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Fatigue Analysis for Copper M1, Aluminum alloys D16 and AMg2N at Elevated Temperature

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Original Research Article

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Abstract: The fatigue durability of copper M1, aluminum alloys D16 and AMg2N was investigated at room elevated temperatures (293 K-673 K) and at remarkable frequencies (copper M1 at 8.8 KHz and 0.2 KHz, D16 at 8.8 KHz, and AMg2N at 8.8 KHz). Experimental studies were performed at different frequencies on copper M1, aluminum alloys D16 and AMg2N for establishing the influence of high test temperatures, the kinetics of micro -hardness and micro –strain, and dislocation density on fatigue characteristics. The effect of the test temperature on the performance of endurance limits was conducted. The experimental results revealed that the increase of temperature has no influence on the fatigue curve forms; however, it shows a monotonic decrease in the fatigue durability tests. The property of fatigue curves certainly at elevated temperature does not change at remarkable frequencies and tests, suggesting the potential use of the test at high frequencies for low frequency definitions fatigue properties at different temperatures. Test results of aluminum alloys demonstrate that the monotonic increase in temperature decrease the fatigue performance on all tested data.
Keywords: fatigue, aluminum alloys, copper M1, elevated temperatures, kinetics of microhardness, dislocation density.

INTRODUCTION

Fatigue property is considered as one of the most significant factor for the damage mechanisms in materials particularly at high temperatures. It has a considerable effect on the properties of material and on the possible running life [1].

The evolution of the environment needs engineering materials with high physical and mechanical properties. Massive strain deformation, crack initiation and development are due to fatigue at high temperature [2]. The structure of material fails in several manners, rupture, damage, fatigue and high deformation. High temperature has serious effect on the properties and fatigue life of the material [3]. The processes of damage initiation and propagations of aluminum alloys structures increase with increasing temperature. Some studies are performed on aluminum alloys D16 and AMg2N [4]. For feasible usage of high loading frequencies at elevated temperatures, it is necessary to study the influence of the temperature agent in the effect of the procedure of fatigue damageability, that is, study the change in physical-mechanical characteristics of materials and alloys [5, 6].

In this work, a novel technique for the analysis of fatigue characteristic at elevated temperature and various loading frequencies is studied. The experiments are performed on copper M1, aluminum alloys D16 and AMg2N at various loading frequencies (copper M1 at 8.8 KHz and 0.2 KHz; D16 at 8.8KHz; AMg2N at 8.8KHz) at a range of temperatures (293 K-673 K).

EXPERIMENTATION

The experiments are performed on copper M1, aluminum alloys D16 and AMg2N at various loading frequencies (copper M1 at 8.8 KHz and 0.2 KHz; D16 at 8.8KHz; AMg2N at 8.8KHz) at a range of temperatures (293 K-673 K). The subject-matters of the research are 2-mm thick flat beam specimens from copper M1, aluminum alloys D16 and AMg2N.

As the previously conducted studies [7, 8] have shown, a very promising method for these purposes is the use of high-frequency oscillations that allow ensuring development of a significant number of load cycles over a short time and identifying the patterns of the effect of deformation frequency on cyclic damageability of the examined metals and alloys.

A complex of magnetostrictive resonance units allowing testing of various construction materials (both metal and non-metal) at large test basis within wide ranges of frequencies (0.2 kHz – 8.8 kHz) and temperatures (293–673 k) was developed for implementation of high-frequency [9]. Tests at high frequencies (0.2 and 8.8 kHz) were performed using magnetostrictive units operating in auto oscillatory mode. Active element of the fatigue unit is magnetostrictive package in the form of closed loop composed from thin sheets of an active material (nickel, permendure, e.t.).

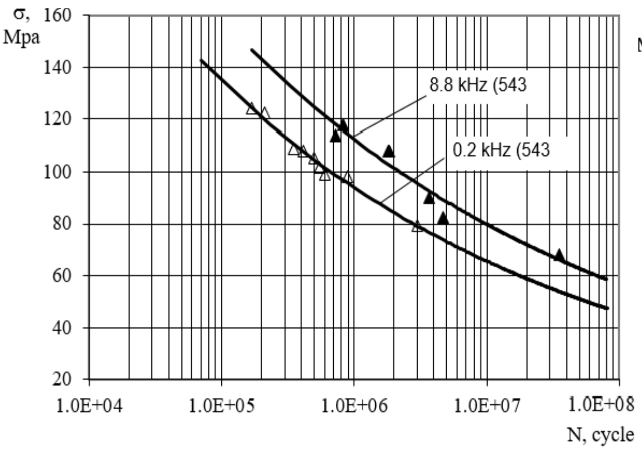
All dimensions of components of the system were executed with the same natural frequency, which allowed us to obtain maximum values of the amplitude of cyclic stresses in the sample during operation of the unit at a given resonant frequency. The transducers were powered with high-frequency current of an OLA-5 amplifier (frequencies of 0.2 and 8.8 kHz).

The complex work was performed by an auto-oscillation mode. Since the quality of this auto-oscillation system is largely determined by the quality of the sample, the use of fatigue tests gives a real possibility to study kinetics of accumulation of fatigue damages by monitoring the changes in the system oscillation frequency with the help of an electronic counting frequency meter. Pre-adjustment and calibration of the vibration meter was carried out using a MBC-2 optical microscope. Shape and amplitude of the electrical signals were controlled using the electronic oscilloscope connected to the circuit for the time of testing.

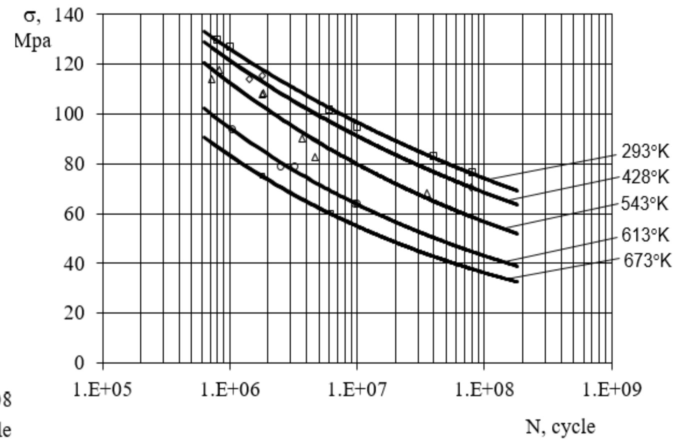
Operational factors having a significant impact on fatigue resistance of construction elements include such environmental parameters as temperature and its composition. The influence of abnormal temperature alters the development of the fatigue processes. In this regard, a test complex was equipped with stationary heating furnaces with measuring equipment in order to account for the influence on fatigue characteristics. Nevertheless, the study of fatigue properties of construction materials at low temperatures (below 273 K) is of great interest. To solve this problem, modular construction of the part of the complex maintaining temperature mode of the tests was proposed. Resonant mode of sample oscillations is used for excitation of cyclic loads. The loading consists in a narrowband random process. Deformations in the sample are controlled by strain gauges and accelerometers.

RESULTS AND DISCUSSIONS

The investigation of the behavior of the fatigue strength in the case of copper demonstrated that increasing the temperature of the test substantially has no influence on the shape of the fatigue curves, but result in a monotonic decrease in fatigue durability tests for all information of copper M1 (figure 1). Due to the fact that copper M1 in this temperature range (293 K-673 K) does not submit stage transformations decrease fatigue characteristics approximately proportional to the evolution temperature test. Property of fatigue curves definitely at elevated temperature does not change at different frequencies and tests, assumed that the possible use of the test at high frequencies for low frequency definitions fatigue characteristics at different temperatures.



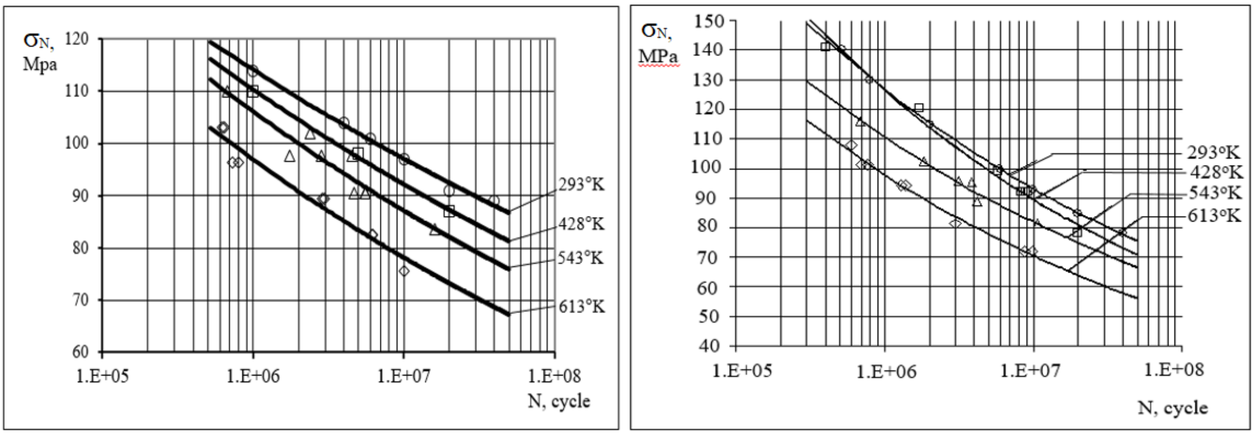
a)



b)

Fig-1: Fatigue curves of copper M1at: a) different frequencies; b) different temperatures and 0.2 KHz.

A similar fatigue curves were obtained for aluminum alloys D16 and AMg2N (figure 2). Test results of aluminum alloys demonstrated that the monotonic increase in temperature diminishes the fatigue performance on all tested data. Definition of the endurance limits demonstrates that the temperature increases to a great range affected by this index than the number of cycle tests.



a) b)

Fig-2: Fatigue curves with test frequency 8.8 kHz for: a) alloy D16; b) AMg2N alloy

The analysis of results of figures 2 and 3 demonstrated that with increasing temperature effect, test base value (σ_N) decreases. Thus, if an alloy with the increase in temperature AMg2N from 273 K to 373 K, i.e. at 100 K results in a decrease of limited endurance limit values at 10^7 based on the cycle of 3 MPa, the temperature increase from 373 K to 423 K, i.e. 50 K only on the basis of the same cycle lead to a decrease of 8 MPa. This reliance is increasingly clear on smaller bases tests at higher voltage levels. So for the base 10^6 of frame difference values at 373 K and it has 423 K increases 2 times, up to 16 MPa. Thus, for a correct application progressed a technique for improving the temperature test is necessary to consider the influence of temperature on the development procedure of the fatigue damage, i.e. to study the kinetics of physic-mechanical properties of materials.

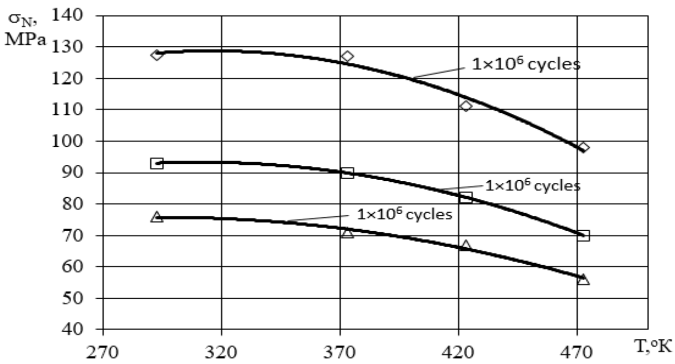


Fig-3: behavior of endurance limits for AMg2N alloy

A study of the kinetics of the microhardness showed (figure 4a) that the nature of its changes are fixed with increasing frequency under both normal and high temperatures. The curves for copper M1 kinetics microhardness at a high temperature to 543 K stored section of softening-hardening property and when tested under the conditions of normal temperature.

It is suggested that the maximum value is notably lower, which is due to the higher flexibility of lattice imperfection at high temperature, and prior beginning of softening process. This suggestion is proved through the analysis of the kinetics of dislocation density as appeared in the figure 4b and micro-strain figure 4c. Due to the fact that changes are recorded in the earlier stages of the development process of fatigue damage in comparison to the micro-hardness, high dislocation density is achieved by 2×10^6 - 4×10^6 cycle.

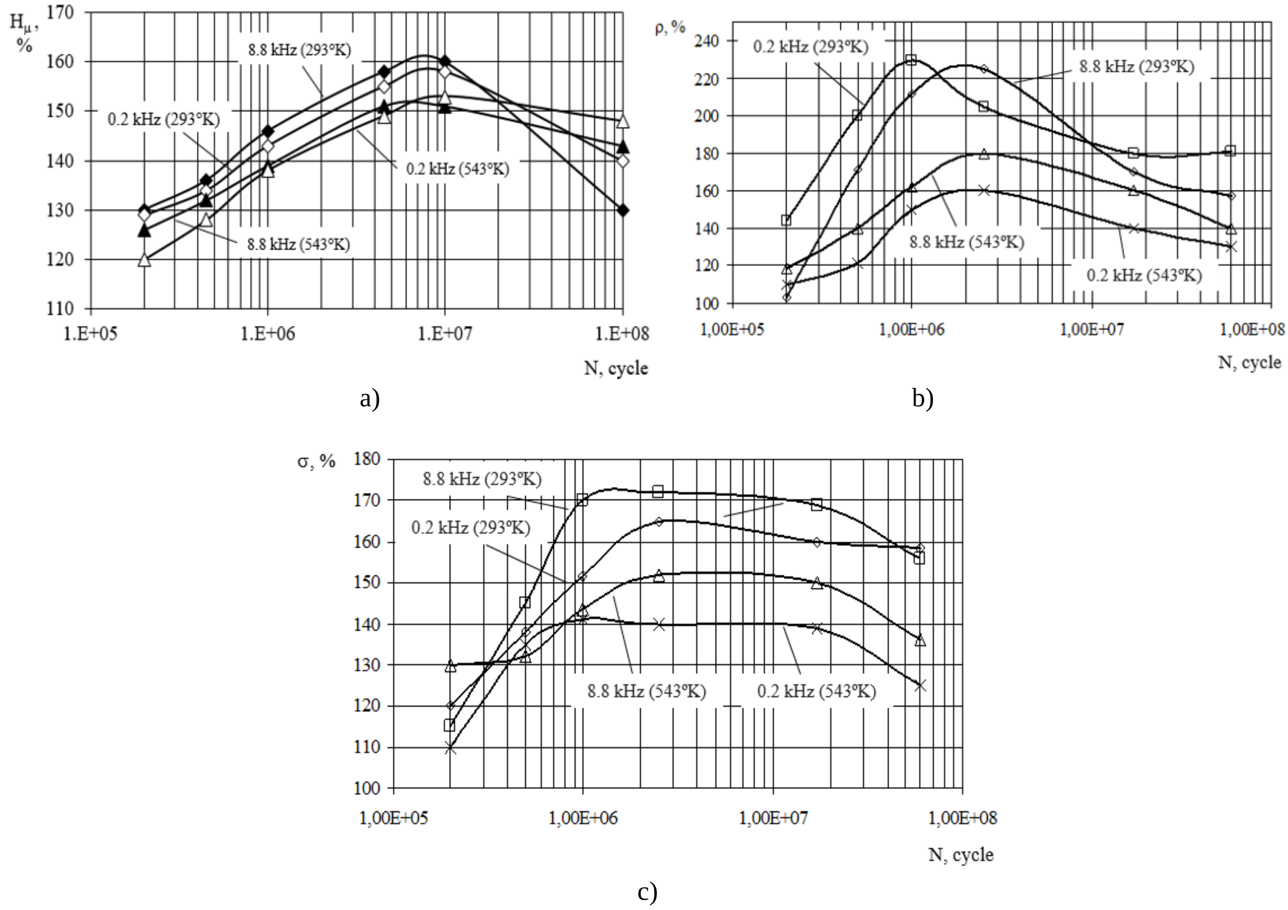


Fig-4A: Kinetics micro-hardness for Copper M1; B) Kinetics of dislocation density Copper M1; C) Kinetics micro strain for Copper M1

A similar reliance obtained for both tests of studied frequencies. The kinetics curves physic-mechanical properties in the considered frequency range and the temperature do not change notably and the alloy AMg2N that asserts the fatigue tests on results on the possibility of using high frequencies and tests at high temperatures.

CONCLUSION

In this study the analysis of fatigue property for copper M1, aluminum alloys D16 and AMg2N is conducted at various loading frequencies and at various temperatures (293 K-673 K). It is noticed that the fatigue strength for copper M1 and aluminum alloys D16 and AMg2N demonstrated that the monotonic increase in temperature reduces the fatigue performance on all tested information. Also a study for the kinetics of the microhardness is carried out and demonstrated that the nature of its changes are conserved with increasing frequency under both regular and elevated temperatures. However, more experiments on fatigue strength response at various frequencies are required for better evaluation of fatigue performance. It is also required to derive mathematical models that correlate fatigue strength with temperature and frequencies variation.

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