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Texture development of Mg AZ80 after cyclic loading at 80% yield stress

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Abstract. In situ experiments with a 20kN loading device were carried out at the high energy beam line Harwi-II at Hasylab/Desy-Hamburg/Germany. Main goals were firstly to investigate lattice dependant strain development in the elastic as well as in the plastic region and secondly to perform cyclic loading for strain and texture development. Due to the high energy of about 100keV the synchrotron beam has a high penetration power. Moreover, measurements were comparably fast. The test sample was rectangular extruded Mg AZ80. According to the bar extrusion process, the Mg AZ80 sample has the typical texture with two ideal fibre components, $\langle 10\bar{1}0\rangle$ parallel RD and $\langle 0001\rangle$ parallel ND, and an ideal texture component $\{0001\}\langle 10\bar{1}0\rangle$. Tensile samples were cut with loading direction parallel to transfers direction. The sample diameter of round tensile samples was 4mm. Stress strain curves were carried out ex situ to get an overview of the materials behaviour and in situ to get strain dependant lattice values for at least 6 Mg reflections.

The cyclic loading was carried out with a maximum load of about 80% of the yield stress so that one stays always in elastic region. Nevertheless, after 3800 cycles a texture change of the quantitative texture was obtained. Existing texture components are stable but the volume fractions of the three texture components change and additionally a new but weak texture component is growing.

Introduction

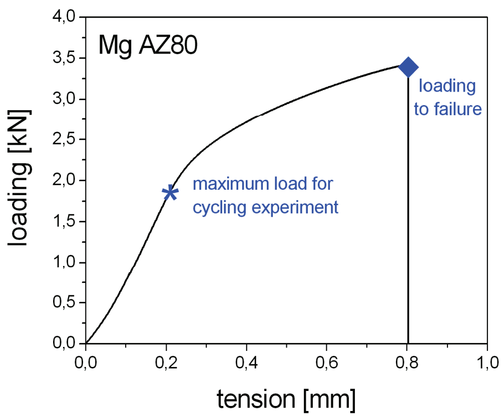
Mg-alloys are well known for anisotropy properties particular in the plastic behaviour. Comparing hexagonal materials, Mg is special because of the c/a ratio of 1.6234Å which is close to the ideal ratio of hexagonal close packed crystal structure. That means, Mg-alloys are more sensitive to changing c/a ratio than other hexagonal materials. The plastic anisotropy is based on one hand on the grain orientation and on the other hand on different twinning under tension or compression. Many interesting applications of Mg-alloys can include both impacts. Due to the grain orientation different combinations of glide system plus twinning are activated [1, 2] for plastic deformation. Thus, stress-strain curve and connecting properties depend on the crystallographic texture. It should be noticed that deformation temperature, grain size and distribution of precipitations have also an important influence on the materials properties.

To get more information about the anisotropy lattice dependant strains in correlation to the as received crystallographic texture and cyclic loading experiments can be done. Both types of experiments will give more inside in the materials behaviour. Previous investigations have shown that in a polycrystalline Mg-alloy the lattice dependant yield point varies from the macroscopic one. Some of the questions to solve is: What happens during cyclic loading under the macroscopic yield point? Does one observe hardening or weakening? There is no unique answer because of the heavy influence of crystallographic texture and precipitations.

Experiment

In situ experiments with a 20kN loading device [3] were carried out at the high energy beam line Harwi-II at Hasylab/Desy-Hamburg/Germany [4]. Main goals of this experiments were firstly to investigate the lattice dependant strain development in the elastic as well as in the plastic region and secondly to perform cyclic loading for strain and texture development. Due to the high energy of about 100keV the synchrotron beam has a high penetration power that tensile sample can be measured in transmission mode non-destructively. Moreover, measurements were comparably fast. The test sample was rectangular extruded Mg AZ80. Tensile samples were cut with loading direction parallel to transverse direction preparing as round tensile samples was 4mm in diameter. Stress strain curves were carried out ex situ and in situ to get an overview of the materials behaviour and in situ to get strain dependant lattice values for at least ten Mg reflections. Figure 1 shows the stress strain curve measured in situ at Harwi-II with parallel data collection of scattering data and a sample after failure inside the loading device. All in situ experiments were done at room temperature.

a



b

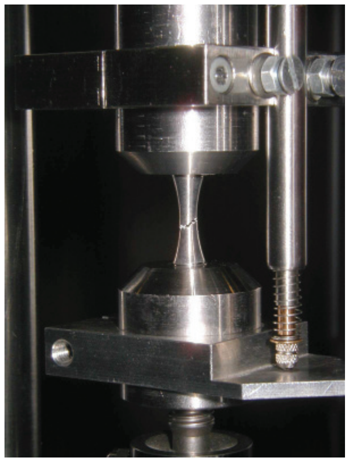


Fig. 1: a-Stress strain curve of Mg AZ80; b- Sample after tensile load till failure

Due to the bar extrusion process, which was chosen for sample deformation, the Mg AZ80 sample has developed typical Mg texture components. A detailed description of texture analysis using synchrotron radiation is given elsewhere [5]. In the present experiment with 100keV photons and a sample to detector distance of 1000mm, the Mar345 image plate detector allows data collection of up to 12 pole figures simultaneously. Data extraction was carried out by STECA – **S**tress**TE**xture**CA**lculator [6]. Output are sets of pole figure data in equal angular format so that many pole figure plot programs and software package for quantitative texture analysis (orientation distribution function ODF) can be used. STECA is able to extract intensity pole figure data as well as peak shift pole figures and peak broadening pole figures in order to get a complete overview about crystallographic textures, macro-stresses and micro-stresses. In this work the focus is made on the texture evolution. In figure 2 the experimental pole figures (00-2) and (10.0) are shown for the as received sample before tension.

Two ideal fibre components, <$10\bar{1}0$> parallel RD and <0001> parallel ND dominate the orientation distribution. In addition to these strong texture components an ideal texture component {0001}<$10\bar{1}0$> with less volume fraction exists.

Cyclic loading was carried out with a maximum load of about 80% of the yield stress (Fig. 1a), so that the sample was always in the elastic region. Strain data were collected after 100, 200, 500, 1000 and 2000 cycles. Texture measurement was performed in unloaded state after in total 3800 cycles and compared with the texture before loading. In addition texture was also measured for samples after failure (Fig. 1b).

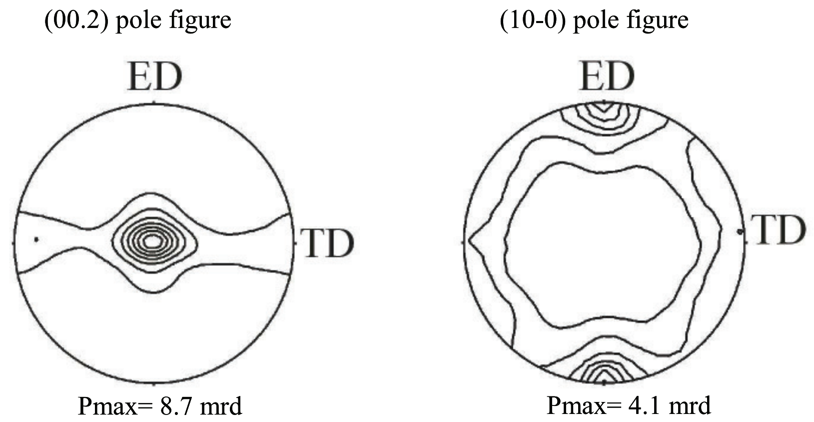


Figure 2: Measured pole figures Mg AZ80 (000.2) and (10.0) before tension
(contour lines (00.2) = 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0;
contour lines (10.0) = 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

Results

Texture evolution of Mg-alloys during tension or compression has been demonstrated previously on some examples and correlated with texture simulations [1,2]. Due to sample preparation with TD direction parallel to the loading axis the pole figures of figure 2 were reoriented which makes texture changes better visible in figure 3.

The present result of texture development till failure agrees with previous results so that a detailed discussion of this result is not necessary. New is that after 3800 cycles a texture change was obtained. Existing texture components are stable but the volume fractions of the three texture components change. One can see clearly that the texture component close to the pole figure centre increases strongly. All texture components which are concentrated at 90° to ED accumulate in the (10.0) pole figure point at ED so that an increase in (10.0) pole figure is observed to 5.0 mrd (mrd – multiple of random distribution). Additionally, a new texture component is growing during cyclic loading.

There are two options for this plastic behaviour. Firstly, the macroscopic yield stress did not take into account the anisotropic behaviour in Mg-alloys. Lattice dependant strains main influence the plastic behaviour of grains with favoured grain orientation to the loading axis for easy deformation. Secondly, the anisotropy of tension and compression in Mg-alloys will influence the materials behaviour during cyclic loading.

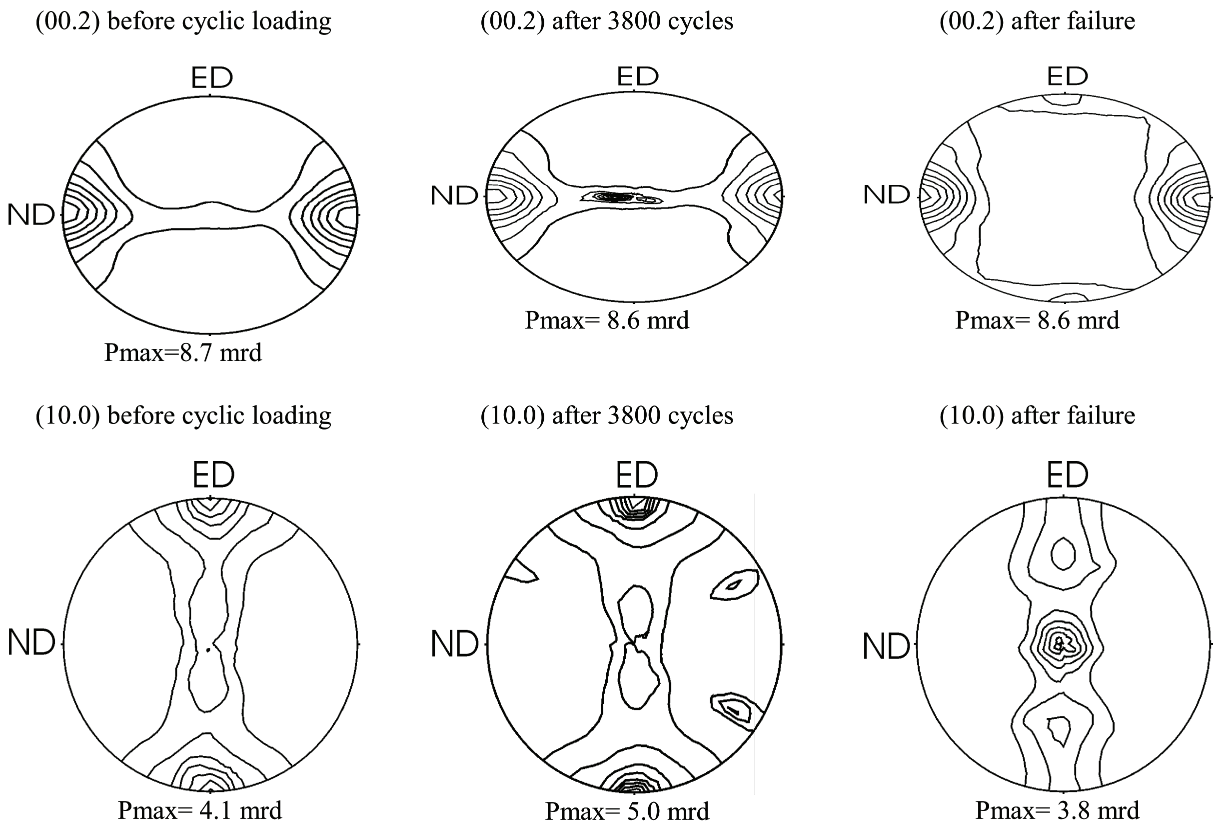


Figure 3: Pole figures before loading, after cyclic loading and after failure
(contour lines (00.2) = 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0;
contour lines (10.0) = 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

Summary

Hard X-rays are excellent to measure texture and strain variations under load non-destructively on standard tensile samples. In short time an enormous amount of data were obtained able to focus on crystallographic texture changes, on macro- as well as on microstrain developments and of course on the crystallography itself (lattice constants developments, elastic constants, phase transitions). A texture change has been observed after cyclic loading with maximum load of 80% yield stress after 3800 cycles.

One needs additional experimental results for detailed description because the determined phenomena can be related to the primary texture in quality (existing texture types) and quantity (texture sharpness of each texture component), to the microstructure (grains size and grain shape), to the alloy (precipitations, c/a ratio) and to the cyclic loading parameters itself.

References

[1] S.B. Yi, C.H.J. Davis, H.-G. Brokmeier, R.E. Bolmaro, K.U. Kainer and J. Homeyer: Acta Mat. Vol. 54 (2006), p. 549

[2] C.H.J. Davis, S.B. Yi, J. Bohlen, K.U. Kainer, H.-G. Brokmeier and J. Homeyer: Mater. Sci. Forum: Vol: 495-497 (2005), p. 1633.

[3] H.-G. Brokmeier, U. Zink, T. Reinert and W. Murach: J. Appl. Cryst. Vol. 21 (1996), p. 501.

[4] H.-G. Brokmeier, Sangbong Yi, N.J. Park and J. Homeyer: Solid State Phenomena Vol. 105 (2005), p. 55.

[5] H. J. Bunge: Adv. X-ray Analysis Vol. 47, (2004), p. 359

[6] C. Randau, H.-G. Brokmeier and U. Garbe: J. of Appl. Cryst. (send to publisher).