DIMENSIONAL CONTROL OF QUASISINGLE CRYSTALS
OF ALUMINUM ALLOY IN PRODUCTION

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The article deals with a method of controlling the dimensions of quasisingle crystal grains of an aluminum alloy used instead of single crystal specimens in static fatigue tests with the object of substantiating a discrete probabilistic model of the fatigue of metals and alloys. We obtained a mathematical model of dimensional control of quasisingle crystals of the aluminum alloy.

Single crystals [1-4] are an ideal object for investigating processes occurring in metals and alloys subjected to static and cyclic loads. The use of single crystals simplifies the investigation of the dislocation structure and makes it possible to establish a correlation between crystallographic orientation and mechanical properties.

It is known that reliable conclusions concerning endurance can be obtained on condition that tests are made under a static aspect [5, 6], but in view of the expensiveness of single crystal specimens such investigations are often impracticable. In that case it seems very promising to use polycrystalline specimens with coarse grains whose dimensions make it possible to reduce to a minimum the influence of neighboring grains in the central part of the investigated grain. Such grains may be regarded as quasisingle crystals.

To investigate the processes occurring in cyclic loading we used quasisingle crystals of the aluminum alloy D16 in the present work. The results of static tests enabled us to verify experimentally a discrete probabilistic model of the fatigue of metals and alloys [7], and also to substantiate the method of predicting the endurance of single crystal objects.

As an example Fig. 1 presents a comparison of the true endurance of single crystals of nickel in thermal fatigue [8] with its theoretical value obtained with the use of the mathematical model of fatigue.

The suggested model is also important in application because single crystals have found widespread application in recent years in the production of gas turbine engine and stationary turbine blades and other products.

To obtain coarse grains in metals and alloys, the method of critical deformation and annealing [9] is now widely used; it consists in preliminary annealing (first annealing), deformation of the specimen, and second annealing. In that case the grain sizes depend mainly on a combination of five parameters, and also on the initial structure.

These parameters are: the temperature t and the length r₁ of the first annealing, the magnitude of deformation ε, the temperature t₂ and the length r₂ of the second annealing. This makes it very difficult to obtain quantitative relations between the mentioned parameters and the grain sizes. The literature therefore usually contains information on actual regimes of thermomechanical treatment by the method of critical deformation and annealing which different researchers used for solving certain concrete problems.

Experimental Program and Obtained Results. The initial material for obtaining quasisingle crystal specimens was the aluminum alloy D16 which is widely used in aircraft. The alloy has the following chemical composition: 4.2% Cu, 1.4% Mg, 0.5% Mn, Fe < 0.5%, Si < 0.1%, Zn < 0.1%. The main strengthening phases are Cu₂Al and Al₂CuMg(S) [10]. The specimens were cut out of one clad sheet 1.0 mm thick. The longitudinal axis of the specimen was perpendicular to the rolling line.

After thermomechanical treatment by the method of critical deformation and annealing the specimens were etched in 10% solution of NaOH for removing the cladding layer and revealing the macrostructure. The products of etching were removed by washing in concentrated nitric acid and in running water.

The mechanical properties of annealed material D16 are the following: ultimate strength 220 MPa, conventional limit of elasticity 100 MPa, relative elongation at rupture 13%. The mean grain size of the material in the initial state is 0.05 mm. The maximal size does not exceed 0.1 mm.
Fig. 1. True and predicted endurance of single crystals of nickel alloy in thermal fatigue.

TABLE 1. Parameters of the Regimes of Thermomechanical Treatment

<table>
<thead>
<tr>
<th>Regime parameter</th>
<th>Alternatives 1</th>
<th>Alternatives 2</th>
<th>Alternatives 3</th>
<th>Alternatives 4</th>
<th>Alternatives 5</th>
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<td>$t_2$</td>
<td>$T_1$ mm</td>
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<td>$T_1$ mm</td>
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<td>$T_1$ mm</td>
<td>$T_2$ mm</td>
</tr>
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Published data and the results of preliminary investigations show that the change of grain size during thermomechanical treatment sets in when some deformation, called critical deformation and designated $\varepsilon_c$, is attained. Experiments showed that when a specimen is subjected to critical deformation, thermomechanical treatment leads to the formation of grains with maximal size $D_e$. If relative deformation $\varepsilon > \varepsilon_c$, its increase entails a steepless decrease of the grain size $D$ up to its initial value.

It is not advisable to use the regime of obtaining quasisingle crystals at critical deformation because it is characterized by high sensitivity to random fluctuation of the parameters of thermomechanical treatment. This requires a large number of specimens, it is therefore necessary to have a mathematical model which has to make it possible to predict the size of quasisingle crystals with different combinations of the parameters of thermomechanical treatment.