Study on the Dynamic characteristics of an Aluminium Metal Matrix-Carbon particulate composite with uniform and graded dispersion using 3D-FEM and FDM

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Introduction

Composites are non-homogenous and anisotropic in nature and have a random dispersion of particles of different nature throughout an isotropic matrix. There is a classical rule of mixtures to estimate the properties of such a system. Though popular, it considers a uniformity, homogeneity and isotropy that are non-existent in a composite. This can be better illustrated in case of a graded composite where rule of mixtures, which considers the volume fractions gives the same value irrespective of the particle location or concentration. Moreover, the behaviour of a composite cannot be defined by a rule of mixtures.

Response of a composite material subjected to dynamic loading is assessed by the frequency and amplitude of the resulting vibration. Present paper deals with the dynamic characterisation and damping behaviour of composite employing Finite Element Method (FEM) and Finite Difference Method (FDM). FEM to model the composite and FDM, to study the transient behaviour and its variation with different volume fractions under different loading situations .The response of an LM6 alloy-Carbon metal matrix particulate composite is studied and results are obtained.

Methodology

The reinforcement particles are dispersed randomly throughout the matrix. In a random oriented uniformly distributed composite mesh, all elements enjoy the same probability of being a reinforcement particle. Random numbers equalling the number of particles are generated. The elements with the same number are all particle elements. Particle occupies the mesh location given by the random number. Thus it can be made sure of having a random matrix of elements meeting exact volume fraction. The mesh with the concentration gradient is also generated with similar technique. The elements are separated as layers depending on the concentration gradient. Each layer has varying number of particles depending on the gradient. Layers are then filled randomly by the previous method. Refer figures 1 and 2.

FEM Analysis

The governing equation to be solved for finding the response is

$$[k][\delta]+[c][\dot{\delta}]+[m][\ddot{\delta}]=\{f\} \qquad (1)$$

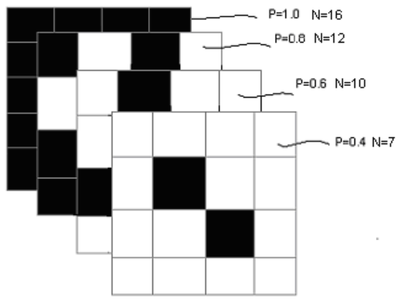

Fig.1 Mesh with concentration gradient

The FEM analysis is based on Rayleigh-Ritz method employing principle of stationary total potential [5]. Mass, stiffness and damping matrices are obtained by FEM principles. For transient analysis, the governing equation for the transient dynamic response of the structure is solved using direct integration method. Central difference method is employed, in which the time derivatives are substituted assuming a linear variation in displacement with time as given by equation 2

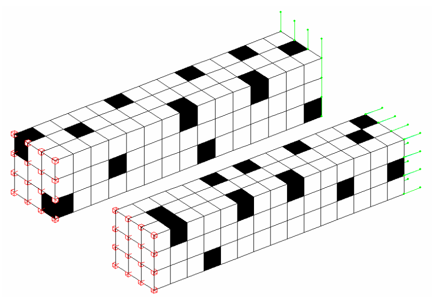

Fig.2. Three dimensional mesh of the composite

$$[\delta_{n+1}] = \frac{\{f(t)\} - \left[[k] - \frac{2[m]}{\Delta t^2}\right][\delta_n] + \left[\frac{[c]}{2\Delta t} - \frac{[m]}{\Delta t^2}\right][\delta_{n-1}]}{\left[[m]\frac{1}{\Delta t^2} + [c]\frac{1}{2\Delta t}\right]} \qquad (2)$$

Since this method is conditionally stable, Δt should be lesser than a specific limit, without which the resulting solution could actually grow unbounded $\Delta t < \frac{2}{\omega_{\max}}$

For loading in the transverse direction to get bending vibrations, mesh refinement is also done. The program is run for getting the response for various loadings. Natural frequencies and mode shapes are also obtained in a free vibration Analysis.

Convergence test as well as validation is carried out to find the amount of fineness required for the mesh to reflect the exact behaviour of the beam and to check the accuracy of results.

Results

Response for an axial unit impulse is given in Fig 3

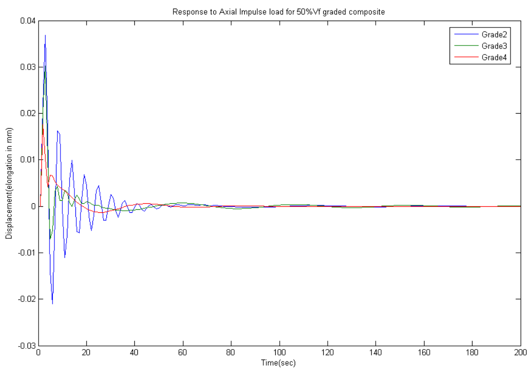

Fig. 3 Response of different gradient 50% AL-C loaded as a cantilever

The composite shows increase in damping factor with volume fraction till 50% after which the damping factor tends to be constant. This effect could be because of the material being more predominantly loaded with reinforcing element Carbon. Refer figures 4 and 5 for axial and transverse cyclic loading respectively.

Conclusion

The behaviour of Aluminium–Carbon MMC under different loading situations is modelled and analysed using FEM and FDM techniques. There is an improvement in the damping behaviour of the composite for axial as well as transverse fatigue loading. For random dispersion composites, damping factor increases with volume fraction up to a certain extent and approaches that of carbon for 50% volume fractions and more.

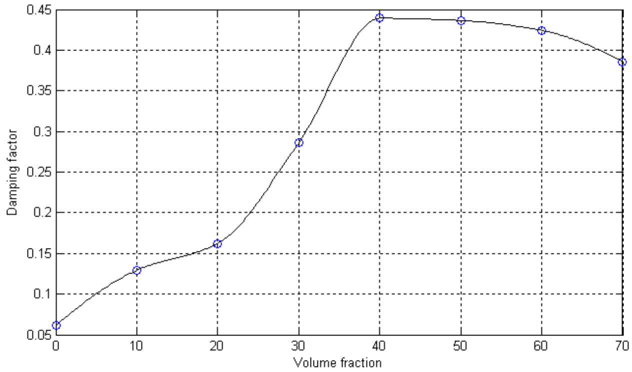

Fig. 4 Variation in damping factor with volume fraction for axial loading

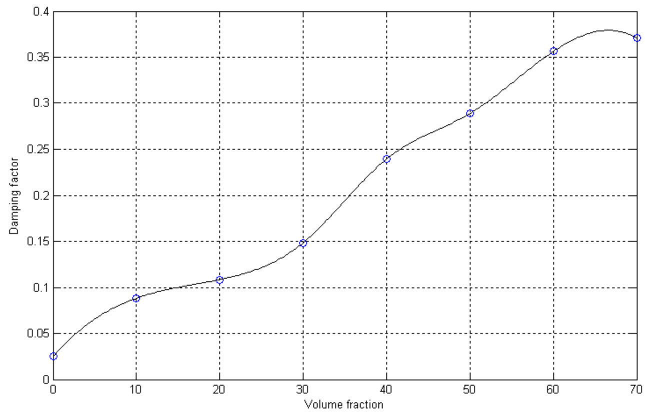

Fig. 5 Variation in damping factor with volume fraction for bending loads

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