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Cutting process for aluminum foam fabricated by sintering and dissolution process

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A B S T R A C T

In this study, a cutting process using a milling machine for Al foam with and without remaining NaCl fabricated by a sintering and dissolution process was proposed. By comparing the surface pore structures of the Al foam after the cutting process, the possibility of cutting Al foam using a milling machine while retaining its pore structures was investigated. Although some flashes were observed around the pores, most of the pores remained at the cutting surface and retained their shape. Therefore, it was found that Al foam can be cut using a milling machine without fracturing its pore structures at the surface by retaining the NaCl spacers. Namely, NaCl, which was used as spacers to generate pores in Al, can also have the role of strengthening Al foam during the cutting process.

1. Introduction

Lightweight materials have high potential for use in various fields such as automotive industries. Aluminum (Al) foam has a light weight and superior energy absorption properties to dense Al, suggesting its potential use in vehicle components such as shock absorbers [1,2]. However, cutting Al foam using a milling machine is difficult because the thin cell walls of the foam fold and fracture during processes using a rotating tool. Kwon et al. have demonstrated a friction surface modification process and Matsumoto et al. have demonstrated friction stir incremental forming to form a nonporous skin layer on the surface of Al foam by inducing the folding of cell walls by traversing a rotating tool [3,4]. Namely, it is difficult to fabricate complicated vehicle components by a cutting process using a milling machine, which is easy to operate and widely available, while retaining the pore structures on the surface. The cutting of Al foam is normally performed by wire electric-discharge machining [5,6] or laser cutting [7].

Zhao and Sun developed a novel sintering and dissolution process for fabricating Al foam [8]. In this process, Al powder and sodium chloride (NaCl) powder as spacers are thoroughly mixed and sintered. The pores in the sintered Al are generated by leaching the sintered mixture in water to dissolve the NaCl. Hangai et al. conducted compression tests on specimens with and without NaCl remaining in the sintered mixture. It was found that the remaining NaCl increases the strength of Al foam compared with the Al foam without the remaining NaCl [9,10]. Therefore, it is expected to be possible to cut Al foam using a milling machine without folding the cell walls if the cutting process is conducted before the dissolution of NaCl.

In this study, a cutting process using a milling machine for Al foam with and without remaining NaCl fabricated by a sintering and dissolution process was proposed. By comparing the surface pore structures of the Al foam after the cutting process, the possibility of cutting Al foam using a milling machine while retaining its pore structures was investigated.

2. Experimental procedure

2.1. Fabrication process of Al and NaCl sintered mixture

Fig. 1 shows a schematic of the fabrication process of the Al and NaCl sintered mixture. As shown in Fig. 1(a), as-received pure Al powder (average particle diameter of 20 µm) and NaCl powder (sieved to a particle diameter ranging from 300 µm to 425 µm), manufactured by Kojundo Kagaku (Japan), were first mixed with a volume ratio of Al to NaCl of 3:7 (corresponding to a porosity of approximately 70%). Fig. 2(a) and (b) respectively show scanning electron microscope (SEM) images of the Al powder particles and NaCl powder particles used in this study. The Al particles have an elongated shape and the NaCl particles have a cubic shape. Next,

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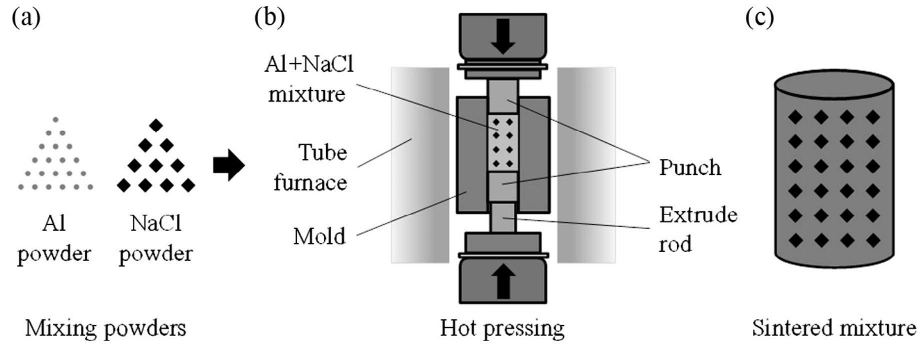

Fig. 1. Schematic illustration of fabrication process of Al and NaCl sintered mixture, (a) mixing of Al and NaCl powders, (b) hot pressing of mixture, (c) sintered mixture.

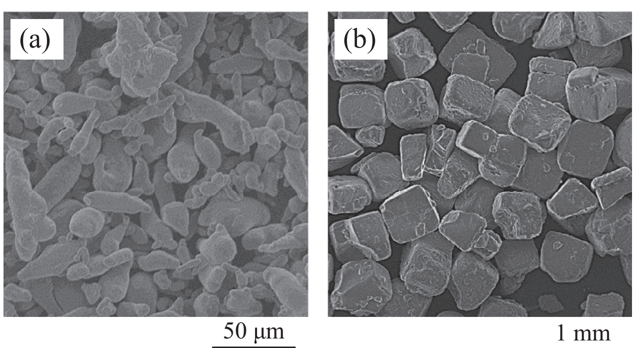

Fig. 2. SEM images of (a) Al powder particles and (b) NaCl powder particles.

as shown in Fig. 1(b), the mixture was sintered by hot pressing with a die temperature of 510 °C and a pressing load of 58.8 kN for 4 h. Then, as shown in Fig. 1(c), a sintered mixture with a diameter φ of 25 mm and a height h of 50 mm was obtained.

2.2. Cutting process

Fig. 3 shows a schematic of the cutting process for Al foam. The obtained sintered mixture (Fig. 3(a)) was cut in half using a band saw. Half of the sintered mixture (Fig. 3(b)) was first leached in water to dissolve the NaCl before cutting (Fig. 3(c)), then the obtained Al foam without NaCl (Fig. 3(d)) was subjected to the cutting process (Fig. 3(e)). The other half of the sintered mixture (Fig. 3(f)) was first subjected to the cutting process (Fig. 3(g)), then leached in water to dissolve the NaCl (Fig. 3(h)) and obtain Al foam (Fig. 3(i)). A tool rotation rate of 530 rpm and tool traversing rates of 700 mm/min and 1000 mm/min were used during the cutting process.

3. Experimental results and discussion

3.1. Characteristics of fabricated Al foam

Fig. 4(a) shows the as-sintered mixture before NaCl dissolution, corresponding to Fig. 1(c). The mixture was well sintered, and no collapse of the mixture during its removal from the mold of the hot-pressing equipment was observed. Fig. 4(b) shows the pore structures of the initial Al foam after NaCl dissolution, which is the surface obtained after wire electric-discharge machining of the compression test specimen described below. The shape of the pores was almost cubic, which was almost the same as that of the NaCl particles as shown in Fig. 2(b).

Fig. 5 shows the stress-strain curves of the Al foams fabricated in this study obtained during static compression tests conducted in accordance with JIS H7902 [11]. For the preliminary tests, an Al foam specimen with φ25 mm × h50 mm, corresponding to the specimen in Fig. 4(a) after the dissolution of NaCl, was subjected to the compression test. However, the specimen buckled during the compression test. Therefore, an Al foam specimen after the dissolution of NaCl was cut in half in the height direction by wire electric-discharge machining to obtain two φ25 mm × h25 mm Al foam specimens (Samples I and II), which were subjected to compression tests. In the stress-strain curves, three specific regions; an elastic region, a plateau region and a densification region, can be observed, which are similarly observed for Al foams fabricated by

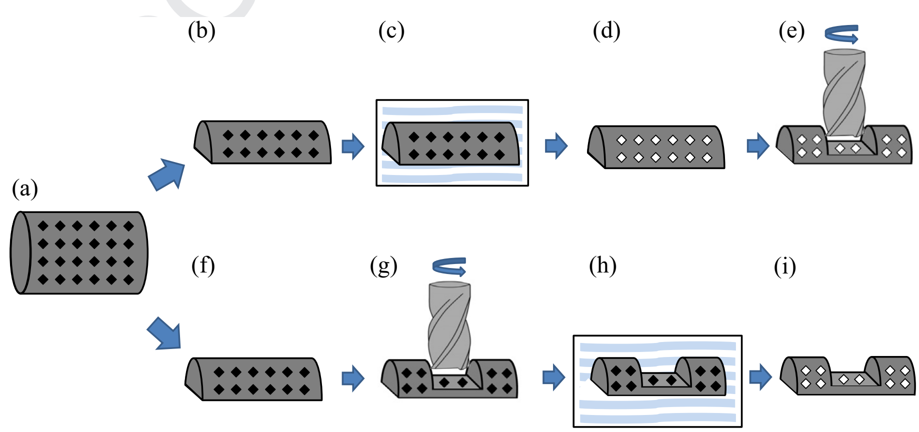

Fig. 3. Schematic illustration of cutting process for Al foam using milling machine. (a) As-sintered mixture. In (b)–(e), the cutting process was conducted after the dissolution of NaCl. In (f)–(i), the cutting process was conducted before the dissolution of NaCl.

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