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Experimental contribution to the comprehension of Ti6Al4V saw-toothed chip formation in orthogonal cutting

Context

- Mechanisms of Ti6Al4V saw-toothed chip formation = question still opened in literature
- 3 theories are found in literature:
  - Formation by adiabatic shear band
  - Formation by crack propagation
  - Formation by adiabatic shear band and crack propagation
- Recent literature: adiabatic shear band = most likely theory
- Our opinion: Ti6Al4V saw-toothed chip formation mechanism = combination
  - with preponderance depending on the cutting conditions (+ Ti6Al4V state)
  - in very variable proportions

→ Goal: make an advancement in this problem

Experimental setup

Configuration

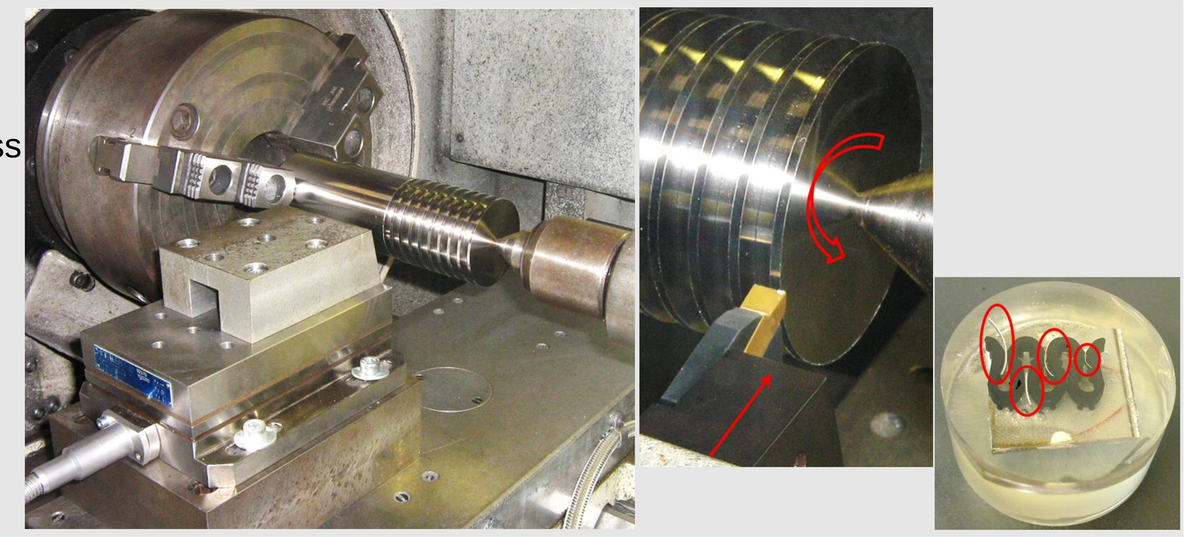
- Machined material = annealed Ti6Al4V (AMS 4928)
- Workpiece = shaft + flanges: successive slices (ϕ 60 mm) of equal thickness
- Tool: tungsten carbide, r = 10 µm, γ = 15° and α = 2°
- Tailstock to avoid workpiece displacements and vibrations

Cutting conditions

v_c = 75 m/min and h = 0.28 mm/rev

Orthogonal cutting

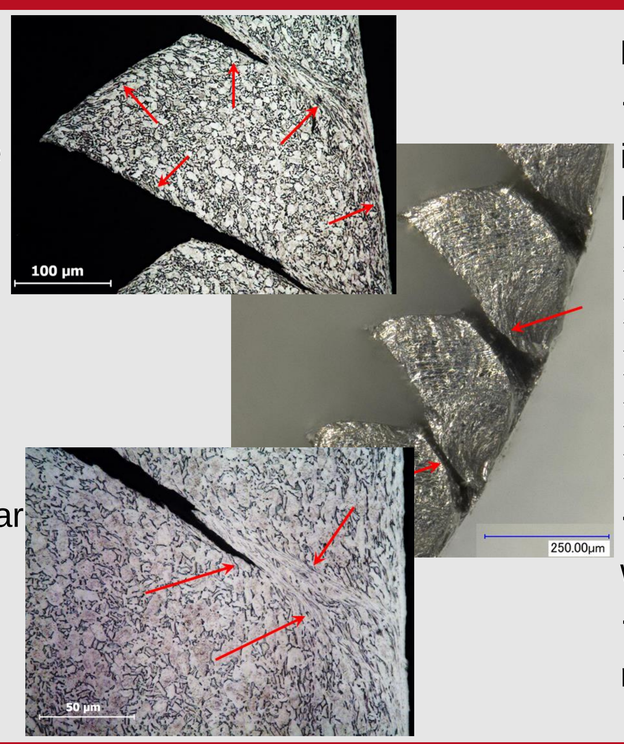
- Plunge cutting on each slice + dry cutting conditions
- Tool width (6 mm) > disks width (2 mm) → plane strain conditions



Results

Optical microscope

- Highly deformed grains in PSZ
- Deformed grains on the continuous surface of the chip:
  - Contact with tool
  - Zone where chip comes off the workpiece
- Deformed grains on the free surface of the chip: workpiece preparation or previous tool passage during experiments
- Teeth sides: almost not deformed grains + irregular surfaces → crack propagation characteristics
- Crack propagation inside PSZ, from the free chip surface to the tool
- Split shear band as in [2]



Microstructure analysis

→ Chip formation = large deformation + crack propagation inside PSZ

Numerical microscope

- Chip observation: ~~embedding~~ + ~~polishing~~ + ~~etching~~
- Lateral chip faces ≠ central part (obtained after polishing)
- No material between teeth in PSZ
- Width varies depending on the tooth
- High surface roughness

→ Not observable with an optical microscope and disappear with polishing

→ **Characteristic of Ti6Al4V saw-toothed chip not mentioned in literature**

Conclusions and perspectives

- For these cutting conditions, Ti6Al4V saw-toothed chip formation mechanism = adiabatic shear band + crack propagation inside PSZ
- Measure chip micro-hardness to study its evolution when crossing PSZ → phase transformation?
- Compare these experimental results to these of the finite element model we have developed [3]

References

[1] Y. Bai and B. Dodd: Adiabatic Shear Localisation: Occurrence, Theories and Applications. Pergamon Press, 1992

[2] M. Bäker, J. Rosler and C. Siemers: A finite element model of high speed metal cutting with adiabatic shearing. Computers and Structures, 80: 495-513, 2002

[3] F. Ducobu, E. Rivière-Lorphèvre and E. Filippi: A Lagrangian FEM Model to Produce Saw-toothed Macro-chip and to Study the Depth of Cut Influence on its Formation in Orthogonal Cutting of Ti6Al4V. Advanced Materials Research, 223: 3-11, 2011

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