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High Damping Mn-Cu Alloy with Microcrystalline Structure

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Abstract.
By the internal friction method the relaxation phenomena in Mn75Cu25 alloy type are studied. It's shows that the microcrystalline structure metal alloys produced by the method of rapid quenching possess have unique properties. It is proved that the specimens after applying certain aging conditions have high damping properties exceeding several times those of macro specimens made of the same alloy or subjected to quenching and subsequent tempering.

Keywords: high damping alloys, internal friction, Mn-Cu alloy, micro crystalline structure, rapid quenching.

1. Introduction

Currently, in machine building and electronic industries, alloys of extremely high damping abilities under external low frequency loads are developed [1, 2]. The most promising for the moment are the manganese alloys. However, they are economically unfavorable and because of their high flammability their processing requires special installations and protection means [3, 4]. Therefore, the manganese copper based alloys find today more and more applications in practice as alloys of high damping.
The purpose of the present paper is to examine the damping properties of Mn-Cu copper alloy and determine the effects of the preparation process and heat treatment on them.

2. Materials and method

Object of investigation is the alloy Mn75Cu25 known in publications as high damping one. Specimens are prepared of that alloy by the method of rapid quenching. They have the shape of a band, practically of unlimited length, about 10 mm width and 60 μm thickness. They are prepared at casting temperature of 1410^{0}C by means of a rotor stand with a massive drum for rapid quenching, at rotor rotation speed of 1050 rev/min.
Solid specimens of the same alloy prepared by standard process, casting and rolling, are also tested.
The specimens are treated in standard conditions of heat treatment comprising quenching after 10 min holding at temperature of 800^{0}C and aging for 2 hours at 400^{0}C. Another part of the band specimens with microcrystalline structure are subjected only to two hours of aging at 400^{0}C after their preparation by rapid quenching.
It is known that besides the electrodynamics balance method [7], measuring only stress relaxation in specimens at static loads, the method of internal friction is the basic one to verify the damping properties of certain alloy in the low frequency range of mechanical vibrations [10]. The internal friction value at certain frequency, relative deformation and temperature is a measure for the damping properties in these conditions.

Apparatus for examination of the internal friction built on the principle of reverse balanced pendulum or the known Ke's pendulum is used. The apparatus is fully automated and computerized. The operational frequency of examination is 1-2 Hz and the relative operational deformation from 5.10^{-4} to 5.10^{-6}. The specimen relaxation spectra are recorded in the temperature range of 20-600°C at heating rate of 1.5°C.

3. Experimental results and discussion

It is well known that the main carrier of damping properties in certain alloy is its solid solution and particularly the condition and mobility of its dislocation structure as well as the availability and diffusion mobility of the alloying components in it. In this sense the potential for improving the damping of an alloy is determined also by the possibility to increase the quantity and area of alloy "defects" that make contact with the external sign-variable or pulsating loads. First, that means presence of higher grain boundary surface, i.e. fine grain structure, which is normally achieved by high quenching rate. That is the concept set in the production of microcrystalline structure alloys by process different from the standard with the purpose of improving their service properties.
Fig. 1 presents the relaxation spectrum of a solid specimen. It is typical for metal alloys and consists of internal friction low temperature background, in this case up to temperature of the order of 400°C, after which it passes over to high temperature one. Relaxation maximum of resonance nature overlaps at temperature of 280°C on the internal friction background and it is observed under high magnification of the experimental data, Fig. 2 and Fig. 3.

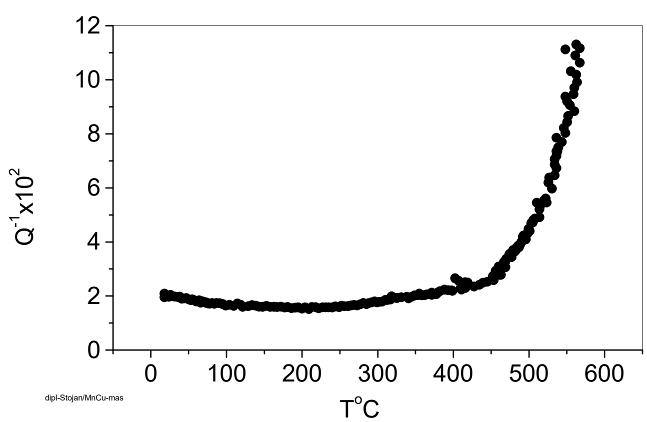

Fig.1. Temperature dependence of internal friction after quenching and aging of solid specimen

The internal friction low temperature background is determined by relaxation dislocation mechanism related to conservative dislocation motion in a plane. That means up to 400°C alloy characterizes by stable dislocation structure and low damping ability, respectively. It is known [10] that the internal friction high temperature background is proportional to the energy diffused by the non-conservative dislocation movement in different crystallographic planes. This is the temperature range where the internal friction value gradually increases and there the high damping properties of all alloys are manifested. Unfortunately, at these temperatures the practical importance of this effect is very small.

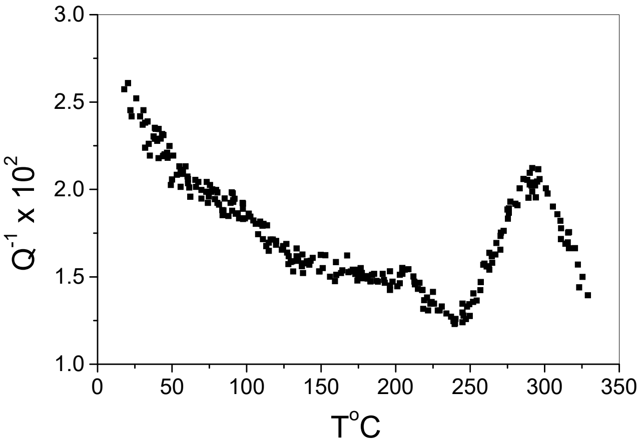

Fig.2. Temperature dependencies of the internal friction – micro crystalline specimens after quenching and aging

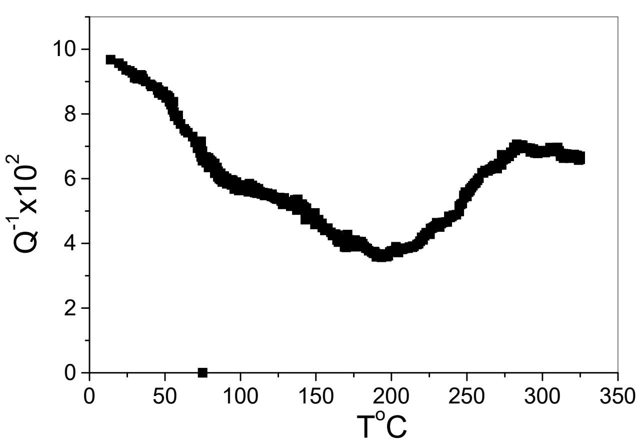

Fig.3. Temperature dependencies of the internal friction – Micro crystalline specimens after aging (without quenching)

Fig. 2 and Fig. 3 present the relaxation spectra of microcrystalline structure specimen preliminary treated by the two sets of heat treatment conditions, with and without intermediate quenching [9] and subsequent aging. They are characterized by high internal friction values even at room temperature and gradually decrease, in the first case to 100°C and in the second to 150°C. Practice has shown that these temperatures are normal for parts operating under vibration loading. Therefore, the alloys prepared in this way have practical value with their damping properties. The aged specimen (without quenching) has internal friction values twice higher, i.e. possesses twice higher damping ability than the aged, after quenching, Fig. 2 and Fig. 3.

That guarantees lost long life of these damping properties in practice. It is known that the binary alloy Mn-Cu has phase composition γ-Mn and α-Mn with copper crystals precipitated in them [11]. In both cases the structure is balanced and suggests presence of polygonal and well fixed by precipitates dislocation structure. In conditions of rapid quenching processes run

which are connected with fixation of high internal stresses and respectively higher non-equilibrium dislocation density in the solid solution.
The results presented in Fig. 2 and Fig. 3 show the high possibility to produce alloy of damping properties at room temperature in the low frequency range of mechanical vibrations. In analogy with the relaxation spectrum of many copper and aluminum alloys [10, 12, 13] in the range of the manganese alloys internal friction relaxation maximum is observed at 280°C, Fig. 4.

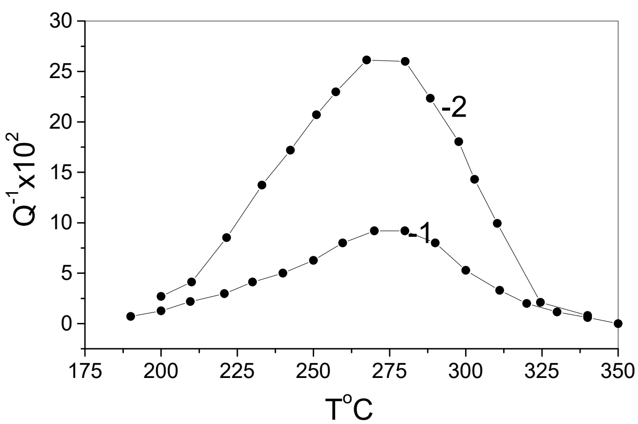

Fig.4. Internal friction relaxation maximums: 1- after quenching and aging; 2- after aging

The physical interpretations made for them are connected with the process of grain boundary diffusion. Robert and Barand [10] show that the diffusion related to matrix atoms can be accepted as basic reason for the process.
For approximate practical calculations Virt and Marx [11] give graphical dependencies between the activation energy and temperature of the maximum at definite value of the relaxation constant by which the process activation energy can be easily found [10].
Fig. 4 shows the relaxation maximums separated from the background and the calculated activation energies are for beryllium bronze 1,7eV and manganese alloy 1,5eV, respectively. These values are close to the activation energies of copper and manganese, respectively, and confirm Robert and Barand's theory [10].

4. Conclusions

The investigations show that the microcrystalline structure metal alloys produced by the method of rapid quenching possess unique properties related to the non-equilibrium conditions of preparation. For the first time it is proved that the specimens after applying certain aging conditions have high damping properties exceeding several times those of macro specimens made of the same alloy or subjected to quenching and subsequent aging.

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