# Hardened Steel Turned with a Rotary Cutting Tool

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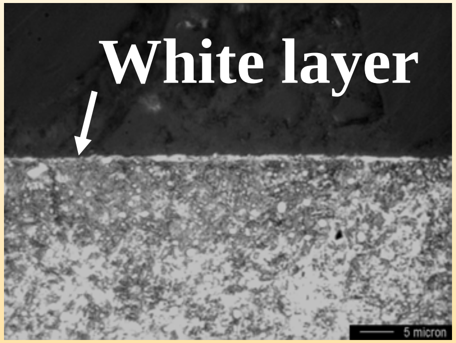
# Hard Turning Challenges

1. Heat Generation
   - Accelerated Tool Wear
   - Thermal Softening




2. White layer formation near surface

# Solution

1. Rotary cutting tools
   - Self-Propelled
   - Driven

# Research Objectives

## Assess Performance of Rotary Tools for Hard Turning

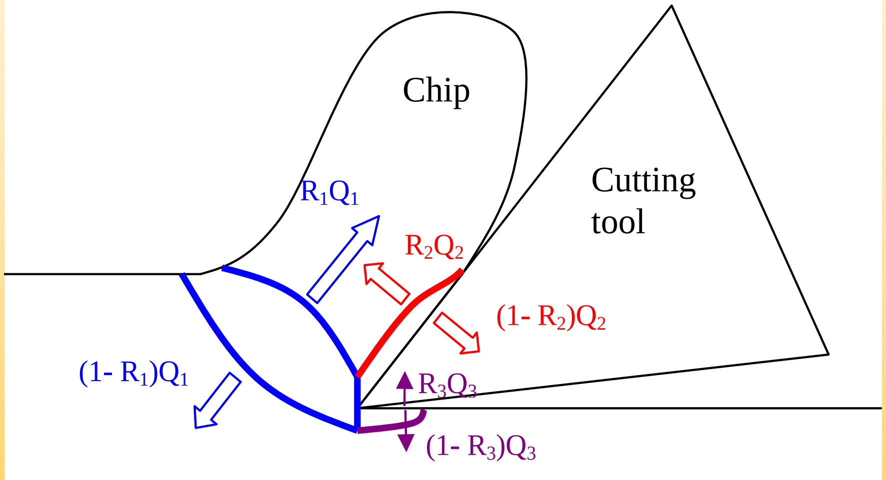
1. Surface Integrity Issues - specifically white layer formation
2. Model Temperature Distribution
   - Develop Finite Element Method (FEM) Model
   - Validate Model
     - Measure Temperature Distribution w/ IR Thermal Camera
     - Compare Rotary & Fixed Cutting Tools
3. Compare Tool Wear for Different Tool Materials

# FEM Model Assumptions

1. Cutting Edge is always SHARP
2. All energy involved in plastic deformation is converted into heat
3. Primary & secondary deformation zones are plane surfaces
4. Heat generated along friction interface is evenly distributed

# Model Basis

## Energy Partitioning Diagram




## Temperature

$$\rho_t c_t \frac{\partial T}{\partial t} - \nabla.\left(k_t \nabla T\right) = \rho_t c_t \omega_r \left(-y\frac{\partial T}{\partial x} + x\frac{\partial T}{\partial y}\right)$$

## Heat Flux

$$q_f = \frac{P_f}{A_{ct}}$$

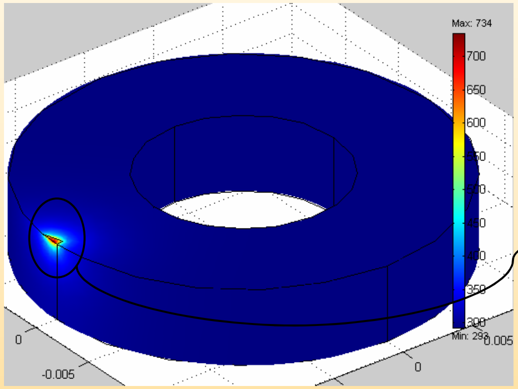
$$q_f = \frac{FV_{cr}}{A_{ct}}$$

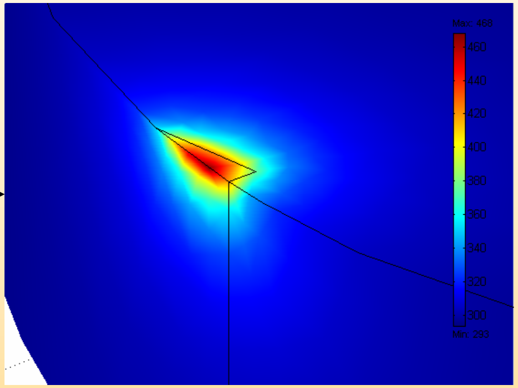
$$q_f = \frac{2\,FV_{cr}}{ml}$$

## $R_2$ = Heat partitioning coefficient

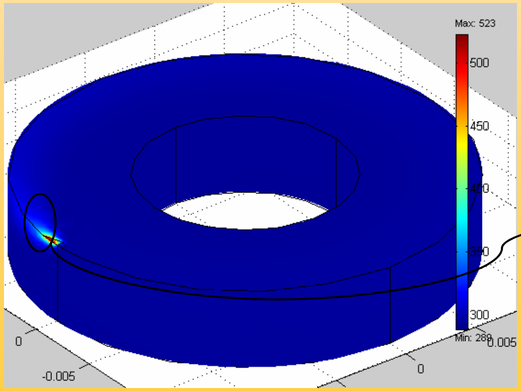
- related to tool & chip conductivity

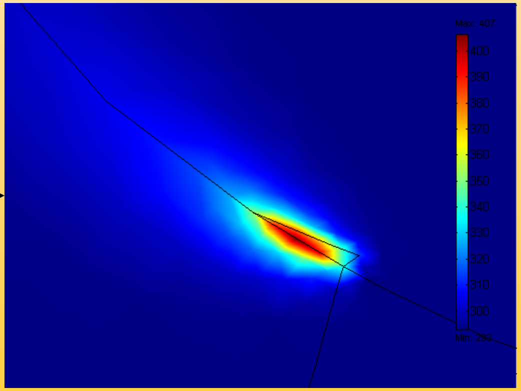
# Model Results






Fixed Tool






Rotary Tool

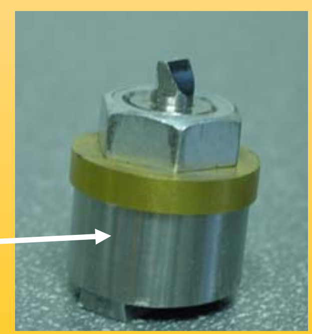
# Experimental Work


Cutting Insert

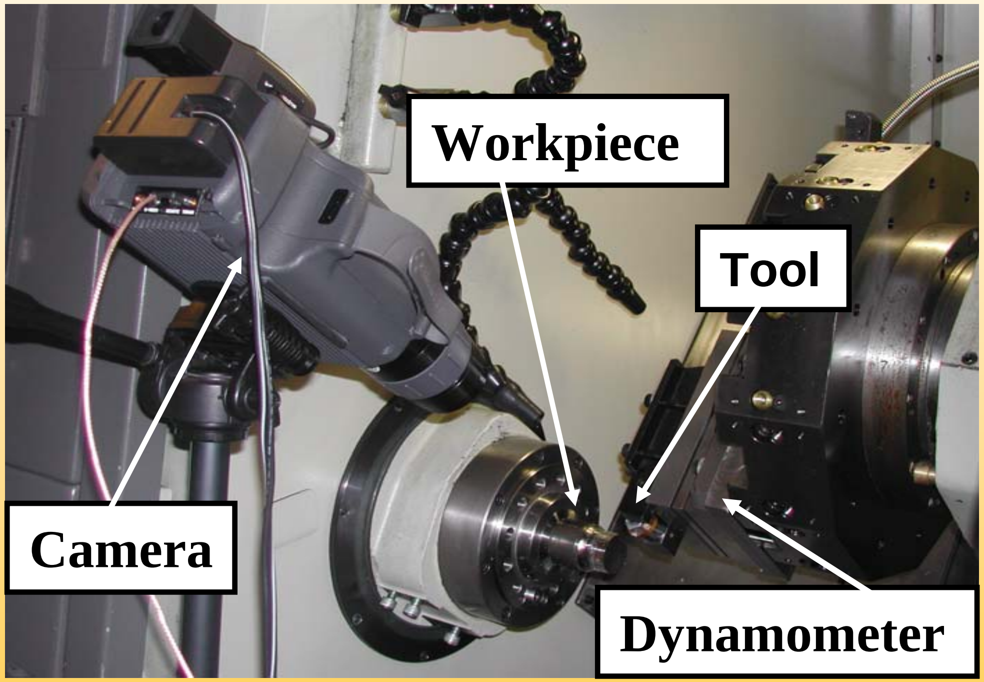
Rotary Cartridge

Rotary Technology Tool Holder

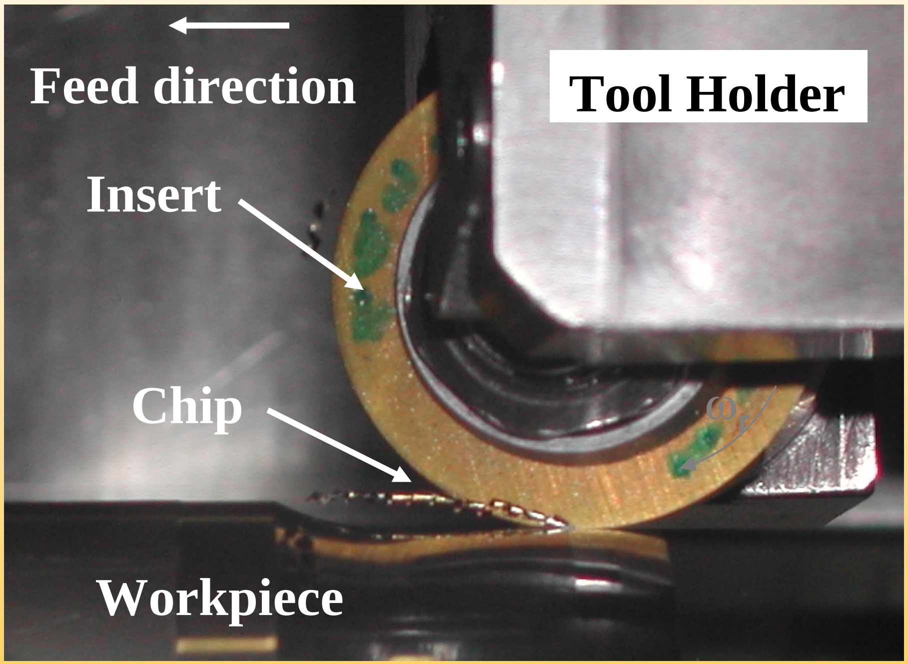
Fixed Cartridge



# Experimental Work

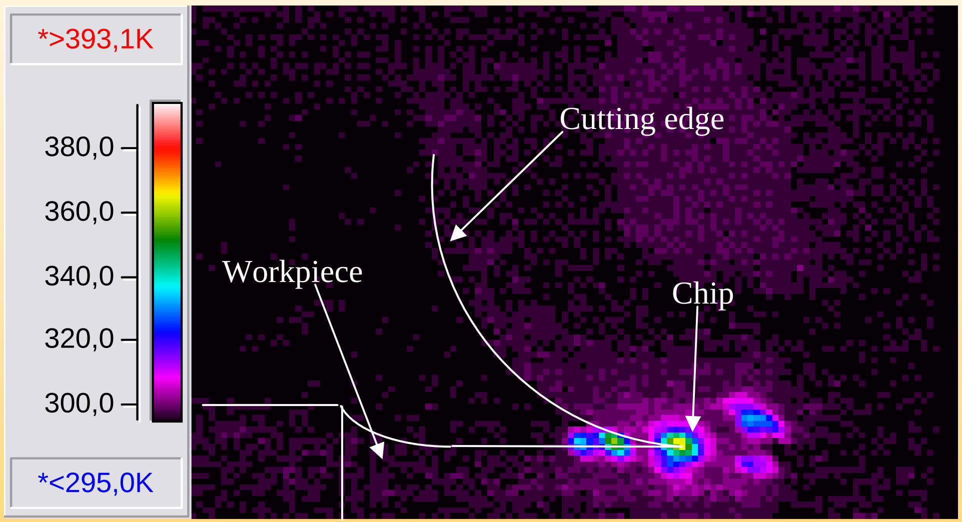


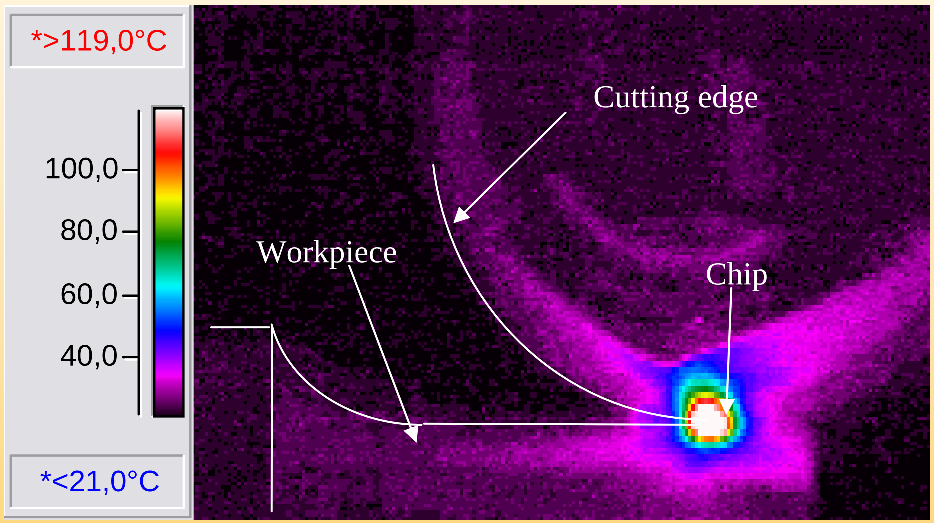

Setup for temperature measurements




Self-Propelled Rotary Tool (SPRT) process

# FT vs. SPRT Temp. Distribution

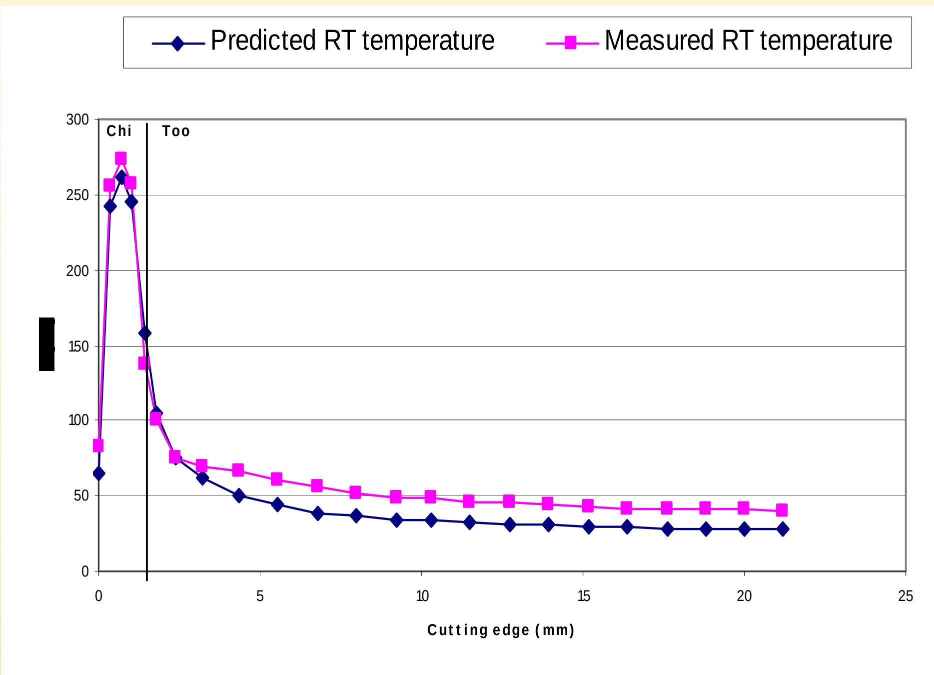


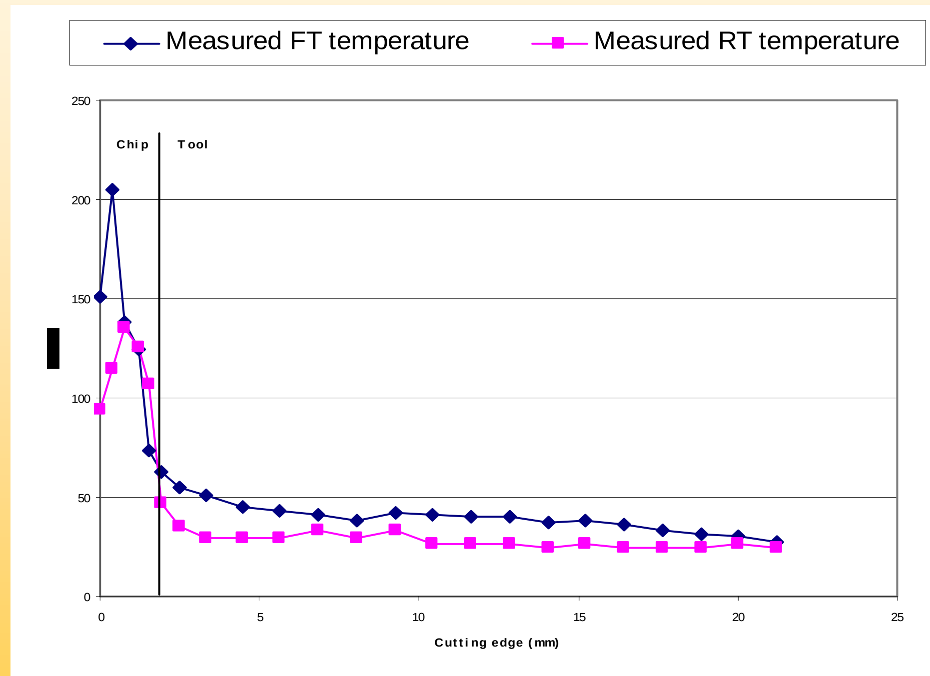

**Measured FT Temperature**
**$V_w$ = 10 m/min**
**f = 0.1 mm/rev**
**DOC = 0.05 mm**

**Measured SPRT Temperature**
**$V_w$ = 10 m/min**
**f = 0.1 mm/rev**
**DOC = 0.05 mm**

# Model vs. Experimental




**SPRT Predicted vs. Measured**



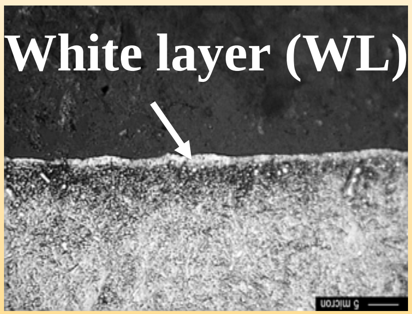

**FT vs. SPRT**

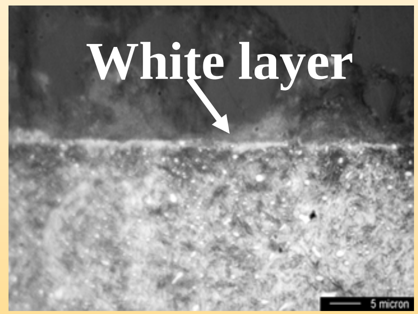
# Microstructure Results

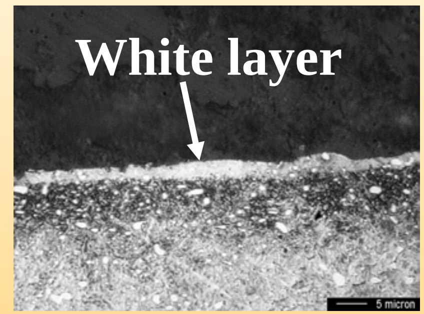
**Cutting Velocity (m/min)**

**60** | **80** | **100**

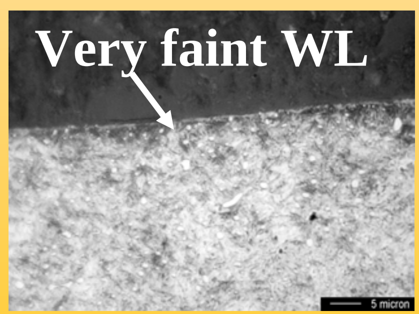
**Fixed**




**Rotary**

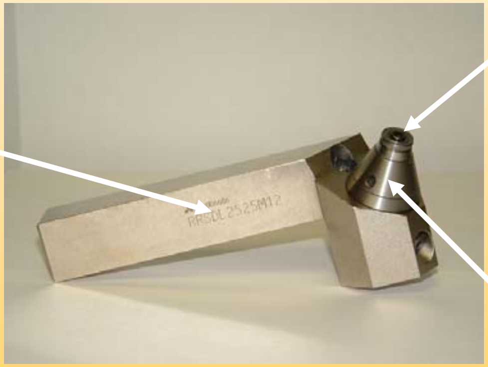




# Current Work

## Compare Tool Wear for Different Tool Materials

1. **Utilizing 2 rotary tool holders**
   - **Rotary Technology Tool Holder**
   - **Mitsubishi Carbide Tool Holder**

2. **Utilizing 4 rotary insert tools**
   - **PCBN**
   - **CBN-TiN coated carbide**
   - **$Si_3N_4$**
   - **TiN coated carbide**



# Summary

1. **Rotary & fixed tools show different surface integrity**
   - **Surfaces turned with rotary tool show lower tendency to form white layer**

2. **Model & experiments result in rotary tools providing lower cutting temperatures (~50°C for these conditions) vs. equivalent circular fixed tool cutting**

3. **Fixed tool observed to wear faster than rotary tool**

# Acknowledgement …

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