Material characterization of AZ31B & ZEK100 sheets

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Introduction

Wrought magnesium alloys are attractive for use in the automotive industry due to their low density and high specific strength, which leads to potential improvements in fuel efficiency and reduced emissions due to weight reduction. However, commercial magnesium alloys, such as AZ31B sheet usually have poor formability at room temperature due to a pronounced basal texture [1], which limits their industrial application. One of the techniques used to improve the room temperature formability of magnesium alloys is the addition of rare earth elements such as Ce, Nd, Y and Gd, for example, which have been shown to weaken the basal texture. Prior to the introduction of rare-earth magnesium alloys in automotive body structures, their forming and crash performance must be known.

In this work, the tensile and compressive response of a rare-earth magnesium alloy ZEK100 sheet is compared with commercial grade magnesium alloy AZ31B, over a wide range of strain rates. In order to detect any in-plane anisotropy of the mechanical properties, tests were performed in the rolling and transverse directions and at 45° with respect to the rolling directions (respectively RD, TD and 45°). The initial crystallographic textures are shown in Figure 1.

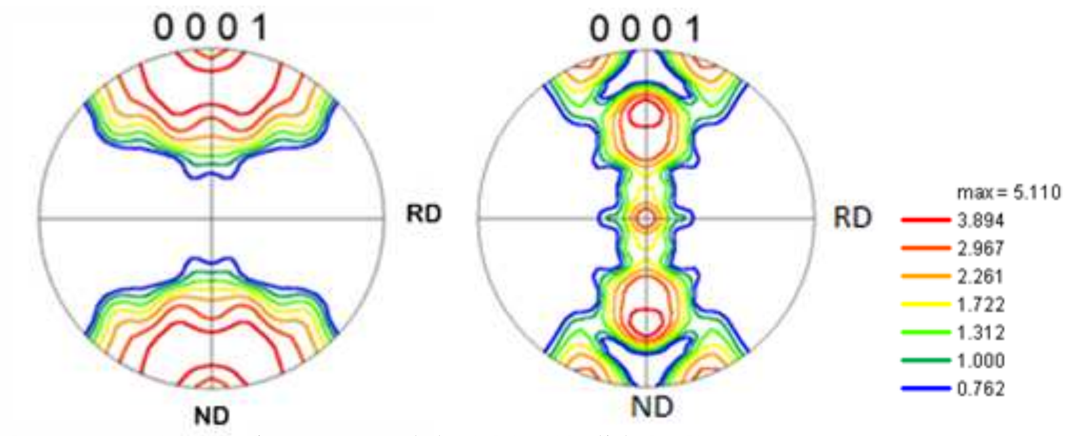


Figure 1: Initial texture (a) AZ31B (b) ZEK100.

Experiments

The quasi-static ($1\,s^{-1}$) experiments were performed using a servo-hydraulic Instron testing machine. The intermediate strain rate ($10\,s^{-1}$) tensile experiments were conducted using the hydraulic intermediate strain rate (HISR) apparatus. The high strain rate ($1,000\,s^{-1}$) tensile and compressive experiments were conducted using the tensile split Hopkinson bar (TSHB) and compressive split Hopkinson bar (CSHB) apparatus respectively. For compression testing, adhesively bonded sheet specimens were prepared in order to overcome any buckling during testing.

Strain rate sensitivity

Figure 2 compares the strain rate sensitivity of the flow stress response for the AZ31B and ZEK100 sheets in the RD and TD, respectively. The AZ31B response along the RD and TD is similar to that of the ZEK100 sheet along the RD insofar as the entire stress-strain curve shifts upwards with increasing strain rate. Such a response is characteristic of a bcc metal for which yield strength is strongly rate sensitive, but hardening rate is often rate insensitive. The increase of tensile yield stress with the increase of strain rate can mainly be attributed to the strain rate dependency of the CRSS of non-basal slip. In contrast, the TD response of ZEK100 sheet (Figure 2 (b)) exhibits a rather different behavior; *i. e.* the yield strength appears to be rate insensitive, while the hardening rate is strongly rate sensitive.

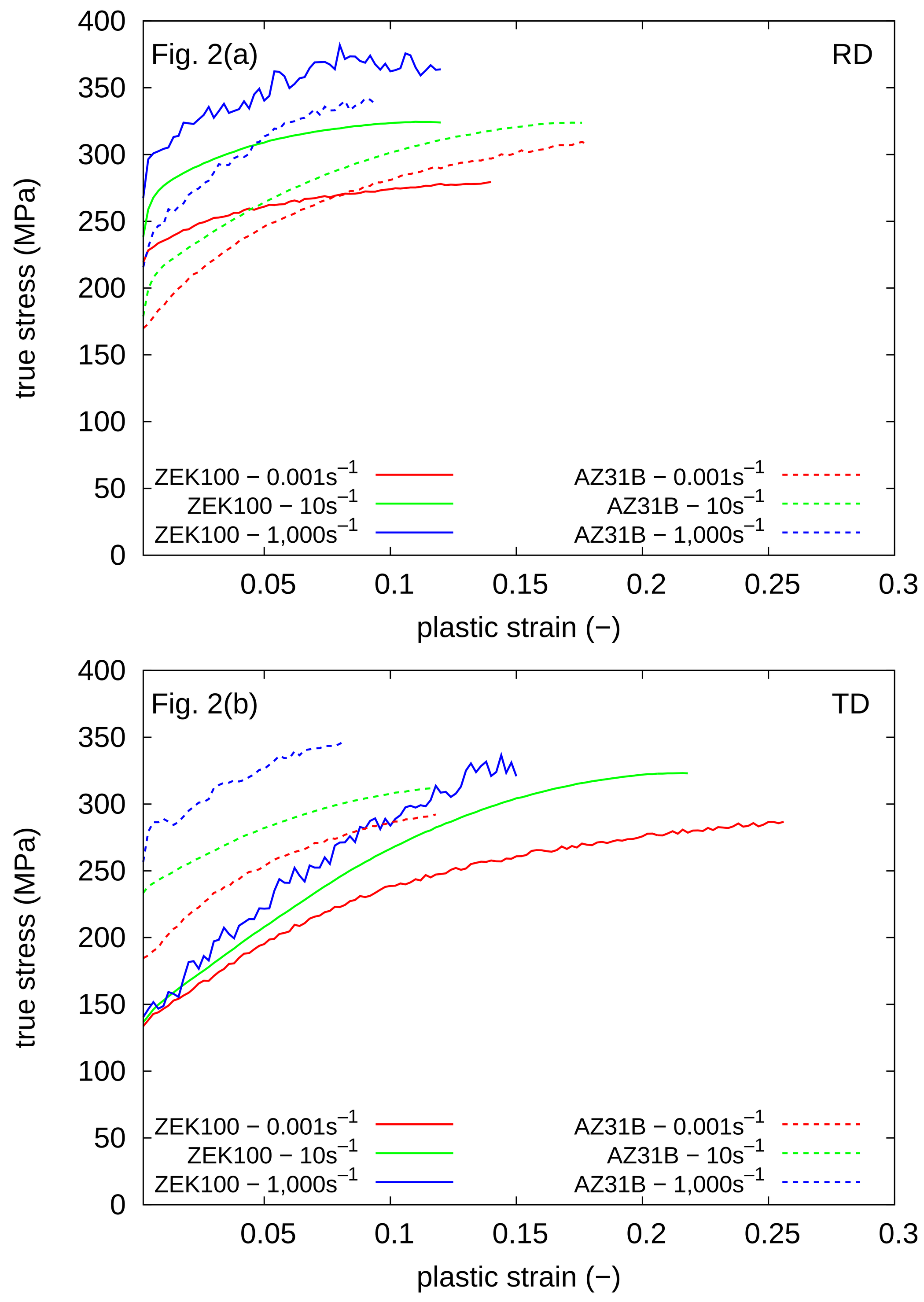
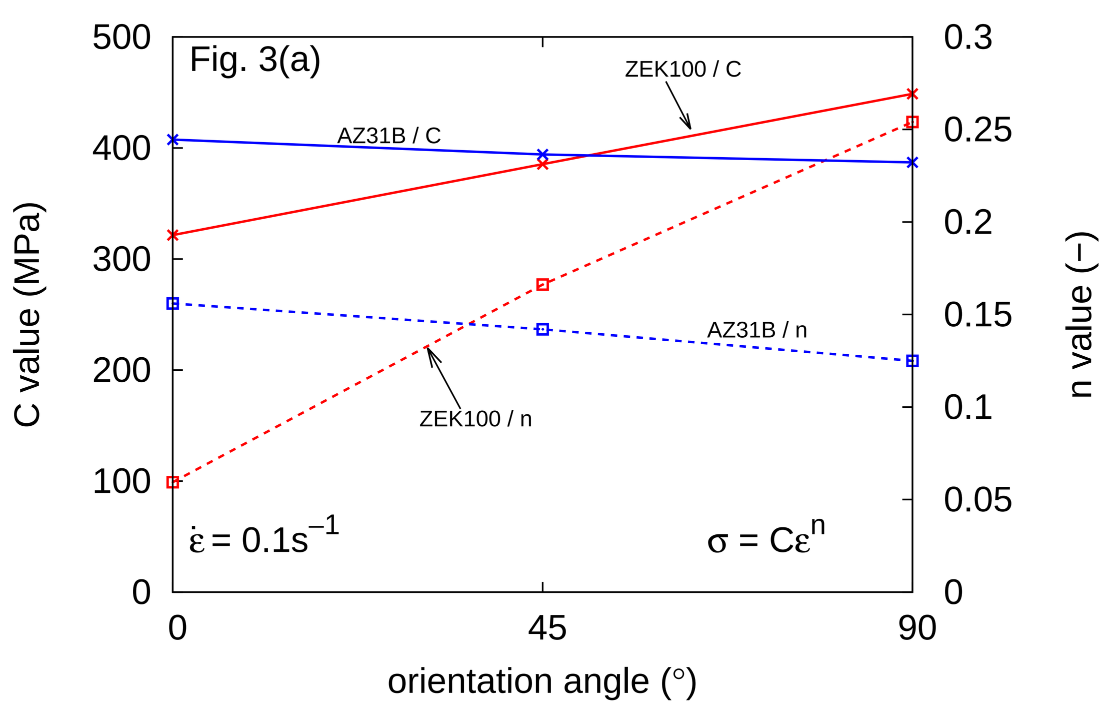


Figure 2: Comparison of rate sensitivity of flow stress for the AZ31B and ZEK100 sheet (a) in the RD and (b) in the TD.

Such behavior is similar to that of fcc metals. This ZEK100 TD initial yield response is related to the strain rate independency of the CRSS of basal slip and the extension twinning mechanisms activated in the majority of the grains for which the crystallographic c-axes are oriented towards the TD in the initial material and the rate dependent hardening is due to the rate sensitivity of pyramidal slip in the remaining grains.

Effect of anisotropy

The effect of orientation is examined by fitting the flow curves with a power law function. The strength coefficient, C and the strain hardening exponent, n are plotted in Figure 3 (a). These fits reveal that orientation has moderate effect on the power law parameters for AZ31B sheet, as the values C and n are slightly lower for the 45° and the TD compared to the RD. In contrast, orientation has a strong effect on the hardening parameters of the ZEK100 sheet, since the values of C and n are much higher for the 45° and the TD compared to the RD. Typically, higher n-values are indicative of higher formability characteristics. Figure 3 (b) is a plot of ultimate tensile strength (UTS) and yield strength (YS) versus orientation illustrates that the ZEK100 sheet exhibits reduced strength and increased ductility (Figure 3 (b)) as the orientation changes from 0° to 90° compared to AZ31B sheet. Figure 3 (c) illustrates that for the ZEK100 sheet, the uniform elongation and failure strains also change as the orientation changes from the RD to TD.



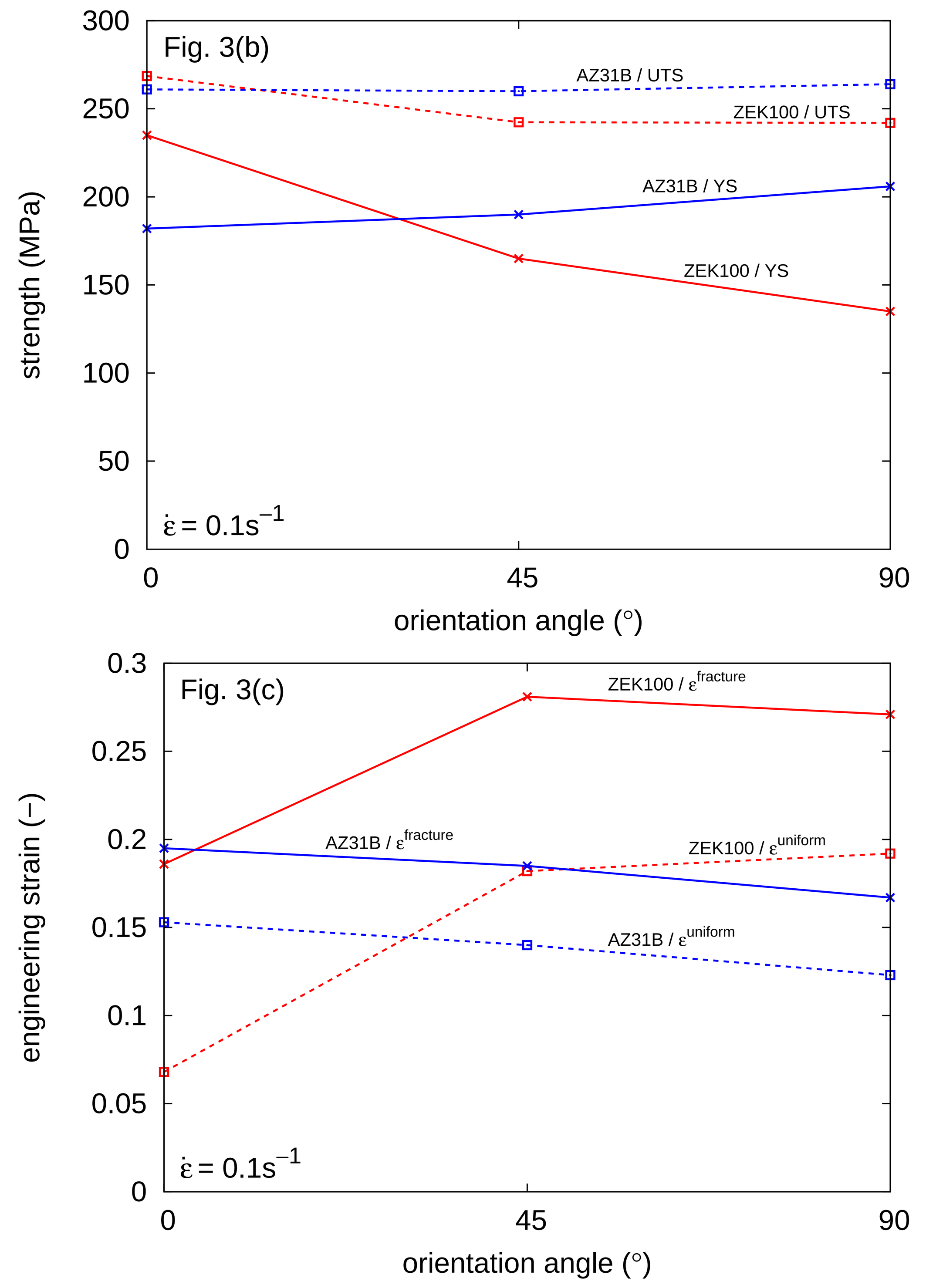


Figure 3: Effect of orientation on mechanical properties, (a) power law parameters C and n, (b) UTS and YS and (c) uniform and fracture strains.

Tension-compression asymmetry

Figure 4 illustrate the comparison of dynamic response of AZ31B and ZEK100 rolled sheets in the tension and compression along the TD. In compression, both the materials exhibit similar flow behavior in the twinning regime, however in the subsequent crystallographic slip regime, ZEK100 exhibits much lower stress level for a given strain compared to the AZ31B. When pulling the sample in the TD, ZEK100 exhibits much lower stress level in the entire strain range as compared to the AZ31B. This behavior is attributed to different deformation mechanisms activated.

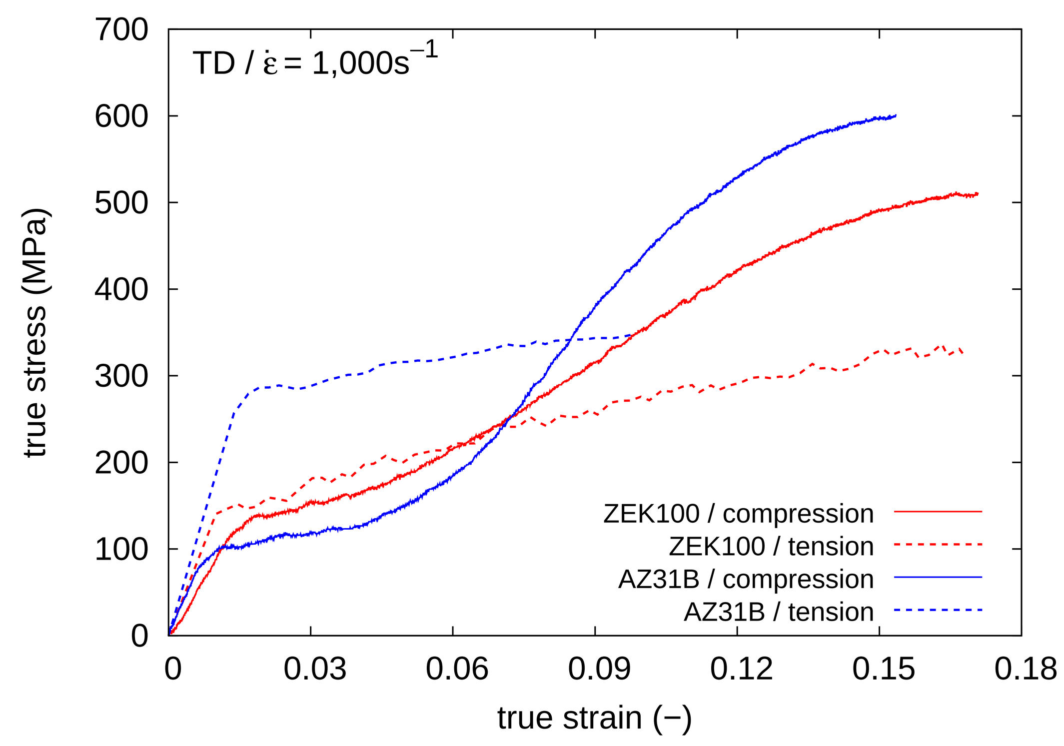


Figure 4: Tension-compression asymmetry in AZ31B and ZEK100 sheets in the TD at a nominal strain rate of $1,000\,s^{-1}$.

Discussion

The characteristics of the ZEK100 TD behavior, that is, low yield strength, high hardening rate and high rate sensitivity, are all known to be favorable for good formability. This response is indicative of the potential advantage of the more random textures imparted by the rare-earth additions to this alloy. However, it is noted that the major challenge in taking full advantage of wrought magnesium alloys in automotive applications is how to process the magnesium alloy sheet to obtain "ZEK TD-like response" in all directions.

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