MECHANICAL PROPERTIES OF TITANIUM/ALUMINUM COMPOSITE MATERIAL BY COMPRESSION SHEARING METHOD AT ROOM TEMPERATURE

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Abstract

In this study, to produce Ti/Al thin plate, Ti/Al mixed powders were formed by Compression Shearing Method at Room Temperature (COSME-RT). COSME-RT is adding a compressive stress and shear strain at the same time on the metal powders in air, and a thin plate metal can be obtained. Then, the Ti content ratio was changing from 25 to 75 vol.%. Their mechanical properties were measured. As a result, tensile strength of 75vol.%Ti was around 400 MPa, the value was similar to rolled Ti (ASTM grade 2).

1 Introduction

Ti and Ti alloys have excellent corrosion resistance, heat resistance, specific tensile strength and biocompatibility. Therefore, they are used in diverse applications in aviation, medical, and marine structures. In particular, TiAl of intermetallic compounds is expected in future generation material, because of that has lightweight, excellent corrosion resistance and specific tensile strength. However, TiAl formed by metal casting, it can't to be thinly below 0.75 mm [1]. Furthermore, TiAl formed by ordinary powder metallurgy, need for heating and adding to Vanadium for reactive stabilization. However, Vanadium is rare metal, and it has toxicity. Based on above, we consider to developing for Ti/Al new composite material, and that has excellent strength equality TiAl of intermetallic compounds.

One way to achieve high-strength materials is by severe plastic deformation, which causes a large strain in the material and yields finer grains. Two typical methods that have been developed for this purpose are ECAP (Equal Channel Angular Pressing) [2-3] and ARB (Accumulative Roll-Bonding) [4]. These methods produce strain in the bulk material forming finer grains, and the material strength is consequently improved based on the Hall-Petch relationship [5-6].

Our research group has developed the Compression Shearing Method at Room Temperature (COSME-RT) wherein metal powder is simultaneously loaded by a shearing force and a compressive stress in air at room temperature to form a plate [7-10]. Usually, heat is necessary for powder metallurgy forming processes such as hot pressing. Although powder metallurgy forming is useful for the production of bulk materials, the elevated temperature leads to an increase in grain size and a subsequent reduction in strength. In contrast, in the COSME-RT process, since the powder is processed at room temperature, grain coarsening does not occur, thus yielding good mechanical properties. When pure Al powder was processed by COSME-RT, it yielded a high-strength metal with a mean grain size of 200 nm and a tensile strength twice that of rolled material [8].

In the present study, the fabrication of Ti/Al composite was carried out by COSME-RT. The X-ray diffraction, microstructure and mechanical properties of the compacted powder were measured.

2 Experimental procedures

2.1 COSME-RT

COSME-RT is a method of forming a thin metal plate by simultaneously applying a shearing strain and a compressive stress to metal powder [7-10]. A schematic of COSME-RT is shown in **Figure 1(a)-(b)**.

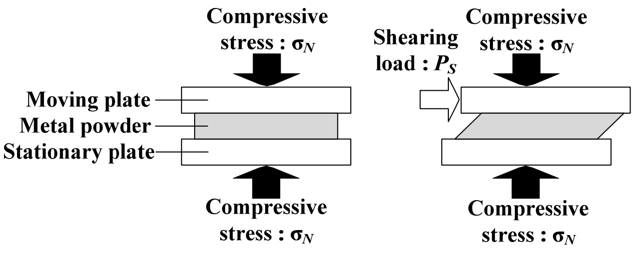
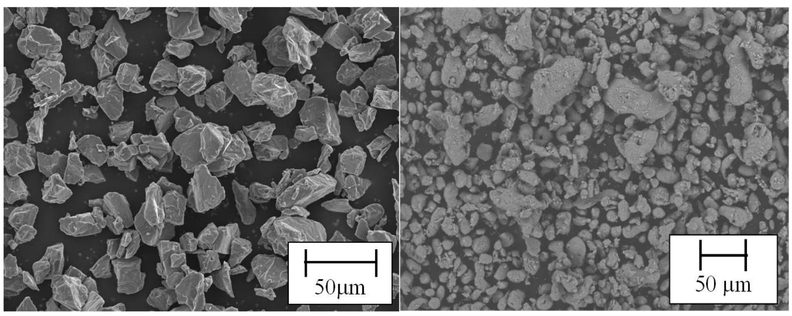


Figure 1. Schematic diagram of COSME-RT.

2.2 Materials

The powder used for the solidification in this study were 99.65% purity Ti (ASTM grade 2) and 99.7% purity Al. **Figure 2** show a scanning electron microscopy (SEM, HITACHI : S4100) image of pure Ti powder and pure Al powder. The mean particle size of pure Ti and pure Al were 45 μm and 31μm, respectively. The shape of the powder particles, formed by a hydrogenation-dehydrogenating method, was non-spherical.



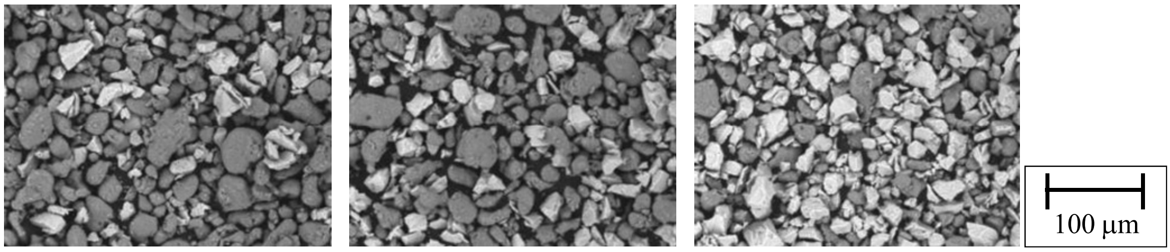
(a) pure Ti powder, (b) pure Al powder

Figure 2. SEM images of materials

2.3 Solidification condition

Ti and Al powders were mixed by uniaxial ball milling machine for 10 min. Then, mixed powder volume fraction were 25, 50, 75vol.%Ti. Figure 3 shows that after milling powder, (a) 25vol.%Ti, (b) 50vol.%Ti, and (c) 75vol.%Ti.

Mixed powders were formed by Compression Shearing apparatus. Then, the net amount of Ti powder is 0.45g that calculated by theoretical packing density. The shearing strain γ was determined by $\gamma = L / t$. Then, t is after compaction thickness (mm), and L is shearing distance (mm). The condition of forming: compressive stress was set to be 1250 MPa, the forming target size was fixed at 40 × 10 × 0.25 mm, and the shearing strain was set to be 20.

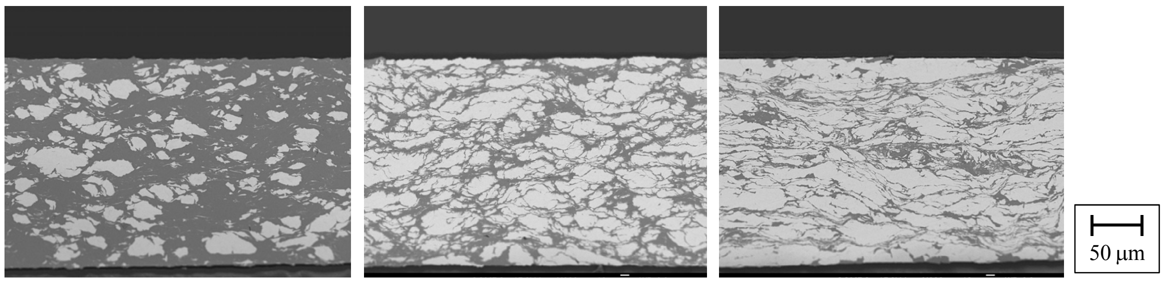


(a) 25vol.%Ti (b) 50vol.%Ti (c) 75vol.%Ti

Figure 3 Mixed powder after uniaxial milling for 10 min.

2.4 Cross section observation of samples

After solidification sample's cross sections were polished by sand paper and diamond particle. Cross sections were observed by SEM. Cross section SEM images are shown in Figure4, (a) 25vol.%Ti, (b) 50vol.%Ti, and (c) 75vol.%Ti. All samples are based on Ti, and Al powders dispersion. However, Figure4 (a)-(c) are only found to Ti and Al layer. Since, it seems to be Ti and Al has not been alloying.



(a) 25vol.%Ti (b) 50vol.%Ti (c) 75vol.%Ti

Figure 4 Cross section images of samples.

3 Result and discussion

3.1 X-ray diffraction

To investigate the micro structure of sample, X-ray diffraction of the Ti/Al thin plates was carried out using the X-ray diffractometer. Typical XRD patterns for (a) 75vol.%Tipowder and (b) 75vol.%Ti thin plate are shown in Figure 5. XRD patterns of the 75vol.%Ti thin plate was found to be as same as powders. However, Ti (0 0 2) plane peak of both thin plates were higher than powder peaks. It is thought that the basal sliding of Ti (0 0 1) plane produced by COSME-RT.

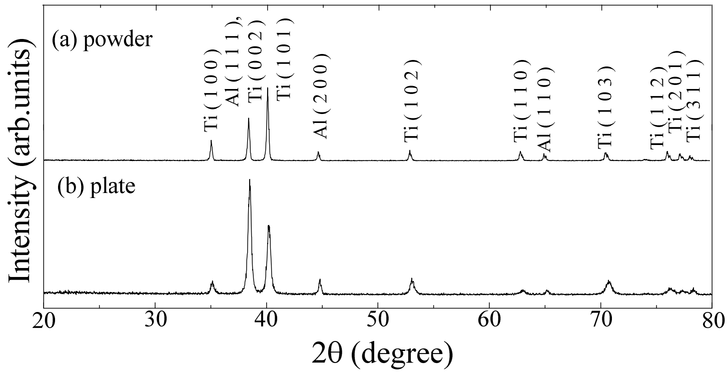


Figure 5 XRD patterns of 75vol.%Ti; (a) powder, and (b) plate

3.2 tensile test

To investigate the mechanical properties, tensile testing of the Ti/Al thin plates was carried out using a small tabletop universal testing machine (SHIMADZU, EZ-L-5kN). A tensile velocity of 0.5 mm/min was used. The specimen shape and dimensions are shown in Figure6.

The relation between the Ti content ration and the tensile strength is shown in Figure 7, and the tensile strength of rolled Ti (ASTM grade 2) and rolled Al (A1100) are also shown for comparison. It can be seen that the tensile strength initially increases with Ti content ratio. The tensile strength of the 75vol.%Ti thin plate was found to be as same as for the rolled Ti. However, Tensile strength of TiAl poly crystal is 500 MPa. Since, there is a need to improve further strength.

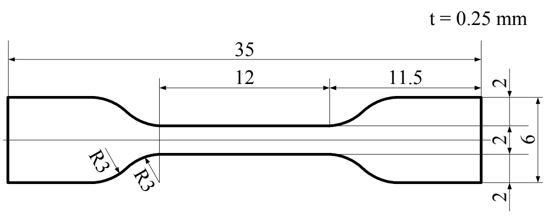


Figure 6 Schematic diagram of tensile test piece

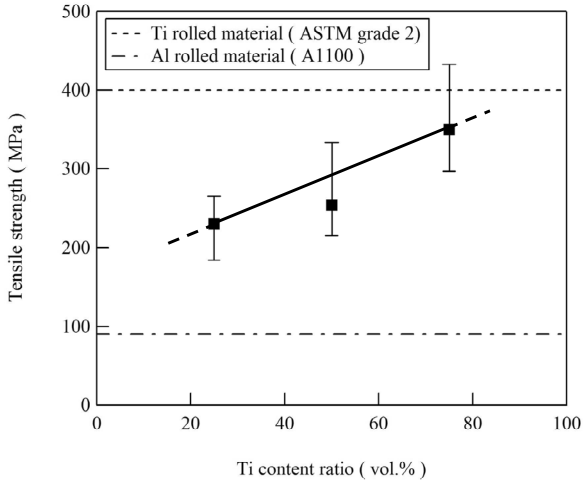
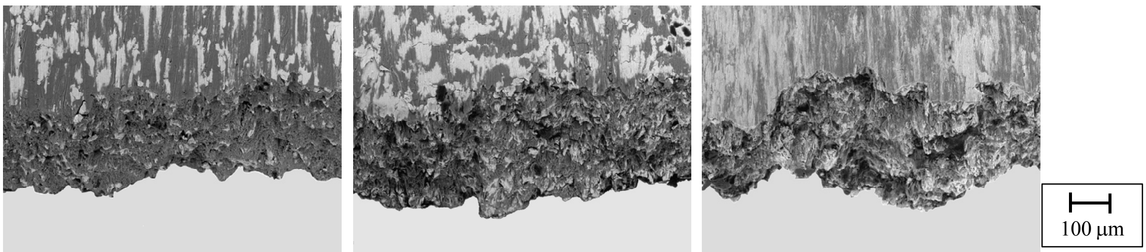


Figure 7 Relationship between Ti content ratio and tensile strength.

The fracture surfaces of Ti/Al thin plates produced under different Ti content ratio were next observed by SEM, as shown in Figure (a)-(c). It can be seen that the fracture surfaces are dimple near the Al, but crack occur the surrounding area of Ti. Since, binding force of Ti and Al boundaries are progress to improve future strength



(a) 25vol.%Ti (b) 50vol.%Ti (c) 75vol.%Ti

Figure 8 SEM images of fracture surfaces

4 Summary

The purpose of this study was Ti/Al thin plate using COSME-RT, and to examine the effect of the ratio of concentration. The following results were obtained.

1) Micro structures of all samples are based on Ti, and Al powders dispersion.
2) Ti/Al composites thin plate by COSME-RT has not been alloying.
3) The tensile strength of the 75vol.%Ti thin plate was found to be as same as for the rolled Ti.

Thus, COSME-RT can be used to produce Ti/Al composite plates that has near strength of rolled Ti (ASTM grade 2). However, there is a need to improve further strength.

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