Study on Anisotropic Plastic Deformation of Mg-Alloys using Crystal Plasticity

wissen schafft nutzen

GKSS FORSCHUNGSZENTRUM in der HELMHOLTZ-GEMEINSCHAFT

AEM

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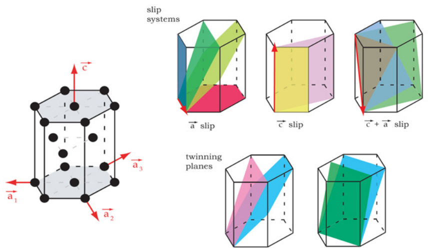
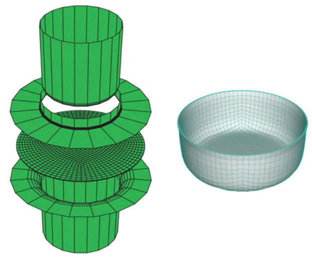
Motivation



Deformation Mechanisms of Magnesium Hexagonal Closed Packed Crystal

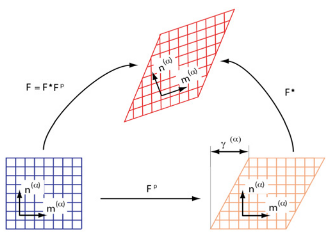
Despite its attractive specific strength, applications of Magnesium alloys have been restricted to cast or simply formed products. For production of complex shaped parts, e.g. in automotive and aerospace industries, a prediction of forming capacities with help of finite element method is required. For a fast and efficient simulation, the anisotropic mechanical behavior of Magnesium has to be described by a phenomenological plastic potential. Crystal plasticity helps to identify its parameters.

Crystal Plasticity for Process Simulation



Finite Element Model for Deep Drawing Process of Magnesium Sheets.

Crystal Plasticity Model



Deformation gradient: $F = F^* \cdot F^p$

$$\dot{F}^p \cdot F^{p^{-1}} = \sum_\alpha \dot{\gamma}^{(\alpha)} m^{(\alpha)} n^{(\alpha)}$$

Schmid's law: $\tau = n^{*(\alpha)} \cdot \frac{\rho}{\rho_o} T . m^{*(\alpha)}$

Rate of the RSS:

$$\dot{\tau}^{(\alpha)} = n^{*(\alpha)} \cdot \left[T^{\nabla *} + T(I:D^*) - D^* \cdot T + T \cdot D^* \right] \cdot m^{*(\alpha)}$$

Rate-dependent viscoplasticity:

$$\frac{\dot{\gamma}^{(\alpha)}}{\dot{\gamma}_0^{(\alpha)}} = \left| \frac{\tau^{(\alpha)}}{\tau_Y^{(\alpha)}} \right|^n sign\left(\frac{\tau^{(\alpha)}}{\tau_Y^{(\alpha)}} \right)$$

$$\dot{\tau}_Y^{(\alpha)} = \sum h_{\alpha\beta}(\bar{\gamma}) \dot{\gamma}^{(\alpha)}$$

$$\bar{\gamma} = \sum_\alpha \int_o^t \left| \dot{\gamma}^{(\alpha)} \right| dt$$

Linear hardening: $h(\bar{\gamma}) = h_o$

Voce-hardening: $h(\bar{\gamma}) = h_o \left(1 - \frac{\tau_o}{\tau_\infty} \right) \exp\left(- \frac{h_o \bar{\gamma}}{\tau_\infty} \right)$

Linear-power law hardening:

$$h(\bar{\gamma}) = \begin{cases} h_o & \bar{\gamma} \le \gamma_{ref} \\ h_o \left(\frac{\bar{\gamma}}{\gamma_{ref}} \right)^{m-1} & \bar{\gamma} > \gamma_{ref} \end{cases}$$

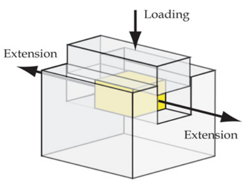
Validation of Model Parameters

one set of $(\dot{\gamma}_o, n)$
four sets of $(\gamma_{ref}, m, h_0, \tau_o, \tau_\infty)$
sixteen values of $(h_{\alpha\beta})$
Total $= 38$ parameters

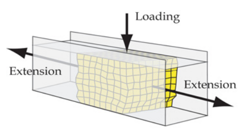
Crystal Plasticity model introduces **38** parameters.

Identification with help of **Channel Die Test**:

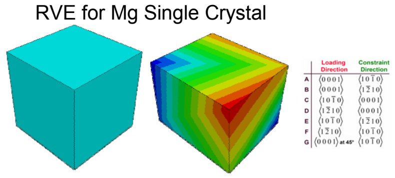
Setup of Channel Die Test



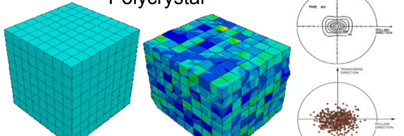
Finite Element Model for Channel Die Test

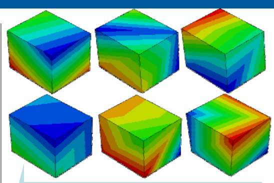


RVE for Mg Single Crystal

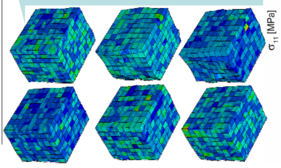


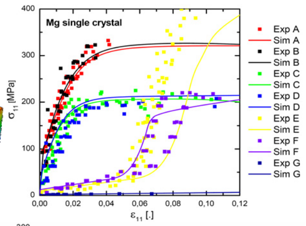
RVEs for Textured Mg Polycrystal

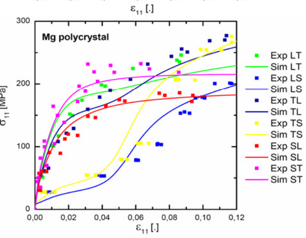




Comparison with experimental results (Kelley & Hosford,1968) validates the sets of the identified parameters for single and polycrstals:



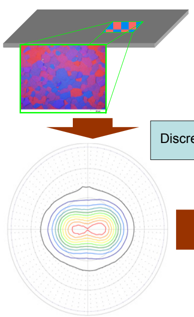




Plastic Potential for Process Simulation

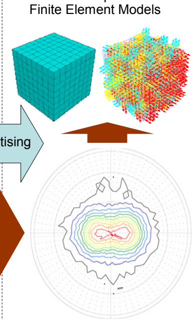
Experiment ⟺ Simulation

Texture Analysis of ZM21 Mg Alloys (WZW, GKSS, 2007)



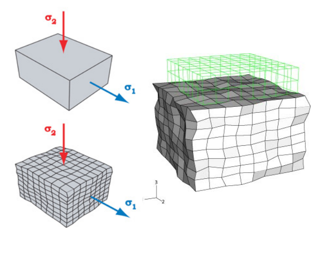
Discretising of Materials Texture to Implement in Finite Element Models

Discretising



Biaxial Test

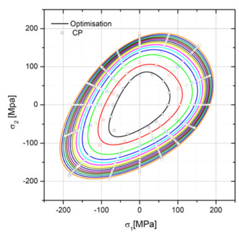
Finite Element Model of Biaxial Test for Proportional Loading Paths



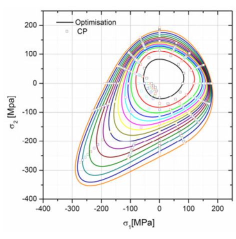
Phenomenological Model

Isostrain Curves for Different Magnesium Alloy Textures

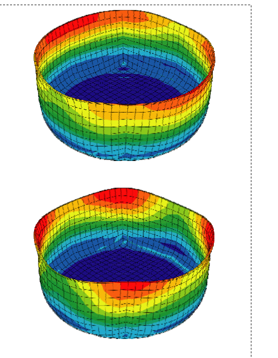
Random Texture (cast product)



Rolled Plate Texture



Deep Drawing Process



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