STUDY OF TRANSFORMATIONS IN BERYLLIUM BRONZES BY MEANS OF INTERNAL FRICTION

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UDC 669.35'6:669.725

Microadditions of magnesium to beryllium bronzes increase the resistance to microplastic deformation [1, 2]. However, the mechanism of the effect is unclear. We investigated the mechanism of this effect by the internal friction method.

The following alloys (see Table 1) were investigated: bronze BNT1.9 of standard composition; BNT-1.9Mg, additionally alloyed with surface-active magnesium; and BNT1.9MgF, additionally alloyed with surface-active magnesium and inactive phosphorus, which, due to the buffer effect, may reinforce the surface activity of magnesium, as has been suggested.

We investigated the amplitude-dependent and amplitude-independent internal friction (background).

The internal friction was measured with a relaxation oscillator based on the principle of a torsional oscillation machine with a frequency of vibrations of 1 Hz.

The tests were made on band samples 50 × 2 × 0.3 mm. Measurements at elevated temperatures were made in vacuum. The amplitude dependence of internal friction was measured on quenched alloys and also after aging at 340°C for 1-4 h. Aging of the samples for measurements of the amplitude dependence of internal friction was conducted in a laboratory furnace. The internal friction was measured with a relaxation oscillator at room temperature, while the background of internal friction was measured in the process of aging (directly in the relaxation oscillator) at 340°C. From the amplitude dependences we determined the basic parameters of the amplitude-dependent internal friction – the critical stress τ_{cr} at which internal friction begins to increase and the tangent of the slope of the amplitude dependent branch of internal friction $\tan \theta$.

Figure 1 shows the change of the amplitude dependence for the quenched alloys. The background of internal friction was lowest for alloy BNT1.9MgF. This can be explained by the low mobility of point defects fixed by quenching, since the energy of the bonds between vacancies and atoms of magnesium and phosphorus is highest. Previous measurements of the bonding energy of atoms with vacancies gave the following values: $E_V = 0.2$ eV for beryllium atoms, $E_V = 0.45$ eV for magnesium, $E_V = 0.30$ eV for phosphorus. The effect of the increase in the bonding energy of vacancies with atoms of magnesium and phosphorus is predominant despite the large concentration of quenching vacancies in the bronze. In the alloy with magnesium and phosphorus no amplitude-dependence of internal friction in the quenched condition was noted (at amplitudes up to $\varepsilon = 4.5 \cdot 10^4$) due to intensive pinning of dislocations by magnesium and phosphorus atoms.

TABLE 1

Heat No.	Bronze	Composition, wt.%				
		Be	Ni	Ti	Mg	P
1	BNT1.9	1,96	0.29	0.15	—	—
2	BNT1.9Mg	1,95	0,29	0.15	0,12	—
3	BNT1.9MgF	1,95	0,29	0,23	0,12	0,03

From bronze BNT1.9Mg the background of internal friction is higher than for the bronze without magnesium, although the bonding energy of vacancies with magnesium atoms is larger than with beryllium atoms. This indicates that in the quenched bronze containing magnesium the vacancy concentration is high as compared with the bronze without magnesium. However, their mobility is smaller than in the bronze without magnesium but larger than in the bronze with magnesium and phosphorus. The critical

N. É. Bauman Moscow Technical College. Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 11, pp. 70-72, November, 1974.

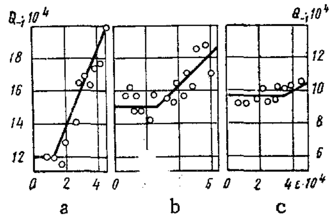

Fig. 1. Amplitude dependences of internal friction for quenched samples of beryllium bronzes 1 (a), 2 (b), and 3 (c) (see Table 1).

stress at which internal friction begins to increase due to the loss of dislocations in bending and the rate of the process during further increase of the amplitude are smaller for the bronze alloyed with magnesium. Thus, atoms of magnesium exhibit surface activity where structural defects are grouped.

During subsequent aging of bronze BNT1.9 at 340°C there is an increase of the critical stress (amplitude) at which amplitude dependence of the internal friction begins, the rate of increase, determined from the value of $\tan\theta$, decreasing (Fig. 2). The critical stress τ_{cr} reaches the highest value (5.6 kg/mm^2), while $\tan\theta$ is minimal (0.21) after aging for 3 h, when the elastic limit also reaches its highest value (Fig. 3). Thus, a certain correlation is noted between the parameters characterizing the rate of reversible inelastic effects and the resistance to small plastic deformations. This is confirmation of the fact that in both cases the mobility of dislocations is of basic importance. Also, aging sharply reduces the level of the background, which indicates a reduction of the mobility of point defects and their concentrations.

In bronzes microalloyed with magnesium or magnesium and phosphorus no correspondence is observed between the inelastic properties of the alloys and the resistance to microplastic deformation, although a fairly good correlation is observed between the general character of the changes in the critical amplitude and the rate of increase of the internal friction with increasing amplitude. In contrast to the bronze of standard composition, after aging of heats 2 and 3 for 1 h (see Table 1) at 340°C the critical stress τ_{cr} increases and then decreases, and after holding for a longer time it increases again (Fig. 4). The value of τ_{cr} has still not reached a peak after aging for 4 h. The value of $\tan\theta$ changes in the same manner. The value of $\tan\theta$ is low after aging (especially BNT1.9Mg) and tends to decrease further, and therefore it can be considered that with aging for more than 4 h the value of $\tan\theta$ will be still lower and the values of the critical amplitude higher.

The lower values of τ_{cr} and higher values of $\tan\theta$ for microalloyed bronzes after aging at 340°C for 2 h match the change in the background of internal friction measured at 20°C and directly at the aging temperature of 340°C. Thus, as the result of aging at 340°C for 2 h the atoms of magnesium or magnesium and phosphorus transfer to the phase being formed and therefore dislocations and vacancies acquire reversible mobility, which leads to an increase in the level of the background (Fig. 5).

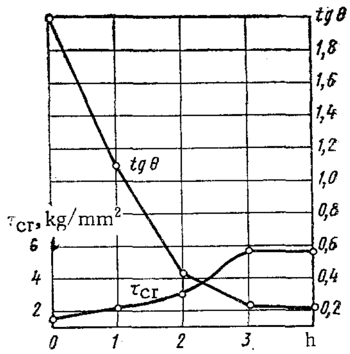

Fig. 2

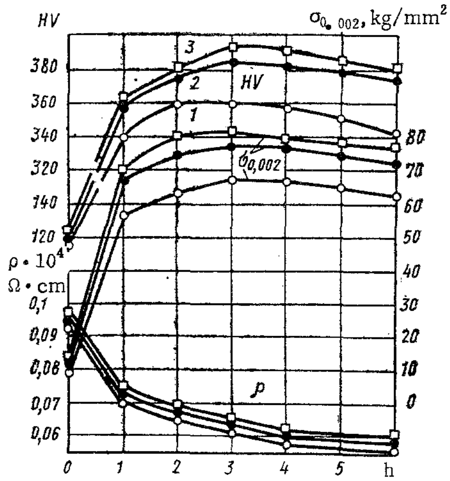

Fig. 3

Fig. 2. Parameters of internal friction as a function of aging time at 340°C for heat 1.

Fig. 3. Effect of aging time at 340°C on the properties of beryllium bronzes. The heat numbers (see Table 1) are given on the curves.

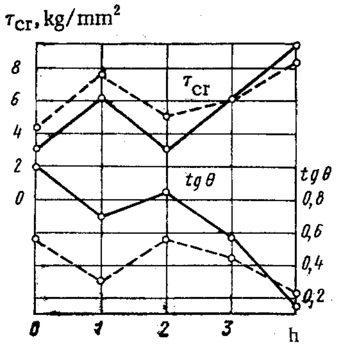

Fig. 4

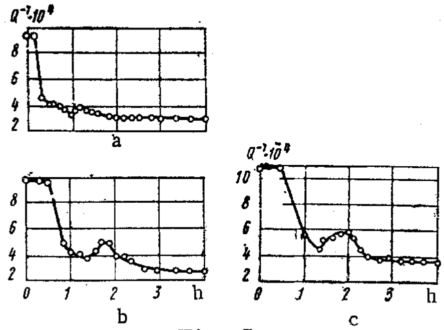

Fig. 5

Fig. 4. Parameters of internal friction of bronzes 2 (solid lines) and 3 (dashed lines) in relation to aging time at 340°C.

Fig. 5. Background of internal friction of beryllium bronzes 1 (a), 2 (b), and 3 (c) in relation to aging time at 340°C. Measured at 340°C.

In the presence of magnesium some metastable precipitates of excess phase evidently change into others, while in standard bronze the change from less stable to more stable precipitates occurs continuously or these precipitates are formed simultaneously but in different microvolumes of the crystals due to the large heterogeneity of decomposition in this alloy. However, these changes in the process of decomposition do not affect the generation of dislocations during loading or the reactions inducing their irreversible movement, since the elastic limits of all the bronzes are higher after aging at 340°C for 2 h than after aging for 1 h (Fig. 3).

CONCLUSIONS

1. Microalloying of beryllium bronze with magnesium and phosphorus changes the character of the amplitude dependences of internal friction in the quenched condition, which is due to a difference in the concentrations and mobility of point defects, depending on the energy of the bond with impurity atoms.

2. For beryllium bronze of the BNT1.9 type there is a correlation between the changes in the basic parameters of internal friction characterizing the increase of resistance to movements of structural defects and the elastic limit.

3. For beryllium bronzes microalloyed with magnesium or with magnesium and phosphorus there is no correlation between the changes in the parameters of internal friction and the elastic limit. Microalloying has a stronger effect in the early stages of aging than in the later stages, since the pinning of structural defects is considerably larger than in standard bronze.

4. Two stages were noted in the process of hardening of beryllium bronzes microalloyed with magnesium and with magnesium and phosphorus. These stages in the increase of the reversible mobility of structural defects are distinguishable after aging at 340°C for 2 h.

LITERATURE CITED

1. Kh. G. Tkhagapsoev et al., "Structure and properties of beryllium bronze microalloyed with magnesium," Metal. i Term. Obrabotka Metal., 2, 19-24 (1970).
2. A. G. Rakhshtadt et al., "Modification of beryllium bronzes with magnesium," Tsvetnye Metally, 6, 58-60 (1970).