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Material Modeling of Particle Reinforced In Metal Matrix Composite

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Abstract*: The FEA model of particulate reinforced metal matrix composite which will be used for material optimization application. A particle distribution method will be introduced to get a random pattern of particles reinforcement model in the metal matrix FEA model. A FEA model of particle metal matrix composite that allows to vary particle distribution and the model is developed in ANSYS commercial FEA code .The particle distribution pattern is generated using sphere packing method for a given percentage of particulate mixture ratio. The effect of particle concentration and distribution and its mechanical behavior and metal matrix can be Analyzed and studied in this model. This model will be useful in optimizing the particle metal matrix against a given mechanical behavior or performance required for the variation of percentage in particle mixture ratio, particle grain size, particle material and matrix material.

Keywords: FEA Code; Particle Distribution Pattern; Metal Matrix Composite; Particulate Mixture Ratio.

I. INTRODUCTION

Optimization is wide method for creating or finding best solution by means of iteration process. In the metal matrix composite the metal and material concentration and the mixing ratio plays vital role to get better mechanical behavior. Based on particle concentration and distribution the performance of meal matrix composites enhances its mechanical and thermal characteristics. To accomplish best performance characteristic properties in composite material a coupled field analysis with hygro-thermo-mechanical model is used for reinforcing fibre polymers, constrained within the domain of computational homogenization [1].

1.1 Particle reinforced Composite Square

For making the model of particle reinforced composites a square or irregular domain of size under plane stress conditions has been considered. Particle of required size and shape are generated in the whole model with the help of MATLAB, and this data is import to the ANSYS program to inspect distribution pattern in matrix and analyzing the mechanical behavior of MMC. So we should investigate the characteristics of particle, in fact which is the ultimate thing in this paper.

1.2 Particle shapes

The stress and strain acting on the particles is depend on the particle shapes, which will affect the macroscopic mechanical properties of the composite [2].

1.3 Development of MATLAB code for sphere packing in cube or cylinder

MATLAB to calculate the characteristics of particles such as, area and perimeter of each particle, in which the image processing technique was employed. Based on the calculations, the sizes and shape factors of each particle were investigated.

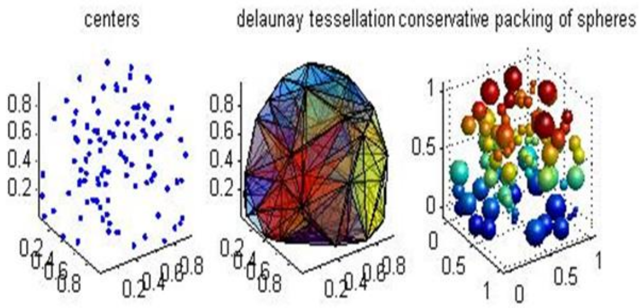

Fig. 1. Sphere packing diagram using MATLAB

II. FEM PROCESS

The investigation of elastic properties in a 3D PRMMC unit cell in which particles are prepared randomly and distributed in an array manner in order to assess the consistency of these micro models. From the previous literatures studied most of the unit cells are investigated in the two-dimensional unit cells.

Moreover in the finite element analysis the results could be affected based on the elements size during the mesh. Hence it was necessary to evaluate the micro models and their meshing range with the different loading conditions, although they undergo elastic deformation.

The validation procedure to assess these micro-models was performed by investigating elastic properties of a particle and by comparing its numerical results data with analytical and/or possibly experimental data available in the literatures.

The ANSYS MULTIPHYSICS version 11 is used for the analysis. Here the mesh was built using initially (8-node solid brick) to get a better accurate results.

The Finite Element Analysis were carried out with different volume fractions for the particular volumes, the following particle volume fractions were taken into account: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60 and 70. The discretization of element is based on the particle volume fraction and the element type used in the mesh.

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2.1 Boundary and Load Condition

The simplest treatment of the elastic behavior of this model is based on the properties, the materials are considered as two constituents perfectly merged together, with relative amount of thicknesses in the proportions related to the rein-forcement and matrix volume fraction. The matrix are prepared with the same lengths parallel to the attached inter-faces. Hence if the stress is applied in the x-direction of the model, then the constituents (particle and matrix) exhibit closely the same strain, but read only particle behavior.

III. Result and Discussion

An characteristics of silicon carbide addition on the mechanical behavior of aluminum matrix alloy composites was examined in this study by virtual simulation. Five different additions of silicon carbide was carried out and results were investigated. They are listed in table 1.

Table 1. Percentage of silicon carbide in reinforced aluminum matrix composites

% SiC	Addition Explanation
Al – 10% SiCp	10wt% particulate reinforced, with aluminum matrix
Al – 30% SiCp	30wt% particulate reinforced, with aluminum matrix
Al – 40% SiCp	40wt% particulate reinforced, with aluminum matrix
Al – 50% SiCp	50wt% particulate reinforced, with aluminum matrix
Al – 60% SiCp	60wt% particulate reinforced, with aluminum matrix

3.1 Load Vs Time

The model gives various choices to designate convergence criteria.

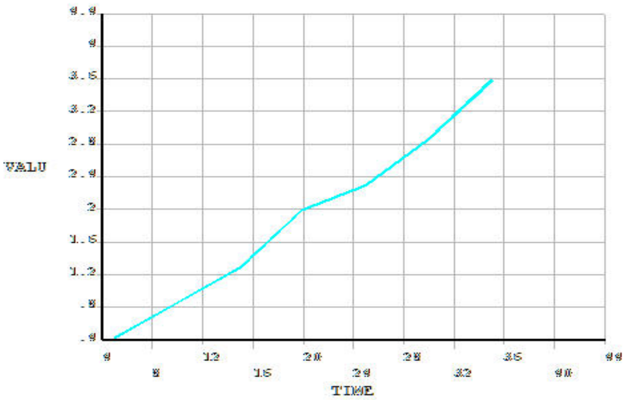

Fig 2. Load VS time step

We can have a base convergence checking on the pressure force at any combination of these materials.

Accumulating each material has its own convergence tolerance value. For multiple constrain problems, you also have a choice of convergence norms.

We always make the use of force, displacement based (moment, rotation based) convergence tolerance for checking.

Here the graph has the X-axis in time and Y- axis in load. It shows the FEM model contains 3kg/m^2 load for 5 sec, similarly all load cases for remains time steps, which is illustrated in the above table.

3.2 Load Vs Stress

The bellows figure shows the effect of stress influence in these models with reinforcement volume percentage against transient loading conditions. Generally, this measure has taken for predicting the rapture of the micro model. Here the different volume fraction curve has been plotted between stress (y-axis) and transient load (x-axis).

Fig 3. Load Vs Stress

From the graph taken from the experiment we have concluded that the stress is increased against time with continuously increasing the reinforcement volume fraction

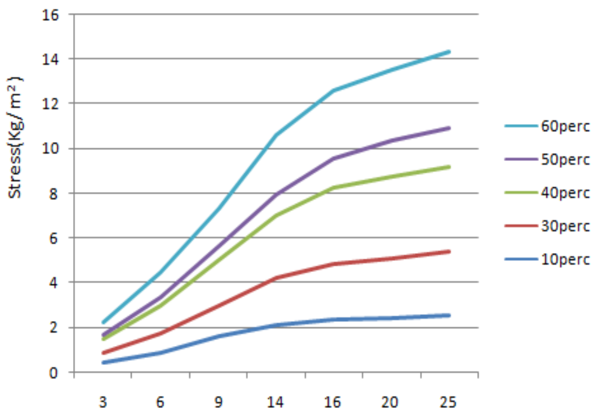

Table 2. Load Vs Stress

3.3 Load Vs Strain

The quantities you measure are load (force) and

Stress / Load	LOAD VS STRESS WITH RESPECT TO VOLUME PERCENTAGE				
	10%	**30%**	**40%**	**50%**	**60%**
3.00	0.41	0.46	0.61	0.18	0.57
6.00	0.82	0.92	1.22	0.36	1.14
9.00	1.35	1.23	1.02	0.62	1.71
14.00	2.13	2.04	2.84	0.92	2.65
16.00	2.38	2.45	3.44	1.29	3.03
20.00	2.43	2.61	3.71	1.66	3.12
25.00	2.55	2.82	3.83	1.74	3.38

displacement. These are the properties of sample material under test, and any mechanical properties derived from them - for example, stiffness also sample properties. These may be of use to us, want to check when a particular type of material will fail.

As materials scientists though, we want to know about the properties of the material. Properties that change with the load size of the sample.

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For this reason, the load is distributed to the sample area to get strain and displacement in a span. Now the derived quantity of composite and its modulus, is independent of sample size and can be regarded as a true material property.

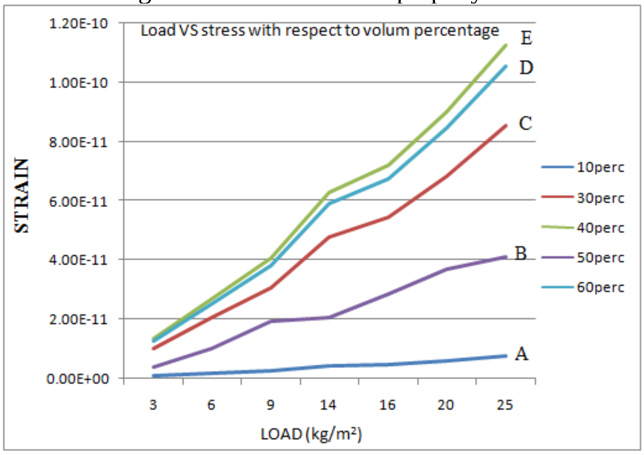

Fig 4. Load Vs Strain

From the above graph, show that the effect of SiC particle with a different load cases. We conclude that the plastic deformation of the model against transient loading condition. Curve A is a brittle material. It was observed that a very huge strain for a small load.

Curve B is a almost nearer to the brittle property, because it also behave like the curve A.

And other three curves like C, D, E are relatively increase the deflection with increasing the load case, so those curves have ductility in maximum load case.

Table 3. Load Vs Strain

STRAIN Vs LOAD	LOAD VS STRAIN WITH RESPECT TO VOLUME PERCENTAGE				
	10%	30%	40%	50%	60%
3	9.13^{13}	1.02^{11}	1.35^{11}	4.11^{12}	1.26^{11}
6	1.83^{12}	2.05^{11}	2.70^{11}	1.03^{11}	2.53^{11}
9	3.02^{11}	4.06^{11}	4.74^{12}	2.96^{11}	3.01^{11}
14	4.26^{12}	4.78^{11}	6.31^{11}	2.05^{11}	5.90^{11}
16	4.87^{12}	5.47^{11}	7.21^{11}	2.87^{11}	6.74^{11}
20	6.09^{12}	6.83^{11}	9.01^{11}	3.70^{11}	8.43^{11}
25	7.61^{12}	8.54^{11}	1.13^{10}	4.11^{11}	1.05^{10}

3.4 Stress Vs Strain

To Inspect inherent elastic properties of linear objects like wires, rods, or columns which are long-drawn-out or compressed, to get the ability parameters of the material, the ratio of the stress to the strain, a parameter called the "Young's modulus" or "Modulus of Elasticity" of the material.

We can describe these details by the graph as:

- P indicates the limit of proportionality, where the linear correlation between stress and strain ends.
- E shows the elastic limit of the material. Below the elastic limit, the wire will come again to its original shape.
- Y indicates the yield point, where plastic deformation begins. A long drawn out in the material creates strain, it is seen in a small increase in stress. If the stress applied to a wire is maximum without it snapping. It is sometimes called the breaking stress. Notice that beyond the UTS, the force required to snap the wire is less.

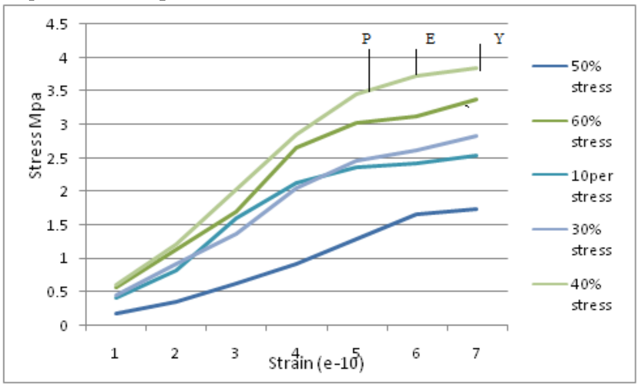

Fig. 5 stress VS strain

IV. CONCLUSIONS

The particle distribution method will be introduced to get a random pattern of particle reinforcement model in the metal matrix FEA model. A sphere packing code is created in MATLAB and the results for the mechanical properties of composites are exported to Ansys framework.

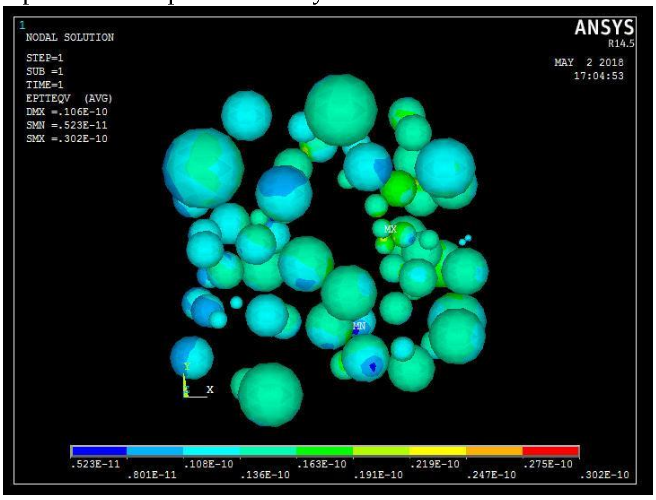

Fig 6. Von mises Stress value 9kg/m^2 load (Al – 10% Si Cp)

The effect of particle concentration based on its distribution in the model the mechanical behavior of metal matrix composites is analyzed and studied in this model. This particle distribution method enables metal matrix against a given mechanical behavior or performance required for the variations.

Some of the von mises stress and strain figure as shown below to identify the stress value based on percentage of particulate reinforced, with aluminum matrix

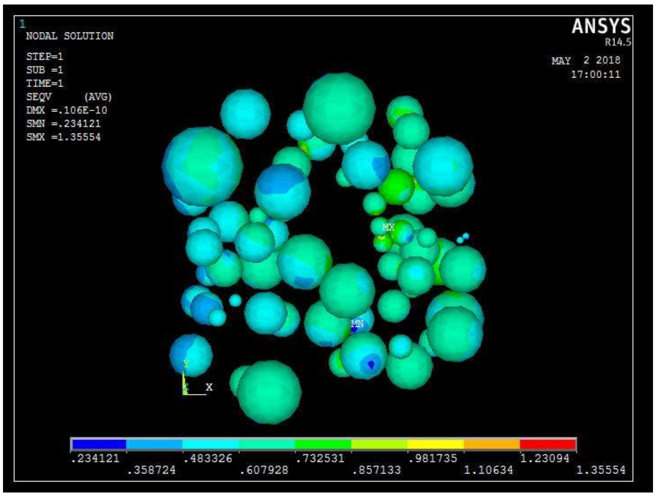

Fig 7. Von mises Stress value 9kg/m² load (Al – 30% SiCp)

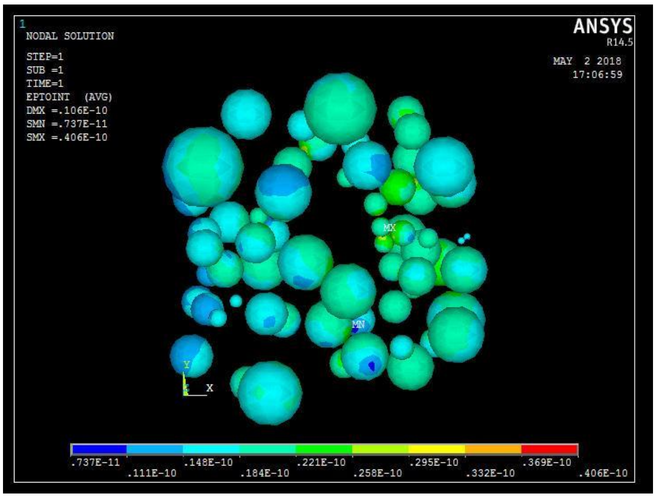

Fig 8. Von mises Stress value 9kg/m² load (Al – 10% SiCp)

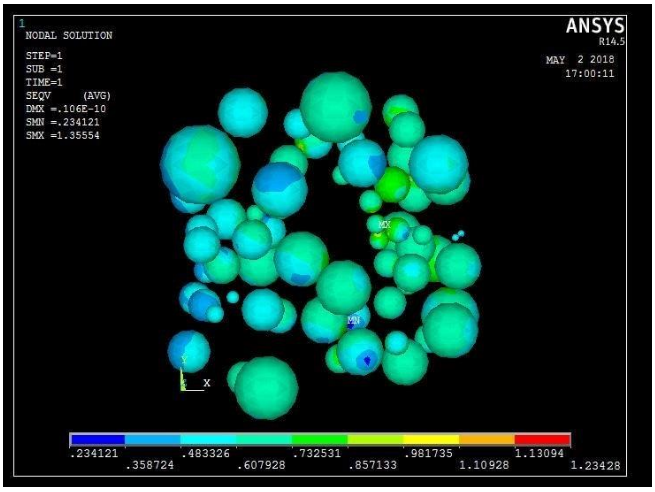

Fig 9. Von mises Stress value 9kg/m² load (Al – 30% SiCp)

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