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ARTICLE

Liquid Penetration Phenomenon of Gas Atomized Powders during Semi-solid Rolling

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Abstract: Under an H_2 atmosphere, the green strips were prepared from Al-5.8Zn-1.63Mg-2.22Cu-0.12Zr(wt%) powder by the semi-solid rolling process. The effects of different holding time at 610 °C (i.e. liquid phase fraction is f_s 53 %) on the microstructure evolution, especially the liquid penetration phenomenon of the strips were investigated. Results show that a higher degree of liquid penetration will accelerate the disappearance of the primary particle boundaries in the plane of contact, and a more obvious change of powder primary boundaries will occur. With increasing of holding time from 10 min to 30 min at 610 °C, the amount of η ($MgZn_2$) phase decreases and more particles Al_2Cu precipitate at grain boundaries. The optimum holding time for Al-5.8Zn-1.63Mg-2.22Cu-0.12Zr (wt%) powder semi-solid rolled at 610 °C is suggested to be between 20 min to 30 min. The present experimental analysis indicates that the strips with high mechanical properties can be produced by optimizing semi-solid powder rolling process.

Key words: metal powder; semi-solid rolling; liquid penetration; aluminum alloy powder

The process of metal powder rolling in the semi-solid temperature range is attractive due to its conceptual simplicity and economical operation cost. This process shows a promising for providing a new method of strip production with energy and materials saving, short production run for the metal processing industry.

According to the available literatures, the strips can be prepared by different methods. T. Haga devised a melt drag twin roll caster in order to cast aluminium alloy strips at a higher speed[1]. This method could cast thinner strips than the conventional twin roll caster for aluminium alloys. Thixo-rolling is widely used to produce strips [2]. In 2003, spray rolling proposed by E. J. Lavernia and K. M. Mchugh provided a new method of strip production for the metal industry[3,4]. However, little information was obtained for this new strip manufacturing process, which restricted its industrial application. Usually, materials in the form of powders are compacted through powder metallurgy, hot rolling, spark plasma extrusion etc. to acquire fine microstructures with unique properties[5-8]. Here, it should be noted that the previous work only focused on a lower forming temperature compared with that in semi-solid rolling.

The semi-solid rolling process involves high-temperature applications affecting the microstructure of the bulks, thus altering the mechanical properties.

Based on our previous work[9], it is interesting to note the examples of liquid in the process of penetrating down boundaries, this research was carried out to investigate the effects of different holding time at 610 °C on the microstructure evolution of strips. This work will facilitate a full control over the process in terms of properties.

1 Experiment

In this work, semi-solid rolling experiments were carried out using the atomized powder with a composition of Al-5.8Zn-1.63Mg-2.22Cu-0.12Zr(wt%). All the powder particles were spherical, shown in Fig.1a.

The size distribution of the powder was measured by laser diffraction technique using the Mastersizer 2000 particle size analyzer. The average particle size of the powder was 65 μm. The cumulative size distribution indicates D_{10}=14.2 μm, D_{50}=41.2 μm and D_{90}=87.5 μm corresponding to mass fractions

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of their particle sizes at 10 %, 50 % and 90 %, respectively, shown in Fig.1b. Green strips were prepared by powder rolling mill where the roll diameter used was 150 mm and length 100 mm. The speed of rotating was 31.8 mm/s, rolls were preheated to a temperature about 230 °C. In order to understand the effect of high temperature on the microstructures, the metal powder was heated at 580 °C for 20 min and at 610 °C for 10 min, 20 min, and 30 min, and then naturally fed into the rolls gap by gravity. Then strips were produced with 100 mm wideness and 0.7 mm thickness, as shown in Fig.1c. The longitudinal cross-sections of the green strips were polished. Keller's etchant was used to reveal grain structures and constituent phases. The morphology and cross-sectional microstructure of the green strips were observed by a microscope and a scanning electron microscopy (SEM). Crystal structure was characterized by X-ray diffractometer (XRD) using high energy monochromatic radiation in the 2θ range from 10° to 90° at a scan rate of 17.7 s/step.

2 Results and Discussions

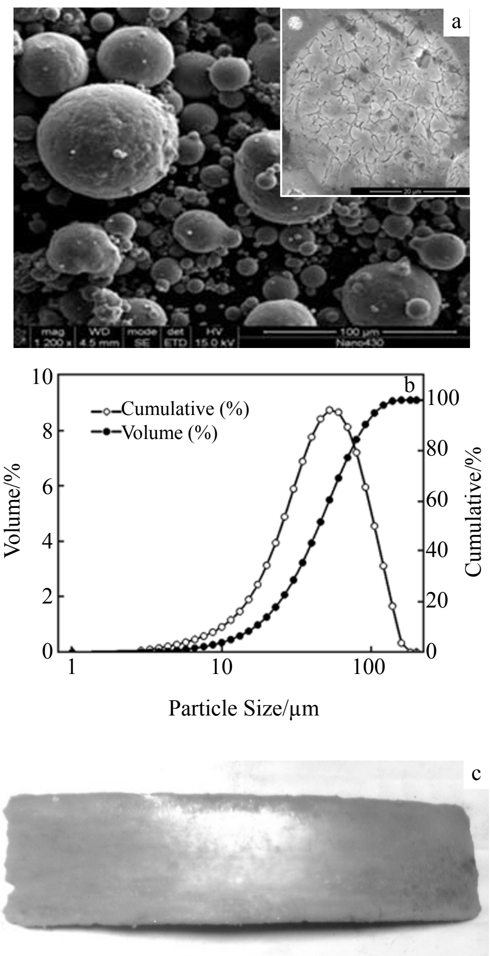

Fig.1 (a) Morphology of the gas atomized Al- 5.8Zn -1.63Mg -2.22Cu-0.12Zr(wt%) powder; (b) normal and cumulative size distributions of gas atomized powder; (c) photo of the green strip

Fig.2 presents the microstructures of green strips after semi-solid rolling under different temperature conditions. At semi-solid temperature of 580 °C, the solid fraction f_s is 86 % according to the Scheil function, which is often adopted to relate the alloy liquid fraction to temperature during solidification for the 7050 aluminum alloy[10]:

$$f_l = \left(\frac{T - T_s}{T_l - T_s}\right)^{\left(\frac{1}{1-ke}\right)} \quad (1)$$

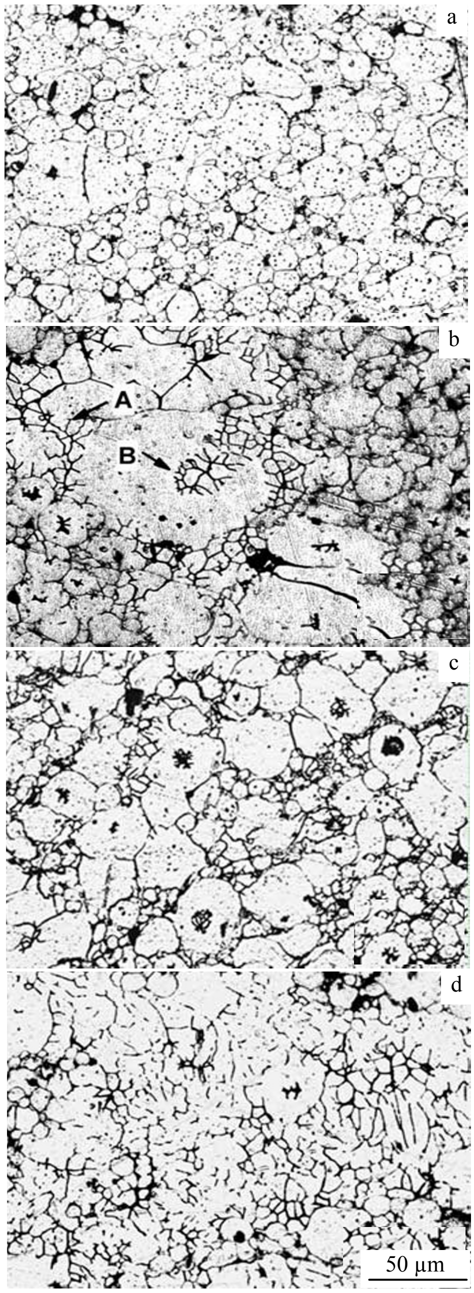

Fig.2 Microstructures of strips semi-solid rolled under following different conditions: metal powder heated at 580 °C for 20 min (a); 610 °C for 10 min (b); 610 °C for 20 min (c); 610 °C for 30 min (d)

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