A numerical model to study the tool wear influence in Ti6Al4V orthogonal cutting

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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...

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)

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

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
- Tool wear = rake angle = −1°, clearance angle = 8°, cutting edge radius = 50 µm
- Tool wear = rake angle = −3°, clearance angle = 8°, cutting edge radius = 50 µm
- Tool wear = rake angle = −5°, clearance angle = 8°, cutting edge radius = 50 µm
- Tool wear = rake angle = −7°, clearance angle = 8°, cutting edge radius = 50 µm

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Results

Temperatures

- The location of the maximum temperature moves with tool geometry from SSZ to TSZ
- Increase of the temperature with tool wear

Plastic strains

- Normalized value = value with current 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


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