to fill a mould of different cross sections and thus provides a wider specification of actual casting conditions.

Experimental Procedure

A consumed car engine pistons were used in the present investigations, The chemical composition of the piston alloy was determined using FOUNDARY-MASTER Pro emission spark spectrometer. Table 1 shows the chemical composition of alloy.

Table 1: The chemical composition of investigated alloy.

Element	Cr	Zn	Mg	Mn	Cu	Fe	Si	AL
Wt.%	ˉ0.0260	0.714	0.257	0.151	2.59	0.762	11.5	Bal.

For the purpose of preparing specimens at various pouring temperatures, the pistons were cut into small pieces and remelted. The tests were conducted in the pouring temperature range of 680 - 860 °C with a step of 10 °C after the pieces had been melted in an electrical furnace fitted with a graphite crucible. Since one of the many different types of fluidity tests uses fluidity as an empirical measure of a processing characteristic, this attribute is measured. Two common types are the mould fluidity spiral and the strip fluidity test. According to the previous studies [6, 10, 11], a strip fluidity testing mould (a tool steel strip type mould) was chosen to use in this investigation, whose design is shown in Fig. 1, which including four strips, a pouring basin, and running system. Each strip was of 10 mm width and 200 mm length. The thicknesses of the strips were 1, 1.25, 1.55, and 1.85 mm.

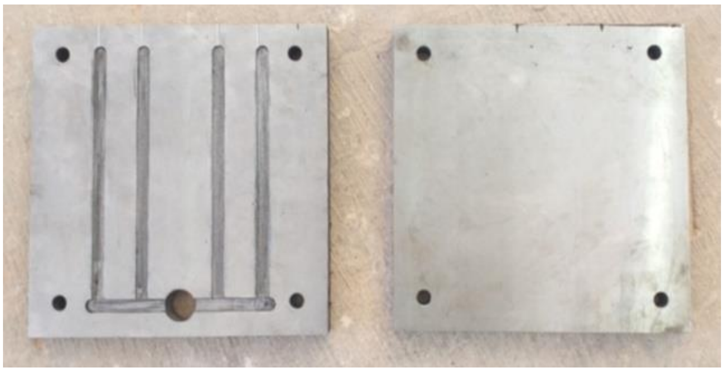

Fig. 1: Fluidity test mould

The temperature of the melt was measured using a K-type thermocouple. The melt was finally poured into the mould, then, the length of fluidity was measured. The samples were examined via an optical microscope to detect the formed porosity into microstructure of specimens.

Results and Discussion

Figure 2 shows the ingot after solidified, it can seen the molten metal did not flow through the strips but does flow into the running system for both sides due to the mould is not heated (casting with mould at room temperature), same result where found by A. Heidarzadeh et. Al **[10]** as the molten metal did not pass through the strip with 1 mm thick and solidified at running system which was cast without preheat the mould. However, the length of the metal flow in all strip mould summed together is taken as a measure of casting fluidity.

Fig. 2: Photographic view of strip fluidity test casting

The effect of pouring temperature on the fluidity alloy is shown in Figure 3. It can be seen that the fluidity increases with increasing pouring temperature. The degree of super heat of the alloy increases with increase in pouring temperature, this leads to keep the alloy as a molten form for a longer period, also the super heating of alloy decrements the fluid viscosity, so the liquid melt is able to flow over a longer distance due to increase in fluid life [6, 10]. In addition, increasing the pouring temperature delays the nucleation and growth of fine grains at the tip of the flowing metal into the mould channel, which lead to increment of the fluidity. [12, 13].

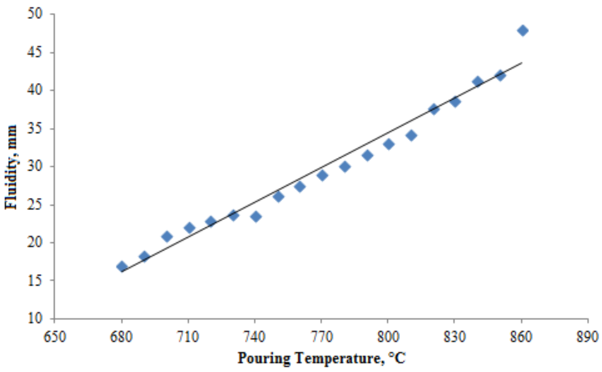

Fig. 3: Effect of pouring temperature on fluidity

On the other hand, an increase in the fluidity of the alloy as a result of an increase in the pouring temperature may lead to one of the most important defects of the microstructure, which is porosity. Porosity in castings mainly occurs due to gas entrapment in the melt at a highly turbulent flow of liquid metal into the die cavity [14, 15]. Figure 4 showed the microstructure of alloys with different pouring temperatures. The images showed that the porosities were formed at higher values of pouring temperature. The overheating in aluminum foundry causes gas porosity, solidification shrinkage, and dross formation [16]. In Figure 4 (a, b and c) no structure defects have been detected, otherwise in Figure 4 (d, e and f) some drosses were formed during solidification which referred with the circles.

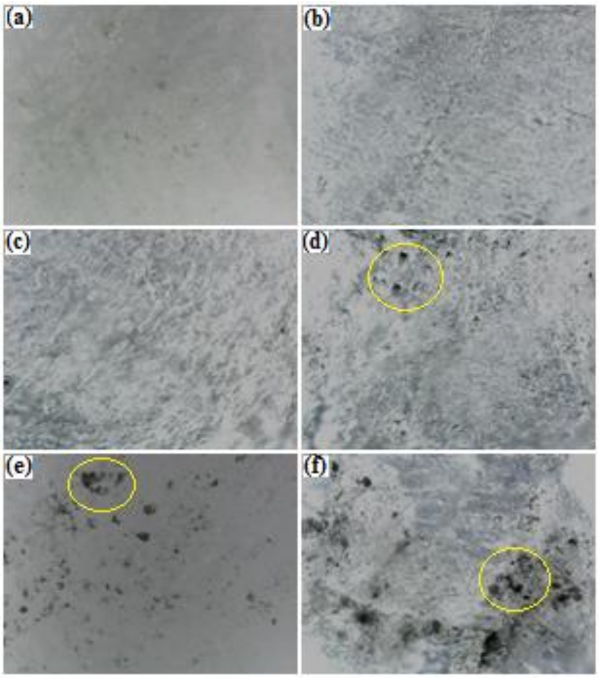

Fig. 4: Microstructure images of (a) 680, (b) 720, (c) 760, (d) 800, (e) 830 and (f) 860 °C pouring temperature, 50x.

Figure 5 showed formation of the solidification shrinkage defects caused by overheating at 840 °C pouring temperature.

Fig. 5: Microstructure images of the alloy melted at 840 °C, 50x.

Furthermore, the images of microstructure for the alloys were pouring at a high temperature also showed another structure defect, which was porosity, as shown in Figure 6 as clusters noted by circles. Porosity in cast parts is primarily caused by gas entrained in the melt as the liquid metal flows in a highly turbulent flow within the mold cavity. [16, 17]. In liquid metal die casting, the main filling mode is turbulent flow, so it is easy to form entrained gas in the cavity, which leads to the formation of porosity defects inside the casting, which greatly affects the compactness and mechanical properties of the casting structure [18, 19].

Fig. 6: The formed porosity into microstructure of the alloy at 840 °C, 50x.

When the aluminum alloys are melted at high temperatures, gases such as hydrogen are likely to be generated in the molten metal, causing defects such as gas pores and shrinkage pores. [20]. The increased porosity can cause a reduction in the mechanical properties [21]. As shown in the above results, melt the alloy at a high temperature caused increase in fluidity; on the other hand, led to form common casting defects, which can no longer be treated.

Conclusion

The effect of pouring temperature on strip fluidity of aluminum piston alloy was investigated. From the analysis, the following can be summarized:

1. Casting fluidity of alloys increases with increasing pouring temperature of melt.
2. The mould with strips less than 3 mm thicknesses needs pre-heating, where the molten metal did not reach the strips.
3. Casting defects were observed for the alloys with pouring temperature more than 760 °C.
4. The consumed aluminum piston alloy can be re-melted and used to produce many parts, as a recycling is the most effective ways to produce the alloys in our country.

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