Analysis of MMNC using RVE Models

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Abstract

Development of Nanocomposites is one of the rapidly evolving areas of composite materials research. Metal matrix Nanocomposites (MMNC) are attractive because they produce balanced mechanical properties between Nano- and Microstructured materials; these materials display enhanced hardness, Young's modulus, 0.2% yield strength, and ultimate tensile strength and ductility, and these enhancements are due to the addition of nanosized reinforcement particles into the matrix. In this work we developed geometric representative volume element based models to analyze these composites using 3D finite element analysis. MgZn-SiC Metal Matrix Nanocomposite are analyzed by capturing process conditions from scanning electron microscope images and the geometry of experimental samples. The results are being presented by their stress-strain behavior of metal matrix Nanocomposites and are then compared to experimental values. The presented models can perform a quick ' What if analysis ' and change parameters easily for cost effective manufacturing.

Modeling approach

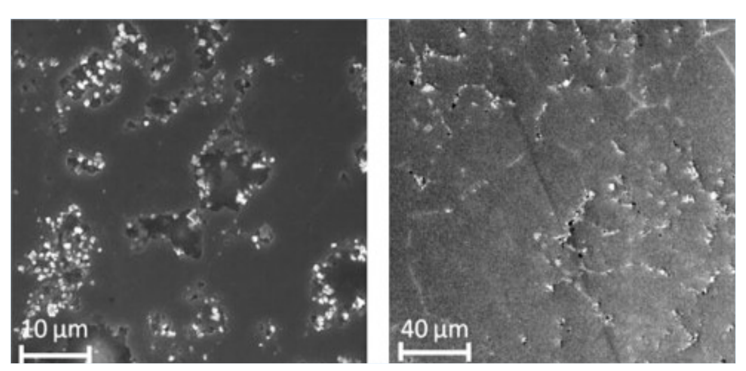


Image 1.0 [3]

IMAGE ANALYSIS → GEOMETRIC MODEL → 3D SOLID MODEL → FINITE ELEMENT ANALYSIS

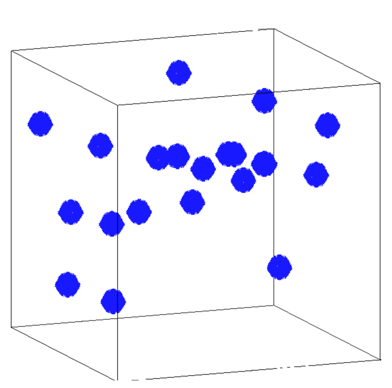


Diagram 1.0 Cubic RVE 1% Volume fraction

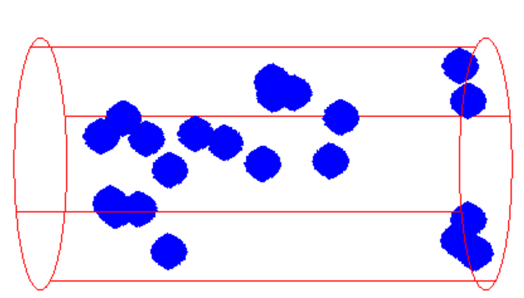


Diagram 1.1 Cylindrical RVE 1% Volume fraction

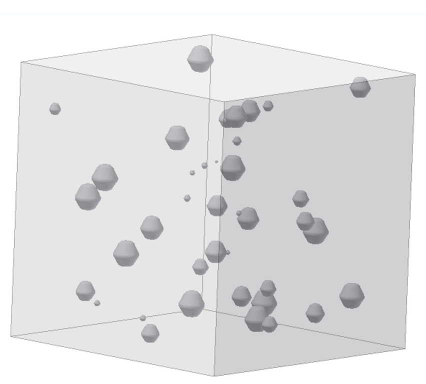


Diagram 2.0 Cubic RVE 1% Volume fraction

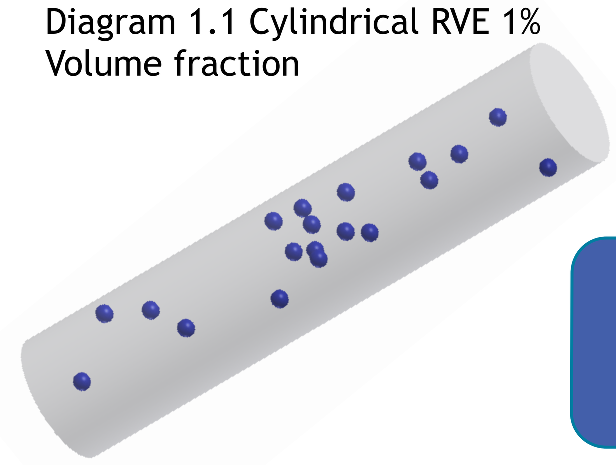


Diagram 2.1 Cylindrical RVE 1% Volume fraction

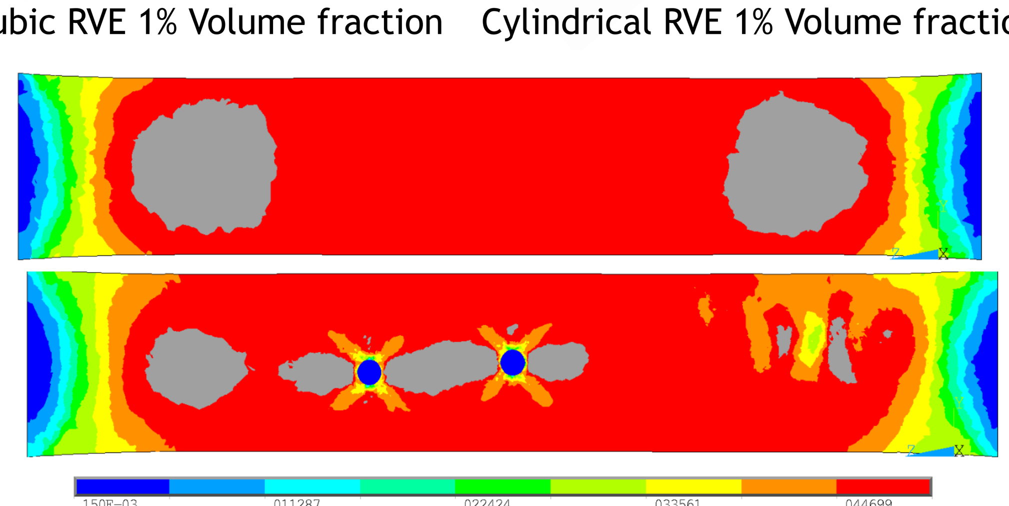


Diagram 3.0 Horizontal cross-section of sample. Top no particles. Bottom with particles

Metal Matrix Nanocomposites (MgZn-SiC)

- We are working with Magnesium Zinc as the Metal Matrix and Silicon Carbide as the Nanomaterial. There are a few input parameters that we provided to match experimental samples. Volume fraction, RVE size, Particle Size, Distribution, and Material properties
- We create initial model in MATLAB where all of the input parameter have to be provided. This outputs an Excel file as well as a script for the Finite Element Analysis (FEA).

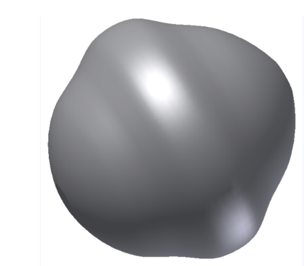


Diagram 4.0
Single SiC Solid Model [2]

Material Properties

	Magnesium Zink	*Silicon Carbide*
Modulus	*45 GPa*	*500 GPa*
Poisson's Ratio	*.35*	*.19*
Average Particle		*50 nm*
RVE ratio	*4.68*	
RVE size	*1780x380*	

Table 1.0 Material Properties that were used for computations

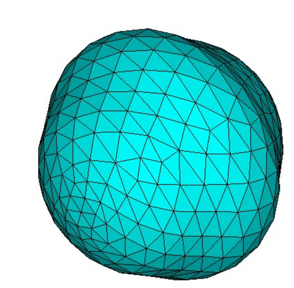


Diagram 4.1
Single SiC Meshed in FEA [2]

Diameter Image Analysis

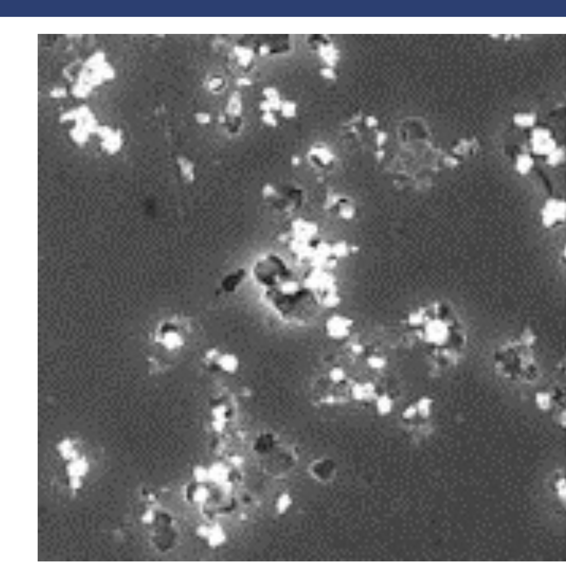


Image 2.1 [3]

- In order to receive accurate results in modeling the nanocomposites we use image analysis to determine some parameters and in this case we are interested in Diameter size of the Particles. We can determine probability distribution functions from analyzing scanning electron microscope images.
- We take the values that are created by the PDF and evenly take random samples to determine the diameter of the particles while still keeping them at an average value of 50nm to stay consistent. This presents us with a model that more accurately represents experimental samples as they have different sizes for particles depending on the type of manufacturing method that is being used.

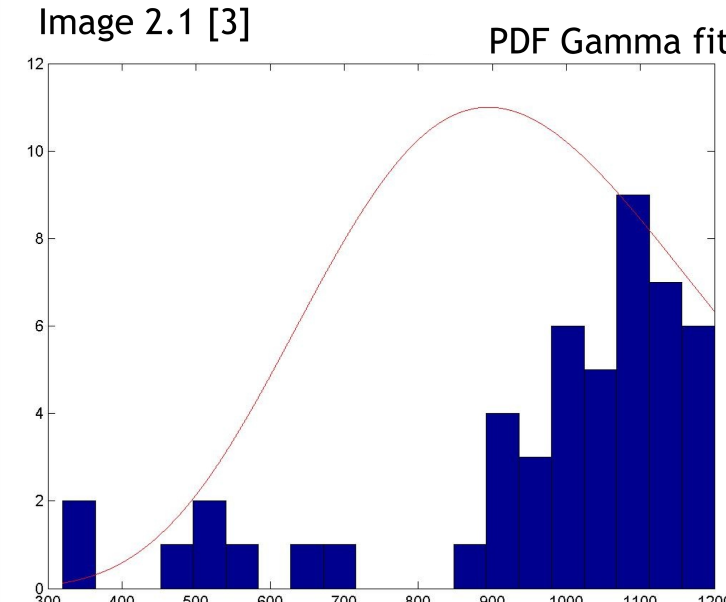


Image 2.2

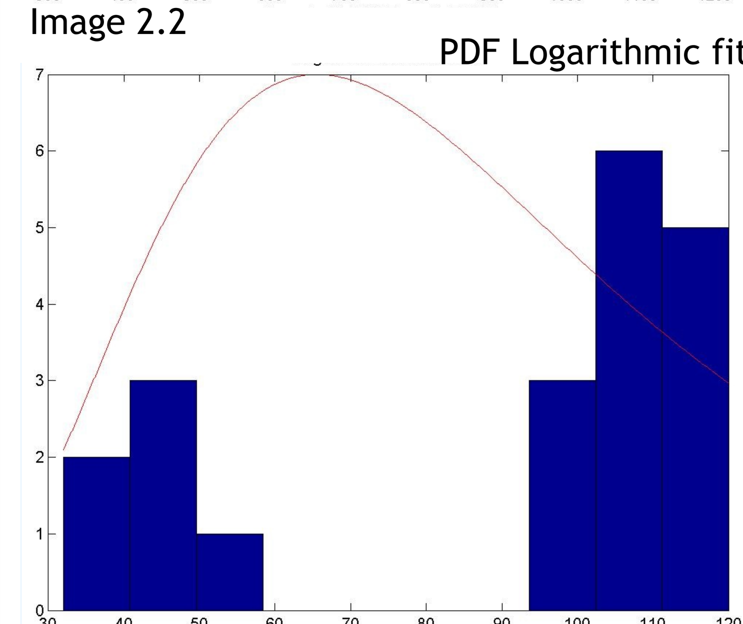


Image 2.3

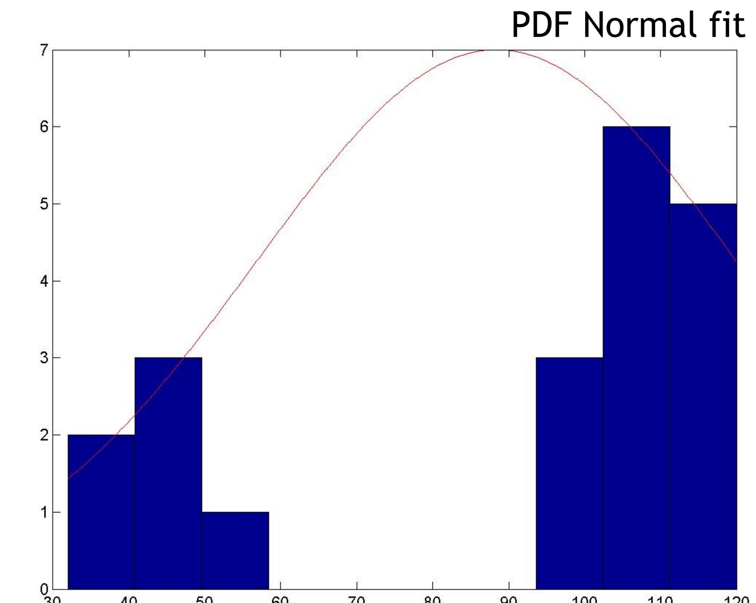


Image 2.4

Results

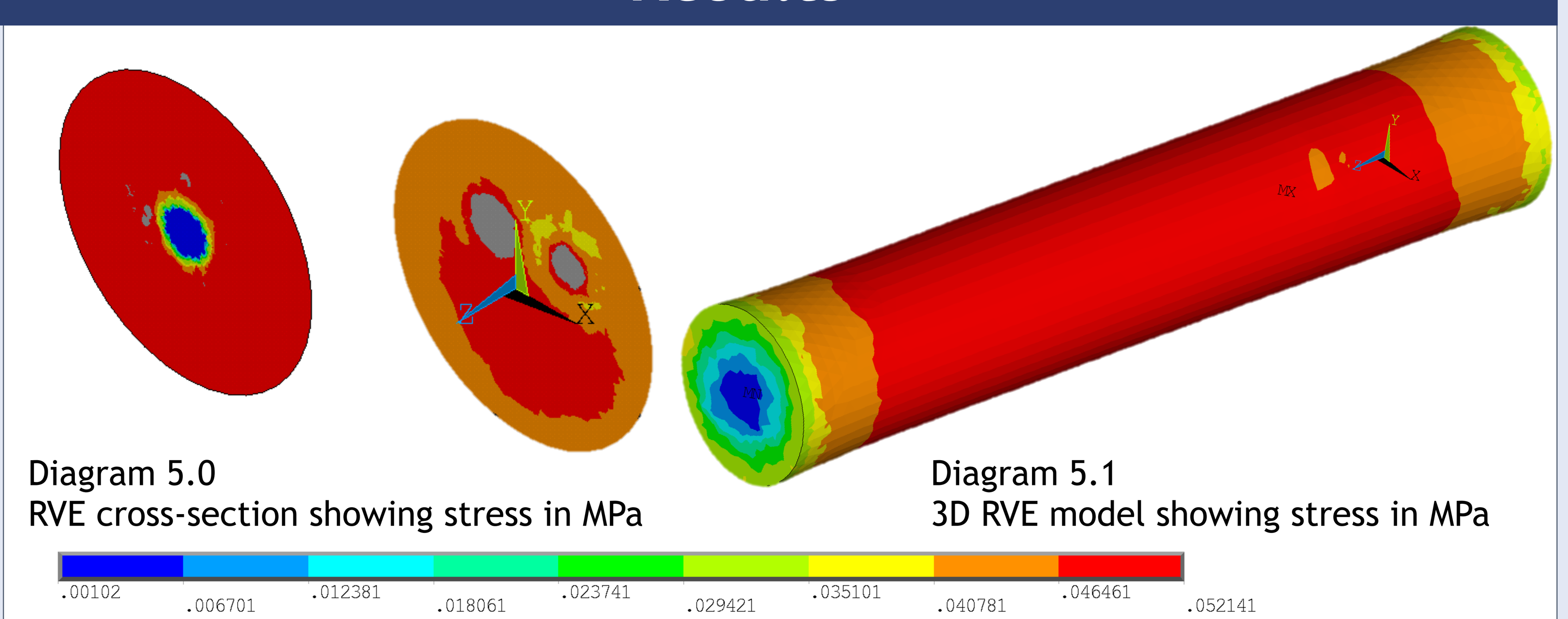
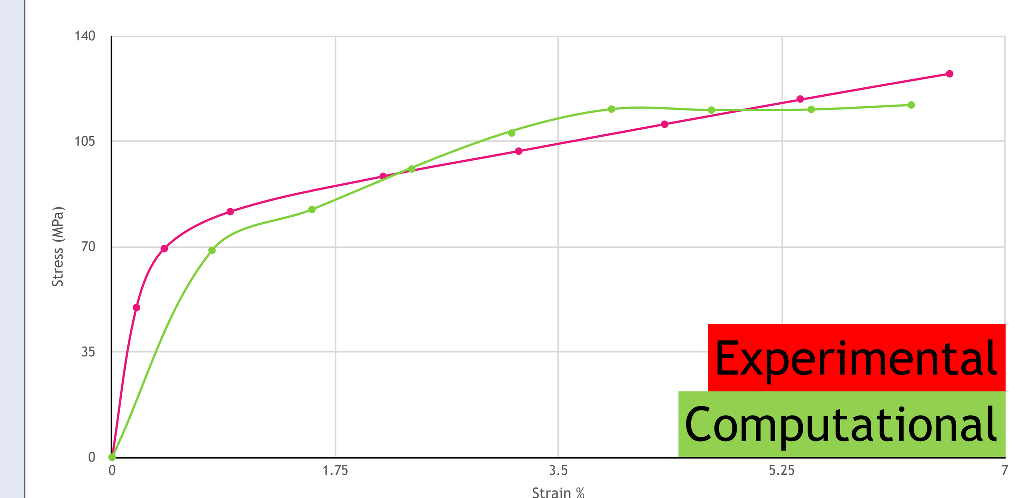


Diagram 5.0
RVE cross-section showing stress in MPa

Diagram 5.1
3D RVE model showing stress in MPa



Graph 1.0 Experimental vs Experimental results showing a close correlation between them

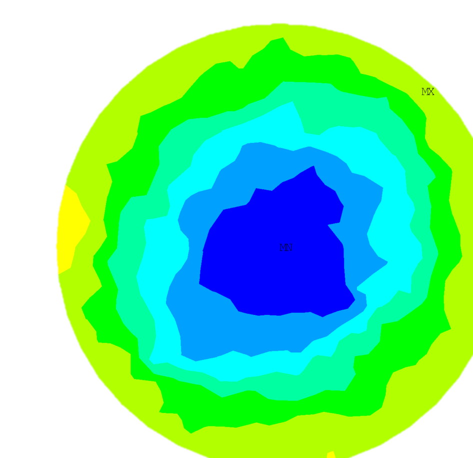


Diagram 5.2
RVE YX-Plane showing stress in MPa

Conclusion

- By using image analysis from the experimental data and a few other preconceptions we can predict with a certain accuracy Young's modulus of stress and strain. This will allow manufacturers to test ideas without wasting time and money to prototype and still getting accurate results.
- To keep improving the accuracy of the models we are going to implement probability distribution functions for dispersion of particles as well agglomeration.

References

1) Dr. Raghu Pucha *Journal of composite materials [0021-9983] Pucha yr:2014 vol:48 iss:17 pg:2117 -2129*
2) Johnny Worthy Thesis, Design Tool for Simulation of Nanocomposite Material Properties
3) CIRP Journal of Manufacturing Science and Technology 5 (2012) 348-356

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