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Cooling slope casting to produce EN AW 6082 forging stock for manufacture of suspension components

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Abstract: The potential of cooling slope casting process to produce EN AW 6082 forging stock for the manufacture of EN AW 6082 suspension components was investigated. EN AW 6082 billets cast over a cooling plate offer a fine uniform structure that can be forged even without a separate homogenization treatment. This is made it possible by the limited superheat of the melt at the start of casting and the fractional solidification that occurs already on the cooling plate. Suspension parts forged from cast and homogenized billets with or without Cr all showed a uniform structure, and the hardness reached HV 110 after the standard artificial ageing treatment.

Key words: aluminium alloys; forging; cooling slope casting; heat treatment

1 Introduction

Forging is an attractive forming process to produce high-precision near-net shape parts with excellent surface qualities with a minimum number of finishing operations [1]. The ever increasing need for light weight solutions in the transportation industry provides aluminium forgings a good prospect since any reduction of the unsprung masses offers significant additional advantages [1]. In addition to light weight, aluminium forgings provide superior structural rigidity, higher strength and fatigue resistance as compared to cast and machined parts. High-performance aluminium parts such as control arms and steering columns have thus become standard in most passenger cars.

The most extensively used aluminium forging alloy is the age-hardenable EN AW 6082 because of its excellent combination of mechanical properties and corrosion resistance [2]. The EN AW 6082 forging stock is conventionally produced with the extrusion of direct chill cast ingots as this appears to be the most convenient way to reduce the diameter of the ingot to forging stock dimensions. Friction and high shear strains in the contact zone between the billet and the extrusion die lead to small recrystallised surface grains that tend to grow abnormally when exposed to high temperatures [3−6]. This is a major concern since 6082 forgings are almost always submitted to a solution heat treatment before ageing. Such a heterogeneous section with coarse grains on the surface not only impairs the surface quality but also degrades the service performance of the forging.

There has been some interest recently to replace the extruded forging stock with cast billets of the same diameter since the latter not only avoids coarse grained sections but also reduces the production costs by 15%−20% as compared to the extruded bars [7−12]. However, cast stock is not available in the market in diameters below 100 mm. Hence, alternating simple methods to produce cast forging stock may be of interest. One potential method is the cooling slope (CS) casting process that has been widely investigated in recent years to produce feedstock for semi-solid processing [13,14]. CS casting provides uniform equiaxed grains, with much less resistance to plastic flow [15,16]. The objective of this investigation is to explore the potential of CS casting process to produce 6082 forging stock in the manufacture of EN AW 6082 automotive suspension components.

2 Experimental

The EN AW 6082 alloys with the composition shown in Table 1 were melted in an induction furnace at

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Table 1 Chemical composition of EN AW 6082 billets used in present investigation (mass fraction, %)

No.	Si	Fe	Mn	Mg	Cu	Zn
1	0.947	0.204	0.612	0.720	0.041	0.025
2	0.993	0.206	0.642	0.722	0.091	0.024

No.	Ti	Cr	Zr	V	Al
1	0.022	0.006	0.001	0.013	97.34
2	0.040	0.134	0.005	0.013	97.12

750 °C. The melt was then allowed to cool to 700 °C. The CS casting involved pouring the molten alloy over a 50 mm wide and 300 mm long, inclined steel plate into a permanent mould (Fig. 1). The cooling plate was inclined at 45°. The round billet thus obtained had a diameter of 42 mm and a length of 400 mm. The surface of the plate was coated with a thin layer of boron nitride in order to avoid sticking of the molten alloy on the plate surface.

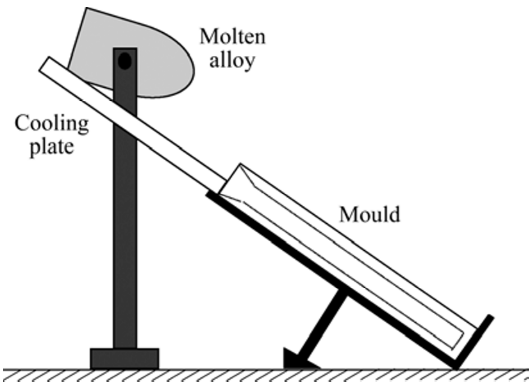

Fig. 1 Schematic illustration of cooling slope casting unit

One set of the cast billets were homogenized at 570 °C for 8 h to dissolve coarse eutectics and Mg_2Si particles formed during solidification and to obtain a fine distribution of dispersoids to control recrystallization during processing. They were subsequently cooled to room temperature at an average rate of 400 °C/h to achieve a delicate balance between the precipitation and solute saturation. The cast and homogenized billets were preheated to 500 °C and were forged on a 1600 t forging press into suspension parts as shown in Fig. 2. The forged components were solutionized at 520 °C for 4 h and quenched in water before they were artificially aged at 180 °C for 8 h.

Samples sectioned from the cast and homogenized billets were prepared with standard metallographic techniques: ground with SiC paper, polished with 3 μm diamond paste and finished with colloidal silica. They were examined after etching with a 0.5% HF solution using an Olympus BX51M model optical microscope. The X-ray diffraction (XRD) patterns were recorded with a Shimadzu XRD 6000 diffractometer equipped with Cu K_α radiation. Sections from the cast, extruded, forged and heat treated components were anodized in Barker's solution, 5 mL HBF_4 (48%) in 200 mL water, and then examined with an optical microscope under polarized light. Hardness was measured across these sections with a microhardness tester under a load of 2.94 N and with a dwell time of 20 s.

3 Results and discussion

The microstructure and the grain structure of the CS cast EN AW 6082 billet No. 1 are shown in Figs. 3(a), (b) and (c), respectively. The CS casting has produced fine, equiaxed dendrites. This made it possible by the limited superheat of the melt at the start of casting and the limited amount of solidification that has started already on the cooling plate. The temperature drops below the liquidus temperature when the molten alloy flows over the cooling plate and α(Al) crystals start to nucleate soon after. These crystals are detached from the cooling plate, trapped in the flowing melt and are

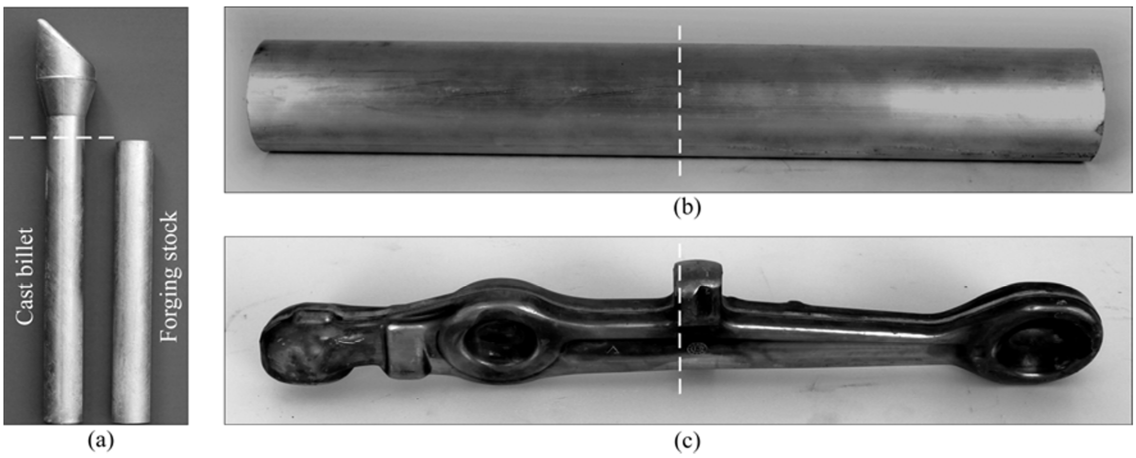

Fig. 2 CS cast billet (a), forging stock (b) and control arm (c) produced from cast and homogenized EN AW 6082 billet (The dashed lines in (b) and (c) mark section investigated for grain structures in the present work)