Characterization of Elektron 21- an Aerospace Magnesium Alloy Cast by Counter-Gravity in Magnesia Mixed Fused Silica Investment Shell Moulds

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Abstract: Magnesium alloys today are found in applications as diverse as jets, helicopters, inline skates, and vascular stents. The counter-gravity pouring method was employed to cast Elektron 21 alloy in the investment shell moulds. The fluidity of counter-gravity poured Elktron 21 was excellent. The Elektron 21 alloy composed mainly of a solid solution structure α-Mg with eutectic α-Mg + Mg3Gd on the grain boundaries.

Keywords: Investment casting, Elektron 21, colloidal silica binder, magnesia, fused silica, counter-gravity pouring.

1. INTRODUCTION

Elektron 21 is a new high strength fully heat treatable magnesium based casting alloy for use at temperatures up to 200°C. The use of rare earth elements, such as neodymium and gadolinium, enhances the creep properties, corrosion and thermal stability of structure and mechanical properties of magnesium alloys. This alloy precipitates from the solid solution according to the sequence of phases: α-Mg → β" → β' → β. The β" phase is metastable and fully coherent with the matrix. It has a $D0_{19}$ crystal structure. The intermediate β' phase is also metastable and semi coherent with the matrix. The equilibrium β phase is face-centered cubic [1].

The majority of work done with Elektron 21 has been for sand cast applications. Investment casting is a means of reducing wall thickness of complex components. This process is generally restricted to small components for magnesium due to metal mould reaction. The thermal conductivity of mould wall is very important as this can influence grain structure in the castings. During heating or cooling, transformations between the crystalline forms fused silica take place. Fused silica has too low a conductivity of 1.3 W/m-K.

In the present work, magnesia (thermal conductivity is 60 W/m-K) was added to fused silica to increase thermal conductivity of investment shell mould walls. The purpose of this investigation was micro-mechanical characterization of Elektron 21 cast by counter-gravity in magnesia mixed fused investment shell moulds.

Table 1: Chemical composition of Elektron

Element	Zinc	Neodymium	Gadolinium	Zirconium	Magnesium
%Wt.	0.3	2.8	1.5	Saturated	Balance

2. MATERIALS METHODS

The chemical composition of Elektron 21 alloy is given Table 1. In the present work, the colloidal silica binder was used to fabricate the investment shell moulds from magnesia (25% wt.) mixed fused silica (75% wt.) as reinforced filler materials. The silica content in the colloidal silica binder was 30%. Two grades (primary and backup sands) of stuccoing sand were employed in the present investigation. Finer grade fused silica sand having AFS grain fineness number 140 was employed for primary coats. This is synthetic sand. This sand was used for first two coats, called prime coats to get good surface finish and every detail of the wax pattern. Coarser grade sand having AFS grain fineness number 60 was employed for back up coats. The backup sand was employed to develop more thickness to the shell walls with minimum coats [2-26]. The thickness of shell moulds were 10 mm. After all coats, the shells were air dried for 24 hours. Two shells of each treatment were made as shown in figure 1. The Elektron 21 alloy was melted in an induction furnace under vacuum.

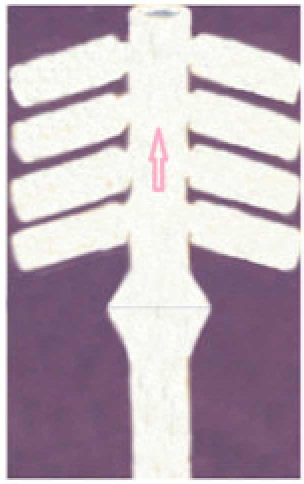

Figure 1: Counter-gravity poured investment shell mould.

The liquid alloy was counter-gravity poured under vacuum into the pre-heated investment shell moulds as soon as the molten alloy is ready to be cast, a preheated (750^{o}C) investment shell mould was placed on the bottom opening of a mould chamber. A preheated investment shell mould was transferred into the chamber and placed on top of the ceramic tube. Support media is packed around the preheated shell mould and the chamber containing the shell mould is transferred to the melting furnace. The shell mould at the bottom of the chamber is then inserted into the argon atmosphere above the molten alloy. Argon was drawn into to the shell mould chamber by creating a vacuum in the shell mould. This action essentially displaced air in the shell mold cavity through the semiporous mould with argon. The mould was then inserted deep into the molten alloy and the vacuum in the shell mould cavity was increased at a controlled rate, enabling the mould filling. The level of vacuum in the mould cavity was 1/3 of an atmosphere to fill the mold in 6 seconds. The shell moulds were knocked off by hand hammer after solidification of the molten. The castings were cleaned with soft brush and visually inspected for pins and projections.

Castability was also investigated by determining the flow length with an investment mould featuring a spiral shaped cavity. The as-cast specimens were solution treated at 520 °C for 6h in air and quenched into water. Ageing treatments were performed at 200°C. Tensile properties were obtained from the testing UTM (universal testing machine of 5 ton capacity) as per ASTM standard. Micro-hardness was measured on Vickers hardness tester.

Figure 2: Fluidity spiral of Elektron 21 alloy.

3. RESULTS AND DISCUSSION

The length of fluidity spiral is 500 mm. The Elektron 21 has castability of 482 mm fluidity length as shown in figure 2. The Elektron 21 alloy composed mainly of a solid solution structure α-Mg with eutectic α-Mg + Mg_3Gd on the grain boundaries (figure 3). Neodymium has good solid solubility in magnesium. This allows full solution treatment (homogenization) and good precipitation strengthening. Benefits from the gadolinium and zinc additions include increased hardness, improved age hardening response, delay of the onset of overaging, and changes to the morphology of the as-cast eutectic. Uniformity of properties is underpinned by zirconium grain refinement. As the gadolinium has the higher solid solubility than neodymium, gadolinium allows dissolution of some of the gadolinium-rich grain boundary phase into the matrix during heat treatment. As a result, the total rare earth level may be increased without detriment to tensile properties. At ambient temperatures, typical tensile strength hardness of Elektron 21 are 280 MPa and 47 HV.

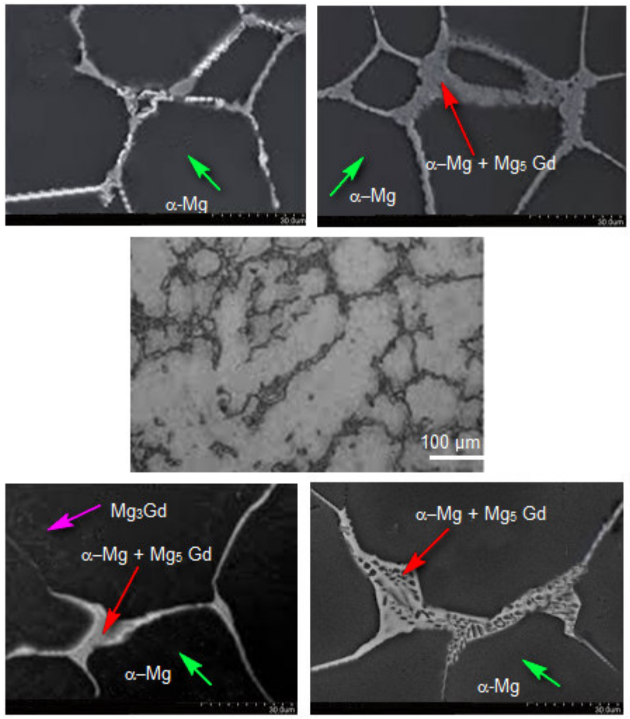

Figure 3: Microstructure of Elektron 21 alloy.

4. CONCLUSIONS

The counter-gravity pouring of Elektron 21 alloy in investment shell moulds has promoted good fluidity of the castings. The Elektron 21 alloy composed mainly of a solid solution structure α-Mg with eutectic α-Mg + Mg_3Gd on the grain boundaries. The gadolinium has the higher solid solubility than neodymium.

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