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INTERNAL FRICTION OF HIGH DAMPING CAPACITY MANGANESE ALLOYS

I.Z. Harangozó, L. Egri*, F.J. Kedves and S. Kiss

*Institute for Applied Physics, Kossuth L. University, Debrecen, P.O. Box 2, H-4010, Hungary***Csepel Metal Works, Csepel 1, P.O. Box 49, H-1751, Hungary*

Résumé - Le frottement intérieur /IF/ et sa dépendance de l'amplitude /ADIF/ sont étudiés dans divers alliages de haut amortissement Mn/71/-Cu avec une addition de quantité faible de Ni ou/et Si. Le IF et ADIF mesurés à température ambiante dans la région du déformation relative, ϵ_m , /0.1 - 2/ x 10^{-4} diminuent avec le temps de vieillissement /0.5 - 15 hrs/ à 450°C. La diminution du ADIF dépend de la composition de l'alliage et de la durée du traitement thermique préalable à 850°C fait avant le laminage à froid final. La présence simultanée de Ni et Si n'a pas augmenté la capacité spécifique d'amortissement /à $\epsilon_m = 10^{-4}$ / mais elle conduisait à grain fin après un court traitement thermique préalable.

Abstract - The internal friction /IF/ and the amplitude dependence of it /ADIF/ were studied in different Mn/71/-Cu high damping alloys with additional small amounts of Ni or/and Si. The IF and ADIF at room temperature measured in the relative deformation range, ϵ_m , /0.1 - 2/ x 10^{-4} decrease with increasing ageing time /0.5 - 15 hrs/ at 450°C. The decrease of the ADIF depends on the composition and the length of the previous annealing time at 850°C performed before final cold rolling. The simultaneous presence of Ni and Si did not increase significantly the specific damping capacity /at $\epsilon_m = 10^{-4}$ / but led to much smaller grain sizes also with short previous annealing.

Introduction

High damping Mn-Cu alloys were studied intensively [1 - 10] because they possess high damping capacity /HDC/ being important for various applications besides their good mechanical properties [2]. This high damping capacity state /HDCS/ is associated with a metastable face-centred-tetragonal structure developed from the γ -phase. When quenched from the γ region the alloys containing 50 - 82 wt%Mn have cubic structure but performing an ageing treatment /400 - 600°C/ the unit cells become tetragonal and simultaneously α -Mn precipitates appear along grain boundaries [3, 6]. Maximal HDCS could have been achieved in a Mn/75 wt%/-Cu alloy after an ageing at 400°C [10] when precipitates of 15 - 20 nm size having δ K-Mn structure have been formed and α -Mn precipitates within the grain boundaries just appeared.

The HDCS can be affected by small amounts of third alloying elements /eg. Fe, Co, Al, Ga/ [9, 10], several of them /eg. Cu, Ni, Ga/ could be advantageous by stabilizing this state. The HDCS can be studied by measuring the internal friction /IF/, the amplitude dependence of IF /ADIF/, the electrical resistivity, and different mechanical properties /eg. hardness, Young modulus/ [1-10]. The height of IF is connected with the direct energy dissipation in the structure, the ADIF reflects the dislocation interaction with precipitates, phase boundaries and impurity atoms [11].

The purpose of the present work was to collect information on the HDCS of Mn/71 wt%/-Cu alloy and on the effect of small amounts of additional Ni and Si.

Experimental procedure

The alloys /composition in Table 1/ were smelted in a vacuum induction furnace then cast and after appropriate cleaning cold rolled. A part of the series of every composition was annealed at 850°C for 10 hours in vacuum then cooled down there /marked by H/. An other group of the samples was annealed also at 850°C but for 1 hour and cooled down in air. All samples were then cold rolled down to thickness of 1 mm and annealed again at 850°C for 2 hours in air and quenched in water.

All specimens of 75x1x1 mm³ size were aged at 450°C in air for different times and quenched in water. The IF measurements realizing in an inverted torsion pendulum at about 1 Hz at room temperature /RT/ were started several minutes after quenching. The micromorphology of the samples were investigated by transmission electron microscopy on electrologically thinned foils.

Table 1.

Material	Composition /wt%/			
	Mn	Cu	Ni	Si
7	71	29	-	-
8	72	26	2	-
9	71	28.5	-	0.5
10	72	25.5	2	0.5

Results and Discussion

The IF was measured at RT in the ϵ_m range: $/0.1 - 2/ \times 10^{-4}$ on specimens aged for different time intervals $/0.5 - 15$ hours/. Typical results can be seen in Fig.1, where the ageing time $/t_{age}/$ are indicated on the curves $/0$ means no ageing/. The position and the slope of each curve are characteristic to all specimens. The highest IF value is achieved after $t_{age} = 0.5$ hours for all samples except those which do not contain Ni or Si. These specimens reached the highest IF value after $t_{age} = 1$ hour. It has to be noted that all measurements have been performed in the amplitude dependent region. The IF value measuring below $\epsilon_m = 10^{-6}$ at RT does not change on similar samples after being made an ageing at 450°C for 20 min [12].

We determined the specific damping capacity /SDC/ values from the IF data belonging to $\epsilon_m = 10^{-4}$ relative deformation /Table 2/, which do not differ essentially from the values found in the literature [10]. The change in IF is also significant and characteristic but the absolute value of the damping is important.

Fig. 1

Table 2.

condition	7	7H	8	8H	9	9H	10	10H
SDC /% /	17	15	12	13	10	14	15	13

The choice of ϵ_m is arbitrary and does not reflect the changes found, therefore we determined further characteristic parameters of the curves. It was found that for different $\epsilon_m = \text{const}$ the Q^{-1} vs $\log t_{\text{age}}$ curves are straight lines /Fig. 2/. Such connection was found for each sample listed in Table 2. If we now plot the slopes of the straight lines /i.e. $\partial Q^{-1} / \partial \lg(t_{\text{age}}/\tau)$, where τ is the period of the vibration of the pendulum/ belonging to $\epsilon_m = \text{const}$ we get again one straight line for each state /Fig. 3/. It can be seen in Fig. 3 that alloys 7 and 8 differ essentially in homogenized /H/ and not homogenized states but at the same time the difference be-

Fig. 2

tween these two states is much smaller for alloys containing Si. The difference is the smallest between these two states for alloys containing Ni and Si. It seems that the simultaneous presence of Ni and Si has the highest effect in this respect. This could be caused by the formation of a Ni_3Si phase with fcc lattice which can be coherent in the $\delta\text{K-Mn}$ matrix.

The results of the electron-microscopic investigations confirm the above establishment, i.e. the simultaneous presence of Ni and Si produces similar states in the homogenized and in the not homogenized alloys. In alloy 10 the grain structure is much finer than in the simple Mn-Cu alloy.

Fig. 3

The Q^{-1} vs log t_{age} plots help in determining the validity limits of the connection between the studied parameters. The amplitude dependence of the IF hold off below a definite value and the IF becomes constant. All straight lines in Fig. 2 /neglecting the last points/ can be extrapolated to the same $t_{\text{age}} \approx 125$ hrs/ except for the lowest $\epsilon_m = 0.2 \times 10^{-4}$. This fact can be caused by a change in the amplitude dependence. The decrease of the IF with increasing ageing times could refer to the change in the kinetics of the process. This can also be concluded from the fact that at a relatively high ageing time /22 - 25 hours/ the points do not fit onto straight lines.

If we plot the curves shown in Fig.1 in a log - log scale /Fig. 4/ we receive parallel straight lines for shorter annealing times. For longer ageing times /6 hours/ the points belonging to low deformation amplitude give a part having lower slope. We observed essential difference between the homogenized and the non-homogenized states of alloy 7, i.e. in the homogenized state we found a break after the first annealing /0.5 hour/ and on the contrary in 7H only after about 10 hours annealing. In all the other alloys in both states this breaking point appeared after an annealing for 6-8 hours. On the basis of the development of the HDCS [3, 6] we think that the decrease of the ADIF can be connected with the increase of the amount of the α -Mn phase.

Fig. 4

of ADIF of Mn-Cu high damping alloys was also similar in the four alloys. The simultaneous presence of Ni and Si produced a similar behaviour of IF in the homogenized and in the not homogenized states, and at the same time the IF of the alloys 7 and 8 differed essentially in these two states.

Of course, a more exact picture can be build up when further results gained by other methods /microprobe, transmission electron microscopy/ are also available besides the IF measurements.

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