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Textures in multi-directional forged Mg by neutron diffraction

Weimin Gan[1, a], Heinz-Guenter Brokmeier[2, b], Mingyi Zheng[3, c] and Kun Wu[3]

[1]GKSS Out Station at FRM-II, Lichtenberg strasse 1, D-85747 Garching, Germany

[2]Institute of Materials Science and Engineering, Clausthal University of Technology, Argicolastrasse 6, D-38678 Clausthal-Zellerfeld, Germany

[3]School of Materials Science & Engineering, Harbin Institute of Technology, 150001 Harbin, China

[a]weimin.gan@gkss.de, [b]heinz-guenter.brokmeier@gkss.de, [c]zhenghe@hit.edu.cn

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Abstract. Texture evolution in the MDF processed ZK60 along forging axis was investigated by advanced neutron diffraction. Texture analysis was related to the deformation mechanism. Results showed that basal planes deformation was dominated and accommodated by non-basal and twinning. Gradient texture indicated an inhomogeneous distribution of imposed strains along forging direction. This could be related to the non-precise MDF processing.

Introduction

Multi-directional-forging (MDF), one of the severe plastic deformation (SPD) technique, can be applied to fabricate large scaled materials by using a conventional forging machine without any special equipments [1, 2]. Texture investigation in SPD processed materials is essential to be related to the thermomechanical deformation and vice versa to tailor and optimize the process. However, most of those texture investigations using EBSD or laboratory X-rays limit on the centre or researchers' interested area under an assumption of the homogeneous microstructure distribution. Very few researches have been paid on the texture homogeneity property over the cross section or along the main processing axis in bulk materials because of the technical difficulties.

Neutron diffraction is a standard method in large variety of investigations in physical, chemical, material, and geological researches. The first great improvement on neutron texture analysis was done by Bunge to combine this new experimental method with the quantitative texture description by the orientation distribution function (ODF) on copper sheet [3]. Since that time neutron diffraction became the standard method in bulk texture analysis with the highest quality of ODF-data compared to all other methods. The newly developed materials science diffractometer Stress-Spec at FRM-II (Garching, Germany) is designed to be equally applied to texture and residual stress analyses by virtue of its very flexible configuration [4].

Due to its high penetration and comparably high neutron flux Stress-Spec allows a combining non-destructive analysis of global texture and local texture in large variety of materials, e.g. metals, multi-phased composites and geological materials, etc. Neutron flux as well as slit arrangement is available to measure non-destructively texture gradients in semi-finished products [5]. To get sufficient description of the gauge volume a radial collimator in front of the detector is essential. As a function of the scattering behaviour (scattering power and absorption) the local volume inside a compact body can go down to 1 mm^3 at Stress-Spec in current state.

In this research, texture gradient over the sample's height along the forging direction in MDF processed Mg alloy from 1 pass to 2 passes will be investigated using neutron diffraction. Since the loading direction in principle is unaxial, it is still unknown about the homogeneity distribution of the imposed strains. Texture evolution will be related to the deformation mechanism.

Experimental

The material used for current study as the samples for MDF is commercial as-cast ZK60 with chemical composition of Mg-5.54% Zn-0.65% Zr (in mass %) and initial grain size of about 200 µm. The MDF was carried out at 300 ºC with the forging ram rate of about 2 mm·s^{-1} using a rectangular sample with dimension of 30×30×60 mm^3. This dimensional ration of 2×1×0.5 was kept during MDF processing with consequent change of the loading direction along the three perpendicular axes from pass to pass, as shown in Fig. 1. A single pass strain was about 0.8 [6]. In order to characterize the processing three axes x, y and z are defined as forging direction (FD), restricted deformation direction (ResD) and free deformation direction (FreD), respectively.

Neutron diffractometer Stress-Spec at FRM-II in Garching, Germany was used for texture characterization. A wavelength of 0.172 nm produced by Ge (311) monochromator was selected for texture measurement. The specimen with a dimension of 10×10×30 mm^3 for neutron diffraction was machined from the centre part along forging direction of the MDF large billet. Upper and lower positions along forging direction of this specimen were measured, respectively. Five reflections of (10.0), (00.2), (10.1), (11.0) and (10.3) were simultaneously measured for a complete pole figure using the combination of reflection and transmission method at two 2-theta area detector positions. The detector to sample distance was 900 mm. The measured pole figures were calculated by software package StressTexCalculator.

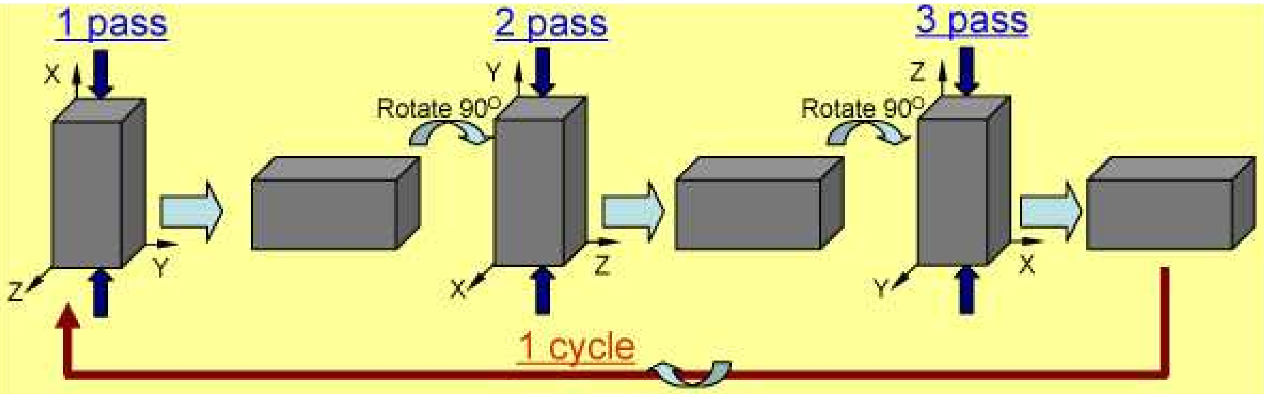

Fig. 1 Schematic illustration of the MDF process in which the loading direction was changed in 90º with pass to pass (x→y→z); here x, y, and z designate FD, ResD and FreD, respectively.

Results and discussions

Fig. 2 (a) shows the (00.2) and (10.0) pole figures at upper and lower regions in 1 pass MDF processed ZK60, respectively. The forging direction is in the pole figure center. It can be found that basal planes in large number of grains are oriented normal to the forging direction at both upper and lower parts. However, at lower part there is a small rotation of about 5º from the symmetric axis ResD which is similar as a shear effect. This small shear effect should come from the non-precise forging process, especially the mismatched difficult to control friction between specimens and die channels. The maximum intensity in pole figures at lower part is smaller than that at upper part, which results from a lesser strain at this region. This indicates a relatively inhomogeneous distribution of the imposed strain along forging direction.

Looking on the (00.2) pole figure at both parts two interesting intensity distributions are found. Firstly, a splitting angle of about 15º of the maximum pole from FD to FreD is obvious. This doubled poles distribution is widely reported in uniaxial compression or rolling deformed Mg and its alloys at elevated temperatures [7]. The activation of non-basal planes sliding at high temperature is generally proved to be attributed to this phenomenon [8]. Similar textures were also obtained in as-rolled Ti and Zr alloys [9], in which prismatic slip is predominant. Moreover, pyramidal slip also can be activated at high temperature which contributes to the spread of maxima poles. Second is a weak intensity distribution around ResD with its more obvious at lower part. This small component should associate with the twinning deformation. Basal plane slip accommodated by twinning deformation is widely happened, especially at initial stage in deformed Mg and its alloys. Twinning deformation is greatly related to the grains size and its orientation [10]. Since the start ZK60 has relatively large grains about 200 μm twinning deformation is preferred to happen. During MDF the ZK60 billet can only flow along FreD direction with its decrease of height which is similar as channel die deformation, the deformation along normal direction is greatly hindered. Twinning deformation therefore occurs in the first pass MDF processed ZK60.

Similarly, Fig. 2 (b) illustrates the textures at upper and lower parts in 2 passes MDF processed ZK60. A girdle distribution with its sharpness in (10.0) pole figure along FreD increased is observed, which is quite well with the textures obtained by normal rectangular extrusion of Mg alloys [11]. Texture sharpness in FD was decreased with its increase along FreD. This significant change from 1 pass to 2 passes should come from the MDF processing itself in which the input texture plays an important role; because the 2 pass must destroy the existed proffered orientation. This will be discussed in the following research considering the effect of input texture between successive passes. A twist at upper and lower parts is also noticed which should result from the same non-precise forging process. And a relatively weak texture at lower part is still obtained which similarly shows the non-equal distribution of the imposed strains as discussed above in 1 passed processed billet.

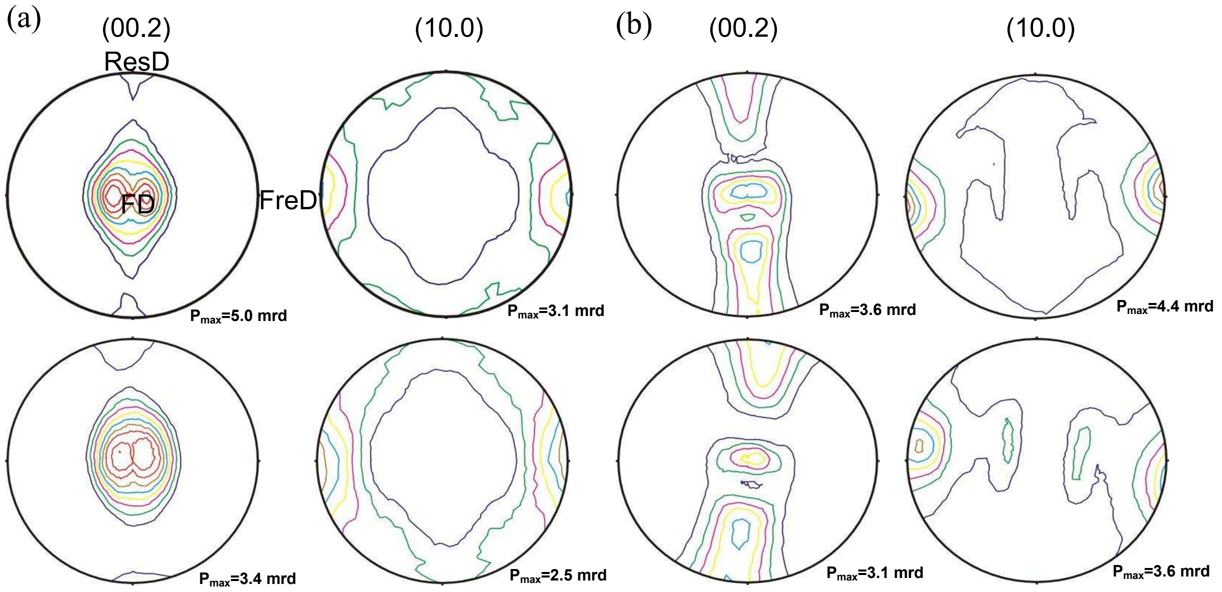

Fig. 2 The (00.2) and (10.0) pole figures in (a) 1 pass and (b) 2 passes MDF processed ZK60 at upper (first row) and lower (second row) regions, respectively. Contour levels=1.0×, 1.5×, 2.0×, …

Conclusions

(1) In general, the basal planes are preferred orientated normal to forging direction after 1 pass MDF processing which indicates a dominated basal planed sliding. Pole figure analysis also shows the accommodation deformations of non-basal planes slip and twinning.

(2) Due to the input texture effect similar as an extruded Mg pole figures with its sharpness increase in FreD are obtained.

(3) Texture gradient from upper to lower parts along forging direction is observed in both pass processed samples. And relatively weak texture at lower part is obtained which designates a non-equal distribution of the imposed strains.

(4) Asymmetry of the pole figure axis is obtained and should be related to the non-precise forging processing combining the friction effect.

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References

[1] J. Xing, X. Yang, H. Miura and T. Sakai: Mater. Sci. Forum Vol. 488-489 (2005), p. 597.

[2] T. Sakai, H. Miura and C. Yuang: Mater. Sci. & Eng. A 499 (2009), p. 2.

[3] J. Yobisch and H.J. Bunge: Texture Vol. 1 (1972), p. 125.

[4] M. Hofmann, G.A. Seidl, J. Rebelo-Kornmeier, U. Garbe, R. Schneider, R.C. Wimpory, U. Wasmuth and U. Noster: Mater. Sci. Forum Vol. 524-525 (2006), p. 211.

[5] H.-G. Brokmeier, C. Randau, U. Garbe, P. Spalthoff and J. Bohlen in: Magnesium, edited by K.U. Kainer, proceeding of 8th International conference on magnesium alloys and their applications, WILY-VCH (2009), p. 583.

[6] A. Belyakow, T. Sakai, H. Miura and K. Tsuzaki: Phil. Magn. A81 (2001), p. 2629.

[7] M.T. Perez-Prado, J.A. Valle. J.M. Contreas and O.A. Ruano: Scripta Mater. 50 (2004), p. 661.

[8] S.B. Yi, S. Zaefferer and H.-G. Brokmeier: Mater. Sci. & Eng. A424 (2006), p. 275.

[9] L. Jiang, M.T. Perez-Prado, P.A. Gruber, E. Aeyt, O.A. Ruano and M.E. Kassner: Acta Mater. 56 (2008), p. 1228.

[10] M.R. Barnett, Z. Keshavarz, A.G. Beer and D. Atwell: Acta Mater. Vol. 52 (2004), p. 5093.

[11] W.M. Gan, E. Maawad, H. Chang, G.D. Fan, C. Randau, M.Y. Zheng, K. Wu and H.-G. Brokmeier: Solid State Phenomena Vol. 160 (2010), p.117.

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