AN INFLUENCE OF COLD WORK ON CREEP OF ENGINEERING MATERIALS

Zbigniew L. Kowalewski*

*IPPT PAN, Department for Strength of Materials, PL 00-049 Warsaw, Poland

Summary An influence of deformation history on the basic creep parameters of pure copper and PA6 aluminium alloy (notation according to Polish Standards) is analysed for creep due to uniaxial tension at elevated temperatures. Prior plastic deformation up to the several selected levels of strain was realised by means of tension at room temperature. The experimental data achieved are used to verify the assumptions of the recovery creep theory.

INTRODUCTION

During manufacturing and exploitation processes most engineering structures or some their elements are subjected to deformation. Therefore, it is important from engineering point of view to know the influence of this deformation on such different material properties at high temperatures as minimum creep rate, ductility, lifetime, fracture and crack propagation. It has been found that plastic deformation at both room and elevated temperatures prior to creep testing has either beneficial or detrimental effect on the materials. Although the problem has been previously studied experimentally for several materials [1 ÷ 6], only limited amount of available data reflects the influence of plastic predeformation on creep process up to rupture [1, 2, 4, 5]. It is well known that the problem is particularly important during fabrication or assembly processes, where a number of materials used in critical elements of engineering structures may receive such cold work and, as a consequence, it may change significantly their lifetime. Up to now the amount of experimental data is still insufficient to estimate exactly whether the increase or decrease of creep strengthening occurs up to a certain amount of prestrain only, or whether this creep property is in some way proportional to the amount of predeformation. Thus, in order to achieve better understanding of this problem further systematic investigations are required. The aim of this paper is to identify an influence of prior plastic deformation of pure copper and aluminium alloy on the basic creep parameters under uniaxial tension.

EXPERIMENTAL PROCEDURE

Thin-walled tubular specimens were used in all tests. For both materials the experimental programme comprised creep tests under uniaxial tension carried out at two different temperatures (523K and 573 K in case of pure copper, 423K and 473K for aluminium alloy). Creep tests were performed for materials in the as-received state and for the same materials plastically prestrained at the room temperature. In the case of copper the prestrain values of 2.5%, 5.0%, 7.5% and 10.0% were selected in tests at 523 K, whereas tests at 573 K were carried out for testpieces prestrained up to 5% and 10%. The aluminium alloy specimens were prestrained up to 1%, 2%, 6% and 8% for both creep test temperatures taken into account. Experiments were carried out with the use of the Instron 1343 testing machine and standard creep testing stand. The mechanical extensometer connected to the protrusions machined on each testpiece was used for creep strain measurement. These protrusions were applied to transfer the displacement occuring during creep to a location outside of the high temperature furnace where the linear voltage displacement transducers could accurately measure displacement at ambient temperature.

RESULTS

The experimental results for copper and aluminium alloy are presented in Figs. 1 and 2, respectively. It has been shown that the minimum creep rate, and elongation decreases as the amount of the plastic prestrain increases. Such type of response was proportional to the plastic predeformation only up to $\varepsilon = 5\%$ in the case of copper, and up to $\varepsilon = 6\%$ - for aluminium alloy. Higher magnitudes of prior deformation led to increase of the minimum creep rate for both materials. Predeformation also changes the duration of typical creep stages of both materials tested. The duration of the primary creep period decreases, in practice, independently on the amount of prior plastic deformation. In the case of pure copper the duration of secondary creep stage decreases as the magnitude of plastic prestrain increases. An opposite behaviour was observed during creep of prestrained aluminium alloy specimens.

In comparison to the nonprestrained copper a little increase of the time to rupture with the increase of plastic predeformation has been observed for the prestrained specimens tested at higher temperature (573 K). In the case of lower temperature (523 K) the lifetime decreased significantly with the increase of plastic predeformation. The creep data for aluminium alloy exhibit the same tendency of lifetime variation due to prestraining in both temperatures under the question, namely, an extension of lifetime proportional to the magnitude of plastic prestrain. It has to be noted however, that plastic prestrain magnitudes greater than 6% led to the opposite effect, i.e. lifetime reduction.

In the paper the experimental data achieved are discussed in detail and used to verify of the basic assumptions and predictions of the recovery creep theory. It has been found that a good agreement between experimantal data and predictions of the recovery creep theory can be achieved only for sufficiently low level of predeformation, lower than 5% in the case of copper, and lower than 6% for aluminium alloy.

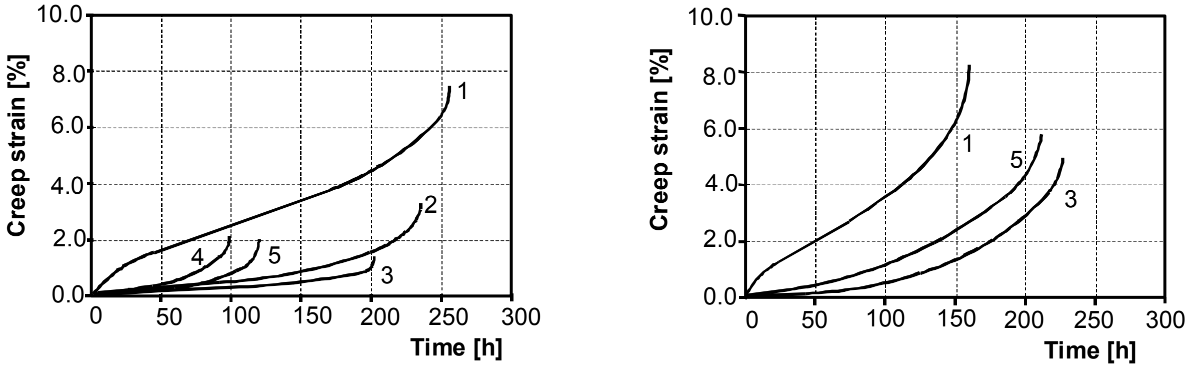

Fig. 1 Creep curves of copper at: (a) σ = 70 MPa and T = 523K: (b) σ = 45 MPa and T = 573K (1 – material in the as-received state; 2, 3, 4, 5 – material prestrained up to 2.5, 5.0, 7.5, 10.0 %, respectively.

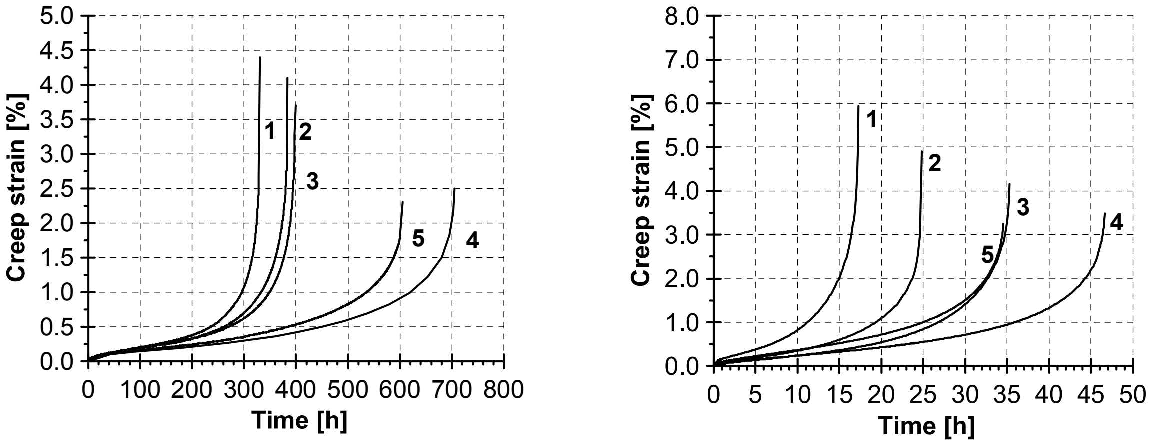

Fig. 2 Creep curves of PA6 aluminium alloy at: (a) σ = 300 MPa and T = 423K: (b) σ = 200 MPa and T = 473K (1 – material in the as-received state; 2, 3, 4, 5 – material prestrained up to 1.0, 2.0, 6.0, 8.0 %, respectively.

CONCLUSIONS

The main remarks stemming from this research can be summarized as follows:

1) The tensile creep resistance was generally enhanced by plastic prestrain, which was expressed by significant decrease of the steady creep rate. However, the amount of this effect, in the case of both tested materials, is not proportional to the increase of predeformation.
2) The results demonstrate that creep fracture process can be modified by prior cold working. In the case of tested copper the creep life dependently on testing temperature may either be increased or decreased to very low levels.
3) The amount of creep deformation for both temperatures considered was markedly reduced by prior tensile plastic strain, yielding very low levels. Elongations of the testpieces were proportionally decreased when the magnitude of plastic prestrain was increased.

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