Mechanistic models for the study of the machining by chip removal and its application in case of milling and drilling of precious metals

A. Blatter[1], J.Brelle[1], J.Charpy[3], M. Hennequin[3], L.Germann[1], N. Moutarlier[3] , P.Sisini[2], L.Zaquini[3], R.Ziegenhagen[2]

1 - PX Group; Boulevard des Eplatures 42, 2304 La Chaux-de-Fonds (Switzerland)

2 - Cartier Horlogerie (Branch of Richemont International SA ; 10, Chemin des Aliziers 2300 La Chaux-de-Fonds (Switzerland)

3 - University of Applied Sciences Western Switzerland - He ARC ingénierie – Laboratoire Machines-Outils; Av Hôtel de Ville 7, 2400 Le Locle

Abstract: The optimization of the cutting parameters is time consuming and costly (costs related to the tools, time required for machining tests, uncertainties about the results, etc.), especially when dealing with precious metals. In order to overcome those disadvantages, we developed mechanistic models for the machining of metals and applied it to several real cases.

With only a few tests, these models allow the prediction of the cutting forces (F) and of the specific energy in several cutting conditions. Thus, the number of machining tests and the waste of material are reduced. There are two separate models for milling and for drilling. The structures of the models are:

$$F_t = F_{0t} + Kc_{1t} {h_{0_m}}^{1-m_t} * a_p$$

$$F_n = F_{0n} + Kc_{1n} {h_{0_m}}^{1-m_n} * a_p$$

$$F_b = F_{0b} + Kc_{1b} {h_{0_m}}^{1-m_b} * a_p$$

In case of milling (Ft, Fn, Fb, cutting forces in cutter reference).

$$F_z = F_{0z} + Kc_{1z} h_0^{1-m_z} D$$

$$M = M_0 + Kc_{1M} h_0^{1-m_M} \frac{D^2}{4} \left(\frac{1}{\sin(\frac{\varphi}{2})}\right)$$

In case of drilling (Fz, M, axial force and moment).

The coefficients of the models are obtained fully automatically through a very simple and unique test of milling or drilling. The reliability of the model can be improved by performing few additional tests. In case of milling, the test needs that just a single tooth is engaged at a time. The coefficients are obtained through the correlation between the instantaneous cutting forces and the instantaneous thickness of the chip. The forces are measured by using a dynamometric table. A very limited axial engagement is sufficient for the extraction of the coefficients. In case of drilling the coefficients are obtained through the correlation between the instantaneous cutting forces and the instantaneous thickness of the chip due to the reduction of the velocity of the machine coming to the bottom of the hole. Just

a very small depth of hole is sufficient for the extraction of the coefficients. A difficulty that we overcame was related to the unavoidable run out of the tools that needs to be calculated and compensated, in order to introduce the instantaneous and actual thickness of the chip and not the theoretical one.

The paper shows the method and the algorithms used for the realization of the model and the special algorithms for the compensation of the run out. The validation of the models is based on a campaign of test on several precious metals:

18 carat white gold with 150‰wt Pd,

18 carat red gold (5N),

Palladium,

Platinum.

Each material has been studied in the following states: work-hardened, annealed, and age-hardened. The data collected represent also a good validation of the models and the models represent a very good solution for the reduction of the cutting tests.

1. FIGURES

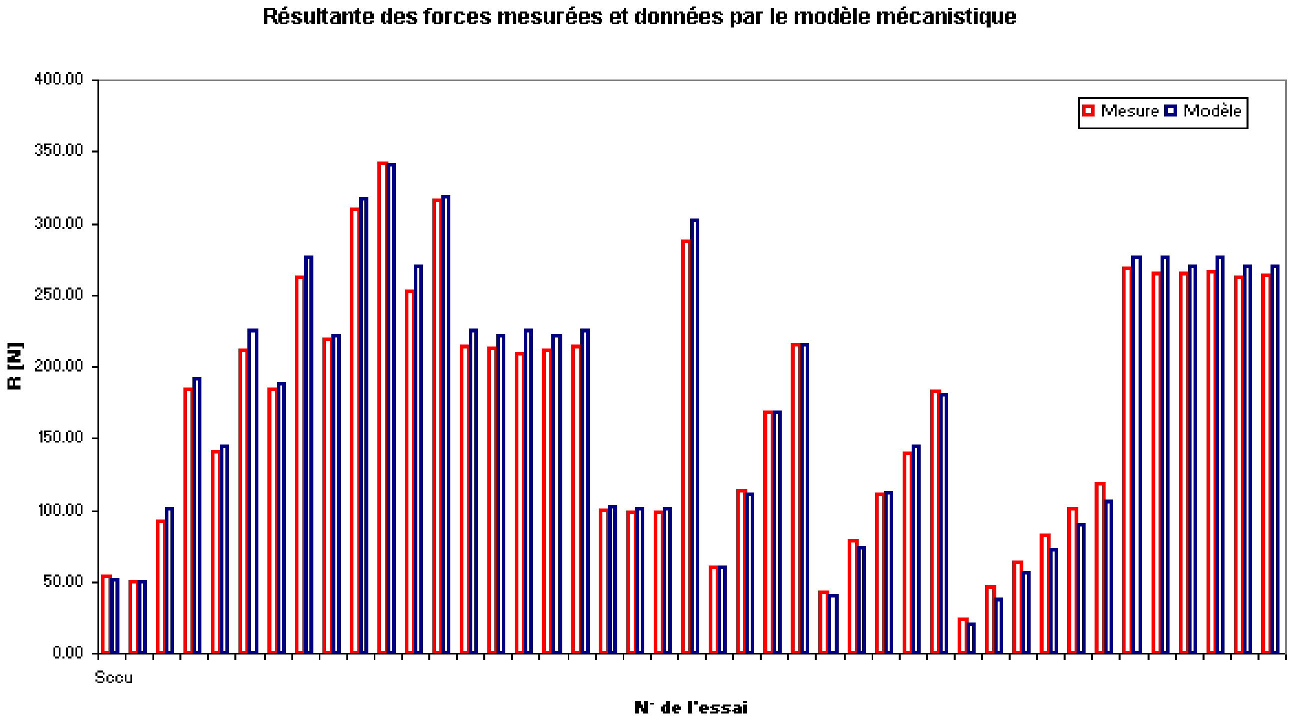

Figure 1; The graph shows the measured values (Red lines) of the resulting force (R) in several different cutting conditions compared to the values predicted by the mechanistic model (Blue lines). The cut material was age -hardened 18 carat red gold (5N).
The coefficients of the model were calculated using data acquired during a milling test with a tool having a different diameter.

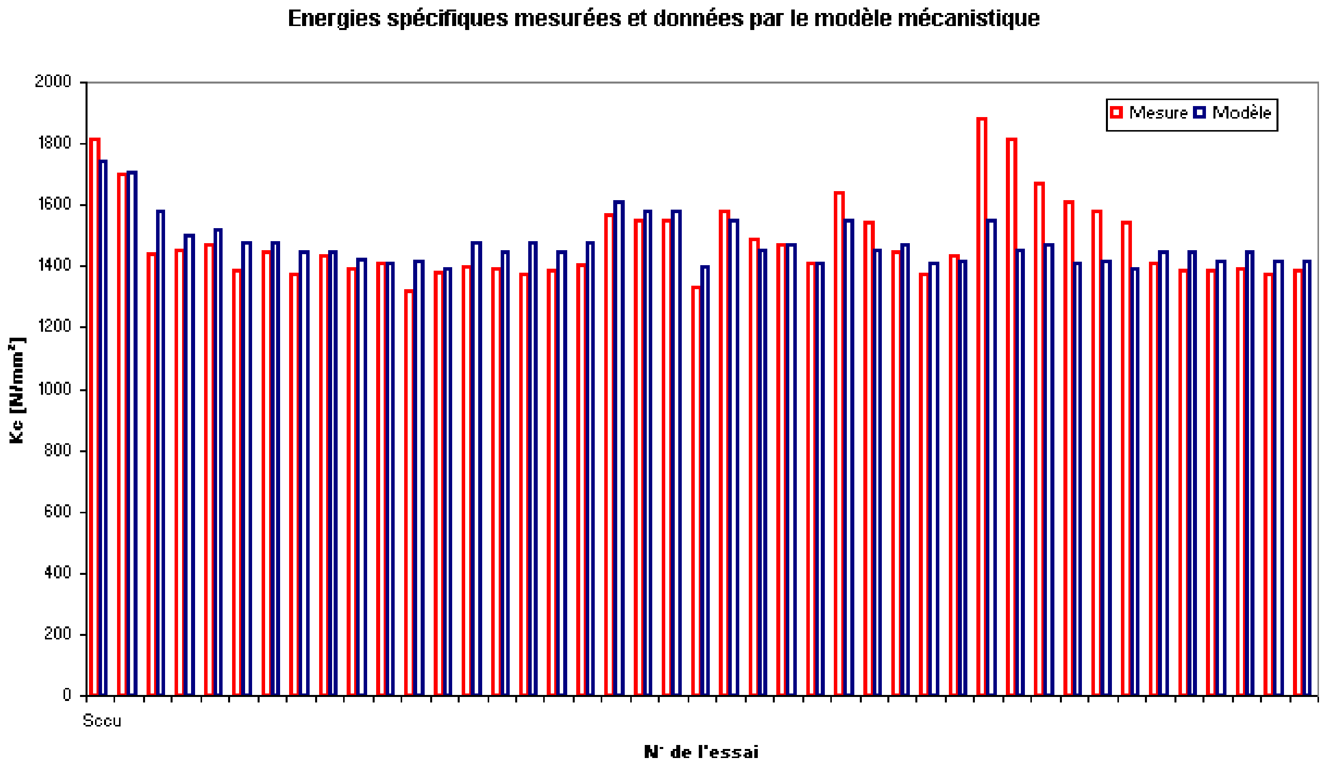

Figure 1;The graph shows the specific energies measured (Red) and modeled (Blue) in the same test as before.