We describe a procedure for modeling the structural inhomogeneity of a material by the finite element method. We consider the material as a composite consisting of an elastoplastic matrix and brittle inclusions (dispersoids). The finite element model is based on experimental data on the concentration of inclusions and their geometrical sizes. The proposed finite element model describes well the jump-like deformation of AMg6 alloy.

In the tensile stress-strain diagrams of some materials, there appear strain jumps [1–4]. In particular, such jumps were detected in the course of tension of AMg6 alloy with the destruction of disperse inclusions of the secondary phase depending on their size and distribution [5]. In the present work, we describe a procedure for modeling the influence of structural components on the deformation of AMg6 alloy with the help of the ANSYS program package, based on the finite element method (FEM).

Microstructural Investigations

In the tensile stress-strain diagram of smooth cylindrical specimens at a temperature of 20°C, there appear strain jumps due to the cracking of disperse inclusions of the secondary phase and scattering of dislocation clouds [5].

We studied the number of disperse inclusions in the cross section of specimens and their cracking after plastic deformation in the longitudinal direction by the method of transmission electron microscopy of thin foils on a PEM-125K microscope. The dispersoids of length from 0.2 to 5 μm and diameter from 0.08 to 0.15 μm were stretched in the direction of forge-rolling. Their number in the matrix of the α-solid solution of Mg in Al in cross section is about $3 \times 10^6$ /mm$^2$ (Fig. 1a) [5].

After stretching in the longitudinal direction, the dispersoids crack (Fig. 1b) into $2–7$ fragments depending on the initial form factor $\alpha$ (the ratio between the length and width of an inclusion) till it reaches a value of 3.4. The dispersoids with initial $\alpha \leq 3.4$ are not destroyed.

Modeling by the Finite Element Method

Our computations by this method were carried out with the help of the ANSYS program package, version 9.0. The computational model was based on experimental data on the number of inclusions according to the histograms of their distribution depending on the initial form factor [5]. The number of inclusions in the model was $n = 100$. According to experimental data, for the cross section area $S_2 = 10^{-8}$ m$^2$, the total area of inclusions is $S_1 = 5.42 \cdot 10^{-10}$ m$^2$.

We assumed the following:

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Fig. 1. Microstructure of AMg6 alloy: disperse inclusions in the cross section of specimens (a), destruction of disperse inclusions in the longitudinal direction, $\times$ 30000 (b), and computer model of the material (c).

Fig. 2. An eight-node plane element plane 82.

(a) the ratio between the area $S_1$ of inclusions in the cross section and the area $S_2$ of this section is equal to the ratio of the area $S_3$ of inclusions in the longitudinal section to its area $S_4$: $S_1/S_2 = S_3/S_4$; we find from here $S_3 = 1.84 \cdot 10^{-11} \text{ m}^2$ and $S_4 = 3.39 \cdot 10^{-10} \text{ m}^2$;

(b) the diameter of all inclusions in the model is identical $d = 0.115 \mu\text{m}$ (averaged value), and their length is $l = \alpha d$;

(c) the inclusions are rigidly adherent to the matrix.

Taking into account these assumptions and the histogram of the number of dispersoids depending on their form factor $\alpha$ [5], we determined the number of inclusions $n$, their lengths, total area in the longitudinal cross section of the model $S_3$, and the sizes of the computational model (Table 1).

We took the computational model in the form of a square, and then $S_4 = a^2$, where $a = 1.842 \cdot 10^{-15} \text{ m}$ is the model size.

We assigned the coordinates of placement of the inclusions inside the model according to the two-dimensional normal distribution. As the basis of the finite-element grid, we took an eight-node plane element plane 82 (Fig. 2), which has the properties of plasticity and creep, can increase its rigidity under loading, and also admits large displacements and strains. The number of elements in the model was 115,731.