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### ACCEPTED MANUSCRIPT

# Forming limit curves analysis of aluminum alloy considering the through-thickness normal stress, anisotropic yield functions and strain rate

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#### Abstract

Based on three anisotropic yield functions including Karafillis-Boyce (K-B), Yld96 and Yld2011, directional normalized uniaxial yield stresses, directional r-value and forming limit curve (FLC) for AA3104-H19 aluminum alloy under plane stress condition are numerically investigated in this article. Moreover, considering the through-thickness normal stress effect the forming limit diagram (FLD), stress-based forming limit diagram (FLSD) and extended forming limit stress diagram (XFLSD) is also studied theoretically based on Yld2011 yield criterion and modified Marciniak–Kuczynski (M-K) model. The nonlinear equations set are solved through employing Newton-Raphson numerical method to calculate limiting strains. The anisotropic plastic behavior and FLC of AA3104-H19 predicted by Yld2011 yield criterion are in good agreement with experimental data and are more accurate than those of K-B and Yld96 yield functions. In addition, according to FLD, the formability of sheet metal increases by applying the through-thickness normal stress. The effects of strain rate at quasi-static condition and temperature are theoretically investigated on the FLD of AA3104 aluminum alloy. The positive temperature sensitivity and negative strain rate sensitivity are observed of FLD of AA3104.

#### Keywords:

Forming Limit Curve, Through-Thickness Normal Stress, Yld2011 Yield Function, Anisotropic Aluminum Alloy, Strain Rate Sensitivity.

#### Nomenclature

$\psi$	Yield function
Y	Yield stress
S	Isotropic plasticity equivalent (IPE) stress tensor
σ	Chauchy stress tensor
L	Linear-transformation tensor
а	Material coefficient in the K-B, Yld96 and Yld2011 criteria

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