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CREEP PROPERTIES OF 7075 ALUMINIUM ALLOY UNDER INTERMITTENT STRESSING

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AA-7075 alminium alloys are being extensively used in aircraft structures and also as ultracentrifuge rotors. At times they are subjected to cyclic loading at high temperatures. We have investigated creep phenomena, under constant and intermittent stressing, of flow-turned AA-7075-T6 tubes of 1mm wall thickness using hydraulic pressure at 70°, maximum temperature to which a centrifuge rotor is usually subjected in operation. It has been concluded that AA-7075 under intermittent loading has lower creep rate than that at continuous loading due to the precipitation of G.P. Zones at a faster rate. These results are consistent with the theoretical expectations and are also in complete agreement with the observations made by other investigators on similar alloys. Such experiments can easily be used to forecast the life of an ultracentrifuge in a uranium enrichment plant.

Key words: Creep, Aluminium-magnesium-zink-copper alloys, cyclic loading, Centrifuge rotors Creep life, Flow-turned tubes.

INTRODUCTION

Creep, i.e. plastic deformation with time under constant load, is important in the design of high precision components for long service lives at high stresses and high temperatures. When materials are cycled between stress limits such that plastic flow occurs during each cycle, creep may take place even at temperatures below which steady state power law creep is not observed [1-3]. In case of mean stress, creep behaviour is particularly pronounced and is also observed in the absence of such a stress. Creep of this type is referred as cyclic creep.

Since aluminium alloy 7075 due to its high strength, low weight and good corrosion resistance is a suitable material for rotor of an ultracentrifuge for uranium enrichment, therefore, it has been investigated here. The temperature of the rotors lies in the range of 60 to 70° and at regular intervals the plant is shut down for maintenance and other reasons. As such rotors are subjected to intermittent (cyclic) loading. Although problems of creep under intermittent loading is rather complex and is not as well documented as that of under constant loading, there are a few papers dealing with this subject.

Kennedy [4] and Greenwood [5] worked mostly on lead and showed that intermittent loading of lead caused a higher creep rate as recovery of the less stable atomic distortion under the joint action of residual stresses and thermal agitation (temperature) played an important role. Somewhat similar results were found by others [6-7] regarding 14S-T and 2024-T Al-alloys. Kennedy [4] also found out that cyclic loading either accelarated or delayed creep in Al-alloys, including Al-Zn-Mg, Inconel,Steels, Mg-alloys and Ti-alloys.

Shepard and co-workers [8] established that the creep strain and time to the rupture of Al-alloys was not affected by intermittent temperature as compared to tests under constant load and temperature if time under stress is considered at elevated temperature, and creep rate is accelarated under intermittent load at constant temperature. It was also noticed that for AA-2024-T3 below 235°, the time under stress was the predominant factor at constant temperature tests and in case of AA-7075-T6 at 150°, the of fload time gave virtually the same creep rate when compared on the basis of the net time at maximum stress and temperature. However Shinn [9] reported that for AA-7075-T6 when load was on half the time, the time to fail was doubled and if load was in the form of pulses, time to fail was reduced drastically. Similarly Giemza [10] reported that longer creep life could be achieved if load was intermittently relieved and material was allowed a period of rest. In literature [2] it is also mentioned that tests must be carried out for each specific case to determine the effect of load interruption on creep. Therefore, the following study was conducted to find out whether intermittent (cyclic) loading of rotor tubes (7075-T6) showed any accelarated creep rate as compared with constant load tests.

MATERIAL AND METHOD

The experiments were carried out on a large number of tubes (7075-T6) of internal diameter 120mm, length 500mm and wall thickness 1mm under constant and intermittent loading. The tubes were hydraulically pressurised in an oil bath kept at constant temperature and care was taken that no air was trapped in the tube. During pressurization the tubes were held in sliding 'O'-ring seals so that no axial stress component was present (Fig.1). The inlet was provided with an automatic valve which was pressure sensitive and in case of a decrease in preset pressure value, the valve opened automatically to maintain constant pressure (stress). The outlet was also provided with an automatic pressure valve. An increase in preset value opened the valve till the desired value was attained. Three strain gauges, around the centre of the tube across diameter were used to record the strain at regular intervals. Fig. 2 shows creep-deformed and undeformed rotor tubes.

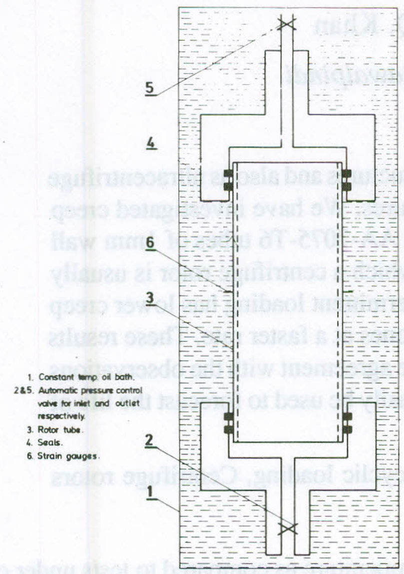

Fig. 1 Schematic diagram of creep testing apparatus.

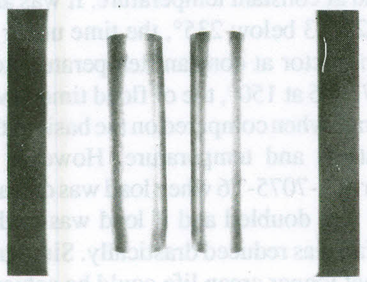

Fig. 2 Creep deformed and Undeformed rotor tubes.

RESULTS AND DISCUSSION

The chemical composition of tube material, AA-7075, is given in Table 1. Extruded tubes of 10mm wall thickness were cold deformed (flow turned) to 1mm wall thickness by intermediate annealing and were artificially aged for 24 hrs. at 120°. In aged condition the ultimate tensile strength, yield strength and Vickers hardness were 52.0 ± 2 kg/mm², 49 ± 2 kg/mm² & 180 ± 5 HV, respectively.

Table. 1. Chemical composition, Wt.%

Zn	5.5	Fe	0.3
Mg	2.3	Mn	0.1
Cu	1.3	Al	Balance
Si	0.3		

Figure 3 presents the change in creep strain as a function of time for constant and intermittent loading. In both cases stresses of the order of 44kg/mm² were used at 70°. The stress value selected here is approximately equal to the hoop stress value on ultracentrifuge rotor of diameter 120mm and operating at 1050 HZ. In case of intermittent loading, a loading period of 144 hrs was used, after which an off load time of 24 hrs was given and process was continued for about 2400 hrs. Fig.4 presents the reversed creep strain as a function of time for 1,24 and 96 hrs off loading time.

A rational approach to understand the phenomena to creep under intermittent stressing requires a thorough knowledge of the parametres playing a significant role in creep under constant stress. During a constant creep load test, if there is no change in the metallic structure, the creep rate

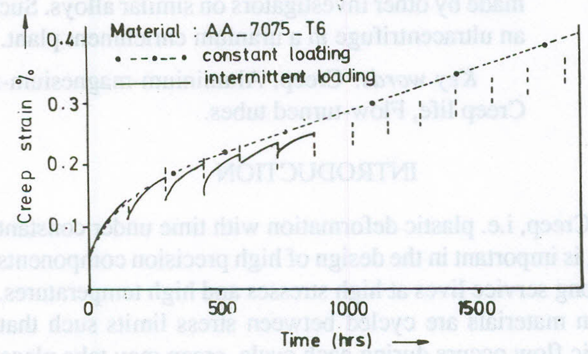

Fig. 3 Comparison of constant and intermittent loading creep at stress value of 44 kg/mm² at 70°. Average loading period is 144 hrs with an off load time of 24 hrs for intermittent loading of experiment.

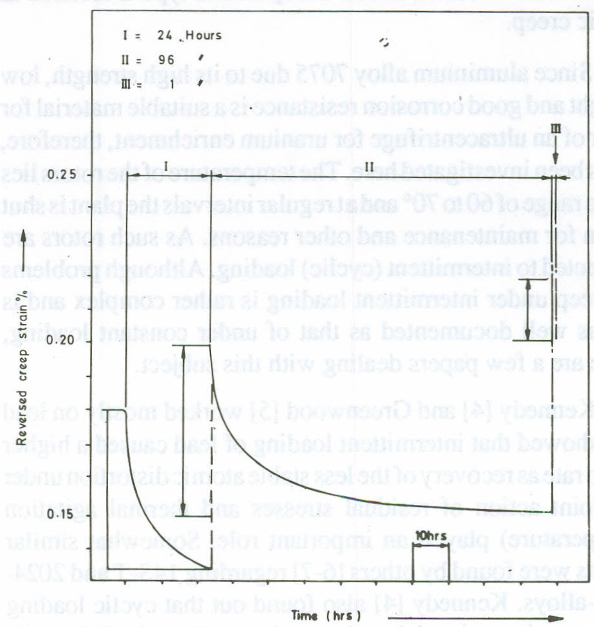

Fig. 4. Reversed creep rate after unloading for 1.24 and 96 hrs.

depends only on the true stress and the test temperature [11]. The creep process under intermittent stressing is complex and no general rule is applicable to all the materials even if they are subjected to identical conditions. The creep behaviour during an intermittent load test will normally depend upon [4], test temperature, the magnitude of the imposed stress and the magnitude of the strain preceding unloading. Further, in materials showing no precipitation or age-hardening the greater the off-load time the greater is the increase in elongation on reapplication of the load. If, however, the material is of the age-hardenable type, the reverse can very likely be the case. The frequency of application of the stresses is also important and if elongation becomes dependent on the number of cycles, the process is essentially that of fatigue. Lastly, the metallurgical state of the material i.e. structural changes during creep and changes due to the decomposition of unstable structures may also play an important role.

The total strain under intermittent stressing is predicted approximately by means of the equivalent-life-fraction expression [12]; $L = \Sigma t_i/t_{F,i}$ where t_i = time under σ_i at temperature T_i, and $t_{F,i}$ = time under σ_i at T_i to attain a given deformation ε. For the prediction to be accurate, L must be equal to 1. This assessment is rather a rough one and applies well to materials which are stable under the effect of temperature in the absence of stress.

As has been pointed out earlier the creep behaviour during an intermittent load test depends, amongst others, on test temperature and whether or not the materials is of a precipitation-hardening type. When precipitation occurs (as it does in many solid solutions including AA-7075 alloy) during creep then this exercises an influence on the creep character even under continuous loading and much more precipitation is expected to take place under creep conditions than would occur at the same temperature in the unstressed material, certainly by a factor of 2 or 3 and or probably even more under certain conditions.

The results of this investigation as presented in Fig. 3 and 4 are in complete agreement with the work of Giemza [10, 15] on AA-7075-T6 alloys. They also found a higher creep resistance at 120° and 150° when a period of no-load is interposed. Fig. 5 and 6 are reproduced from the work of Giemza [15] for ready reference and comparison. This behaviour is easily understandable if one realizes that in 7075-T6 the aging process is hardly influenced by the previous cold work. An increase in the extent of cold work increases the amount of work hardening but progressively decreases the subsequent response to aging and the two effects tend to balance as the aging progresses. Since G.P. zones are formed on the (111) planes which are also the slip planes therefore deformation before aging is not expected to significantly influence the rate of aging. However, precipitation on dislocations during creep can result in enhanced creep resistance or even in hardening. Polmear [13] has shown that precipitation hardening (due to G.P. zone formation) in Al-Zn-Mg alloys can proceed upto

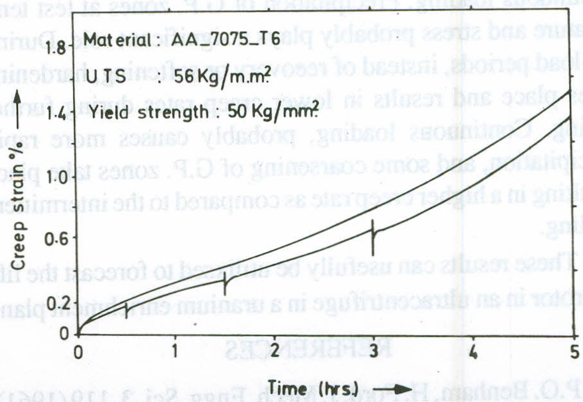

Fig. 5. Creep curves for intermittent and constant stress of 34.7 kg/mm²150° (after Giemza).

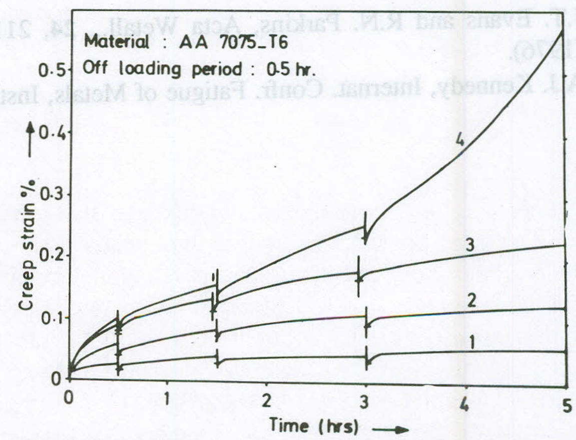

Fig. 6. Comparison of creep curves for intermittent loading. (1) for 40.1 kg/mm² at 93°. (2) 35.9 kg/mm² at 121°. (3) 30.6kg/mm² at 149° and (4) 24.9 kg/mm² at 177° (after Giemza)

1000 days (may even be longer) at 60° - 90° [14]. Since the creep test temperature lies in the same range, it is expected that precipitation of G.P. zones will go on for a very long period and under creep conditions this rate may be a bit faster. Theoretically, one would not observe any increased creep rate under intermittent stressing at temperatures where G.P. zones are continuously formed and are stable (solubility-limit 130° - 135°). On the contrary, it is more likely that hardening due to G.P. zones would result in decreased creep rate. Increased creep rate is expected to occur only under conditions when G.P. zones begin to coarsen and to transform to π-phase, i.e. above 130° at long periods. Thus the results obtained from this investigation are in complete agreement with the work of Giemza [15] on 7075-T6 alloys. Retardation occurs at low stress and accelaration is expected at high stress values for the same material [16]. As such experiments in each specific case under prevailing conditions of temperature and stress must be performed before taking a decision regarding the industrial application of the said part or component.

CONCLUSIONS

Experiments on AA-7075 alloy under intermittent loading have shown that the creep rate is lower than that at continuous loading. Precipitation of G.P. zones at test temperature and stress probably plays a significant role. During off-load periods, instead of recovery or softening, hardening takes place and results in lower creep rates during further testing. Continuous loading, probably causes more rapid precipitation, and some coarsening of G.P. zones take place resulting in a higher creep rate as compared to the intermittent loading.

These results can usefully be utilixsed to forecast the life of a rotor in an ultracentrifuge in a uranium enrichment plant.

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