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2<sup>nd</sup> CIRP CSI - 29/05/2014

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

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Supervised by:






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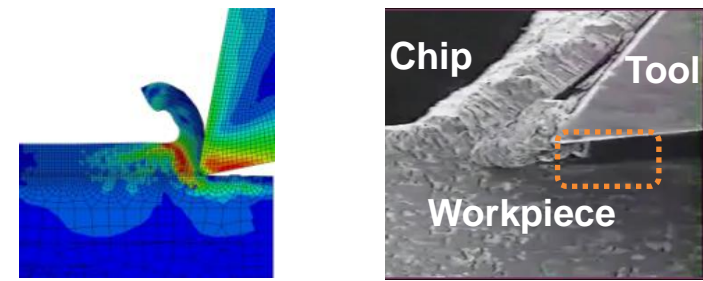
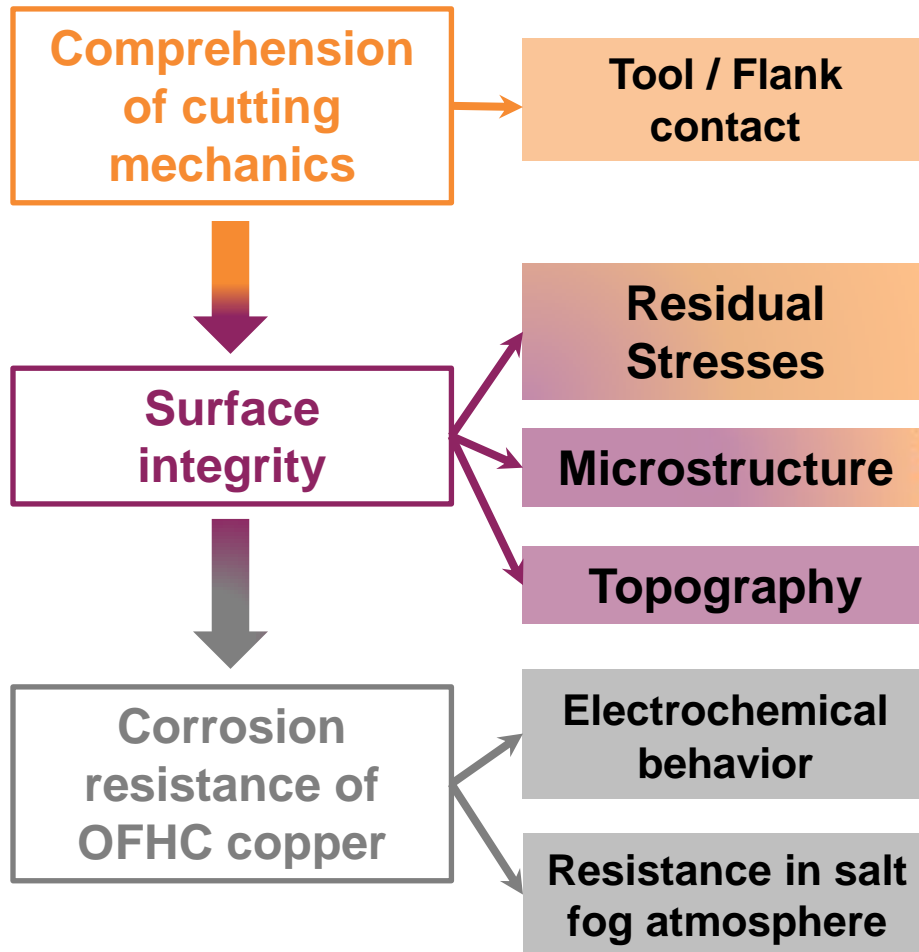
**Prof. Vincent VIGNAL (ICB – UB)**

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# Outline

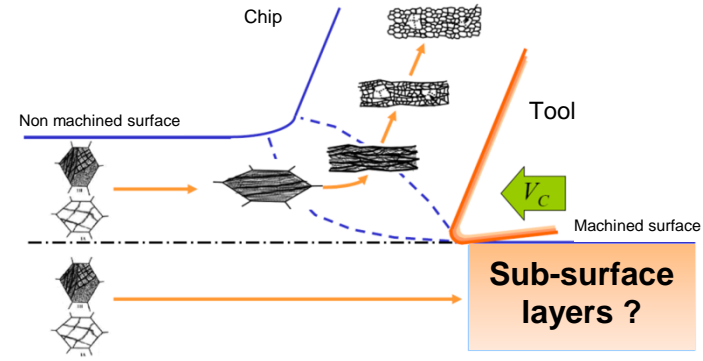
-  **Introduction**
-  **Objectives**
-  **Experimental procedure and parameters**
-  **Results and discussion**
-  **Conclusion and outlook**

# Introduction

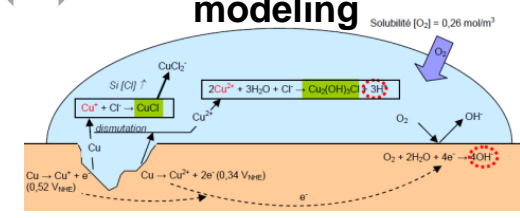
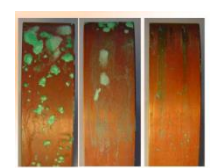


Numerical modeling ↔ Experimental study

F, T°, RS, DRX



Experimental study ↔ Phenomenological modeling

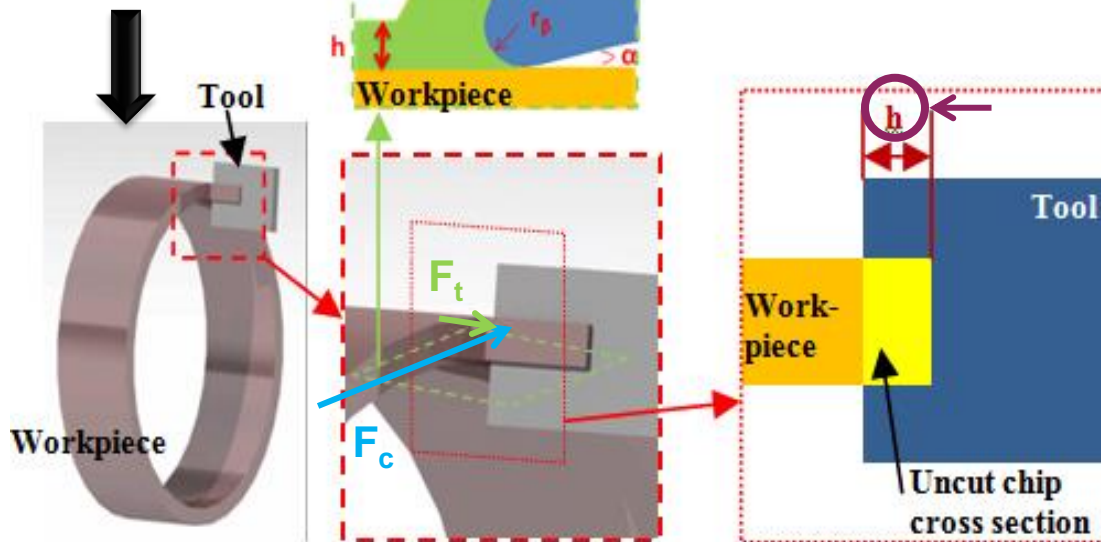


# Objectives

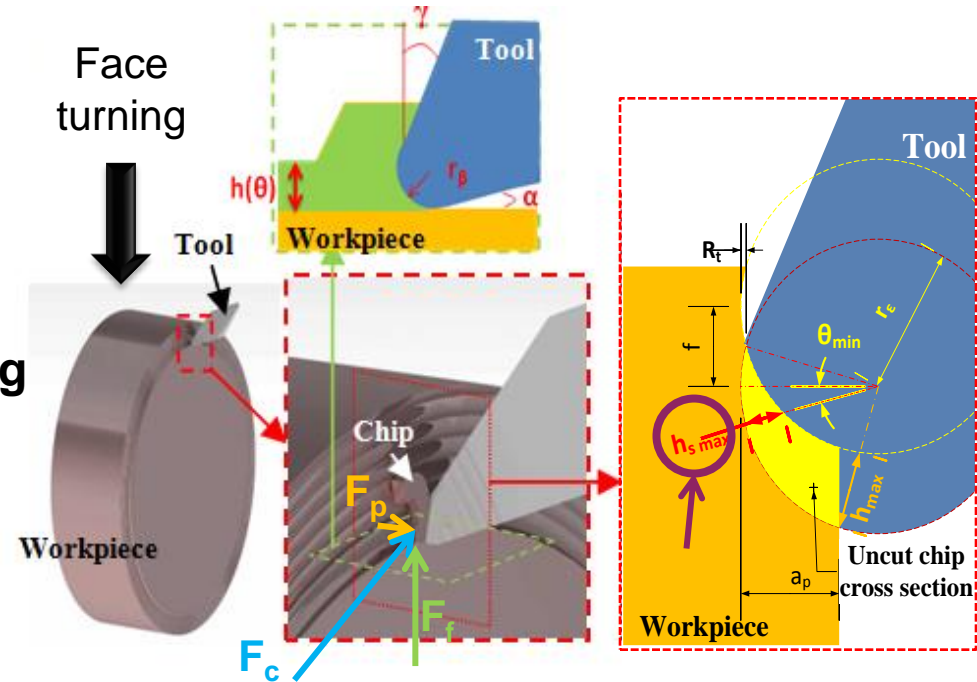
Compare a typical 3D turning with orthogonal cutting

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

Orthogonal cutting



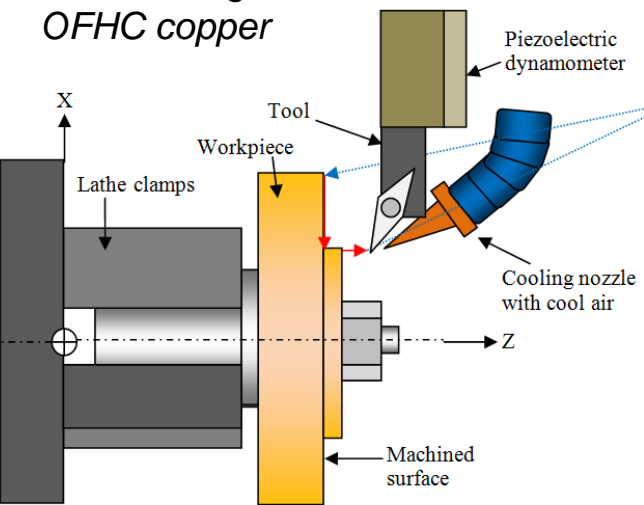
Face turning



*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



$f = 0.1 ; 0.15 ; 0.2 \text{ mm/rev}$   
 $a_p = 0.15 ; 0.30 ; 0.50 \text{ mm}$   
 $V_c = 120 \text{ m/min}$  Air cooling  $-5 \pm 1^\circ\text{C}$   
 $\alpha = 7^\circ$   
 $\gamma = 20^\circ$   
 $r_\beta = 9 \mu\text{m}$

1M NaClO<sub>4</sub> 1 micro-capillary

**3D Face turning**

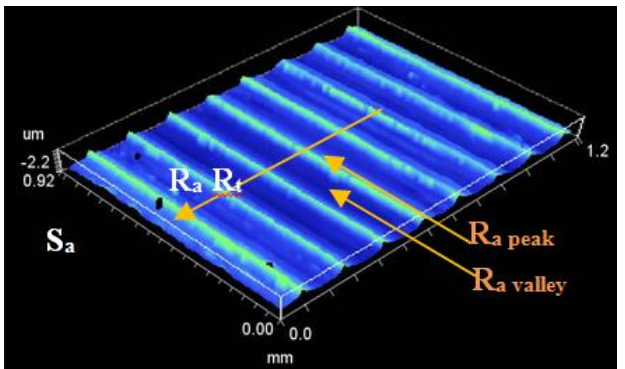
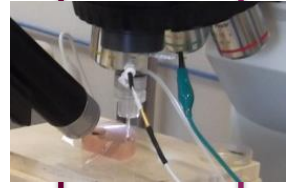
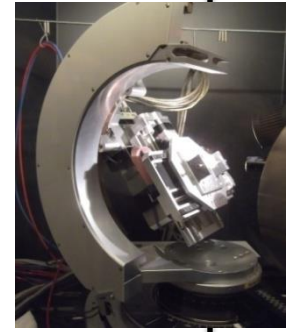
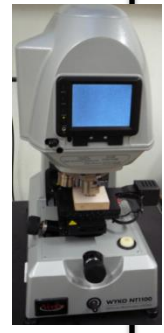


**Local electro-chemical tests**

**Forces**

**Topography**

**RS**



Roughness measurement directions

$F_c, F_p, F_f, K_c$

$R_t, R_a$

$\sigma_{rad}, \sigma_{cir}$

$E_{piq}, I_{pass}, E_{cor}$

**Cutting mechanics**

**Surface integrity**

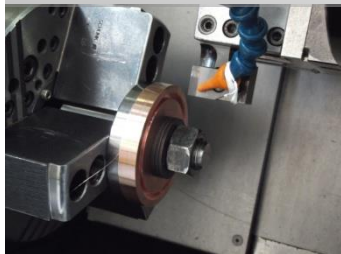
**Electrochemical behavior**



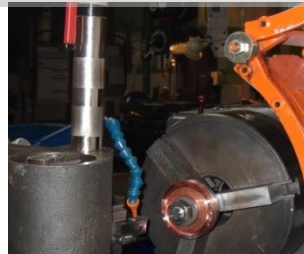
# Experimental procedure and parameters

$V_c = 120 \text{ m/min}$   
 $h = 0,01; 0,03; 0,05; 0,07; 0,10 \text{ mm}$   
 $b = 4 \text{ mm}$   
 Air cooling  $-5 \pm 1^\circ\text{C}$   
 $\alpha = 5^\circ$   
 $\gamma = 20^\circ$   
 $r_\beta = 12 \mu\text{m}$

## Orthogonal cutting tests



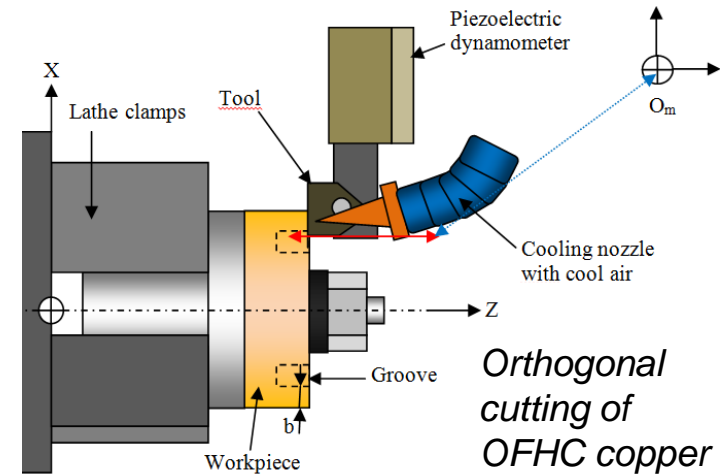
NC machining



QST



$1\text{M NaClO}_4$   
 $1 \text{ micro-capillary}$   
**Local electro-chemical tests**



## Polarization

$E_{piq}$   $I_{pass}$   $E_{cor}$

**Statistical Analysis basing on Pearson's correlation coefficient:**

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

**Forces**  
 $F_c, F_t, K_c$

Cutting mechanics

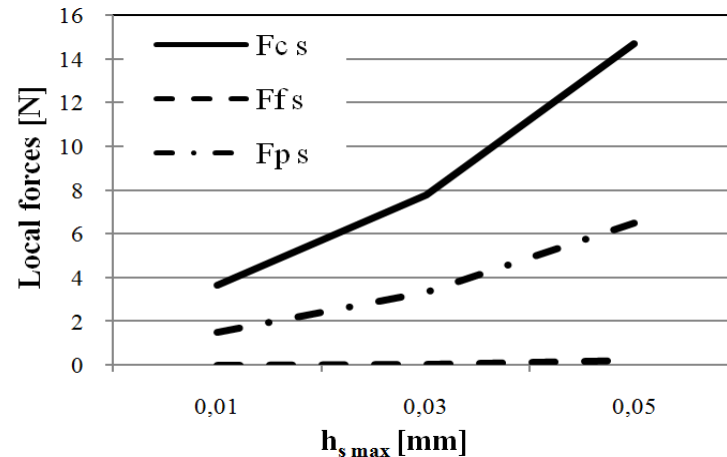
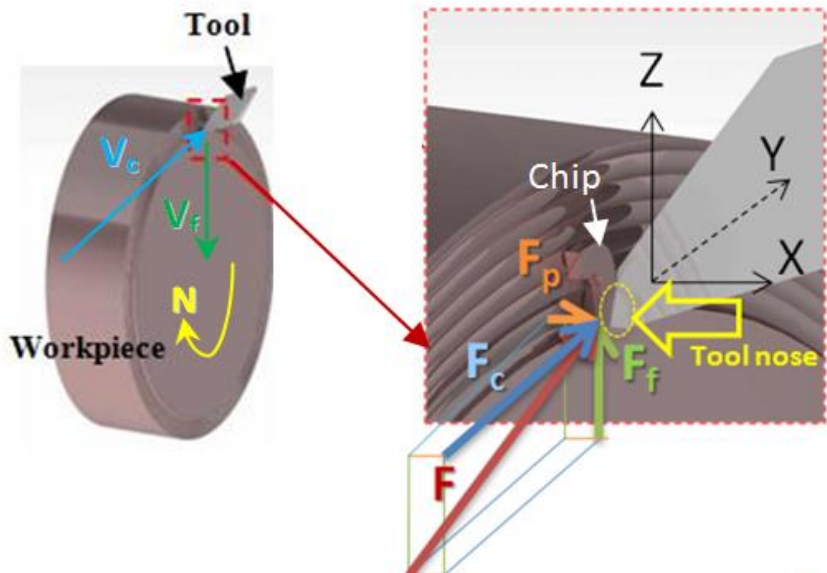
**Topography**  
 $R_t, R_a$

Surface integrity

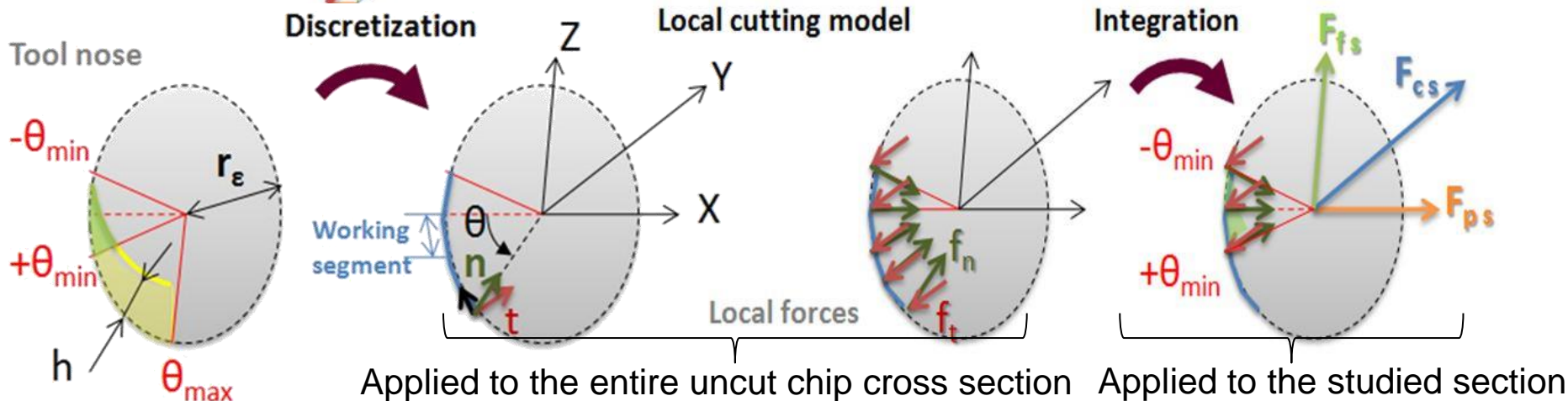
**RS**  
 $\sigma_{rad}, \sigma_{cir}$

Electrochemical behavior

# Results and discussion: Cutting mechanics

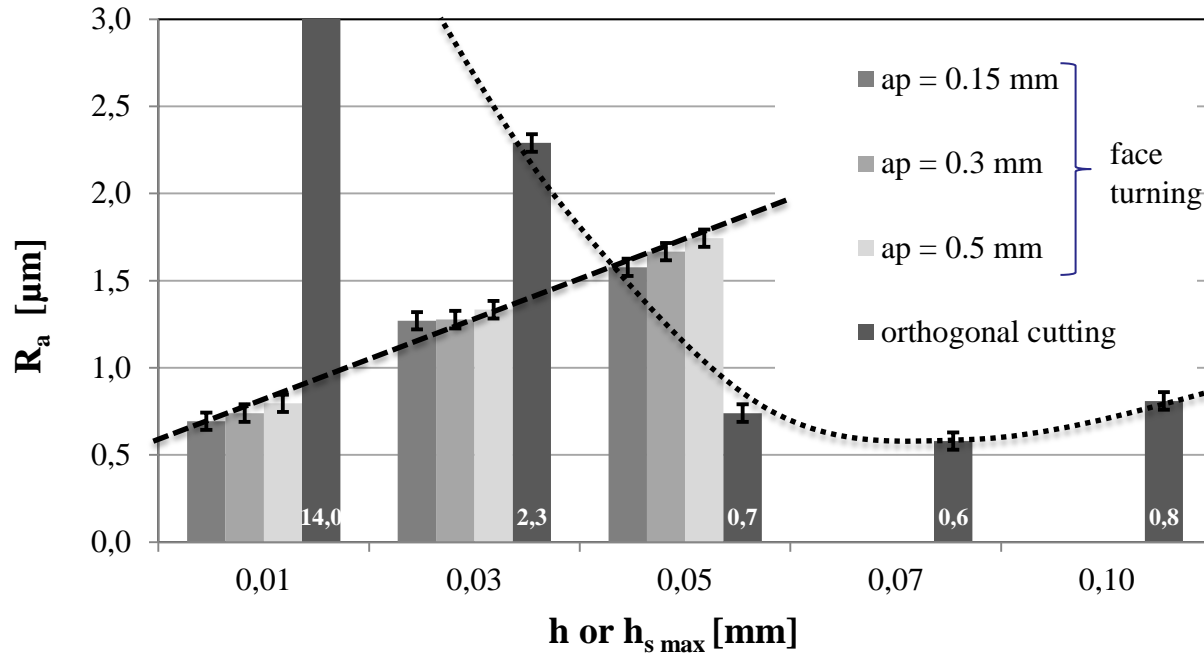


Local forces in face turning  $[f(h_{s \max})]$





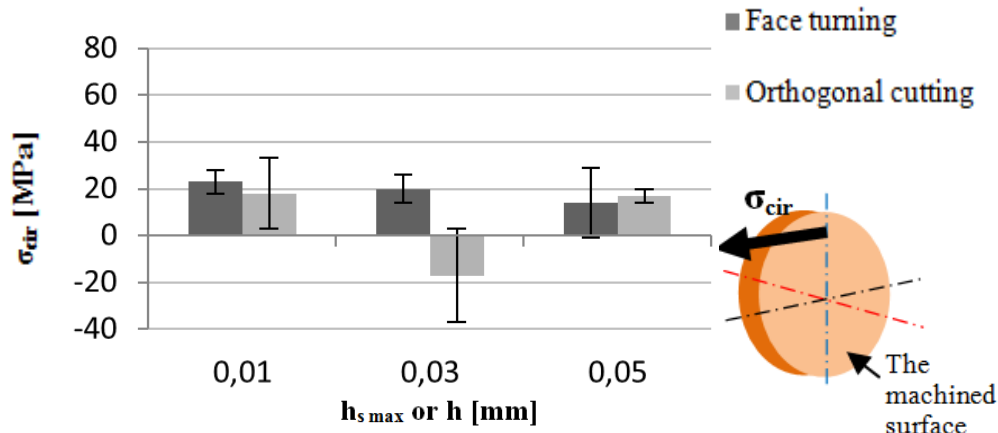
## Results and discussion: Surface integrity



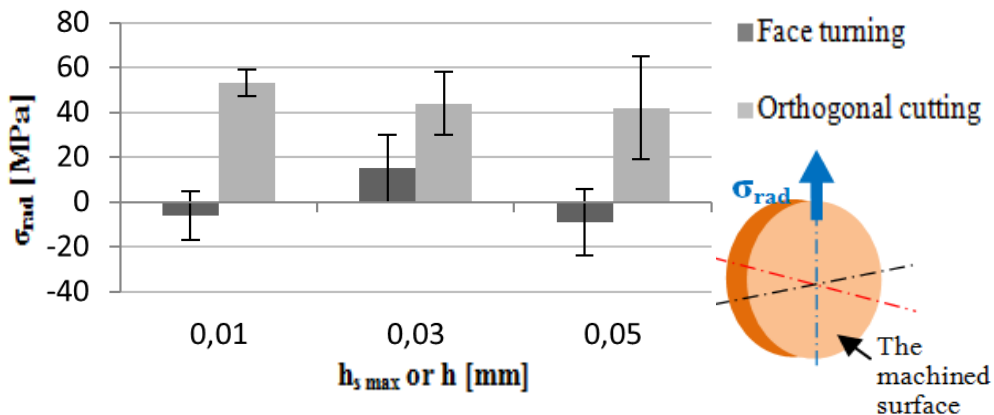
$R_a$  in face turning [ $f(h_{s \max}, a_p)$ ] and in orthogonal cutting [ $f(h)$ ]

- $h_{s \max}$  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  $h/r_\beta$  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



$\sigma_{cir}$  at samples' surfaces



$\sigma_{rad}$  at samples' surfaces

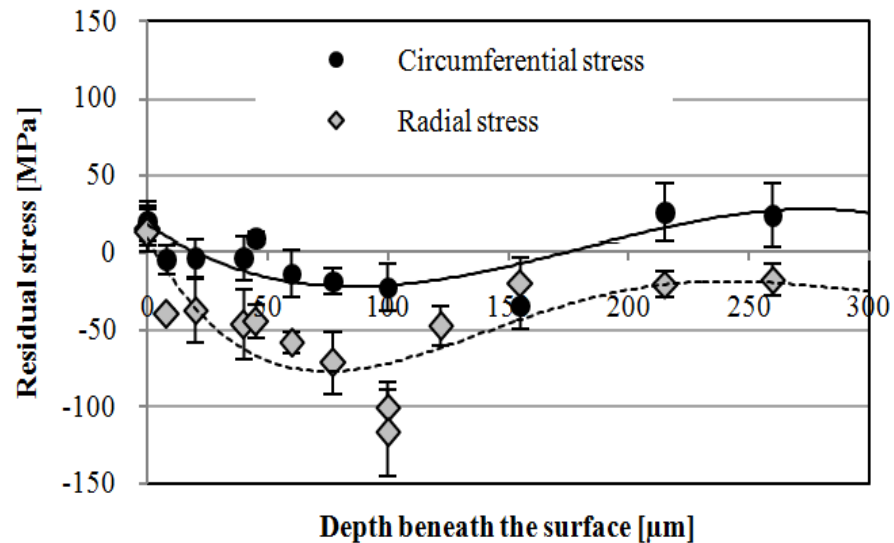
- No significant influence of  $h_{s,max}$  or  $h$  on RS

- Surface RS are **tensile** for face turning and **orthogonal cutting**.

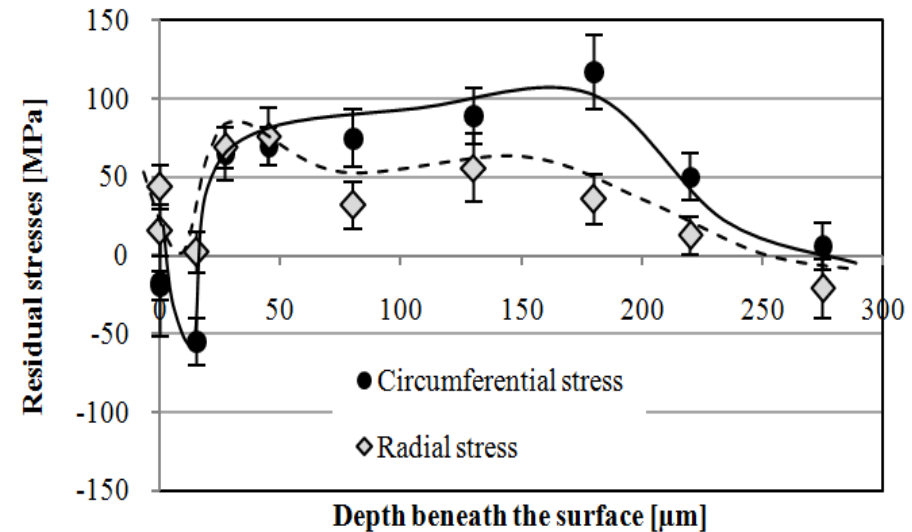
- Surface  $\sigma_{rad}$  in **orthogonal cutting** is **higher** than that in **face turning** ( $\sim 0$ )

- Local forces are **inversely correlated** with surface  $\sigma_{cir}$  [face turning : **>99%**], as well as with the surface  $\sigma_{rad}$  in **orthogonal cutting** (**>74%**).

## Results and discussion: Surface integrity



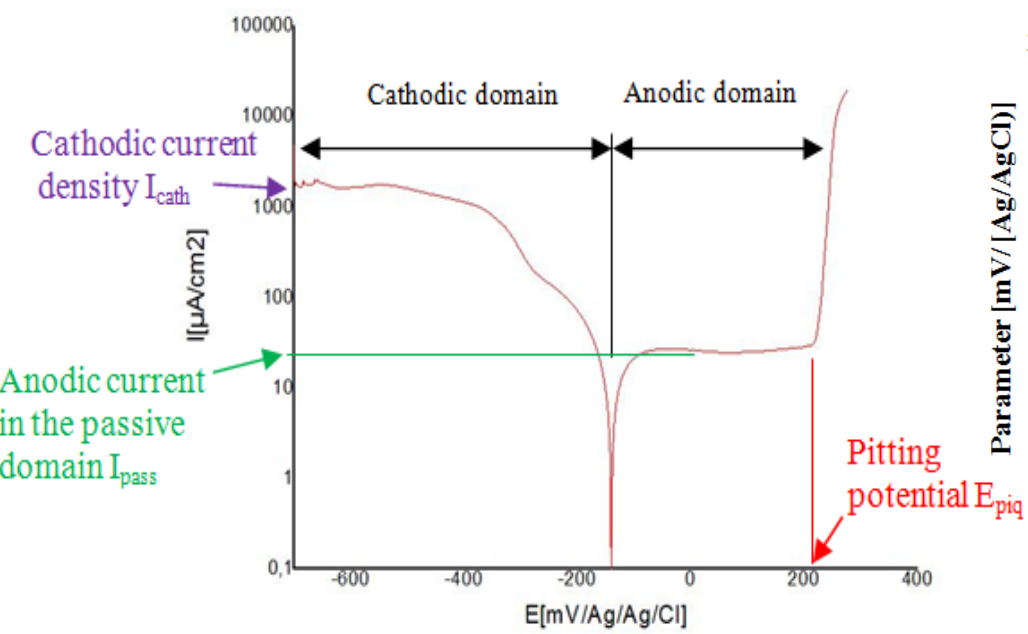
In depth RS profiles  
[face turning;  $h_{s \max} = 0.03$  mm]



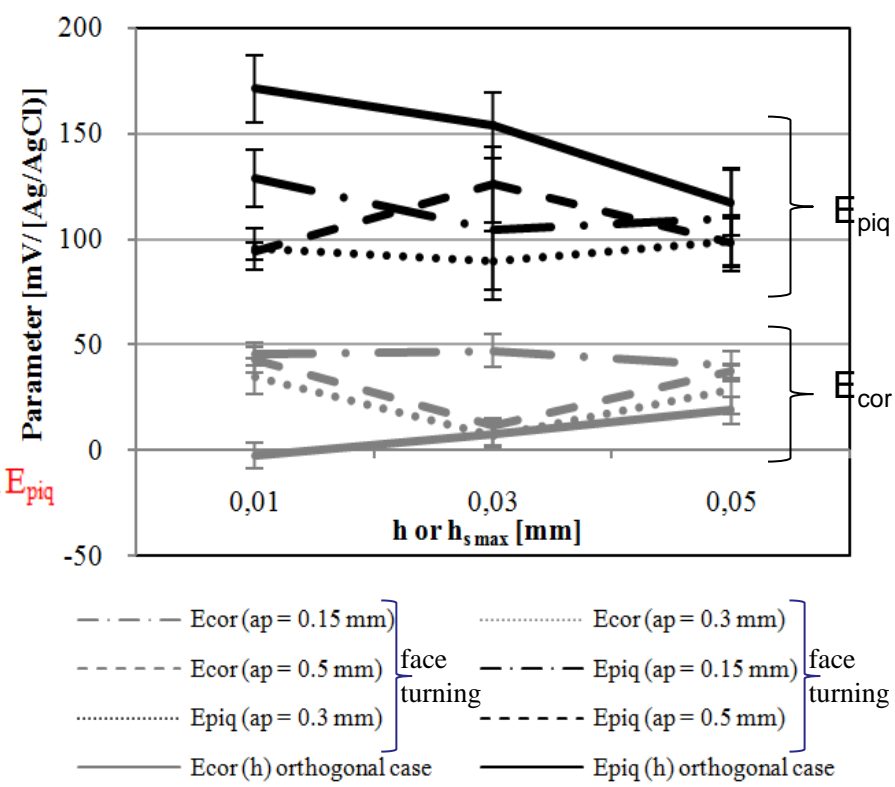
In depth RS profiles  
[orthogonal cutting;  $h = 0.03$  mm]

- 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

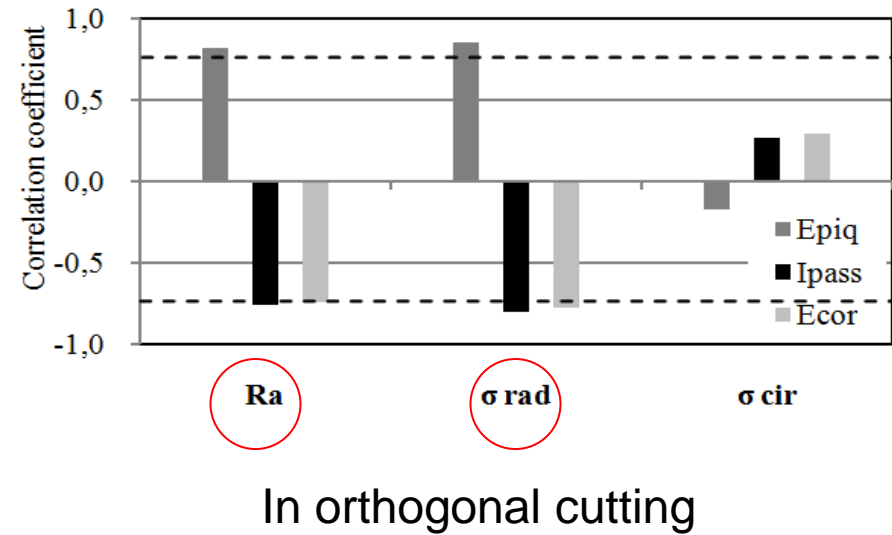
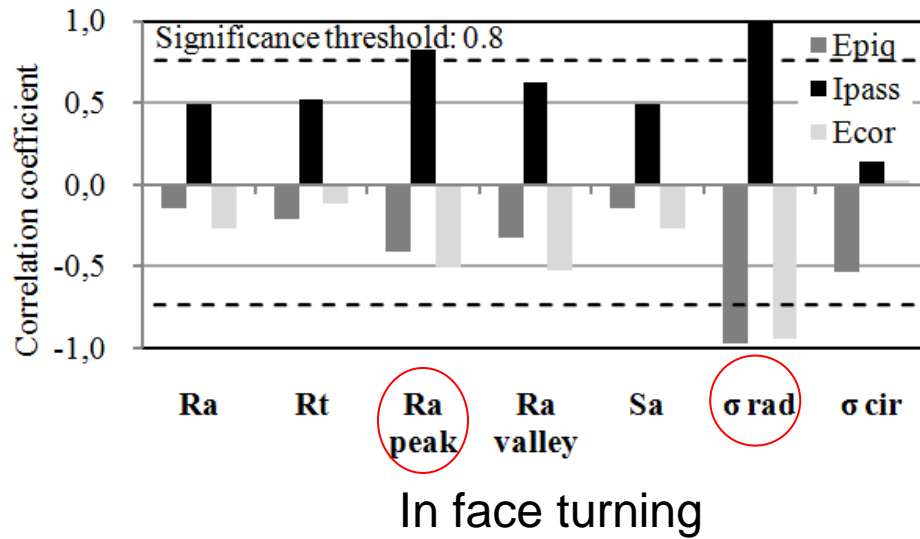


**Polarization curve composition**



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

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



•  $\sigma_{rad}$ ,  $R_{a\_peak}$  (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***

