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

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Outline

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

Comprehension of cutting mechanics

Surface integrity

- Residual Stresses
- Microstructure
- Topography

Corrosion resistance of OFHC copper

- Electrochemical behavior
- Resistance in salt fog atmosphere

Tool / Flank contact

Numerical modeling

Experimental study

F, T°, RS, DRX

Tool

Workpiece

Chip

Experimental study

Sub-surface layers?

Phenomenological modeling

Tool

Machined surface

Non machined surface

Chip

Resistance in salt fog atmosphere

Electrochemical behavior

Experimental study

Sub-surface layers?
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

**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

\[
\begin{align*}
    f &= 0.1 ; 0.15 ; 0.2 \text{ mm/rev} \\
    a_p &= 0.15 ; 0.30 ; 0.50 \text{ mm} \\
    V_c &= 120 \text{ m/min} \\
    \alpha &= 7^\circ \\
    \gamma &= 20^\circ \\
    r_\beta &= 9 \mu\text{m} \\
    1 \text{M NaClO}_4 &\text{ 1 micro-capillary} \\
\end{align*}
\]

Air cooling

\(-5 \pm 1^\circ C\)

3D Face turning

- Forces
- Topography
- RS

Local electro-chemical tests

Polarization

\[E_{\text{piq}}, I_{\text{pass}}, E_{\text{cor}}\]

Cutting mechanics

Surface integrity

Electrochemical behavior

Roughness measurement directions

\(R_a, R_t, R_{a\text{ peak}}, R_{a\text{ valley}}\)

\(S_a, R_z, R_{a\text{ peak}}, R_{a\text{ valley}}\)
Experimental procedure and parameters

\[ \begin{align*}
V_c &= 120 \text{ m/min} \\
h &= 0.01; 0.03; 0.05; 0.07; 0.10 \text{ mm} \\
b &= 4 \text{ mm} \\
\alpha &= 5^\circ \\
\gamma &= 20^\circ \\
r_\beta &= 12 \text{ µm} \\
\end{align*} \]

Orthogonal cutting tests

NC machining

QST

Local electro-chemical tests

1M NaClO₄

1 micro-capillary

Cutting mechanics

Surface integrity

Electrochemical behavior

Experimental procedure and parameters

Statistical Analysis basing on

Pearson’s correlation coefficient:

\[ \text{Correl}(X,Y) = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}} \]
Results and discussion: Cutting mechanics

Cutting mechanics: Local forces in face turning $[f(h_{s_{\text{max}}})]$
Results and discussion: **Surface integrity**

- $h_{s_{max}}$ 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 $b$.

• $h > 0.05 \text{ mm}$ : $R_a$ tends to a steady state and depends only of the tool wear.
Results and discussion: Surface integrity

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

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

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

- Local forces are inversely correlated with surface $\sigma_{\text{cir}}$ in face turning ($>99\%$), as well as with the surface $\sigma_{\text{rad}}$ in orthogonal cutting ($>74\%$).
Results and discussion: Surface integrity

- 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 \[ f(h \text{ or } h_{s_{max}}) \]
Results and discussion: Correlations between SI parameters and electrochemical reactivity parameters

- $\sigma_{\text{rad}}$, $R_{a\text{,peak}}$ (face turning) and $R_a$ (orthogonal cutting) are the parameters influencing significantly the local electrochemical reactivity.
Conclusion and Outlook

• $h_{s \text{ max}}$ (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 $R_{a \text{ peak}}$ (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