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CEL Modelling of Ti6Al4V Orthogonal Cutting

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3rd Researcher's Day of the Materials Research Institute

Context

2 primary formulations in the finite element method : Lagrangian and Eulerian
In cutting modelling :

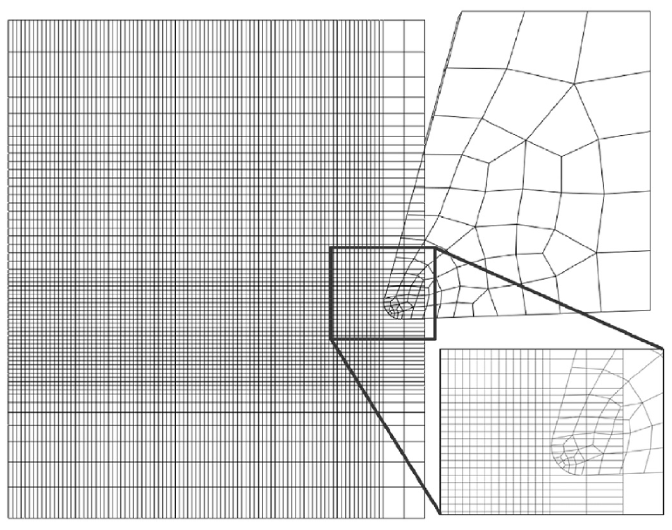
✦ Eulerian = steady-state and final chip geometry is an input
✦ Lagrangian = unsteady-state and severe elements deformation + chip separation criterion
✦ ALE = relative movement of the mesh to reduce elements deformation

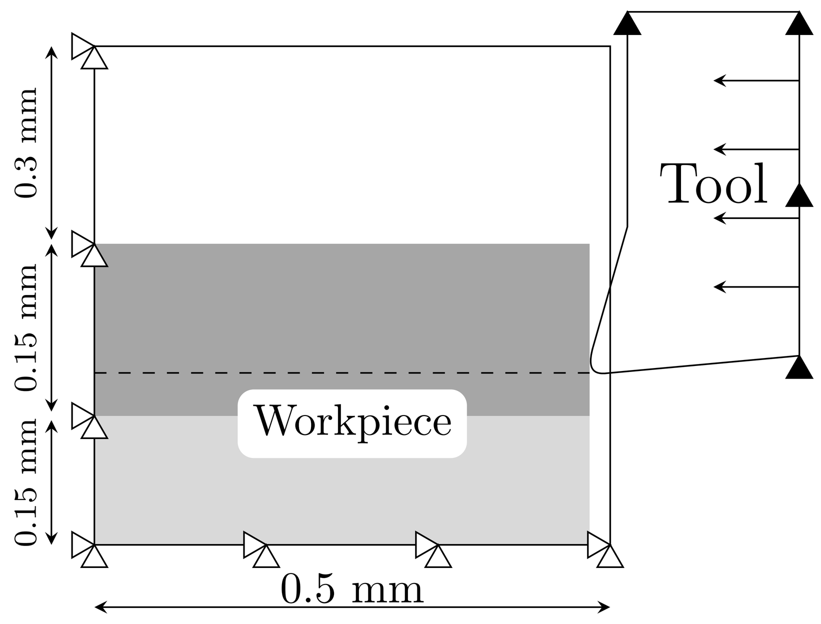
➨ Application of the Coupled Eulerian-Lagrangian (CEL) technique to metal cutting

✧ Involves both Lagrangian and Eulerian formulations
✧ Typically used to study fluid-structure interactions

Numerical model

✦ Tool = Lagrangian part
✦ Workpiece = Eulerian part ➨ Ti6Al4V flows into the volume defined as the workpiece
✦ Workpiece = volume in which Ti6Al4V can go ➨ it includes the chip
✦ V_c = 30 m/min, h = 0.1 mm, 0.06 mm and 0.04 mm (r = 0.02 mm)
✦ Johnson-Cook constitutive model
✦ Coulomb's friction with 0.3 coefficient

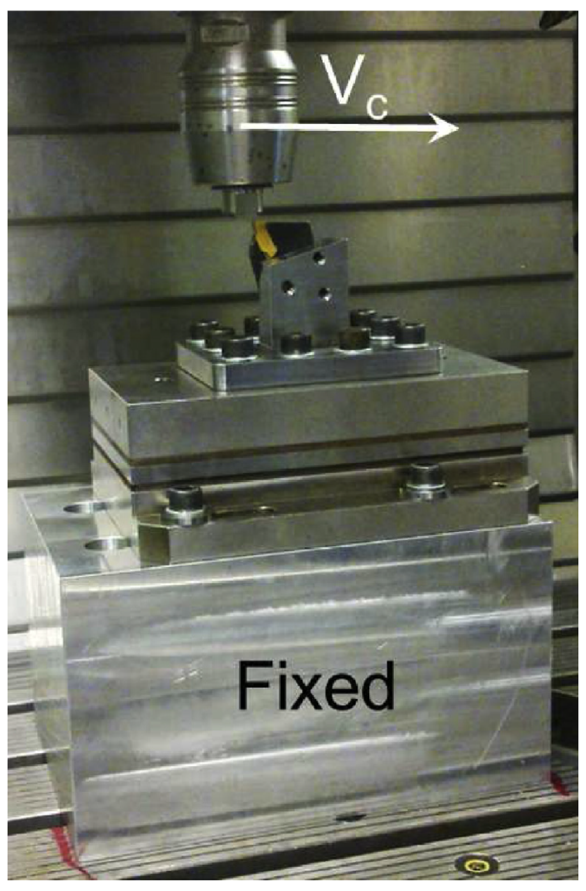


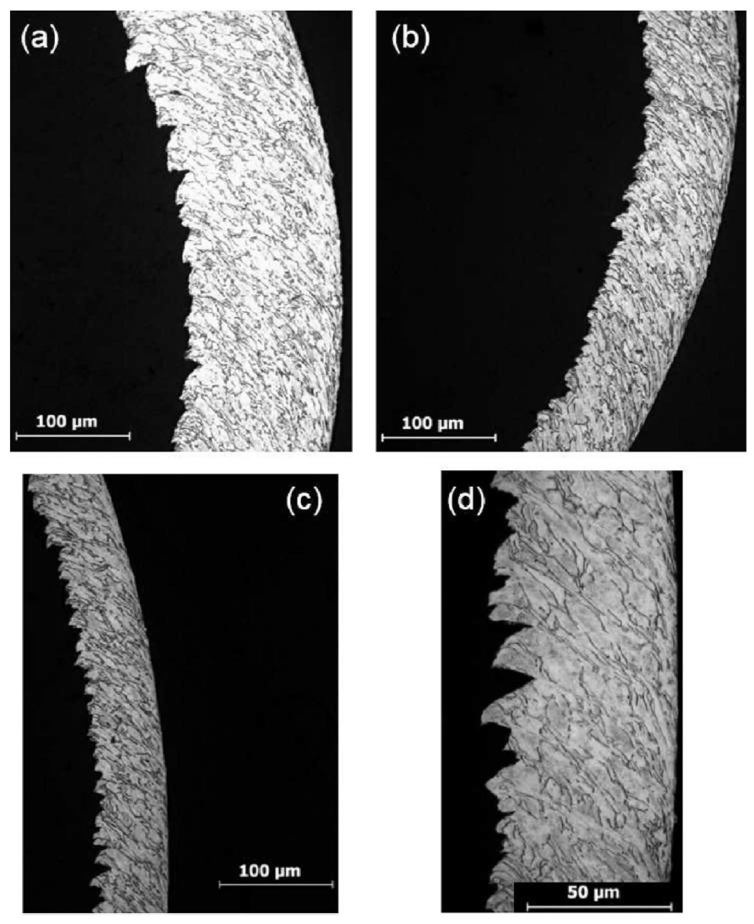


✦ Displacement = 0 outside the plane for the tool
✧ Speed = 0 outside the plane for the workpiece

Experimental Ti6Al4V chip formation

Strictly orthogonal cutting configuration on a 5-axis milling machine





Results

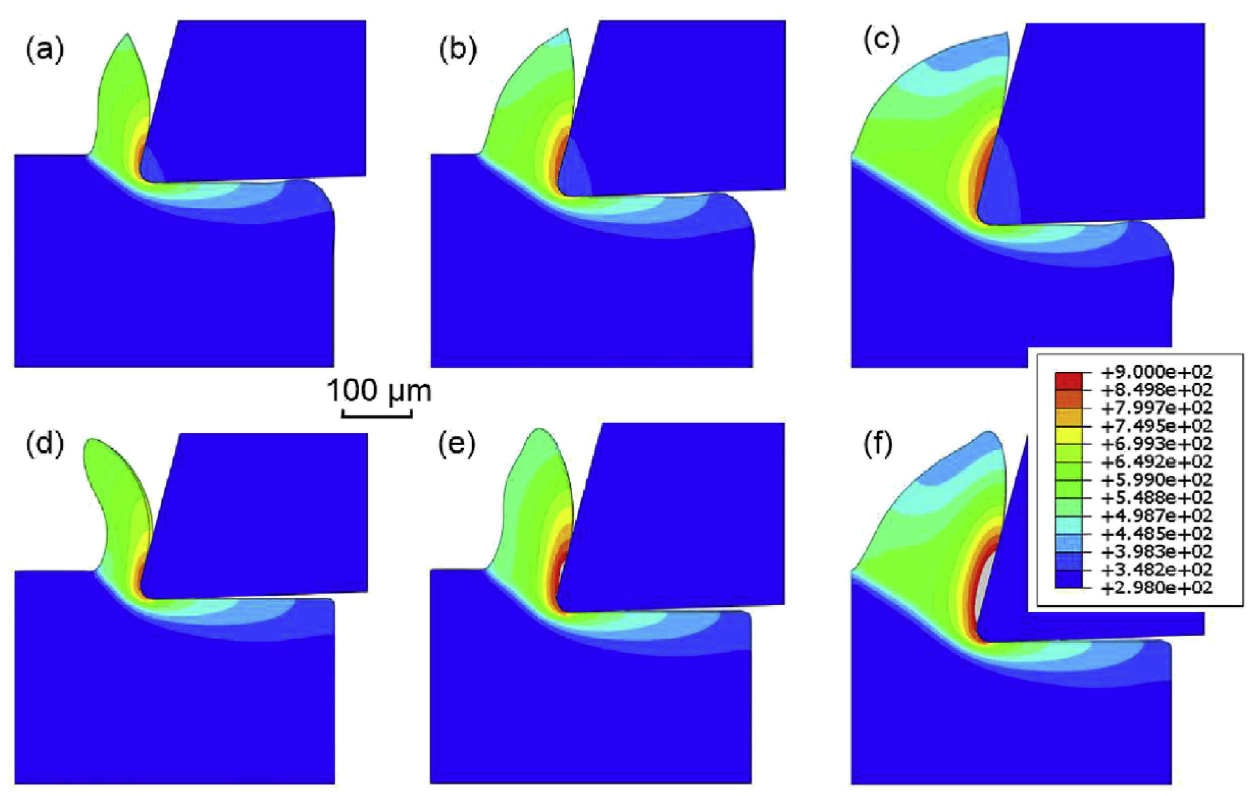
Chip morphology

✧ CEL chips longer, less rigid and more rounded
✧ CEL chip thickness is closer to the experiments
✧ Lateral expansion of chip is neglected in the modelling

h (µm)	Case	h' (µm)	Δ (%)	λ_h	ϕ (°)
	Exp.	135 ± 6	–	1.35	63.5
100	ALE	184 ± 2	– 36	1.84	73.6
	CEL	200 ± 4	– 48	2	76
	Exp.	80 ± 4	–	1.34	63.2
60	ALE	110 ± 1	– 38	1.84	73.6
	CEL	97 ± 1	– 21	1.62	69.7
	Exp.	59 ± 5	–	1.48	66.7
40	ALE	72 ± 1	– 22	1.79	72.8
	CEL	59 ± 1	0	1.48	66.7

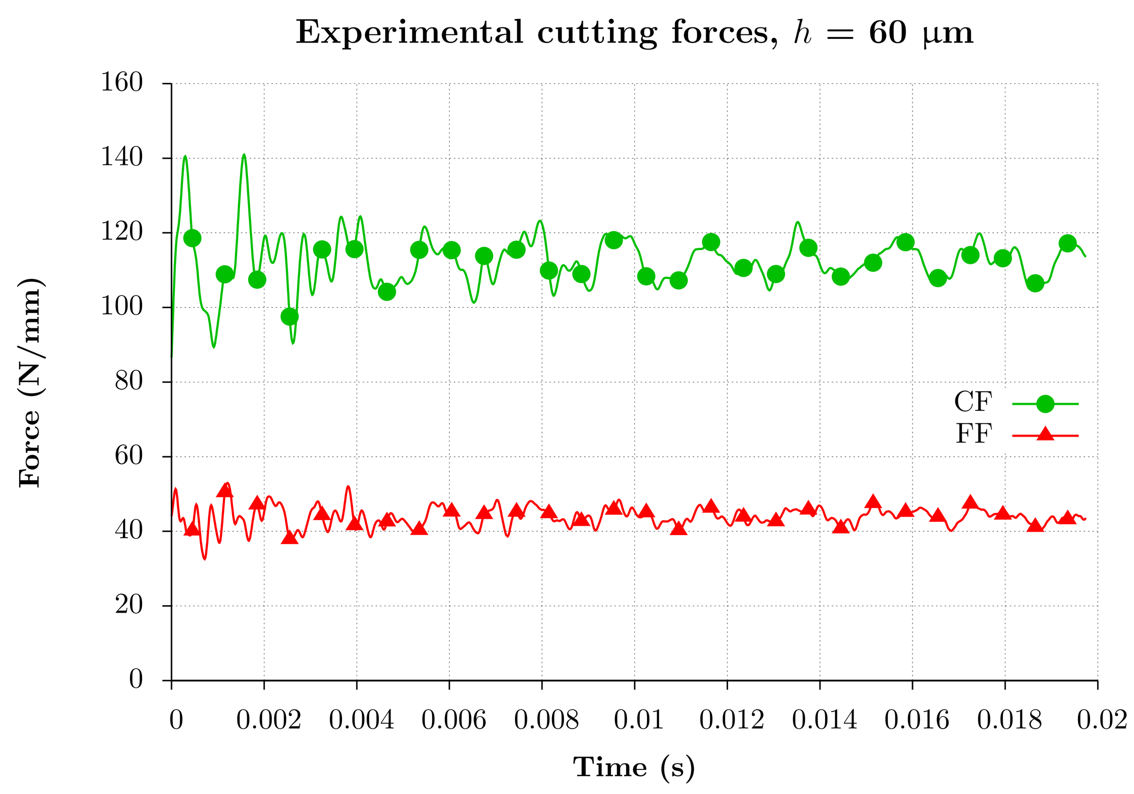
Temperatures

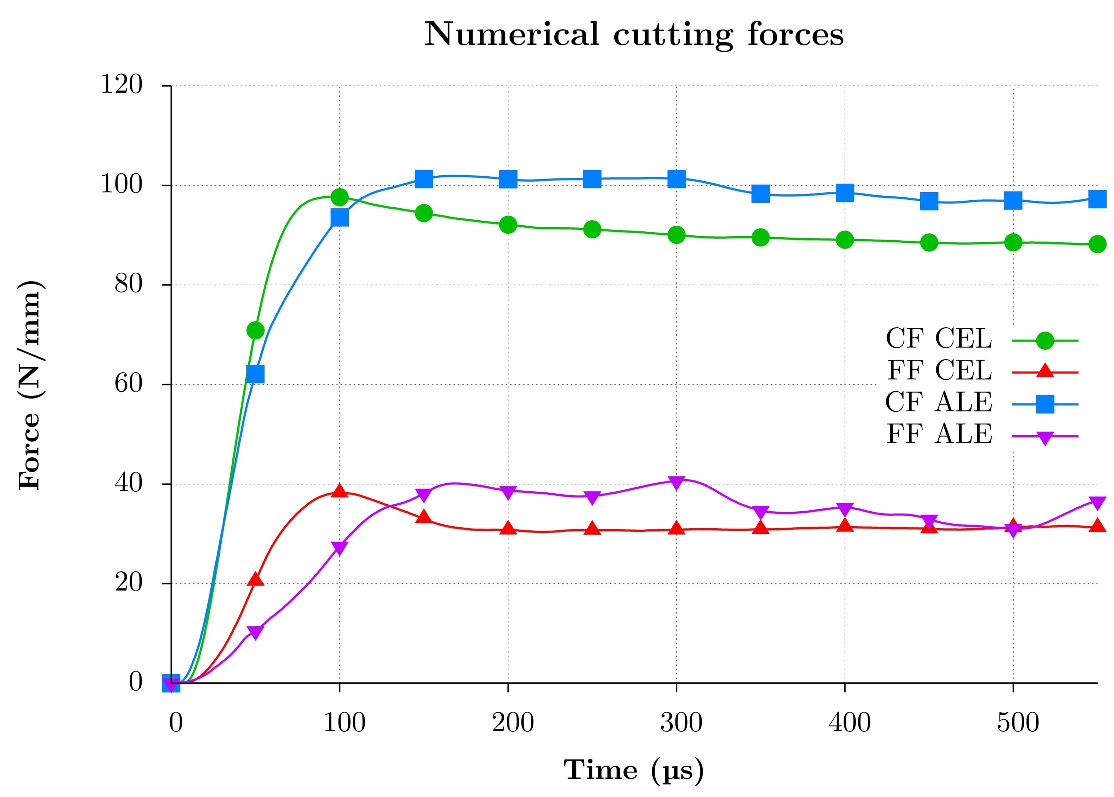
✦ Highest temperature always in the secondary shear zone ➨ OK
✦ Temperature slightly higher for CEL than ALE (no experimental reference for temperatures)



Cutting forces

✦ Cutting force difference with experimental reference : 17-26% for CF and 20-36% for FF
✦ Numerical values close





Conclusions and perspectives

✧ CEL formalism gives results close to the experiments
✧ Tendencies when the uncut chip thickness decreases are globally well captured
✧ Chip morphology looks more natural with CEL than with ALE formalism
✧ Absence of element deformation in the workpiece is a significant advantage

✦ Expand the model to other chip morphologies, harder to model such as segmented chips
✦ Use with other materials, materials constitutive models and friction modelling

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