

Friction modelling in numerical simulation of orthogonal cutting

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Abstract.

Friction is one of the most difficult phenomena to simulate in machining. Extreme conditions of temperature and pressure at the interface involve the development of sticking and sliding zones. Commercial codes incorporate pre-implemented algorithms allowing the user to model the thermo-mechanical contact at the tool-chip interface. The selected algorithm should ensure the consistency of the implemented model of friction.

The Coulomb's model is the simplest formulation, assuming a constant coefficient of friction along the tool/workpiece contact length, however it has been widely used in numerical simulation of machining [1,2].

$$\tau_f(x, t) = \mu \sigma(x, t). \quad (1)$$

Eq.1, relates τ_f and σ , being respectively the frictional and normal stresses at the position x on the interface and instant t of the test. Experimental data of machining have showed the decreasing of friction when the cutting velocity increases [3].

In this work, a numerical model of orthogonal cutting has been developed using the ALE (Arbitrary Lagrangian Eulerian) formulation (see details in [4]). The numerical simulations were performed with the commercial code ABAQUS/Explicit. Tool rake angle was equal to 0° with a small tool tip radius of 15 microns to avoid numerical problems (see fig1-b). This cutting edge radius causes a small feed force even in the absence of friction.

The contact was modeled with a constant coefficient of friction. Numerical results (see fig.1-a) showed that the obtained cutting forces ratio, in other words, the global friction (defined as the ratio of the tangential force to the normal force exerted by the chip onto the tool), is different of the implemented one (especially when high values of friction coefficient are considered) and tend to decrease with velocity according to the trend observed in experimental tests.

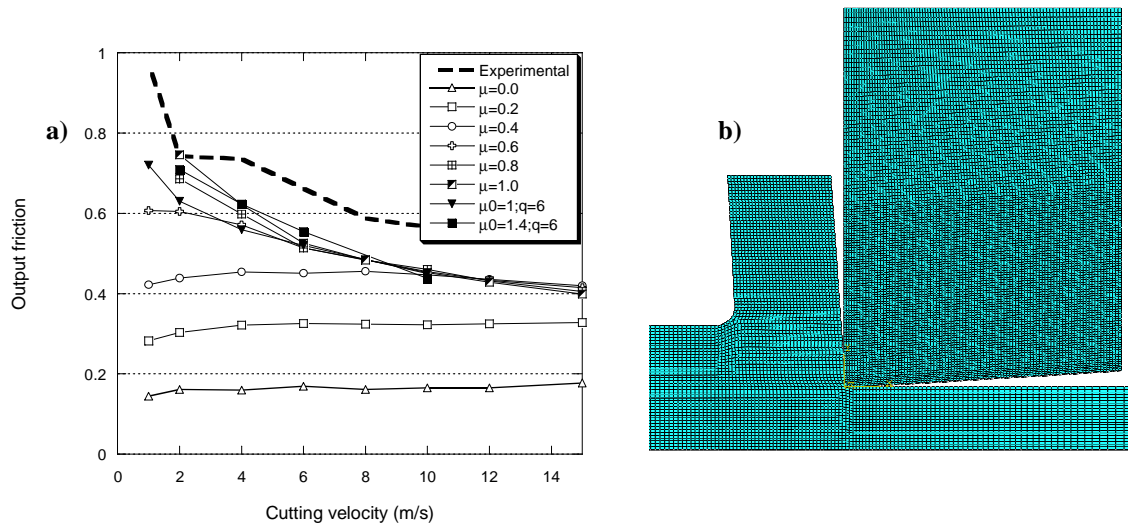


Fig.1: a- Evolution of obtained friction as cutting forces ratio versus the cutting velocity, for different values of implemented friction coefficient and temperature dependent friction coefficient.

b- Detail of the mesh used for the numerical model of orthogonal cutting.

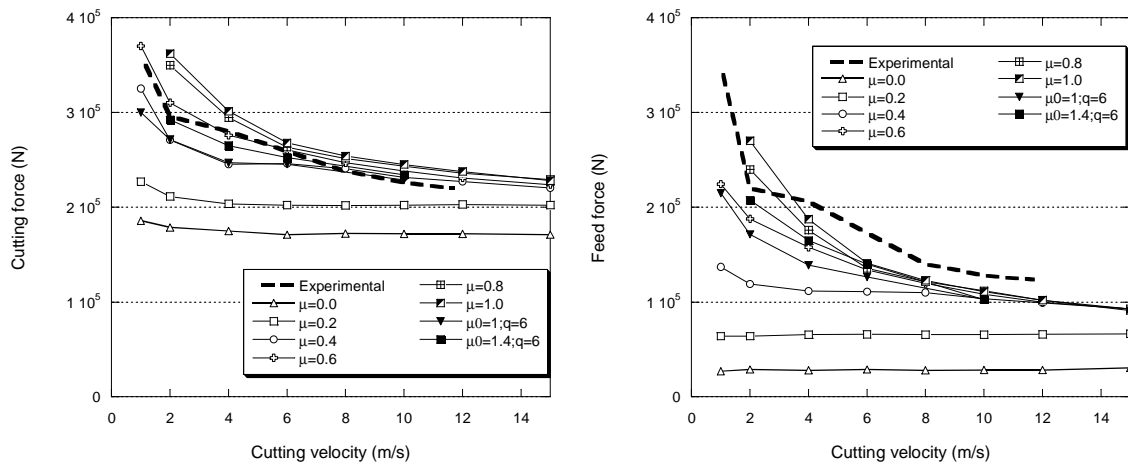


Fig.2: Evolution of cutting and feed forces versus the cutting velocity, for different values of implemented friction coefficient and temperature dependent friction coefficient

Several authors have accorded a particular attention to the improvement of friction formulation and the influence on numerical results [5-7]. The simple Coulomb's law with constant friction (Eq.1), has been modified by Moufki and Molinari [3] to account for temperature dependence of μ :

$$\mu(T) = \mu_0 \left(1 - \frac{T - T_0}{T_m - T_0} \right)^q \quad (2)$$

T is absolute temperature variable, T_0 and T_m are respectively the reference and melting temperatures of the material, and μ_0 and q are material constants.

Numerical simulations using this model show a better agreement with experimental data, particularly in terms of output cutting forces (see fig.2).

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