Microstructure Based Finite Element Analysis for Deformation Behavior of Aluminum Based Metal Matrix Composites

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***Abstract* –A new analytical approach was proposed to study the deformation behavior and failure criteria for a real microstructure of metal matrix composites by developing a two dimensional (2D) model from a microstructure image of aluminum silicon carbide metal matrix composites. The real microstructures were converted into equivalent CAD format using canny edge detection method in order to predict the failures such as matrix yielding, interface decohesion from the analysis of microstructure of MMC.The Finite analysis results emphasize the importance of stress and strain distributions in microstructure level that influence the mechanical behavior of the material. Since the properties depend on particle arrangement in microstructure.**

Keywords- Metal matrix composites (MMC), microstructure, canny edge method

I. INTRODUCTION

Metal matrix composites (MMCs) consist of two or more materials, one of which is a metal (matrix), in which the tailored properties are achieved by the systematic incorporation of different constituents (reinforcements). MMCs attribute includes alterations in mechanical properties and other physical properties by the filler phase. The fabrication of MMCs aim at improving the limiting properties of conventional metals or their alloys for weight reduction and elevated temperature applications and modulus of elasticity, wear resistance and modulus of elasticity.The reinforcements place a vital role for improving the mechanical properties of MMC. Microstructure study of reinforcement in metal matrix helps to understand the material morphology as studied by Chawla.et. al [1, 2]

Previously Ganesh et.al[4,5] correlated the material microstructures with their macroscopic properties were important for understanding the material behavior of existing materials as well as for developing new materials.

Mainly the characterization and modeling of microstructures are important due to the accurate prediction of materials behavior Under external stimuli and the design of new materials with desired properties.

II. MODELING OF MICROSTRUCTURE

A 2D microstructure finite element model is created from a microstructure image of aluminum silicon carbide composite materials. First the microstructure image which is raster form has to be converted into vector format by image processing technique and has to be converted into CAD format (IGES) which is further imported into ansys software for finite element analyses. The microstructure of aluminum silicon carbide which will be in the raster format has to be converted into vector format using Win Topo software which uses cannys edge detection method for detecting the edges of silicon carbide particles. The vector format file has to be converted into CAD file making use of Pro-E software for surface generation.

Image segmentation software which converts the raster form into vector form making use of above cannys edge detection method. The original microstructure of aluminum silicon carbide is shown in Fig 1 [2] using win topo the real microstructure is converted into vector format as shown in Fig 2.The converted vector image of microstructure will be imported into Auto cad software via DXF file format. In auto cad the edges of the microstructure is drafted and the unnecessary asperities which are imported had to be removed.as shown in Fig 3

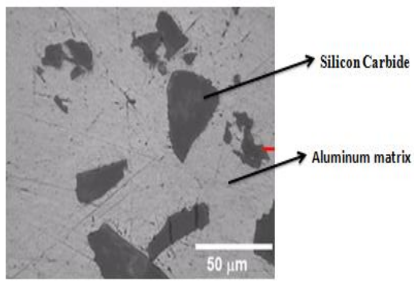

Fig 1 Real microstructure of aluminum silicon carbide [2]

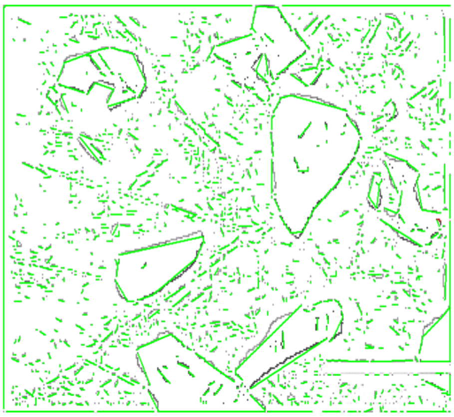

Fig 2 Vector form of real microstructure

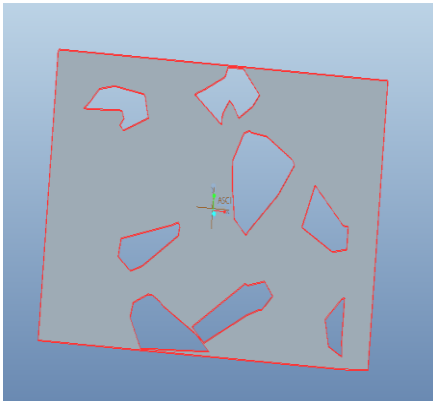

Fig 3Two dimensional drawing of microstructure

The FEM model is generated from the CAD model using hyper mesh software. There are totally 2 components aluminum matrix, silicon carbides. Each of them meshed separately and to create connectivity between them each solid mesh faces are taken and moved to another solid. The mesh was generated with fine density of235384nodes and67348elements were created.Surface is enclosed between the open regions in aluminum matrix .Surfaces are created in-between the matrix shown in the Figure 4. It acts as a connector between the silicon carbide particles and aluminum matrix

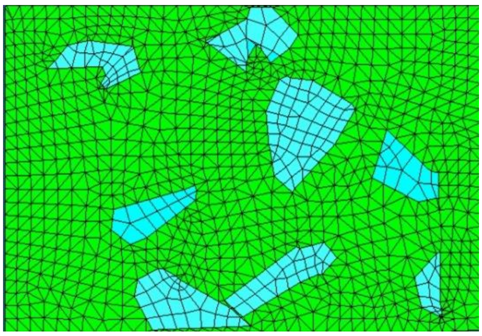

Fig 4 FEA microstructure model

TABLE 1: NO.OF NODES & ELEMENT TYPES

Components	Element type	No of nodes
Aluminum matrix	SOLID 45	47146
Silicon carbide particles	SOLID 45	20204

III. FINITE ELEMENT ANALYSIS

2D microstructure model meshed properly in Hyper Mesh 10.0 and they were imported in ANSYS 14.5 to perform analysis.All elements were defined as homogeneous, isotropic, and linearly elastic. The material properties of the aluminum matrix and silicon carbide particlesare listed in the Table 2

TABLE 2 MATERIAL PROPERTIES

Components	Young's modulus (GPa)	Poisson's ratio
Aluminum matrix	72.5	0.33
Silicon carbide particles	410	0.19

By using Finite Element Analysis (FEA) micro deformation behavior of real microstructure of composite was studied. The distributions of equivalent plastic strain for an applied tensile load of 500 N. From the stress distribution pattern as shown in Fig 6 we can understand that the plastic flow initiates at the particle corners along the loading direction and strain are lower along the sides of the particles as shown in Fig 5.Applying different loading conditions a stress strain graph is plotted as shown in Fig 7 for the real microstructure. From the slope of the curve the young's modulus is found to be 82.5GPa.

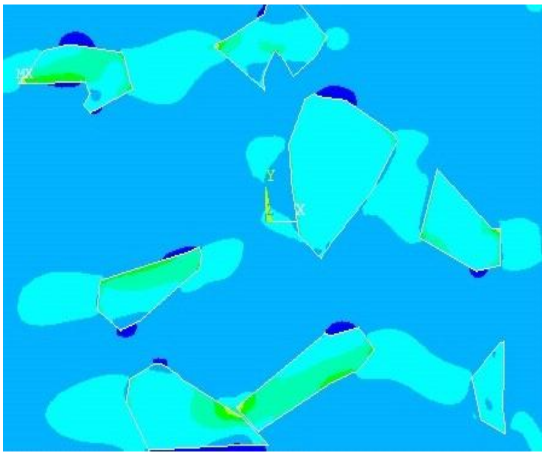

Fig.5 Strain distribution of microstructure model

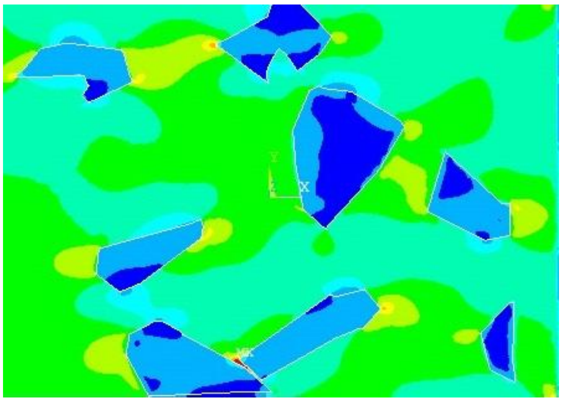

Fig.6 Stress distribution of microstructure model

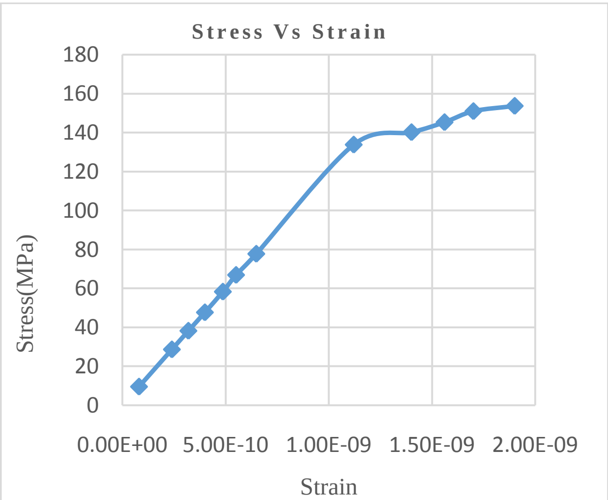

Fig 7 Stress – Strain Curve

IV. CONCLUSION

The micro deformation behavior of aluminum silicon carbide MMC has been studied by modelling real microstructure using canny edge method. From FEA analysis we observe the failure of MMC is initiated by plastic flow of matrix around the particles region. The plastic stress is accumulated around the particles region during loading. The plastic deformation is mainly concentrated at the poles of the particles along the axis of loading and is initiated initially by particle fracture or interface decohesion. The microstructure undergoes failure by matrix yielding but in case of particles microstructure, the failure is dominated by both interface decohesion, and matrix yielding. A stress strain graph is plotted and from the slope of the curve the young's modulus is found to be 82.5Gpa.

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