ISSN 0025-6544, Mechanics of Solids, 2025, Vol. 60, No. 4, pp. 2465–2473. © Pleiades Publishing, Ltd., 2025.

On an Analytical Solution to the Creep Problem of a Viscoelastic Cylindrical Layer under Torsional Loading

A. S. Begun[a,b,*], and L. V. Kovtanyuk[a,]**

[a] *Institute of Automation and Control Processes, Far East Branch, Russian Academy of Sciences, Vladivostok, 690041 Russia*

[b] *Vladivostok State University, Vladivostok, 690014 Russia*

**e-mail: asustinova@mail.ru*

***e-mail: lk@iacp.dvo.ru*

Received February 11, 2025; revised February 24, 2025; accepted February 25, 2025

Abstract—Using a mathematical model of large deformations of materials with elastic, plastic and viscous properties, an analytical solution is obtained for the problem of deformation under creep conditions of a viscoelastic material placed in a gap between two rigid cylindrical surfaces, when the outer rigid cylinder rotates due to a twisting moment applied to it, while the inner cylinder is stationary. The displacements, reversible and irreversible deformations, stresses at all stages of deformation, including residual deformations and stresses under full unloading, are calculated.

Keywords: large deformations, creep, elasticity, residual stresses

DOI: 10.1134/S0025654425600667

1. INTRODUCTION

The problems of determining the strength characteristics of structural elements under complex stress-strain conditions under various thermomechanical effects are urgent problems of the modern aviation, aerospace, and energy industries. The study of the behavior of materials during their intensive shaping is possible only in the case of simultaneous consideration of their elastic, viscous, and plastic properties. In the calculations of cold forming and stretching technologies, which are the most promising technologies for the manufacture of large-sized structural elements in a number of parameters, the creep property of materials is decisive [1–4]. The dimensional accuracy of finished products depends decisively on the elastic response of the product material during the removal of tooling (in unloading processes).

The most developed areas of study for both steady-state and transient creep are thick-walled cylinders subjected to various types of loading [5–10] and thick-walled spherical pressure vessels [2, 11–12]. The case of small deformations is mainly considered, and numerical calculations are performed by the finite element method. For finite deformation theories, there are also some solutions for a rotating hollow cylinder [13] and a spherical pressure vessel [14, 15] made of isotropic and homogeneous material. A semi-analytical solution for the study of creep and relaxation of polymeric materials under finite deformation of torsional-tensile cylinders is presented in [16].

Most problems describing creep processes are geometrically and physically nonlinear. Therefore, it is possible to integrate the constitutive relations or propose analytical methods for their solution only in exceptional special cases. Few such solutions have been obtained [17–22] for steady-state creep: for thick-walled rotating cylinders [17], for a thick-walled sphere under pressure [18], for rotating thick-walled cylindrical shells [19], during torsion and bending of rods [20], during pure tension of tubular samples with a constant load [21]. Numerical and analytical solutions for welded joints of annular pipes under pressure, obtained by the perturbation method, are contained in [22].

Here we present a new solution to the problem of unsteady creep on the deformation of a viscoelastic material located between two coaxial rigid cylinders during rotation of the outer cylinder. The solution was obtained within the framework of the theory of flow of elastic-plastic materials using a model of large deformations of materials with elastic, plastic and viscous properties [23–25], in which, according to the formalism of nonequilibrium thermodynamics, reversible and irreversible deformations, as thermodynamic parameters of state in the process of deformation, are specified by differential equations of their