# MONOTONIC TENSILE, CREEP AND FATIGUE TESTS OF ALUMINUM ALLOY ACCOUNTING FOR DYNAMIC RECRYSTALLIZATION

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## 1. Introduction

In practice, it may occur that a structural element will be subjected to the action of short- or long-term, time-constant mechanical and thermal loading, followed by cyclically varying loadings at ambient temperature after the temperature drops. The paper presents an investigation of monotonic tensile and creep tests at the elevated temperatures of 100 °C, 200 °C, and 300 °C taking into account the effect of dynamic recrystallization (DRX) process. As-received material was subjected to creep process with constant force at elevated temperatures, until two varying degrees of deformation $\varepsilon_s$ and $\varepsilon_t$ were reached. After cooling at ambient temperature, the pre-deformed material was subjected to monotonic and fatigue tests as well as metallographic analysis.

## 2. Experiment details

EN AW-2024 T3511 aluminum alloy, in form T3511, was used in tests [1,2]. Bars with a length of 3 m and diameter of 16 mm were prefabricate for making axisymmetric specimens. According to the attestation, the material was hardened $AlCu_4Mg$, and the rod was manufactured by extrusion.

Specimens applied in monotonic tensile and creep tests were characterized by identical shape and dimensions. Gauge length and diameter dimensions were 13mm and 6.5mm respectively. The gripped part of specimens was threaded, as dictated by the design of the creep testing machine. Monotonic tensile tests and creep tests were conducted on a 4-column Kappa 100 SS creep testing machine from the Zwick/Roell, with an electro-mechanical drive. An electric Maytec furnace with three heating zones, with a temperature range up to 900°C, controlled by universal Zwick/Roell controller, was used for tests at elevated temperature. A device specially designed and made for measuring deformations was used [3]. Axial extensometer (Epsilon 3542050M-50-ST) with a variable measuring base of 25/50mm and a range of +25mm and -5mm was used in cooperation with the grip described above. The samples after the tensile and creep tests were subjected to metallographic analysis. The metallographic specimen were polished and etched with Keller's reagent (1.5%HCl+1%HF+2.5% $HNO_3$+95% $H_2O$).

All low-cycle fatigue tests were conducted on a servo-hydraulic MTS 322 unit with an actuator range of ±50 kN. An Instron 2620-601 dynamic axial extensometer with a gauge length of 12.5 mm and range of ±5 mm was used in tests. Tests were conducted at room temperature (20 °C) with a frequency of $f$=0.2 Hz and strain ratio $S=\varepsilon_{min}/\varepsilon_{max}=-1$. The control variable was the amplitude of total strain $\varepsilon_a$. In the first stage, as-received specimens were tested, followed by specimens made from material with creep pre-deformation at elevated temperature (100°C, 200°C, 300°C) at two different strain levels, $\varepsilon_s$ and $\varepsilon_t$. The idea was that the smaller deformation $\varepsilon_s$ corresponds to the beginning of the second creep stage. The choice of larger deformation ($\varepsilon_t$) was encouraged by the need to achieve a specific strain close to the end of the secondary creep and the beginning of the tertiary creep.

Low-cycle fatigue tests were conducted on as-received material and material with pre-deformation at 100°C, 200°C and 300°C. Undamaged (as-received) material was chosen for comparison purpose. The material with pre-deformation–due to the possibility of investigating the impact of the DRX process on the cyclic properties of the material. Five degrees of total strain amplitude were selected (i.e., 0.02, 0.01, 0.008, 0.005, 0.0035), and tests on each level were repeated three times.

## 3. Results and discussion

The description of the fatigue life was made using Manson–Coffin–Basquin model [1]. In

Fig. 1, typical curves of fatigue life obtained for as-received material are compared with those obtained for material with pre-deformation at 300°C.

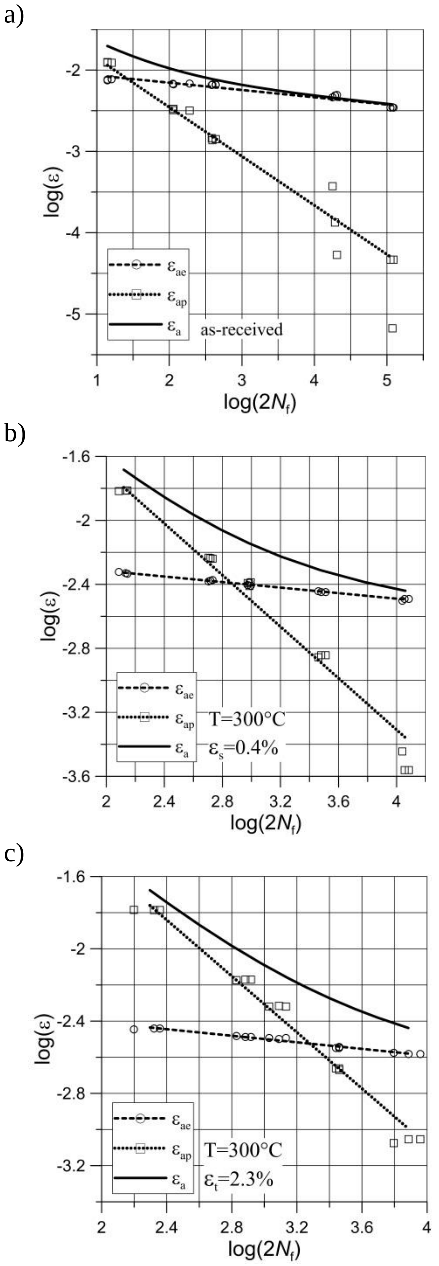


**Fig. 1.** Fatigue life curves at room temperature, obtained for as-received specimens (a) and for specimens with creep pre-deformation at 300°C: b) $\varepsilon_s$=0.4%, c) $\varepsilon_t$=2.3%.

A significant increase in the fatigue life was observed in the area dominated by plastic deformation in the samples with creep pre-deformation at 300°C, where clear dynamic recrystallization occurred. This applied to the samples pre-deformed to both values of strain ($\varepsilon_s$=0.4% and $\varepsilon_t$=2.3%), although the improvement was more significant for $\varepsilon_t$. The inverse situation could be observed in the area dominated by elastic strains. In this case, the fatigue life decreased in comparison with as-received material.

## 4. Conclusion

This paper presents results of the study on the influence of preliminary creep at elevated temperature on the monotonic and cyclic properties of 2024 aluminium alloy. In the case of low temperature (100°C) and high strain value, these properties were determined to be affected mostly by mechanical hardening of the material. In the case of higher temperatures (200°C, 300°C), the possibility of continuous dynamic recrystallization gained significance. This possibility occurred even at low loading speeds (i.e., 0.0015/s), although in the monotonic tension process only at the temperature of 300°C. In the case of creep at 200°C, the recrystallization process occurred only in cases of loading until a greater level of pre-strain $\varepsilon_t$=2.3% was achieved. In the case of creep at 300 °C, this process occurred for preliminary strain of both $\varepsilon_s$=0.4% and $\varepsilon_t$=2.3%. However, in the latter case, the process covered a noticeably greater number of grains.

The improvement of the fatigue life was determined to take place at the cost of the decline of its fatigue strength at constant value of the strain-control variable. Such regularity was most visible in the material pre-deformed at the temperature of 300°C, and was much less visible at 200°C.

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## References

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