DAMAGE DEVELOPMENT IN 2024 ALUMINIUM ALLOY DUE TO CREEP AND PLASTIC FLOW

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1. Introduction

Many responsible structural elements and devices are often subjected to long term loadings associated with elevated temperatures. Such conditions stimulate creep damage development. Therefore, it seems to be interesting to assess how the damage processes in the subsequent creep stages can change mechanical properties of materials. Moreover, it is also interesting to know how the same mechanical parameters variations are related to a type of loading process leading to the same amount of strain [1]. In order to get more thorough understanding of the phenomena associated with an influence of deformation history on mechanical properties of materials the paper considers two types of deformation processes of 2024 aluminium alloy: deformation due to creep and deformation due to plastic flow caused by the monotonically increasing load.

2. Programme

The experimental programme comprised tests for the 2024 aluminium alloy in the as-received state and for the same material subjected to prior deformation due to creep at elevated temperature and due to plastic flow at room temperature. Uniaxial tensile creep tests were carried out on the 2024 aluminium alloy using plane specimens under stress level equal to 320 MPa, and temperature - 423 K. In order to assess a damage development during the process of creep the tests were interrupted for a range of the selected time periods 20h, 56h, 140h, 170h, 271h, 292h, 318h, 333h and 385h, which correspond to the increasing amounts of creep strain equal to: 0.01% (1); 0.04% (2); 0.2% (3); 0.3% (4); 1.0% (5); 1.1% (6); 1.6% (7); 1.9% (8) and 3.0% (9), respectively. The material was also prestrained by means of plastic flow at room temperature for the selected magnitudes of deformation, i.e. 1,3% (1); 2.6% (2); 3.8% (3); 4.4% (4) and 5.8% (5). Numbers in brackets correspond to tensile curves of the prestrained material in Figs. 1 and 2.

3. Results

Variations of the basic mechanical properties of the prestrained 2024 aluminium alloy, i.e. Young's modulus, conventional yield point, ultimate tensile strength and elongation, due to deformation achieved by prior creep or plastic flow were determined on the basis of tensile tests. The results are illustrated in Figs. 1 and 2. The Young's modulus is almost not sensitive on the magnitude of creep and plastic deformations. Contrary to the Young's modulus the other considered tensile test parameters, especially the conventional yield point and the ultimate tensile strength, exhibit dependence on the level of prestraining.

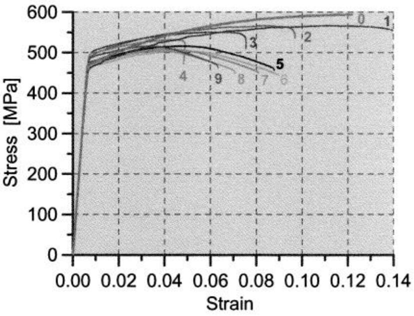

Fig. 1. Comparison of the tensile curve for the as-received material (0) and characteristics for the same material prestrained due to creep.

The metallographic assessments were carried out by means of optical microscope (Olympus PMG3 - in macro- and micro- ranges) as well as by means of scanning electron microscopy (SEM - JEOL 6360 LA) techniques. All observations were performed for the material in the non-etched state.

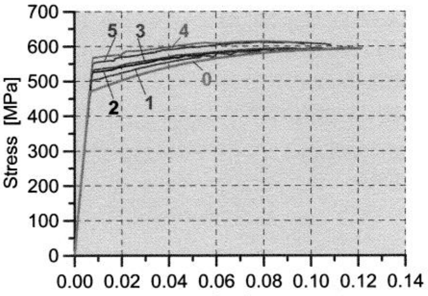

Fig. 2. *Comparison of the tensile curve for the as-received material (0) and characteristics for the same material prestrained due to plastic flow.*

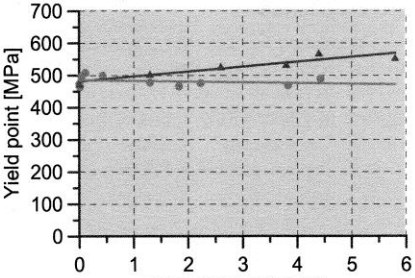

Fig. 3. *Variation of the yield point due to prestrain by means of creep (circles) or plastic flow (triangles) for the 2024 aluminium alloy.*

The macro- and micro- effects induced due to two different kinds of prestraining were evaluated. The results show almost the similar damage effects independently on the deformation type. It was characteristic that apparent cracks initiated in the Si rich areas. A deformed matrix due to micro-plastic deformation was visible in almost all fracture photographs near these places. It means that decohesion process begins on the α-Al/Si boundary. The planes of fissures connected with Si rich precipitations were also observed.

An analysis of the microstructural effects in the 2024 aluminium alloy and geometrical parameters of voids appeared during deformation processes applied shows the greater degradation of specimens subjected to creep under tensile conditions at elevated temperature than that induced by means of plastic prestraining due to standard tension at room temperature. It was characteristic that damage of all specimens appeared in the form of voids created in the area of phase rich in Si. Figure 4 showing distributions of the void area fractions (A_A [%]) evidences that damage development due to creep at elevated temperature is more advanced than that observed after plastic deformation at room temperature.

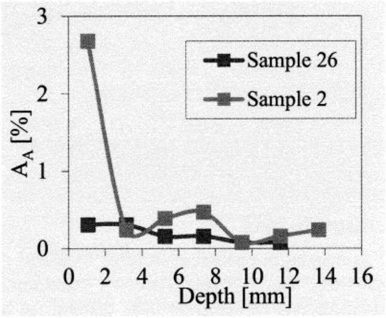

Fig. 4. *Variation of the mean area percent of voids - A_A [%] for the 2024 aluminium alloy prestrained up to 3% due to creep (sample 2) and plastic flow up to 5.8% (sample 26).*

4. Conclusions

The results of tensile tests on the 2024 aluminium alloy show that the effect of prior deformation on the subsequent material behaviour depends not only on the magnitude of prestrain, but also on the way in which such deformation is achieved.

Metallographic investigations allowed to specify two groups of specimens. First one, representing a higher degree of microstructural damage due creep at elevated temperature, and the second, showing its lower degree for specimens prestrained due to plastic flow at room temperature.

References

[1] Z.L. Kowalewski J. Szelążek, S. Mackiewicz, K. Pietrzak, B. Augustyniak, Evaluation of damage development in steels subjected to exploitation loading - destructive and nondestructive techniques, Journal of Multiscale Modeling, 1, 2009, 2, 479-499.