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On On the formation of a sticking layer on the bearing during thin – section aluminium extrusion

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Introduction

In aluminium extrusion process, the formation mechanism of a thick aluminium sticking layer near the entrance is not clear. One of the two mechanisms could be relevant:1)An aluminum layer is formed on the bearing due to shear localisation; 2) Discrete pieces of aluminium are accumlated on the bearing to form a continuous layer. A 1-D transient finite element model was built in Comsol to study such layer formation in two aluminium alloys AA 6063 and AA 7020, and it shows that the heat generated in the shear layer cannot soften the material to the extent that causes localised shearing. Therefore a localised shear layer cannot be formed in the aluminium extrusion process.

The Model

Mathematical formulation

A triangular strain rate distribution is assumed in the localised shear layer that causes viscous heating, as shown below:

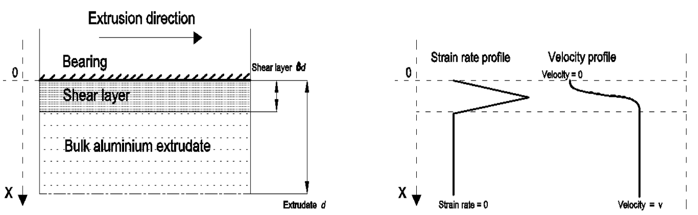

Figure 1 Schematic view of the studied domain: (a) Shear layer; (b) Schematic view of the assumed strain rate and velocity profile

The energy balance in the studied domain can be written:

$$\rho_{al} c_{al} \frac{\partial T}{\partial t} = k_{al} \frac{\partial^2 T}{\partial x^2} + 0.9\sigma\dot{\varepsilon} \qquad (1)$$

Boundary conditions at the bearing – aluminium interface and at the die – air inteface are of Neumann type with prescribed heat transfer coefficients. The minimum work criterion states that the shearing process takes place such that the work required is mininum. The behaviour of aluminium alloys can be described by the constitutive equations below:

$$\sigma(T,\dot{\varepsilon}) = \sigma_m \left[\left(\frac{\dot{\varepsilon}}{A} \exp\left(\frac{Q}{RT} \right) \right)^{\frac{1}{m}} \right] \qquad (2)$$

The Comsol model is used to calculate and determine the thickness of the shear layer at minimum mechanical work.

Comsol modelling

1-D transient model can be used to describe the problem as follows:

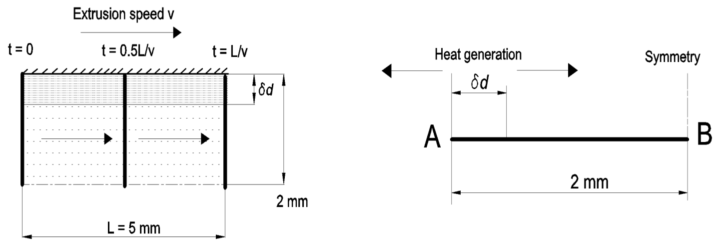

Figure 2 FEM modelling of the problem: (a) 2-D problem (b) Schematic view of the modelled 1-D aluminium element

Temperature is calculated at solution time at which aluminium profile passes the bearing land.

Results

Results show that for AA 6063 thermal softening effect is not enough to cause localised shearing. For AA 7020 thermal softening is only profound at impractically high extrusion speed.

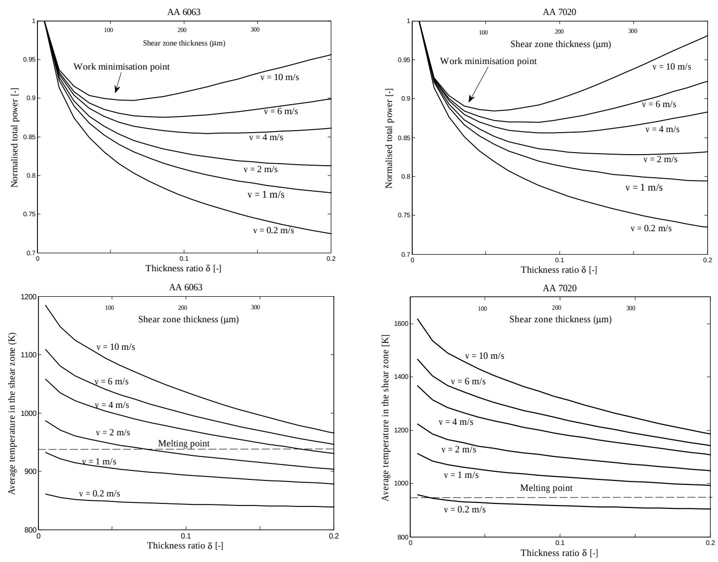

Figure 3 Flow stress as a function of layer thickness and extrusion speed : (a)AA 6063; (b) AA 7020; Average temperature in shear layer: (c) AA6063; (d) AA7020

Conclusions

For both aluminium alloys localised shearing due to thermal softening is not responsible for formation of a sticking layer in thin – wall aluminium extrusion processs.

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