European Journal of Mechanics A/Solids 60 (2016) 315–326

Contents lists available at ScienceDirect

European Journal of Mechanics A/Solids

journal homepage: www.elsevier.com/locate/ejmsol

Steady state creep behavior of thermally graded isotropic rotating disc of composite taking into account the thermal residual stress

Minto Rattan [a,*], Aditya Kaushik [a], Neeraj Chamoli [b], Tania Bose [c]

[a] University Institute of Engineering and Technology, Panjab University, Chandigarh, India
[b] DAV College, Chandigarh, India
[c] Centre for Advanced Study in Mathematics, Panjab University, Chandigarh, India

ARTICLE INFO

Article history:
Received 20 January 2016
Received in revised form
5 August 2016
Accepted 23 August 2016
Available online 30 August 2016

2010 MSC:
74A-10
74E-30
74F-05
74G-15
74K-20
74Q-15

Keywords:
Residual stress
Creep
Isotropic rotating disc
Thermally graded

ABSTRACT

The present paper investigates the steady-state creep behavior of thermally graded isotropic disc rotating at elevated temperature. The composite discs are made of aluminum matrix reinforced with silicon-carbide particulate. The creep analysis is carried out using isotropic Hoffman yield criterion. The stress and strain rate distributions have been calculated for the discs. The creep parameters vary along the radius of the disc and have been estimated by regression fit of the available experimental data. Investigations for disc operating under linearly decreasing temperature from inner to outer radii has been done taking into account the phase-specific thermal residual stress. Further work has been done for discs operating under linearly increasing, parabolically decreasing and parabolically increasing temperatures. The results are displayed and compared graphically in designer friendly format for the above said temperature profiles. It is observed that there is a significant change in the stress distribution due to the presence of thermal residual stress. The radial strain rate is compressive for the discs operating at elevated temperature in the absence of residual stress, but due to the presence of residual stress the strain rate becomes tensile as one gradually moves along the radial distance and again becomes compressive near the outer radius. However, the presence of residual stress led to an increase in the tangential strain rate in the discs as compared to the discs without residual stress. Thus it is concluded that there is a need to extend the domain of thermal gradation in designing rotating discs.

1. Introduction

Processing of the composites often involves cooling from higher temperature resulting in thermal residual stresses in the matrix due to restraint imposed by reinforcements. Thermal residual stresses determinately affect the responses of materials thereby shortening their lifetime (Arsenault and Taya, 1987). The residual stress analysis is an important stage in the design of parts and structural elements as it significantly affects the engineering properties of materials and structural components, notably fatigue life, distortion, dimensional, corrosion resistance, brittle fracture, and so forth (Lohe et al., 2002). Thermal residual stresses exist within a body in the absence of external loading or thermal gradients. Residual stresses may be reduced or eliminated by annealing, by plastic deformation, or just by letting the piece at room temperature for enough time (Dieter, 1988). Because of its influence on the properties, the residual stress in composites has been the subject of several studies, both experimentally and analytically. During cooling, the alloy around ceramic particles contract more than the ceramic constituent and thus, there is a compressive thermal residual stress on the ceramic and a tensile thermal residual stress in the surrounding alloy (Singh and Rattan, 2010; Arsenault and Taya, 1987). A part of the matrix residual stress is relaxed by plastic deformation increasing the density of the matrix dislocation, which contributes to the strengthening of the composite. These residual stresses result in difference in yield stresses in tension and compression, which has led to the application of isotropic Hoffman yield criterion to describe yielding in isotropic materials Singh and Gupta (2013). A number of studies (Singh and Ray, 2003; Singh and Rattan, 2010; Singh and Gupta, 2011; Garg et al., 2013) on the creep analysis of rotating discs have been done because the creep deformation and stress distribution in a turbine disc have practical importance for gas turbine

* Corresponding author.
E-mail addresses: mintor@pu.ac.in (M. Rattan), akaushik@pu.ac.in (A. Kaushik), neeraj_chamoli@yahoo.com (N. Chamoli), justtania12@gmail.com (T. Bose).

http://dx.doi.org/10.1016/j.euromechsol.2016.08.007
0997-7538/