Journal of Alloys and Compounds, 211/212 (1994) 514–517
JALCOM 108

Damping capacity of Zn–Al alloy sheets

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Abstract

The effect of cold rolling on the logarithmic decrement δ of Zn–Al/Zn–Al–0.02%Mg alloy containing less than 22% Al was investigated. A logarithmic decrement δ of 85% for cold rolled Zn–15%Al/Zn–15%Al–0.02%Mg alloy sheets was close in value to that of the same alloy sheets water quenched from 573 K. With an increase in rolling reduction, the value of δ was increased. As a result of tensile properties and hardness testing, the elongation was increased and the hardness was decreased with an increase in the rolling reduction for as-rolled alloys.

1. Introduction

It has been reported that Zn–Al alloys show high damping when quenched above the eutectoid temperature, in the range of the $\alpha+\beta$ phase. Considerable research into this phenomenon has therefore been carried out for rolled or drawn eutectoid alloys by Nutall [1]. Generally, a small amount of magnesium is added to these Zn–Al alloys to improve the intergranular corrosion resistance. However, the addition of magnesium lowers the internal friction considerably. The amount of magnesium added to these alloys should be less than 0.02% [2] to maintain a high damping capacity.

Zn–Al alloy indicates a eutectic formation of about 5% Al at a temperature of 655 K, and a eutectoid decomposition for 22% Al at a temperature of 548 K. Thus there is considerable latitude in the metallurgical variables of these alloys. High aluminum content Zn–Al alloys are advantageous for both higher strength and lower density than eutectic alloys. However, increasing the aluminum content produces a wide temperature range for solidification. This wide solidification temperature range might cause microshrinkage during solidification. Zinc based alloys are usually used in die casting applications with a small amount of Mg [3] and the effect of Mg on these rolled alloys has not been fully investigated. In this study, the internal friction was investigated as a function of cold rolling by varying the reduction in area for binary Zn–Al alloys with an Al content in the range 5%–22% and ternary Zn–Al–Mg alloys with the same Al content and 0.02% Mg.

2. Experimental details

2.1. Alloy preparation

High purity Zn (99.99%) and Al (99.99%) were prepared for castings and the experiments were carried out on alloys of compositions Zn–(5%–22%)Al and Zn–(5%–22%)Al–0.02%Mg which had been melted in a high purity carbon crucible and cast into a metal mold of size $110\times110\times280$ mm^3. The casting temperature was at the melting point of each composition +50 K and the temperature of the mold was 290 K.

After casting, the specimens were rolled with reductions of the section of 0%, 50% and 85%. For all Al contents, the specimens were taken from the same position of the castings for comparative measurements. Then, specimens of $2\times10\times50$ mm^3 for damping tests and $2\times10\times50$ mm^3 for hardness tests were cut from the castings.

2.2. Damping test and mechanical properties

Damping tests were done using the method of the free decay of vibrations in bending oscillation operated at 80 Hz, as illustrated schematically in Fig. 1. These specimens were immersed in air at 293 K. In this measurement, the specimen was supported vertically with its bottom edge held fixed, and the top end was free for vibration. Then the logarithmic decrement δ was determined from the free vibration according to the following equation as shown in Fig. 2:

$$\delta=\ln(A_n/A_{n+1})\times100$$

After measurement of the initial damping capacity, the specimens were heat treated at 573 K for 2 and

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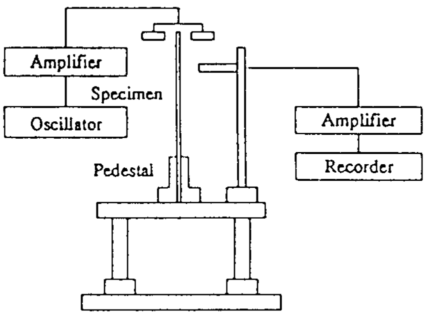

Fig. 1. Schematic diagram of the experimental apparatus.

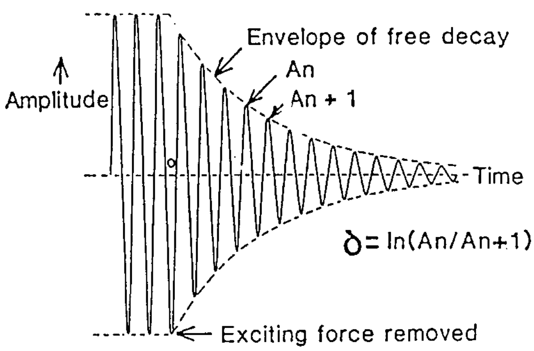

Fig. 2. How to obtain the δ value from free decay of the vibration.

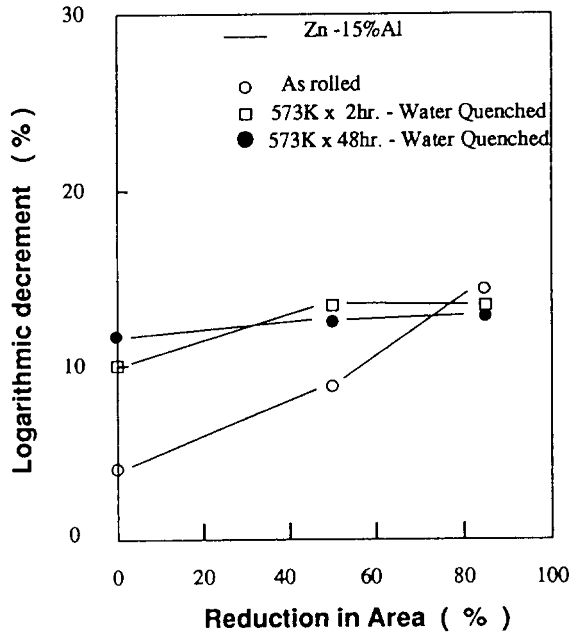

Fig. 3. The effect of rolling reduction on the logarithmic decrement of Zn–15%Al alloys.

48 h followed by a water quench. Consequently, the δ values of the heat treated specimens were measured. Then the hardness was measured under a load of 10 kgf using a Vickers hardness tester.

3. Results and discussion

The damping capacities of as rolled and heat treated alloys are shown in Fig. 3 and 4 for binary and ternary Zn–15%Al alloys respectively.

The measurements were taken with varying reduction ranges of 0%, 50% and 85% in area. The δ value was increased with an increase in rolling reduction under all rolling conditions, and δ assumes an especially high value in the Zn–15%Al rolled alloy with 85% reduction, as shown by the open circles in Figs. 3 and 4. For the as rolled alloys, the increment in the damping capacity by rolling is higher than that of the heat treated alloys.

The results show that the damping capacity of these cast binary and ternary alloys depends strongly on the rolling reduction. The ageing time at elevated temperature has little influence on the damping capacity of rolled alloys, compared with the effect of rolling reduction.

A previous study revealed that the addition of a small amount of Mg to these alloys reduced the damping capacity [2]. For all specimens, the δ value was increased with rolling and heat treatment.

Comparing the effect of cold rolling and heat treatment on both the binary and ternary alloys, the addition of 0.02% Mg has little influence on the δ value of cold rolled and heat treated alloys.

The hardness of the rolled alloy, about 30 Hv, was about equivalent to the value of heat treated Zn–15%Al alloy and was reduced with an increase in rolling reduction, as shown by the filled circles in Fig. 5. As can be seen from Fig. 5, the hardness was reduced with an increase in rolling reduction. These results are in good agreement with the microstructure morphology, as described later. The microstructure of as rolled Zn–15%Al alloys is shown in Fig. 6. Considering the effect of rolling reduction, the lamellar structure still remained under the condition of 50% reduction. On increasing the rolling reduction up to 85%, these lamellar structures disappeared entirely to produce an equiaxed fine $\alpha+\beta$ structure, approximately the same as that observed after quenching [4, 5].

To evaluate the damping characteristics, both δ and the strain amplitude ϵ was determined as a function of time just after quenching and rolling. These results are shown in Fig. 7 and 8 respectively. Under the condition of water quenching, δ was still low after 8 min. After that δ increased to 15% and no strain amplitude damping was observed. This phenomenon is explained by the decomposition of $\alpha+\beta$ by quenching. This deformation started just after quenching and proceeded continuously during a period of several minutes,

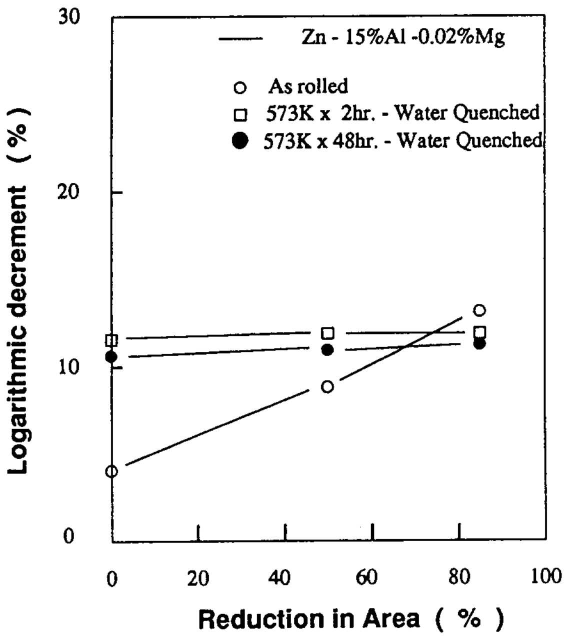

Fig. 4. The effect of rolling reduction on the logarithmic decrement of Zn–15%Al–0.02%Mg alloys.

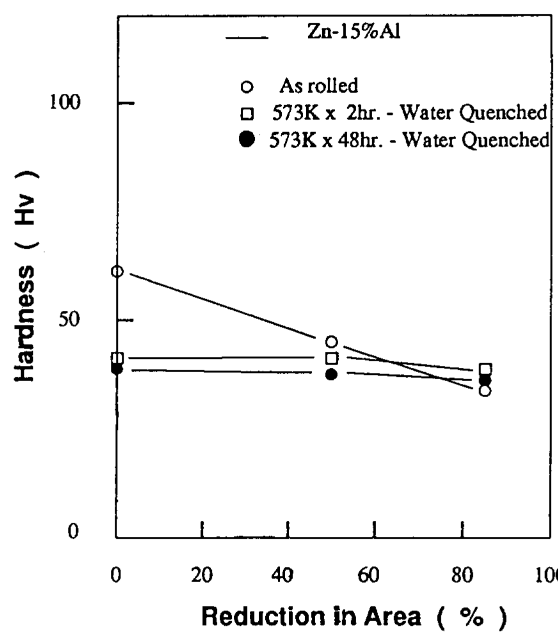

Fig. 5. The effect of rolling reduction on the hardness of Zn–15%Al alloys.

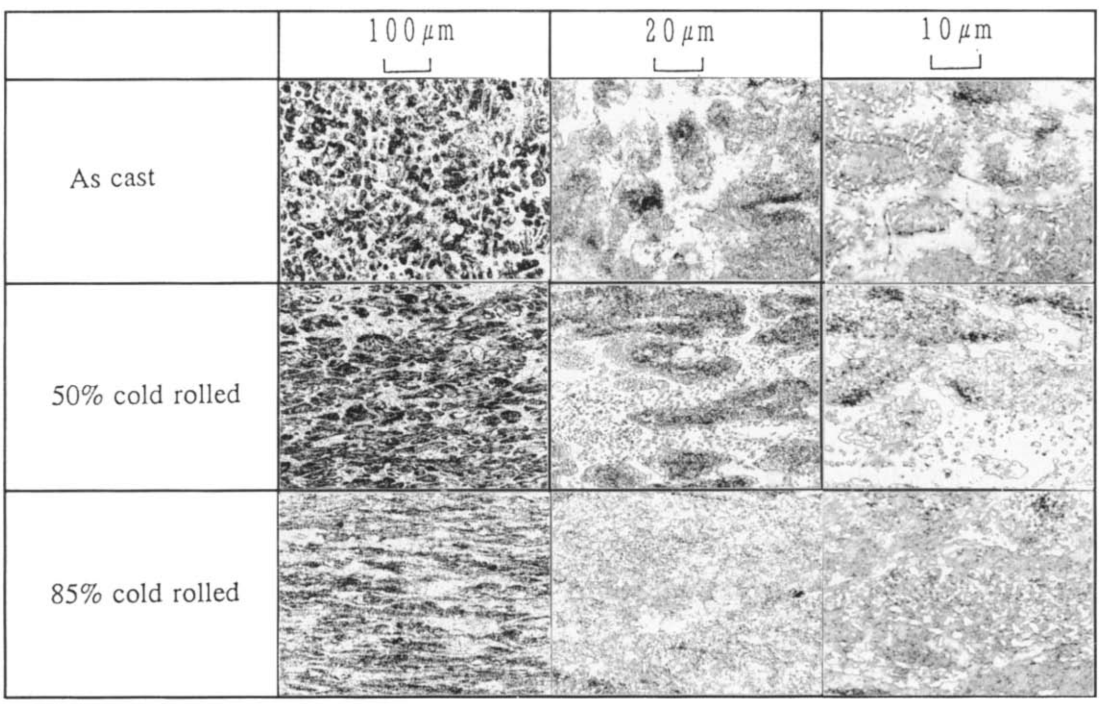

Fig. 6. Microstructure of cold rolled Zn–15%Al alloys.

then gradually stabilized under long-term exposure, as reported by Smith and Hare [6].

However, the rolled sample showed high δ just after rolling and maintained these values during the whole experiment. This damping is essentially amplitude independent at the frequency of 80 Hz and temperature at 293 K. These results are also in good agreement with the results of Ritchie *et al.* [7] for the strain amplitude range 10^{-6}–10^{-4}.

Considering the major increment of δ of the rolled alloy, thermally activated relaxation is not the reason for this damping, whereas grain boundary relaxation is the major component. Generally, many polycrystalline metals show thermally activated relaxation above half

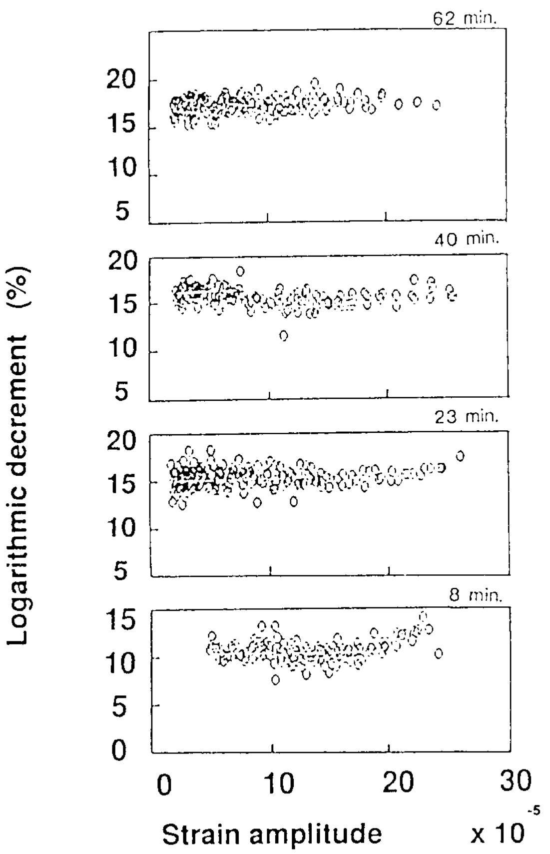

Fig. 7. Relation between the logarithmic decrement δ and strain amplitude ϵ of Zn–15%Al alloys after quenching (573 k for 2 h, water quenching).

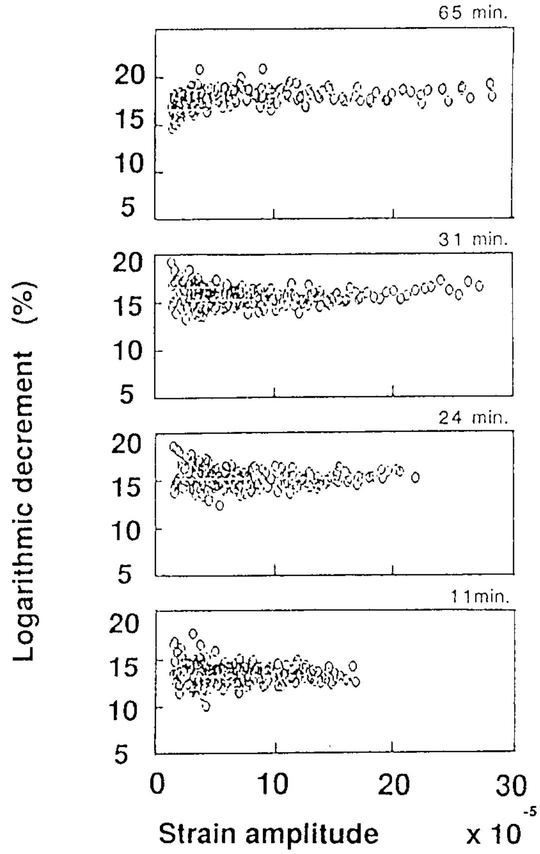

Fig. 8. Relation between the logarithmic decrement δ and strain amplitude ϵ of Zn–15%Al alloys after cold rolling.

the melting temperature [8], and the thermally activated relaxation peak was found at 447 K for the Zn–22% alloy [9].

4. Conclusions

(1) For cold rolled and water quenched Zn–15%Al alloys, the hardness was lower and indicated no significant change with varying rolling reduction.

(2) Grains of 85% cold rolled alloys were not deformed and retained equiaxed features and were similar to those of the alloys quenched from 573 K.

(3) The value of δ of cold rolled alloys was fairly close to that of quenched alloys. The ageing time at elevated temperature has no significant influence on δ.

(4) The addition of a small amount Mg to improve intergranular corrosion resistance lowers the δ value of these alloys; however, the addition of 0.02%Mg has little influence on the damping capacities of Zn–15%Al alloys.

(5) Rolling increases the total amount of grain boundary of equiaxed $\alpha+\beta$ structure.

(6) The damping mechanism of as rolled Zn–Al alloys might be grain boundary relaxation of fine $\alpha+\beta$ phases.

References

1 K. Nutall, *J. Inst. Met., 99* (1971) 266.
2 T. Otani, T. Sakai, K. Hoshino and T. Kurosawa, *J. Phys. (Paris), C10* (1985) 417.
3 S.F. Radtke, *Engineering Properties of Zinc Alloys,* International Lead Zinc Organization, New York, 1980, Chapter 1.
4 A. Ball and M.M. Hutchinson, *Met. Sci. J., 3* (1969) 1.
5 R. Roberge and H. Herman, *J. Inst. Met., 101* (1973) 339.
6 A.E.W. Smith and G.A. Hare, *J. Inst. Met., 101* (1973) 321.
7 I.G. Ritchie, Z.-L. Pan and F.E. Goodwin, *Metall. Trans. A., 22* (1991) 617.
8 K.M. Entwistle, in B. Chalmers and A.G. Quarrell (eds.), *The Physical Examination of Metals,* Edward Arnold, London, 1960, Chapter X.
9 A. Torisaka and S. Kojima, *Acta Metall. Mater., 39* (1991) 949.