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ScienceDirect

Energy Procedia 93 (2016) 197 – 202

Energy Procedia

Africa-EU Renewable Energy Research and Innovation Symposium, RERIS 2016, 8-10 March 2016, Tlemcen, Algeria

Modelling creep behaviour of superheater materials

Getachew Shunki Tibba[a]*, Holm Altenbach[b]

[a]Jimma University, Jimma Institute of Technology, Jimma 378, Ethiopia
[b]Otto-von-Guericke Universitaet Magdeburg, Universitaetsplatz 2 G10-058, Magdeburg 39106, Germany

Abstract

The energy demand of human being is ever increasing. The naturally available energy resources are in a crude form and need conversion to one which is readily available for end use. Power plants play the role of this conversion process. Majority of the conversion processes take place at severe conditions of very high temperature and high pressure. Hence, power plant components always exhibit inelastic behaviours like creep and fatigue. The design of such components should take these inelastic behaviours in to consideration. This work focuses on modelling the creep behaviour of superheater materials. Specifically, creep constitutive model of T91 steel which is commonly used for constructing superheater tubes is developed and validated with results from experimental work. Then a material user subroutine has been written to incorporate the model in commercial software ABAQUS.

Peer-review under responsibility of the organizing committee of RERIS 2016

Keywords: Creep; constitutive model; Material User Subroutine; T91 Steel; ABAQUS.

1. Introduction

To fulfil the ever increasing energy demand of human being, energy conversion is being intensively performed throughout the world [1, 2, and 3]. About 80% of these energy conversion processes involve heat transfer [4] which need high temperature operation to obtain higher efficiency. Such processes are challenging for materials of components involved in the conversion. Different materials with better properties are being engineered to overcome the challenges. Advanced steels are among materials developed for this purpose. This work deals with explanation

* Corresponding author. Tel.: +251911386973; fax: +251478112144.
E-mail address: getachew.shunki@ju.edu.et

Peer-review under responsibility of the organizing committee of RERIS 2016
doi:10.1016/j.egypro.2016.07.170

of the need for high temperature operations, modelling creep behaviour of superheater tube material, implementing the model in computational software and performing simulation of stress distribution in the superheater.

2. Methodology

The mechanical loads, which are commonly in the range of 100 to 200MPa, experienced by power plant components are quite low as compared to the yield strength of the components' materials and may not result in immediate failure of the components. But as these loads act for a long period of time, fluctuating in nature, and accompanied by high temperature conditions, they force the components to exhibit time dependent inelastic behaviour like creep and fatigue. The objective of this work is to model this to model this behaviour.

2.1. Modelling the Inelastic Behaviour

In this work, the mixture constitutive model [5, 6] will be used with aid of conceptual model shown in Figure 1. This modelling assumes that a material consists of hard and soft constituents. The volumes of these constituents evolve with stress and strain. The deformation of the constituents is iso-strain type.

Both constituents show elastic and inelastic behaviour. The elastic properties of the two constituents are assumed to be similar. There is non-uniform distribution of stresses in the two constituents (σ_s in the soft and σ_h in the hard). As deformation progresses, the volume fraction of the hard constituent is assumed to decrease to a certain saturation value due to the physical phenomena that take place in the material. The total stress σ acting in the material can be written in terms of stresses developed in the constituents as

$$\sigma = \sigma_s(1-\eta_h) + \sigma_h\eta_h \tag{1}$$

where η_h is the volume fractions of hard constituent.

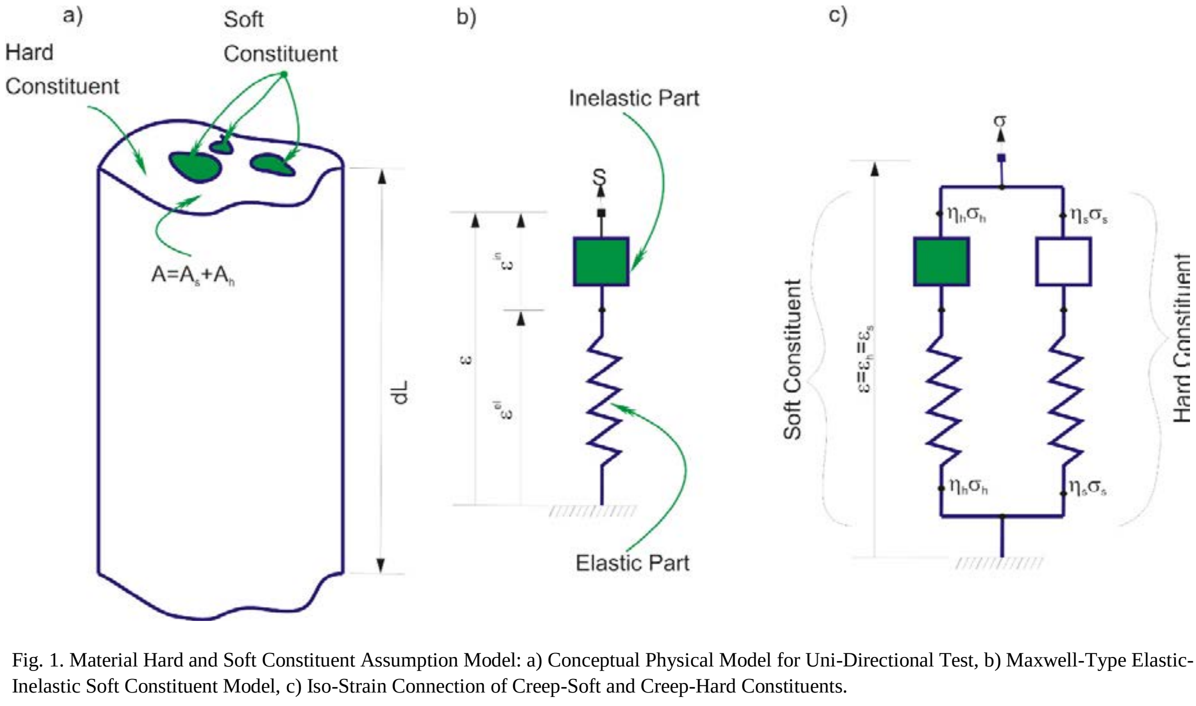

Fig. 1. Material Hard and Soft Constituent Assumption Model: a) Conceptual Physical Model for Uni-Directional Test, b) Maxwell-Type Elastic-Inelastic Soft Constituent Model, c) Iso-Strain Connection of Creep-Soft and Creep-Hard Constituents.