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반용융 직접 압출에 의한 Porthole Die 활용 A7075 심리스 튜브 개발

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Development of Seamless Tube for 7075 Al Wrought Alloys by Direct Thixoextrusion process utilizing Porthole Die

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Abstract

The aim of this study was to improve extrudability limit, eliminate welding line and obtain optimum thixoextrusion conditions for manufacturing tubes of 7075 Al wrought alloy. By thixoextrusion, it was possible to improve deformability, control isotropy with extrusion direction, eliminate welding line (seamless) and save cost due to low energy consumption compared with conventional extrusion processes. The welded part was not observed at the welding line area. The grains of thixoextruded tube were homogeneously distributed and equiaxed grains were observed. Therefore, thixoextrusion is the most effective variable for the control of the magnitude of the welding line.

Key Words : Thixoextrusion, 7075 Al Wrought Alloy, Porthole Dies, Seamless Tube

1. Introduction

Porthole die extrusion has a great advantage in the forming of hollow section products which are difficult to produce by conventional extrusion with a mandrel on the stem. Using the porthole die extrusion, long tubes can be produced without respect to the length of the mandrel. Material in the container flows through the porthole with multi-hole, and this material is divided through the number of portholes and is gathered and welded by high pressure in the welding chamber. Only Al and its alloy with a strong welding faculty are effective [1].

As a result of solid-state welding occurring in the welding chamber of the die during extrusion, there are a number of weld seams along the length of the extruded tube, customarily called the longitudinal weld seams. The formation of the longitudinal weld seams during extrusion through a porthole die is a solid-state bonding process. Thus, the failure of hollow extruded products mostly occurs along one of the weld lines when the products are subject to severe internal pressure or expansion in the practical use [2]. Defects at the weld seams become apparent in the form of streaking after the Al extrusion is anodized. In a number of previous investigations, the causes for the defect formation at the longitudinal weld seams during Al extrusion have been analyzed from the metallurgical point of view, and the measures to improve the weld seam quality proposed with respect to porthole die design [3, 4]. Therefore, it is important to increase the welding strength.

A seamless tube with tight tolerances can be produced using a dedicated extrusion press with a mandrel on the stem that pierces a solid billet and forms the internal shape of the tube. This extrusion technique is particularly suitable for hard Al alloys such as Al–Zn–Mg–Cu alloys

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in the 7000 series.

The 7000 series Al wrought alloys with good mechanical properties have been used with tendency to obtain weight-saving in aerospace, shipbuilding and transport industries. However, they generally allow low extrusion speed and low extrudability index when extruded conventionally and also causes rather high extrusion pressure. Especially, the extrudability index of 7075 Al wrought alloy with high Cu content is below 10 and it is limited under extrusion ratio 35 for conventional extrusion [5]. Also, 7075 Al wrought alloy is impossible to produce tubes by using conventional direct extrusion.

The tubes of 7075 Al wrought alloy are manufactured by indirect extrusion. The indirect extrusion may not supply tubes for market, because indirect extrusion resulted from increase of manufacturing costs and curtailment of production because of slow extrusion speed. The indirect extrusion is limited in view of production and quality, because initial pressure due to the high extrusion ratio is very high during extrusion processing.

By thixoextrusion, it is possible to improve deformability (reduced extrusion pressure with high productivity), control isotropy with extrusion direction and save cost due to low energy consumption compared with conventional extrusion processes[6-9]. Thixoextrusion will be able to expect eliminating welding line (seamless) of thixoextruded tube[10].

The aim of this study is to improve extrudability limit, eliminate welding line and develop of Seamless Tube for 7075 Al Wrought Alloys by Direct Thixoextrusion process utilizing Porthole Die.

2. Experimental Procedures

The material used in this study was commercially available 7075 Al wrought alloy. The 7075 Al wrought alloy (Ø54mm×210mm) has been manufactured by melting in a high-frequency induction furnace. Homogenization treatment was carried out at temperatures of 480°C for 8hrs. The liquid fraction (f_L) at any temperature (T) within liquid-solid two phase range is usually given by the Scheil equation assuming that the liquid is completely homogenous and no diffusion occurs through the solid, where T_M is the melting temperature of the pure metal, T_L is the liquidus temperature of the alloy and ko is the equilibrium distribution coefficient. In this Scheil equation, the value of T_M is about 660°C, the value of T_L is about 641°C and 0.57 ko were taken, based on the DSC (differential scanning calorimetry) result.

The extrusion billet was partially remelted inside the sleeve by cartridge-type heaters. The temperature of the billet in the sleeve was monitored through a K-type thermocouple located at the center of the top surface of the billet. After the required temperature was reached, the ram was horizontally moved for thixoextrusion process. The load and the stroke in extrusion were measured using a load cell and recorded with a personal computer.

During the thixoextrusion of the tubes, the billet flows into the die from three channels at the extrusion end of the die, and then passes through the welding chamber of the die to be connected to form good tubes. The billets used in this paper are Ø48mm×90mm. After extrusion, the outer diameter of the tubes is Ø10mm, the inner diameter is Ø6mm, the thickness is 2mm, and the tubes with the extrusion ratio of 36 were extruded by using the 50ton horizontal thixoextrusion apparatus. The ram speed was 10mm/s. The angle of the thixoextrusion die was $2\alpha=90^{\circ}$ and the die temperature was 500°C. The die bearing length was 10mm.

Table 1 Experimental conditions for the thixoextrusion process

Conditions	Values
Extrusion temp. (℃)	590
Die bearing length (㎜)	10
Initial ram speed (㎜/sec)	10
Extrusion ratio	36
Product thickness (mm)	2

A die was specially designed to obtain a completely solidified bar, just after die position. The specimens were ground and polished. Tensile specimens were machined with the axis parallel to the extrusion direction. The experimental conditions of thixoextrusion process in this study were shown in Table 1.

3. Results and Discussion

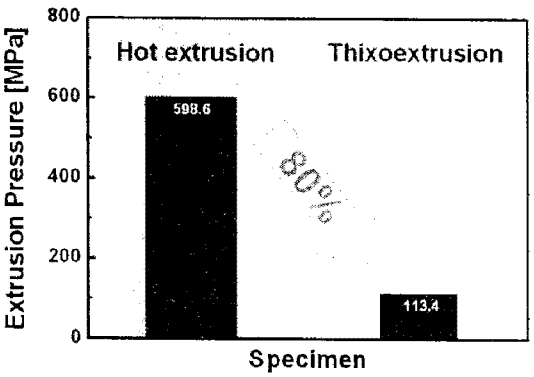

Fig. 1 Comparison of maximum extrusion pressure of 7075 Al wrought alloys in hot Extrusion and thixoextrusion

Fig. 1 shows the comparison of maximum extrusion pressures in hot extrusion and thixoextrusion. The maximum extrusion pressure of thixoextrusion was lower than that of conventional hot extrusion. The maximum extrusion pressure of the thixoextrusion was 113.4MPa and the maximum extrusion pressure of the hot extrusion was 598.6MPa. Because of the low flow stress of the billet in the semisolid state, the maximum extrusion pressure necessary for the thixoextrusion was lower than that of conventional hot extrusion. Owing to the lubrication effect of the liquid phase and the low extrusion pressure, products of complicated cross sectional profiles and thin wall-thickness could be thixoextruded rather easily.

The quality of the metallic bonding along the welding line was evaluated through microstructural observations based on optical microscopy. Fig. 2 shows the formation angle of the welding line in a transverse section of the thixoextruded tube when the initial billet temperature was 590°C, the bearing length was 10㎜, and the tube thickness was 2㎜.

It is known that the formation angle was formed every 120 degrees. The tubes obtained from thixoextrusion were welded at three regions. In view of microstructure, as a result of semisolid state welding occurring in the welding chamber of the die during thixoextrusion, the welded part was not observed at the welding line area. The grains of thixoextruded tube were homogeneously distributed and equiaxed grains were observed. The final welding strength of thixoextruded tubes was therefore expected to be above that of a conventionally extruded position of thixoextruded tube of 7075 Al Mg wrought alloy were shown in Fig. 3.

As shown in Fig. 3, the equiaxed grain structures were observed at the each position. This seems to suggest thatthe coarse solid particles deformed in great deal even at semisolid states and simultaneously dynamic recrystallization occurred. On the relation between the structure of the thixoextruded product and material flow in semisolid state, it has also been reported that the tube. Therefore, thixoextrusion is the most effective variable for the control of the magnitude of the welding line.

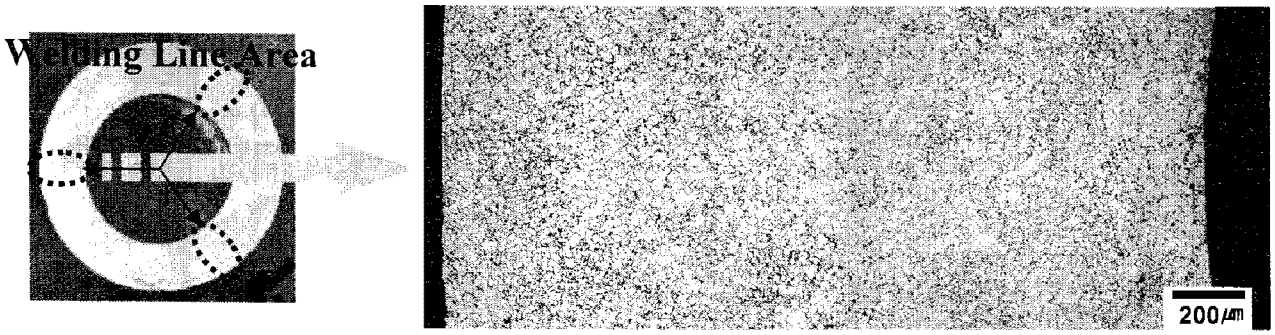

Fig. 2 Microstructure along of the welding line in a transverse section of thixoextruded tube

Fig. 3 Microstructures of thixoextruded tube of 7075 Al wrought alloy

The microstructures of longitudinal section at the each microstructure had become elongated at the region of lower fluidity, in contrast to the spheroidal structure at the location showing a good thixoextrudability. This seems to lead the results of good surface conditions in the thixoextrusion. A press effect, e.g. a particular orientation of the microstructure due to plastic deformation without recrystallization, cannot be observed. The microstructure was entirely globular.

4. Summary

The aim of this study is to improve extrudability limit, eliminate welding line and develop of Seamless Tube for 7075 Al Wrought Alloys by Direct Thixoextrusion process utilizing Porthole Die. The tubes obtained from thixoextrusion were welded at three regions. The welded part was not observed at the welding line area. The grains of thixoextruded tube were homogeneously distributed and equiaxed grains were observed. By thixoextrusion, it was possible to improve deformability, control isotropy with extrusion direction, eliminate welding line (seamless) and save cost due to low energy consumption compared with conventional extrusion processes. Therefore, thixoextrusion is the most effective variable for the control of the magnitude of the welding.

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