

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)

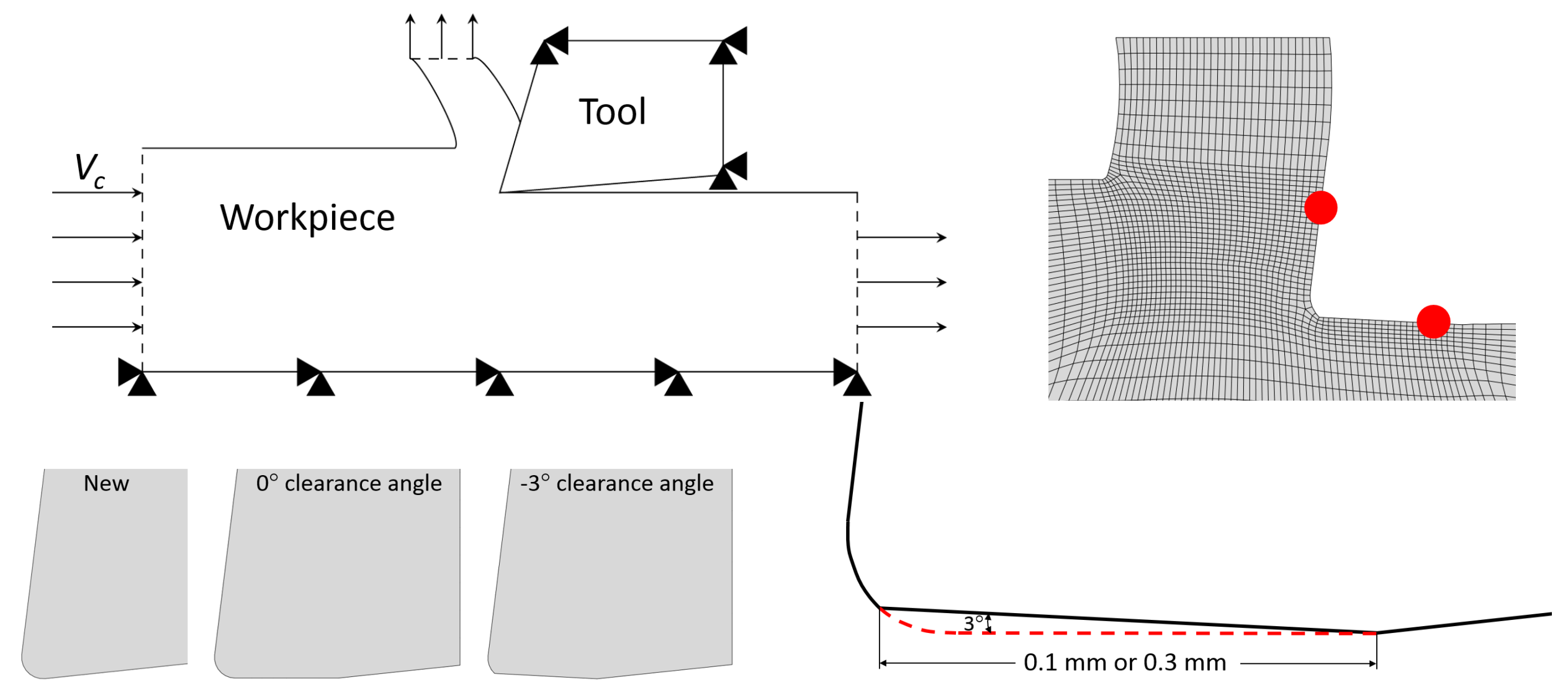
Finite element model

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

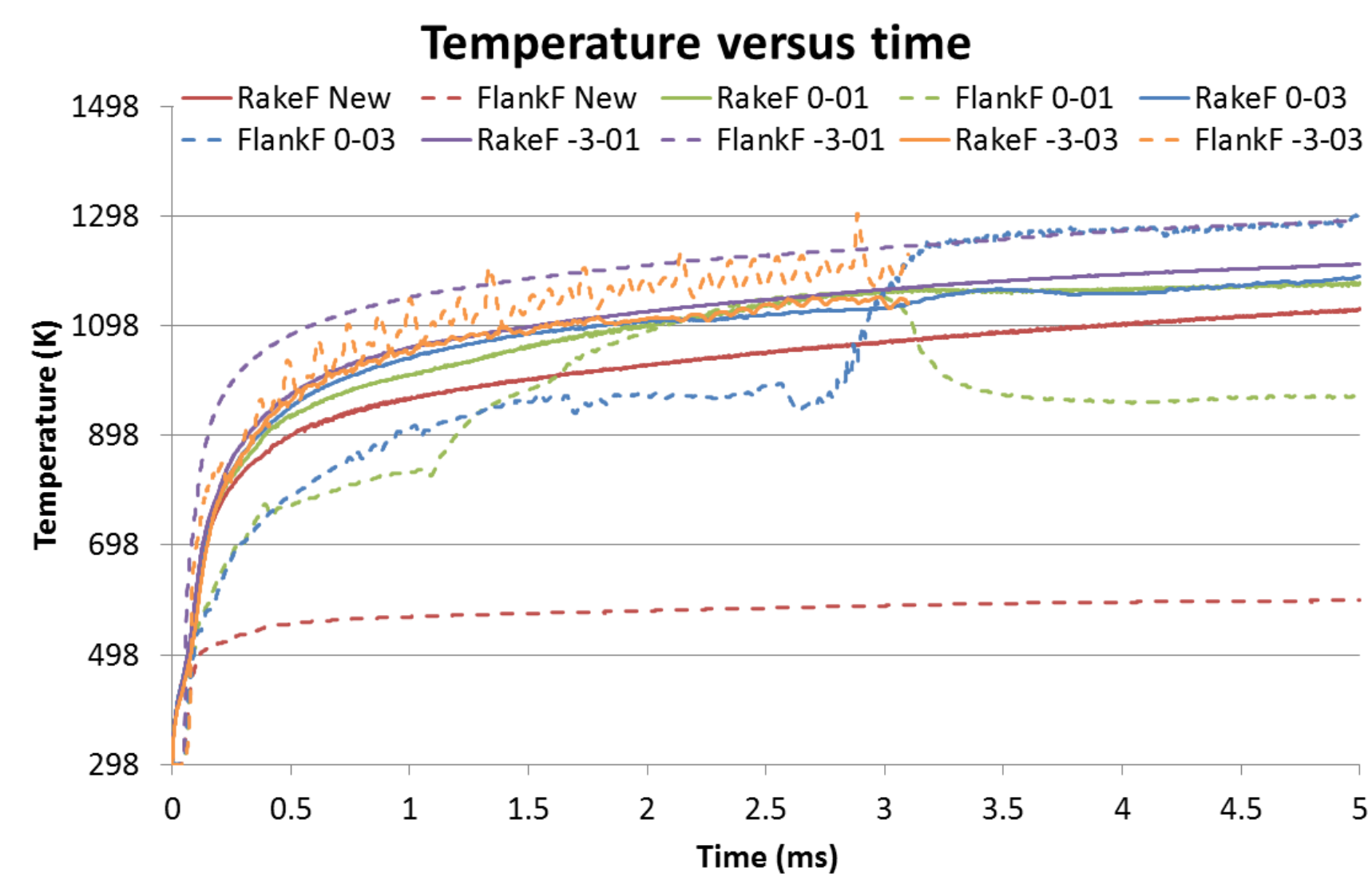
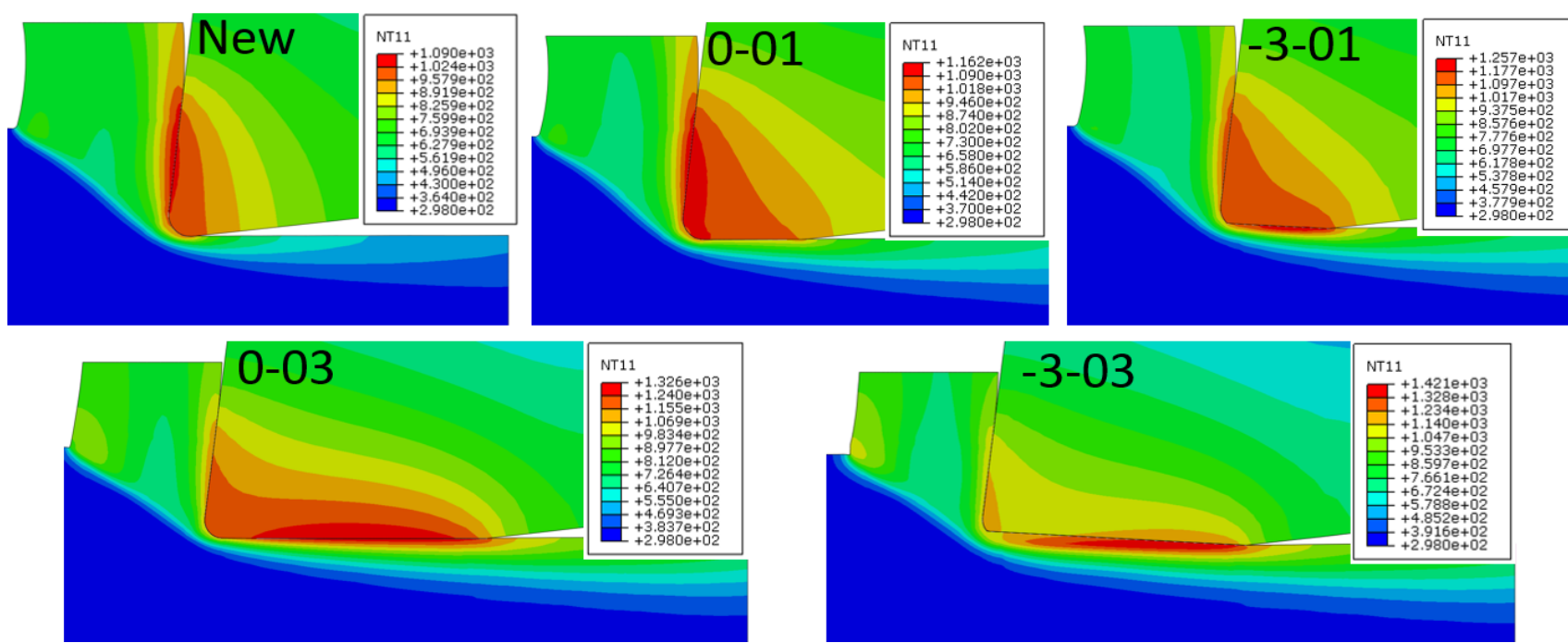
- ♦ 3 types of tool geometry to take tool wear into account, 5 geometries in total
- ♦ Fresh tool = rake angle : 7°, clearance angle : 6°, cutting edge radius : 20 μm



Results

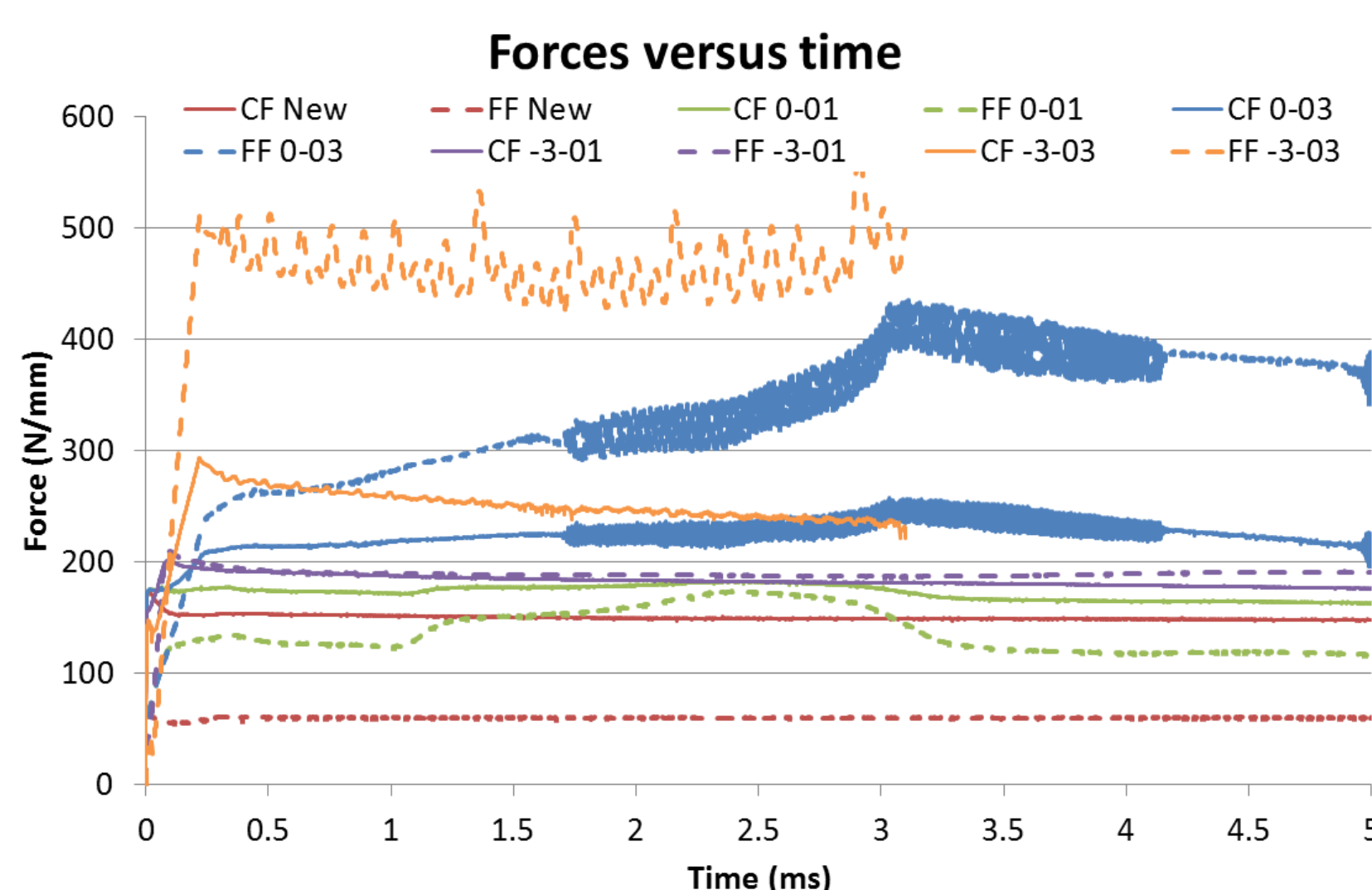
Temperatures

- ♦ 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

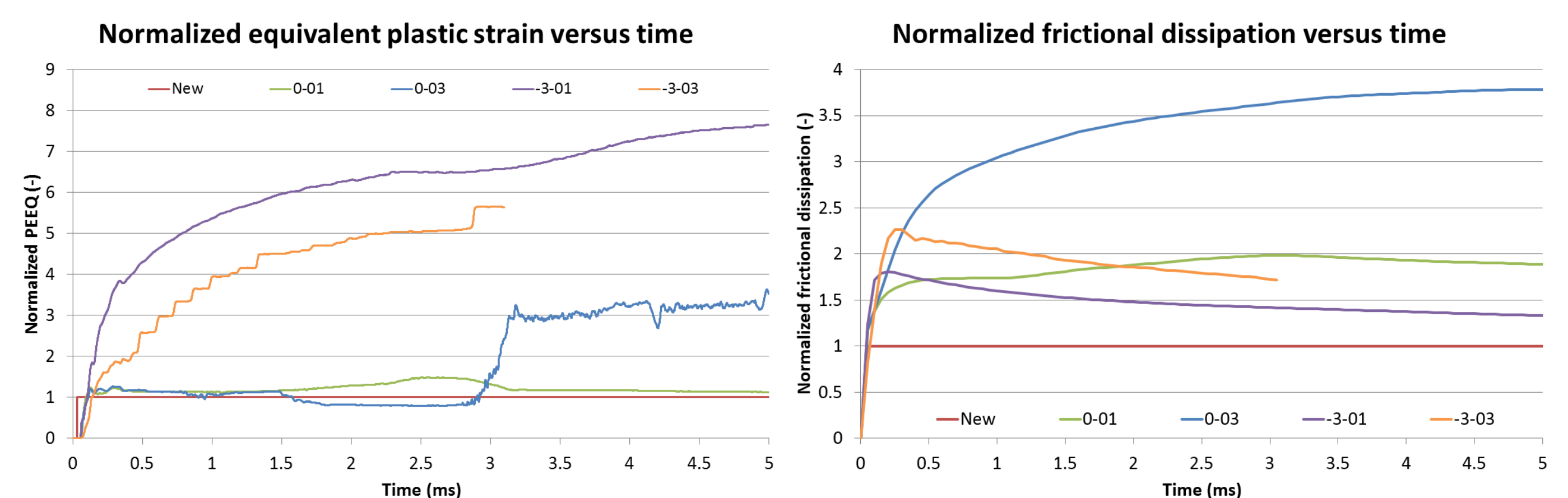


Plastic strains

- ♦ 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

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