Microstructure and Mechanical Properties of Shock Tower Manufactured Using Non Heat-Treated Aluminum Alloy

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ABSTRACT: The tensile testing, Kahn tear testing, optical microscopy, and scanning electron microscopy were used to investigate the microstructure and mechanical properties of the shock tower manufactured using non heat-treated aluminum alloy (DK-NHT-1). The results show that the microstructure of shock tower using non heat-treated alloy is uniform and fine, and its density is high. The as cast DK-NHT-1 alloy exhibits high strength and toughness with a yield strength of 125 MPa, a tensile strength of 275 MPa, and an elongation of 14.6%. Additionally, the alloy demonstrates high fracture toughness with tear strength and unit initiation energy measured at 272 MPa and 34 N/mm respectively. Both tensile fracture and tear fracture exhibit typical ductile fracture characteristics.

Keywords: Non heat-treated alloy, Kahn tear testing, Mechanical properties.

1 Introduction

The shock tower is a key load-bearing component that connects car body and chassis, mainly used to absorb the impact load generated during vehicle motion. Due to a harsh service environment, the material of shock tower needs to fulfill high strength and toughness requirements. The shock tower is mostly manufactured by high-pressure die casting process and made of AlSi10MnMg alloy. The AlSi10MnMg alloy exhibits excellent casting fluidity and high tensile strength, while its elongation is low due to a high Si content. Thus, it usually requires T7 heat treatment to improve the toughness to meet the property requirements [1]. The casting is prone to serious deformation due to stress during the solution treatment and the subsequent quenching processes, owing to its complex shape and thin thickness (2-3 mm). Therefore, the correction treatment is often required afterward. In the meanwhile, the casting is prone to surface blistering during solution treatment at elevated temperature, which seriously reduces product yield and increases production cost.

To effectively solve the problems such as the low strength and toughness of the as cast AlSi10MnMg alloy and the deformation and deterioration of casting surface during heat treatment, we successfully developed DK-NHT-1, a non heat-treated aluminum alloy, which exhibits high strength and toughness in the as cast product. In this study, the microstructure, tensile mechanical properties, and fracture toughness of the shock tower cast were investigated, aiming to provide reference for its production and application.

2 Experimental procedure

The samples were taken from the shock tower of an automobile. The DK-NHT-1 alloy was self-developed, and its chemical composition is shown in Table 1.

Table 1. Chemical composition of DK-NHT-1 Alloy (wt.%)

Si	Fe	Mn	Mg	Ti
7.5-8.5	≤0.20	0.40-0.90	0.10-0.40	0.05-0.15
Sr	**Nb**	**V**	**Ca**	**Al**
0.015-0.025	≤0.15	≤0.15	≤0.001	Bal.

The die-casting process parameters of non heat-treated alloy shock tower are as follows: the pouring temperature is 670 ℃, the mould temperature is 150 ℃, the low plunger velocity is 0.2 m/s, the high plunger velocity is 4.2 m/s, the vacuum degree is 80 mbar, and the casting pressure is 40 MPa. Samples are cut from the shock tower body and machined into tensile and Kahn specimens. The metallographic specimens were ground sequentially with 80-2000 grit SiC sandpapers, and then etched using 0.5% aqueous HF solution for 10 s. Microstructure was observed using a fully automated inverted microscope Zeiss Axio Observer 7 m. The tensile test and Kahn tear test are performed according to ASTM 557 and ASTM B871 standards, respectively. The tests were carried out at room temperature using a Zwick/Roell Z100 testing machine. Five specimens were used for each test and then averaged. The fracture was observed using SEM with Zeiss EVO MA 15.

3 Result and discussion

Microstructure

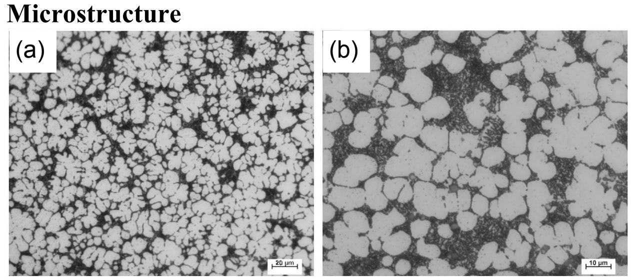

Fig 1. Microstructure of as cast DK-NHT-1 alloy

Figure 1 shows the microstructure of the as cast non heat-treated DK-NHT-1 alloy. It can be seen that the microstructure shows a typical dendrite morphology, consisting of α-Al primary phase, Al-Si eutectic phase and a small amount of Al(Fe, Mn)Si phase. The equiaxed primary α-Al phase is fine and uniform with an average grain size of 19.58 μm, as shown in Fig. 1(a). The Si particles in the Al-Si eutectic phase are extremely fine, with a size at the submicron scale. The Al(Fe, Mn)Si phase exhibits a polygonal morphology and is dispersed in the Al-Si eutectic structure, and no obvious needle-like iron phase is found, as shown in Fig. 1(b).

Tensile testing

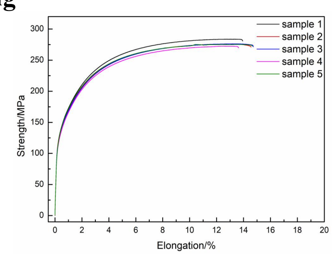

Fig 2. Load-elongation curve from a tensile test

Figure 2 shows the mechanical property curves of the as cast non heat-treated DK-NHT-1 alloy at different locations. It can be seen that the as cast DK-NHT-1 alloy exhibits excellent mechanical properties with an average yield strength of 125 MPa, an average tensile strength of 275 MPa, and an average elongation of 14.6%, meeting the product performance requirements. In DK-NHT-1 alloy, α-Al primary phase is relatively soft, which serves as a barrier to rapid crack propagation to ensure the high toughness of the product (shock tower). The ultra-fine (sub-micron) Si particles in the Al-Si eutectic phase and dispersed Al(Fe, Mn)Si particles can ensure the high strength of the alloy.

Kahn tear testing

The Kahn tear testing is widely used to evaluate the fracture toughness of aluminum alloys [2,3]. The Kahn tear testing can measure the alloy tear strength (TS) and unit initiation energy (UIE). As reported in the literature [4], there is a positive proportional relationship between UIE and fracture toughness KQ^2 (KQ^2 is the fracture toughness). The TS and UIE were measured to be 272 MPa and 34 N/mm, respectively, indicating that the DK-NHT-1 alloy exhibits an excellent fracture toughness.

Fractography analysis

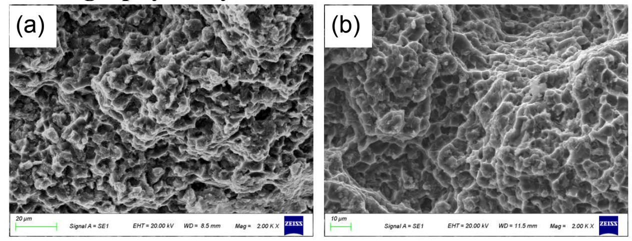

Fig 3. Tensile testing fractography(a) and Kahn tear testing fractography(b) of as cast DK-NHT-1 alloy

The fracture morphology of the tensile testing and the Kahn tear testing are shown in Figure 3(a) and Figure 3(b), respectively. It can be seen that both tensile fracture and tear fracture show typical ductile fracture characteristics, and the fracture contains a large number of small dimples, indicating that the alloy has high toughness.

4 Conclusion

The microstructure of the as cast non heat-treated alloy mainly consists of α-Al primary phase, Al-Si eutectic phase and a small amount of Al(Fe, Mn)Si phase. The α-Al structure is fine and evenly distributed with an average grain size of 19.58 μm. The Al(Fe, Mn)Si phase is polygonal in morphology and dispersed.

The as cast non heat-treated DK-NHT-1 alloy has high strength and toughness with a yield strength of 125 MPa, a tensile strength of 275 MPa, and an elongation of 14.6%. The alloy has a high fracture toughness with tear strength of 272 MPa and unit initiation energy of 34 N/mm.

Both tensile fracture and tear fracture show typical ductile fracture characteristics, containing a large number of small dimples.

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