An Investigation of the Magnetostriction Constant of MnCu Alloys

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Abstract:

The properties and mechanism of energy dissipation of elastic vibrations MnCu alloys containing less than 50% Mn and its relationship between the crystal and magnetic structures are investigated. It is obtained that the magnetostriction constant, $\lambda=4\times10^4$, is found higher than the corresponding characteristic of thypical ferromagnetic material.

Keywords: *Magnetostriction constant, elastic modulus, alloys, structures.*

MnCu alaşımlarının manyetostriksiyon sabitlerinin incelenmesi

Özet

Bu araştırmada, % 50 den az Mn içeren MnCu alaşımlarının elastik vibrasyonundaki enerji dağılım mekanizmaları ve özellikleri incelenmiş ve bunun kristal ve manyetik yapısı ile ilişkileri incelenmiştir. Bulunan magnetostriction sabitinin ($\lambda=4\times10^4$), tipik demirmanyetik malzemelerinin karakteristiklerine göre daha yüksek olduğu bulunmuştur.

Anahtar Kelimeler: *Magnetostriction sabiti, elastik modül, alaşımlar, yapılar.*

1. Introduction

Alloys of MnCu containing less than 50% Mn in the quenched state have a FCC (Face-centered cubic) structure. The damping property is small in this state, and its level is the same in the entire region of the oscillation amplitudes.

Annealing of these alloys at 400°C with various aging times lead to increased dissipative properties. For example, in Fig.1, data on the effect of annealing on the

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duration of the dissipative capacity G40D60 alloy, which are typical for all alloys with a low manganese content are shown.

At the stage of "tweed" structures [1] dissipative properties increase significantly: value of δ reaches 8%. Dissipative properties dependence on the oscillation amplitude is very weak. The sharp increase in damping properties at this stage of aging is explained by the mechanism of the reorientation axis "c" noninteracting tetragonal precipitates in the field of alternating stresses.

Detected by the electron microscopic method in [2, 3] effect "flikkeringa" on the alloy foils of similar composition due to the dynamic reorientation axis "c" tetragonal precipitates indicates the high degree of probability of such a process. With the increase of annealing time and establishment of correlation between the tetragonal precipitates dissipation capacity of the alloy increases, and there is a strong dependence of the dissipative capacity of the oscillation amplitude. This is due to the increased efficiency of the mechanism of reorientation and shift the region of maximum damping toward larger deformation amplitudes.

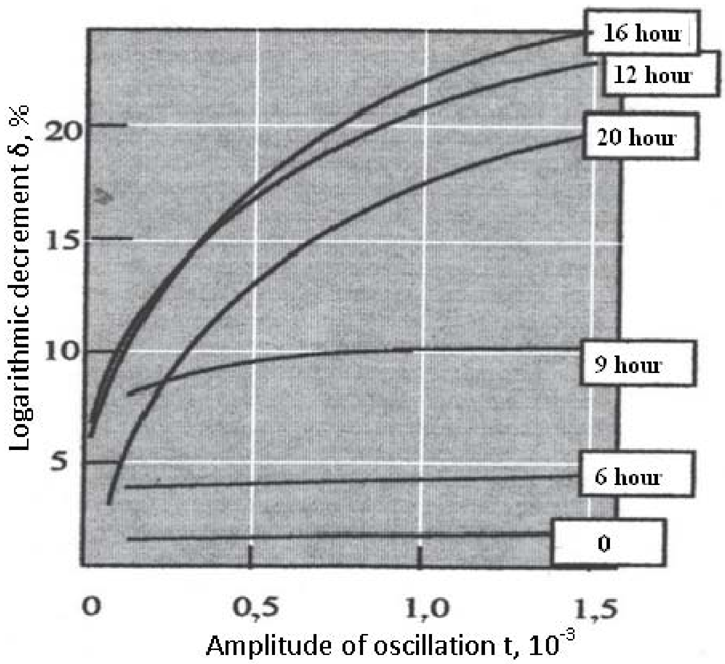

Fig.1. Amplitude dependence of the logarithmic decrement G40D60 alloy in the quenched state and after annealing at a temperature 400 C of varying lengths. Annealing time is indicated by figures.

In the later aging stages when clear quasi twinned microstructure is formed in the alloy dissipation capacity of alloys decreases in the entire region of oscillation amplitudes. This is obviously connected with the difficulty of processes of reorientation axis "c" tetragonal precipitates, since it implies the shifting of boundaries between quasi twins. Border in twin microstructures are less mobile, being fixed by misfit dislocations. Thus, the structure of a dissipative state in low-manganese alloys differed from those of the twin high-manganese alloys. Level of compressive stresses in the above-described "tweed" microstructures is lower, they are more stable

In this regard, it can be expected that low-manganese alloys will have greater temporal stability of damping properties in comparison with high-manganese alloys. In the investigated alloys there is an inextricable link between their crystal and magnetic structures, and hence the dissipation can be described in terms adopted for systems in which the dissipation has magnetoelastic nature.

Indeed, taking place under the action of alternating voltage reorientation axis "c" tetragonal-rich manganese allocation is at the same time reorientation of antiferromagnetic moments of manganese atoms in these secretions. Such a shift, as shown previously [3, 4], gives rise to stresses such as magnetostrictive which is observed in ferromagnetic materials. Consequently, the modulus of elasticity in the areas where the antiferromagnetic ordering takes place, must be lower than paramagnetic areas. By increasing the magnitude of elastic deformation, the elastic modulus decreases. This reduction of modulus is characteristic of ferromagnetic materials known as ΔE-effect [4, 5].

2. Experimental

In the aged alloys of MnCu with "tweed" structure ΔE effect is observed experimentally. The dependence of the elastic modulus on the deformation amplitude for the alloy with 45% Mn content in quenched and aged at 400 ° C conditions are shown in Fig. 2. A significant difference between the amplitude dependence of ΔE values for quenched and aged alloys is seen. For the first paramagnetic alloys, in which there is no deformation of the magnetic component, it is not practically observed, while for the latter expressed clearly.

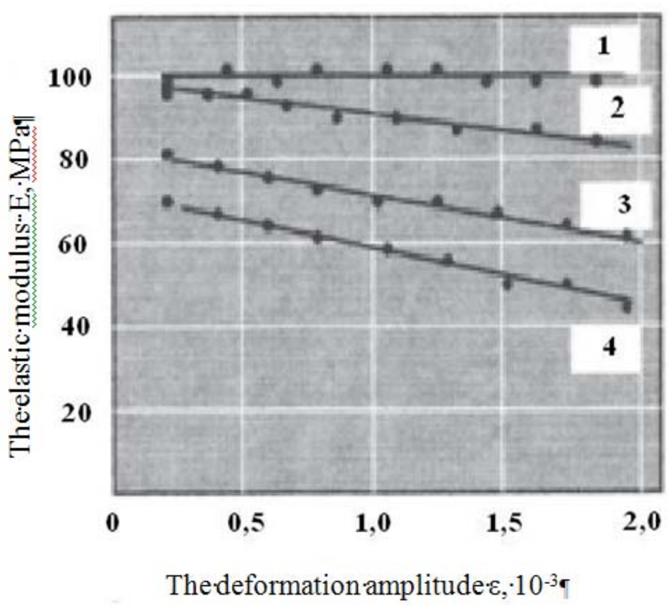

Fig.2. Dependence of the elastic modulus on the deformation amplitude for $Mn_{55}Cu_{55}$ alloy in the quenched state and after annealing at a temperature 400 C during 4(2), 16(3) and 40(4) hours.

Dissipation in ferromagnetic materials, in principle, is a superposition of the three mechanisms. The first two is associated with the existence of microscopic and macroscopic eddy currents, and the second with a magnetomechanical hysteresis. However, as shown by A.W. Cochart [5], in the oscillation frequencies of 1 Hz and a vibration amplitude is greater than 10 ~ 4 the contribution associated with the eddy currents, can be disregarded.

Magnetomechanical hysteresis due to reversible displacement of magnetic domain walls, depends on the oscillation amplitude and does not depend on frequency. Dissipation in heterogeneous alloys of MnCu on the stage of existence of correlated quasi twin structures has such character.

Comparison of experimental data with calculations based on the model A. W. Cochart [5, 6] in which the loop of magnetomechanical hysteresis is considered as complete analogue of the magnetic hysteresis loop, has not led to an agreement of calculated and experimental data (Fig. 3).

Quite a different result was obtained when using the model of C.W. Smith, L.R. Binchak [7], in which the reversible movement of the domain wall in the fields of internal stress sources was considered. It can be seen that in the oscillation amplitudes not exceeding 10^3, the model predictions and experimental data match accurately enough (Fig.3).

3. Results and Discussions

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Another term, widely used for magnetomechanical characteristics of magnetoelastic dissipation is a constant of magnetostriction. For MnCu alloys this constant can be estimated using the following equation [8]:

$$\lambda = \frac{1}{4} V_f \left(\frac{a - c}{c}\right)$$

where V_f - volume fraction of the areas rich in Mn, that have undergone local crystal structure transformation; a and c - the lattice parameters of the tetragonal phase.
Volume fraction Vf may be determined on the base of MnCu alloys phase diagram, namely by the position on it concentration boundaries of immiscibility areas, if the reaction decay will be written as

$$Cu_{55}Mn45 \rightarrow (0,85)Cu_{63}Mn_{37} + (0,15)Cu_5Mn_{95}$$

where the numbers in brackets refer to the proportion of rich and poor areas of Mn. Using experimentally determined values of the lattice parameters, we obtain $\lambda = 3\times10^4$.

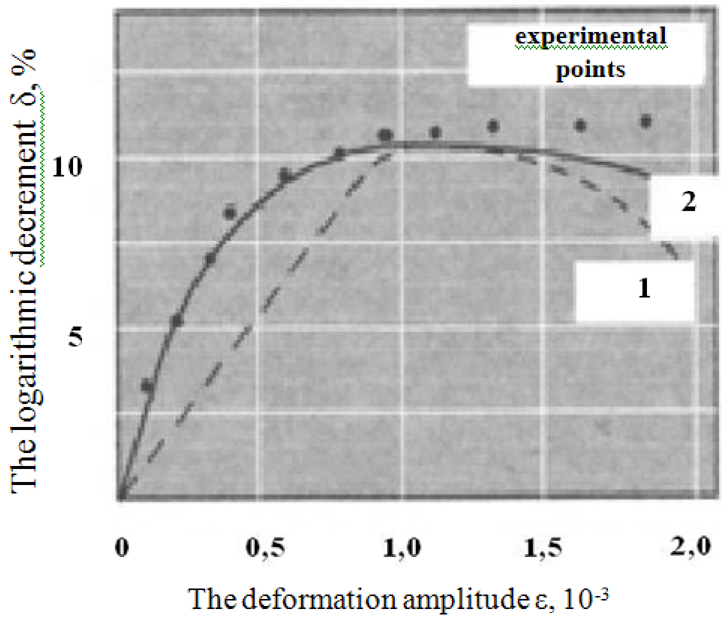

Fig.3. Comparison of experimental data with calculations using models magnetomechanical damping of A.W. Cochart (1) and C.W. Smith, L.R. Birchak (2) for $Mn_{55}Cu_{55}$ alloy.

4. Conclusion

The obtained value of magnetostriction constant lies between the values calculated using models of A.W. Cochart (λ = $1,9\times10^{-4}$), and C.W. Smith, L.R. Bincha ($\lambda=4,6\times10^{-4}$). It should be noted that the magnitude of the magnetostriction constants for alloys of MnCu is about one order higher than the corresponding characteristic of typical ferromagnetic materials, for which $\lambda = 2\text{-}(4\times10^{-5})$.

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