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REVIEW ON ANALYSIS OF CREEP IN AN ISOTROPIC UNIFORM COMPOSITE CYLINDER

Prof. Vyankatesh S. Kulkarni
Department of Mechanical Engineering,
Solapur University /BIT/Barshi/India

ABSTRACT

The steady state creep in Al- SiCP composite cylinder subjected to internal pressure was investigated. The creep behavior of the material was described by threshold stress based creep law by assuming a stress exponent of 5. The effect of size and content of the reinforcement (SiCP), and operating temperature on the stresses and strain rates in the composite cylinder were investigated. The stresses in the cylinder did not have significant variation with varying size and content of the reinforcement, and operating temperature. However, the tangential as well as radial strain rates in the cylinder could be reduced to a significant extent by decreasing size of SiCP, increasing the content of SiCP and decreasing operating temperature.

INTRODUCTION

CREEP AND CREEP MECHANISMS

Creep is the progressive time-dependent inelastic deformation under constant load and temperature. Due to creep, a structural component undergoes time-dependent changes in state of stress and strain such as progressive deformations, relaxation and redistribution of stresses, local reduction of material strength, change of material behaviour from isotropic to anisotropic etc. Kraus (1980) pointed that the creep behaviour is a function of stress, temperature, time, stress history, temperature history and material. Creep behaviour also includes the phenomenon of relaxation, which is the reduction of stress in a structure with time while the total strain remains constant. Further, it also includes recovery, which is characterized by the reduction of inelastic strain with time after the stress has been removed.

The phenomenon of creep is observed in most of the materials. The operating temperature in various industrial and structural applications is sufficiently high to cause significant creep as observed in chemical industries, nuclear power plants, missiles, aero engines, gas turbines etc. The experimental testing and evaluation of creep in composite materials are quite complex, costly as well as time consuming. Therefore, the prediction and analysis of creep properties for assessing service life of components made of composite materials subjected to severe thermo-mechanical loadings is of great practical importance. Accordingly, a thorough understanding and development of methods for analyzing stress in components undergoing creep is extremely important.

CYLINDER

A cylinder is a commonly used component in various structural and engineering applications. In most of the applications, such as pressure vessel for industrial gases, transportation of high-pressurized fluids and piping of nuclear reactors, the cylinder has to operate under severe mechanical and thermal loads, resulting in significant creep and thereby decreasing its service life (Gupta and Pathak, 2001; Tachibana and Iyoku, 2004; Hagihara and Miyazaki, 2008). As an example, in the high temperature engineering test reactor the temperature reaches of the order of 900 oC (Tachibana and Iyoku, 2004). The piping of reactor cooling system are subjected to high temperature and pressure and may be damaged due to high heat generated in the reactor core (Hagihara and Miyazaki, 2008). Therefore, the prediction of long-term creep behaviour is extremely important for these applications.

CYLINDER MADE OF COMPOSITE MATERIALS

Under severe thermo-mechanical loads, cylinder made of monolithic materials may not perform well. The excellent mechanical properties like high specific strength and stiffness, and high temperature stability offered by metal matrix composites (MMCs), such as aluminum and aluminum alloy matrix composites reinforced with ceramics like silicon carbide, make them an appropriate material for applications involving high pressure and high operating temperature (Nieh, 1984; Roy and Tsai, 1988; Fukui et al, 1993; Salzar et al, 1996; Gupta et al, 2004). Numerous investigators carried out analysis of stress and strain in composite cylinders. Some of these salient contributions are discussed as below.

Sherrer (1967) conducted a sensitivity analysis of the resin properties on the failure of a multilayered composite cylinder. He obtained the optimum lay-ups in two layers based on equal fiber stress. Tauchert (1981) studied composite cylinders to obtain an optimal fiber distribution through the thickness to maximize failure pressure and to minimize radial displacement. In this analysis the fibers are assumed to confine only in the hoop direction. 49 Spencer (1986) conducted experimental studies to characterize thickwalled composite structures and to characterize the stiffness and strain of an anisotropic thick-ring subjected to internal pressure. Hose and Kitching (1987) analyzed strain in thick mixed walled glassreinforced plastic pipes subjected separately to internal pressure and bending. Roy and Tsai (1988) proposed a simple and effective design method for thick composite cylinders. They integrated micro and macro mechanics approach by simple relations, which were adopted to enable the designer to instantly study the sensitivity of the micromechanical variables on the final design. The stress analysis was based on 3-dimentional elasticity and the assumption of generalized plane strain condition. The failure of cylinder was predicted by using a 3- dimentional quadratic failure criterion. In addition, the design parameters and material use efficiency of multilayer closed cylinder subjected to internal pressure was also been studied. Fukui and Yamanaka (1992) investigated the effects of composition gradient on the strength and deformation of FG thick-walled tubes under internal pressure based on plain strain condition. The work was further extended by Fukui et al (1993) to include the effect of uniform thermal loading on the performance of a FG thick-walled tube. In this work, the effect of graded components on residual stresses was investigated, in order to achieve the optimum composition gradient generated by compressive circumferential stress at the inner surface. Wang and Lin (1993) analyzed stresses in composite cylindrical shells rotating at a constant speed about its longitudinal axis. The circumferential stress, motivated by the conventional thin shell theory, was assumed to vary linearly through the thickness of the layer. The radial stress was determined in terms of circumferential stress through the equilibrium condition by using an average compatibility condition through the thickness of thin layer. The numerical results obtained through the analysis show nearly perfect agreement with the exact solution reported for homogeneous and isotropic cylinders. Obata and Noda (1994) presented a solution scheme to estimate steady state thermal stresses in a FG hollow circular cylinder to obtain the optimal distribution of reinforcement under different thermal loads. Salzar (1995) evaluated the effects of material property and fiber grading on the overall mechanical response of metal matrix composite tubes subjected to mechanical loadings by developing a fully elastic-plastic axisymmetric generalized plane strain tube model. Micromechanics algorithm was used to obtain elastic-plastic response of a heterogeneous fiber-reinforced composite cylinder. The study indicates that a tube having 40% fiber distributed uniformly undergoes plastic yielding at the inner radius. However, by grading the fiber content, the same tube behaves elastically under the same pressure loading. The grading also results in 60% weight saving of the tube. Salzar et al (1996a) presented an exact elastic-plastic analytical solution for an arbitrary layered tube made of MMC and subjected to axisymmetric thermo-mechanical and torsional loadings. The exact solution was developed for transversely isotropic and off-axis elasto-plastic cylindrical shells. The micromechanics method of cells was employed to calculate the effective elasticplastic properties of the individual layers used in determining the elements of the local and thus global stiffness matrix. The resulting system of equations was solved using Mendelron‟s interactive method of successive elastic solution. The 51 solution strategy was later on (Salzar et al, 1996b) validated by comparing with the available closed-form solutions and FE results.

ANALYSIS OF CREEP IN COMPOSITE CYLINDERS

Creep behaviour of composites with tailored distribution of reinforcement is of importance in view of their applications at high temperature. In recent years, the problem of creep in cylinders made of FGMs and operating under high pressure and temperature has attracted the interest of many researchers. Hulsurkar (1981) applied Seth‟s transition theory of elastic-plastic and creep deformations to solve the problem of creep in composite cylinders subjected to uniform internal pressure. The generalized expressions for creep transition stresses were obtained, which, in a special case reduce to those derived by assuming the creep laws. Hyde et al (1996) presented analytical solutions using creep conditions for the deformations and stresses in thick cylinder made of two-materials and having two-bar structure. The results obtained were compared with those obtained corresponding to single-material solutions and were used to assess the applicability of reference stress and other simple design concepts, established for single-material structures, to two-material components and structures. Loghman and Wahab (1996) developed a model to estimate creep damages in a thick-walled tube subjected to internal pressure and thermal gradient. The study predicted the changes in creep damage rates during life cycle of the tube due to variation in stresses with time and through-thickness variations. The θ projection concept was used to predict the long-term creep properties up to rupture and the creep rupture data. Tzeng (2002) presented a visco-elastic analysis to investigate the creep and stress relaxation in a rotating thick-walled multilayer composite cylinder. The analysis accounts for layer-by-layer variation of material properties, fiber orientation, temperature and density gradients through the thickness of cylinder. A closed form solution based on the corresponding elastic problem was obtained for a generalized plane strain state. Muliana and Ali (2006) analyzed creep behaviour and collapse of thicksection and layered composite structures by using a nonlinear visco-elastic and multi-scale modeling framework. The creep analysis of axially compressed laminated cylinder under surface pressure was presented. It is shown that the compressive loading ratio, along with the residual stiffness of the structure after buckling can affect the creep behaviour and the magnitude of critical time for initiation of unstable response. The proposed models can be used to assess the service life of structures. You et al (2007) analyzed steady state creep in thick-walled cylinders made of arbitrary FGM and subjected to internal pressure. The stresses and strain rates were calculated by using Norton‟s creep law. The impact of radial variations of material parameters was investigated on stresses in the cylinder. Abrinia et al (2008) obtained analytical solution to obtain radial and circumferential stresses in a FG thick cylindrical vessel under the influence of internal pressure and temperature. The effect of non-homogenity in FG cylinder was analyzed in the context of achieving the lowest stress levels in the cylinder.

PROBLEM FORMULATION

The cylinder has been receiving considerable attention due to its wide use in pressure vessels, accumulator shells, emergency breathing cylinders, cylinder for aerospace industries, nuclear reactors, military applications and civil structures etc. In some of these applications like pressure vessels for industrial gases or a media transportation of high pressurized fluids and piping of nuclear reactors, it has to operate under severe mechanical and thermal loads. As a consequence, the cylinder undergoes significant creep deformations, thereby, reducing its service life. The excellent mechanical properties like high specific strength and stiffness and high temperature stability offered by aluminum or aluminum alloy matrix composites containing ceramic reinforcement such as silicon carbide (particles, whiskers or fibers) make them an appropriate material for use in cylinder applications. Keeping this in view, it has been decided to investigate the creep behaviour of a thick-walled cylinder made of aluminum and aluminum alloy matrix composites reinforced with SiC. Since the steady state creep deformation is very large as compared to primary and tertiary creep deformations and covers around 30-40% life of the component. Therefore, the steady state creep behaviour of cylinder made of either Al-SiC or 6061Al-SiC composites subjected to high pressure and temperature have been investigated in the present study The literature consulted so far reveals that the problem of determination of elastic and elasto-plastic stresses and deformations in a cylinder made of monolithic material has been solved by several investigators. However, the literature pertaining to analysis of creep in a cylinder that too of composite materials, are rather scant. Therefore, it is felt that a study must be undertaken to investigate creep behaviour of the composite cylinder subjected to high pressure and temperature.

CONCLUSION

The paper reviews the work carried out by various researchers on creep analysis of composite cylinder. Also the paper presented here forms the base of problem formulation of creep analysis and effect of particle size, Particle content and temperature on creep analysis method.

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