Microstructure and mechanical property of aluminium based die-cast alloy (ALDC6) for spider arm component

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Abstract. In this paper aims on the development of aluminum alloy (ALDC6) using high pressure die casting (HPDC) for spider arm component in washer. Presently, ALDC3 alloy is commonly used for the fabrication of spider arm but it has poor corrosion resistance. ALDC6 alloy which has good corrosion resistance can be used as an alternative material for spider arm. However due to high Si (Silicon) content of 10wt% in ALDC3 alloy it has good castability compared to ALDC6 alloy with 1wt% of Si. Hence there is a need to modify the ALDC6 alloys by increasing the percentage of silicon and magnesium elements so as to improve the castability, strength and corrosion resistance. The optical microstructure of the developed ALDC6 alloy was investigated and its phases were detected by XRD analysis. It was found out that presence of MgSi in ALDC6 alloys is higher than that of the ALDC3 alloy. The microstructure and mechanical properties of ALDC6 alloys were evaluated and compared with existed ALDC3 alloys. The tensile strength and yield strength of the developed ALDC6 alloys has improved but elongation decreased. This implies that the spheroidal primary alpha grains and decrease in grain size due to the presence of Si and Mg within the alloy enhance the strength and yield stress.

1. Introduction
Al-Mg alloys (ALDC-6) are widely used in die casting in different industries because of the high strength to weight ratio, good ductility and good corrosion resistance [1]. The heavier shape component such as spider arm in washer which is coupled to the outer surface of the drum is typically mounted in a tub configured to make contact with water and hence likely to be corrosive. As the washers are fabricated by mass production, the spiders should have good corrosion resistance and castability. Presently, spider arm components are manufactured using ALDC3 aluminum alloy due to its good castability and strength properties. However, in the environments with water having relatively high sodium results in higher corrosion of spider arm made of ALDC3 alloy. Hence ALDC6 aluminium alloy is considered for the fabrication of spider arm component in washer. The ALDC6 alloy has good corrosion resistance due to the protective coating of oxide film on the alloy surface [2]. However, the ALDC6 alloy has low castability due to which such aluminium alloys has limited applications involving simple shaped components with low corrosion resistance. Hence there is a need for weight reduction, improved mechanical properties, wear and corrosion resistance of these aluminium alloys. The high pressure die casting (HPDC) is highly efficient in near net shape manufacturing whereby molten metal is injected into a metallic die cavity under high speed and high
intensification. This paper describes the fabrication of ALDC6 alloy by using die casting and study the microstructure and mechanical properties of ALDC6 alloys.

2. Results and discussion

Figure 1(a) shows the curves of solid fraction with temperature of ALDC6 alloys measured by DSC test. From the profiles it can be clearly seen that near 0.9 solid fractions the slope of curve was narrow due to the high percentage of Si, 10wt%. The figure also indicates the low temperatures with sensitivity ranging from 200°C to 590°C and higher temperature from 590°C to 600°C. The working temperature was fixed at 550-590°C with solid fraction ranging from 0.5-0.1 to avoid changes of void fraction due to the variation in solidification temperatures. In figure 1(b), the results show that the density changes with increase in temperature of ALDC6 alloys. Upon melting, the increase in melt density decreases when the temperature reaches the solidus temperature, indicating the formation of precipitates which cause for the decrease in the density.

![Figure 1](image-url)  
**Figure 1.** (a)Solid fraction vs temperature curves of the ALDC6 obtained by DSC analysis, (b) Density vs temperature of ALDC6 alloy.

3. Optical Microstructural and EDX analysis

![Figure 2](image-url)  
**Figure 2.** Optical microstructure of die casted (a)ALDC3, (b) ALDC6.

The figure 2(a) shows the optical microstructures of ALDC3 alloys, large α-Al grains and needle shaped Si eutectic structures were observed which results in the deterioration of the mechanical properties [3]. The optical microstructure of ALDC6 alloy with compounds such as Al₄(MnFe) and Mg₂Si appears in the grain boundaries (Figure 2(b)). From the EDX analysis by SEM of ALDC6 alloy it indicates that a small fraction of Fe-rich intermetallic compound of β-Al₁₃Fe₄ phase and α-Al₈Si₃Mg₂Fe with Chinese script were observed (Figure 3). The presence of high Fe content and low Si/Fe
ratio cause the formation of $\beta$-$\text{Al}_{13}\text{Fe}_4$ compound in the aluminum alloy. These formations of intermetallic phases were the result of binary eutectic reactions. Moreover, the formations of different types of morphological changes from plate to Chinese script were reported to enhance the mechanical properties [4]. The presence of higher content of silicon can prevent the formation of hot tearing defects and improve the castability of aluminum alloys [5].

4. Mechanical properties of ALDC6 and ALDC3 alloys

The mechanical properties of tensile strength, yield strength and elongation will be evaluated with five tensile samples. Figure 4 shows the tensile strength and yield strength of ALDC3 and ALDC6 alloys. The tensile strength of ALDC6 alloy is higher than that of the ALDC3 alloy with an elongation of 1-2%. However, the elongation decreased significantly from 5% to 2% for ALDC6 alloy. The results reveal that the addition of Si and Mg enhances the mechanical properties of the developed ALDC6 alloy. Therefore, the increase in tensile strength, yield strength and elongation of the sample is attributed to the presence of phases such as Mg$_2$Si and Al$_6$Si$_2$Mg$_2$Fe in the alloys. In the case of ALDC6 base alloy, the Si content is 1wt% and the developed ALDC6 alloy has 10wt%. The presence of Si with 10wt% could significantly improve the castability and reduce hot tearing defects in the ALDC6 alloys. This implies that the addition of Si over 1wt% is required to develop die castings with reduced hot tearing defects.

![Figure 3. EDX analysis of ALDC6 alloy with presence of Mg$_2$Si.](image-url)
Figure 4. (a) Tensile strength of ALDC3 alloy and ALDC6 alloy, (b) Yield strength of ALDC3 alloy and ALDC6 alloy; 1, 2, 3, 4, 5—number of samples.

5. Conclusions
The following conclusions were drawn from this study:

1. The ALDC6 alloys for spider arm component have been developed by using HPDC. The addition of elements such as Si and Mg increase the fraction of intermetallic phases Mg2Si and Al8Si6Mg3Fe, thereby enhancing the mechanical properties.

2. The mechanical properties of the developed ALDC6 alloys are higher than that of ALDC3 alloy. The tensile strength and the yield strength of ALDC6 alloy are 361MPa and 280MPa respectively, with 2% elongation in die cast condition.

3. The results of the study confirm that the developed ALDC6 alloy is suitable for fabrication of spider arm component in washer parts.

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