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Microstructure and mechanical properties of Al/SiC composite fabricated by powder–in sheath rolling method

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1. Introduction

Metal matrix composites (MMCs) have attracted interests of many researchers due to their high specific strength, high wear resistance and good stability in high temperatures. Especially, Al based MMCs have been paid attention for their advantage of weight saving. Al based MMCs are fabricated mainly by liquid phase processes such as stir casting, pressure casting and in–situ reaction and solid state process such as powder metallurgical (P/M) route. P/M route has a merit that the content of reinforcement can be varied in wide range. The authors have proposed the powder–in sheath rolling as a method for fabrication of Al based MMCs. This study was performed to investigate microstructure and mechanical properties of the Al/SiC composites fabricated by the powder–in sheath rolling method.

2. Experimental Procedure

A nitrogen gas atomized high purity Al powder (Cu:1, Fe:1, Si:1, O:553 mass ppm, Al: bal) was used as a matrix. It had a nearly spherical shape and its mean particle diameter was 36μm. The SiC particles with the diameter of 2 to 4μm were used as reinforcement material. The volume content of SiC particle was varied from 0 to 20%. The blended powder was put into the ball mill with zirconia balls of which diameter was 5mm. The weight ratio of blended powder and zirconia was 1:6. The aluminum and reinforcement were mixed in rotating pot mill for 7.2ks of which inner diameter was 92mm and depth was 127mm at the rotating speed of 127rpm. The mixed powder was held at 370℃ for 3.6ks in vacuum for degassing after filling in a stainless steel tube. After degassing, the pipe was sealed and rolled to the shape of the flat bar with the thickness of 3mm at ambient temperature using rolling mill with the roll diameter of 100mm. The cold rolled specimen was sintered at 560℃ for 1.8ks.

The mechanical properties at ambient temperature were determined by tensile test. The test pieces were spark machined so that the tensile axis is parallel to the rolling direction. The gauge length was 15 mm and its width was 6 mm. The initial strain rate was 10^{-3} s^{-1}. The total elongation was calculated from the difference in the gauge lengths before and after the test. Microstructure was revealed by electrical etching in a dilute hydrofluoroboric acid and observed at the plane perpendicular to the transverse direction.

3. Results and discussion

Figure 1 shows the effect of the volume fraction of SiC on the mechanical properties of the specimen after sheath rolling and subsequent sintering. The 0.2% proof stress, tensile strength and elongation of the sheath rolled powder compact exceed 70MPa, 90MPa and 10% respectively at the volume fraction below 15%. These results indicate that the mixed powders are successfully consolidated by the powder–in sheath cold rolling. However, contrary to the well–known tendency in variation of strength with the reinforcement content, the strength of the composite does not increase monotonously with the volume fraction of SiC. It decreases by addition of 5% SiC and also decreases as the volume fraction increases 20 to 30%. It increases with the volume fraction only in

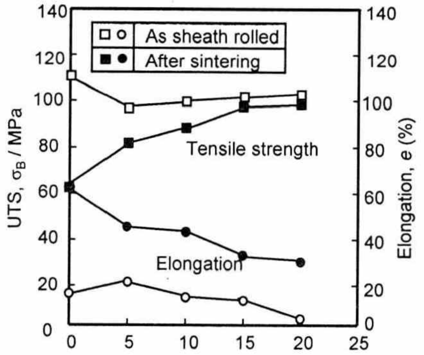

Fig. 1 Mechanical properties of Al/SiC composite fabricated by powder-in sheath rolling.

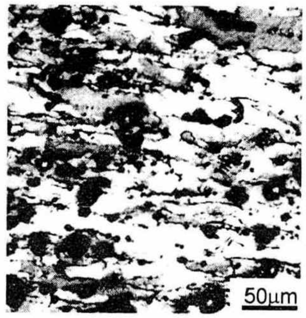

Fig. 2 Optical microstructure of the as-sheath rolled Al-5%SiC composite.

the range of 5 to 20%. On the other hand, the total elongation increases with the additions of 5% SiC, but above 5% it decreases monotonously with increasing the volume fraction of SiC. The decrease in 0.2% proof stress, tensile strength and the increase in the elongation at 5% SiC, are probably due to recrystallization or recovery promoted by temperature rise induced by plastic working [**Fig. 2**]. The increase in strength with SiC content in the range of 5 to 20% was probably caused by the more enhanced strengthening due to reinforcement particles, which canceled the softening by the restoration of metal matrix. Above 20% SiC, the decrease in yield stress, tensile strength and elongation is primarily due to particle cracking and interfacial de-bonding by cold rolling. The tensile strength and 0.2% proof stress of the composite after sintering are lower than those of the sheath-rolled ones because of the recrystallization of metal matrix during sintering. On the other hand, the elongation increases largely due to restoration by sintering and the enhanced adhesion between metal powders by diffusion at any volume fraction. The strength of the composite increases and the elongation decreases with increasing the volume fraction of SiC particle. After sintering, the composite is effectively strengthened by the additions of SiC particle. The tensile strength of the composite above 15%SiC shows a maximum of 100MPa which is as high as 67% than that of unreinforced one. The results of tensile test at high temperatures have proved that the Al/SiC composite fabricated by powder-in sheath rolling method exhibited higher strength than that of unreinforced material even at elevated temperatures.

4. Conclusions

(1) The tensile strength of the as sheath-rolled Al/SiC composite increases with increasing the volume fraction of SiC in the range of 5 to 20%. However, it decreases by addition of 5% SiC and also decreases as the volume fraction increases 20 to 30%.

(2) After sintering, the tensile strength of the composite increases and the elongation decreases with increasing the volume fraction of SiC. The strength of the composite above 15% SiC shows a maximum of 100MPa which is as high as 67% than that of unreinforced one.

(3) The Al/SiC composite fabricated by powder-in sheath rolling method exhibited higher strength than that of unreinforced material even at elevated temperatures.