



IJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: VIII Month of publication: August 2017

DOI: <http://doi.org/10.22214/ijraset.2017.8099>

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Effect of Reinforcement Profile On Creep Rates in a FG Disc

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Abstract: In the present study, we have investigated effect of varying reinforcement profile on creep rates in a Functionally Graded (FG) Rotating Disc. The disc under observation is made of Al-SiC_p composite. The SiC_p particle content is decreasing radially for negative value of reinforcement gradation index (*n*) while it is increasing for the positive value of *n*. It is concluded that the creep rates in the FGM disc reduces significantly with decreasing value of reinforcement gradation index.

Key words: Creep, variable thickness, FGM

I. INTRODUCTION

FGMs are heterogeneous composite materials with variation of volume content continuously from one side to the other [1-2]. Rotating disc is very important due to its extensive use in engineering applications [3].

Singh and Ray [4] investigated steady state creep in a rotating isotropic FGM disc of constant thickness by using Norton's power law. Gupta et al. [3] extended the work to investigate the creep rates for a constant thickness rotating FGM disc operating under thermal gradient. Several authors investigated creep response in rotating FGM disc but using linear thickness profile [3, 5]. In the present study we have investigated effect of reinforcement profile on creep rates in rotating FGM disc.

II. DISC PROFILE AND DISTRIBUTION OF REINFORCEMENT

Let us consider a rotating disc (*a* =31.75 mm and *b* =152.4 mm) rotating at 15000 rpm. The thickness of the disc is varying along radius (*r*) as given by,

$$h(r) = h_b \left(\frac{r}{b} \right)^k \tag{1}$$

where *k* (= -0.5) and *h_b* (= 20.13 mm) are the gradation index and outer thickness respectively.

The SiC_p content in the FGM disc is assumed to vary with radial distance as,

$$V(r) = V_b \left(\frac{r}{b} \right)^n \tag{2}$$

where *n* is gradation index.

On equating equal SiC_p content in constant thickness and variable thickness FGM disc, we get the SiC_p content at the outer radius (*V_o*),

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

The density of disc material is assumed to vary as given by,

$$\rho(r) = \rho_b \left(\frac{r}{b} \right)^m \tag{3}$$

The effective strain rate ($\dot{\epsilon}$) of the disc material is described by the threshold stress (σ_o) based law [5] as given by,

$$\dot{\epsilon} = [M(r) \{ \bar{\sigma} - \sigma_o(r) \}]^5 \tag{4}$$

where

$$M(r) = 0.0288 - \frac{0.0088}{P} - \frac{14.0267}{T} + \frac{0.0322}{V(r)} \tag{5}$$

$$\sigma_o(r) = -0.084 P - 0.023 T + 1.185 V(r) + 22.207 \tag{6}$$

The constitutive equations between stresses (σ_r, σ_θ) and strain rates ($\dot{\epsilon}_r, \dot{\epsilon}_\theta$) for an isotropic disc under plane stress condition

are given by [3],

$$\dot{\epsilon}_r = \frac{\dot{\epsilon}}{2\bar{\sigma}} [2\sigma_r - \sigma_\theta]$$

$$\dot{\epsilon}_\theta = \frac{\dot{\epsilon}}{2\bar{\sigma}} [2\sigma_\theta - \sigma_r] \tag{7}$$

According to von Mises yield criterion, the effective stress ($\bar{\sigma}$) is given by,

$$\bar{\sigma} = \frac{1}{\sqrt{2}} [\sigma_\theta^2 + \sigma_r^2 + (\sigma_r - \sigma_\theta)^2]^{1/2} \tag{8}$$

Considering the equilibrium of forces acting on an element of a variable thickness disc, one may get the following equilibrium equation [6],

$$\frac{d}{dr} [r h(r) \sigma_r] - h(r) \sigma_\theta + \rho(r) r^2 h(r) \omega^2 = 0 \tag{9}$$

where $\rho(r)$ is the density of FGM disc at any radius r .

The disc is assumed to be operate under free-free boundary conditions [3],

$$\sigma_r = 0 \text{ at } r = a \text{ and } \sigma_r = 0 \text{ at } r = b$$

The equilibrium eq. (9) is solved along with set of constitutive eqs. (7) by following the procedure given in [5] to obtain the distribution of stresses and strain rates in the FGM disc.

III. RESULTS AND DISCUSSION

A code has been developed for the calculations. The effect of varying reinforcement gradation index (n) has been investigated on the creep response (Refer Table 1).

Table 1: Description of FGM discs

n	SiC _p Content (vol %)	
	V_a	V_b
0.5	11.51	25.22
0	20	20
-0.5	33.39	15.24

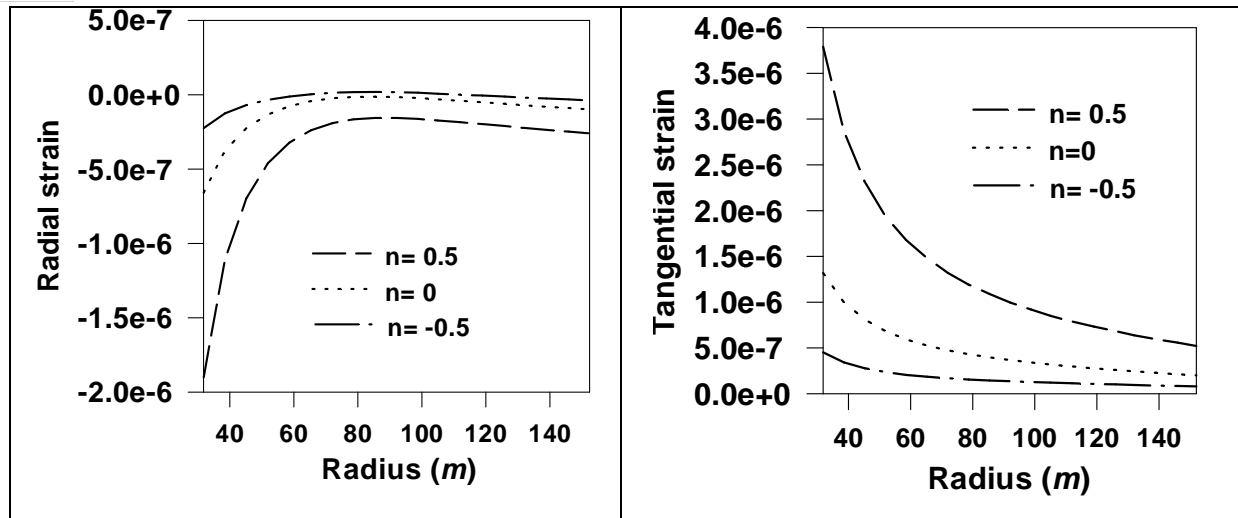


Fig. 1: Effect of particle gradient on creep rates radial and tangential strains.

It is clear above from Fig. 1 that radial strains in the FGM disc are lowest in FGM disc with lowest gradation index ($n = -0.5$) 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.

IV. CONCLUSIONS

The study has led to the following conclusions:

- A. The creep response of the FGM disc with decreasing SiC_p content along the radius is superior to a similar FGM disc with decreasing SiC_p content along the radius.
- B. The creep life can be significantly improved with decreasing SiC_p content along the radius.

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