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Effect of Particle Gradient on Stress Analysis of a FG Disc

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Abstract: In the present study, we have investigated stress analysis of a Functionally Graded (FG) Rotating Disc. The disc under observation is made of Al-SiC$_p$ composite. The effect of increasing particle gradient (PG) on strain in the disc has been investigated. It is concluded that the strains in the FGM disc reduces significantly with increasing SiC$_p$ particle gradient in Al matrix.
Keywords: FGM, Particle Gradient, disc

I. INTRODUCTION

Functionally Graded Material (FGM) is an advanced material in which the volume content of one of the constituent varies [1]. Rotating disc is widely used part in many mechanical applications [2]. Several authors investigated effect of FGM on stress response by assuming arbitrary material properties [2-4].
In the present work, a study is conducted to investigate the stress analysis in a FGM rotating disc by assuming actual profile of material properties. In a previous study it is studied that decreasing profile of SiC$_p$ in Al matrix is beneficial towards reducing deformations. Therefore, it has been decided to study effect of particle gradient on stress response of a rotating FGM disc.

II. MATHEMATICAL FORMULATION

The stresses (σ_r and σ_θ) and strains (ε_r and ε_θ) for isotropic disc are given by [2],

$$\varepsilon_r = \frac{1}{E(r)}(\sigma_r - \nu\sigma_\theta) \quad (1)$$

$$\varepsilon_\theta = \frac{1}{E(r)}(\sigma_\theta - \nu\sigma_r) \quad (2)$$

Let suppose a rotating disc (r_a =40 mm and r_b =100 mm) which is assumed to be made of Al-SiC$_p$ composite. The content of SiC$_p$ in the Al matrix is varying along the radius,

$$V(r) = V_o\left(\frac{r}{b}\right)^n \quad (3)$$

Where V_o is the SiC$_p$ content at the outer radius and n is SiC$_p$ gradation index.
By equating same volume content for uniform composite disc and FGM disc, we get,

$$\int_a^b 2\pi rtV(r)dr = V_{av}\left[\pi(b^2 - a^2)t\right] \quad (4)$$

Substituting eq. (1) into eq. (2), we get,

$$V_o = \frac{V_{avg}\, b^n (2+n)(b^2 - a^2)}{2(b^{2+n} - a^{2+n})} \quad (5)$$

The density (ρ) and Young's modulus (E) are varying according to the power law,

$$\rho(r) = \rho_0\left(\frac{r}{b}\right)^{n_1} \text{ and } E(r) = E_0\left(\frac{r}{b}\right)^{n_2}$$

The equilibrium equation for a rotating FGM disc (ω =1570 rad/s) is given as [1],

$$\frac{d}{dr}[r\sigma_r]-\sigma_\theta+\rho(r)\omega^2r^2=0 \quad (6)$$

Constitutive Eqs. (1-2) are solved with eq. (7) to find stresses as given by,

$$\sigma_r=M_1r^{\frac{n_2+m-2}{2}}+M_2r^{\frac{n_2-m-2}{2}}+Ar^{2+n_1} \quad (7)$$

$$\sigma_\theta=\left[\left(\frac{n_2+m}{2}\right)M_1r^{\frac{n_2+m-2}{2}}+\left(\frac{n_2-m}{2}\right)M_2r^{\frac{n_2-m-2}{2}}+(3+n_1)Ar^{2+n_1}\right]+\rho(r)r^2\omega^2 \quad (8)$$

Where $A=\frac{-\rho_o\,\omega^2(3+v+n_1-n_2)}{b^{n_1}(8+n_1^{\,2}+6n_1-n_1n_2-3n_2+vn_2)}$ and $m=\sqrt{n_2^{\,2}-4vn_2+4)}$

The results are calculated for rotating FGM disc under free-free boundary conditions.

III. RESULTS AND DISCUSSION

A code has been developed for the computation process. The effect of increasing particle gradient (PG) has been investigated on the stress response. (Refer Table 1).

Table 1: Description of FGM discs

n	SiC_p Content (vol %)			ρ_o	n_1	E_o	n_2
	V_a	V_b	PG				
0	20	20	0	2801.12	0	146	0
-0.5	26.66	16.86	9.8	2783.67	-0.019	133.56	-0.2678
-1	35	14	21	2764.64	-.0407	121	.550

It is clear above from Fig. 1 that radial strains in the FGM disc are lowest in FGM disc with highest particle gradient (n= - 1) as compare FGM disc (n= -0.5) and composite disc (n= 0). The effect of increasing PG on the tangential strain in the FGM disc is similar to radial strain.

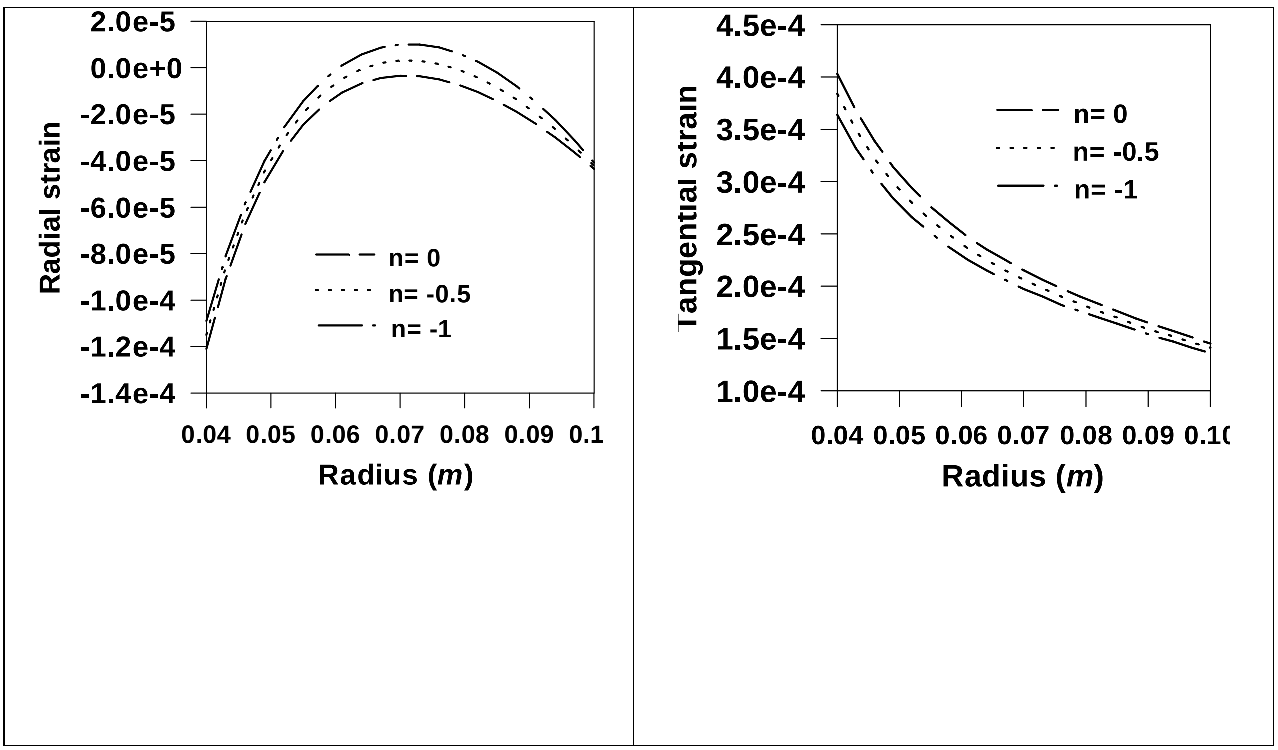

Fig. 1: Effect of particle gradient on radial and tangential strains.

IV. CONCLUSIONS

A. It is concluded that with the rise in particle gradient in the FGM disc, the radial and tangential strains can be significantly minimized.

B. It is further observed that the chances of distortion in the FGM disc significantly reduced with the rise in SiC_p particle gradient in the Al matrix.

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