In-situ Neutron Measurement and Modeling of Phase Stress Evolution During Deformation and Fracture of Al Matrix Composites

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Objectives and Approach

Metal matrix composites (MMCs) are material systems formed by the combination of a hard reinforcement, such as ceramic particles or fibers, in a ductile metal matrix. Al based MMCs have important industrial applications in the automotive and aerospace industry due to their relatively low weight, high stiffness and strength, and abrasive wear resistance at elevated service temperatures. It is important to evaluate the stress/strain evolution in both the matrix and reinforcement phases to understand deformation behavior, and to develop models for failure mechanisms and validate them. In this regard, neutron diffraction is a unique tool for determining the strain partitioning in each of the two components of the composite.

Experimental

Tensile specimens: ASTM-E8M-04, 4mm gauge section diameter
Materials: Al 2080, Al2080/SiC/20_p, Al2080/SiC/30_p

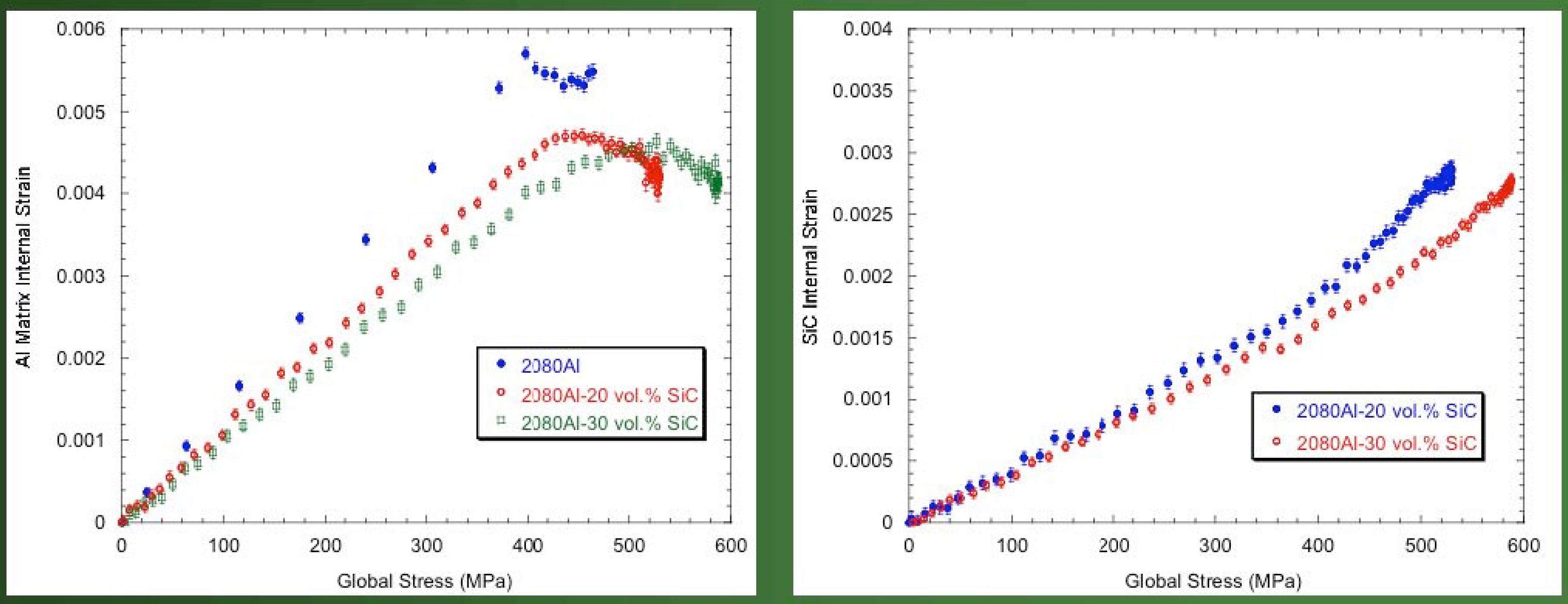
Neutron measurements were made at the High Flux Isotope Reactor, Neutron Residual Stress Mapping Facility (NRSF2)

Neutron wavelength: 0.173 nm
Incident slit: 5mm wide x 5mm high
Receiving slit: 5mm wide
hkl: Al(311) and SiC(116)
Control mode: displacement control
Displacement step size: 0.02 mm
Strain measured parallel to the tensile load
8 minutes per strain measurement

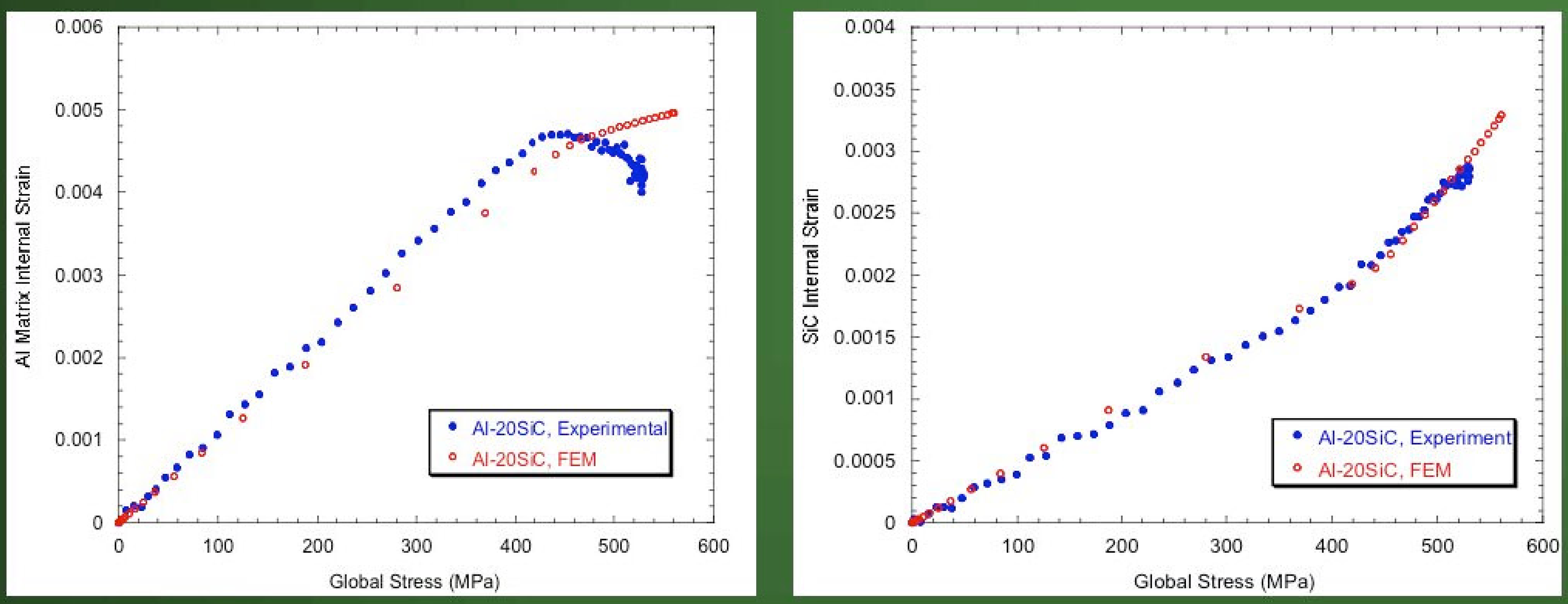
A tensile specimen mounted on load frame on NRSF2.

Measurement and modeling results

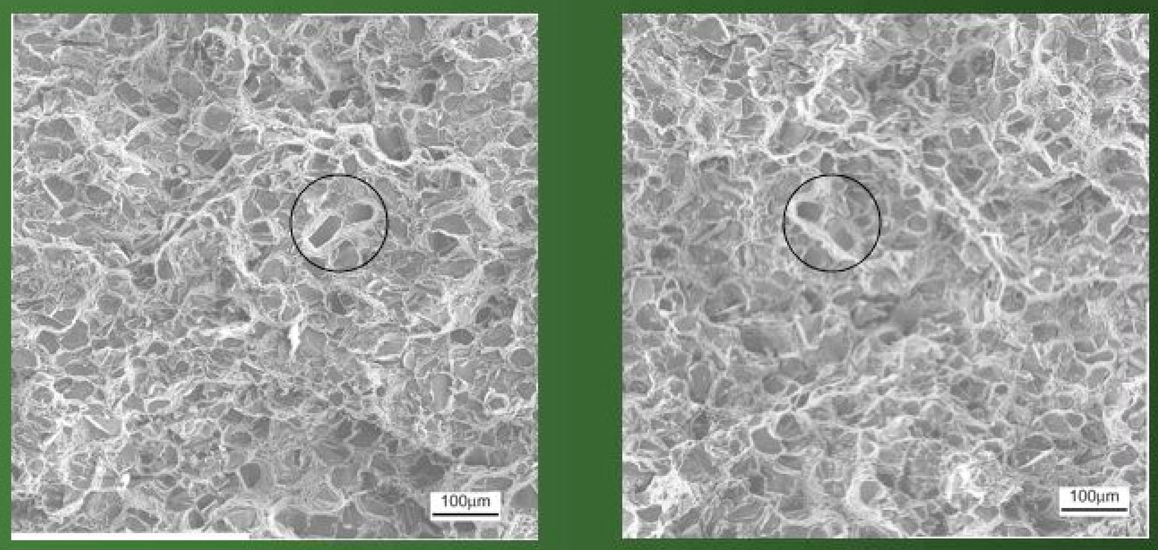
Strain vs. Stress for Al (left) and SiC (right)



Comparison of FEM Model with Experiment



Fractography



Two matching SEM fracture surfaces of Al/SiC composites indicate brittle fracture of SiC particles and plastically tearing fracture of Al matrix.
Y.-L. Shen, J.J. Williams, G. Piotrowski, N. Chawla, and Y.L. Guo, *Acta Mater*., (2001) 49 3219-3229.

Results

- For the Al 2080 tensile sample, the Al matrix plastic deformation initiated at about 380MPa.
- For composites samples, the Al matrix plastic deformation was delayed to relatively higher applied stress.
- The strain/stress in SiC particles continuously increased until tensile sample fracture. After Al matrix yielded, the strain increase is relatively faster.
- SiC particle cracking and Al matrix tearing fracture, instead of Al/SiC interface debonding, is the primary failure mechanism for this type of composite material.
- Preliminary microstructure based 3-D FEM modeling of Al/SiC/20 vol.% shows good agreement with experimental data for both Al and SiC elastic deformation.

Summary and future work

- Neutron diffraction technique was used to uniquely show the phase stress evolution in Al/SiC composites from elastic and plastic deformation to material failure during uniaxial tensile testing.
- Neutron diffraction measurements provided an important understanding of composite materials deformation and strengthening mechanisms study and modeling, materials design and properties improvement.
- Further improvements in FEM models (including particle fracture, for example) are being developed to more accurately predict the experimental behavior.

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