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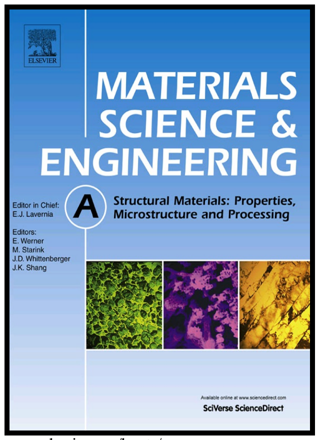

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PII: S0921-5093(17)31643-X
DOI: https://doi.org/10.1016/j.msea.2017.12.045
Reference: MSA35887

To appear in: *Materials Science & Engineering A*

Received date: 20 October 2017
Accepted date: 11 December 2017

Cite this article as: Dayan Nugmanov, Marko Knezevic, Milovan Zecevic, Oleg Sitdikov, Michael Markushev and Irene J. Beyerlein, Origin of plastic anisotropy in (ultra)-fine-grained Mg–Zn–Zr alloy processed by isothermal multi-step forging and rolling: Experiments and modelling, *Materials Science & Engineering A,* https://doi.org/10.1016/j.msea.2017.12.045

Origin of plastic anisotropy in (ultra)-fine-grained Mg–Zn–Zr alloy processed by isothermal multi-step forging and rolling: Experiments and modelling

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Abstract

This paper reports a strong effect of multi-step forging (MIF) followed by elevated temperature isothermal rolling (IR) on the yield stress in ZK60 Mg alloy. After the MIF stage, the yield stress is slightly higher in the rolling direction (RD) than in the transverse direction (TD). After IR at 300 °C, the anisotropy remains small. In contrast, after IR at a lower temperature 200 °C, a significant difference in yield stress between the RD and TD directions is observed, found to increase with rolling strain, and even reverse from being higher to being much lower in the RD than in the TD with rolling reduction at 200 °C. To help determine the possible causes for the anisotropy and its evolution with straining, we use a multi-scale elasto-plastic self-consistent polycrystal model that accounts for dislocation density (Taylor hardening), precipitate hardening, texture, and grain size. The model is extended here to also include the effects of type I and type II residual stresses. With a combination of modeling and electron microscopy, we find that texture, grain size distribution, residual stresses, Taylor hardening, and Orowan hardening only have moderate effects on the plastic anisotropy and cannot fully explain the observations. We rationalize that the primary origin of the yield anisotropy is the evolution of the micron-sized secondary precipitates, which become distributed in the plane of the rolled sheet during rolling. They become more aligned in the RD plane during IR, causing strengthening in tensile yield stress in the TD over that in the RD.

Keywords: Magnesium alloys; Multi-step isothermal forging; Rolling; Texture; Anisotropy

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