# DETERMINATION OF MECHANICAL PROPERTIES OF CARBON NANO-PARTICLES REINFORCED ALUMINIUM COMPOSITE USING FINITE ELEMENT METHOD.

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## Introduction

The increased demand for light-weight materials with high specific strengths, for particles reinforced Aluminium–matrix composites, carbon particles have been found to have compatibility with the Aluminium matrix with relatively low cost [6].These composites have been made by different methods including spray atomization and co-deposition, powder metallurgy, stir casting and liquid-metal infiltration [5].

In this work, the finite element method has been used to determine the mechanical properties of the composite. Randomised meshing technique for uniform distribution as well as graded distribution is used. Graded distribution exhibits orthotropic properties. The domain considered is rectangular plate made of the composite, divided into finite number of rectangular shaped elements.

Each element is having 8 nodes and 3 degrees of freedom per node. The mesh generated is of random meshing, in which the carbon particles and Aluminium are taken as elements of the domain. The distribution of the particles in the matrix is assumed to be uniform initially, and later the concentration gradient is considered in the domain to study the behavior of the desired response (Young's modulus). For orthotropic analysis, the test piece is loaded in all the coordinate directions respectively.

## Formulation

The general algebraic equation for a structural problem is given as:

$$[K] \cdot [U] = [F] \quad (1)$$

Where [K] is the global stiffness matrix, [U] is the global displacement vector and [F] is the load vector. The element stiffness matrix is given as:

$$[K]^e = \iiint B^T DB \, dV \quad (2)$$

The stress strain constitutive relation for a linear, elastic, isotropic material is given by $[\sigma] = E(\varepsilon_x - \varepsilon_{x0}) + \sigma_{x0}$ (3a)

$$dU = [F][du] = [\sigma][d\varepsilon] \quad (3)$$

Integrating over the whole structure gives

$$U = \int [\frac{1}{2} E\varepsilon^2] dV - \int \varepsilon E \varepsilon_0 dV + \int \varepsilon \sigma_0 dV \quad (4)$$

The potential V of external force made up of uniformly distributed q and point load P is given by

$$V = -\left( \int uq du + \sum u_i P_i \right) \quad (5)$$

The total potential of structure is obtained as

$$\Pi = U + V \quad (6)$$

The strain $\varepsilon$, at a point P within the element is given in terms of derivatives of displacement field, $[\delta]$ as

$$\varepsilon = [\partial][u] = [\partial][N][\delta] = [B][\delta] \quad (7)$$

Where [N} is the basis function matrix. Rewriting the generic expression for total potential

$$U=\int [\frac{1}{2}[\delta]^T [B]^T E[B][\delta]] dV - \int [\delta]^T [B]^T E\varepsilon_0 dV + \int [\delta]^T [B]^T \sigma_0 dV$$ using

$$V=-\left( \int [\delta]^T [N]^T q du + \sum [\delta]^T [N]^T_i P_i \right)$$

Principle of Stationary Total Potential

$$\frac{\partial \Pi}{\partial \delta^T} = 0$$

$$[k][\delta] = \{f\}$$

Initially the structure is assumed to be unstressed thus

$$\oiiint [B]^T E[B] dV * [\delta] = \sum [N]^T P_i \quad (8)$$

Where E is the constitutive matrix relating stress and strain and is given by

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix} = \begin{bmatrix} c_{ii} & c_{ij} & c_{ij} & 0 & 0 & 0 \\ c_{ij} & c_{ii} & c_{ij} & 0 & 0 & 0 \\ c_{ij} & c_{ij} & c_{ii} & 0 & 0 & 0 \\ 0 & 0 & 0 & c^*_{ii} & 0 & 0 \\ 0 & 0 & 0 & 0 & c^*_{ii} & 0 \\ 0 & 0 & 0 & 0 & 0 & c^*_{ii} \end{bmatrix} * \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{bmatrix}$$

$$c_{ij} = \frac{1-v^2}{E^2\Delta}; c_{ij} = \frac{v+v^2}{E^2\Delta}; c^*_{ii} = \frac{E}{2(1+v)}$$

$$where \quad \Delta = \frac{1-3v^2-2v^3}{E^3}$$

*Material Data:*

| material | Yong's modulus | Poisson's ratio |
|---|---|---|
| Carbon | 350 GPa | 0.1 |
| Aluminum | 74GPa | 0.33 |

## Results and discussion

The main effects of randomization and Gradient are found to be the significant model factors along with the interaction BC (gradient and randomization) and AB (Specimen size and gradient)

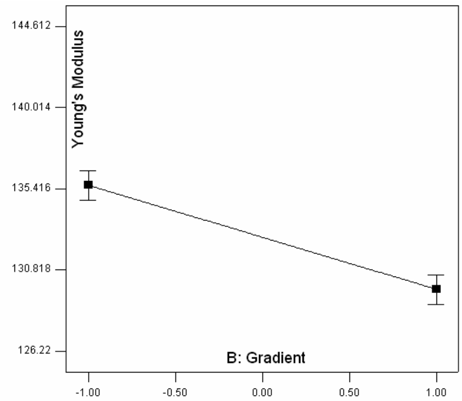


Fig. 1. Model graph for effect of gradient on Young's modulus

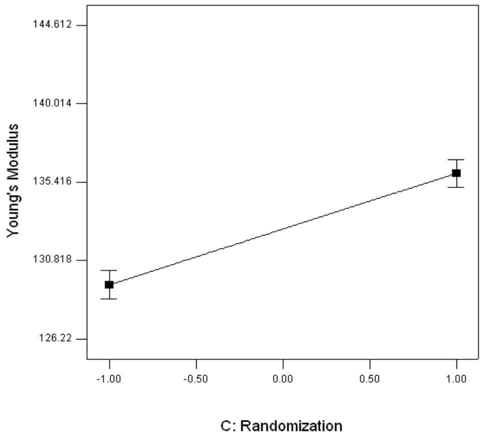


Fig 2. Model Graph for effect of Randomization on young's modulus

## Conclusions

The Young's modulus of the graded composite in x and y directions (lateral)are decreasing with increase in the concentration gradient, but the modulus in z (axial and inline with the gradient) direction is showing some unique behavior increased for fully graded composite when compared with fully homogeneous composite.

It can be concluded that the graded composite has a very beneficial impact on the mechanical properties of the composite, as can cover variety of applications.

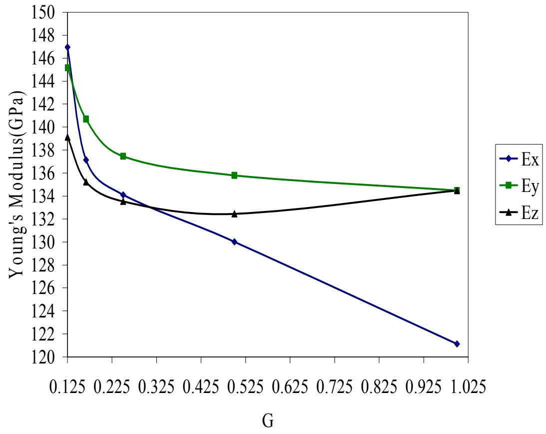


Fig 3. Variation of Young's modulus with gradient

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