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MATERIAL CHARACTERIZATION AND CONSTITUTIVE MODELLING OF ZEK100 Mg ALLOY SHEET OVER A RANGE OF STRAIN RATE AND TEMPERATURES

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Introduction

Wrought magnesium alloys are attractive for automotive light weighting applications due to their low density and high specific strength and stiffness. However, commercial magnesium alloys, such as AZ31B sheet usually have poor formability at room temperature due to limited activity of slip systems. Additionally, due to the twinning deformation mechanism activated in specific loading directions, magnesium alloys exhibit an asymmetric stress-strain response. The formability of magnesium alloys can be improved by deforming at elevated temperatures; however, warm forming requires more complex tooling setup which increases the cost of the forming operation. Alternatively, the formability can be improved by the addition of rare-earth elements such as Ce, Nd, Y and Gd, for example, which have been shown to weaken the basal texture. For instance, commercial grade rare-earth ZEK100 Mg sheet exhibits much weaker basal plane texture, with significant spreading in the transverse direction and much weaker peak intensity, about one-fourth that of typical commercial AZ31B rolled sheet [1].

Objectives

The objectives of this work are twofold. In the first part, how the weaken texture of rare-earth ZEK100 magnesium alloy (1.6 mm thick) sheet influences the mechanical response at different strain rates, and temperatures along different sheet orientations such as in the rolling direction (RD) and the transverse directions (TD) is studied. In the second part of the work, constitutive modelling efforts to capture the observed complex response are presented.

Methodology

In the strain rate effect studies, uniaxial tensile tests were performed at room temperature over a range of nominal strain rates, from 0.001s^{-1} to 1000 s^{-1}, utilizing the miniature dog-bone specimens described by Smerd et al. [2]. Since, miniature dog-bone samples are small enough to minimize signal rise time and achieve dynamic equilibrium during high-rate experiments up to a strain rate of 1000 s^{-1}. The effect of temperature on the tensile flow response and r-values in the quasi-static strain rate range (0.001 s^{-1} to 0.1s^{-1}) was studied using sub-size ASTM specimen (E 8M-04) for the temperatures ranging from 25 °C to 200 °C. In-plane compression testing was also performed on stacked sheet samples (to overcome any buckling during testing) in the rolling and transverse directions at low to high strain rates and at different temperatures. Complete details of tensile and compression testing using different test equipment at different strain rates can be found in [1,3].

Results and analysis

ZEK100 sheet exhibits strongly anisotropic sensitivity of flow stress on temperature and strain rate. At lower temperatures, the tensile RD yield strength is strain rate- and temperature-sensitive, while the hardening rate shows only mild sensitivity to strain rate and temperature. The TD tensile behaviour is the opposite with strong rate- and temperature-sensitivity of hardening rate, but low sensitivity in the yield strength. With increasing temperature, both directions recover a more conventional thermal softening response. In-plane compression testing was also performed on stacked sheet samples in the rolling and transverse directions at low to high strain rates and at different temperatures. The shape of the stress-strain curve for the in-plane compressive loading condition is concave upward (S-shape) at all strain rates and shows strong in-plane anisotropy of flow stress as the orientation changes from the rolling to transverse direction at all strain rates. The cause of this orientation dependent temperature- and rate-sensitivity of ZEK100 sheet can be attributed to the initial crystallographic texture and the corresponding active deformation mechanisms.

A new constitutive model due to Kurukuri et al. [3] to account for strain rate dependency under compressive loading is proposed to fit to the measured sigmoidal compressive flow response over a wide range of strain rates. In addition, the Zerilli-Armstrong hcp model [4] is employed to fit to the measured tensile response over the range of strain rate considered.

References

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