
Reviewed by H. Saunders

Creep is described as the most general type of material behavior and involves the time-dependent deformation and fracture of materials. The quest for greater operating efficiencies pushes temperatures in fossil and nuclear power generating equipment, aircraft gas turbine propulsion engines, and refinery and process equipment to new highs. This in turn propels creep of metal to a more important position. Creep analysis permeates through a number of different aspects of solid mechanics and thus assumes a position of greater importance with each succeeding day.

The book consists of 9 chapters and each is full of information. Chapter I introduces the reader to the experimental observations of the mechanical behavior of structural metals. This includes the tensile test, an introduction to cyclic loading, and a brief description of failure of structures.

Chapter II discusses mathematical modeling of creep phenomena, a discussion which revolves about uniaxial and multiaxial creep models, relaxation, and steady state creep approximation.

After digesting the fundamentals, we delve into creep deformation, stress relaxation, and recovery problems. Two simple problems explain the application of elastic and steady creep laws in Chapter III.

Chapter IV, the most important, considers approximate analytical techniques with special emphasis upon the reference stress method (RSM), which is based on the fact that a given structure can be analyzed with data obtained from simple creep stress at reference temperature. The author dwells upon RSM and applies it to creep under steady state load, combined loading, thermal loading, and stress relaxation. We continue with experimental verification of RSM to steady loads and proceed to creep deformation under variable loads. The chapter concludes with the principle of virtual work applied to creep problems. This is an excellent chapter and well worth delving into to a greater extent.

Chapter V initiates the reader to the failure mode, i.e. breakage of a component; creep rupture is the center of the topic. The Larsen-Miller parameter and Manson-Haferd parameter are discussed. Building an analytical model requires understanding of the damage concept and multiple stress levels, i.e., variation of the well-known Miner’s Rule supplemented by the time factor (although Miner’s Rule is employed in design due to its simplicity). The designer must be alert to the good aspects and shortcomings of this rule. This is more fully explained in books on metal fatigue such as H.O. Fuchs and R.I. Stephens’ Metal Fatigue in Engineering.

This chapter continues with analysis of creep rupture of tensile specimens with extension to multiaxial and nonhomogeneous stress states. Application of RSM to creep rupture concludes the chapter.

Chapter VI focuses upon creep buckling resulting from a column under axial loading. The reader is introduced to a simple analytical solution employing elastic analysis. We then forge ahead into the application of the tangent modulus approach and secant modulus method. The author employs the RSM approach to creep buckling of steel structures and isochronous stress-strain method. Examples are furnished using a boss-loaded hemispherical shell and axially-loaded compressed cylindrical shell.

Chapter VII introduces creep ratchetting. This occurs when plastic behavior results in a gradual change in size or shape of a structure during each application of a cyclic load. Following the format of the author, he progresses from elastic analysis to the elastic-plastic problem. Included in his examination are shakedown, alternating plasticity, and stress relaxation when subjected to high temperature. This chapter concludes with a bounding technique for strains due to creep ratchetting.

Chapter VIII, another important chapter, considers numerical analysis of creep. A short summary of finite element method is presented with emphasis on constant strain applications of 2-D structures. Direct applications to creep analysis, method of initial strain, and strain hardening creep are stressed. An interesting short summary of creep portions of present prominent computer programs is furnished. Illustrative solutions are given concerning stress redistribution in a thick pressure vessel with an ellipsoidal head; stress redistribution in a rotating disk; creep ratchetting of thick tube; and creep relaxation of a circular plate under prescribed transverse deflections. The final two illustrations point out the importance of FE to cycle creep of a primary closure seal and the seal ring of a rotating gas turbine. The reviewer believes this chapter is too brief and provides little justice to FE applications. This chapter should have been extended to include a more detailed study of the incremental strain approach with an introduction to 3-D structures. The isoparametric FE is not considered and in the reviewer’s opinion this will be an important extension of numerical analysis to creep problems.

The concluding chapter reports on methods for evaluating the life of structures under cyclic loadings at elevated temperatures. The pressure vessel industry which is faced with the analysis of creeping structures have adopted the ASME Boiler and Pressure Vessel Code and its so-called Code Case N-47. The previously mentioned Miner Rule-Robinson Method for fatigue damage summation is applied to two examples. An additional method which recently has been a subject of much investigation is the Strain Range Partitioning approach, initially proposed by Manson, Halford, and Hirschberg. This method breaks down the hysteresis loop into plastic (tensile and reversal) and creep (tensile and compressive). The author provides two good introductory examples utilizing a modification of the Manson-Coffin equation for low cycle fatigue. The last section of this chapter considers the frequency separation effect and utilizes a modification of the plastic strain of the Manson-Coffin equation. Coffin contends that environment, and not creep, influences elevated temperature fatigue. The author does furnish a simple but interesting derivation of the Coffin concept.

In summary, this is a good book and contains information usually found in the open literature but rarely in modern texts. The reviewer believes this book could have been strengthened by including an appendix on stress-strain relations instead of the extremely short discussion that was provided. In addition, a detailed explanation of terms employed in approximate analytical techniques would have been of great assistance; and as previously mentioned the FE section should have been expanded to include a sample computer program and to solve problems showing the great strength of this method. The reviewer noticed some typographical errors, but they should not detract from the value of the book, which belongs on the shelf of persons interested in creep analysis.
In materials science, creep (sometimes called cold flow) is the tendency of a solid material to move slowly or deform permanently under the influence of persistent mechanical stresses. It can occur as a result of long-term exposure to high levels of stress that are still below the yield strength of the material. Creep is more severe in materials that are subjected to heat for long periods and generally increases as they near their melting point. Occasionally in creep analysis it is convenient to use a Creep Compliance instead of the creep modulus. This is simply given by \[\text{Compliance} = \frac{\Delta L}{\Delta \sigma}\] where \(\Delta L\) is the creep strain and \(\Delta \sigma\) is the applied stress for a given time period. 

Table 3 Diffusivity of foams for air, estimated from creep analysis

Applied load history and resultant strain history for creep analysis of polyethylene.