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Microstructural Changes During Hot Rolling of Zn-Al Eutectoid Alloy with 2% Cu

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Abstract

The influence of the rolling temperature on the final microstructure and hardness of the rolled Zn-Al eutectoid alloy modified with 2% Cu, was investigated. The alloy rolled above the eutectoid temperature is harder than the alloy rolled below the eutectoid temperature. The final phases of the alloy rolled at 300°C are α, η, and ε. In the alloy rolled below the eutectoid temperature the final phases are α, η, and τ'.

1.0 Introduction

Zn-Al eutectoid alloy is a classical superplastic material that has been studied in quite considerable detail (1,2). The addition of copper to the Zn-Al alloy increases the strength and imparts the superplastic properties (3). The presence of Cu in more than 2% promotes the formation of intermetallics like the $CuZn_5$ (ε) and the aluminum rich τ' phase (4). The ε phase is metastable at room temperature and transforms very slowly, by a solid state reaction, into the room temperature stable τ' phase with prolonged aging at 170°C (5). The stable phases of the Zn-21 wt.% Al-2 wt.%Cu (zinalco alloy) at room temperature are composed of an Al-rich solid solution α, a Zn rich solid solution η and the τ' phase (Al_4Cu_3Zn) (6). Above 280°C the stable phases for this composition are, ε and β

(ZnAl with a distorted fcc structure). When the alloy solidifies from the liquid phase, the first to solidify from the melt is the Al rich primary α phase, which decomposes to the stable phases during cooling by a discontinuous precipitation reaction (7), originating a fine cored dendritic structure that can not be eliminated by simple annealing. The main objective of the present work was to examine the structural changes of the zinalco alloy at room temperature, after hot rolling in the β phase field (above 280°C) and in the multiphase region (below 280°), with the starting material having been obtained by semi-continuous casting.

2.0 Methods

High-purity materials (99.99 Zn, 99.9 Al) were used to prepare ingots of zinalco comprising 77.8 wt.% Zn, 20.2 wt.% Al and 1.97 wt% Cu. All the hot rolling experiments were carried out on material obtained by semicontinuous casting. The starting material showed a fine cored dendritic microstructure with very fine lamellar of α and η phases resulting from discontinuous precipitation. The as-cast material was rolled at 220° (multiphase region) and 300°C (β phase region) from 5 to 0.3 mm-thick strip (280% true strain) in six passes at a speed of 0.083 ms^{-1}.

The effect of deformation by rolling was studied using Vicker's hardness measurements. The hardness value was taken as the mean of 10 diamond impressions using a 100 g load. Microstructural changes following rolling experiments were also examined by SEM and x-ray diffraction which were performed using CuKα radiation applied to a flat-surfaced block specimens in a Rigaku DMAX 2200 diffractometer.

3.0 Results

The microstructure of the starting material, shown in Figure 1 is composed of cored dendrites surrounded by an interdendritic, zinc-rich, eutectic structure. According to the x-ray diffraction results (Figure 2), some metastable ε phase is present but no τ' phase was observed. The amount of ε phase is so small that it was not identified by scanning electron microscope (SEM). This inhomogeneous structure is almost completely homogenized by the rolling process in the single phase region. Figure 3a shows the structure at room temperature after 50% true strain rolling reduction, and Figure 3b is the structure after 200% true strain rolled at 300°C. The lamellar structure observed at room temperature, is finer in the material deformed 200% than in the material deformed 50%. In the 50% rolled material we observe some remnants of the a primary phase and coarse zinc rich phase. Higher deformation (200%) produces a complete disappearance of the α primary phase and the orientation of the interdendritic zinc rich phase in the rolling direction.

The microstructure of the material after 90% reduction at 220°C (multiphase region) Figure 4a, shows an alignment of the dendrites in the direction of rolling. Homogenization still is not observed

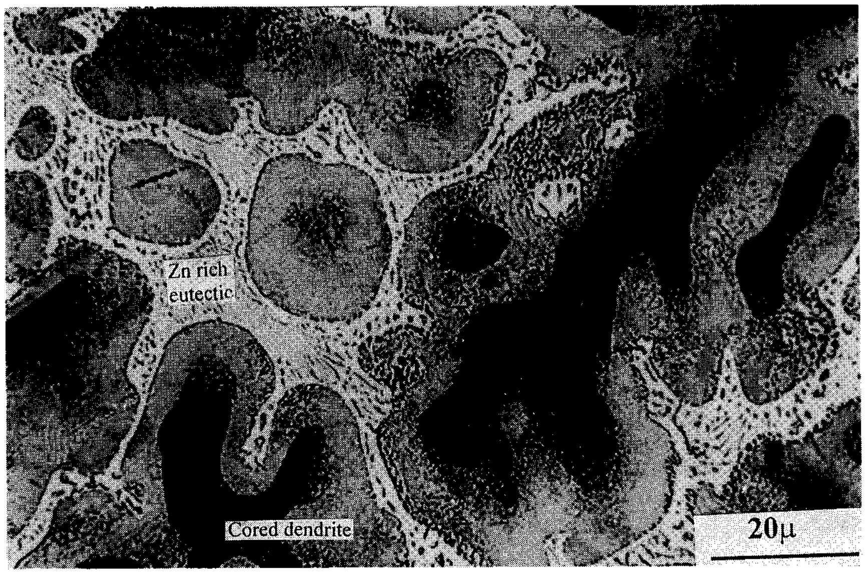


Figure 1: Scanning electron micrograph of the zinalco alloy structure formed in semicontinuous casting. It consists of cored dendrites surrounded by a zinc-rich eutectic constituent.

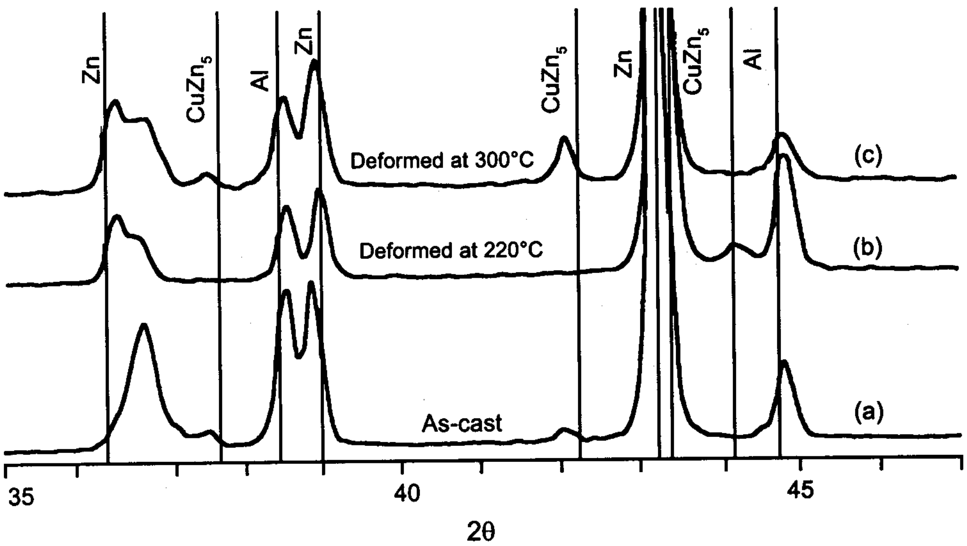


Figure 2: X-ray diffractograms of the (a) as-cast alloy, (b) rolled 280% at 220°C, and (c) rolled 240% at 300°C.

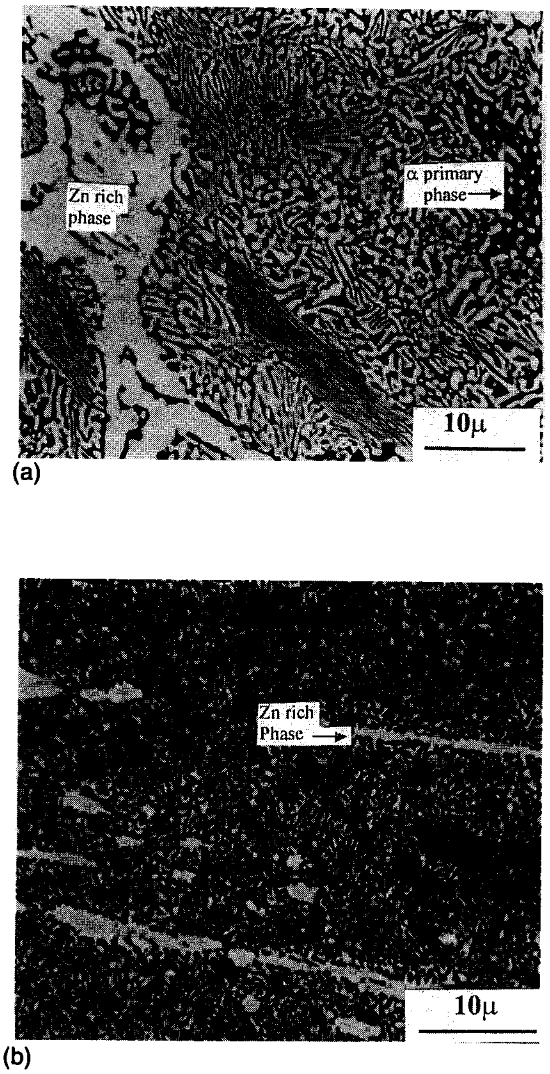
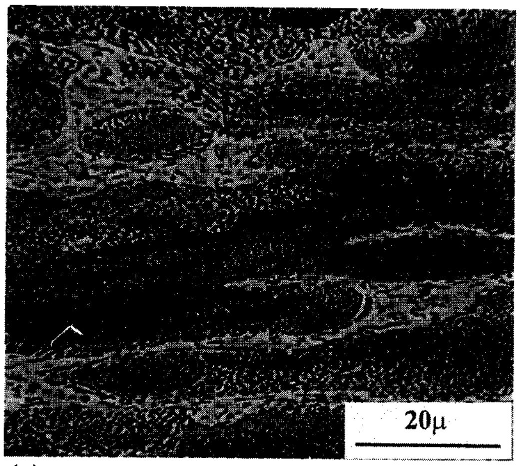


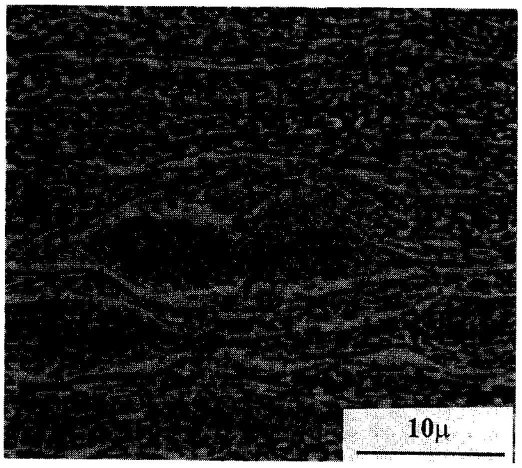
Figure 3: Scanning electron micrographs of the zinalco alloy structure after rolling at 300°C (a) 50% (true strain) reduction and (b) 200% reduction.

because the aligned dendrites still show coring. After 240% true strain deformation, the zinc rich phase and the α primary phase (aluminum rich) are aligned in the rolling direction, with coring having been completely removed (Figure 4b).

Rolling at 220°C produces an interesting softening effect, as demonstrated by a decrease in hardness



(a)



(b)

Figure 4: Scanning electron micrographs of the zinalco alloy after rolling at 220°C (a) 90% reduction and (b) 240% reduction.

as a function of the extent of rolling (Figure 5). The material rolled inside of the β phase (300°C) shows constant hardness when cooled to room temperature. This is possible due to the elimination of the rolling effects by the phase transformation that occurs around 280°C, during cooling of the material after the rolling process. X-ray diffraction of the rolled material showed that after

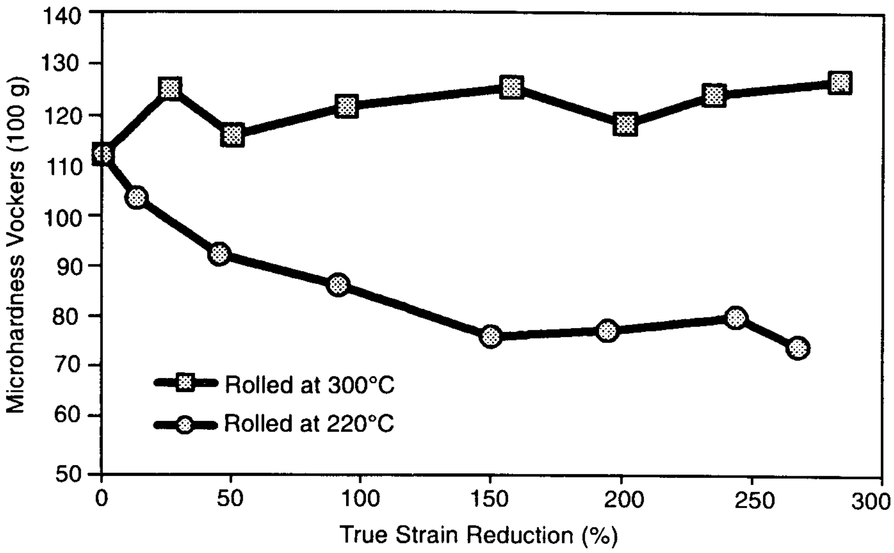


Figure 5: Microhardness variation versus reduction of the zinalco alloy rolled in the single phase region (300°C) and in the multiphase region (220°C).

deformation in the single phase region the alloy is composed by α, η and ε phases. After rolling in the two phase region the observed phases are α, η and τ' as can be seen in Figure 2.

4.0 Discussion

Rolling of the alloy above the eutectoid temperature produces an almost complete homogenization of the phases, because of the high diffusion of the atoms at that temperature and the assistance of deformation energy. The rolling process approaches the Al rich core regions to the interdendritic zinc rich phase, promoting the homogenization of the alloy. This effect cannot be reached by simple annealing at 300°C for long periods of time, because the external region of the dendrite with an almost equilibrium composition acts as a barrier between the aluminum rich core and the zinc rich interdendritic region. Rolling in the multiphase region (220°C) does not promote the homogenization due to the lower diffusion rate at this temperature, and which results in the observed alignment of the aluminum rich regions and zinc rich regions in the rolling direction. At 220°C the aluminum rich phase suffers dynamic recovery (8) and the zinc rich phase is completely recrystallized.

The softening effect may be produced because the supersaturated phases of the as cast material are harder than the more stable phases obtained after rolling in the two phase region. This tendency to the stability is observed in Figure 2 where the unstable ε phase transforms to the stable τ' phase. Another important point in the alloy rolled at 300°C is that the room temperature hardness is higher than the hardness of the alloy rolled at 220°C. The reason for this effect is that α and η phases, originated by the eutectoid transformation are coherent (9). This coherence is broken as a function of the amount of rolling in the alloy rolled at 220°C, as has been observed before for homogenized structures (9,10). The greater the coherence the higher is the hardness.

5.0 Conclusion

The zinalco alloy obtained by semicontinuous casting composed of fine cored dendrites, but when rolled at 300°C produced a harder material in contrast with the material rolled in the multiphase region (below 280°C).

There is a softening effect produced when the alloy is rolled at 220°C, may be because the coherency between phases is broken by the rolling process.

Rolling below the eutectoid temperature promotes the transformation of the ε phase into τ' phase producing a structure with α, η and τ' phases. Rolling above the eutectoid temperature gives a structure with α, η and ε phases.

6.0 Acknowledgment

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