Size dependant material model for micro-roll forming of stainless steel foil

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Aim:

The outcome of this research will help to understand the deformation and fracture of stainless steel foil in micro-roll forming via an advanced finite element model.

Background:

The past few decades have seen an upward trend in the ownership of electric vehicles. The innovation of fuel cell technology is a major factor leading to the electric vehicle market prosperity. A sheet metal forming process to produce bipolar plates from stainless steel foil, which are key components in fuel cells, is investigated in this study. The preferable bipolar plate is a corrugated panel with deep and narrow micro-channels. These channels are produced from a newly develop micro-roll forming process. To analyse how the flat foil can be rolled into channels, finite element simulation is necessary prior to actual experimental trials. Conventional continuum mechanical theories are inherently grain size independent. It is, therefore, difficult to characterise the experimental results adequately when the deformation field is on a sub-micro size scale. Consequently, the extent to which the micro-roll forming process can produce a thin foil without fracture is not a straightforward question and needs to be addressed. Moreover, roll forming is a bending-dominated process, and the understanding of the size-effect on the bending fracture at both micro and macro length scales is limited.

Methodology:

a) Use numerical and experimental analyses to understand the stress states, strain paths and fracture mechanisms presented in the micro-roll forming process.

b) Determine the relationship between fracture mechanism and the ratio of average grain size to sheet thickness for stainless steel foil using experimental forming and microstructural analysis. c) Develop a constitutive material model that accounts for size-effects to predict the initiation and evolution of fracture for the forming conditions found in micro-roll forming.

Key Findings to date:

An efficient solid-shell hybrid finite element model was developed to simulate the micro-roll forming process, as shown in Figure 1.

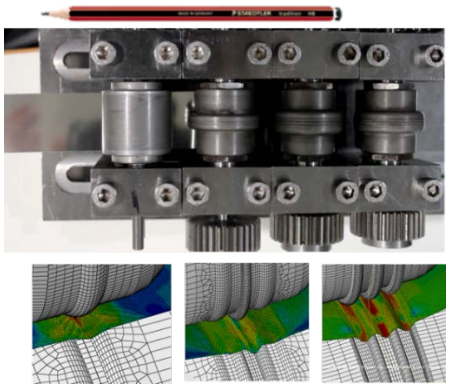

Figure 1 Micro-roll former and the finite element model.

The formability of six types of stainless steel foil from different industry suppliers were tested. Figure 2 shows the impact of the grain size on the formability.

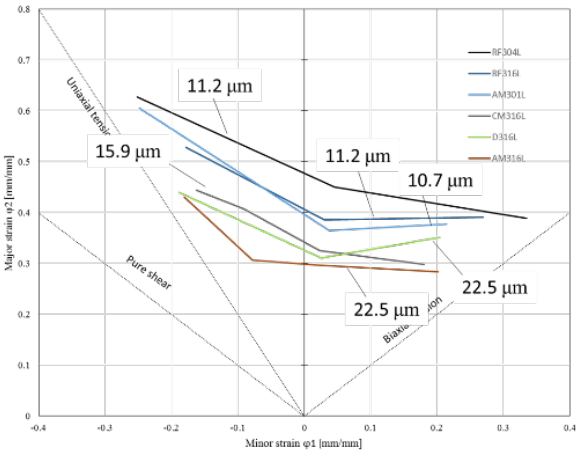

Figure 2. Effect of Grain size on formability of various alloys

Future Work:

- Heat treatment of stainless steel foils to generate microstructures with various numbers of grains through thickness.
- A series of tests on various sample geometries will be conducted to calibrate fracture model parameters.
- Perform Nakajima formability tests on the heat treated samples and use the developed fracture model to predict the FLC curve.
- Validate the model on a newly develop micro-roll former which provides severe forming conditions.

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