# High Precision Machining of Hard-To-Cut Materials with the Ultrasonic Tooling System

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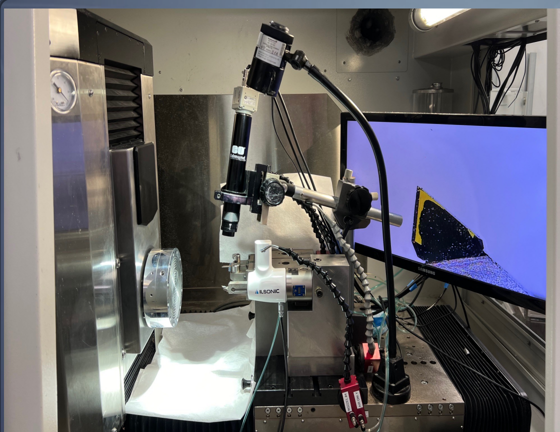
GENERAL ATOMICS

## Objective

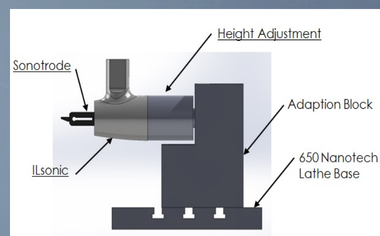
This study investigates the machining method of ultra-precision diamond turning techniques applied to hard-to-cut material such as stainless steel, iron and tungsten. These materials are traditionally challenging to machine to a high precision specification due to the wear and tear of the conventional machine tools used. However, with the application of a specified kilohertz (kHz) ultrasonic vibration in conjunction with a single crystal diamond tool, aka Ultrasonic tooling system, we successfully achieved very fine surface "mirror like" finish on a flat and cylindrical surface. In addition, patterning a sine wave on the material was also achieved. The difficulties encountered in machining hard-to-cut materials are primarily attributed to their exceptional hardness, abrasion resistance, high strength at various temperatures, superior thermal conductivity, and resistance to oxidation and corrosion.

**Surface Finish Goal: Ra ≤ 100 nm**

## Equipment:



**Ilsonic Tooling System on a Nanotech 650 Lathe**




The Ilsonics Ultrasonic tooling system by INNOLITE operates at 100 Khz. The system consists of a piezo drive and a specially designed sonotrode to operate at resonance frequency. With a diamond tool insert on the front tip of the sonotrode, the tool oscillates at resonance frequency in an elliptical motion allowing the diamond tool to periodically lose contact with the material's surface.

## Material

**304 Stainless (SS)**
3mm Diameter Steel Rod
From McMaster-Carr

**Iron (Fe-Ni)**
10mm Diameter Discs
From American Elements

**Tungsten (W)**
1.6mm Dimeter Rod
From Goodfellow Corporation

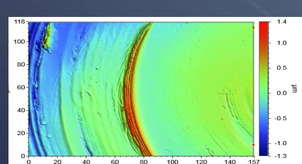
## Procedure

Experimental process was implemented with known parameters, surface measurements taken, data analyzed, reiterate until goal is met. A Wyco ContourGT 3D Optical Profiler was used to take surface measurements.

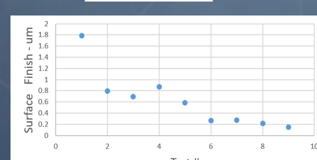
**Lathe Parameters**

**Spindle Feed (RPM)**
**Feed Rate (mm/m)**
**Depth OF Cut (um)**

**Wyco Surface Scan**



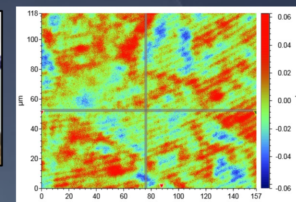
**Data Collection**




## Results

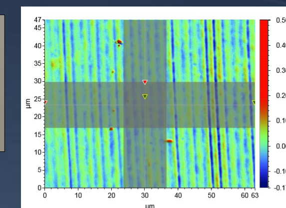
### SS Mirror Like Finish

Surface Finish Goal Ra = <100nm , Actual Ra = 10nm

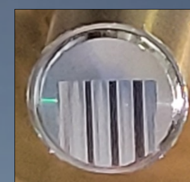


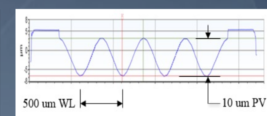
### Fe Mirror Like Finish

Surface Finish Goal Ra = <100nm , Actual Ra = 26nm

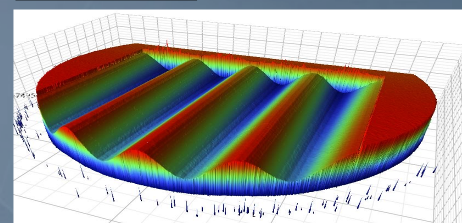


### SS Sinusoidal Pattern

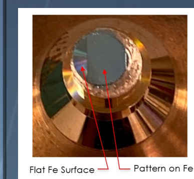


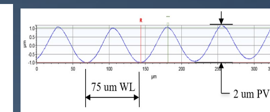



Achieved goal to machine a sine wave on SS

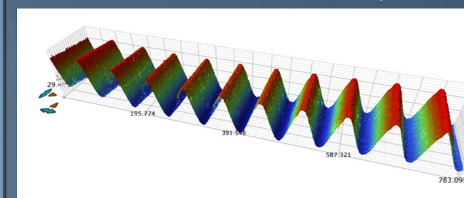


### Fe Sinusoidal Pattern



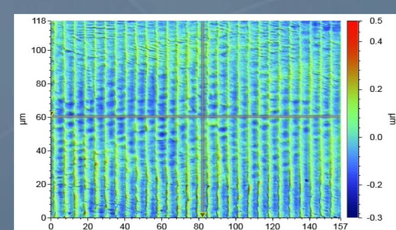




Fidelity goal: Sine FFT ≥ 95%,
Acheived FFT 98% Fidelity
FFT = Fast Fourier Transform Analysis in MATLAB



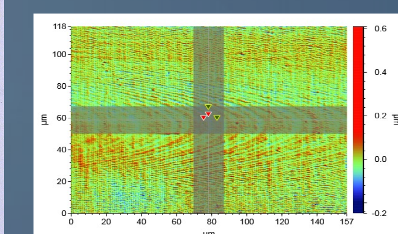
### SS Cylindrical Part

Surface Finish Goal Ra = <100nm , Actual Ra = 54nm



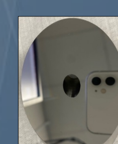
### W Cylindrical Part

Surface Finish Goal Ra = <100nm , Actual Ra = 26nm

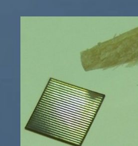


## Conclusion

In conclusion, the Ilsonic tooling system was able to accomplished the goals of machining stainless steel, iron and tungsten to a mirror like surface finish of Ra below 100nm. Furthermore, we demonstrated the ability to machine sinusoidal patterns on both stainless and Iron.
This development increased IFT micro-machining capabilities enabling production of these parts and targets;
A - Soft X-Ray System Stainless Mirror (GA)
B - Iron Rayleigh Taylor "Strength Target' Sin Wave design (LLNL)
C - Stainless Steel and Tungsten Mykonos Target (LLNL)



A



B (next to toothpick)

C

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