Transactions of the Korean Nuclear Society Virtual Spring Meeting
July 9-10, 2020

Effect of Reinforcement Size on Stress Deviation Characterized by Neutron Diffractionand FEM simulation

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1. Introduction

As non-destructive testing, the neutron diffraction method is one of the powerful ways to measure strain inside of materials [1]. It has become more important nowadays due to the development of multi-phase materials, such as TRIP, TWIP, and composites materials [2]. However, the neutron diffraction method is not able to evaluate the stress deviation and the maximum stress in a material [3]. Measuring maximum stress value is very important for brittle materials because they are fractured without yield. In this study, the relationship among the applied stress, reinforcement size, neutron diffraction patters, and stress distribution was investigated.

2. Methods and Results

2.1 Preparation of Material and its Characteristics

Sizes of SiC powder were 10 μm, 30 μm, and 40 μm and 80 μm sized 7075 aluminum alloy powder were prepared. The powders were mixed using a 3D mixer with 50 rpm for 5 hours and the volumetric ratio of two powders was 1:1. The mixed powder was consolidated using the liquid pressing technique [4]. The liquid pressing technique was conducted at 900 °C temperature and 100 MPa pressure then cooled in air. The fabricated composites were cut into ø6 × 8 cylinders to perform a compression test.

The density of fabricated samples was measured by the Archimedes method and the result shows less than 3% of porosity. Fig. 1 is the scanning electron microscopy (SEM) image of the microstructure of fabricated samples.

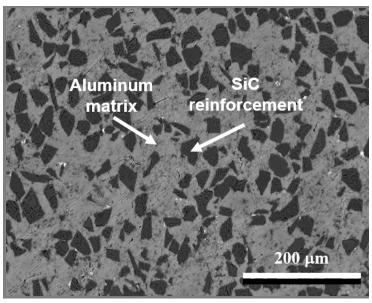

Fig. 1. The microstructure of fabricated composites.

2.2 In-situ Neutron Diffraction

In-situ Neutron diffraction was obtained during the compression test at the VULCAN beamline of Oak Ridge National Laboratory. In the compression test, the stress increasing rate was controlled as 0.75 N/s. During the compression test, the frequency of choppers was 30 Hz.

In the tensile test result (Fig. 2), 10 μm sized SiC reinforced composite shown higher strength and lower ductility and 30 μm sized SiC reinforced composite shown lower strength and higher ductility. The composites showed very high strength compared to 7075 aluminum alloy due to the high fraction of reinforcement.

The neutron diffraction test result is shown in Fig. 3. The shaded area colored in red indicated the plastic deformation of the composites

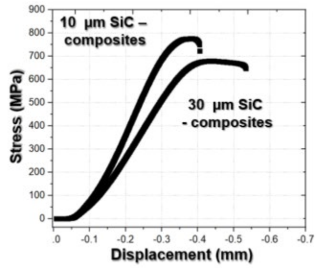

Fig. 2. Strain-stress curves of tested composites.

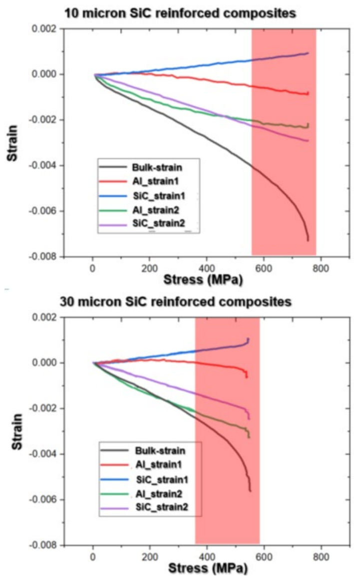

Fig. 3. Strain-stress curves measured by neutron diffraction.

2.3 Finite Element Method Analysis

The geometry of the finite element method (FEM) simulation was attained by SEM images of each sample. The attained images were processed by OOF2 codes to make an image-based mesh.

The simulation of the compression test was mimicked by FEM simulation. The embedded properties are listed in the table. 1. The result of mesh generating and the compression test simulation is shown in Fig. 4. the larger reinforcement containing composites shown the higher stress deviation and the higher maximum stress.

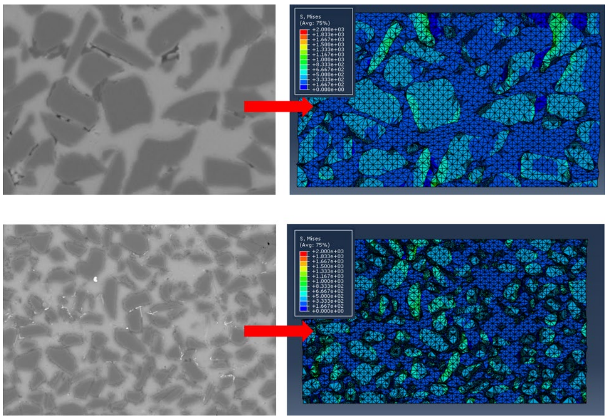

Fig. 4. Original microstructure images and the generated meshes with stress contour.

Table I: Properties of simulated materials

	SiC	Al
Modulus	400 GPa	70 GPa
Yield strength	1400 MPa	280 MPa
Poisson ratio	0.19	0.33

3. Conclusions

The relationships between diffraction patterns, stress deviation, and reinforcement size are investigated in this study. The measured average value of internal stress matched with the simulation results well. Furthermore, higher stress deviation was observed in larger particle reinforced composites in the simulation.

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