

Rheo-Extrusion of an Alloy Developed for Rheo Process base on Al-Zn-Mg-Cu System

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1. Introduction

Super high strength aluminum alloys have been extensively studied for decades. Some limitations of the extrusion processes for these alloys exist. Conventional extrusion generally is defined as a complex and expensive process. As an alternative to conventional extrusion, semisolid methods have been introduced. In the past years, extensive efforts have been made to utilize super high strength alloys in semi-solid metal (SSM) processes. A new SSM processing technology named twin-screw rheo-extrusion was developed. High shear rate and high intensity of turbulence are two important characteristics of fluid flow in the twin screw. Basically in this technique molten metal is exposed to high shear rate and high intensity of turbulence by means of two intermeshed and self-wiped screws. In a few seconds molten metal converts to slurry with certain amounts of solid shearing between screws and barrel inner surfaces. There are three main parameters in the technique that could affect product properties, which are shearing temperature, rotation speed, and shearing time. In this innovative technique, the increase of screw rotation speed causes to promote shear rate, $\dot{\gamma}$ according to following equation.

$$\dot{\gamma} = \pi N \left(\frac{D}{G} - 2 \right)$$

Where N is the rotating speed of the screw, D is the outer diameter of the screw, and G is the gap between screw flight and the barrel surface.

Regardless of the process parameters, rheo-formability and final properties of alloys extremely depend on some thermodynamic parameters. The temperature sensitivity (TS) of solid fraction is defined as the most important parameter, which could be enhanced with chemical composition of an alloy to be amenable for SSM process. TS is defined as $-\frac{df_s}{dT}$ which is derived from F_s -T diagrams obtaining from Scheil solidification curves. Low amounts of TS are suitable for SSM processing. The present study focused on a new thermodynamic parameter determining exact temperature window for rheo-extrusion. The process parameters such as rotation speed and process temperature were also examined. The microstructural evolution and solidification behavior of the semi-solid slurry during the

REX (rheo- extrusion) process were discussed, and the tensile properties of the components were studied as well.

2. Experimental procedure

Thermodynamic analysis was carried out by Thermo-Calc AB, Version 2.2.1.1, developed by the Foundation for Computational Thermodynamics.

Commercially pure aluminum, magnesium, copper, and zinc were weighed and melted in a graphite crucible in a resistance furnace under argon gas protection. The composition of the melt (Al-14Zn-9Mg-5.2Cu wt. %) was determined by thermodynamic assessment. All samples were over heated up to 50°C and held for 1 hour to obtain chemical homogeneity. The molten alloy was then poured in the melt feeder that was embedded on the twin-screw rheo extruder.

Fig. 1 1 shows the schematic illustration of twin screw rheo- extrusion. The slurries of the alloy were sheared in semi-solid state at three different solid fractions of 0.5, 0.55, and 0.6. Process time and die orifice diameter were 25 seconds and 10 mm, respectively. Extruded cylindrical samples were immediately quenched in water. T6 treatment applied for selected extruded specimens of tensile test.

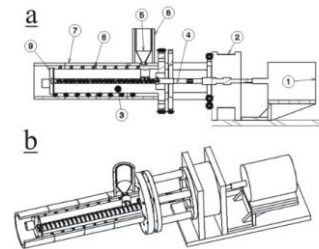


Fig. 1. Schematic illustration of the twin screw rheo-extrusion

3. Results and discussion

Figure 2 shows the solidification calculation for three alloys with different Zn/ (Mg+Cu) keeping constant the sum of Zn+Mg+Cu= 17.5 % wt. (see Figure 2a), and three alloys with different Zn+Mg+Cu keeping constant the ratio of Zn/ (Mg+Cu) =1 (See Figure 2b). In a certain solid fraction, the lowest TS. value is obtained at the lowest Zn/ (Mg+Cu) ratio and the highest sum of Zn+Mg+Cu.

The best alloy was rheo-extruded at different rotation speeds with three solid fractions. Figure 3 shows the resulting microstructures of alloy 6, rheo-extruded with solid fractions of 0.6, 0.55, and 0.5 at highest rotation speed.

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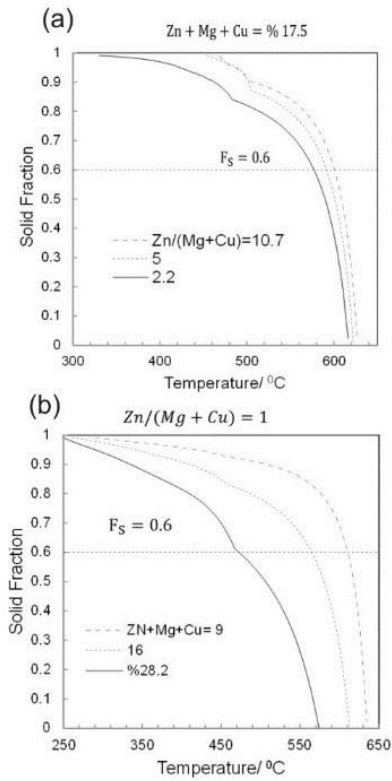


Fig. 2. Non-equilibrium solidification curves of six alloys

4. Conclusion

1. In super high strength 7000 aluminum alloys, the lower Zn/ (Mg+Cu) ratio and higher amount of Zn+ Mg +Cu could decrease the TS and caused a higher rheo-formability.
2. The diagram of $^{-d_{fs}}/dT$ vs. temperature showed the minimum of TS was occurred at temperature just above the eutectic point.
3. The diagram of the d_{fs}^2/dT^2 vs. temperature showed the promising stable process window for REX process.
4. Alloy with nominal composition of Al-14Zn-9Mg-5.2Cu was predicted to be suitable for rheo-extrusion.

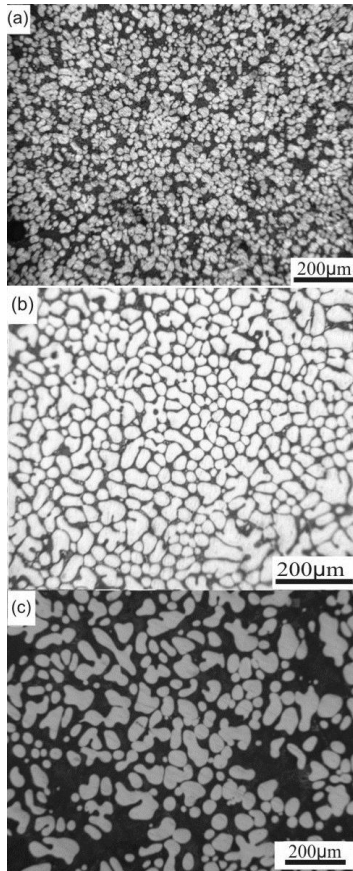


Fig. 3. Microstructures of rheo-extruded alloy 6 by twin screw at highest rotation speed for each solid fraction and constant processing time of 25 sec: a) $F_s=0.6$, 450 rpm, b) $F_s=0.55$, 450 rpm, and c) $F_s=0.5$, 550 rpm