Texture gradient in a bonelike extrusion profile of Mg Ze10

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1 Introduction:

Deformation by rolling or extrusion leads to the development of typical texture in any kind of materials. Typical textures are related to crystal structure dependant deformation regimes (glide systems, and twinning), to recrystallization and to phase transition. These textures have been published in many papers since 80 years and books. However, the activation of glides systems or of twinning as well as the recrystallization behaviour can be influenced by alloying elements and thermo-mechanical process parameters. That means, well known fundamental crystallographic texture of pure Mg can be varies for different Mg-alloys. In figure 1 typical basal plane pole figures (00.2) are shown for round extrusion (Fig 1a), quadratic extrusion (Fig. 1b), rectangular extrusion (Fig. 1c) and rolling (Fig. 1d).

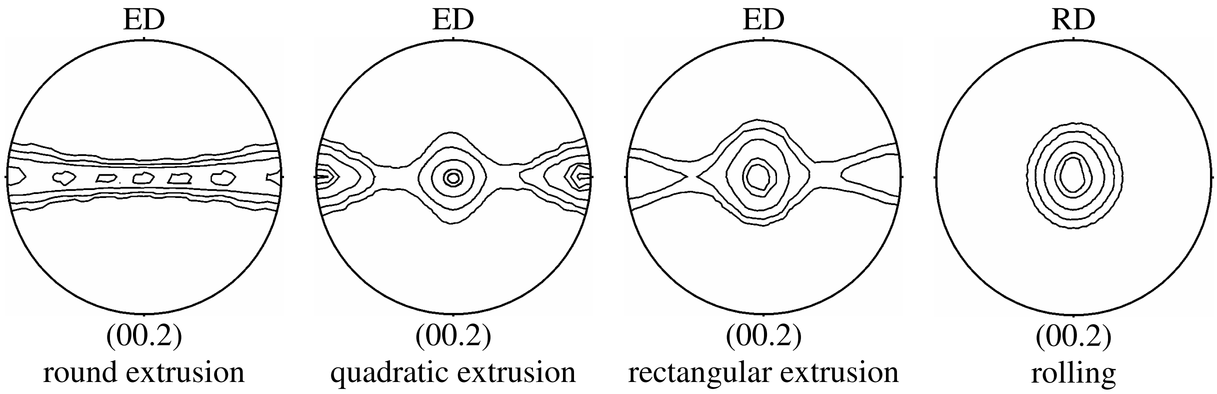

Figure 1: Typical Mg textures for extrusion and rolling: a) round, b) quadratic, c) rectangular and d) rolling

One can see that the main orientation of (00.2) tends to be parallel to major flow plane. For rolling (00.2) planes orient parallel to the rolling plane, while for round extrusion the (00.2) planes orient around the perimeter of the rod with the normal parallel to extrusion direction. Quadratic and rectangular extrusion is in between. All pole figures shown in figure 1 are obtained by neutron diffraction without any correction (without background correction).

Materials flow in profile extrusion is more complicated than extrusion of simple geometries such as round rods or quadratic and rectangular bars. Consequently, a change to more complicated extrusion profiles results in a mixture of different texture types. Therefore, a bonelike extrusion structure is an ideal candidate, where a texture gradient from ideal round to rectangular is expected. Open is the local gradient between possible ideal textures. Further open questions are:

- Will the inhomogeneous materials flow in different parts of the bonlike profile lead to shear deformation
- Beside the texture gradient, is there also a stress gradient?
- How strong is the influence of the texture gradient on the gradients in the materials properties?
- How to measure the texture gradient?

Texture measurements can be done by conventional X-rays (Cu-Kα, Co-Kα), EBSD-techniques, neutrons and hard X-rays (synchrotron – up to 200 kV). While conventional X-rays and EBSD belong to surface methods with a high need of precise sample preparation, the other two methods work with bulk samples of some centimetres. Non-destructive bulk methods are always preferred if larger samples are helpful and if stress and texture measurements have to be done. Stress analyse requires non-destructive samples of semi-finished products not to relieve the stresses by sample preparation. The present paper will concentrate only on the investigation of the texture gradient.

2.0 Experiment:

Different types of samples were prepared from a much longer extruded profile, as show in figure 2. Both, thermal neutrons as well as 100 keV synchrotron radiations have a penetration power of some cm [1] which makes them ideal for non-destructive investigations.

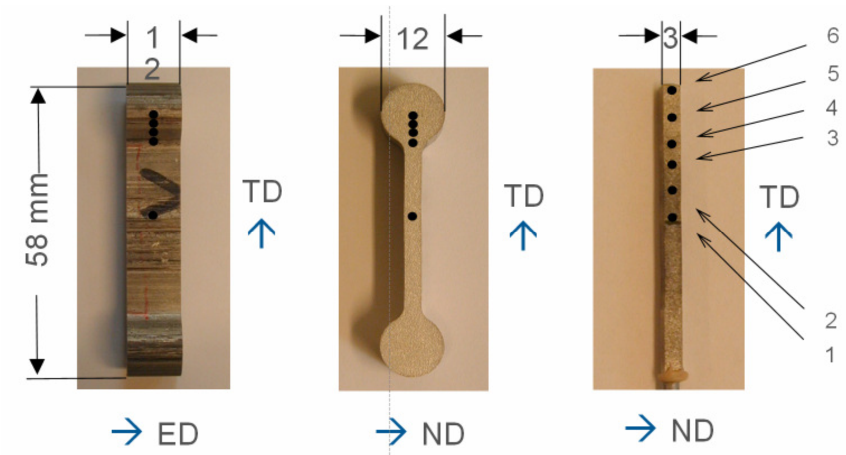

Figure 2: Set of samples cut from a long bonelike extrudate, marked points are for texture gradient investigations

The neutron experiments were carried out at TEX-2 at FRG-1/GKSS Research Center and at STRESS-SPEC at FRM 2 / TU Munich. Due to the limited beamtime and the low scattering intensity of Mg a gage volume of 2x2mm² was used. The marked points in figure 2 describe the investigated areas. STRESS-SPEC is working with an area detector so that three reflections Mg (10.0), (00.2) and (10.1) were obtained simultaneously. Moreover, in case of 5x5 counting grid the area detector leads to reduced counting time by a factor 2. A description of STRESS-SPEC was given by Hofmann et al. [2]. The neutron texture measurements particular at TEX-2 are much slower than synchrotron measurements. There is also a heavy restriction in available space if the sample is mounted inside an Eulerian cradle. Particular STRESS-SPEC as multipurpose instrument for strain and texture analysis shows a restriction in z-movement. For future experiments a robot system controlled by a Laser tracker will over excellent experimental facilities at STRESS-SPEC.

The synchrotron measurements were done at the high energy beamline BW5 at HASYLAB/ DESY Hamburg [3]. For the present study photon energy of 113.7 keV (0.1039Å) was used. With a MAR345 image plate area detector complete Debye-Scherrer cones were detected in 50 sec. Figure 3 shows two examples for image plate pictures of sample position 1 (middle section) and sample position 6 (head part). Around the Debye-Scherrer cones the intensity varies, and is different for both positions. This is the first indications of the different texture at these two positions.

sample position 1 sample position 6

Figure 3: Image plate picture of Mg bonelike extrudate (position 1 – middle section, position 6 – head part)

The gage volume was obtained by cross slits of 1 x 1 mm². Related to the scattered intensity a much smaller gage volume is possible, but the grain statistics for sufficient texture evaluation gives a lower limit. One can see that the smallest Debye-Scherrer cone (Mg (10.0)) is little spotty. Compared to other techniques, only sample rotation for complete pole figure coverage is necessary. Therefore, a set of 36 image plate pictures with $\Delta\omega = 5°$ were used to get complete pole figures. Including the readout time of the MAR345 detector the complete texture with 6 pole figures was obtained in about 70 minutes.

3 Results

First step of data evaluation was done by StressTexCalculator a program system to extract pole figure data from area detector data. This program works for both data sets obtained a STRESS-SPEC (neutron) and BW5 (synchrotron). In a second step the orientation distribution function (ODF) was calculated by the iterative series expansion method. In the following from ODF recalculated pole figures were shown. Both methods give similar results, due to different pole figure window for STRESS-SPEC and BW5 the texture sharpness varies. In the following only the synchrotron data are presented.

The texture of the middle section shows three texture components, see figure 4. Strongest texture component is the double maximum in ND for (00.2) pole figure. This double maximum has a strong anisotropy. A second texture component is at TD, which is slightly weaker. A third texture component is the <10.0> fibre, visible in both pole figures of figure 4. One can find these textures in normal rectangular extruded material. The reason for the anisotropy is not fully understood.

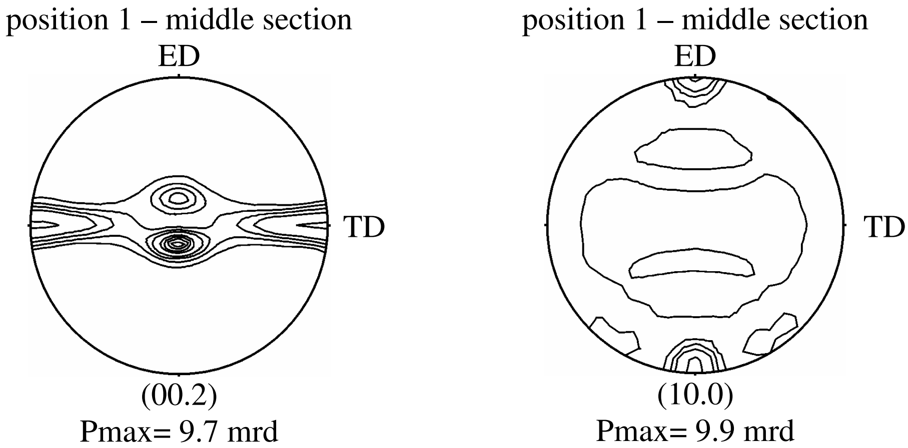

Figure 4: (00.2) and (10.0) pole figure of the middle section

Positions 2 and 3 were also in the middle section, see figure 2, but closer the intermediate region. The texture shown in figure 5 is nearly constant with same texture components than for position 1. Comparing the intensity relation of the double maximum in pole figure centre a weak gradient occurs. The strong pole varies from 9.7 mrd (mrd – multiple random) for position 1 to 10.0 mrd for position 2 and 10.4 mrd for position 3. Together with this increase the weaker pole region degreases from 4.7 mrd (pos. 1) to 4.0 mrd (pos. 2) and 3.8 mrd (pos. 3). That means the anisotropy of the central texture component is stronger close to the intermediate region and shows a factor of about 2 in the middle section (pos. 1) and a factor of 2.7 at position 3.

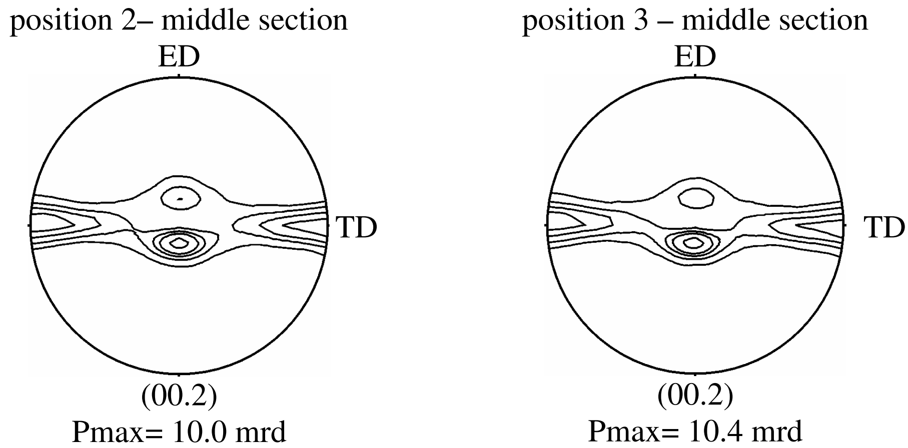

Figure 5: (00.2) pole figure at sample positions 2 and 3

The intermediate region (pos. 4) between rectangular middle section and round head part has a stronger texture 11.9 mrd than in the middle section, see pole figure (10.0) in figure 6. The TD component is nearly stable ((00.2) pole figure while double component at ND is gone. Only a final rest of this anisotropy can be observed. One can see clearly a small tilt around TD indicating a shear component.

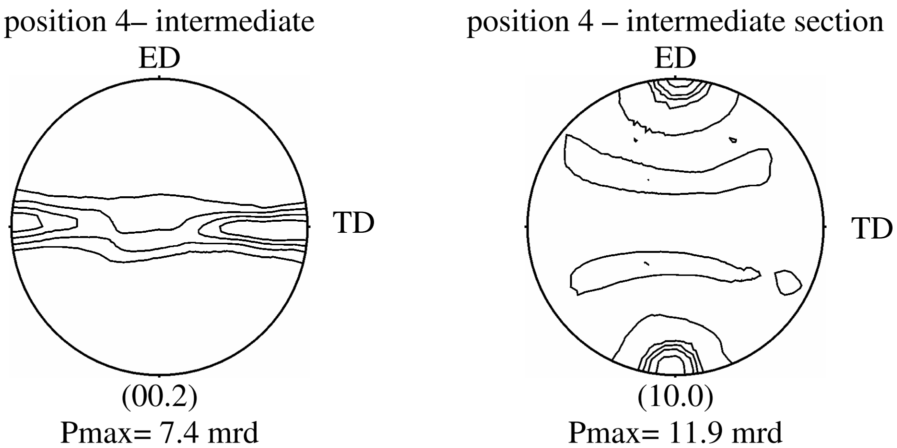

Figure 6: (00.2) and (10.0) pole figure of the intermediate region (pos. 4)

Positions 5 and 6 are in the head part of the bonelike extrusion profile, see figures 7 and 8. The texture at position 5 is much weaker and the shear which was already seen in the intermediate region is little stronger. The texture is dominated by the maximum 7° tilt from TD. The <10.0> fibre texture with the girdle in (00.2) and part of the point maximum in (10.0) is always present, but not comparable to the expected texture proposed for round extrusion.

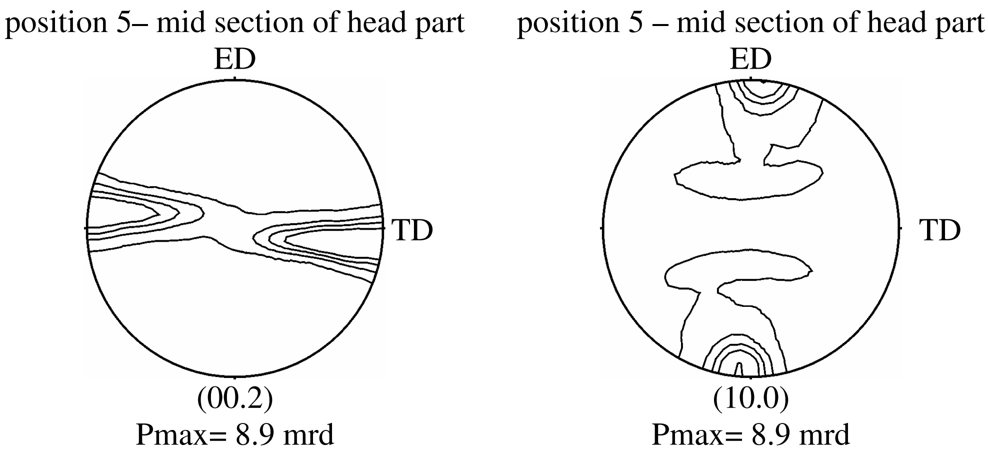

Figure 7: (00.2) and (10.0) pole figure of the mid section of head part (pos. 5)

Position 6 is on the top of the bonelike profile. At this position outside the centre of the round head part we found a relatively strong <10.0> fibre texture with 11.2 mrd. The fibre axis is rotated around 10° and the intensity girdle in the (00.2) pole figure has a soft waving with three submaxima. The waving maybe related to a shear due to the neighbourhood of the intermediate part.

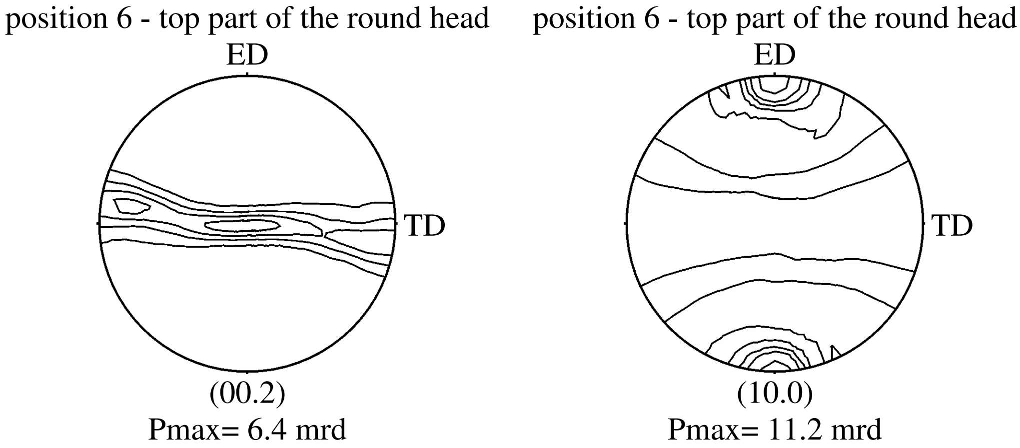

Figure 8: (00.2) and (10.0) pole figure of the top part of the round head (pos. 6)

4 Conclusion

First of all it has to be concluded that hard X-rays as well a neutrons are suitable for non-destructive texture measurements of the presented types of sample geometries. A texture gradient was determined describing the materials flow during extrusion of a bonelike profile. In the middle section with a rectangular cross section a comparison with rectangular extrusion is possible. Remarkable is the anisotropy of the double maximum in the (00.2) pole figure which depends on the position related on the intermediate state. An explanation is not possible, needs additional experiments and texture simulations. The round head part has a <10.0> fibre texture with rotated fibre axis of about 10°. Shear can be observed in the head part as well as in the intermediate part. Comparing to ideal extrusion geometries the materials flow in the head part was strongly influenced by the bonelike profile.

5 Acknowledgements

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6 References

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