Powder Technology 275 (2015) 344–350

Contents lists available at ScienceDirect

Powder Technology

journal homepage: www.elsevier.com/locate/powtec

Processing and pore structure of aluminium foam sandwich

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ARTICLE INFO

Article history:
Received 11 August 2014
Received in revised form 25 January 2015
Accepted 29 January 2015
Available online 7 February 2015

Keywords:
Aluminium foam sandwich
Pack rolling
Foaming behaviour
Microstructure

ABSTRACT

Aluminium foam sandwich had been prepared by modified powder compact melting process (powder pack rolling melting process). During the process, the effect of reduction on relative density of the precursor was studied by Archimedes' principle. The foaming behaviour and pore microstructure of precursor were determined. It is found that with the reduction increasing, the relative density of the precursor increases and the uniformity of the precursor can also get improved. The optimized reduction is 80% because the relative density and its distribution hardly change when the reduction is larger than 80%. The foaming process can be divided into three stages, pore forming, pore growing and pore cracking. During the stage II, the expansion factor of the precursor reaches a maximum 2.37. The microstructure of pore wall varies at different stages. At the second stage and third stage, the microstructure evolves into dendritic structure and eutectic phase, which is similar to the modified microstructure of cast $AlSi_{12}$ alloy.

1. Introduction

Metallic foam has many interesting combinations of mechanical or physical properties [1], such as the high stiffness to low specific weight ratio, or high gas permeability combined with high thermal conductivity. Metallic foam sandwich has not only the physical properties of metallic foam, but also better mechanical properties than metallic foam because the face sheet can improve compression strength significantly [2] and also protect the metallic foam core. Thus, there is an extensive interest in using metallic foam sandwich for automotive, aerospace, railway, and other industrial fields [3–8].

At present, there are two common methods for manufacturing metallic foam sandwich, adhesive bonding and roll-cladding bonding based on powder compact melting. Adhesive bonding is easy to fail under high temperature. Furthermore, the properties of adhesive bonding are related to moisture [9]. Powder compact melting is one way to prepare closed-cell aluminium foam, which is developed at Fraunhofer-Institute in Bremen. The detail process of powder compact melting has been reported [10–13]. The two face sheets are roll cladded on the precursor prepared by powder compact melting. However, the process is very complicated, which causes the high production cost.

Here, we modify the powder compact melting to prepare to aluminium foam sandwich as shown in Fig. 1. The mixed powder is sealed in aluminium box, and then the box are rolled. Pack rolling enables not only the consolidation of powder, but also the bonding between face sheet and core of aluminium foam sandwich. Compared with roll-clad, pack roll can get precursor with better quality without edge cracking, because the distribution of stress is more homogeneous during rolling process. So the modify process is more simple than typical powder compact melting, and its cost is lower.

In this study, we experimentally demonstrate the above modified process using aluminium sheets and TiH_2 powder. The effect of rolling reduction on precursor was investigated. The foaming process of precursor was studied, and the microstructure was also evaluated.

2. Experimental procedure

Aluminium foam sandwich, having nominal composition $AlSi_{12} + 1.0\%TiH_2$, was prepared by powder pack roll melting process, whose face sheet is 1060 pure aluminium. The morphology of $AlSi_{12}$ and TiH_2 were shown in Fig. 2 (a)–(b). According to B.Matijasevic's studies [14], the TiH_2 was tailored by heat treating with 480 °C/60 min in air prior to its use. The decomposed temperature of TiH_2 rises from 530 °C to 550 °C, which is closer to the melting point (577 °C) of $AlSi_{12}$.

The $AlSi_{12}$ and pre-treated TiH_2 powder were mixed in a three-dimensional mixing machine for 2 h. The mixture was then sealed up by argon-arc welding into 1060 pure aluminium box, whose size is 150 × 100 × 38 mm. The thickness of face sheet is 4 mm. After the box was kept at 450 °C for 30 min in the chamber furnace, it was got out and rolled in air with different reduction, which was achieved in one rolling pass. The chamber furnace temperature was measured by K-type thermocouple. The density of precursor without skins was evaluated by Archimedes' principle, and the microstructure of precursor was investigated by an optical microscope.

The 30 × 30 mm^2 square specimens were cut from the precursor by electron discharge machining. The specimen was put into the chamber

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http://dx.doi.org/10.1016/j.powtec.2015.01.066
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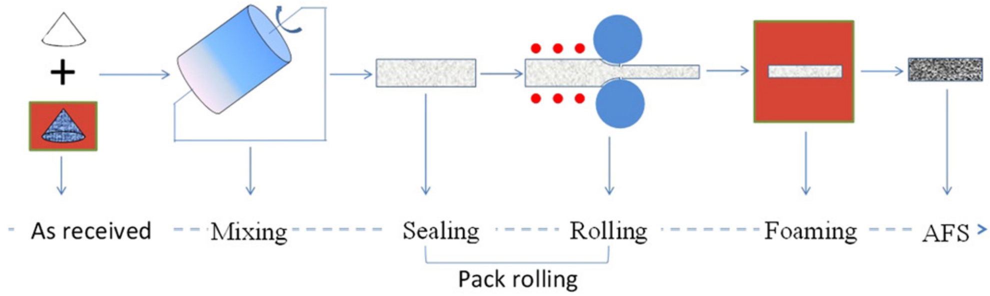

Fig. 1. Powder pack roll melting process of aluminium foam sandwich.

furnace with the foaming temperature, and the specimen temperature was also measured by K-type thermocouple which was fixed on the side of the specimen. After the foaming time reached the test value, the specimen was got out from the chamber furnace and cooled down to room temperature in air. In order to get exact test result, the foaming test under same foaming parameter was repeated three times. The result was the average value. The foaming behaviour of precursor was studied, and pore structure and microstructure of aluminium foam sandwich were investigated by optical microscope.

3. Results and discussion

The thickness of face sheet and core is an import geometry parameter for aluminium foam sandwich, which is related to the failure mode of aluminium foam sandwich. The thickness of face sheet and core was measured five times at different position in the cross-section photo of aluminium foam sandwich by microstructure analysing software. The result was the average value. During the process, the relationship between thickness and deformation rate ($\frac{t_0-t}{t_0} \times 100\%$, t_0-original thickness, t-thickness after rolling) of face sheet and core and reduction is shown in the Fig. 3. With the reduction increasing, the thickness of face sheet and core decreases. When the reduction is higher than 50%, the relationship between the thickness and reduction can be expressed as Eq. (1). The fitted result shows that $\alpha_f = 6.1$ and $\alpha_c = 24.4$ in this study. The strength of core is lower than face sheet because the powder core is not compact, so that deformation rate of core is higher than face sheet, which mainly

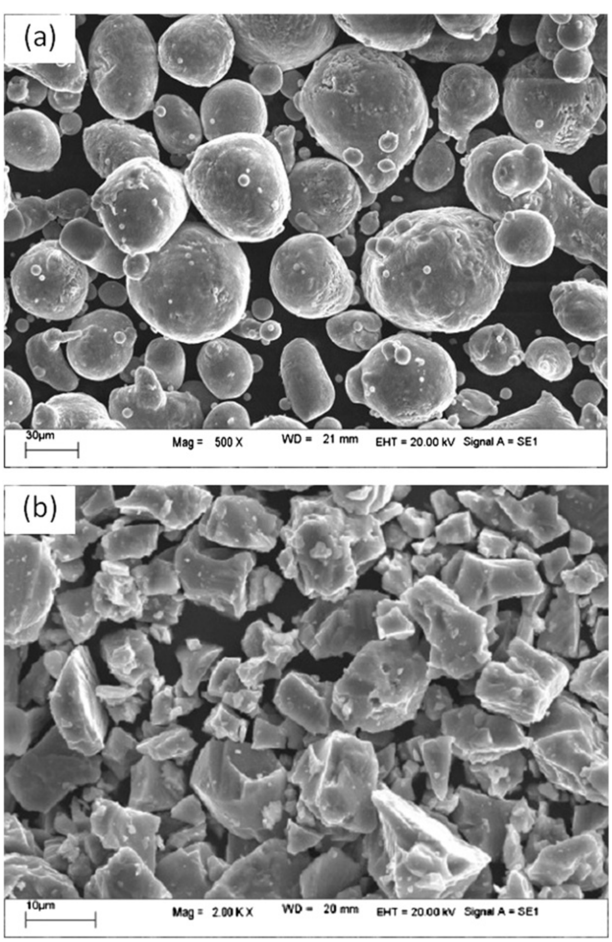

Fig. 2. Morphology of (a) $AlSi_{12}$ and (b) TiH_2.

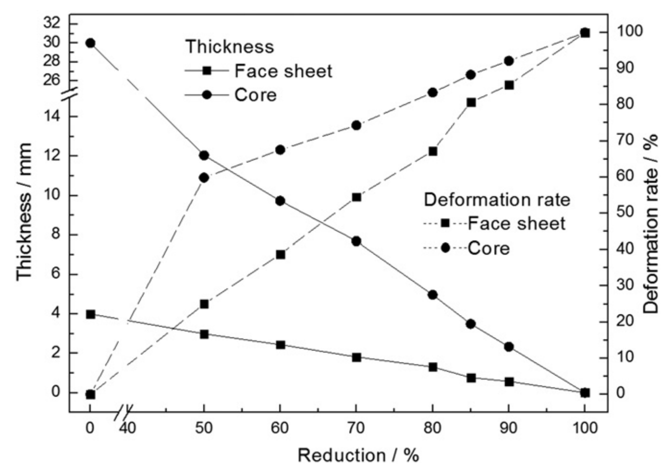

Fig. 3. Thickness and deformation rate of face sheet and core with different reductions.

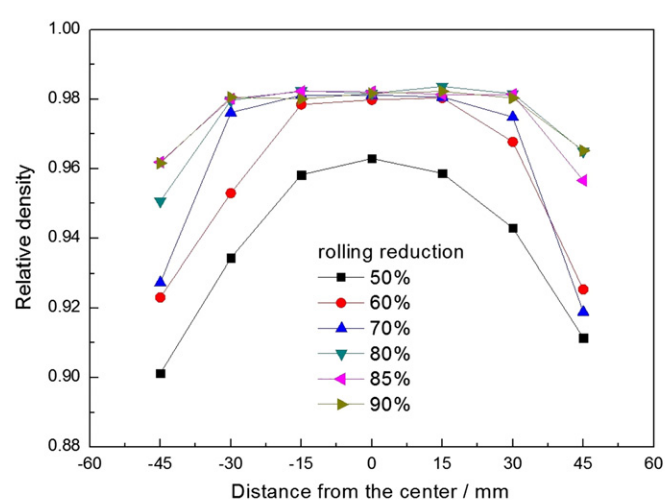

Fig. 4. Relative density of precursor with different reductions.