Damping Capacity of Hypo-Eutectic Zn-Al Alloys

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Abstract. Damping capacity of hypo-eutectic Zn-Al alloys as a function of rolling ratio is investigated. Effect of heat treatment after cold rolling on the damping capacity is discussed. Damping tests were carried out using the method of the free decay of vibrations in bending oscillation. With an increase in rolling reduction, the damping capacity was increased. As the results of tensile and hardness testing show, the elongation was increased and hardness was decreased with an increase in rolling reduction. An increase in the damping capacity indicates higher value for the as rolled alloys with an accompanying work-softening effect. And the increment in the damping capacity by rolling was higher than that of the heat treated alloys. As a results of the microstructural analysis of the alloys, the grains of as rolled alloys were changed to equiaxed structures after a large rolling reduction. And the grains of the heat treated alloy was coarsened during the heat treatment. Tensile testing revealed that the maximum strain rate sensitivity, m , was 0.35 for Zn-5%Al after 85% rolling reduction.

1. Introduction

It has been reported that Zn-Al alloys show high damping when quenched from above eutectoid temperature, in the range of $\alpha + \beta$ phase. Considerable research of this phenomenon has, therefore, been carried out for rolled or drawn eutectoid alloys by Nutall [1][2] et al. Zn-Al alloys indicate an eutectic formation at about 5% Al at a temperature of 655 K, and an eutectoid decomposition at 22% Al at a temperature of 548 K. High aluminum Zn-Al alloys are advantageous for both higher strength and lower density than those of eutectic alloys. However increasing aluminum content gives a wide temperature range for solidification. This wide solidification temperature range might cause the microshrinkage during solidification. So, many studies were done for hyper-eutectic alloys, especially for Zn-22%Al eutectoid alloy for its superplastic behaviour. Zinc base alloys were usually used in die casting applications and the effect of rolling to the alloys was not fully investigated. In this study, the internal friction as a function of cold rolling by varying the reduction in area was investigated for binary hypo-eutectic Zn-Al alloys with an Al content in the range from 2 to 5% wt.

2. Experimental details

2.1 Alloy preparation

The material used was a zinc alloy of 99.99%, and an aluminum alloy of 99.99% in purity. Then the specimens were prepared with chemical composition, in wt%, Zn-2-5% Al which had been melt in a high purity carbon crucible then cast into a metal mold of size 30x160x150 mm. The casting temperature was at the melting point of each chemical composition +50 K and the temperature of the mold was 290 K. After the casting, the specimens rolled for 0, 25, 50 and 85% in reduction were prepared. For all Al contents, the specimens were made from the same part of the castings for comparative measurement. Then, specimens with a size of 2x10x150 mm for the damping test and with a size of 2x10x50 mm for hardness test were cut from the castings.

2.2 Damping test and mechanical properties

Damping test were made for the free decay of vibration in bending oscillation by the impact hammer method schematically illustrated in Fig. 1. These specimen were in air at 293 K. In this measurement,

the specimen was supported vertically with its bottom edge held fixed and the top end free for vibration.

Figure 1: Schematic diagram of the experiment

Figure 2: How to obtain a damping capacity

Then the damping capacity $\Delta W/W$ was determined from the free vibration as shown in Fig. 2. After cold rolling to 25, 50 and 85%, one specimen was heat treated at 573K for 24 hours followed by a water quench and the others were furnace cooled. Consequently, the damping capacity of the heat treated specimens were measured. Then the hardness was measured under a load of 98.1 N using a Vickers hardness tester. In tensile tests, the nominal stress σ is given by

$$\sigma = K \dot{\epsilon}^m$$

where $\dot{\epsilon}$ is the strain rate and m is a strain rate sensitivity index. [3]. The strain rate sensitivity was then measured by varying the cross head speeds of 0.5, 1, 2, 4, 6, 8, 10 mm/min using a screw drive Instron machine. Then the m value is obtained by the following equation[4]

$$m = \log(\sigma' / \sigma) / \log(\dot{\epsilon}' / \dot{\epsilon})$$

where $\dot{\epsilon}'$ is the strain rate at a nominal stress is σ' . These tensile tests were also carried out at a 293K in air.

Figure 3: Relation between damping capacity and rolling reduction of Zn-2%Al alloy

Figure 4: Relation between damping capacity and rolling reduction of Zn-4%Al alloy

Figure 5: Relation between damping capacity and rolling reduction of Zn-5%Al alloy

Figure 6: Relation between tensile strength and strain rate of 85% cold rolled Zn-5%Al alloy

3. Results and discussion

The damping capacity of as cast and heat treated alloys is shown in Fig. 3-5. The measurements were made for the alloys by varying reduction 0, 25, 50 and 85% in area. The damping capacity was gradually increased with an increase in rolling reduction, and shows especially a higher value in the Zn-5% Al alloy with 85% reduction as shown in Fig. 5. For the as rolled alloys, the increment of the damping capacity by rolling is higher than that of the heat treated ones. The results show that the damping capacity of these cast alloys depends strongly on the rolling reduction. Hence the heat treatment had little influenced on the damping capacity of rolled alloys compared to the effect by rolling. The decrement of hardness of Zn-5%Al alloy by rolling is greater than that of the heat treated alloy as shown in Fig. 7. As can be seen from Fig. 7, hardness was reduced with an increase in rolling reduction and indicated a minimum value of about 35 Hv. These results are in good agreement with the

Figure 7: Hardness change by rolling of Zn-5%Al alloys.

microstructure morphology. Microstructures of the alloys are shown in Fig. 8. Considering the effect of the rolling reduction, the lamellar structure was still remaining under the condition of 50% reduction. Increasing the rolling reduction up to 85%, these lamellar structure was entirely disappeared to produce an equiaxed fine $\alpha + \beta$ structure approximately the same as that of a quenched sample.[5]. The damping of the polycrystalline alloys, fine equiaxed structure is essentially amplitude-independent previously reported by Ritchie et al. [6,7] and the grain sliding must be a major component. It is reported that, in the condition of superplastic deformation, the m value is higher than 0.3-0.4[8]. And also reported by Packer et al[9], Zn-4.9%Al alloy indicated superplasticity with $m=0.5$ in a temperature range from 473 to 633K. In this experiment, for the 85% cold rolled Zn-5%Al alloy, a maximum m value of 0.35 at 293K was found with a elongation up to 100%. These m values ranged 0.11-0.35, and a mean value of m determined by least squares fitting to the experimental data was 0.21.

Figure 8: SEM micrographs of Zn-5%Al alloys.

4. Conclusions

- The grain sliding deformation by finer equiaxed $\alpha + \beta$ microstructure after large rolling reduction must be a major component for this damping
- For cold rolled Zn-5% Al alloys, hardness showed lower value and indicated significant change by varying rolling reduction by a work softening effect.
- Grains after 85% cold rolling showed equiaxed features.
- With an increase in the rolling reduction, a total amount of grain boundary of an equiaxed $\alpha + \beta$ is increased to resulted the increase in the damping.
- The tensile strength strongly depends on the strain rate for Zn-5%Al alloy, and indicated a maximum m value of 0.35.

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