

Features of the damping capacity of Mn – Cu alloys

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Abstract. Data on the damping capacity of Mn – Cu alloys are adduced. The results of studying the influence of alloying elements, natural ageing at temperatures of 293 K, 273 K and 263 K on the stability of the damping capacity of Mn – Cu alloys are presented. The high damping capacity of Mn – Cu alloys decreases by 4 ... 6 times during natural ageing at 293 K, remains during 1,7 years of natural ageing at 273 K and 263 K. The analysis of factors that should be considered responsible for a sharp decrease in the damping capacity of Mn – Cu alloys during natural ageing is submitted.

1 Introduction

The development of modern industrial production is associated with an increase in the speed of movement of parts of mechanisms and machines, which cause vibrations and noise. Mn – Cu alloys can effectively dissipate vibrations and noise, since they have a high damping capacity at small (relative scattering, $\psi = 3 \dots 6 \%$) and large (relative scattering, $\psi = 30 \dots 50 \%$) amplitudes of deformation and have good mechanical properties (tensile strength, $\sigma_b = 380 \dots 550$ MPa; relative elongation, $\delta = 20 \dots 30 \%$) [1–4].

The high damping capacity of Mn – Cu alloys is associated with the movement of twins of the martensitic f.c.t. phase, obtained as a result of the martensitic f.c.c. – f.c.t. transformation (f.c.t. – face-centered tetragonal; f.c.c. – face-centered cubic). The results of some studies show, that spinodal decomposition occurs in Mn – Cu alloys with the formation of microsegregations of two isomorphic phases with f.c.c. lattices, which are enriched in manganese and copper [5–7]. During cooling from the ageing temperatures of 673 ... 733 K the microsegregations enriched in manganese serve as the fetus of the martensitic f.c.c. – f.c.t. transformation. According to some authors, the high damping capacity of Mn – Cu alloys depends not only on the density of the twinned plexuses, but also on their mobility [4, 8]. However, it was determined that the high damping capacity of Mn – Cu alloys, obtained by optimal heat treatment, significantly decreases after natural ageing at a temperature of 293 K [4, 9]. It's assumed that the decrease in the damping capacity of Mn – Cu alloys during natural ageing is caused by a decrease in internal stresses in martensite, point defects in the crystal structure, atoms of impurity elements [4, 9–12].

The influence of these factors on the reduction of the damping capacity of Mn – Cu alloys has not been sufficiently studied. Therefore, in this paper, a study of the magnitude

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and stability of the damping capacity of Mn – Cu alloys during natural ageing at temperatures 293 K, 273 K, 263 K is conducted, and also an analysis of the influence of internal stresses in martensite, point defects and atoms of impurity elements on a decrease the damping capacity of Mn – Cu alloys is implemented.

2 Experimental procedures

The chemical composition of the studied Mn – Cu alloys is provided in Table 1. Electrolytic manganese, cathodic copper, alloying elements in the form of copper ligatures were used as a charge material. Ingots weighing 5 kg were annealed at temperatures of 1103 K for 3 hours and rolled in the hot state into strips with a thickness of 10 mm, from which cylindrical samples of 7,7 mm in diameter and 115 mm were obtained. The samples were heated to 1093 K in an argon atmosphere, kept for 2 hours and quenched in water.

The damping capacity of Mn – Cu alloys (the logarithmic decrement of attenuation of oscillations) was studied at the transverse oscillations of the samples on the installation «Elastomat» in the frequency range of 1,6 ... 2,2 kHz and the amplitudes of the relative shift $(1 \dots 3) \cdot 10^{-6}$. The relative scattering ψ (attenuation) was determined by the formula (1):

$$\psi = 2\delta \cdot 100\%, \quad (1)$$

where δ is the logarithmic decrement.

The measurement error by this method was 2 ... 4 %.

The phase composition of Mn – Cu alloys was analyzed on diffractometer «Dron – 2,0» at a voltage of 30 kV. Diffractograms were made in Cu – $K\alpha$ radiation.

Table 1. The composition of Mn – Cu alloys

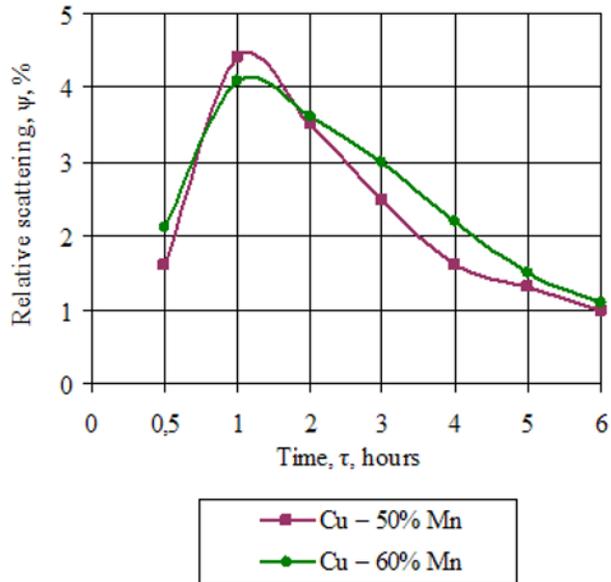
Content of elements, wt. %											
Nominal manganese content, %	Mn	Cu	Fe	Ni	Al	Ti	Zn	Ga	C	N	H
50	48,52	51,48							0,06	0,028	0,0008
50	49,70	49,80						0,50			
50	49,40	50,00	1,10	1,10	1,10				0,07	0,04	0,0012
60	59,40	40,10									
60	58,62	40,38					1,00		0,06	0,015	0,0009
60	59,74	39,56				0,70			0,06	0,041	0,0006

Studies of the damping capacity of Mn – Cu alloys in the range of small amplitudes of the relative shift ($< 2 \cdot 10^{-5}$) first of all were performed on double alloys with a manganese content of 50% and 60%. Small amounts of iron, nickel, aluminum, zinc and gallium were used as alloying elements, which are employed in high-damping alloys to improve their damping ability, physical, mechanical and technological properties [4–11]. The used amounts of the listed elements ensured their solubility in a γ -solid solution Mn – Cu.

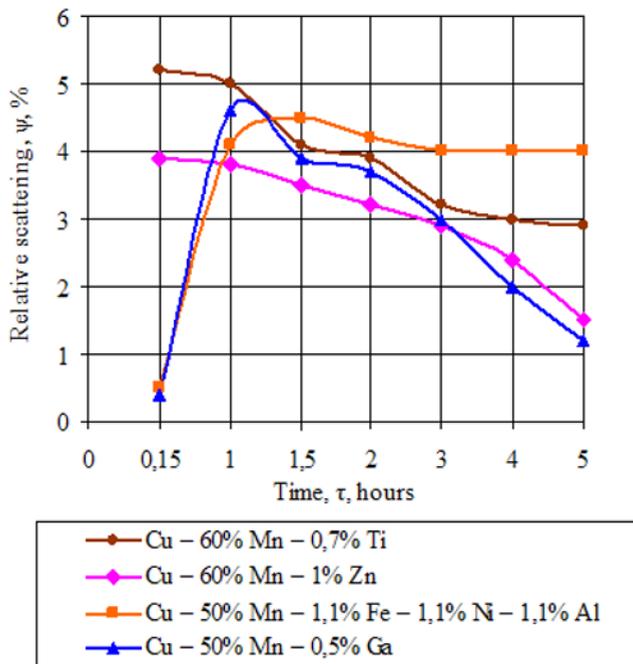
3 Results and discussion

The dependences of the damping capacity of Mn – Cu alloys quenched with 1093 K in water on the ageing time at 723 K for 5 hours are shown in Fig. 1. It can be seen that the addition of 0,7% Ti or 1,0% Zn to the Cu – 60% Mn alloy reduces the ageing time to reach the maximum damping capacity from 1 hour to 0,4 hours. The addition of 1,1% Fe, 1,1% Ni and 1,1% Al to the Cu – 50% Mn alloy shifts the maximum damping capacity of this alloy towards a longer aging time at 723 K from 1 hour to 1,5 hours. Consequently, the additives of Ti and Zn in concentrations of 0,7% and 1,0%, respectively, contribute to the

decomposition of the γ -solid solution Mn – Cu by the spinodal mechanism into microsegregations enriched and depleted in manganese, and the complex alloying with Fe, Ni and Al in concentrations about 1,0% of each element holds back this process. An increase in the ageing time of the studied alloys to 6 hours at 723 K causes a decrease in the damping capacity associated with the release of the stable phase α -Mn.



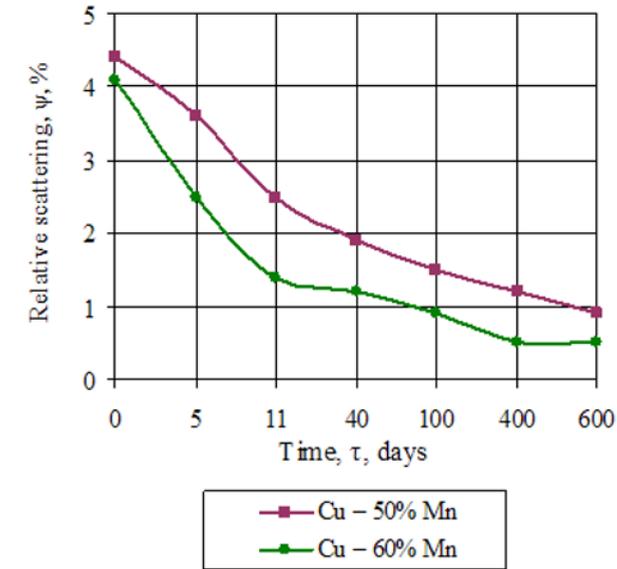
a



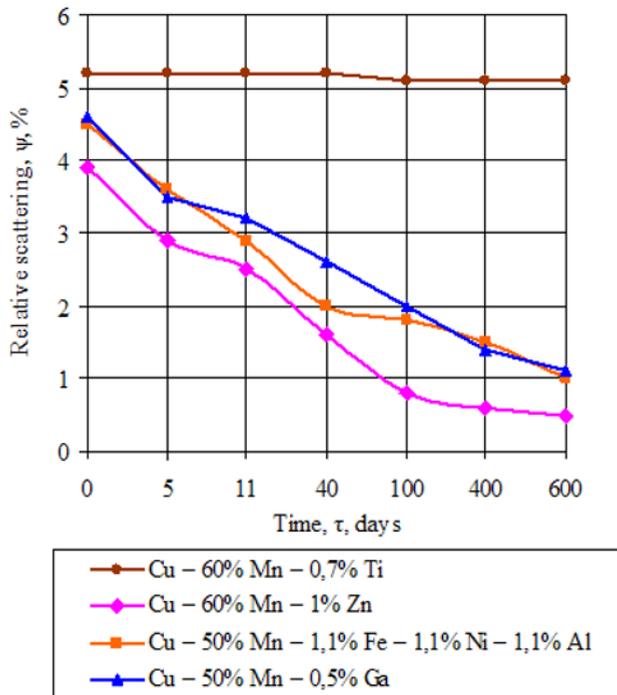
b

Fig. 1. The dependence of the damping capacity, ψ , of double (a) and alloyed (b) Mn – Cu alloys

quenched with 1093 K in water on the ageing time, τ , at 723 K for 5 hours



a



b

Fig. 2. The dependence of the damping capacity, ψ , of double (a) and alloyed (b) Mn - Cu alloys on the ageing time, τ , at 293 K for 600 days

The study of the stability of the damping capacity of the studied alloys during natural ageing was performed at temperatures of 293 K, 273 K and 263 K (Fig. 1, Fig. 2). In Fig. 2

it's seen that the high damping capacity of Mn – Cu alloys decreases by 3 ... 4 times after natural ageing at a temperature of 293 K for 50 days. Fig. 3 shows that the high damping capacity of double and alloyed Mn – Cu alloys does not decrease during natural ageing at 273 K and 263 K for 1,7 years.

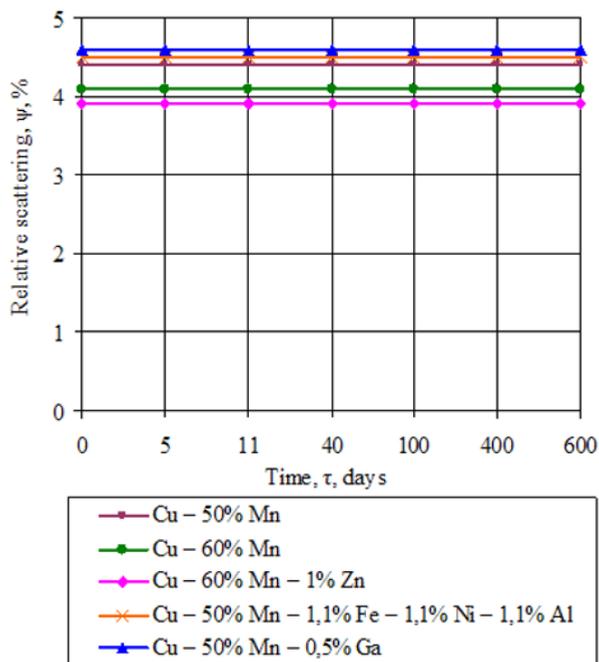


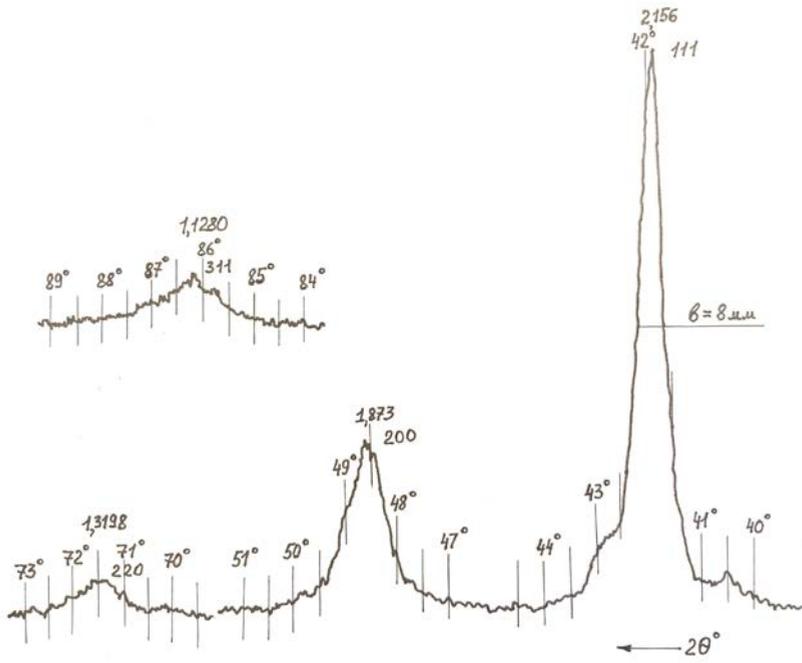
Fig. 3. The dependence of the damping capacity, ψ , of double and alloyed Mn – Cu alloys on the ageing time, τ , at 273 K and 263 K for 600 days

The addition of 0,7% Ti to the Cu – 60% Mn alloy significantly increases the stability of the damping capacity of this alloy. The high damping capacity of this alloy is preserved at the temperature of natural ageing 293 K for 1,7 years.

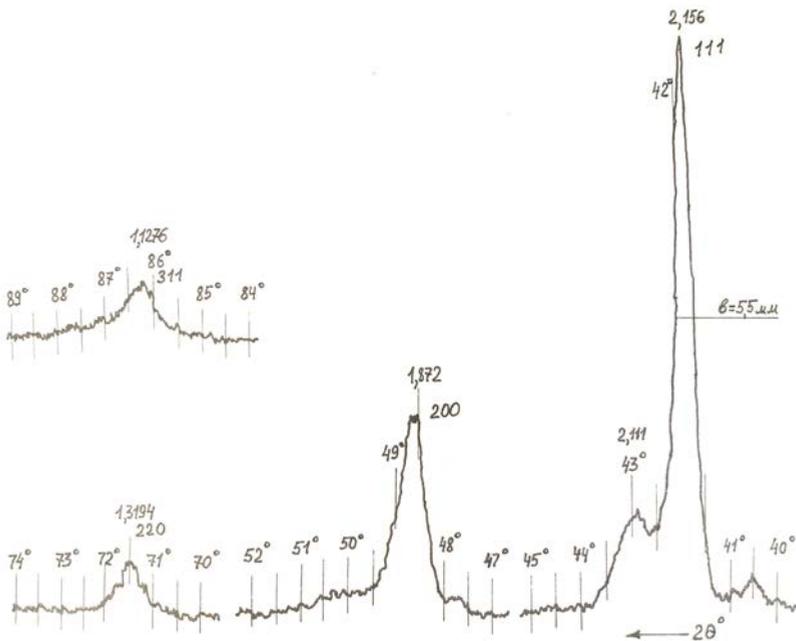
Changes in the structure of Mn – Cu alloys occurring during natural ageing at 293 K were studied by X-ray diffraction analysis. Fragments of diffractograms of a Cu – 50% Mn – 0,5% Ga alloy sample with a low damping capacity after natural ageing at 293 K for 8 months and a high damping capacity restored by heating to 573 K and cooling in air are adduced in Fig. 4. The diffractograms show that in a sample with a low damping capacity, the width of the X-ray spectrum lines at half the height is approximately 1,5 times greater than in a sample with a high damping capacity. A sample with a low damping capacity has slightly larger crystal lattice parameters. Probably, the broadening of the X-ray lines in the diffractograms of the Cu – 50% Mn – 0,5% Ga alloy sample is associated with elastic distortions in the crystal lattice of the martensitic f.c.t. phase. In addition, a sharply isolated (114) peak of α – Mn phase is revealed in the diffractogram of the sample with a restored high damping capacity. The diffractogram of a sample with a low damping capacity doesn't clearly show this peak, since it's embedded in the base of the (111) line of the γ -solid solution Mn – Cu. Consequently, heating the sample with a low damping capacity to a temperature of 573 K and subsequent cooling in air leads to the formation of the α - Mn phase.

It's known that the damping capacity of Mn – Cu alloys at small amplitudes of deformation is due to a structure saturated with defects and imperfections in a metastable unrelaxed state [2]. Any relaxation process reduces the level of damping capacity. A

number of studies have shown that the dissipation of the energy of mechanical vibrations in Mn – Cu alloys is associated with the movement of the twinned boundaries of the martensitic phase and is unstable during natural ageing [2, 5].



a



b

Fig. 4. Fragments of diffractograms of the Cu – 50% Mn – 0,5% Ga alloy: a) after heat treatment for

high damping capacity and natural ageing at 293 K for 8 months; b) after natural ageing at 293 K for 8 months and heated to 573 K with subsequent cooling in air

Some researchers attribute the decrease in the damping capacity of Mn – Cu alloys during natural ageing to the formation of subdomains that inhibit the movement of the boundaries of doubles of the martensite phase [10]. The authors of [2] believe that the decrease in the damping capacity of Mn – Cu alloys is caused by the interaction of the twinned boundaries with the atoms of the impurity elements of the introduction.

It follows from the results of work [11] that the high damping capacity of Mn – Cu alloys is due to the high stresses between the f.c.c. and f.c.t. phases. According to the authors, alloying the Cu – 70% Mn alloy with Fe, Ni and Al in a total amount of up to 5% reduces the difference in the volume mismatch of the f.c.c. and f.c.t. phases and should contribute to obtaining a material with stable damping properties [11]. The study [9] notes that alloying Mn – Cu alloys with various elements reduces the stability of the damping capacity of Mn – Cu alloys during natural ageing. The results of this study (Fig. 2) show that the damping capacity of the Mn – 50% Cu – 1,1% Fe – 1,1% Ni – 1,1% Al alloy decreases with natural ageing, almost similar to the decrease in the damping capacity in the Mn – 50% Cu alloy. The obtained result of the damping capacity of Mn – Cu alloys in the time of natural ageing indicates that a decrease in the difference in the volume mismatch of the f.c.c. and f.c.t. phases doesn't contribute to the preservation of a high damping capacity in these alloys.

Let us consider the influence of subdomains and impurity elements of the introduction on the damping capacity of Mn – Cu alloys. Possibly, these factors responsible for reducing the damping capacity of Mn – Cu alloys are related. Arguably, the formation of subdomains is caused by the deposition of impurity elements of the introduction at the boundaries of twins of the martensite phase. Apparently, impurity elements of the introduction will be the leading factor that leads to the damping capacity of Mn – Cu alloys.

It's known that impurities of carbon very sharply reduce the stability of the damping capacity of Mn – Cu alloys over time [10]. In steels with a content of 0,05...0,07% carbon after quenching, a rapid decrease in the damping capacity occurs during the storage time at 293 K, and alloying with titanium leads to the preservation of the damping capacity of steels for a long time of storage [13]. The interaction of nitrogen and carbon, nitrogen with dislocations in low – carbon steels and β -alloys of the Cu – Zn system is noted [14]. Alloying Mn – Cu alloys with titanium, as well as in low – carbon steels, stabilizes the level of damping capacity of these alloys over time. The use of negative storage temperatures delays the decrease in the damping capacity of low – carbon steels [15] and Mn – Cu alloys over time. The analysis of the content of impurity elements of the introduction in the studied alloys showed that the average content (wt.%) of carbon is 0,06%, nitrogen is 0,028% and hydrogen is 0,00087%. It's obvious that the impurity atoms of carbon and nitrogen make the greatest contribution to the reduction of the damping capacity of Mn – Cu alloys.

4 Conclusions

The study showed that the high damping capacity of Mn – Cu alloys, obtained after quenching from 1093 K with holding for 2 hours and ageing at 723 K, decreases 4 ... 6 times for 1,7 years of natural ageing at 293 K. Alloying of Cu – 60% Mn alloy with 0,7% titanium retains its high damping capacity during natural ageing at 293 K for 1,7 years was determined. The high damping capacity of Mn – Cu alloys does not decrease during 1,7 years of natural ageing at 273 K and 263 K was found. Impurity carbon and nitrogen atoms are obviously the main factor causing a decrease in the high damping of Mn – Cu alloys during natural ageing.

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