

# The use of numerical simulations to improve analytical chip formation model

F. Salvatore<sup>1</sup>, T. Mabrouki<sup>2</sup>, H. Hamdi<sup>1</sup>,

<sup>1</sup>LTDS, UMR 5513 CNRS/ECL/ENISE – 58, rue Jean Parot- 42023 Saint Etienne – CEDEX 2-France- fferdi3@free.fr

<sup>2</sup>LAMCOS UMR 5259 CNRS/UNIVERSITE DE LYON/INSA LYON – 18-20, rue des Sciences – 69621- Villeurbanne- CEDEX- France.

**Abstract** — In this paper, an analytical approach is proposed to model chip formation in the case of turning process. Numerical simulations of chip genesis are performed in order to fit efficiently the proposed analytical model. In particular, the variables like temperature and internal stress distribution are studied using finite element modeling. Numerical model setting is made with experimental and literature data using forces and the thickness of the primary shear zone.

**Keywords** — Johnson-Cook, analytical, cutting model, chip formation.

## 1 Introduction

Turning and abrasion processes are widely used in different industries to cut different engineering parts. Usually the optimization of these processes is made by experimental methods often expensive and not able to be extrapolated to other machining configurations. To overcome these drawbacks some numerical simulations were carried out by many researchers but the major inconvenience of those methods are the long computing time, the high cost of numerical software etc.

For all these reasons, in manufacturing industry, a highly interest in analytical methods like that of Merchant [5] is usually researched because it is very practice and simple to use. Recently, Gilormini, Molinari and Oxley [2,6,7] have proposed thermo-mechanical approach more complete for industry but not easy to use. Nevertheless, the present model [8] can be qualified as a compromise between accuracy and simplicity. It can be directly and efficiently exploited by engineers.

## 2 The proposed analytical model

An Orthogonal cutting case represented by a 2D model is studied (Fig. 1). The tool moves with a cutting speed  $V_C$  and remove with its cutting edge ( $R=0$ ) a specific layer of material presented by an uncut chip thickness  $f$ .

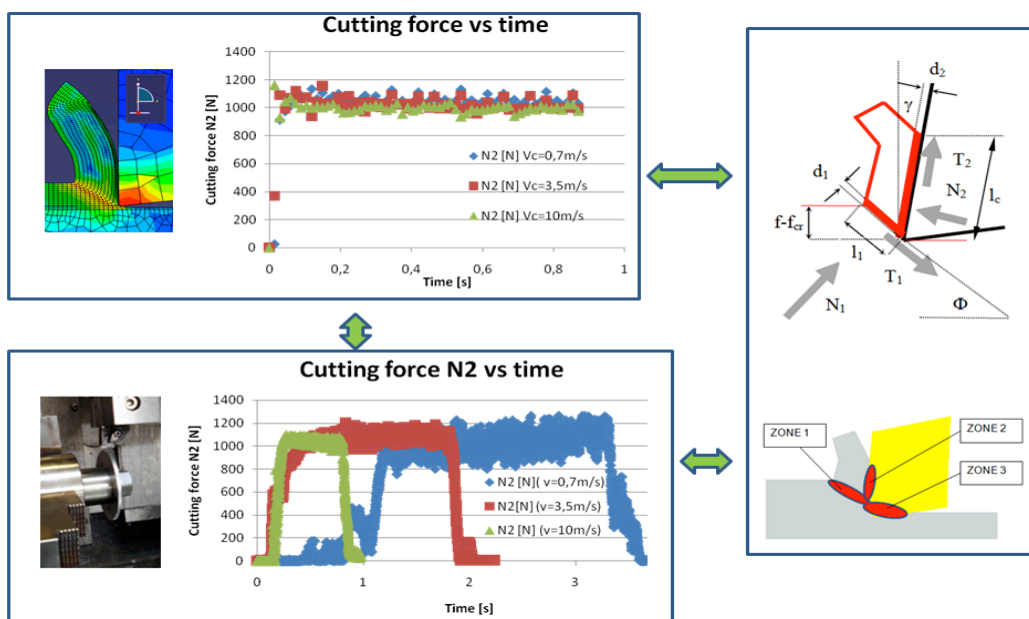


Fig. 1 – Description of the analytical model and the experimental and numerical methods used

Different parameters, related to chip formation, can be expressed based on the balance of forces and moments in mechanical static conditions (like Merchant), applied to chip. Nevertheless, in our proposition stresses are not constants but described with Johnson and Cook law [1,3]. In particular shear stresses in zone 1 and 2 (Fig. 1) are computed. Consequently, it is possible to write equations 1 and 2 and having forces  $N_1$ ,  $N_2$ ,  $T_1$ ,  $T_2$ , temperatures, shear plastic strain  $\gamma_{pl}$ , angle  $\Phi$  and the contact length  $l_c$  (Fig. 1).

$$N_2 = \frac{T_1 (\cos(\Phi) + \tan(\Phi) \sin(\Phi))}{\cos(\gamma) + \mu \sin(\gamma) - \tan(\Phi)(\mu \cos(\gamma) - \sin(\gamma))}, N_1 = \frac{N_2 (\mu \cos(\gamma) - \sin(\gamma))}{\cos(\Phi)} + T_1 \tan(\Phi) \quad (1)$$

$$T_1 = T_{10} + cN_2 \quad \text{with } T_{10} \text{ simple shear force, } T_2 = \mu(V, Temp) N_2, l_c = \frac{3l_1 N_1}{2N_2}, T_1 = \tau_1 \quad (2)$$

In particular,  $\Phi$ , stresses and plastic strains in zone 1 and 2, are investigated with numerical simulations to fit the analytical model and obtain a better accuracy.

### 3 Numerical contribution to fit the proposed analytical model

Numerical simulations were carried out based on Lagrangian approach [1,4]. Value of coefficient  $c$  in equations 2 is determined with F.E. modeling according to Fig. 2.

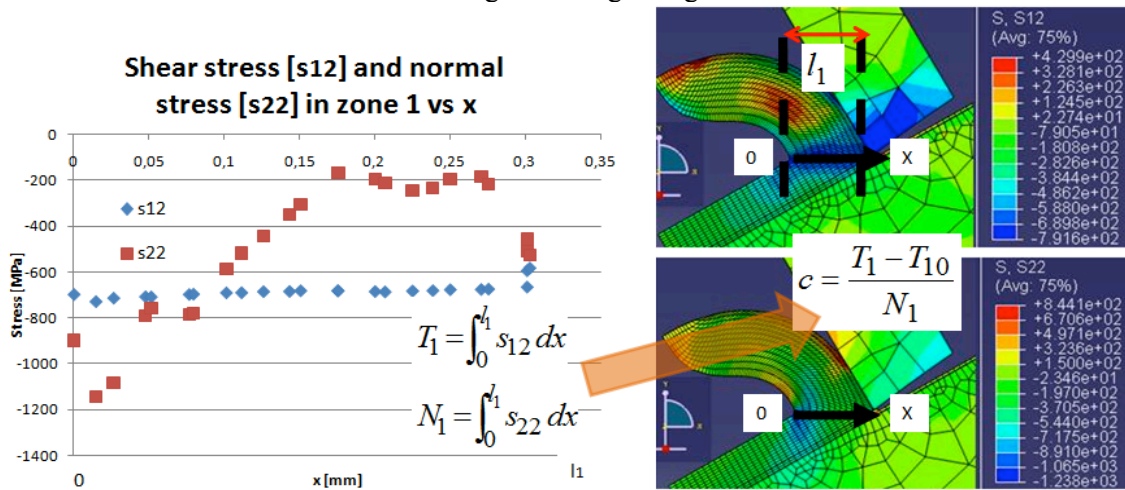


Fig. 2 – Description of the method used to calculate  $c$  in equation 2 and the thickness ( $d_1$ ) of the zone 1

Forces and  $\Phi$  depend of the accuracy of  $c$  (equations 1 and 2). It is also important to underline that only numerical approach gives a “direct value” of  $c$ . Analytically  $c$  can be expressed by equation 2 where  $T_{10}$ , is a constant and  $T_1$ ,  $N_2$ , are calculated with method showed in Fig.2.

### 4 References

- [1] M. Barge, H. Hamdi, J. Rech and J. M. Bergheau, “Numerical modelling of orthogonal cutting: influence of numerical parameters”, Journal of Materials Processing Technology, VOL. 164-165, 2005, pp. 1148-1153.
- [2] P. Gilormini, E. Felder “Modelisation thermomécanique de la formation du copeau en usinage à grande vitesse”. Bulletin du Cercle des Métaux - Tome 15, n°9 mars 1985.Paris
- [3] G. R. Johnson, W. H. Cook. “A constitutive model and data for metals subjected to large strains, strain rates and high temperature”s. 7th Int. Symp. Ballistics, pp. 541-547 (1983)
- [4] T. Mabrouki, J.F.Rigal. “a contribution to a qualitative understanding of thermo-mechanical effects during chip formation in hard turning” journal of material processing technology, n 176 pp 214-221, (2006)P.
- [5] M.E. Merchant “Mechanics of the metal cutting process. I. Orthogonal cutting and a type 2 chip” Journal of Applied Physics (USA), American Institute of Physics New York (1945)
- [6] A. Molinari. “A new thermomechanical model of cutting applied to turning operations ” Part 1 Theory –int- J. Mach. Tools-Manufact 45, 166-180 (2004)
- [7] P.L.B. Oxley. “Mechanics of machining an analytical approach to assessing machinability”, Ellis Horwood limited , Chichester (1989)
- [8] F.Salvatore, T. Mabrouki, H. Hamdi. “analytical model of removal material in case of cutting and abrasion processes”. Proceedings of the 4th. ICTMP 2010, pp 141-150.