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PRODUCTION OF DISSIPATIVE ALLOYS WITH MINIMUM ALLOY

Abstract. The paper provides a literature review on the mechanisms of damping in alloys. The goal of the authors was to obtain the maximum damping with the minimum alloying. Samples of alloys in cast, annealed and quenched form were investigated. According to the research findings, the characteristics of the damping properties of the alloys are provided and the possible reasons for the high values of the damping parameters are explained. An analysis of the nature of non-metallic inclusions shows that very small non-metallic inclusions do not result in high damping. A very high content of medium-sized non-metallic inclusions leads to low sound emission. High alloying with elements such as Mn, Ni, Nb, Al, one percent each, 1.5% Cr, 1.5% V, 0.5% Mo, 0.5% Ti, 0.5% Cu, does not always provide increased damping properties.

Keywords: alloying, damping properties, microstructure of the alloy, sound emission, non-metallic inclusion.

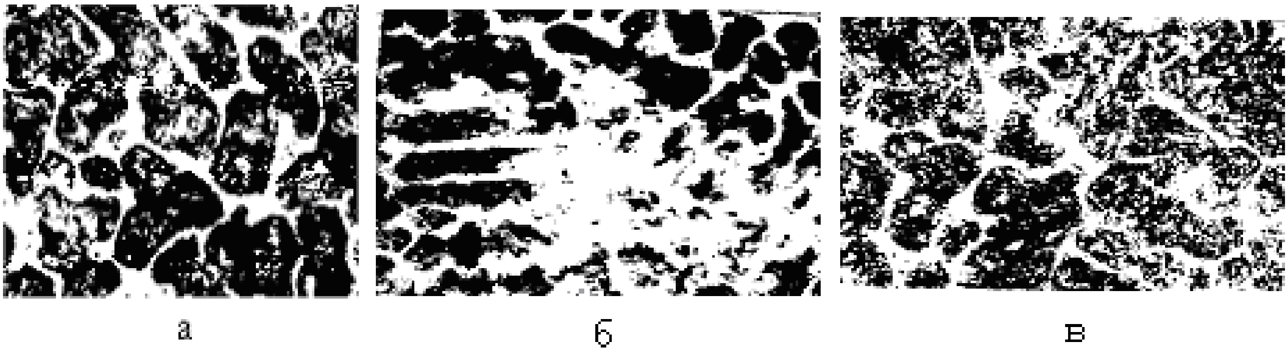
Introduction. The authors set the goal of obtaining maximum damping with minimum alloying [1]. The authors investigated alloys 133, 134, 172, 174, 132, 137, 126, 135 in cast, annealed and quenched forms. Figure 10 shows the microstructure of alloy 133. Damping properties of alloy 133 L_A = 83,6 дБА, $V_{сзз}$ = 700 дБА/С, $\delta=3\cdot10^2$. The alloy is complex alloyed (1,5% Mn; 1,0% Ni; 1,5% Cr; 1,5% V; 0,5% Nb; 0,5% Mo; 0,5% Ti; 1,0% Al; 0,5% B; 0,5% Cu).

Methods. Samples for the study of damping properties were cut from forged strips. The surface finish after machining corresponded to class 5. Forged samples were milled, planed, cut, and polished. The deviations of the specified dimensions (50x50x5 mm) did not exceed 0.2 mm. The acoustic (sound level, sound pressure levels) and vibration properties (the level of vibration acceleration and the level of vibration velocity) were determined after forging, then the same samples were subjected to annealing, normalization, quenching, and low tempering. Annealing mode – heating up to Asz + 50°C, holding for 0.5 hours, furnace cooling. Normalization was carried out according to the following regime: heating to Asz + 50°C, holding for 0.5 hours, air cooling. Quenching was carried out according to the following regime: heating to Asz + 50°C, holding for 0.5 hours, water cooling. At low heating tempering, the hardened steel was up to 200-250°C and cooled in water. Heating and holding during quenching, normalization and annealing were carried out in quartz ampoules in vacuum with a discharge of 10^{-3} atm.

Results. Figure 1 shows that in the as-cast condition, the structure is ferrite with pearlite. Complete annealing of the cast sample leads to grain refinement, Figure 10 (b), since recrystallization has occurred. A new grain has formed. Due to the refinement of the pearlite-ferrite grain, the damping properties decreased. After quenching (heating up to Asz + 50°C, cooling in oil) the structure of the alloy is trostomartensite.

Building of this alloy with manganese (1.5%), nickel (1.0%), chromium (1.5%) provided high values of the decay rate and logarithmic decrement. But the sound emission (L_A) of this alloy is very high – 83.6 dBA, which suggests that alloying with manganese, nickel, chromium, vanadium in the selected proportions does not guarantee a low-noise alloy.

Alloy 134 contains a small amount of alloying elements (Si, Ni, V, Nb, Ti, B), with 2.04% Mn; 1.92% Cr; 1.07% Mo; -1.0% Al; 1.5% Ca; 1.5% La. This structure provided the lowest LA value (72.1 dBA) and the average Vsz and δ values. The low value of sound emission is caused by the presence of large non-metallic inclusions [1].



Microstructure of alloy 133 in cast (a), annealed (b) and quenched (c) conditions. x250 [1]

Alloy 172 contains 1.10% Si; 1.33% Mn; 0.75% Ni; 1.11% Cr; 0.92% V; 0.34% Mo; 0.93% Ti; 1.5% Al; 1.0% La. The alloy is characterized by very high damping properties (sound decay rate, logarithmic decrement), but the sound emission is 82.8 dBA, which does not classify this alloy as low-noise.

The reason for the high damping properties of the alloy is the high content of non-metallic inclusions 9.796x10-2.

Alloy 174 (0.10% C; 1.05% Si; 1.0% Nb; 1.5% A1; 0.7% La) is characterized by the following damping properties: L_A = 84.3 dBA; Vszz = 140 dBA/s, δ = 0.0116. The content of nonmetallic inclusions in the alloy is very high ($7{,}593 \text{x} 10^{-2}$), but analysis of the nature of these inclusions shows that these are mainly very small nonmetallic inclusions that do not provide high damping [1].

Alloy 132 (2.26% Mn; 1.78% Mo; 1.0% Al) is characterized by the following properties: L_A = 74.3 dBA; Vszz = 628 dBA/s, δ = 0.0228. The content of non-metallic inclusions is very high ($7{,}273 \text{x} 10^{-2}$), which guarantees low sound emission (non-metallic inclusions of medium size).

Alloy 137 (one percent Mn, Ni, Nb, Al, 1.5% Cr, 1.5% V, 0.5% Mo, 0.5% Ti, 0.5% Cu) is complex alloyed, but damping properties it is not high (L_A = 83.7 dBA, δ = 0.013, Vsz = 261 dBA/s). The findings of the study of this alloy show that high alloying with the indicated scarce elements does not always provide an increase in damping properties [1].

Alloy 126 (1.0% Nb; 0.72% Mo; 0.73% Ti; 1.5% Al; 1.0% Ca; 0.5% La; 0.76% Cr; 0.58% Ni ; 0.73% V) is characterized by the following damping properties: L_A = 80.7 dBA, δ = 0.026, Vcz = 533.3 dBA/s. The content of non-metallic inclusions is average ($4.526 \cdot 10^{-2}$). The structure of the alloy consists of a mixture of ferrite and pearlite with some content of non-metallic inclusions.

Discussion. Scientists and specialists have already proven that varying the chemical composition can significantly affect the vibro-acoustic properties of metallic materials [2-17].

The composition and structure of metallic ferromagnetic materials play a decisive role in the magneto-mechanical damping of MMD mechanical vibrations [18]. Methods of metallographic analysis, powder figures, a torsion pendulum, X-ray diffraction analysis were used to study the effect of crystal and magnetic structures on the magneto-mechanical damping (MMD) of Fe alloys of various compositions. The effect on the MMD of the grain size, the clarity of the powder figures on the sample surface (the energy density of the domain boundaries), and the degree of crystalline anisotropy was demonstrated. The features of the crystal and magnetic structures for Fe alloys with a high MMD are reviewed. The assumption about the connection of the maximum of the MMD on its dependence on the amplitude of deformation with the transformation of the magnetic structure of the A B type [19].

The features of the formation of a high-damping state of α-solid solutions of the Fe-16Cr type have been investigated by the methods of thermal neutron refraction, magnetometry, X-ray diffraction, electron microscopy, amplitude-dependent internal friction and small-angle neutron scattering. It was demonstrated that the high-damping condition of the investigated materials is characterized by both an optimal combination of internal stress levels, reversal magnetization losses, coercive force, and the formation of a specific fine domain structure, characterized by an increased fraction of 900 magnetic domains neighborhoods. The dependence of the damping capacity on the average size of the domain h_d is described by a smooth curve with a maximum in the region of h_d 7-9 μm [20].

Mn-Cu binary alloys quenched from the high-temperature γ-region with a content $C_{Mn}^{кр} \geq 80\%$ have a complex of unique physical and mechanical properties: high damping [21]. This is a consequence of the occurrence in them of a low-temperature fcc-fct transition of the martensitic type, which is closely correlated with the antiferromagnetic ordering of the atomic magnetic moments of manganese. Aging at $300^0 < T < 500^0$, due to the presence of a metastable region of separation into two isomorphic γ-solid solutions of different concentrations, has a significant effect on the course of this process in Mn-Cu alloys.

In [22], the structure and damping properties of Mn-Cu alloys with 50-85% Mn in the state quenched from the homogeneity region of the γ-phase and annealed to metastable equilibrium at 400 and 4500 C. Features of the fine structure of the martensite of these alloys, caused by the spinodal character of the decomposition. A structural mechanism of the formation of a high-damping state in Mn-Cu alloys is proposed.

The propagation of acoustic waves in polycrystals is accompanied by the effects of amplitude-dependent internal friction (ADIF). This phenomenon leads to a dependence of the attenuation and propagation velocity of an acoustic wave on its amplitude and in many cases is due to the motion of dislocations. The author in [23] presents the results of experimental and theoretical studies of nonlinear acoustic effects of internal friction in rods made of technical lead: amplitude-dependent losses and resonance frequency shift, nonlinear sound decay on sound and nonlinear limitation of the wave amplitude. The discovered effects are described within the framework of phenomenological equations of state containing elastic and dissipative nonlinearities.

Conclusion. Among the investigated alloys 133, 134, 172, 174, 132, 137, 126, 135 with the best damping indices, there was alloy 132 (2.26% Mn; 1.78% Mo; 1.0% Al), which is characterized by the following properties: L_A = 74.3 dBA; Vszz = 628 dBA/s, δ = 0.0228. Here, the content of non-metallic inclusions of medium size is very high ($7,273x10^{-2}$), which guarantees a low sound emission.

It was also revealed that according to the results of the study of alloy 137 (one percent of Mn, Ni, Nb, Al, 1.5% Cr, 1.5% V, 0.5% Mo, 0.5% Ti, 0.5% Cu), which is complexly alloyed, its damping properties are low (L_A = 83.7 dBA, δ = 0.013, Vcz = 261 dBA/s). This shows that high alloying with the indicated deficient elements does not always provide an increase in damping properties.

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КІШІГІРІМ ЛЕГІРЛЕУ КЕЗІНДЕ ДИССИПАТИВТІ ҚОРЫТПАЛАРДЫ АЛУ

Аңдатпа. Мақалада қорытпалардағы демпферлеу механизмдері бойынша әдеби шолу өткізілді. Мақала авторларының мақсаты қорытпаны аз ғана легірлеу арқылы максималды демпферлеу әсерін алу болып табылады. Құйылған, жасытылған және шыңдалған қорытпалардың үлгілері зерттелді. Зерттеу нәтижелері бойынша қорытпалардың демпферлеуші қасиеттеріне сипатталар берілді және жоғары демпферлеу параметрлерінің мүмкін пайда болу себептері түсіндірілді. Бейметалл қосылыстардың сипатын талдау өте ұсақ бейметалл қосылыстар жоғары демпферлеуді қамтамасыз етпейтінін көрсетті. Орта өлшемді бейметалл қосылыстардың жоғары құрамы төмен дыбыс шығаруға алып келеді. Бір пайыз көлемінде Mn, Ni, Nb, Al элементтерімен, 1,5% Cr, 1,5% V, 0,5% Mo, 0,5% Ti, 0,5% Cu элементтермен жоғары легірлеу жоғары демпферлеуші қасиеттерді әрдайым қамтамасыз ете алмайды.

Негізгі сөздер: легірлеу, демпферлеуші қасиеттер, қорытпаның микроқұрылымы, дыбыс шығару, бейметалл қосылыс.

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ПОЛУЧЕНИЕ ДИССИПАТИВНЫХ СПЛАВОВ ПРИ МИНИМАЛЬНОМ ЛЕГИРОВАНИИ

Аннотация. В статье проведен литературный обзор по механизмам демпфирования в сплавах. Целью авторов являлось получение максимального демпфирования при минимальном легировании сплавов. Исследовались образцы сплавов в литом, отожженном и закаленном виде. По результатам исследования предоставлены характеристики демпфирующих свойств сплавов и объяснены возможные причины высоких значений параметров демпфирования. Анализ характера неметаллических включений показывает, что очень мелкие неметаллические включения не обеспечивают высокое демпфирование. Очень высокое содержание неметаллических включений среднего размера ведет к низкому звукоизлучению. Высокое легирование такими элементами как Mn, Ni, Nb, Al, по одному проценту, 1,5% Cr, 1,5% V, 0,5% Mo, 0,5% Ti, 0,5% Cu, не всегда обеспечивает повышение демпфирующих свойств.

Ключевые слова: легирование, демпфирующие свойства, микроструктура сплава, звукоизлучение, неметаллическое включение.