Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 81 (2014) 173 – 178
Procedia Engineering
www.elsevier.com/locate/procedia

11th International Conference on Technology of Plasticity, ICTP 2014, 19-24 October 2014, Nagoya Congress Center, Nagoya, Japan

Simulation of rolling process of AZ31 magnesium alloy sheet

Di Liu, Zuyan Liu*, Lumeng Wang

National Key Laboratory for Precision Hot Processing of Metals, Harbin Institute of Technology, Harbin, 150001, P. R. China

Abstract

To understand more about the rolling process of an AZ31 magnesium alloy sheet and the difference of simulation results between 2D and 3D, the rolling experiment of AZ31 was carried out and some useful data were obtained, and then the rolling processes were simulated by DEFORM2D and 3D respectively. The simulation results are in good agreement with the experimental results based on selecting the correct parameters of stress-strain relationship of AZ31, the friction factor with or without lubricant and the interfacial heat transfer coefficient. The influences of rolling reduction, workpiece temperature and roller temperature on the rolling load and torque are discussed and the difference of simulation results between 2D and 3D is illustrated.

Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University

Keywords: AZ31 magnesium alloy; Rolling process; Simulation

1. Introduction

Magnesium is the lightest structural material in engineering applications [1] and is widely used in automotive and aerospace industries due to its superior properties, such as high specific strength and stiffness [2]. Magnesium also exhibits sound casting and cutting properties, furthermore, it has high vibration damping and effective electromagnetic screening. It has actually been named the 21st century's green structural metallic material [3]. The advent of new magnesium alloys, the development of heat treatment and processing technology has led to

* Corresponding author. Tel.: 86-451-86417629; fax: +86-451-86412064.
E-mail address: lzy@hit.edu.cn

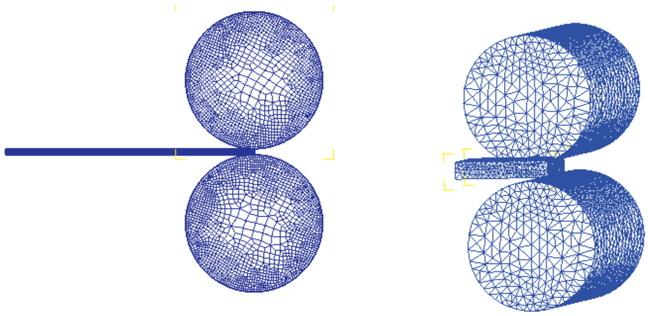
Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University
doi:10.1016/j.proeng.2014.09.146

utilization of the properties of magnesium alloys, therefore they have become a substitute for materials such as steel, copper, aluminium and engineering plastics. With the implementation of research proposals on magnesium alloys as well as the increasing demand from automobile and electronic industry for magnesium alloys, the development of high-strength, heat-resistant, corrosion-resistant and low cost magnesium materials and products has a bright future [4-7]. However, the processing cost is high due to the plastic deformation characteristics of magnesium and its alloys [8]. This restricts the application of magnesium alloys, hence the research focus on the plastic process ability of AZ31 magnesium alloy.

In this paper, research on rolling of AZ31 magnesium alloy was carried out, DEFORM software was used to simulate the rolling process and the process parameters were analyzed in detail to provide a theoretical basis for practical production.

2. Establishment of Geometric Model and Selection of Parameters

DEFORM-2D and 3D systems were used to simulate the rolling processes of AZ31 magnesium alloy, and the geometric models are shown in Fig. 1. The roller diameter is 220 mm, and the length and width of the workpiece is 400 mm and 131.5 mm, respectively. The objective was to ascertain whether a significant difference exist between the two systems of simulation.



a. DEFORM-2D b. DEFORM-3D

Fig. 1. The rolling models in DEFORM.

To improve the calculation accuracy, it is essential to determine the parameters in the actual deformation of magnesium alloys, such as the friction factor, interfacial heat transfer coefficient, stress-strain curves. The dry friction factor between AZ31 magnesium alloy and steel is about 0.5, and when graphite oil is used as the lubricant, the friction factor is about 0.069. The interfacial heat transfer coefficient between magnesium alloy and air is about 0.016 N/s/mm/°C, and that between magnesium alloy and die is 11N/s/mm/°C [9].

3. The experimental verification of rolling simulation

The experiments were carried out to verify the simulation results, during which the thickness of AZ31 workpiece was 28.5 mm, the initial temperature of the workpiece was 270 °C and that of the rollers was 400 °C. The rolling speed was 5m/min and there was no lubricant.

The workpiece thickness was reduced from 28.5 to 5.3 mm in 5 passes, the rolling reductions were 18, 8.5, 31.9, 36.6 and 42.4% and the temperatures of the workpiece were 270, 286, 265, 252 and 244 °C.

Fig. 2 show the results of steady rolling load in experiments and 2D simulations, the spots of different colours represent different passes, and the error of simulation results to the experimental results was about 10% implying that the simulation results are reliable.

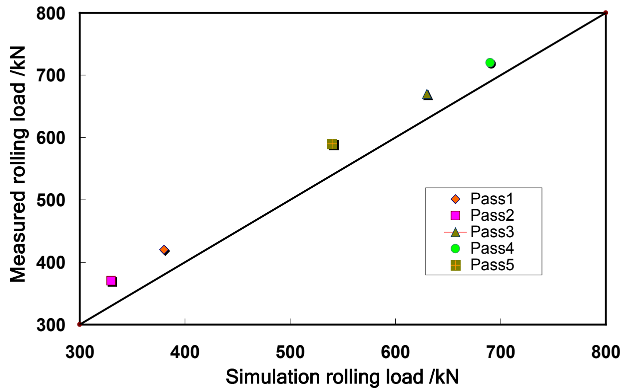


Fig. 2. The experimental results and 2D simulation results of steady rolling force.

Here, the rolling load is high, even the high temperature of rollers has no obvious effect on the decrease of rolling load. The results of DEFORM 2D and 3D are very close, and the relative error is less than 5%. Fig. 3 show the simulation results of rolling load as a function of time obtained using DEFORM 2D and 3D, in which the work-pieces of 100mm in width were rolled from 10mm to 8mm. In Fig. 3a the temperature of both the workpiece and roller was 20 °C while in Fig. 3b the temperature of the roller was 450 °C and that of the workpiece was 20°C. It can be observed that the rolling load is high in both cases meaning that increasing the temperature of the rollers has no significant effect on reduction of the rolling load. The results obtained using DEFORM 2D and 3D are very close, and the relative error is less than 5%.

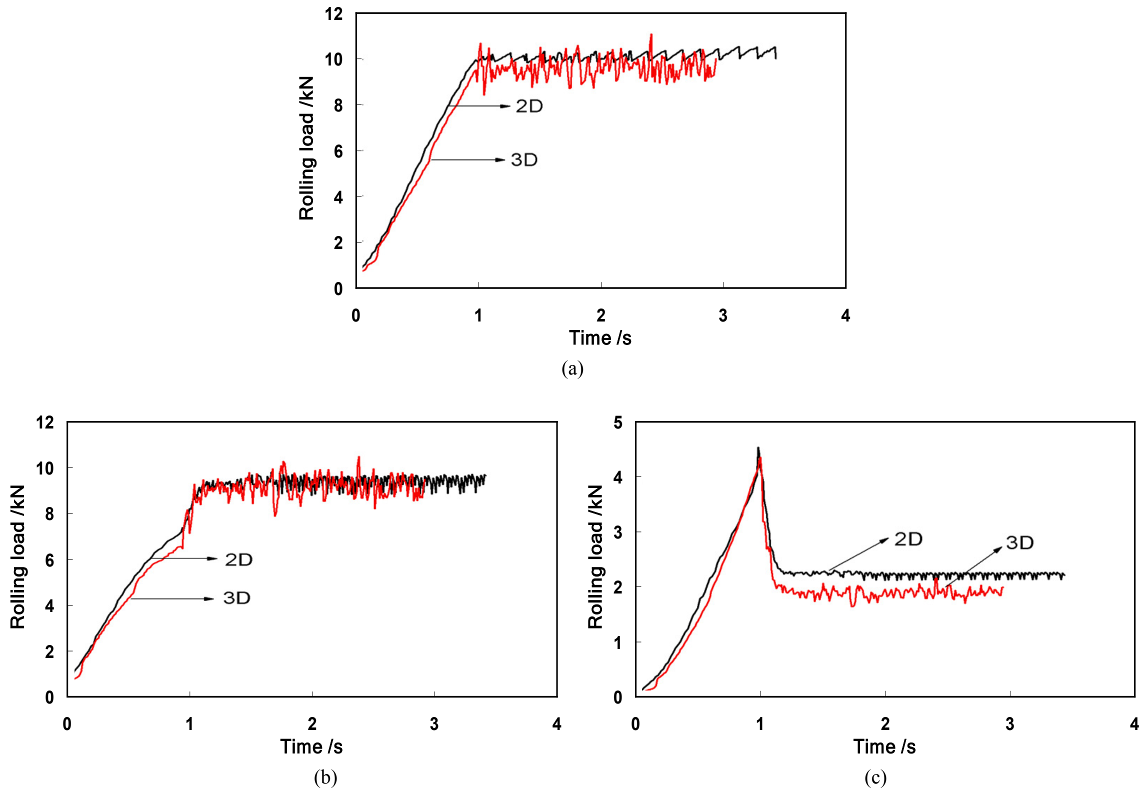


Fig. 3. Steady rolling load.

Fig. 3c shows the results obtained when the workpiece was heated to 450 °C, and the temperature of rollers at 20 °C. In this case, the rolling load is decreased greatly. However, the relative error of the results between DEFORM 2D and 3D is increased to 15%.

The fluctuation of the rolling load by DEFORM 3D is larger than that of 2D, this proves that, DEFORM 2D is a good choice when the temperature of the workpiece is not high (workpiece temperature < 450 °C).

4. Influence of process parameters on rolling load

4.1 Influence of tension on rolling load

It is known that during sheet rolling process, if there is tension on the workpiece, it will prevent the workpiece from moving off the rolling track, sticking and warping. Additionally, the tension compensates for non-uniform deformation along the width of the workpiece. An appropriate uni-direction or bi-direction tension would reduce the rolling load significantly.

Fig. 4 shows the effects of tension on the rolling load. The workpiece is rolled from 10 mm to 6 mm, and in Fig. 4a, the temperature of the workpiece and rollers is 20 °C, in Fig. 4b, the temperature of rollers is 400 °C, while the temperature of the workpiece is 450 °C in Fig. 4c. These results show that the bi-direction tension has more effect on reduction of the rolling load.

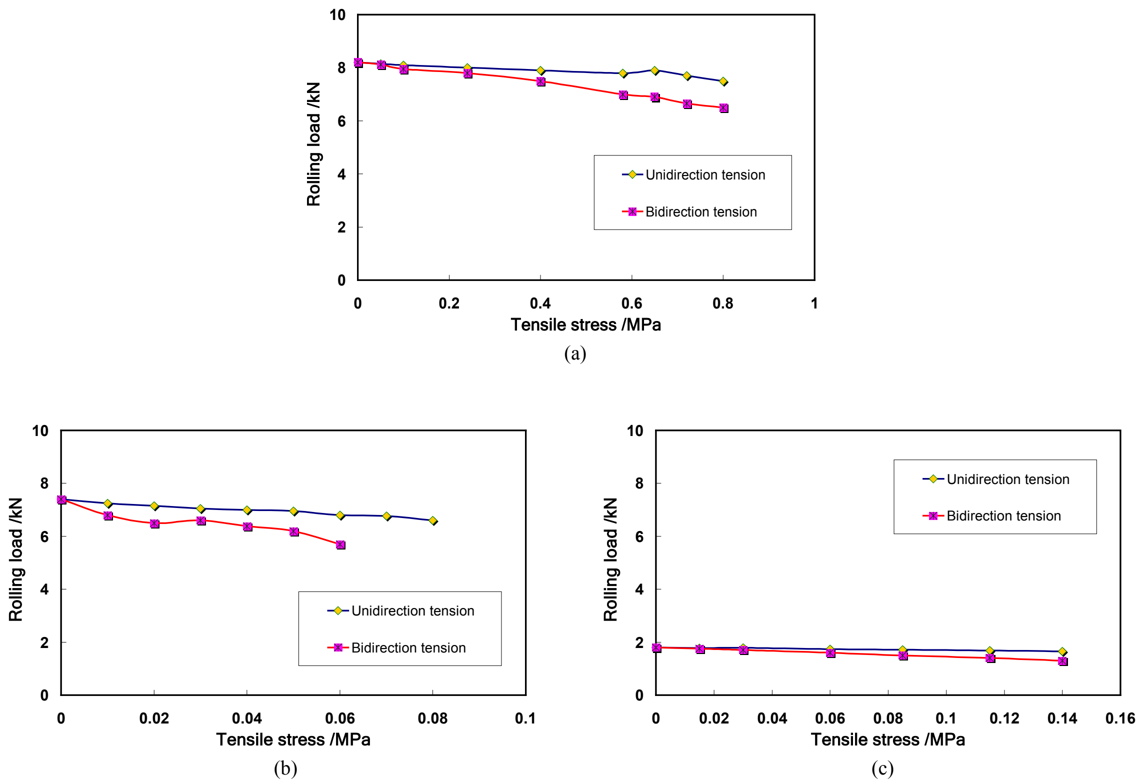


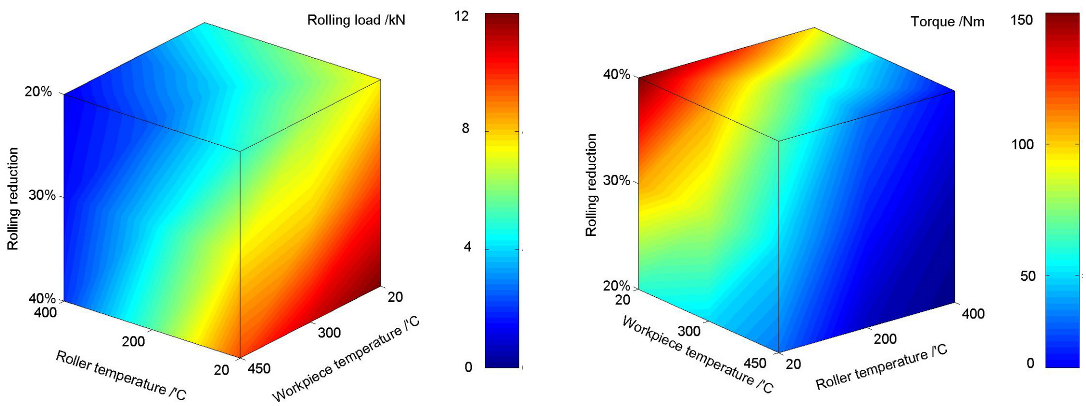
Fig. 4. Influence of tension on rolling load.

4.2 Influence of temperature and rolling reduction on rolling load and torque

Except the tension, other parameters, such as temperature of the workpiece and rollers, rolling reduction, also have great effects on the rolling load. Fig. 5 shows the simulation results of the influence of these factors on the rolling loads and torques. During the simulation, the diameter of roller was 600 mm, the initial thickness of workpiece was 5mm, and the temperatures of roller were 20, 200 and 400 °C, the temperatures of workpiece were 20, 300 and 450 °C, the rolling reductions were 20, 30 and 40%, respectively. In this situation, a four-dimension model was used to describe the effect of three variables on one other variable, which meant that the relationship among four variables could be displayed in one model quantitatively.

For example, when the rolling reduction is 20%, the temperature of the workpiece is 20 °C, as the roller temperature increases from 20 to 400 °C, the rolling load decreases from 7.5 to 4.9 kN. If the temperature of the workpiece is 300 °C, the rolling force decreases from 6.0 to 2.5 kN. If the temperature of workpiece is 450 °C, the rolling force decreases from 4.5 to 1.2 kN. This indicates that when the size of rollers is large, their temperatures would have appreciable effect on the reduction of rolling load. However, it is clear that the effects of rolling reduction and workpiece temperature on the reduction of rolling load are larger than that of roller temperature, which can be seen easily from the change of colours.

The influence of rolling reduction, workpiece temperature and roller temperature on the rolling torque is also shown clearly in Fig. 5b. The four-dimension model is an effective method to express a complex relationship among four variables.



(a) (b)

Fig. 5. Influence of workpiece temperature, roller temperatures and rolling reduction on rolling load(a) and torque(b).

5. Conclusions

(1) In the simulation, all the parameters, such as the stress-strain relationship of AZ31 magnesium alloy, the friction factor between workpiece and die with or without lubricant and the interfacial heat transfer coefficient between magnesium alloy and air, and between magnesium alloy and die, are correct which ensure the simulation results agree well with the measured results.

(2) Both DEFORM 2D and 3D can be used to simulate the rolling process of AZ31 magnesium alloy and provide valid results. Compared to DEFORM 3D, DEFORM 2D is very simple and easy to use. However, when the workpiece temperature is high, the relative error of rolling load between DEFORM 2D and 3D is about 15%.

(3) Most important factors which influence the rolling load and torque are rolling reduction, workpiece temperature and roller temperature. By simulation, the effects of these factors on the rolling load and torque can be explained quantitatively.

(4) The four-dimension model is an effective method to express a complex relationship among four variables.

References

[1] Miao Q, Hu L X, Wang G J, Wang E D, 2011. Fabrication of excellent mechanical properties AZ31 magnesium alloy sheets by conventional rolling and subsequent annealing[J]. Materials Science and Engineering A, 528(22), 6694-6701.

[2] Rao K P, Prasad Y, Suresh K, 2011. Materials modeling and simulation of isothermal forging of rolled AZ31B magnesium alloy: Anisotropy of flow[J]. Materials & Design, 32(5), 2545-2553.

[3] S.Y. Zhang, M. P. Geng, S. S. Xie, 2006. The research process of magnesium alloy forming technology. The thermal processing. 35(13), 79-80

[4] Wang Q J, Du Z Z, 2006. The research process of magnesium alloy plastic processing technology. The light alloy fabrication technology. 34(1), 14-16

[5] Ding H, Hirai K, Homma T, 2010. Numerical simulation for microstructure evolution in AM50 Mg alloy during hot rolling[J]. Computational Materials Science, 47(4), 919-925

[6] Homma T, Kunito N, Kamado S, 2009. Fabrication of extraordinary high-strength magnesium alloy by hot extrusion. Scripta Materialia, 61(6), 644-647.

[7] Nick Fantett, 2006. Supply and demand of the global magnesium. China Nonferrous Metals. (8), pp. 22-23.

[8] Cheng Y Q, Chen Z H, Xia W J, 2007. Drawability of AZ31 magnesium alloy sheet produced by equal channel angular rolling at room temperature[J]. Materials characterization, 58(7), 617-622.

[9] Wang L. M., 2008. Study on numerical simulation of rolling process of AZ31 magnesium alloy sheet. Master dissertation, Harbin Institute of Technology, Harbin, China. 11-12.