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Effect of thermal gradation on steady state creep of functionally graded rotating disc

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ABSTRACT

The paper presents the steady state creep behavior of isotropic rotating disc made of parabolically varying functionally graded material in the presence of thermal gradient. The creep rates have been obtained for the discs rotating at elevated temperatures. Investigations for disc rotating at uniform temperature from inner to outer radii has been done using von Mises' yield criterion. Further, work has been extended for discs rotating at parabolically decreasing temperature. The results are exhibited graphically for the said temperature profiles. A small variation is observed for radial and tangential stresses for said thermal gradations. However, in the presence of thermal gradation the strain rates vary significantly as compared to disc at uniform temperature. Thus in functionally graded rotating disc the temperature gradation significantly effect the creep behavior of a rotating disc.

1. Introduction

Advancement in technology has made it possible to fuse materials with components that display modification in their properties. The conventional materials like metals or ceramics might not sustain alone under high temperature or thermal gradient. Thus, functionally graded materials (FGMs) were invented and thus led to the development of high-calibre heat resistant materials (Singh and Gupta (2014)). The concept of FGM was proposed in 1984 by material scientists in the Sendai area of Japan. Uemura (2003) suggested many commercial applications of FGM such as machining tool, optical fiber, optical filter, surface material for wristwatch, blade of electric shaver, spike for baseball shoes, etc. The design, process and characteristics of FGM have been described by Hirai and Chen (1999). With the introduction of graded structures, many fabrication processes and various new materials with unique properties have been developed and prepared. The constituents or their contents vary in some direction in FGMs thus enhancing the performance of these materials. FGMs have been designed in ultra high temperature resistant materials for numerous applications in aircrafts, space vehicles, and other components working at elevated temperature. FGMs are used for components which are subjected to high mechanical and thermal loadings because of their unique performance due to spatial tailoring of properties at a microscopic level as in Singh and Gupta (2014). Suryanarayanan et al. (2013) studied the use of Al-SiC metal matrix composite (MMC) which have applications in the aerospace industry. Duc and Thang (2014) investigated the nonlinear static buckling for imperfect eccentrically stiffened functionally graded thin circular cylindrical shells with temperature dependent properties surrounded on elastic foundation in thermal environment. Both shells and stiffeners were deformed simultaneously due to temperature. Material properties were graded in the thickness direction according to Sigmoid power law distribution in terms of volume fractions of constituents (S-FGM) with meta-ceramic-metal layers. Numerical results were given for evaluating effects of function and Bubnov-Galerkin method were applied. Duc and Quan (2015) presented an analytical investigation on the nonlinear dynamic analysis of functionally graded double curved tin shallow shells using a simple power-law distribution (P-FGM) with temperature-dependent properties on n elastic foundation and subjected to mechanical load and temperature. The obtained results showed the effects of temperature, material and geometrical properties, imperfection and elastic foundation on the nonlinear vibration and nonlinear dynamical response of double curved FGM shallow shells.

Gupta et al. (2004a,b) investigated the creep behavior of a rotating disc having thermal gradient in the radial direction made of isotropic FGM by Sherby's law. The analysis indicated that the steady-state strain rates were significantly lower in disc with linear particle distribution as compared to that in an isotropic disc with uniform distribution. It was concluded that the strain rates in discs operating under thermal gradient were less in comparison to similar discs at uniform temperature.

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