Constitutive Descriptions and Microstructure Evolution of A5083 Aluminum Alloy during Hot Compression

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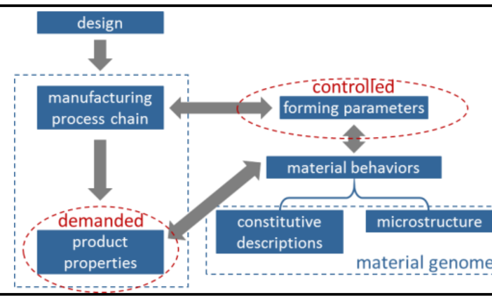
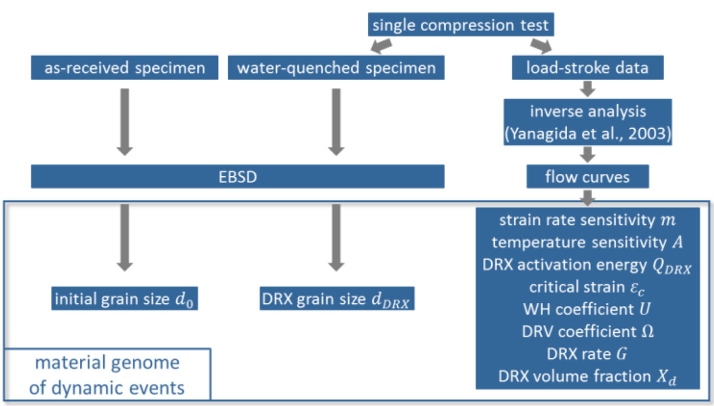
Introduction

A5083, one of the common 5000 series of aluminum alloys, is widely used in industries for its low density and high strength. The material behaviors during deformation are usually represented through constitutive equations and these equations can be termed as “material genome” since they are the fundamental understanding of hot forming process. Hot condition should be understood in order to form the product with designable geometry and acceptable mechanical properties. A great opportunity lies in the manufacturing process if the relations between the forming parameters, material genome and product properties are clearly understood by means of theoretical analysis of deformation and microstructure.

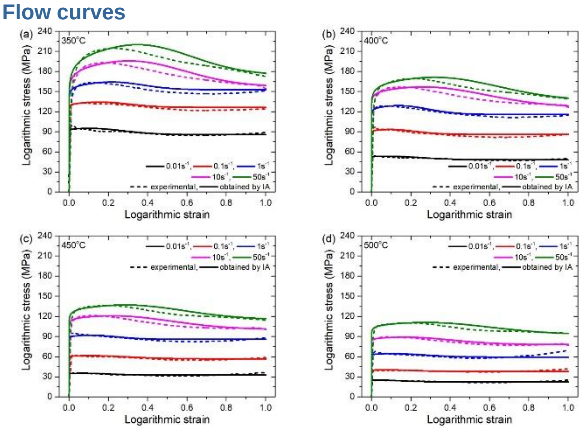


Experimental procedures and results

Research roadmap

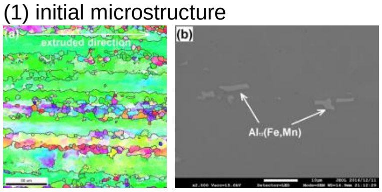


Flow curves

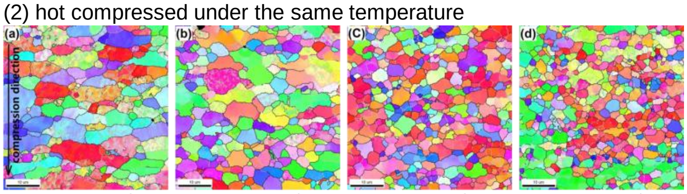


Microstructure evolutions

(1) initial microstructure

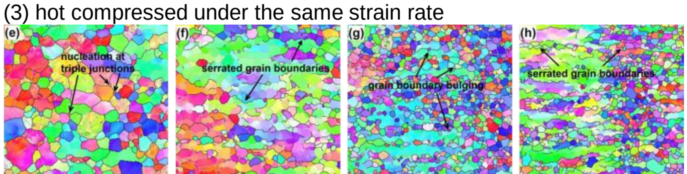


(2) hot compressed under the same temperature



450°C, $0.01s^{-1}$ | 450°C, $0.1s^{-1}$ | 450°C, $1s^{-1}$ | 450°C, $10s^{-1}$

(3) hot compressed under the same strain rate



500°C, $50s^{-1}$ | 450°C, $50s^{-1}$ | 400°C, $50s^{-1}$ | 350°C, $50s^{-1}$

Predicted flow curves

$$\begin{cases} \sigma = \sigma^* \cdot \{\dot{\varepsilon}^m \exp[A(1/T - 1/T^*)]\} \\ \sigma^* = \begin{cases} 97.61\varepsilon^{0.02} & (\varepsilon < \varepsilon_c) \\ F_2{}^* \exp\left[a(\varepsilon - \varepsilon_p)^2\right] + 82.23 & (\varepsilon \geq \varepsilon_c) \end{cases} \end{cases}$$

Material genome

Parameter	Equation
DRX activation energy	$Q_{\mathrm{DRX}} = 193.19\ \mathrm{kJ/mol}$
Strain rate sensitivity	$m = 5.80 \times 10^{-4}T - 0.28$
Temperature sensitivity	$A = 3016.19$
WH coefficient	$c = 13.29\dot{\varepsilon}^{0.13}\exp(4610.59/T)$
DRV coefficient	$b = 250.62\dot{\varepsilon}^{0.84}\exp(-1991.54/T)$
Critical strain	$\varepsilon_c = 0.0037\dot{\varepsilon}^{0.18}\exp(2145.88/T)$
DRX rate	$G = 20.20\dot{\varepsilon}^{-0.14}\exp(-1813.11/T)$
Avrami exponent	$P = -0.03\ln Z + 2.29$
DRX volume fraction	$X_{\mathrm{DRX}} = 1 - \exp[-G(\varepsilon - \varepsilon_c)^P]$
DRX grain size	$d_{\mathrm{DRX}} = 215.69\dot{\varepsilon}^{-0.09}\exp(-2995.14/T)$