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PARAMETRIC COMPUTER SIMULATION AND METALLOGRAPHIC ANALYSIS OF ALUMINUM ALLOY DIES

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Abstract: According to computer simulation method, the influence of die exterior angle and die interior angle on the deformation of 6082 aluminium alloy during ECAP extrusion was analysed under the condition that other factors remained unchanged. The effects of the internal and external angles of the die on the load, deformation and deformation uniformity of 6082 aluminium alloy during ECAP extrusion were analysed by load-stroke curve, deformation diagram of grid nodes, equivalent strain rate, equivalent stress distribution and variation curve. By comparing and analysing the microstructure, tensile properties, hardness, XRD and texture of 6082 aluminium alloy before and after ECAP deformation, it is concluded that after ECAP deformation, the microstructure of 6082 aluminium alloy is refined, and the yield strength, tensile strength and elongation of the specimen are effectively improved. The tensile fracture surface of ECAP is typical shear fracture.

Keywords: computer simulation, finite element, aluminium alloy, metallographic

I. INTRODUCTION

In different industrial applications, the increasing demand for new materials has prompted material researchers to improve the properties of traditional alloys through new processing techniques. At the same time, new alloys have been developed to meet the changing requirements of users. For example, the manufacturer must consider two main factors at the same time. First, the factor is customer expectations, such as fuel consumption, mechanical properties, structural design, corrosion resistance, durability and low investment. Second, it should meet the legal requirements and production standards, such as explosion and safety, gas emissions and noise emissions. Because of its excellent comprehensive properties, such as low density, corrosion resistance, high strength, workability, high conductivity and thermal conductivity, aluminum alloy is widely used in the production of automobile, aircraft, ship and other structural parts. Based on the vigorous development of the automotive industry, researchers predict that the use of aluminum alloys in European passenger cars will continue to increase in the next decade. Therefore, it is particularly important to optimize the comprehensive properties of aluminum alloys by appropriate forming methods.

Finite element analysis (FEA) is a method based on computer three-dimensional or two-dimensional software, which uses advanced mathematics and engineering mechanics knowledge to solve practical processing problems. In the process of finite element calculation, it is generally assumed that the deformed body is a plastic or elastic-plastic continuum without any voids. In the process of finite element calculation, the amount of deformation and the deformation force are expressed by equivalent strain and stress. In this paper, the effects of die structure, friction, temperature and extrusion pass on stress, strain and mechanical properties of 6082 aluminum alloy in ECAP process are analyzed by combining finite element analysis with experiment.

II. FINITE ELEMENT NUMERICAL SIMULATION

A. *Computer simulation scheme*

The finite element numerical simulation software DEFORM-3D V10.2 used in this paper can be used to analyze the deformation of samples in different forming and heat treatment processes. By computer simulation of processing technology, DEFORM not only reduces the cost of actual processing, but also shortens the development cycle of new technology. DEFORM software has friendly user interface, huge material library and simple pretreatment. Users do not need to spend a lot of time in the early software learning, and can focus on billet deformation analysis.

In DEFORM, mesh generation is divided into absolute and relative mesh generation. After simulation and comparison, the network partitioning method in this paper adopts relative network partitioning. Solution control in DEFORM simulation includes solution and selection of iteration methods. In order to accurately grasp the influence of different die structures on extrusion load, strain and strain inhomogeneity and strain distribution in different deformation regions of 6082 aluminum alloy during ECAP deformation, three-dimensional finite element analysis was carried out. By using DEFORM-3D V10.2, the load-stroke curve, mesh node deformation diagram, equivalent strain, equivalent strain rate, equivalent stress distribution, average equivalent strain and non-uniformity index of 6082 aluminum alloy during ECAP extrusion were analyzed with the external and internal angles of the die as the analysis variables.

B. *Extrusion load of samples with different external angles*

The load-stroke curve of 6082 aluminum alloy during ECAP deformation was obtained by simulation calculation. Fig. 1 is a load-stroke scatter plot with an outer angle of 10 degrees and an inner angle of 90 degrees. The discrete degree of points can be seen that the load change process of 6082 aluminum alloy ECAP extrusion can be divided into three stages. In the first stage, the specimen begins to enter the cross passage of the die, and the load increases rapidly from zero to zero, resulting in asymmetric shear deformation. The specimen is filled with the lower edge of the die passage at first. After b-point, the load enters the second stage. From the grid deformation diagram, it can be seen that the shear deformation area of the specimen is generated, the load scatter plot becomes dense and the load increases slowly. The specimen enters the transverse passage, the load enters the third stage, the load is stable, the scatter plot is densely distributed in order, and the specimen mesh produces uniform shear deformation, as shown in Fig.2. Fig.3 shows the load-stroke curves of the extrusion process when the inner angle of the die is unchanged and the outer angle of the die is 10, 25, 37 and 50 degrees respectively. It can be seen from the figure that the internal angle of the die is unchanged, and the load change trend is the same under different external angle deformation of the die. However, with the increase of the die outer angle, the load value is different when the load enters the stationary stage. The load decreases with the increase of die outer angle.

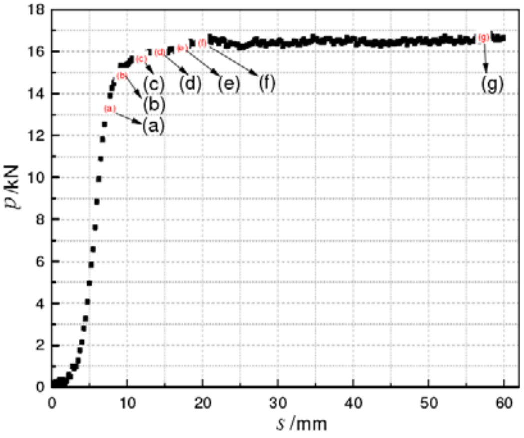


Fig.1 Load-stroke curve

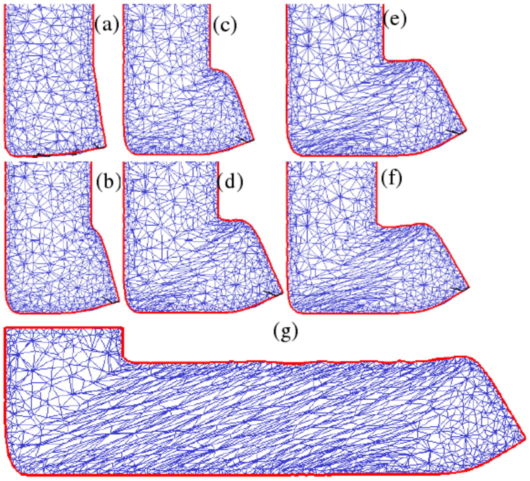


Fig.2 Deformation corresponding to different load points

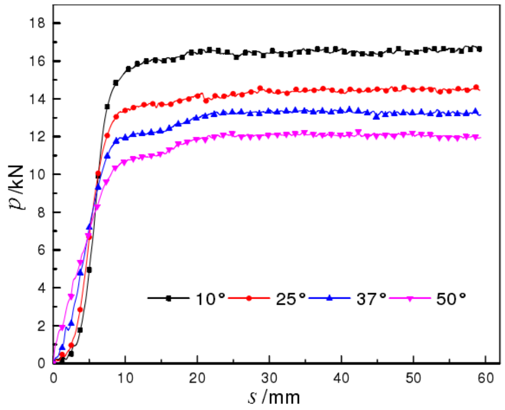
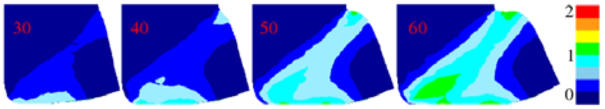


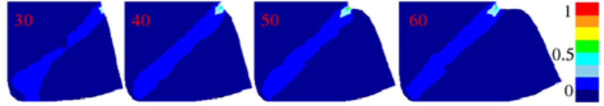
Fig.3 Load-stroke curves corresponding to different die exterior angles

C. *Deformation process of samples with different external angles*

Fig. 4 shows the equivalent strain, equivalent strain rate and equivalent stress distribution when the outer angle of the die passage is 10 degrees and the inner angle of the die passage is 90 degrees and the steps are 30, 40, 50 and 60 respectively. The same column corresponds to the same extrusion step, and each row corresponds to a continuous extrusion step. The first deformation chart shows that when the sample is extruded to 30 steps, the sample begins to enter the cross channel of the die. The equivalent strain and stress of the specimen near the outer corner of the die are the largest. Deformation occurs in the region where the equivalent stress is the largest. When the specimen is extruded to 50 steps, the head of the specimen enters the cross channel. From the strain rate diagram, it can be seen that the deformation band of the sample is located at the angle between the die passage and the cross passage of the die, and the deformation begins to stabilize. In the third column, the equivalent strain, the equivalent strain rate and the distribution of the equivalent stress form a stable shear deformation zone, and the deformation tends to be stable. It can be seen that the maximum equivalent strain value of the specimen is located at the outer and inner angles of the die passage.



(a) Equivalent strain



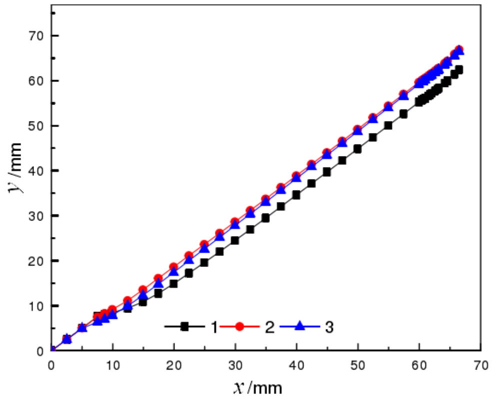
(b) Equivalent strain rate

Fig.4 Equivalent strain and strain rate at different extrusion steps

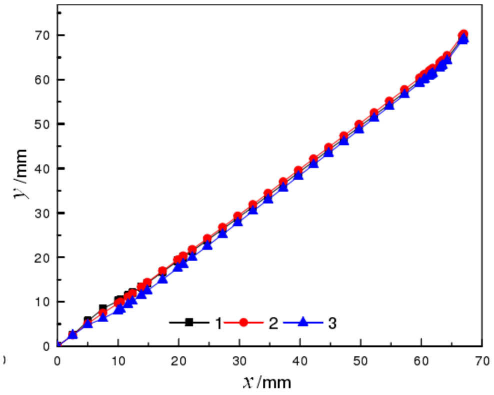
In the process of passing through the corner arc of the die passage, the sample is not fully filled with the die to form a void. At the angle gap, the specimen and the die did not fully contact during the extrusion process. When the exterior angle of the die is 10 degrees, the angle clearance is located in the area between the bottom of the transverse channel of the die and the outside of the vertical channel of the die. The formed angle clearance is not symmetrical, and the vertical length is longer than the transverse length. With the increase of the die outer angle, the transverse length decreases, the vertical length increases, and the angle gap decreases gradually. When the exterior angle of the die is 50 degrees, the angle gap formed is slender and narrow. This is because the radius of the outer corner of the die is more and more close to the sample diameter with the increase of the outer corner of the die. Under ideal conditions, no angular gap will be formed, and the specimen will always be in the state of three-dimensional stress during extrusion. However, when angular clearance occurs, the extrusion force on the specimen is no longer triaxial stress, the specimen will have the possibility of cracking, and the deformation will be more uneven.

D. Head deformation of samples with different external angles

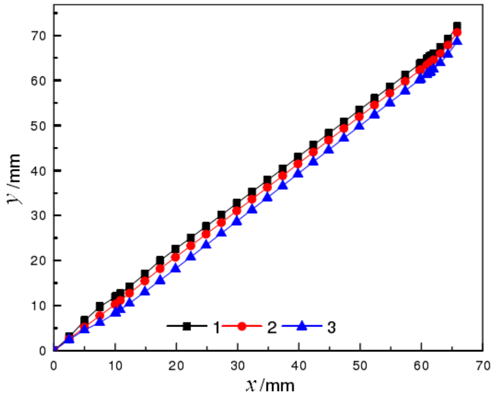
In order to better understand the uneven deformation of 6082 aluminum alloy with different die exterior angles during ECAP processing, four nodes are selected at the head of the specimen in the deforming region, and the deformation results are shown in Fig. 5. Each node is located in different equivalent strain range, and each independent node is no longer subjected to extrusion force when it is extruded into the cross channel of the die. Equivalent stress is closely related to the plastic deformation of the specimen. The strain value of the same node increases with the decrease of the inner angle of the die. For the equivalent strain rate, the specimen is in an asymmetric upsetting deformation stage, which is equivalent to 30 to 60 steps of extrusion. The equivalent strain rate value is very small. With the continuous extrusion, the equivalent strain rate gradually increases to the maximum. After the specimen is extruded into the cross channel of ECAP die, the region of the joint of the specimen head is no longer located. When deformation occurs, the equivalent strain rate gradually tends to zero.



(a) 10°



(b) 25°



(c)37°

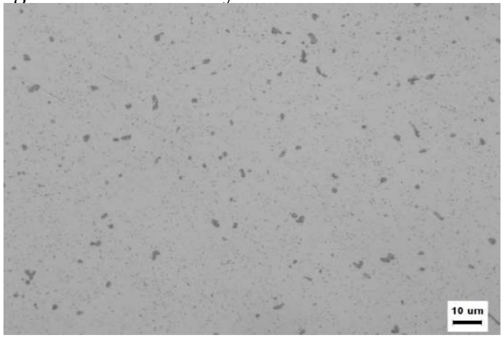
Fig.5 Head deformation of samples with different external angles

III. MICROSTRUCTURE AND PROPERTIES OF ALUMINUM ALLOYS

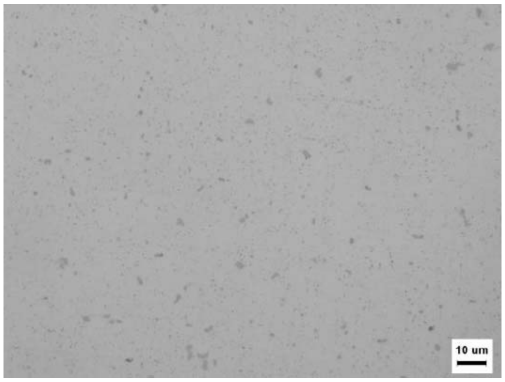
A. Microstructure of 6082 aluminum alloy

The ECAP experiment of 6082 aluminium alloy was carried out at room temperature. In the initial stage of extrusion, the extrusion force on the hydraulic press began to increase with the vertical downward extrusion of the extrusion rod. When the sample passes through the channel corner, the extrusion force of the extruder increases rapidly and then reaches stability. The process of extrusion force change is consistent with the process of numerical simulation load change. According to the simulated deformation degree, the specimen can be divided into three regions: the head deformation zone, the middle deformation zone and the tail deformation zone. The deformation of the head and tail is not uniform, and the middle deformation zone is uniform deformation zone. Its length accounts for about 75% of the total length of the specimen.

In order to characterize the microstructures of 6082 aluminum alloy before and after ECAP extrusion, the uniform deformation zones of 6082 aluminum alloy in solution state and ECAP state were sampled and analyzed respectively. Fig. 6 and Fig. 7 show the microstructures of 6082 aluminum alloy in solid solution state and ECAP state respectively. It can be seen that the microstructure of ECAP before and after deformation is composed of uniformly distributed gray matrix and black particle phase. The particle phase of solid solution 6082 aluminum alloy is irregularly distributed on the matrix. The number of particles on the matrix decreases, the flake size decreases, and the gray matrix is evenly distributed. That is to say, after ECAP deformation, the structure is evenly distributed and the grain size is obviously refined.

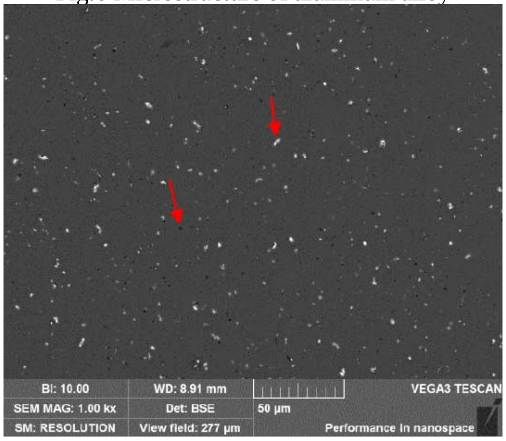


(a) Solid solution state

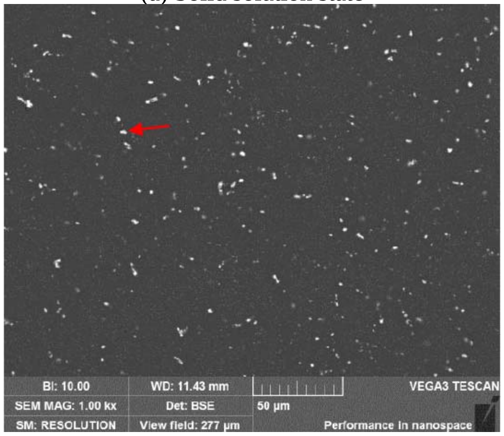


(b) ECAP state

Fig.6 Microstructure of aluminum alloy



(a) Solid solution state

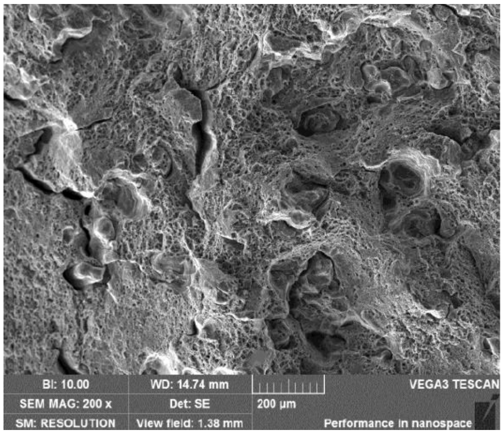


(b) ECAP state

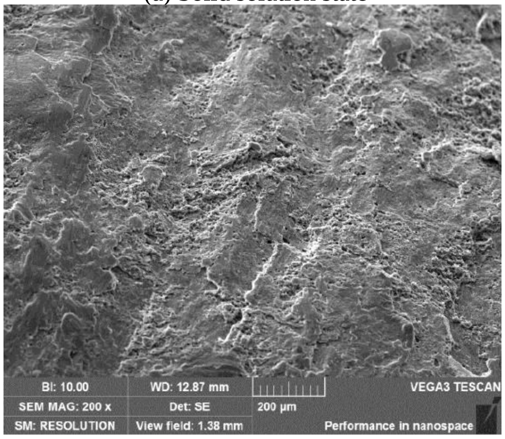
Fig.7 SEM morphology of aluminum alloy

B. Mechanical properties of aluminium alloys

The fracture surface of 6082 aluminum alloy in solution state and ECAP state after tensile fracture is shown in Fig.8. The fracture surface of 6082 aluminum alloy in solution state is cubic cone, and that of ECAP sample is shear fracture. Obviously, the direction of shear fracture and tensile stress is 45 degrees. The tensile strength and elongation of 6082 aluminum alloy extruded by ECAP increased. The fracture morphology of 6082 aluminum alloy after ECAP extrusion is composed of fine dimples and fish scale structure. In conclusion, ECAP extrusion improves the strength and plasticity of 6082 aluminum alloy.



(a) Solid solution state



(b) ECAP state

Fig.8 SEM morphology of fracture surface of aluminum alloy

IV. CONCLUSION

Through analysis, it can be concluded that the load required for deformation, the degree of shear deformation, the average equivalent strain, the non-uniformity index and the maximum equivalent strain decrease inversely with the increase of the outer angle of the die when the inner angle of the die remains unchanged. In the process of ECAP deformation, the exterior angle of the die should be properly increased to ensure that the deformation uniformity of the deformed aluminum alloy sample can be guaranteed as well as the appropriate deformation amount. Therefore, when the inner angle of the die is 90 degrees and the outer angle of the die is 25 degrees to 37 degrees, the deformation size and uniformity of the specimen are within a desirable range. When the exterior angle of the die is kept constant and the inner angle of the die is greater than 90 degrees, the specimen does not get a large strain after deformation. Therefore, in the follow-up research process, the ECAP die with an outer angle of 37 degrees and an inner angle of 90 degrees was adopted. After ECAP deformation, the microstructure of 6082 aluminum alloy is refined, which effectively improves the yield strength and tensile strength of the sample.

V. ACKNOWLEDGEMENT

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VI. REFERENCES

[1] H. Xiuhua. “Research and Simulation of motion feature registration method for three-dimensional images,” Computer Simulation, vol.32, pp.206-209, October 2015.

[2] L. Liu-min, H. Guiyun. “Optimal detection simulation after attenuation change of intrusion data,” Computer Simulation, vol.33, pp. 234-237, August 2016.

[3] L. Hongsheng. “Simulation of Robot Path Planning Optimization Method under Complex Path,” Computer Simulation, vol. 31, pp. 407-411, January 2014.

[4] L. Qiaohua. “Hybrid Electric Vehicle Regenerative Braking Simulation Analysis,” Journal of Automotive Engineering, vol. 01, pp. 464-468, April 2014.

[5] Q. Canwen. “Braking simulation of vehicles on opposite pavement,” Agricultural Equipment And Vehicle Engineering, vol.3, pp. 45-47, June 2018.

[6] Z. Zhiguo, P. Yugang. “Series Electro-hydraulic Hybrid Braking Simulation for Four-wheel Hybrid Electric Vehicle,” Journal of Systems Simulation, vol.24, pp.208-215, July 2015.

[7] W. Kesheng, Z. Leiqiang. “Braking simulation analysis of field off-road vehicle based on virtual prototype,” Computer Simulation, vol.28, pp.342-347, April 2013.