RESEARCH ARTICLE

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Creep Behaviour of Materials: Concept and Methods

Hemant M. Bansod [1*], Sarvesh R. Kale[2], Vrushabh S. Gajbhiye[3], Mayur M. Chandrikapure[4], Amit B. Shahare[5], Sahil R. Phate[6]

[1,*] Deptt. of Mechanical Engineering, S. B. Jain Institute of Technology, Management and Research, Nagpur, India; email: hemantbansod@sbjit.edu.in

[2-6] Deptt. of Mechanical Engineering, S. B. Jain Institute of Technology, Management and Research, Nagpur, India.

ABSTRACT

Creep phenomenon is critical to design of mechanical components subjected to high temperature and loading conditions. This work presents a brief review on the creep phenomenon and its effects on solid material. Research work carried out in creep study is extensively reviewed, corresponding methodology and outcomes are studied.

Keywords: Creep, creep testing method, material behaviour.

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INTRODUCTION

Mechanical components are used nowadays in diverse environmental and complex loading conditions in various engineering applications [1]. For example, turbine components such as blades are subjected to high pressure and high temperature condition in repeated cycles resulting in creep effects [2]. Also, prediction of creep behaviour in advance is gaining significant importance nowadays particularly in the field of reinforced and composite materials [2]. A thorough knowledge of creep characteristics and deformation mechanisms of reinforced and non-reinforced materials is required to utilize these composites in high stress and high temperature applications. In recent years, extensive investigations have been conducted to predict the steady state creep behaviours of various materials [2].

Creep is slow and permanent deformation that happens over time either due to the action of constant load or due to self-weight of a component [3]. So far as load conditions are concerned, type and magnitude of load is relevant to its occurrence. Temperature also plays a critical role in setting up of creep phenomenon [3].

Creep behaviour is normally classified into two categories namely long-time creep behaviour and short time transient creep behaviour [4]. Long term creep behaviour is significant for components having large service life and that are subjected to different weather and loading conditions. Short time transient creep behaviour is significant in case of large loads applied for short repetitive cycles. Creep is normally visible in metals and alloys like aluminum, brass, steel, copper etc. at increased temperature conditions [4,5]. However, for a few metals like zinc, tin, lead and their alloys, creep is also evident at room temperature. It has been reported that some organic materials are also quite sensitive to creep [5]. The creep test is normally carried out by applying a static load to one end of the specially designed lever system [5,6]. The other

Corresponding Author : Hemant M. Bansod, Deptt. of Mechanical Engineering, S. B. Jain Institute of Technology, Management and Research, Nagpur, India; email: hemantbansod@sbjit.edu.in

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end is connected with the specimen to be tested, in a controlled environment and constant temperature conditions [6].

Types of Creep

Creep is normally classified into three types as seen in figure 1 namely primary, secondary and tertiary.

Primary Creep : Primary creep is significant in initial stages during initial elastic deformation of any material subjected to load and temperature conditions. This elastic deformation is normally proceeded by plastic deformation resulting in reduced creep rate thereby known as strain hardening [5].

Secondary Creep : Secondary creep signifies a steady creep behaviour due to settling down of strain in a material to a constant rate [5]. At this stage creep is slow and no significant micro-structural changes are observed [6].

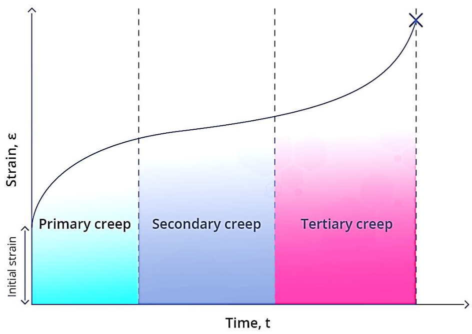

Figure 1: Types of Creep [6]

Tertiary Creep : Tertiary creep is the last stage of creeping in a material and is characterized by considerable micro-structural changes [5]. Due to this, strain continuously builds up resulting in appearance of voids in the structure of material [6]. Tertiary creep therefore paves way to the fracture failure of a material [5,6].

The current study concerns with the strain behaviour of dispersion-hardened aluminium materials [6]. Mostly it focuses on uniaxial creep in a varied temperature range. Experimental studies are available on aluminium (hardened by carbides/ oxides). Corresponding research is reviewed with an aim to understand microstructural effects in these materials [5].

Methods of Creep Testing

Tensile Creep Testing : In this, a specimen is loaded against a tensile load under constant stress condition [7]. Temperature and other environmental conditions are kept controlled while performing the tests. In order to measure the temperature of the specimen, a thermocouple is attached normally in the gage length. Corresponding strain behaviour is measured using extensometer which is sensitive to small deformations [7]. Current day's tensile creep testing machines accompanies a furnace to obtain high temperature conditions as well as a non-contact type laser extensometer [8]. Also, in case of ceramic materials, different designs of specimens and gripping techniques are evolved for instance, simple, bone-shaped, having rectangular or round cross section as in figure 2 [8]. In such materials, gripping is critical to avoid bending during testing. Also, testing of miniature specimen have become increasingly relevant due to increasing requirements of small and concise mechanisms and devices [7,8]. Normally such specimen is often disc type with 8 mm diameter or a square type with 10 × 10 mm cross-section and 0.5 mm thickness.

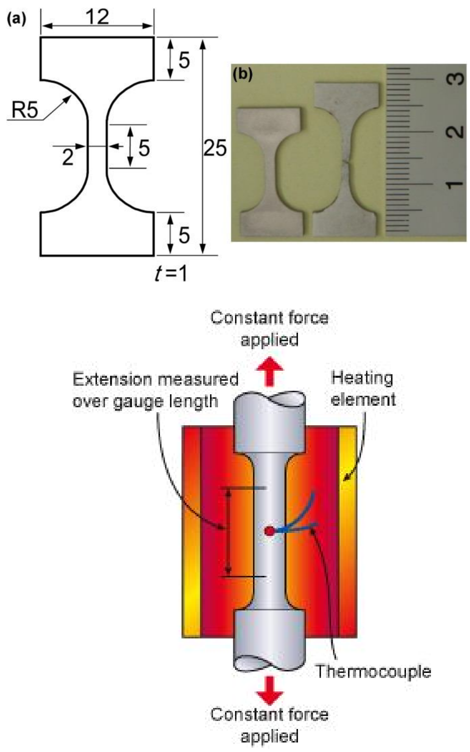

Figure 2: Specimen for creep test [7]

Compressive Creep Testing : Compressive creep testing as seen in figure 3 is normally carried out using a small punch. In this, a hemispherical faced puncher or a ceramic ball is preferably used to deform a thin metal disc [9]. For this, the applied force is increased as a function of time so as to create a rupture of disc. Temperature is kept constant during the test. This kind of testing method was developed for testing transition temperature from brittleness to ductility for a material [9,10]. Later on, it was utilized to calculate fracture toughness and to study degradation of coatings [10]. This type of test is considered important as full uniaxial creep curve is plotted out of this test.

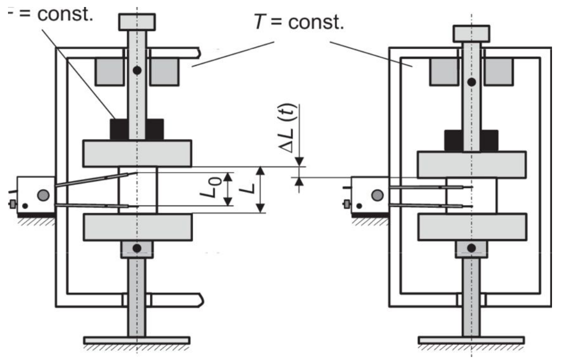

Figure 3: Creep Testing Machine [10]

Flexural (Bend) Tests: Testing gets difficult particularly in case of brittle material like ceramics due to difficulty in specimen preparation as a result of absence on plasticity [9]. At the same time, a small misalignment of specimen in grips causes fracture in the vicinity of grips [8]. Therefore, the flexural creep test is used for such materials gives smooth specimen preparation and easy experimentation [10]

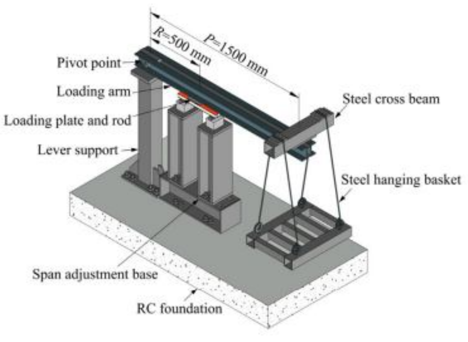

Figure 4: Flexural test apparatus [10]

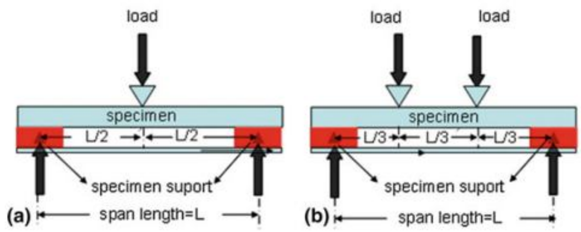

Figure 5: Arrangement for bend test [2]
(a. Three point bend test, b. Four point bend test)

Flexure test as seen in figure 4 and 5 is normally utilized to calculate flexure strength. In this, a specimen is laid in a perfect horizontal condition in one or more points of contact. It is then proceeded by application of load at the point(s) of contact which increases gradually until the material fails. Thereby the flexure strength is calculated. The test is subjected to all three kind of loading effects as tensile, compressive and shear mixed together and hence cannot be utilized to evaluate the fundamental properties.

Indentation (Hardness) Tests : Another important technique is the indentation hardness technique preferably used for ceramics subjected to varied loading and temperature conditions. Different techniques are available to perform indentation test and usually nano-indentation test is used for ceramics to avoid crack development during testing. [2] Creep is directly related to plastic deformation and therefore in a nano-indentation test, every load step within the plastic regime results in certain amount of creep. This exhibits strong influences on slope of loading curve as well as initial part of unloading curve however, it is directly dependent on ratio of displacement to creep rate. Indentation depth at a certain load is dominated by duration of hold period at a maximum load and deformation rate during loading.[11]

Creep in steel is not so significant at ordinary temperatures and is important only at the elevated temperatures. Consequently, creep becomes significant above about 0.4 Tmp where Tmp is the absolute melting temperature [2,11].

Parameters Affects The Creep Behavior

1. Effect of grain size: The grain size affects the creep strain rate of deformation i.e.; strain rate is inversely proportional to grain size.[12]
2. Elastic Modules of material: Generally, materials having high elastic Modulus or shear modulus have high creep resistance property. In this case as we increase stress the elastic Modulus also increases within particular limit.[13]
3. Materials having high stacking fault energy have poor creep resistance.[13]
4. If the impurities in material increases or in the alloying addition reduce the creep resistance due to diffusivity. [12]

In case brittle material like ceramics the tensile creep test is not suitable. Hence, for brittle material flexural test is suitable for creep testing.[14]

In case of soft materials and polymers the tensile and compression creep testing methods are used.

Conclusion

This work presented the concept behind creep, its importance in engineering, its types and methods of identification. It is seen that different testing methods are utilized to test the creep behaviour of materials subjected to different conditions. Normally, to test a material, test specimens are prepared and tests are conducted in controlled environmental and temperature conditions. Correspondingly, the strain and microstructures modifications are observed.

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[14] Sadia Nazneen Karobi, Tao Lin Sun, Takayuki Kurokawa, Feng Luo, Tasuku Nakajima, Takayuki Nonoyama, and Jian Ping Gong, Graduate School of Life Science, Faculty of Advanced Life Science, and Global Station for Soft Matter, Global Institution for Collaborative Research and Education, Hokkaido University, Sapporo 060-0810, Japan.