ISSN: 2688-8645

Research Status of Twinning Mechanism and Twinning Segmentation Mechanism in Magnesium Alloy During Low Temperature Deformation

Minghua Yuan, Lianyao Tang

Guangdong University of Science & Technology, Guangdong, 523000, China.

E-mail: 1058363715@qq.com

Abstract

It is the low temperature formability of LZ magnesium alloy with different Li content (4-13wt%) that was studied, and The influence of different Li content (4-13wt%) on the twinning mechanism of magnesium alloy (such as the type and quantity of twins) was studied. As a result, the systematic analysis of the twinning mechanism and twin segmentation mechanism during the low and medium temperature deformation of this series of magnesium alloys can lay a foundation for comprehensively mastering the twin characteristics of LZ series magnesium alloys and realizing the application of low temperature deformation of LZ series magnesium alloys.

Keywords

Twinning mechanism; twinning segmentation mechanism;magnesium alloy; low temperature deformation.

1. INTRODUCTION

Magnesium alloy is a metal which is light weight and high specific strength. As far as it is found that Mg-Li alloy is the lightest metal structure material Among all metal materials. Because the characteristics of the alloy crystal structure closely related to Li content, it has attracted great attention. In order to research the formability of LZ series magnesium alloy at low temperature, the deformation law and mechanism of LZ series alloy with different Li content (4-13wt%) were explored. The influence of different Li content (4-13wt%) on the twinning mechanism of magnesium alloy (such as the type and quantity of twins) was studied. The systematic analysis of the twinning mechanism and twin segmentation mechanism during the low and medium temperature deformation of this series of magnesium alloys can lay a foundation for comprehensively mastering the twin characteristics of LZ series magnesium alloys and realizing the application of medium low temperature deformation of LZ series magnesium alloys. The deformation mechanism of magnesium alloy is mainly twinning and base slip.

There are three common twinning modes in magnesium alloy, tensile twins, compression twins, and secondary twins represented [1, 2]. The twin mechanism of magnesium alloy is greatly affected by the initial conditions and deformation conditions of sheet metal, and the magnesium alloy presents low-temperature deformation behavior and mechanical anisotropy [1]. Barnett et al. [3] believe that the grain size can influence the number and total volume of twins are affected, and the number of twins increases with the increase of grain size. Jiang et al. [4] considered that the effect of twin interaction on stress was much greater than that of grain size.

2. DOMESTIC RESEARCH STATUS ON THE INFLUENCE OF TWINNING TYPE ON LOW- TEMPERATURE DEFORMATION OF MAGNESIUM ALLOY

In terms of the effect of twinning type on the low-temperature deformation of magnesium alloy, Beer. [5] found that the peak stress of extruded magnesium alloy is higher than that of as cast magnesium alloy because the increase of twin number with Z parameter is becoming high. Studied on tensile and compressive twins in magnesium alloys, it is found that the compression twins and secondary twins have adverse effects on the deformation and reduce the elongation due to strain softening and voids (similar to the Twin Size). However, twinning can increase the elongation appropriately, which is beneficial to deformation [6]. Jiang. [7] considered the softening and hardening effects of compression twins and secondary twins in AM30 magnesium alloy during low temperature deformation. The results show that the softening effect of compression twinning and secondary twinning in AM30 magnesium alloy is greater than that of hardening. However, these studies have not involved how to overcome the shortcomings of compression twin and secondary twin, so as to improve the plasticity of magnesium alloy at medium and low temperature. In addition, the study on softening and hardening of other twin types has not been carried out.

3. THE RELATIONSHIP TWINNING AND DEFORMATION SOFTENING MECHANISM OF MAGNESIUM ALLOY

In terms of the relationship between twinning and deformation softening mechanism of magnesium alloy, myshlyaev.[8] studied the relationship between dynamic recovery and twinning, and considered that the twin boundary gradually evolved into high angle dislocation and finally evolved into zigzag grain boundary. Yin. [9] proposed twin induced dynamic recrystallization. It is found that a-dislocation and a+c dislocation at the intersection of twin and grain boundary are greatly excited during deformation at medium temperature. These dislocations entangle each other and lead to the formation of dynamic recrystallization nucleus. Galiyev. [10] have studied the morphology and mechanism of dynamic recrystallization of magnesium alloy. In view of this, the formation of twin dynamic recrystallization grains in magnesium alloy during low temperature deformation can be summarized into two types: one is the interaction of primary twins, the other is that secondary twins occur in the coarse primary twin layer, and the primary twin and secondary twin intersect each other to form a microcrystalline core and evolve into recrystallized grain chain in the twin region. The relationship between twinning and softening mechanism is well described, but there are still some deficiencies. For example, the mechanism of dynamic recovery and twin dynamic recrystallization, the initial temperature, the influencing factors and the role of deformation have not been discussed in depth. Moreover, the differences and relations between twin dynamic recrystallization and twin induced dynamic recrystallization have not been systematicly studied. Kleiner etal.[12] used low temperature prepare deformation to produce tensile twins. The twin makes the grains rotate 86.3 ° and all the basal planes in the twin are nearly perpendicular to the extrusion direction after compression, and are in a favorable orientation in the subsequent tension, and the yield strength decreases. Inspired by this, the applicant proposes to use low-temperature prepare stretching method to generate a large number of compression twins and secondary twins in magnesium alloy sheet, so as to weaken the texture of magnesium alloy sheet and improve the low-temperature plastic property of the sheet.The main principle of strain induced grain refinement is to induce dislocation (high-level fault energy alloy), phase transformation or twins (low-level fault energy alloy) in the alloy through a certain amount of strain, so as to form random oriented interface and achieve the purpose of grain segmentation [13, 14]. First proposed the theory of strain induced grain refinement. The ferrite grain size is refined to 1-3 μ m by using the induced ferrite transformation. With the deepening of the research, the principle of strain induced grain refinement has been summarized into three mechanisms, "dislocation segmentation", "phase transformation segmentation" and "twin segmentation". Dislocation segregation mainly occurs in face centered cubic (FCC) and body centered cubic (BCC) alloys with high fault energies, such as Al, Fe and Ni. The mechanism is that with the increase of strain, the deformation band formed by dislocation slip, the geometrically necessary dislocation interface and dislocation wall are transformed into random oriented interface, which separates the original grains. X Wu. Carried out ultrasonic shot peening (USSP) on the surface of 7075 aluminum alloy, resulting in surface strain, which induced dislocation, and segmented and refined grains to about 100nm [15]. N r Tao et al. Used the dislocation caused by strain to divide the grain on the surface of pure iron to 12NM [16]. For example, beladi. Used strain induced ferrite transformation in fe-c-mn-v alloy to refine the grain from 84 μ m to less than 1 μ m. Twinning segmentation is mainly used in low stacking fault energy alloys, such as Zr based, Ni based alloys, stainless steel and nano copper. First prepared a kind of electrodeposited copper containing a large number of nano to submicron growth twins. This kind of twin copper not only has ultra-high strength, but also has high ductility [13]. Ma. Have shown that the twin boundary, as a special low-energy grain boundary, hinders the dislocation movement in twin copper. A large number of twins divide the grains into a nano scale twin matrix lamellar structure. The smaller the thickness of the twin thin layer, the higher the material strength and the better the elongation [15]. Radetic. Observed the transformation process from twin boundary to large angle grain boundary in Cu Ti alloy by transmission electron microscope.

4. STUDY ON TWINNING SEGMENTTION TO REFINE MAGNESIUM ALLOY GRAINS

Jiang Y P. Studied the twinning cross behavior of extruded AZ61 Magnesium Alloy under high temperature cyclic bending, and considered that the twin crossover under high strain rate induced dynamic recrystallization [15]. Li X. Studied the effect of different types of twins on static recrystallization in AZ31 magnesium alloy [16]. It is found that the recrystallization nucleation point is preferentially located at the intersection of tensile twin and compression twin or at the intersection of tensile twin and compression twin. The influence of twinning cross on static recrystallization is analyzed, but the problem of twin cutting grain directly is not involved. Yang Xuyue. Carried out multi-directional and multi-pass compression deformation at room temperature for as extruded AZ31 magnesium alloy, resulting in compression twins, and the grain size was refined to 80-150nm [17]. However, due to the absence of Li element, the twinning mechanism of magnesium alloy without bcc structure β phase is quite different from that of Laz alloy; the original grain size of magnesium alloy is coarse, and the alloy needs to be repeatedly compressed for 30-50 passes to obtain nano scale grain. The work hardening is obvious and the grain size is not uniform, which is very unfavorable to the improvement of alloy plasticity. The stress concentration caused by work hardening can affect the degradation behavior of the alloy [18]. Denkena Found that the residual compressive stress on the surface of magnesium alloy can reduce the corrosion rate [19]. Therefore, when the grain is refined to a certain extent, the twin segmentation will help to reduce the cumulative deformation passes. At the same time, the plasticity of the alloy can be improved by adjusting the stress relief annealing process to eliminate the excessive stress concentration.

5. EFFECT OF TWIN NUMBER ON GRAIN SIZE STRAIN AND STRAIN RATE

According to barrent, the twinning type is related to the stress of grains in different stress directions. When the stress direction is parallel to or perpendicular to the c-axis, the tensile twins with convex lens shape are produced; when the stress direction is parallel to or perpendicular to the c-axis, the elongated linear compression twins and secondary twins are mainly produced. Due to strain softening and voids (similar to twin size), linear compression twins and twin twins have adverse effects on deformation and reduce elongation [20-21]. As mentioned above, according to the mechanism of twin segmentation, the smaller the thickness of twin thin layer is, the higher the material strength and the better the elongation. Therefore, the introduction of twin segmentation can refine the grain size of the alloy at the same time and make the compression twins "turn waste into treasure", which is beneficial to deformation. Barrent Believe that there is a corresponding relationship between the number of twins and the grain size, strain and strain rate. The larger the grain size and strain, the higher the twin density in a single grain [22, 23]. Ghaderi. Found that when the grain size is greater than 15 μ m, the number of twins is not sensitive to the variable [23]. However, when the grain size is 6.4 μ m, the number of twins is very sensitive to the variables. When the strain increases from 0.005 to 0.015, the twinning area increases from 60% to 100% [23]. Therefore, on the basis of controlling the grain size of the alloy during rapid solidification, it is very important to properly adjust the strain and strain rate during multi-directional accumulative deformation to control the number of twins and to adjust the effect of twin segmentation.

6. CONCLUSION

(1) the understanding of twinning mechanism and twinning characteristics is not comprehensive and in-depth, and more stay at the macro qualitative level, but far from the understanding of its micro nature.

(2) The mechanism of twin segregation in magnesium alloys is also rarely involved. Therefore, it is of great scientific and practical significance to study the twinning mechanism and twinning characteristics of LZ series magnesium alloy during low temperature deformation.

REFERENCES

[1] Chen Z H, Xia W, Yan H G.Wrought magnesium alloy.Beijing: Chemical Industry Press , 2005, (2): 6-78.

[2] Wang Y N, Huang J. The role of twinning and untwinning in yielding behavior in hot-extruded Mg–Al–Zn alloy. Acta Materialia, 2007, 55(3): 897-905.

[3] Barnett M R. A rationale for the strong dependence of mechanical twinning on grain size. Scripta Materialia. 59(7): 696-698.

[4] Jiang L, Jonas J, Mishra R K.Twinning and texture development in two Mg alloys subjected to loading along three different strain paths. Acta Materialia. 2007, 55(11): 3899–3910.

[5] Beer A G, Barnett M R. Influence of initial microstructure on the hot working flow stress of Mg–3Al–1Zn. Materials Science and Engineering A, 2006, 423(1-2): 292-299.

[6] Barnett M R. Twinning and the ductility of magnesium alloys Part II contract twins. Materials Science and Engineering A, 2007, 464(1): 8-16.

[7] Jiang L, Jonas J J, Luo A A, et al. Twinning-induced softening in polycrystalline AM30 Mg alloy at moderate temperatures. Scripta Materialia. 2006, 54(5): 771-775.

[8] Myshlyaev M M,McQueen H J,Mwembela A. Twinning dynamic recovery and recrystallization in hot worked Mg-Al-Zn alloy. Materials Science and Engineering A.2002,337(1):121-133.

[9] Yin D L,Zhang K F,Wang G F,Han W B.Warm deformation behavior of hot-rolled AZ31 Mg alloy. Materials Science and Engineering: A,2005,392 (1):320-325.

[10] Galiyev A, Kaibyshev R, Gottstein G. Correlation of plastic deformation and dynamic recrystallization in magnesium alloy ZK60. Acta materialia, 2001, 49(7):1197-1207.

[11] Chino Y, Kimura K, Hakamada M, Mabuchi M.Mechanical anisotropy due to twinning in an extruded AZ31 Mg alloy. Materials Science and Engineering A.2008, 485(1-2): 311-317.

[12] Kleiner S, Uggowitzer P J. Mechanical anisotropy of extruded Mg-6Al-Zn alloy. Materials Science and Engineering A, 2004, 379(1-2): 258-263.

[13] Lu L, Shen Y F, Chen X H, et al. Ultrahigh strength and high electrical conductivity in copper. Science, 2004; 304: 422.

[14] Priestner R. Strain induced gamma/alpha transformation in the roll gap in carbon and microalloyed steel. Proceedings of an International Conference on the Thermomechanical Process of Microalloyed Austenite. Pittsburgh: ASM International, 1981: 455-466.

[15] Wu X, Tao N, Hong Y, et al. Microstructure and evolution of mechanically-induced ultrafine grain in surface layer of AL-alloy subjected to USSP. Acta Materialia, 2002, 50: 2075-2084.

[16] Tao N R, Wang Z B, Tong W P, et al. An investigation of surface nanocrystallization mechanism in Fe induced by surface mechanical attrition treatment. 2002, 50: 4603-4616.

[17] Beladi H, Kelly G L, Shokouhi A, et al. Effect of thermomechanical parameters on the critical strain for ultrafine ferrite formation through hot torsion testing. Materials Science and Engineering A, 2004, 367: 152-161.

[18] Ma E, Wang Y M, Lu Q H, et al. Strain hardening and large tensile elongation in ultrahighstrength nano-twinned copper. Applied Physical Letter, 2004, 85: 4932.

[19] Radetic T, Radmilovic V, Soffa W A. elettron microscopy observations of twin-twin intersections in a particle hardened copper-titanium alloy. Scripta Materialia, 1999, 40(7): 845-852.

[20] Barnett M R. Twinning and the ductility of magnesium alloys Part I tension twins. Materials Science and Engineering A, 2007, 464(1): 1-7.

[21] Barnett M R. Twinning and the ductility of magnesium alloys Part II contract twins. Materials Science and Engineering A, 2007, 464(1): 8-16.

[22] Barnett M R. A rationale for the strong dependence of mechanical twinning on grain size. Scripta Materialia. 2008, 59: 696-698.

[23] Ghaderi A, Barnett M R. Sensitivity of deformation twinning to grain size in titanium and magnesium. Acta Materialia. 2011, 59: 7824-7839.