
**REPORTS OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN**

ISSN 2224-5227

Volume 1, Number 1 (2015), 15– 19

**MAGNEOMECHANICAL DAMPING CHARACTER
IN MN-CU ALLOYS**

B. E. Vintaykin¹, T.A. Turmambekov², P.A. Saidakhmetov³, R.T. Abdraimov³, G.N. Kozbakova³
vintaikb@mail.ru, tore_bai@mail.ru, timpf_ukgu@mail.ru, nurmarat75@mail.ru, raha_ukgu@mail.ru

¹Moscow State Technical University named after Bauman, Moscow, Russia;

²Ahmet Yasavi International Kazakh-Turkish University, Turkestan, Kazakhstan;

³M. Auezov South-Kazakhstan State University, Shymkent, Kazakhstan

Key words: dissipative properties, dislocation, elastic modulus, alloys, structure.

Abstract. The properties and mechanism of energy dissipation of elastic vibrations Mn-Cu alloys containing less than 50% Mn and its relationship with the crystal and magnetic structures are considered.

**ХАРАКТЕР МАГНЕОМЕХАНИЧЕСКОГО ДЕМПФИРОВАНИЯ
В СПЛАВАХ Mn-Cu**

**Б. Е. Винтайкин¹, Т. А. Турмамбеков², П. А. Саидахметов³,
Р. Т. Абдраимов³, Г.Н.Козыбакова³**

¹Московский государственный технический университет им. Н. Э. Баумана, Москва, Россия;

²Международный Казахско-Турецкий университет им. Ахмета Ясави, Туркестан, Казахстан;

³Южно-Казахстанский университет им. М. Ауезова, Шымкент, Казахстан

Ключевые слова: диссипативные свойства, дислокации модуль упругости, сплавы, структура.

Аннотация. Рассмотрены свойства и механизм диссипации энергии упругих колебаний в сплавах Mn-Cu с содержанием Mn меньше 50% и их связь с кристаллической и магнитной структурой сплавов.

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

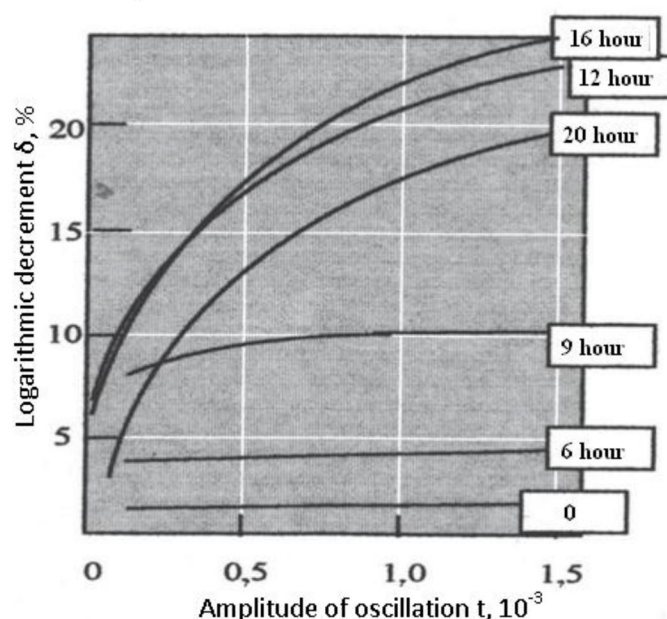


Fig. 1. Amplitude dependence of the logarithmic decrement G40D60 alloy in the quenched state and after annealing at a temperature 400°C of varying lengths. Annealing time is indicated by figures.

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] "flickering" effect 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.

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 of 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].

Notably, in the aged alloys of Mn-Cu 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.

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 third 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.

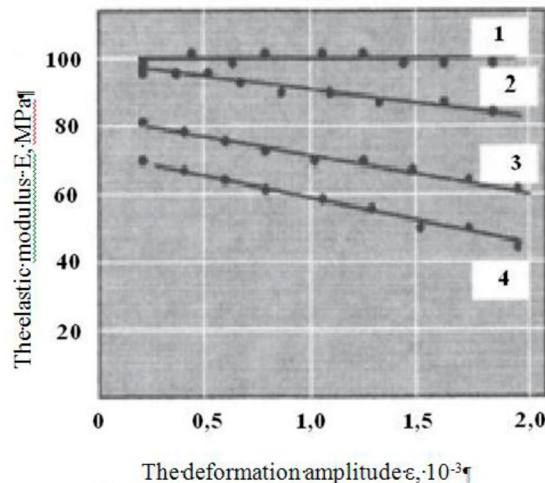


Fig.2. Dependence of the elastic modulus on the deformation amplitude for $Mn_{55}Cu_{45}$ alloy in the quenched state and after annealing at a temperature $400^{\circ}C$ during 4(2), 16(3) and 40(4) hours.

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).

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.

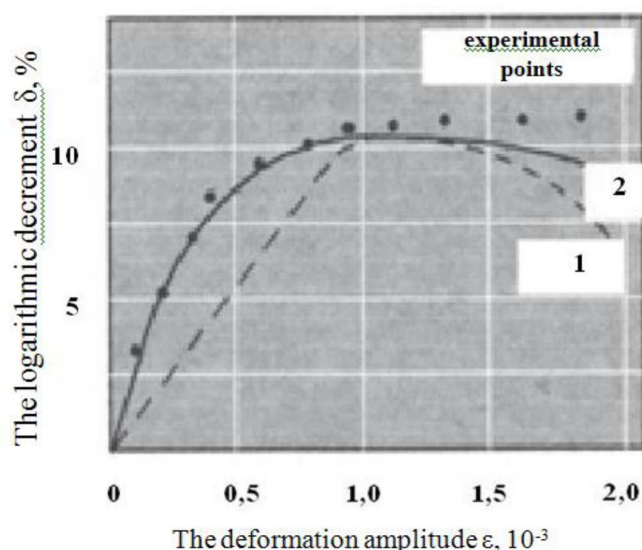
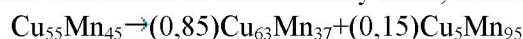


Fig.3. Comparison of experimental data with calculations using models magnetomechanical damping of A.W. Cochart (1) and C.W. Smith, L.R. Birchak (2) for $Mn_{55}Cu_{55}$ alloy.

Volume fraction V_f 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



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 $\lambda = 3 \times 10^{-4}$.

The obtained value of magnetostriction constant lies between the values calculated using models of A.W. Cochart ($\lambda = 1,9 \times 10^{-4}$), and C.W. Smith, L.R. Binchak ($\lambda = 4,6 \times 10^{-4}$). 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 $\lambda = (2 - 4) \times 10^{-5}$.

REFERENCES

- [1] Udovenko V.A., Polyakova N.A., Turmambekov T.A. Structure and damping properties of FCC alloys Mn-Cu. FMM. 1991. №11. p.142-149. (in Russ.).
- [2] Udovenko V.A., Polyakova N.A., Turmambekov T.A. Step process of formation of martensitic structure and damping properties during annealing alloys Mn-Cu. FMM. 1994. V. 77, № 2. p. 134-140. (in Russ.).
- [3] Farkas D.M., Yamashita T., Perkins J. On the energetic of flickering contrast observed in TEM images of an aged 53Cu-45Mn-2Al alloy. Acta met. mat. 1990. Vol. 38, № 10. P. 1883-1995.
- [4] Street R., Smith J. H. Elasticity and Antiferromagnetism of metallic antiferromagnetics. J. de physique et de Radium. 1959, №20. P. 82-87.
- [5] Cochart A. W. Magnetomechanical damping magnetic properties of metals and alloys. American Society for metals, Cleveland, OH. 1959. P. 251-279.
- [6] Cochart A. W. The origin of damping in highstrength ferromagnetic allays. Trans. Of American Soc. Of mechanical Engineers, Journal of:Applied mechanics. 1959. Vol. 75. P. 196-200.
- [7] Smith C. W., Binchak L. R. Internal stress distribution theory of magnetomechanical Hysteresis-An Extention to include Effects of magnetic Field and applied stress. J.of applied phys. 1969. Vol. 40, № 13. P. 5174-5178.
- [8] Laddha S., Van Aken D. C. On the application of magnetomechanical models to Explain Damping in an antiferromagnetic Coppermagness Allay. Metallurgical and material transaction A. 1995. Vol. 26. P. 957-964.

Mn-Cu ҚОРЫТПАСЫНДАҒЫ МАГНИТТІ МЕХАНИКАЛЫҚ ДЕМПИРЛЕНУДІҢ СИПАТТАМАСЫ

Б. Е. Винтайкин¹, Т. А. Турмамбеков², П. А. Саидахметов³, Р. Т. Абдраимов³, Ғ.Н.Қозыбақова³

¹ Н. Э. Бауман атындағы Мәскеу мемлекеттік техникалық университеті, Мәскеу, Ресей;

² А. Ясауи атындағы Халықаралық Қазақ-түрік университет, Түркестан, Қазақстан;

³М. Әуезов атындағы Оңтүстік Қазақстан мемлекеттік университеті, Шымкент, Қазақстан

Тірек сөздер: шашырау қасиеттері, дислокациялар, серпімділік модуль, қортпалар, құрылым.

Аннотация. Құрамында 50 %-дан кем Марганец бар Mn-Cu қорытпасындағы серпімді тербеліс энергиясының шашырау механизмі және қасиеттері қарастырылады, және бұл қасиеттердің қорытпаның кристалдық және магниттік құрылыммен байланыс қарастырылады.

Винтайкин Евгеньевич, профессор	Борис ф.-м.ғ.д.	Винтайкин Евгеньевич, профессор <i>Московский государственный технический университет им. Н.Э.Баумана, Москва, РФ</i>	Борис д.ф.-м.н.	Vintaykin Boris Evgenevich d.p.s.-m. Professor N. Bauman Moscow State Technical University, Moscow	vintaikb@mail.ru
Турмамбеков Абдрахманович профессор Қ.А. Ясауи Халықаралық қазақ-түрік университеті	Төребай ф.-м.ғ.д.	Турмамбеков Абдрахманович профессор Международный казахско- турецкий университет имени Х.А.Ясауи	Төребай д.ф.-м.н.	Turmambekov Abdrakhmanovich d.p.s.-m. Professor International Kazakh- Turkish university of the name H.A. Yesevi	tore_bai@mail.ru
Саидхметов Аблатыевич кафедра менгерушісі М.Әуезов Оңтүстік Қазақстан мемлекеттік университеті	Полат ф.-м.ғ.к.	Саидхметов Аблатыевич зав.кафедра Южно-Казахстанский государственный университет имени М.Ауезова	Полат к.ф.-м.н.	Saidahmetov Polat Ablatyevich c.p.s.-m. Head of Department South-Kazakhstan state university of the name M.Auezov	timpf_ukgu@mail.ru
АБДРАИМОВ Рахымжан Турисбекович физика магистрі, М.Әуезов Оңтүстік Қазақстан мемлекеттік университеті		АБДРАИМОВ Рахымжан Турисбекович магистр физики, Южно-Казахстанский государственный университет имени М.Ауезова		Abdraimov Rakhymjan, master's degree of physics, South-Kazakhstan state university of the name M.Auezov	Raha_ukgu@mail.ru
Нұрруллаев Амангельдиевич М.Әуезов Оңтүстік Қазақстан мемлекеттік университеті	Марат	Нұрруллаев Амангельдиевич Южно-Казахстанский государственный университет имени М.Ауезова	Марат	Nurrullaev Marat Amangeldievich South-Kazakhstan state university of the name M.Auezov	nurmarat75@mail.ru

Поступила 18.01.15 г.