

# Increasing Stability of Meso/Micro Milling Cutting by means of Ultrasonic Vibration Assisted Machining

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## Ultrasonic Vibration Assisted Machining

- Chip Removal (cutting kinematics and cutting action)
- Cutting force reduction (friction)
- Machinable Materials (hard/brittle)
- Burr formation
- Tool Wear (including thermal and chemical)

**Process Improvement**

### GOALS:

- To verify experimentally the force reduction by applying UVAM in different directions with very high vibration frequency
- To investigate the increased cutting stability with respect to the regenerative chatter phenomenon

## Experimental Setup

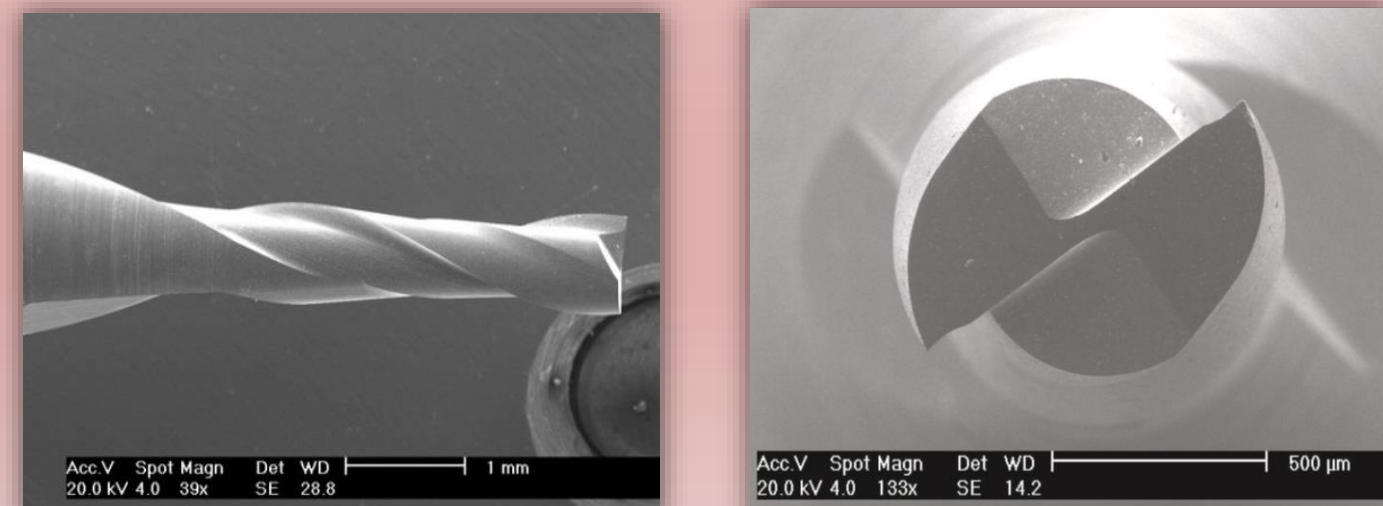
### Kern CNC machining center

Spindle: 60000 / 150,000 rpm  
Resolution 0.1  $\mu\text{m}$   
Positioning tolerance  $\pm 1.0 \mu\text{m}$   
Controller Heidenhain



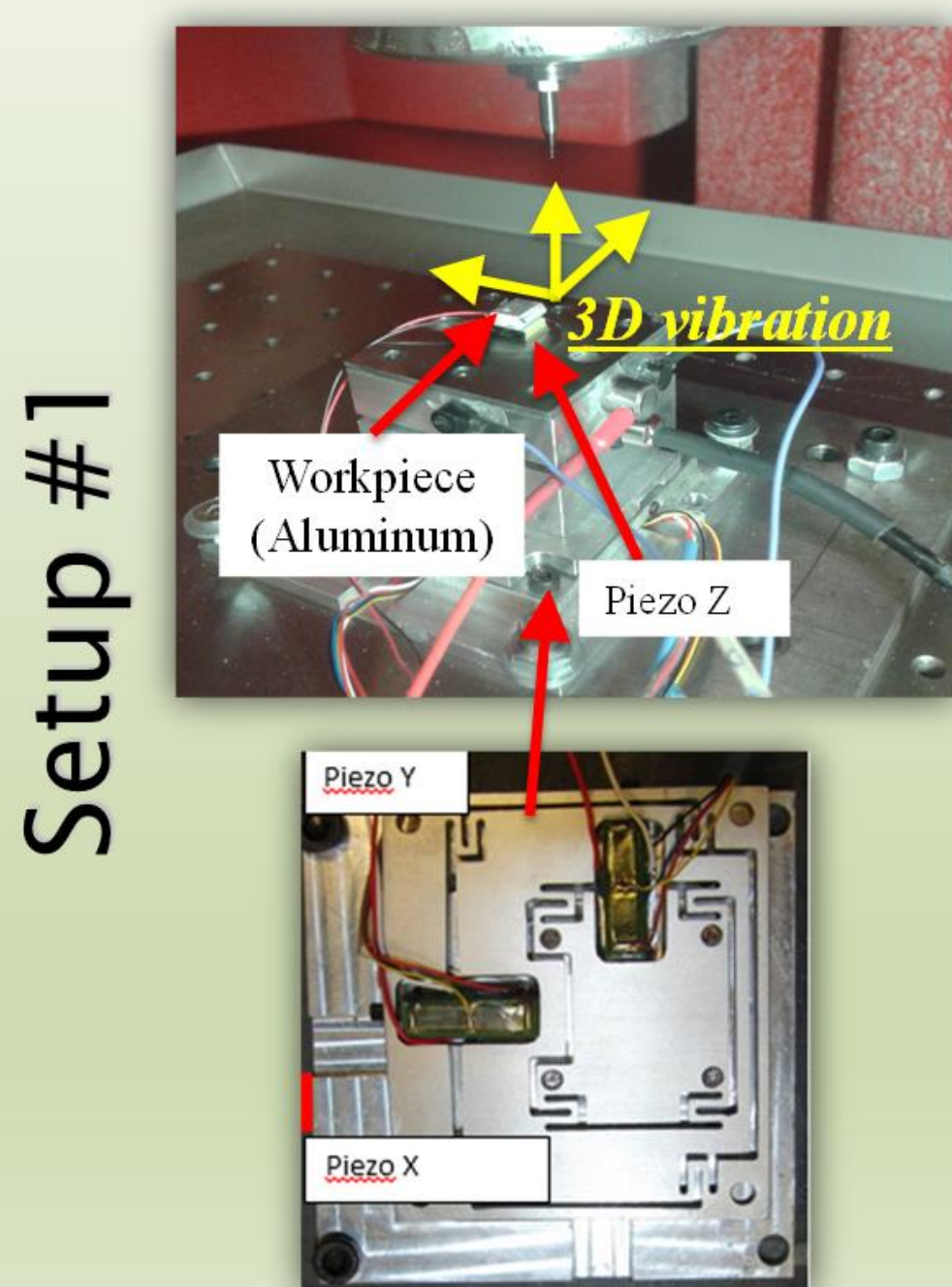
### End mill 2 Flutes

Diameter=500 $\mu\text{m}$   
Edge radius $\approx 2\mu\text{m}$   
Helix=30° / Clearance=10°  
Young's Module $\approx 690\text{Gpa}$



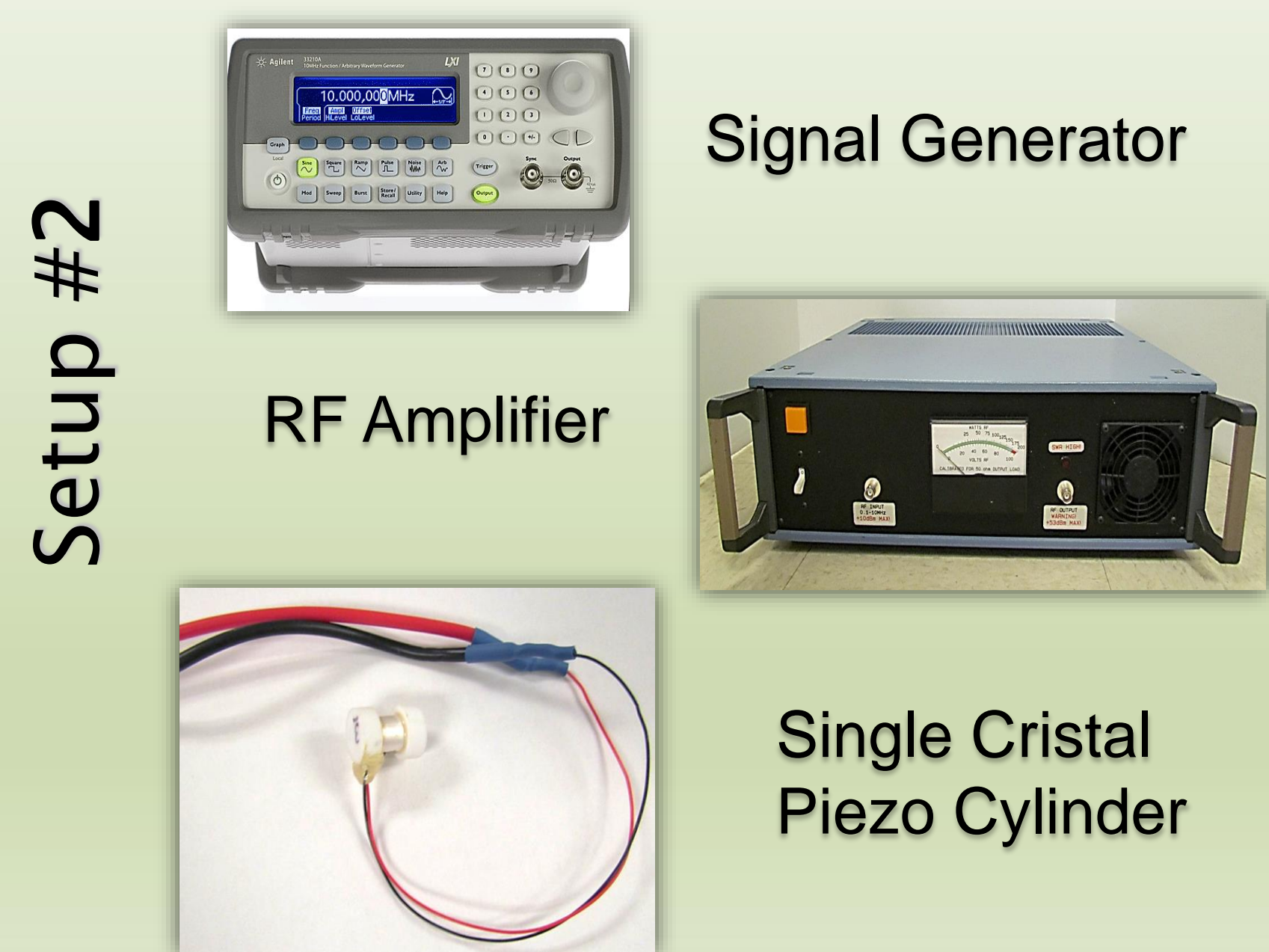
## Piezo-Electric Actuators

### 3-Axial Vibration at 20KHz



Setup #1

### Single-Axis Vibration at Ultra-High Frequency (100KHz-3MHz)



Setup #2

## Milling Process instability (Regenerative Chatter)

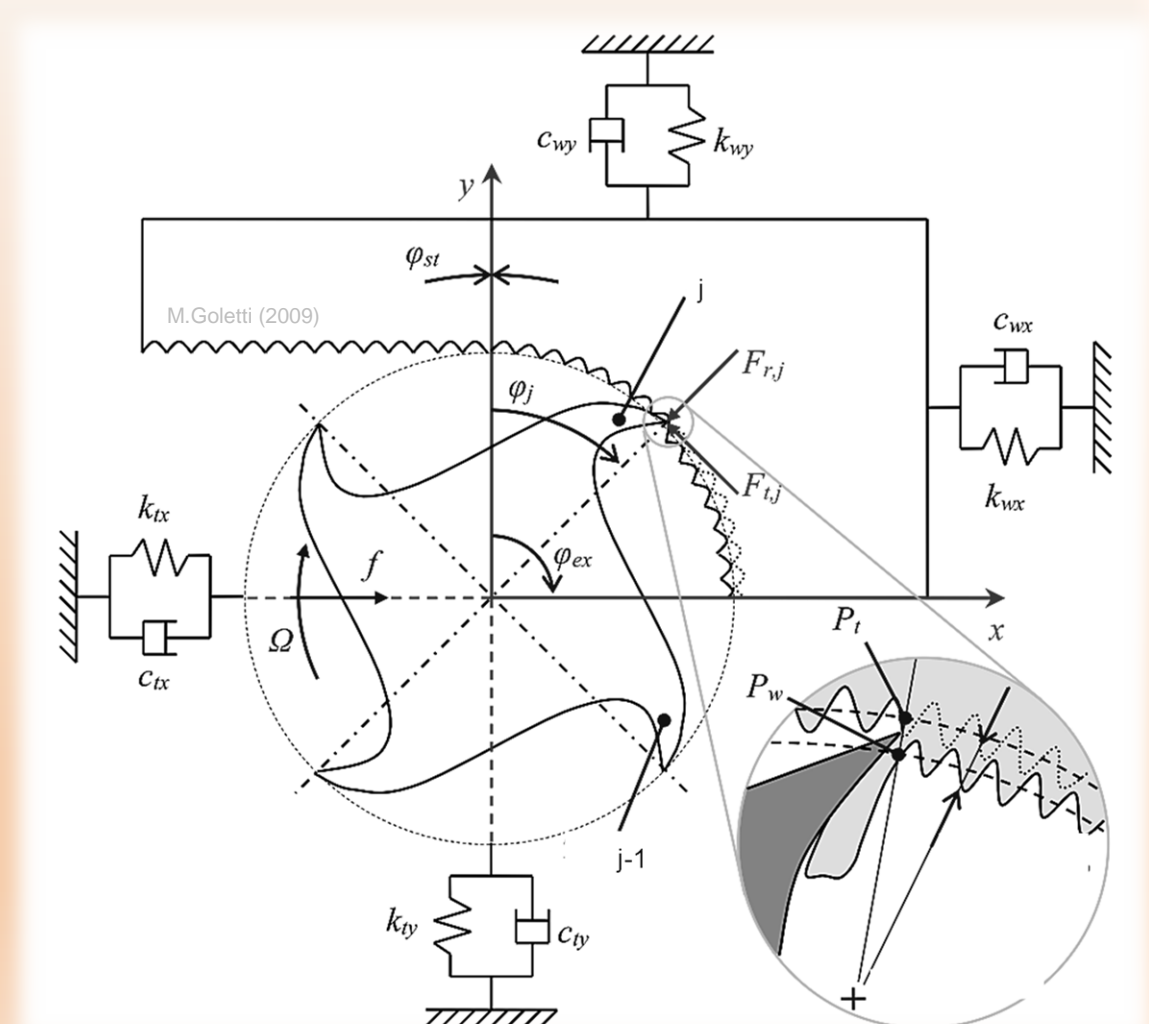
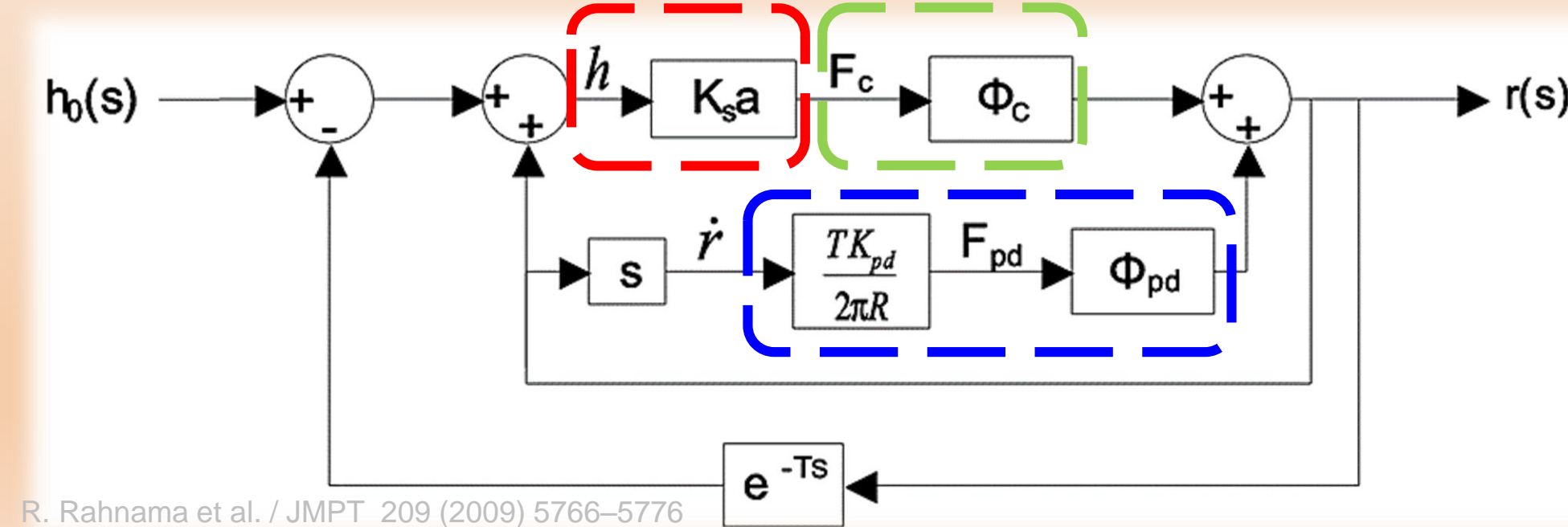
- Poor Surface finish
- Reduced Productivity
- Excessive Tool Wear
- Tool Breakage

to avoid

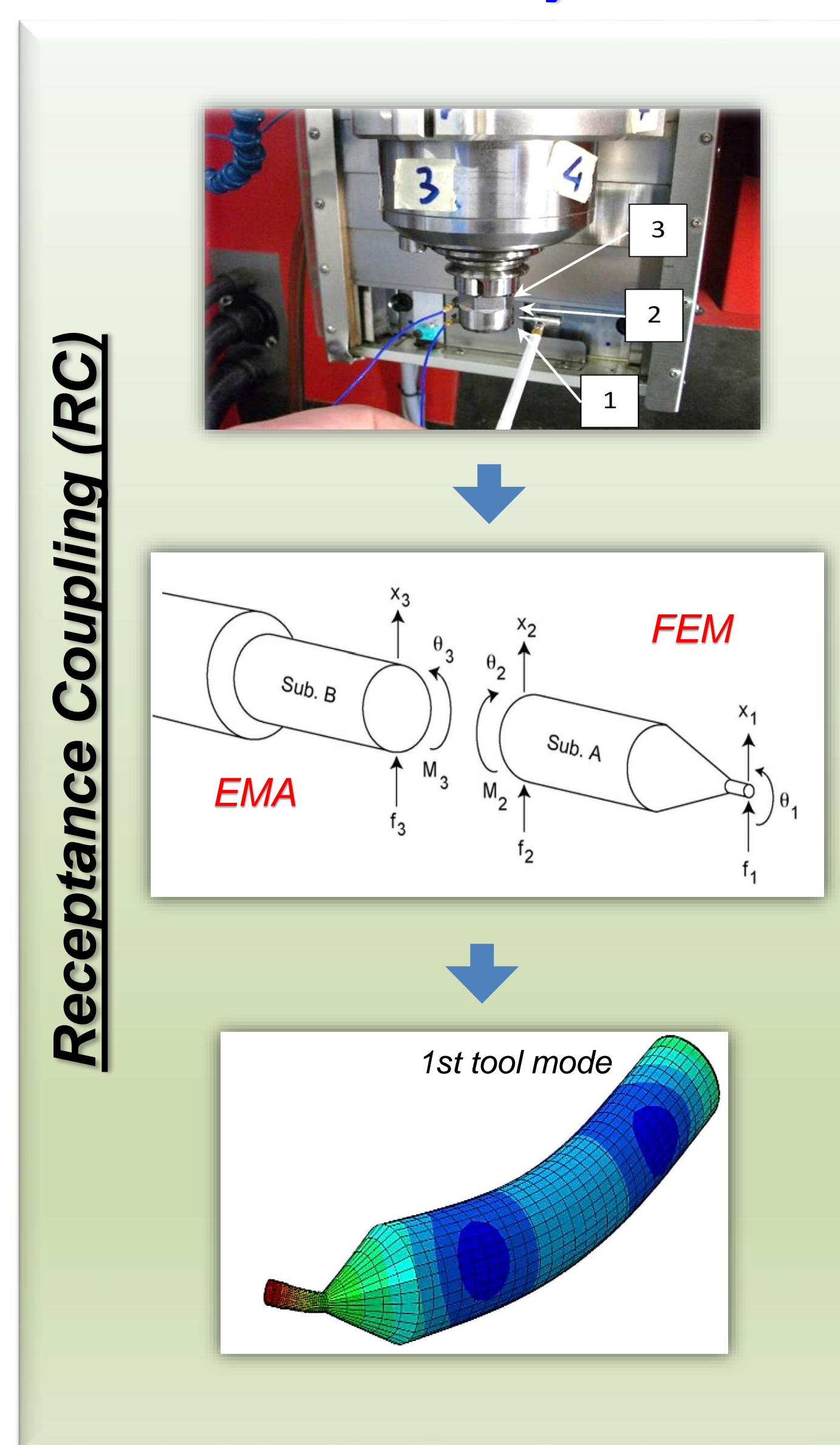


## Effects on Cutting Stability

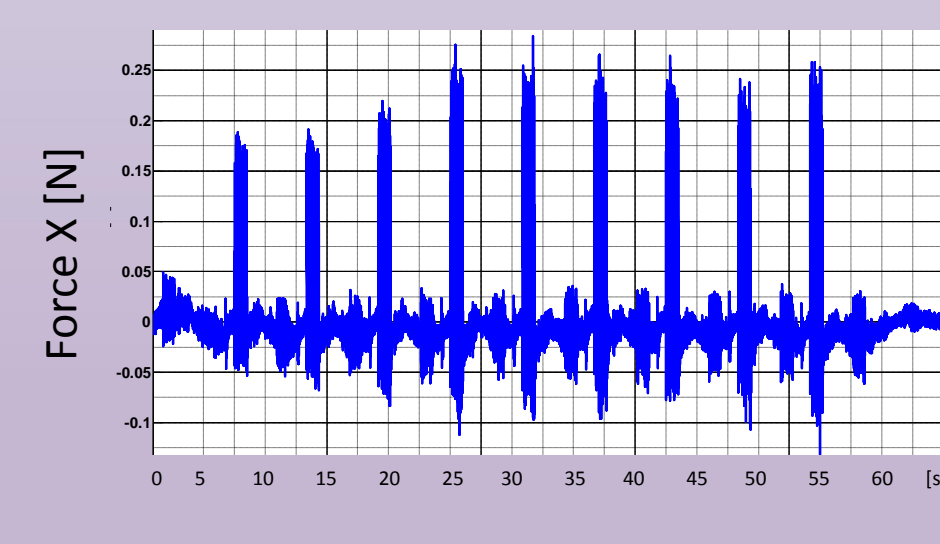
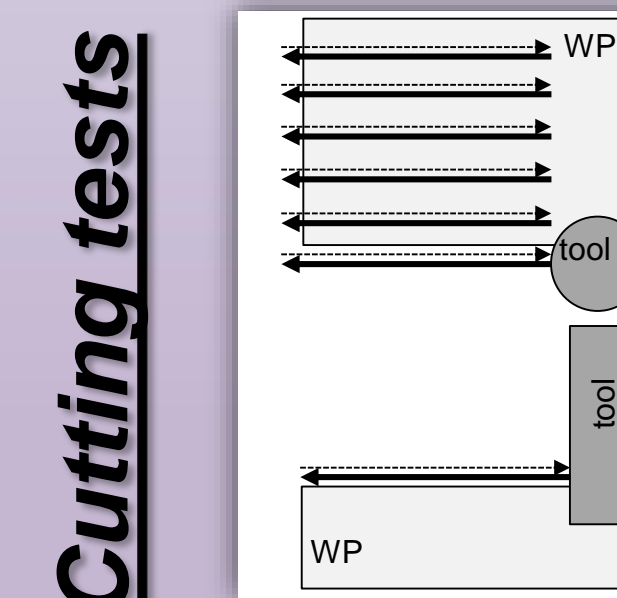
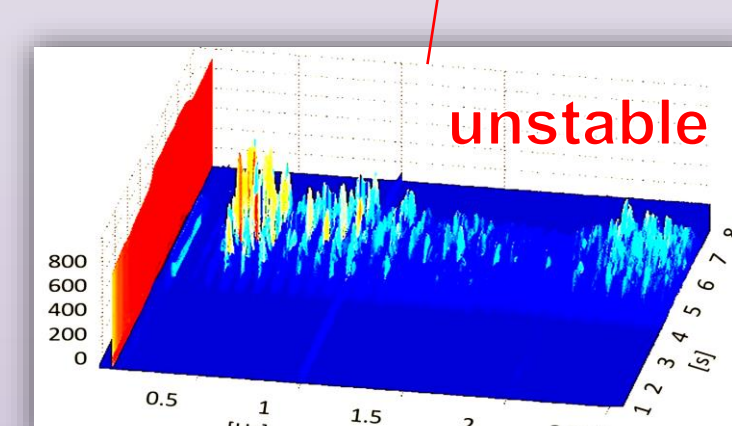
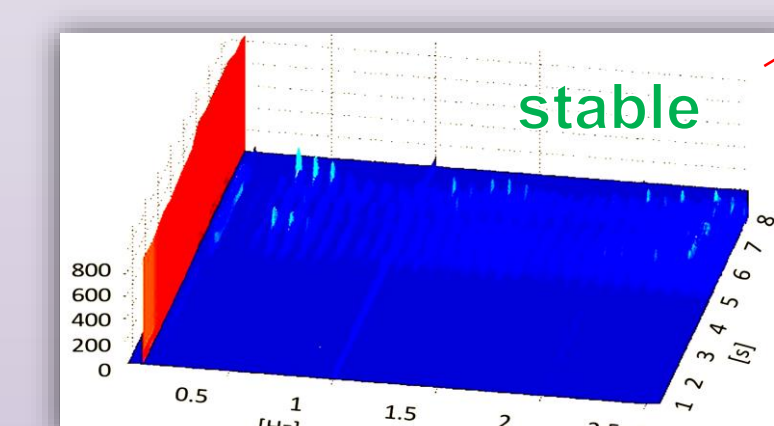
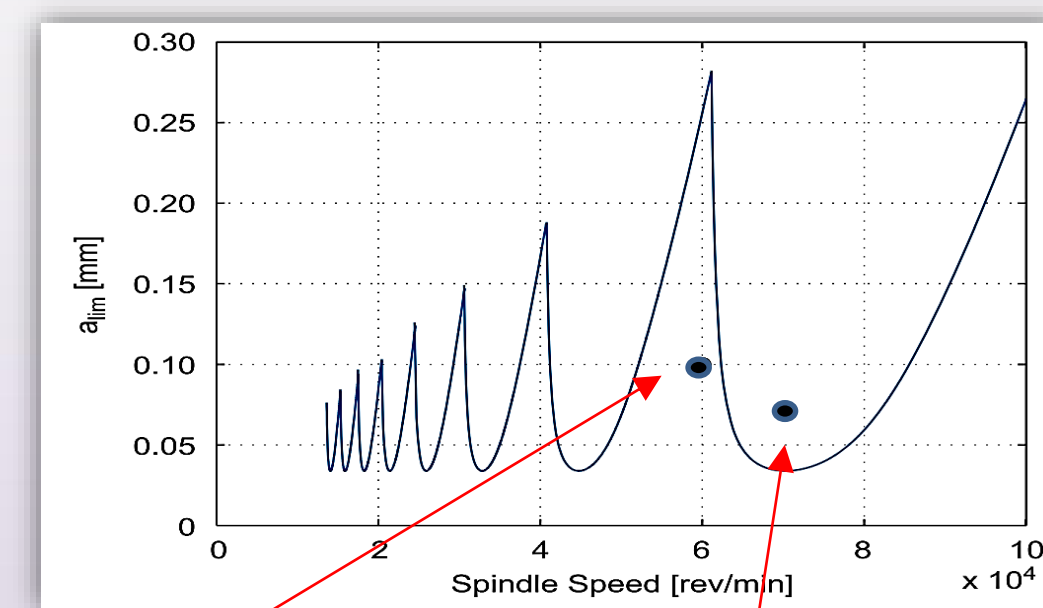
- Cutting Coefficients reduction (rake angle)
- Tool dynamic modification (clamping)
- Increased Process damping



## Dynamic Characterization



### Lobes Diagram Calculation and Verification

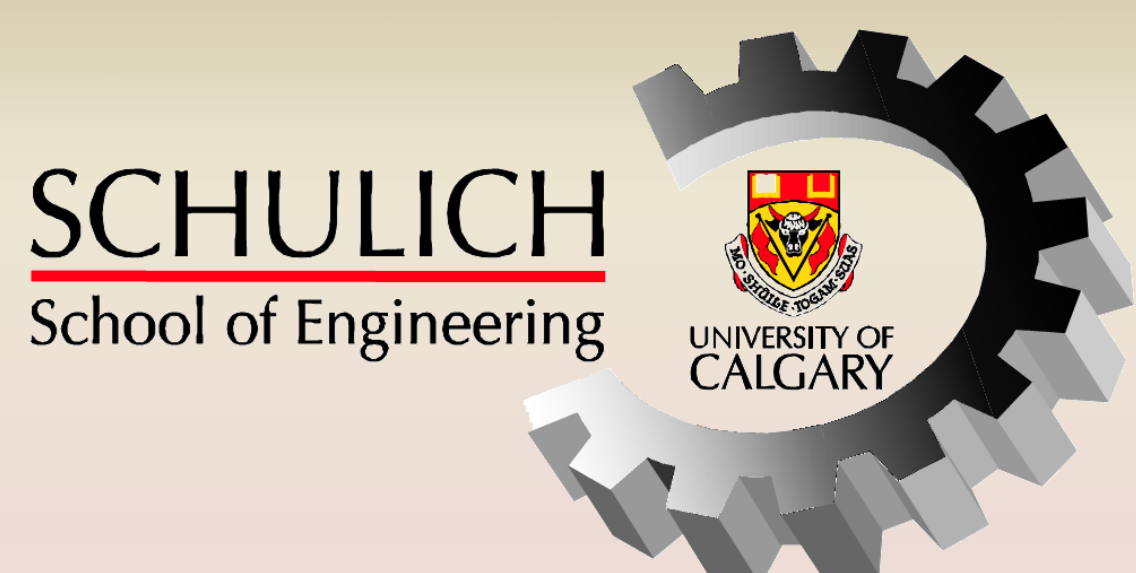


### Monitoring signals (chatter detection)

- Acoustic Emission
- Accelerometers
- Forces (up to 5KHz)

- Reduction of cutting forces are measured through dynamometer during stable cutting
- Chatter detection is based on AE sensor/ Accelerometer
- Stability Lobes diagram is verified with and without application of UVAM technique

- Effects of high assisting frequency (>100KHz) are investigated and compared with lower frequency (20KHz)
  - Process cutting modelling through Mechanistic and FEM approach are foreseen
  - Industrial exploitability of the solution is also addressed



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