A first step to study numerically the tool wear influence in Ti6Al4V orthogonal cutting

Francois.Ducobu@umons.ac.be

2nd Researcher's Day of the Materials Research Institute

Context

✦ Aeronautical industry : part reliability = important requirement

✦ Part reliability ➨ surface integrity should be mastered = still a challenge in machining up to now

Experimental challenges

✦ Influence of tool wear on microstructure and surface integrity (SI) [1], evolution of tool geometry with the increase of wear ➨ difficult ongoing problem

✦ When should the tool be replaced ? Not damaging the surface but using it until its end of life...

Numerical challenges

From a numerical point of view, challenges : prediction of residual stresses [2], influence of tool geometry on residual stresses (RS) [3], prediction of tool geometry which evolves with the increase of wear [4, 5] + Current finite element models with updating tool geometry are rather heavy to compute

For Inconel 718 [6], experimental study shows the link between tool wear, cutting forces and machined surface ➨ no numerical equivalent so far ➨ first numerical step : influence of tool wear in Ti6Al4V machining with a non-adaptive tool geometry and a classical material constitutive law (Johnson-Cook)

Finite element model

General features

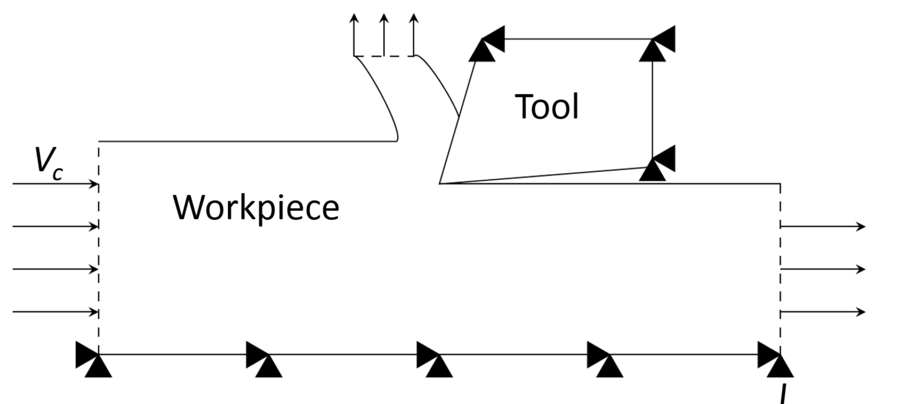
✦ 2D plane strain orthogonal cutting model, Abaqus/Explicit v6.11

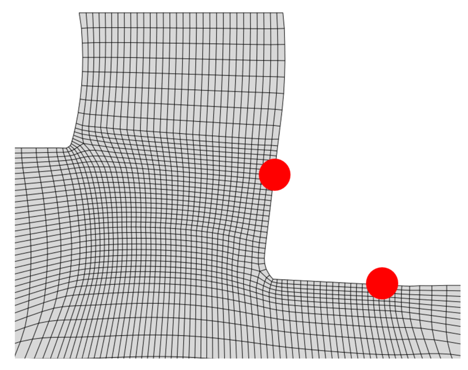
✦ Arbitrary Lagrangian Eulerian (ALE) formulation with Lagrangian and Eulerian boundary conditions

✦ Chip formation = adaptive meshing and plastic flow of material

✦ Refined meshes close to the cutting edge radius and shear zones (SZ)

✦ Typical industrial cutting speed : 80 m/min, uncut chip thickness : 0.1 mm

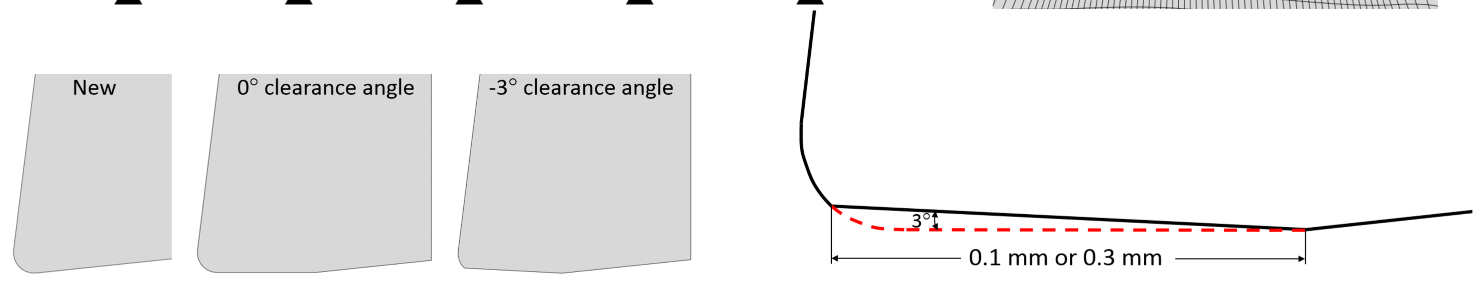




Tool geometries

✦ 3 types of tool geometry to take tool wear into account, 5 geometries in total

✦ Fresh tool = rake angle : 7˚, clearance angle : 6˚, cutting edge radius : 20 µm

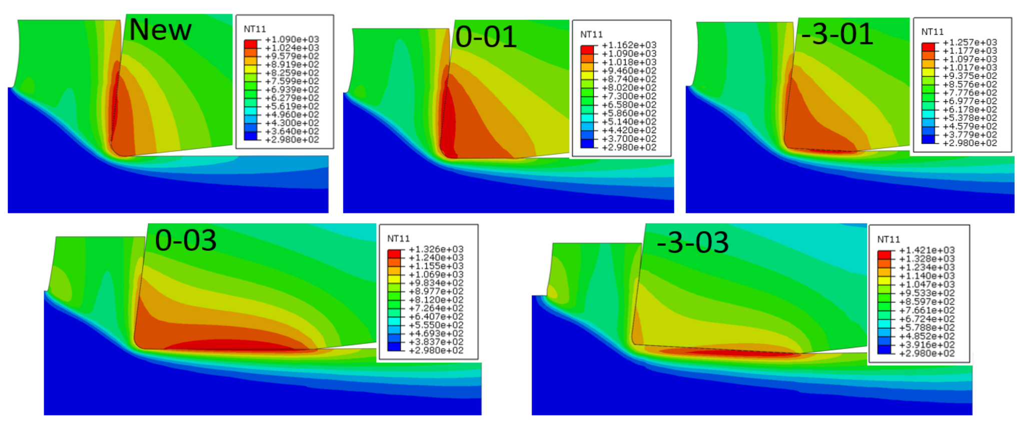


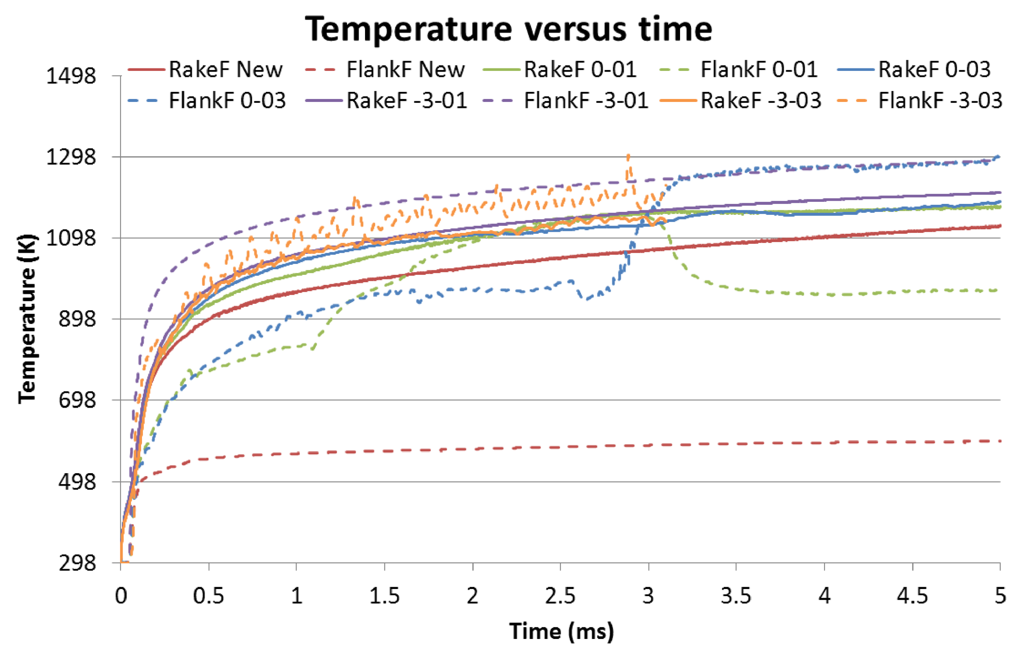
Results

Temperatures

✦ The location of the maximum temperature moves with tool geometry from SSZ to TSZ

✦ Increase of the temperature with tool wear



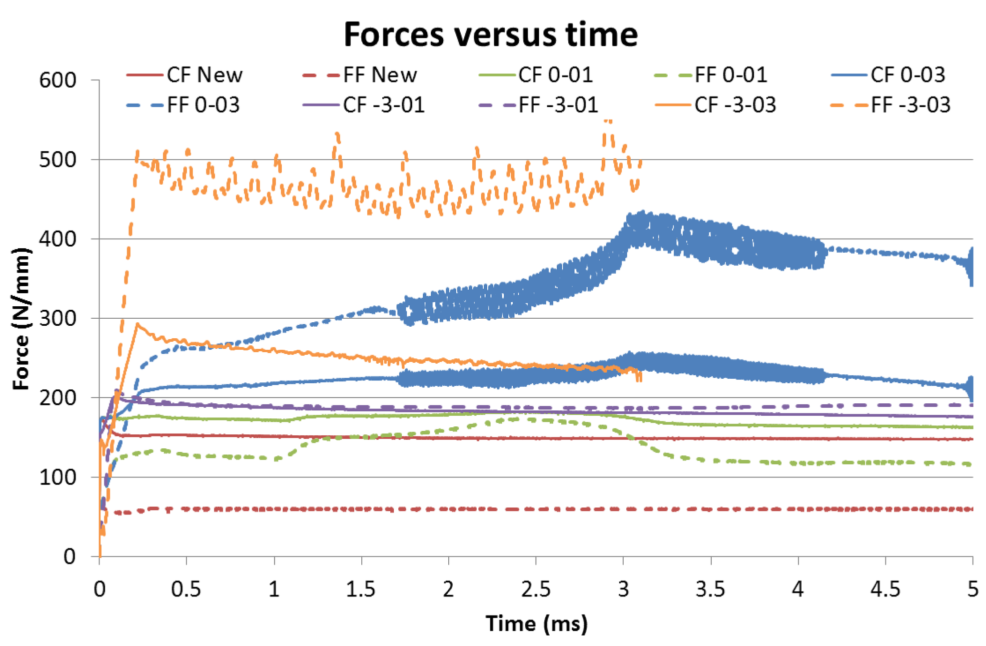


Cutting forces

✦ Tool wear ➨ increase of friction on clearance face ➨ forces increase with tool wear and particularly feed force

✦ Forces evolution ➨ chip are not continuous anymore

✦ 2 distinct evolutions depending on the clearance angle



Plastic strains

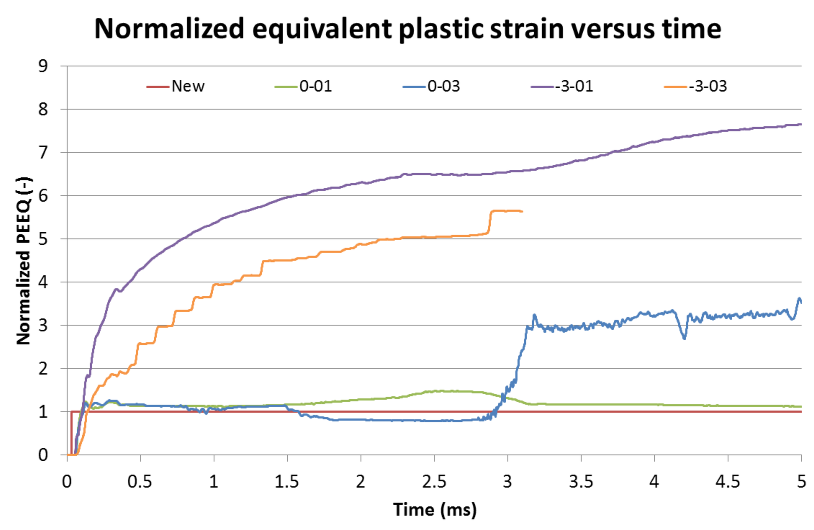
✦ Normalized value $= \frac{\text{value with current tool geometry}}{\text{value with initial tool geometry}}$

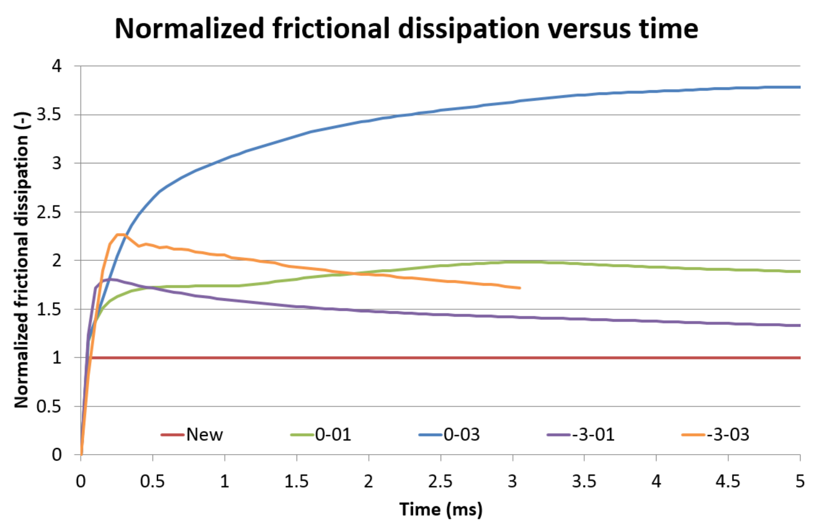
✦ Higher equivalent plastic strain ➨ higher RS ➨ decrease in the quality of the part

Friction

✦ Frictional dissipation higher with wear, when clearance angle is 0˚ and when flank wear is larger

✦ 2 distinct evolutions depending on the clearance angle





Conclusions and perspectives

✧ Tool wear influences the chip formation notably

✧ The most worn tool impacts the most the machined surface and the chip formation

✧ The chip morphology is influenced by the tool geometry

✧ Measuring the cutting forces should help to detect experimentally a too much worn tool

✧ All the results were qualitatively in accordance with the literature

✦ An experimental campaign in the same cutting conditions is planned to validate the numerical predictions

✦ Improvements of the model will include an adaptive tool geometry and a constitutive law taking the microstructure modifications into account

References

[1] Arrazola, P., Özel, T., Umbrello, D., Davies, M., Jawahir, I.. Recent advances in modelling of metal machining processes. CIRP Annals ? Manufacturing Technology 2013 ;62 :695-718
[2] Jawahir, I., Brinksmeier, E., M'Saoubi, R., Aspinwall, D., Outeiro, J., Meyer, D., et al. Surface integrity in material removal processes : Recent advances. CIRP Annals - Manufacturing Technology 2011 ;60 :603-626.
[3] Chen, L., El-Wardany, T., Harris, W.. Modelling the effects of flank wear land and chip formation on residual stresses. CIRP Annals ? Manufacturing Technology 2004 ;53 :95-98.
[4] Schulze, V., Michna, J., Zanger, F., Pabst, R.. Modeling the process-induced modifications of the microstructure of work piece surface zones in cutting processes. Advanced Materials Research 2011 ;223 :371-380
[5] Filice, L., Micari, F., Settineri, L., Umbrello, D.. Wear modelling in mild steel orthogonal cutting when using uncoated carbide tools. Wear 2007 ;242 :545-554
[6] Arrazola, P., Garay, A., Fernandez, E., Ostolaza, K.. Correlation between tool flank wear, force signals and surface integrity when turning bars of Inconel 718 in finishing conditions. International Journal of Machining and Machinability of Materials 2014 ;15 :84-100

Acknowledgements

The authors thank the *Fonds de la Recherche Scientifique de Belgique* (FRS-FNRS), Wallonie-Bruxelles International (*Bourse d'excellence WBI.World*) and the projects InProRet (code IE12-342), InProRet II (code IE13-365) for the financial support provided for the research presented trough this paper.

Université de Mons

Dr F. Ducobu[a], Prof. P. Arrazola[b], Prof. E. Rivière[a], Prof. E. Filippi[a] | [a]University of Mons, [b]Mondragon University