Cluny

ARTS ET MÉTIERS ParisTech

ICB Institut Carnot de Bourgogne

LaBoMaP Laboratoire Bourguignon des Matériaux et Procédés

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INFLUENCE OF CUTTING PROCESS MECHANICS ON SURFACE INTEGRITY AND ELECTROCHEMICAL BEHAVIOR OF OFHC COPPER

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INSTITUT CARNOT ARTS

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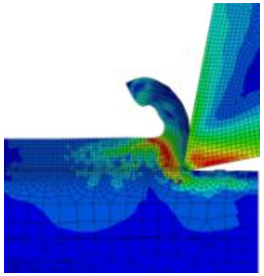
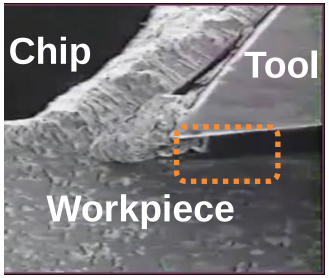
Outline

Introduction

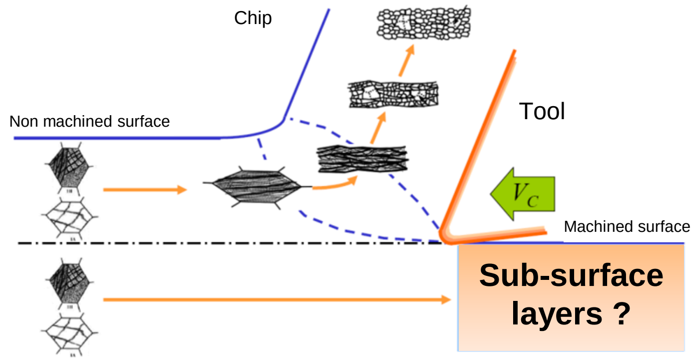
Comprehension of cutting mechanics → **Tool / Flank contact**





Numerical modeling ↔ **Experimental study**

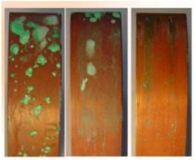
F, T°, RS, DRX

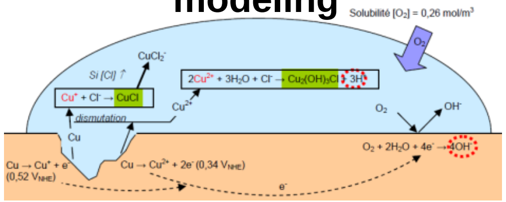


Surface integrity → **Residual Stresses** / **Microstructure** / **Topography**

Corrosion resistance of OFHC copper → **Electrochemical behavior** / **Resistance in salt fog atmosphere**

Experimental study ↔ **Phenomenological modeling**



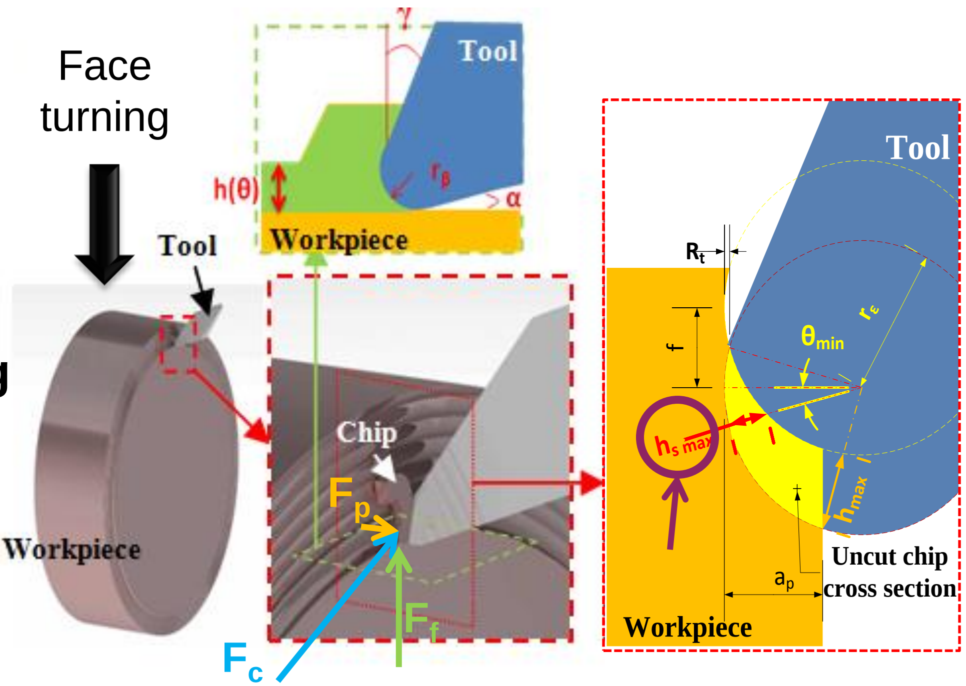


Objectives

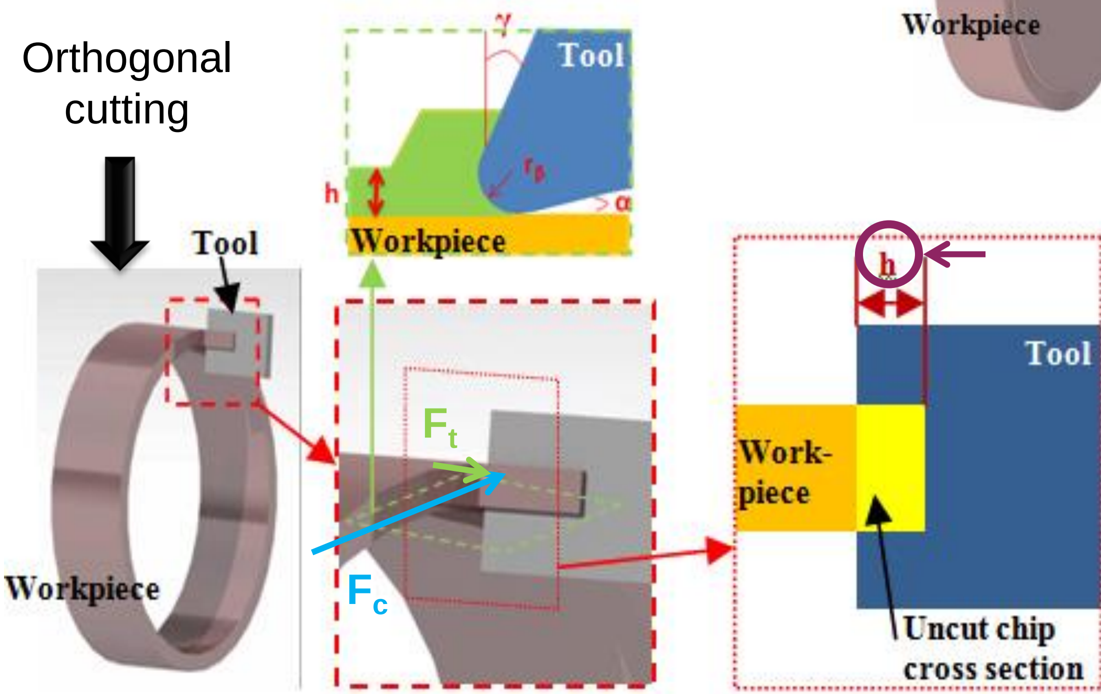
Compare a typical 3D turning with orthogonal cutting

- Influence of superfinishing machining conditions on surface integrity and corrosion resistance of OFHC copper

Face turning



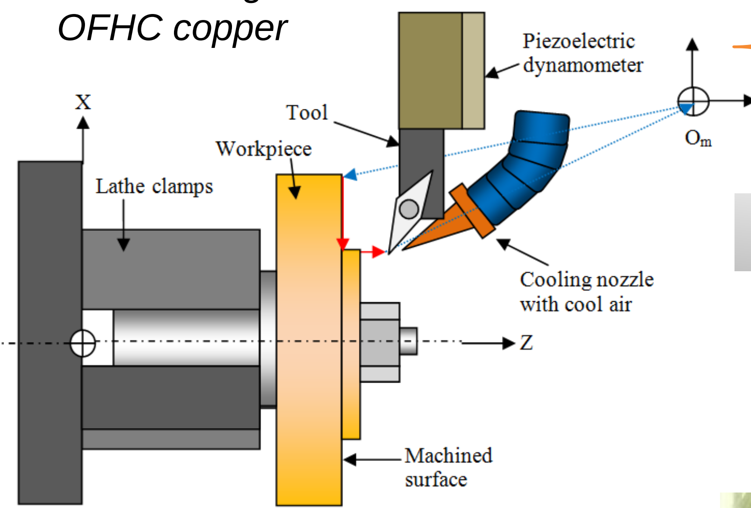
Orthogonal cutting



Is orthogonal cutting process able to provide a surface integrity similar to that one generated by 3D cutting?

Experimental procedure and parameters

Face turning of OFHC copper



f = 0.1 ; 0.15 ; 0.2 mm/rev
a_p = 0.15 ; 0.30 ; 0.50 mm
V_c = 120 m/min   Air cooling
-5±1°C

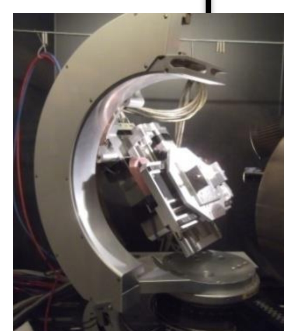
α = 7°
γ = 20°
r_β = 9 µm

1M $NaClO_4$
1 micro-capillary

3D Face turning

Local electro-chemical tests

Forces | **Topography** | **RS**



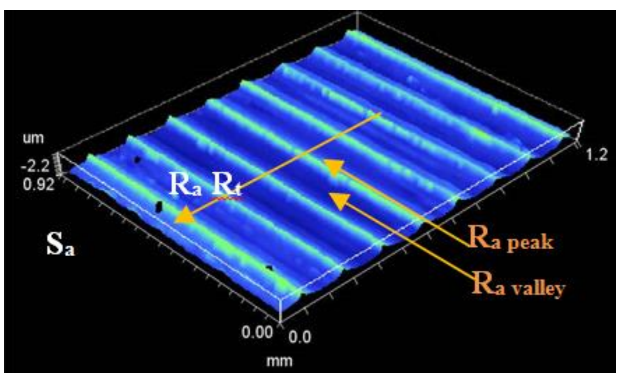
Polarization

F_c, F_p, F_f, K_c | R_t, R_a | σ_{rad}, σ_{cir} | E_{piq} I_{pass} E_{cor}

Cutting mechanics

Surface integrity

Electrochemical behavior



Roughness measurement directions

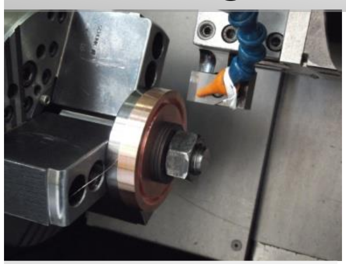
Experimental procedure and parameters

V_c = 120 m/min
h = 0,01; 0,03; 0,05; 0,07; 0,10 mm
b = 4 mm

Air cooling -5±1°C

α = 5°
γ = 20°
r_β = 12 µm

Orthogonal cutting tests



NC machining

QST

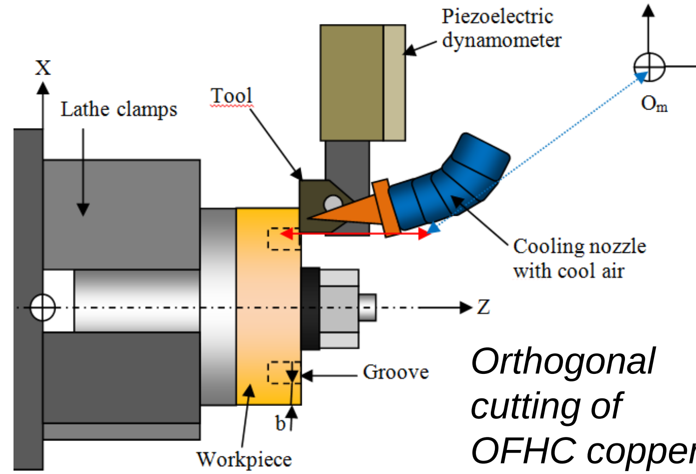
- NC machining → Forces → F_c, F_t, K_c → Cutting mechanics
- QST → Topography → R_t, R_a → Surface integrity
- QST → RS → σ_{rad}, σ_{cir} → Surface integrity

1M $NaClO_4$

1 micro-capillary

Local electro-chemical tests

- Polarization → E_{piq}, I_{pass}, E_{cor} → Electrochemical behavior



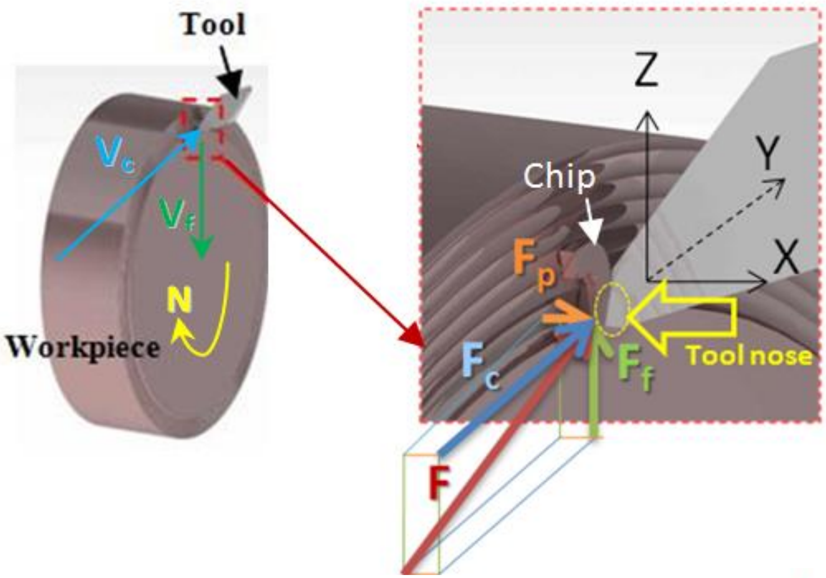
Orthogonal cutting of OFHC copper

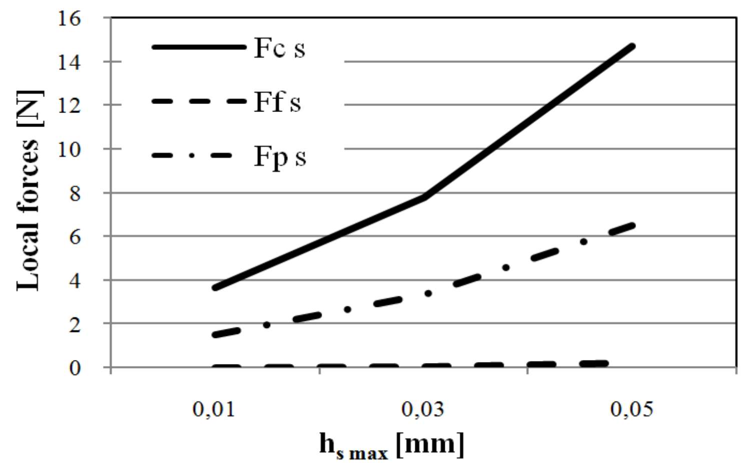
Statistical Analysis basing on

Pearson's correlation coefficient:

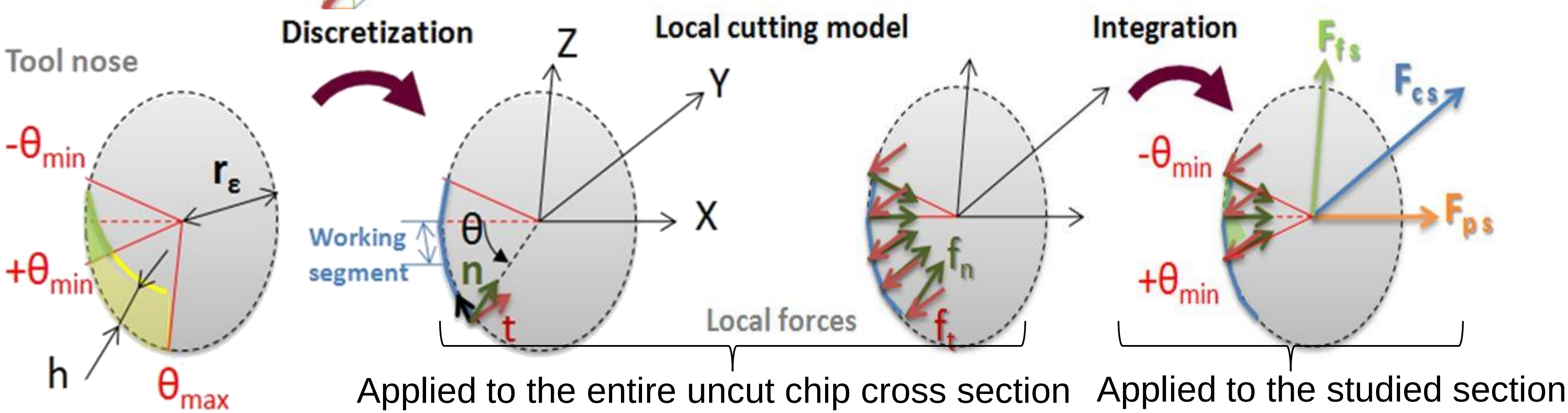
$$Correl(X,Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}}$$

Results and discussion: Cutting mechanics

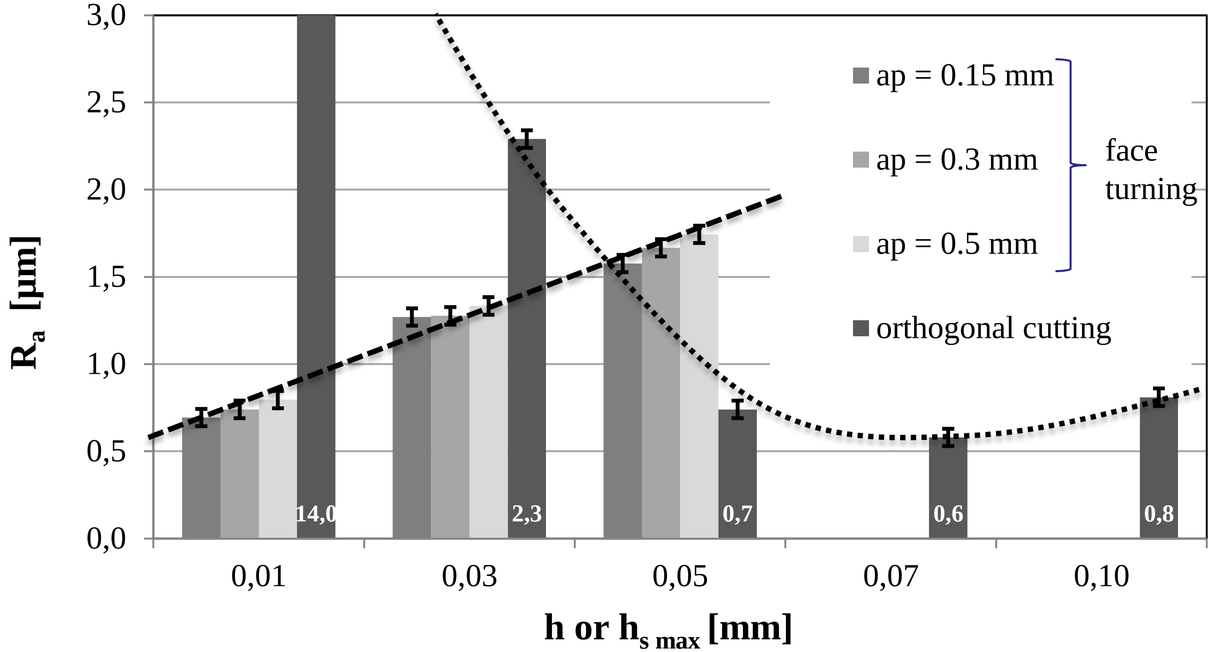




Local forces in face turning [f($h_{s\ max}$)]



Results and discussion: Surface integrity



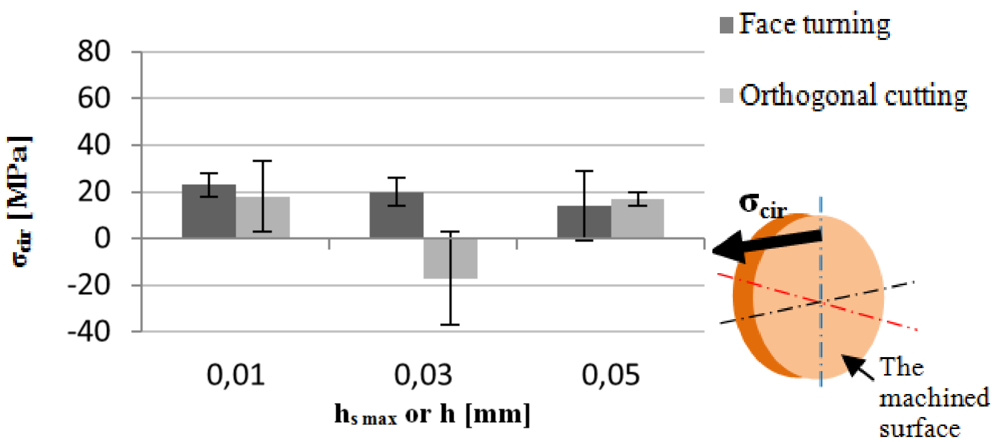
R_a in face turning [f($h_{s\ max}$, a_p)] and in orthogonal cutting [f(h)]

- $h_{s\ max}$ is correlated to R_a, R_t and S_a by **> 97%**.
- The influence of h on the surface roughness is opposite to the orthogonal cutting.

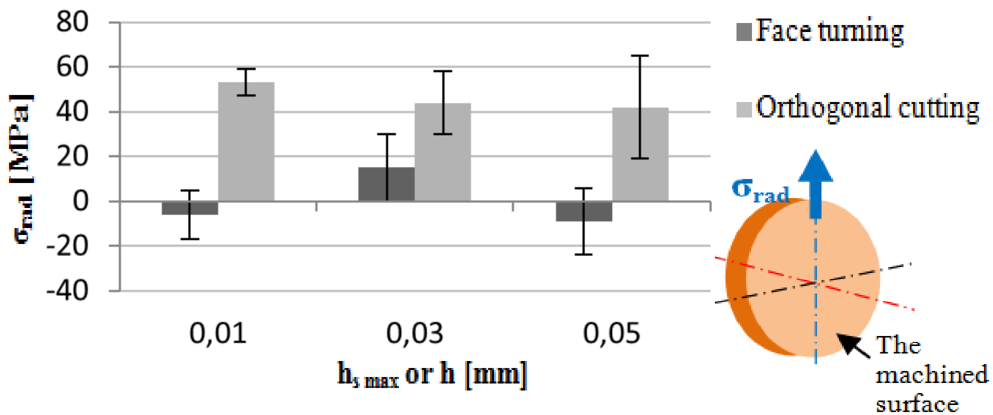
➡ Cutting instability for very low h/r_β ratios and very large b.

- *h* > 0.05 mm : R_a tends to a steady state and depends only of the tool wear.

Results and discussion: Surface integrity



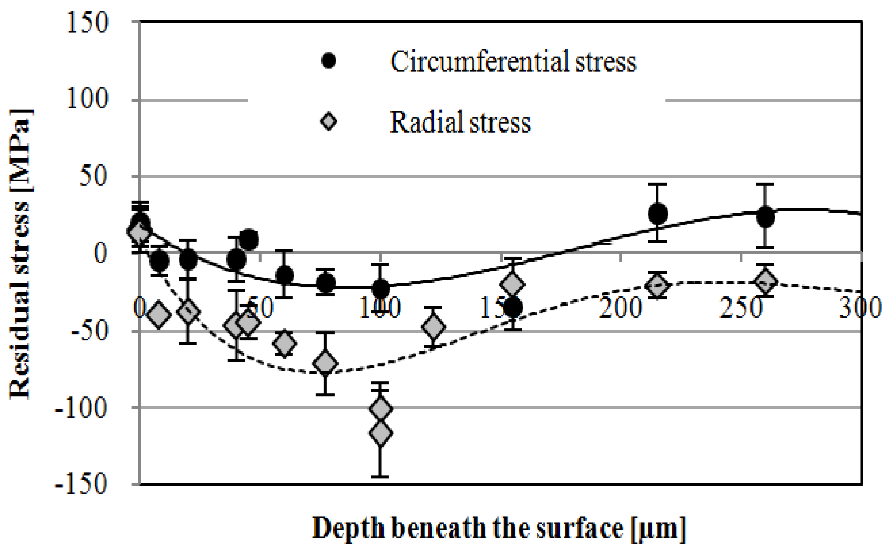
σ_{cir} at samples' surfaces



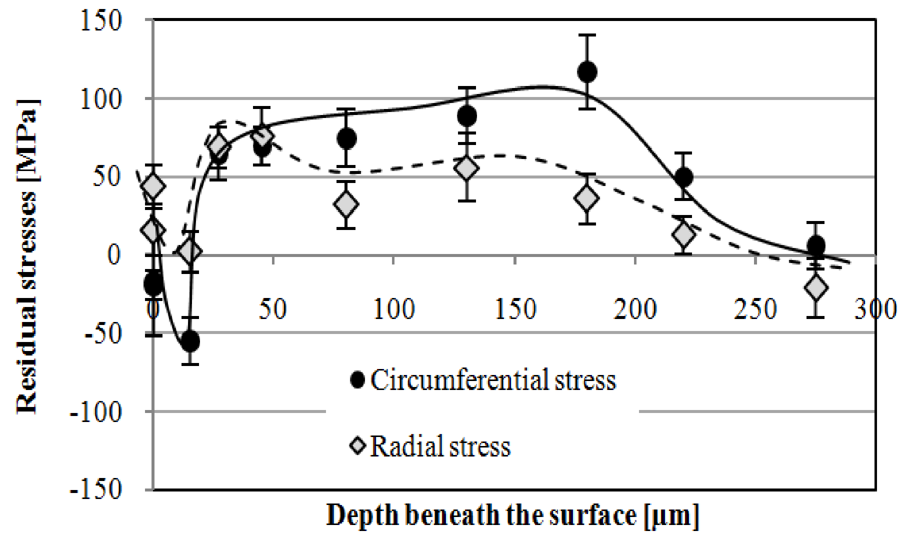
σ_{rad} at samples' surfaces

- No significant influence of $h_{s\ max}$ or h on RS
- Surface RS are **tensile** for face turning and orthogonal cutting.
- Surface σ_{rad} in orthogonal cutting is higher than that in face turning (~ 0)
- Local forces are inversely correlated with surface σ_{cir} [face turning : **>99%**], as well as with the surface σ_{rad} in orthogonal cutting (**>74%**).

Results and discussion: Surface integrity



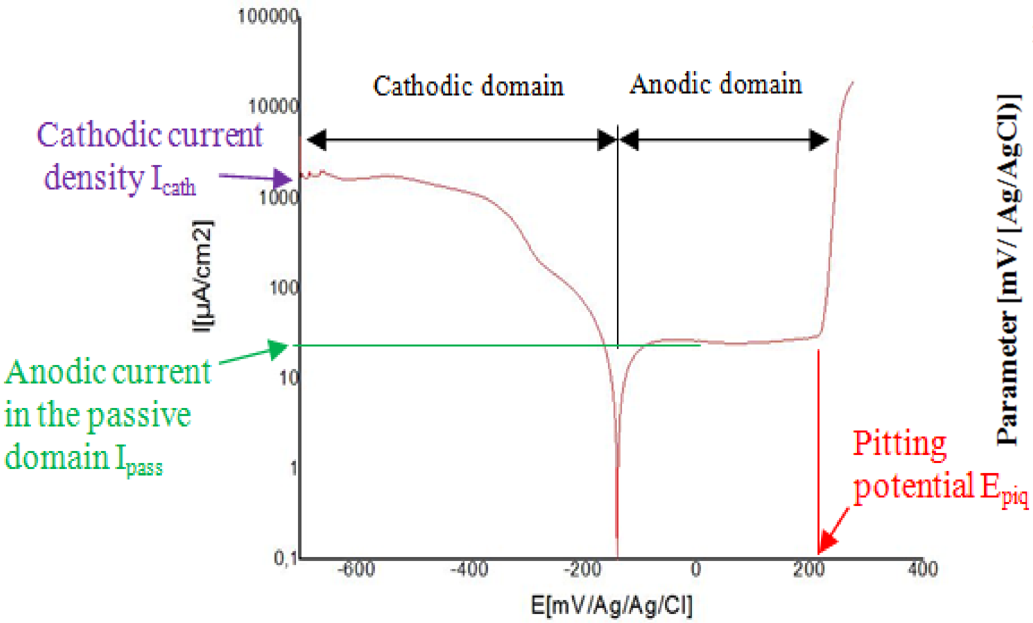
In depth RS profiles
[face turning; $h_{s\ max}$ = 0.03 mm]



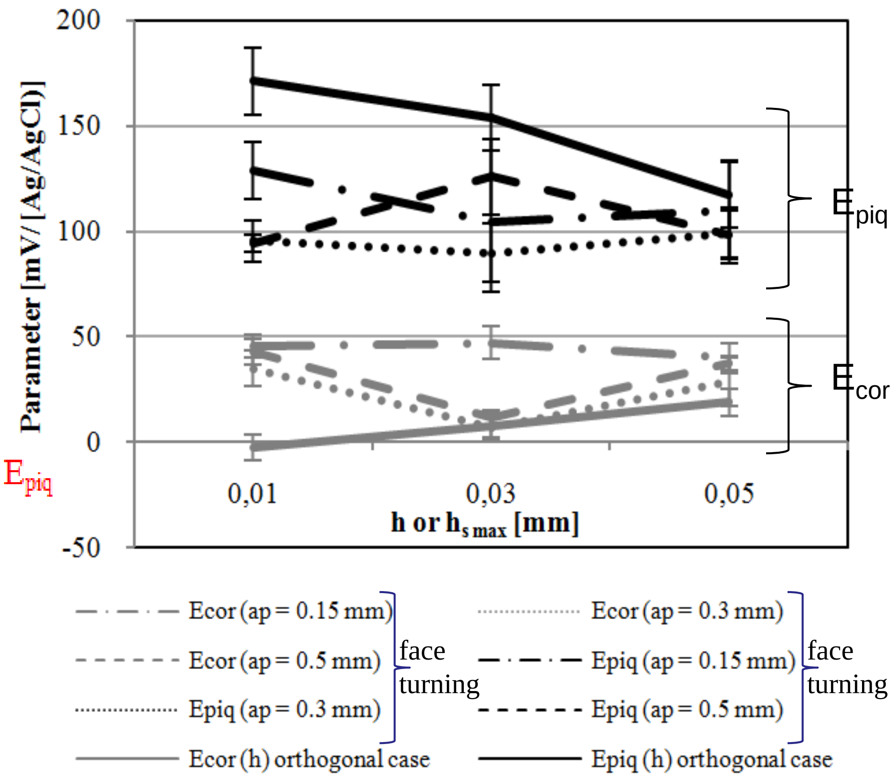
In depth RS profiles
[orthogonal cutting; h = 0.03 mm]

- Below the surface, compressive stresses are generated by face turning, while orthogonal cutting generates tensile stresses for depth greater than 20 µm.

Results and discussion: Local electrochemical behavior

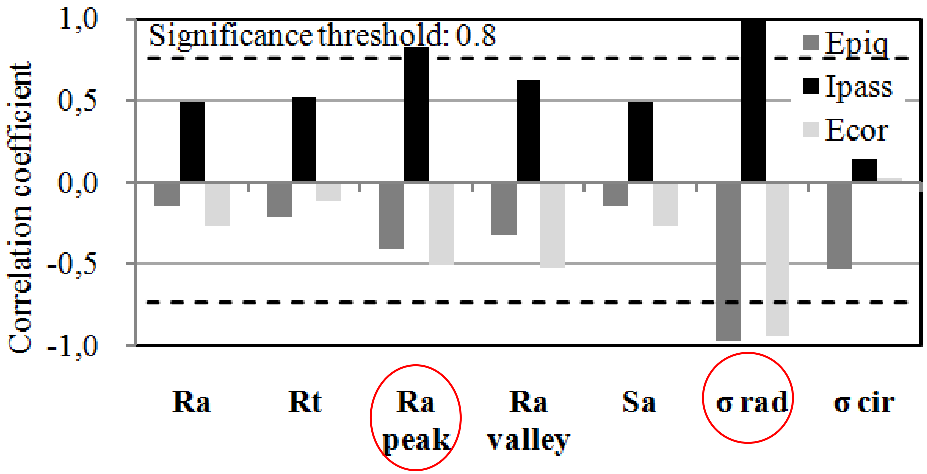


Polarization curve composition

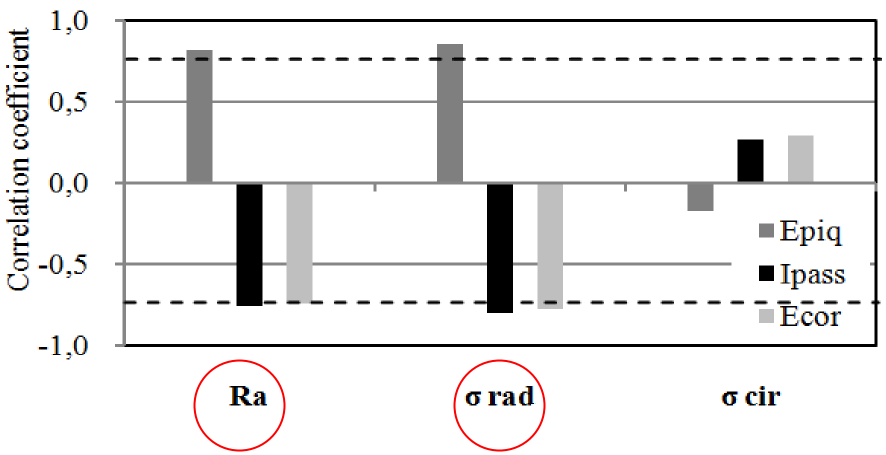


E_{cor} and E_{piq} evolution [f(h or $h_{s\,max}$)]

Results and discussion: Correlations between SI parameters and electrochemical reactivity parameters



In face turning



In orthogonal cutting

- σ_{rad}, R_{a_peak} (face turning) and R_a (orthogonal cutting) are the parameters influencing significantly the local electrochemical reactivity.

Conclusion and Outlook

- $h_{s\ max}$ (face turning) and h (orthogonal cutting) are strongly correlated to the local forces and surface roughness, but not to the surface residual stresses.

- Concerning to the in-depth residual stress profiles, face turning generates a thicker layer having compressive residual stresses, while orthogonal cutting generates a thicker layer having tensile residual stresses.

- Correlation analysis has proven that R_{a_peak} (face turning) and R_a (orthogonal cutting) are the most influencing parameters on the local electrochemical reactivity.

Conclusion and Outlook

The present results are not enough to confirm the hypothesis that identical deformation process is applied to generate the machined surface in both superfinishing turning and orthogonal cutting.

➡ Further experiments are required with closer analysis to the thermal and mechanical phenomena developed at the tool flank contact.

Thanks for listening