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Microstructure and shape of aluminum alloy extruded bar at semisolid condition

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The microstructure of 6082 extruded bar was investigated when re-heated to the semisolid state. In comparison, the microstructures of 6082 ingots, as cast using a cooling slope and as low superheat castings were also investigated. The primary crystals of the materials being produced by both these process became spherical when re-heated to the semisolid state. Similarly, the primary crystals of the extruded bar re-heated to the semisolid state was spheroidal but of smaller grain size than that of either cast ingots. In addition, the outer part of the re-heated extruded bar was harder than inner part when in the semisolid condition. This could prove useful during the thixoforming process by preventing premature slumping of the semisolid slug, i.e. the characteristic ‘elephant foot’ behavior.

1. INTRODUCTION

It is known that the primary crystals of strain-induced metals become spherical, through a process of recrystallisation and partial melting, when the metal is heated up to semisolid condition. This allows the strain induced metal to be used as feedstock material for thixoforming -the Recrystallisation and Partial Melting (RAP) & Strain Induced Melt Activated (SIMA) Routes [1,2]. There are a number of methods available that can induce the necessary strain in the metal, for example rolling, forging and extrusion. Extrusion has some advantages over other processing routes, such as that large strains can be induced into the metal, and that the billet can be made directly to size and therefore directly used for thixoforming only by cutting it into the right length to make the slug. Thixoforming of aluminum casting alloys has been thoroughly investigated, using a variety of feedstock production routes. However, although by its nature, the strain inducing method is more suitable for the wrought aluminum alloys than casting aluminum alloys, comparatively much less research has been carried out using the former method than the latter. Recently, although the use of 6082 for automotive applications is on the increase, there are few reports about the thixoforming of 6082. In this paper, the microstructure of 6082 alloy in the form of extruded bar has been investigated when re-heated into the semisolid state. The microstructures of ingots cast using the cooling slope and by low superheat casting, also re-heated into the semisolid state were used for comparison to that of the extruded bar.

2. EXPERIMENTAL WORK

Conventional commercial extruded bar of 6082 was used. The diameter of the bar was 50 mm. Extrusion ratio was not known. The extruded bar was heated up to the semisolid condition (640°C) and water cooled immediately in order to investigate the microstructure in the semisolid condition. Ingots were cast using a cooling slope and by low superheat casting. These ingots were heated up to semisolid condition and after quenching their microstructures were also investigated. The ingots cast from the semisolid slurry using a cooling slope, was carried out using two kinds of dies, a copper and an insulator die.

3. DUPLEX STRUCTURE OF THE EXTRUDED BAR

When the extruded bar was in the semi-solid state, it exhibited different strengths in its inner and outer parts. Figure 1 shows this dual shape behavior of the extruded bar when heated up to semisolid condition. When the extruded bar was rested in a conical barrel, as shown in Fig. 1, the outer part appeared to be hard and kept its shape, i.e. remained unbroken. In contrast, the inner part appeared to be much softer and dropped out of the hard shell by gravity alone. The thickness of cylindrical hard outer shell was about 6mm. This hard shell has also been observed with extruded bars of 2014 and 7075 alloys. Therefore, it appears that this hard outer shell is a feature of the extrusion route. Figure 2 shows the microstructures of the soft inner part, the hard outer part and the interface at the cross section of the extruded bar after being heated up to semisolid state and water quenched. The primary crystals of the inner part appear to be near spheroidal, whilst those of the outer part have failed to do so. This dramatic difference in crystal morphology is the reason that the outer part is harder than inner part in the semisolid condition. The stain of the outer part is larger than inner part in the extrusion. When employing either the RAP or SIMA thixoformable feedstock production routes, it is expected, in general, that the primary crystals become more spheroidal and smaller as the strain increases. However, this was not observed in the case of the present study. It is quite possible that the strain in the outer part was released due to dynamic recrystallization and as a result, the primary crystals failed to spheroidise. It is worth noting that the microstructures of the outer and inner parts also appeared to be different in the as extruded condition.

4. ELEPHANT FOOT

It is known that the deformation due to gravity of a slug when in the semisolid state, 'elephant foot', is a common occurrence in thixoforming. Figure 3 illustrates this phenomenon using the two kinds of ingots produced and the extruded bar. The ingots were cast using the cooling slope; one was cast using the copper die and the other was cast using the insulator die. The deformation, or the extent of the elephant foot, is more pronounced in the ingot obtained using the insulator mold. Cooling rate may also affect the extent of the elephant foot deformation, i.e. the extent of elephant foot increased when the cooling rate became lower. In contrast, the degree of the elephant foot deformation in the extruded bar was quite low. This appears to be the direct effect of the hard outer shell of the extruded bar. The outer hard shell is an effective way to prevent the elephant foot and therefore making easier the handling of slugs in the semisolid state. The thickness of the hard outer shell can be controlled through the extrusion ratio.

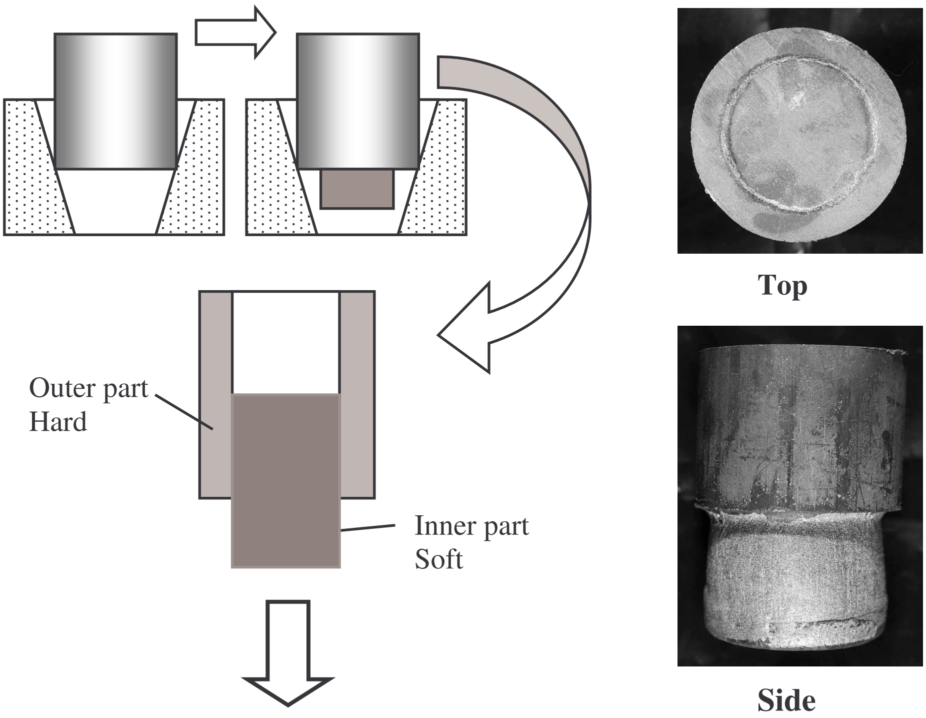

Fig. 1 Schematic illustrations and photographs showing behavior of extruded bar of A6082 at semisolid condition

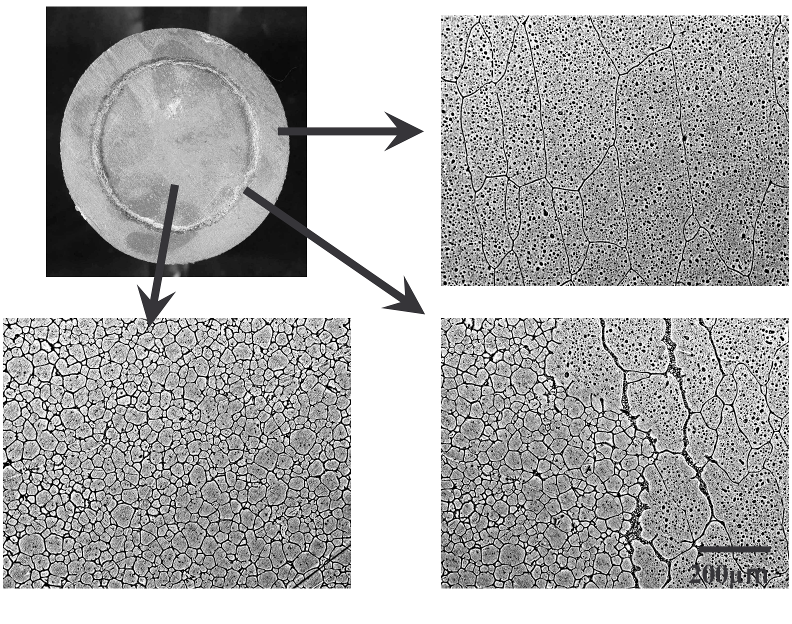

Fig. 2 Microstructures at semisolid condition of extruded A6082 bar

(a) (b) (c)

Fig. 3 Photographs of showing elephant foot of A6082 at semisolid condition
(a) ingot cast using the cooling slope by the insulator die, (b) ingot cast using the cooling slope by the copper die, (c) extruded bar

4. CONCLUSIONS

6082 extruded bar, and 6082 ingots made by casting using a cooling slope and casting using low superheat were heated up to semisolid state, and the resulting microstructures were investigated. It is clear that the primary crystals of 6082 become spherical in the semisolid condition. The primary crystals of the extruded bar were smaller than those of ingot cast both using the cooling slope and by low superheat casting. In the semisolid state, the outer part of the extruded bar appeared to form a shell that was harder (stronger) than the inner part. This shell served the very useful purpose of preventing the deformation of the slug due to gravity, the ‘elephant foot’ condition, therefore allowing easier handling of semisolid slugs.

REFRRENCES

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