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Creep Behavior Analysis of Aluminum Alloy 1050 A

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تحليل سلوك الزحف لسبائك الألومنيوم *A1050*

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Abstract:
The creep behaviour of materials is an important factor in the design for structures subjected to high temperatures and constant loads. Creep is a sustained plastic deformation that occurs in the time to rupture once a material experiences constant load or stress. This phenomenon is observed in many materials such as metals, ceramics and polymers. Creep test is a process in which sample of any material is applied with a constant load or stress at high temperature and permanant deformation is measured for specified time period. The creep rate is derived based on the strain rate, which is defined as the ratio of the amount of strain achieved by the material to its time. In creep testing, different experimental methods including applying constant load to the specimens (or constant stress) or stepped loading. Material composition, temperature, level of applied stress, and time contribute to creep behavior. Elevated temperature and stress contribute primarily to an increase in the rate of creep. Knowledge of the creep behavior and mechanism in relation to these conditions becomes increasingly important for engineers and designers in order to achieve long-term structural integrity and reliability of materials under high temperature and stress working conditions. In the current study, the creep behavior of A1050-A aluminum alloy was examined via an available creep testing machine. Preparation of Samples: (ASTM D2990-09) The results indicate typical cracking life of such material being 66 min with 2.5 kg load and at 63A degrees Celcius.

Keywords: Creep, Strain Rate, Aluminum Alloy

الملخص
تُعد ظاهرة الزحف (Creep) في المواد عاملاً مهماً عند تصميم الهياكل التي تتعرض لدرجات حرارة عالية وأحمال ثابتة. والزحف هو تشوه لدن مستمر يحدث بمرور الوقت حتى الوصول إلى مرحلة الكسر، وذلك عندما تتعرض المادة لحمل أو إجهاد ثابت. وتظهر هذه الظاهرة في العديد من المواد، مثل المعادن والسيراميك والبوليمرات. يتضمن اختبار الزحف تعريض عينة من المادة لحمل أو إجهاد ثابت عند درجة حرارة مرتفعة، ثم قياس التشوه الدائم الذي يطرأ عليها خلال فترة زمنية محددة. ويُشتق معدل الزحف بناءً على معدل الانفعال، الذي يُعرف بأنه النسبة بين مقدار الانفعال الذي تتعرض له المادة والزمن المستغرق. وتستخدم في اختبارات الزحف طرق تجريبية متنوعة، منها تسليط حمل ثابت (أو إجهاد ثابت) على العينات، أو استخدام أحمال متدرجة. وتتأثر ظاهرة الزحف بعدة عوامل، وهي: تركيب المادة، ودرجة الحرارة، ومقدار الإجهاد المطبق، والزمن؛ حيث تؤدي درجات الحرارة المرتفعة والإجهادات العالية بشكل رئيسي إلى زيادة معدل الزحف. وتكتسب معرفة سلوك الزحف وآلياته في ظل هذه الظروف أهمية بالغة للمهندسين والمصممين؛ لضمان السلامة الهيكلية والموثوقية طويلة الأمد للمواد عند تشغيلها في ظروف تتسم بارتفاع درجات الحرارة والإجهادات. وفي هذه الدراسة، تم فحص سلوك الزحف لسبائك الألومنيوم (A1050-A) باستخدام جهاز مخصص لاختبارات الزحف، وذلك وفقاً للمواصفة القياسية (ASTM D2990-09). وقد أظهرت النتائج أن العمر الافتراضي لهذه المادة قبل حدوث الكسر يبلغ 66 دقيقة، وذلك عند تعرضها لحمل قدره 2.5 كيلوغرام ودرجة حرارة 63 درجة مئوية.

Introduction

Creep is one of the basic properties of materials, This peculiarity determines how materials behave when under prolonged mechanical stresses or loads [1]. Creep Creep is the phenomenon of material deformation under constant stress or load over time. This deformation may become permanent and eventually result in the failure of the material [2]. Creep is an important factor in the design of parts and structures that are exposed to long- term stress or loads with potential application - such as gas turbine blades, nuclear reactor components, conductor wires used in electric power supply lines, and high pressure high temperature piping. The creep response of materials is known to depend on the specimen temperature, level of stress, and the material microstructure [3]. The creep response of a material can be defined using mechanical tests, for example performing the creep test on a sample of the material by applying a constant stress/strain to it and recording the strain/deformation over time. The results of these tests are usually reported in the form of a creep curve that plots the deformation versus time under a constant load. Knowledge of the creep behavior of materials is necessary to assure the safety and reliability of high-temperature structures and components [4]. Materials that are good in creep resistance can stand long term stresses and loads without too much deformation, but materials that are with a poor creep resistance rate may deform permanently or fail under the same conditions. Thus, creep property is critical to the selection and design of materials for high-temperature applications [5]. They were broadly studied over the years by many investigators in order to understand long-term behavior of various materials subjected to creep at high-stresses, elevated temperatures. Momoh JJ, Ajueyitsi ONA, Onipede AIM (2008) [6] worked on the improvement of a low cost mechanically operated.creep and tensile testing machine which they inspired the machine by addition changes to the lab Baldwin universal hydraulic test machines existing in mechanical engineering department by students. K. Alaneme, B. Bamike and G. Omlenyi et al., in 2014[7] Design of a Sustained Load Dual Grip Creep Testing Machine Performance Evaluation investigated the Performance as well, it gives a low cost prone, locally sources support material efficient creep device which is easy to operate instrumented one. S. Ravi, K. Laha, S. Sakthy, M. D. Mathew and T. Jayakumar,(8), 2014 reported an analysis on Design of a creep device & specimen box chamber for performing creep test in special case of flowing liquid sodium[8]. M. Latif et al., in 2015 [9], conducted a study on the construction and designing of machine send to perform creep test on various materials utilized for high heat situation applications with maximum sample temperature reaching (700º C) and it is subjected to maximum load that gives (10 KN). J. Chukwuneke, P. Okolie, D. Ugwuegbu and J. Sinebe in (2016) [10] conducted a wrote on the 'analysis of design and Fabrication of a 'Creep Machine' and continue experiment on Teflon (polytetrafluroethyline) specimen at constant 100ºC for different stresses is performed 1&2&3KG within every two hours. Ola et[13], The paper had the objective of enhancing the creep rupture life to enhance the performance of heat exchangers in heat pipes. The purpose of the work presented here is to investi-gate creep behavi-or and predict creep rupture life value for aluminum alloy (1050 A).

1. Experimental Work:

2.1 Material

Aluminum alloy (1050 A) was used for the work. The chemical composition and the property of the chosen material are described as follows:

2.1.1 Aluminum Alloy (1050 A)

A 1050 A is a commercial purity aluminum such that the of Bo from an impeller with disk (its composition is not reported) and, in a specific additives are 99.05% and other elements, among which only case, consists of: (1) making the best estimate or calculation for small amounts of Al), it will be provided by commercial companies. It is a non-heat-treatable alloy, because its mechanical properties can be altered under the influence of heat.

The chemical composition of Aluminum Alloy 1050A was given by microstructural studies and standard comparison as:

Table 1.Chemical Analysis of aluminum alloy 1050A

Chemical Element	Composition %
Aluminum (Al)	99.05%
Iron (Fe)	0.40%
Silicon (Si)	0.25%
Copper (Cu)	0.05%
Zinc (Zn)	0.05%
Titanium (Ti)	0.05%
Manganese (Mn)	0.05%
Magnesium (Mg)	0.05%
Chromium (Cr)	0.05%

2.1.2 Characteristics of Aluminum Alloys A 1050:

Commercially pure aluminium is a very good material, and because it contains at least 99.0 5% of aluminium its just pretty fine for most jobs. Here are a few of its notable properties:

Good corrosion resistance: It is suitable for use in outdoor applications.

Good formability: it has good formability, which means that the product can be made with the desired shape without cracking and so on.

Good weld ability: The granted weld ability is good, it means that the proper methods for w elding may be used with ease.

Weak strength: The 1050A aluminium alloy has weak strength (80 MPa) when compared t o other creep-resistant aluminium alloys It is not used for high-strength applications as the lo w strength of this alloy is imperative.

Excellent electrical: It has excellent electrical insulating ability and used in electronic equi pment, such as wiring and cables.

Lightweight: It is light in weight, therefore suitable for applications the require a low dens ity.

Very Good Heat Reflection: Aluminum 1050A can genuinely reflect heat and light, It can r eflect more than 90% of the radiation energy.

Nice surface finish : It has a mini textured finishing, perfect for uses requiring finished ap pearance such as architectural applications.

2.1.3 Uses of Aluminium Alloys 1050A:

1050A aluminum is a 1000-series aluminum alloy: it is considered commercially pure, and is formulated for primary forming into wrought products. Here are just a few things it is used

for: Uses of aluminium alloy 1050A Include:

Walls and roofing: Aluminium 1050A is used for walls and roofs for its high ability to fig ht corrosion.

Cookware: Due to its high heat conductivity and ease of forming, it is used to make cookw are.

Signs: Aluminum 1050A is lightweight making it easier to handle and install, with light w eight and corrosion resistance ideal for indoor or outdoor use including in the most severest of weather conditions.

Electronics: Electronic components like capacitors and printed circuit boards are fabricate d from graphite for its electrical conductivity.

Packaging: Aluminium alloy 1050A is used for packaging, due to its combination of stren gth, formability and resistance to corrosion.

Automobile parts: Aluminum alloy 1050A is one of the most popular types of aluminum u sed for automobile parts.

Construction: It is used for construction materials, such as windows, doors, and gutters, be cause of its corrosion resistance.

Cable sheathing

Chemical processing plants equipment

2.2 Specimen Preparation:

2.2.1 Standard Specimen

Specimen utilized in the creep property test by this machine should be prepared with a qual ified sample acceptable to ASTMD2990-09 and be machined using appropriate methodology so that one can measure an accurately dimensioned test specimen without any micro-crack w hich can behave stress concentrator resulting a sudden failure during the test. As in Fig1., the specimens are machined by fiber laser cutting machine..

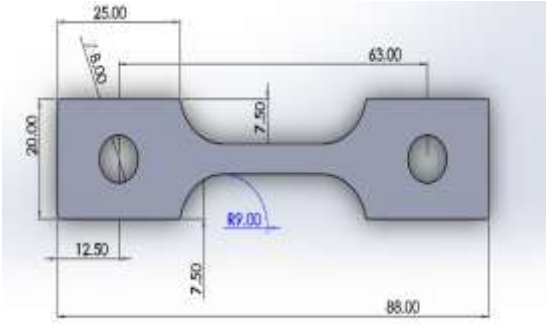


Fig. 1. Aluminum Alloy (1050 A) specimen which prepared according to ASTM standard [11].

2.2.2 Microstructure of the Specimen:

The Microstructure examination was conducted using the Optical Microscope in the Technical Institute -Mosul /Mechanical Techniques Dep. /Metal Laboratory, as shown in Fig.2.

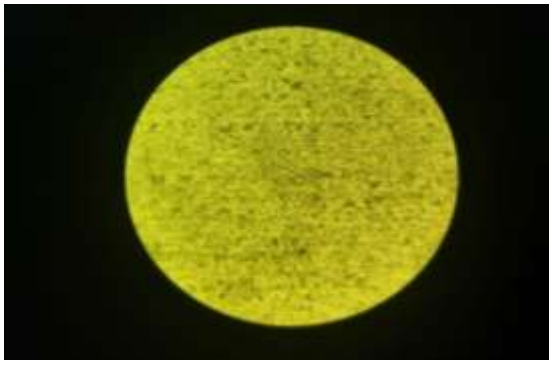


Fig. 2. The Microstructure of aluminum alloy 1050A

2.3 Experimental Setup

2.3.1 Creep Testing Machine

A creep test engine is a tool by which materials can be tested for creep. Typically, a creep machine consists of a loading frame, a furnace or heater assembly, and some form of control and data acquisition systems. The load frame provides a steady state load (EG), which is a constant stress, to the test sample that is generally cylindrical or rectangular in shape. The furnace or heater generates the required temperature conditioning for the test. The control system controls and detects the applied load or stress, temperature and time to provide precise test results repeatedly. A data acquisition system was used to monitor and store data such as load, deflection, and strain during the test.

t can analyse the creep behaviour of materials. Creep testing, an indication of the material behavior during prolonged loading, is a valuable source for design and engineering. The testing machine used by in this study may be presented with Fig. 3. & Fig. 4.

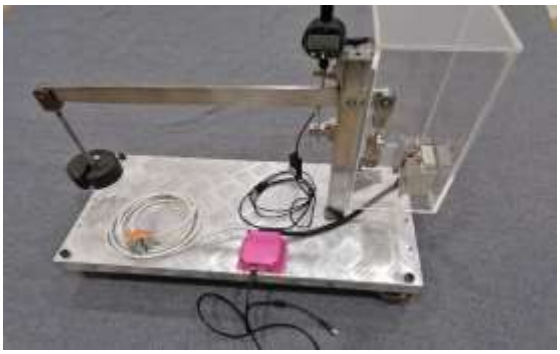


Fig. 3. Creep testing machine

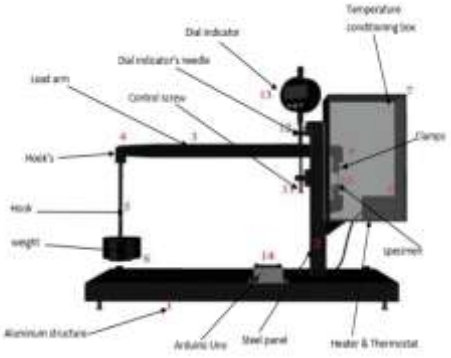


Fig. 4. Parts of Creep Testing Machine [12].

Results and Analysis:

3.1 Results:

The test has been done under constant load of 2.5 kg at 63 Celsius degrees. 15780 readings were recorded from the test to draw the creep rupture life. The rupture life was 66 minutes and 6 seconds as shown in Fig.5.

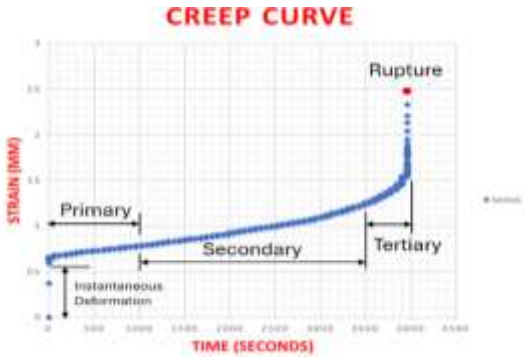


Fig. 5. Creep Rupture Life for Aluminium Alloy 1050A

3.2 Analysis

As soon as the tensile stress is applied to the sample, we notice that an instantaneous strain occurred in parts of the first second of the test by 0.63 mm, followed immediately by primary creep stage, the strain rate is initially high but gradually decreases over time. This stage is characterized by a rapid increase in strain at the beginning of the test, followed by a decreasing rate of deformation. The primary creep is primarily governed by the adjustment and alignment of dislocations within the crystal lattice. During this stage, the material experiences microscopic plastic deformation and undergoes strain hardening, which leads to a decrease in the strain rate, and the primary creep continues for approximately 1000 seconds (16.6 minutes). After 1000 seconds, the second stage of creep begins, and it is characterized by a relatively constant and steady-state strain rate. The strain-time curve exhibits a linear or near-linear relationship during this stage, indicating a constant rate of deformation. The secondary creep stage is of particular interest as it provides information about the alloy's long-term stability and resistance to time-dependent deformation, this stage ends at approximately 3500 seconds (58.3 minutes). After 3500 seconds, the tertiary stage of creep begins, in this stage the strain-time curve exhibits a steep increase in strain rate, indicating rapid and localized deformation. The tertiary creep stage is often associated with the nucleation and growth of voids, cracks, or other types of microstructural damage. It signifies the impending failure of the material and is crucial in determining the creep resistance and maximum allowable operating conditions for the alloy, this stage ends with the occurrence of complete fracture of the sample at 4000 seconds (66.6 minutes).

Conclusion:

The creep test is a fundamental mechanical test used to study the time-dependent deformation behavior of materials under a constant load or stress. It provides insights into the material's creep resistance, which is essential for applications where long-term stability is critical, such as in structural engineering, aerospace, and materials science. From the results of the present works, the following conclusions were recorded:

The rupture life of aluminum alloy 1050 is 66.6 minutes which represent the strength of this material when it subjected to a constant load of 2.5 Kg and temperature of 63 degrees Celsius.

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