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Grain Growth Model of AZ80 Magnesium Alloy Under Isothermal Condition

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Abstract： Microstructure evolution of AZ80 magnesium alloy under isothermal condition is researched by experiment. Effect law of heating temperature and holding time on grain size for AZ80 magnesium alloy is researched. With increasing of holding time and with rising of heating temperature, the grain size increases obviously. According to the test data, the grain growth model of AZ80 magnesium alloy under isothermal condition is established based on Seller's model, and the activation energy of grain growth of AZ80 magnesium alloy is determined, Q=85900J/mol. The model calculation results are in good agreement with that of experiment, and the relative errors between the model calculation results and that of experiment are less than 15.6%.

1. Introduction

The grain growth model of materials under condition of isothermal is one of the very important theories to represent the microstructure and mechanical properties. It is a necessary theoretical model for numerical simulation of microstructure evolution and process design. The accuracy of grain growth model has direct influence on the computational accuracy of numerical calculation. Zhao [1] studied grain growth behavior of ZK60 magnesium alloy, and the grain growth model is established. Tan [2] studied the grain growth law during continuous dynamic recrystallization. Mechanism of grain refinement is that the grain boundary misorientation and small angle grain boundaries translated gradual to high angle grain boundaries. Wang [3] studied the microstructure evolution law of hot deformation of bulk AZ31 magnesium alloy. A kinematic model of grain growth is established, which can predict the grain size accurately. Samman [4] studied the influence of deformation temperature and strain rate on dynamic recrystallization during AZ31 magnesium alloy compression deformation, and the influence of initial texture on grain size of dynamic recrystallization. Ciccarelli [5] had studied the flow stress and microstructure evolution of ZK60 magnesium alloy, and a new constitutive equation was proposed to consider the motion of grain boundary and dislocation. Liu [6] found that base slip and twinning are the plastic deformation mechanisms of magnesium in six square crystals. The local stress distribution, multi twin, twin nucleation and twin growth of magnesium alloy were explained by

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elastic viscoplastic simulation method. Bhattacharyya [7] studied the evolution of microstructure and texture during the annealing process of rolled AZ31B magnesium alloy. The influence of texture on grain growth of magnesium alloy was analyzed. Bhattacharya [8] had studied the relationship between dynamic recrystallization flow stress, strain rate, strain rate and temperature of AZ31 magnesium alloy under hot working conditions, and the constitutive equation under hot deformation condition has been established, and the size of dynamic recrystallization grain has been quantitatively analyzed. Li [9] had studied the effect of strain rate on the microstructure evolution and mechanical response of AZ31 magnesium alloy, and the synergism of slip and twin deformation was clarified.

In this paper, the aim is to study the microstructure evolution of AZ80 magnesium alloy at different heating temperature and holding time. Grain growth model of AZ80 magnesium alloy is established which describes the grain growth law of AZ80 magnesium alloy under isothermal condition.

2. Experiment results

The material is AZ80 magnesium alloy sheet, and the thickness is 7 mm, and the original grain size of AZ80 magnesium alloy is 12.2 μm. During annealing treatment, the range of heating temperature is 290℃- 410 ℃, and holding time is 15 min- 60 min.

When holding time is 30 min, the effect of heating temperature on microstructures of AZ80 magnesium alloy are shown as Fig.1. With increase of heating temperature, the grain size increases significantly.

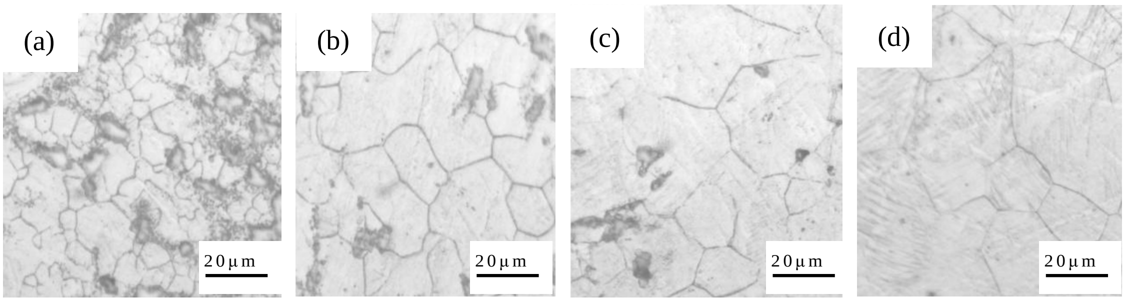

Fig.1 Effect of heating temperature on microstructures of AZ80 (holding time 30 min)(a, 290℃; b, 340 ℃; c, 390℃; d, 440℃)

When heat temperature is 290℃, the effect of holding time on microstructures of AZ80 magnesium alloy are shown as Fig.2. The grain size increases with increase of holding time. The grain size of AZ80 magnesium alloy after annealing treatment, under different conditions is shown in Fig.3.

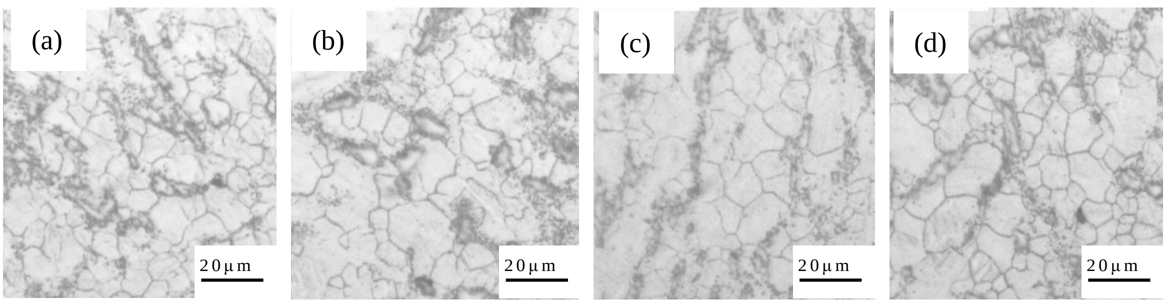

Fig.2 Effect of holding time on microstructures of AZ80 (heat temperature 290℃) (a,15min; b, 30min; c, 45min; d, 60min)

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3. Model of Grain Growth

The grain growth model of austenitic is used to AZ80 magnesium alloy, which was proposed by Sellars [10], seen as equation (1).

$$d = d_0 + A t^m \exp\left[- Q/(RT)\right] \tag{1}$$

In which, d is ultimate grain size (μm); d_0 is original grain size (μm); T is heating temperature(K)； t is holding time(min)； R is gas constant, R=8.314 J/(mol K); Q is activation energy of grain growth (J/mol); A, m are coefficients, which are related with materials, and determined by test data.
Taken equation (1) logarithms, equation (2) can be obtained.

$$\ln(d-d_0) = \ln A + m \ln t - Q/(RT) \tag{2}$$

When the holding time (t) is constant, the value of Q can be calculated by equation (3).

$$Q = -R \cdot \left.\frac{\partial\left[\ln(d - d_0)\right]}{\partial(1/T)}\right|_t = -Rk \tag{3}$$

In which, $k = \partial\left[\ln(d - d_0)\right]/\partial(1/T)\big|_t$.

When heating temperature (T) is constant, the value of m can be calculated by equation (4).

$$m = \left.\frac{\partial\left[\ln(d - d_0)\right]}{\partial(\ln t)}\right|_T \tag{4}$$

According to the test data which is shown as Fig.3,， the curves of $\ln(d - d_0)$ —1/T can be plotted under different holding time, shown as Fig.4. The value of k equals the slope of the curve, and the value of Q can be determined by equation (3).

According to the test data which shown as Fig.3,， the curves of $\ln(d - d_0)$ —ln$t$ can be plotted under different heating temperature, shown as Fig.5. According to slope of the curves, the value of m can be determined by equation (4). According to equation (1) — (4), the value of Q, m, and A can be calculated.

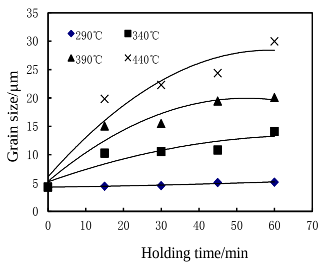

Fig.3 Grain size results

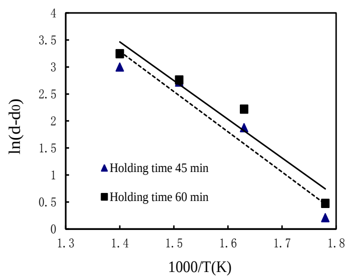

Fig.4 Grain size vs. temperature

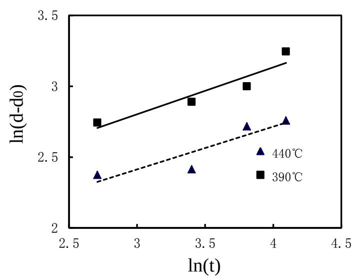

Fig.5 Grain size vs. holding time

According to the curves of Fig.4 and Fig.5, the values of *Q*, *m*, and A can be determined, *Q*=85900 J/mol，*m*=0.599，A=1.3×10^7. Taken the coefficients into equation (1), the grain growth model of AZ80 magnesium alloy under isothermal condition is obtained, seen as equation (5).

$$d = d_0 + 1.3\times10^7 t^{0.599} \exp\left[-85900/(RT)\right] \quad (5)$$

Comparison of calculation results of model with that of experiment, the relative errors are less than 15.6%, shown as Fig.6.

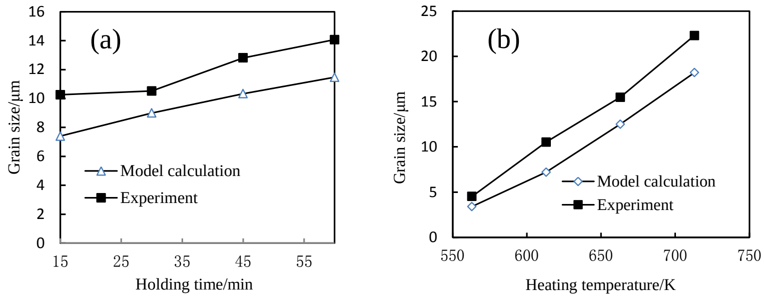

Fig.6 Comparison of calculation results of model with that of experiment(a, temperature 340℃; b, holding time 30 min)

4. Conclusions

(1) The effect law of heating temperature and holding time on grain size for AZ80 magnesium alloy is researched. With increasing of holding time and with rising of heating temperature, the grain size increases obviously.

(2) According to the test data, the grain growth model of AZ80 magnesium alloy is established, and the activation energy of grain growth of AZ80 magnesium alloy is determined, *Q*=85900J/mol.

(3) The model calculation results are in good agreement with that of experiment, and the relative errors between the model calculation results and that of experiment are less than 15.6%.

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