

Microstructure of AZ31 Magnesium Alloy deformed by indentation-flattening compound deformation technology

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Abstract: Characteristic of indentation-flattening compound deformation technology (IFCDT) is discussed, and the parameters of IFCDT are defined. Performance of magnesium alloy AZ31 sheet deformed by IFCDT is researched. The effect of IFCDT coefficient, temperature and reduction ratio on the microstructure of magnesium alloy sheet is analyzed. The research results show that the volume fraction of the twin crystal decreases gradually and the average grain size increases with increasing of coefficient of IFCDT. With increase of the reduction ratio, the volume fraction of the twin crystal gradually increases, and the average grain size also increases. With increase of deformation temperature, the volume fraction of the twin crystal decreases gradually, and the twin crystal grain size increases.

1. Introduction

Although plasticity of magnesium alloy sheet is increased at high temperature, but because of its easy oxidation, the popularized and application of magnesium alloy is limited. Therefore, to improve the performance and formability of magnesium alloy at low temperature is great significance. To increase the strength and ductility of magnesium alloys by refining grain is studied by some researchers[1]. Grain of magnesium alloy sheet is refined by alternate biaxial reverse corrugation(ABRC) pressing, and the grain size is to 1.4 μ m[2]. When AZ31 Mg alloy is deformed by integrating forward extrusion and torsion deformation, the dynamic recrystallization is induced by the heavily accumulated strains, and the grains are refined and the basal texture is dramatically weakened[3]. Shingo[4] have proposed the novel rolling process to improve the microstructure property and plastic formability of AZ31 magnesium alloy, which is called periodical straining rolling (PSR). During deformation twinning of AZ31 magnesium alloy, twin nucleation is found to be mostly controlled by a combination of grain size, and bulk dislocation density while twin propagation is affected most by grain boundary length [5]. The microstructure and mechanical properties of AZ31 magnesium alloy sheet were improved significantly by severe plastic deformation (SPD) and short time post-annealing [6]. In this paper, performance of magnesium alloy AZ31 sheet which is deformed by



indentation-flattening compound deformation technology (IFCDT) had been researched. The influence law of parameters of IFCDT on twins and grain size of magnesium alloy sheet has been analyzed.

2. Characteristic of IFCDT

Indentation-flattening compound deformation technology (IFCDT) is defined that the plane sheet is deformed by indentation technology (regarded as first deformation process), and then the wave sheet is deformed by flattening technology continuously (called second deformation), seen as Fig.1. The parameters of IFCDT include deformation temperature (T), deformation speed (V), the distance of waves (s), the reduction of IFCDT ($2h$), and the coefficient of IFCDT ($\lambda=2h/s$). The reduction ratio (Φ) is $\Phi=2h/t_0$, in which, t_0 is the thickness of original sheet, which are defined as Fig.1.

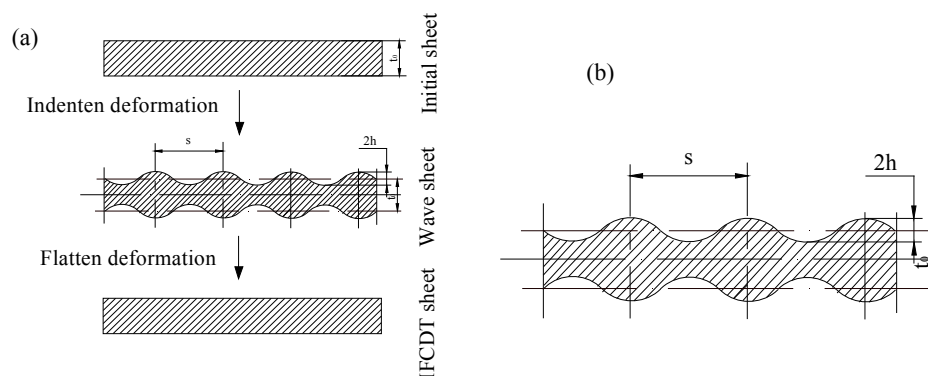


Fig.1 Principle of IFCDT (a, Principle of IFCDT; b, Deformation parameters.)

3. Experiments

Experiment material is AZ31 magnesium alloy which the thickness is 7mm. After annealing treated at temperature 450°C and holding time 60 min, the microstructure of the material is shown in Fig.2a, which the average grain size is about 56 μm , and grains distributed more uniformly and there are no twins.

In experiment study of IFCDT, the tools temperature is 150°C, and the reduction is 2 mm, and the coefficient of IFCDT(λ) is 1/1, 1/2 and 1/3, respectively. Deformation temperature is 150°C, 200°C, 250°C, 300°C, 350°C, respectively. And reduction ratio being 14%, 29%, 43%. Speed of deformation is 10mm/s.

4. Influence of deformation ratio on microstructure

When deformation temperature is 250 °C, and the reduction is 2 mm, and the reduction ratio is 43%, and the coefficient of IFCDT is 1/1, 1/2, 1/3, respectively. The microstructure of position of wave top and wave root is shown as Fig.2. It can be seen that with decrease of coefficient of IFCDT, the grain size of wave root of Mg alloy increases gradually and the volume of twins decreases gradually. The reason is that when the coefficient of IFCDT is small, the stress state in wave root of deformation zone is two compress stress, and is conducive to the formation of twins and the grains are broken into smaller grains.

Microstructure of deformation zone of wave top is shown as Fig.3. It can be seen that the average grain size is 17 μm when the coefficient of IFCDT is 1/1. When the coefficient of IFCDT is 1/2, the average grain size is fine and uniform, and the average grain size is 7 μm . When the coefficient of

IFCDT is $1/3$, the average grain size is $10\mu\text{m}$. The reason is that twins are occurred in position of wave top deformation zone of by compress stress. During the intermediate annealing process, the static recrystallization occurs, which makes most of the twins disappear. When the coefficient of IFCDT is $1/1$, the effect of the large stress in deformation zone of wave top makes store a lot of energy of twin. During flattening deformation, grain nucleates and grows rapidly, and the grain size is large. When the coefficient of IFCDT is $1/3$, the twin volume becomes smaller and the stores energy of twin is less, and the grain nucleation and growth is slowly. There is no recrystallization region, and the microstructure uniformity is poor, the average grain size is larger.

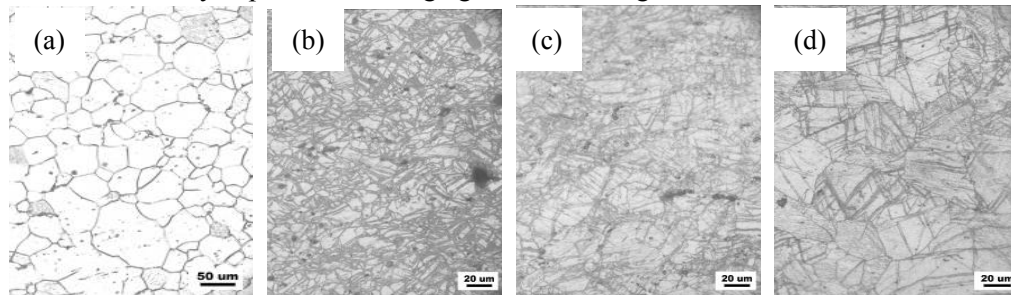


Fig.2 Microstructure at wave root under different coefficient of IFCDT of AZ31 Mg alloy when reduction ratio is 43% and 250°C (a, original; b, $1/1$; c, $1/2$;d, $1/3$)

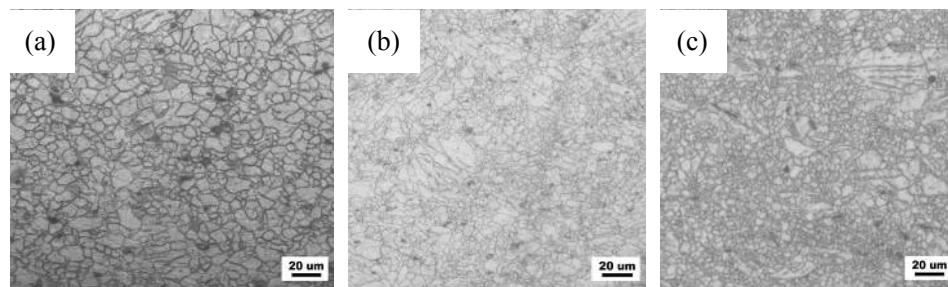


Fig.3 Microstructure at wave top under different deformation ratio of AZ31 Mg alloy when reduction ratio is 43%, and 250°C (a, $1/1$; b, $1/2$; c, $1/3$.)

5. Influence of reduction ratio on microstructure

When deformation ratio is $1/2$ and the temperature is 250°C , the influence of reduction of IFCDT on microstructure of the magnesium alloy sheet was studied by experiment. The microstructure of the deformed sheet in the zone of wave root is seen as Fig.4. With the increase of reduction, the volume fraction of twin increases gradually. The reason is that twins occurred is not a thermal activation process but the stress activation process. With increase of reduction, the stress of deformation zone increased gradually, and the number of twins increases.

The microstructure of the deformed sheet in the zone of wave top is seen as Fig.5. Recrystallization appeared significantly in deformation zone of deformed sheet. When reduction ratio is 14%, the average grain size in wave root is $12\mu\text{m}$, and the grain size is not uniform. When reduction ratio is 29%, because of the organization distribution not uniformly and the individual larger twin grains, the average grain size is $10\mu\text{m}$. When reduction ratio is 43%, the amount of grain refinement is obviously, and the average grain size is $7\mu\text{m}$, and twins disappeared. When the coefficient of IFCDT is $1/2$, the average grain size reduced with increase of reduction ratio. The reason is that the large amount of deformation caused more twins appeared, and more activation energy increased. It can be prone to recrystallization behavior in the middle annealing process of IFCDT, and grain is refined.

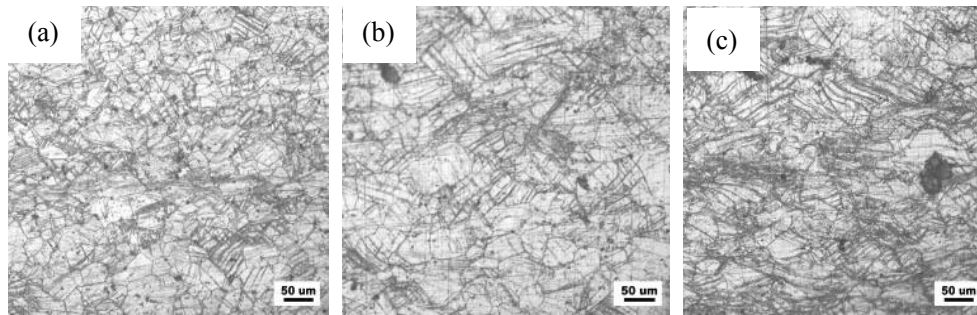


Fig.4 Microstructure at wave root under different reduction ratio of AZ31 Mg alloy when deformation temperature is 250 °C (a, 14 %; b, 29 % ; c, 43 %)

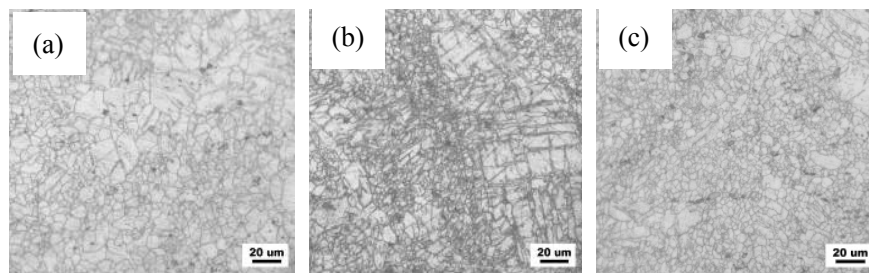


Fig.5 Microstructure at wave top under different reduction ratio of AZ31 when deformation temperature is 250 °C (a, 14 %; b, 29 % ; c, 43 %)

6. Influence of deformation temperature on microstructure

The influence of deformation temperature on microstructure is shown as Fig.6. With increase of temperature, the volume fraction of twins decreased gradually, and twins disappeared fully at temperature 350 °C. The reason is that the cylinder and cone slip system is not easy to start at low temperature for magnesium alloy, and the main deformation mechanism is twin. With increase of temperature, the critical shear decreased, resulting cylinder and cone slip stress to start, and thereby replacing the twin. Main deformation mechanism is dislocation slip replacing the twin. Under the same deformation conditions, the twins decrease until disappear fully.

The influence of deformation temperature on microstructure in top of wave is shown as Fig.7. When temperature is below 150 °C, during process of IFCDT, there is some twin appeared, but no recrystallization occurred, and the average grain size is 32 μm. When temperature is over 250 °C, recrystallization occurred, and twin disappeared, and the average grain size is 12 μm, and distribution is uniform. When temperature is 350 °C, the grains grow up, and the average grain size is 21 μm. The reason is that high temperature is beneficial to grain growth.

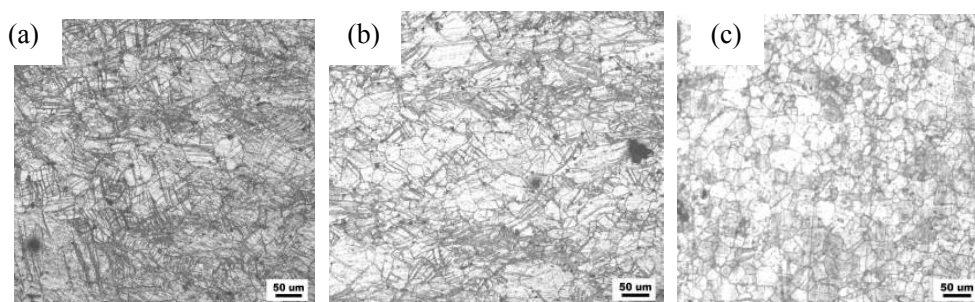


Fig.6 Microstructure at wave root under different temperature of AZ31 when the reduction ratio of IFCDT is 14% (a, 150 °C; b, 250 °C c, 350 °C)

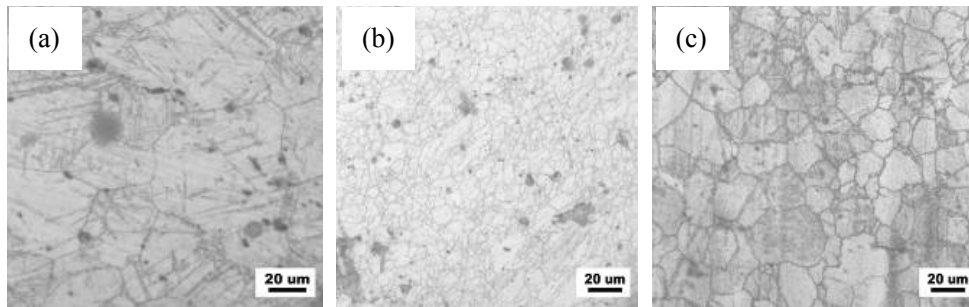


Fig.7 Microstructure at wave top under different temperature of AZ31 when the reduction ratio of IFCDT is 14% (a, 150°C; b, 250°C; c, 350°C)

7. Conclusions

- (1) During indentation-flattening compound deformation technology (IFCDT) of AZ31 magnesium alloy sheet, with increase of the coefficient of IFCDT, the volume fraction of the twin crystal decreases gradually, and the average grain size tends to decrease.
- (2) With increase of the reduction ratio, the volume fraction of the twin crystal gradually increases, and the average grain size also has a tendency to decrease.
- (3) With increase of deformation temperature, the volume fraction of the twin crystal decreases gradually, and the twin crystal grain size increases.
- (4) When temperature is below 150 °C, no complete recrystallization occurred, and grain size is 32 μm; when temperature is over 250 °C, recrystallization appeared completely, twins disappeared, and grain size is 12 μm, and most uniform. When temperature is 350 °C, the grains grown up, and the grain size is 21 μm.

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