



# Industrial Advisory Board Meeting Miniaturization of Machine Tools

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10/20/04



# Outline

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- Objective and Motivation
- Machine Setup
- Experimental Results
- Theoretical Calculations
- Conclusion

# Project Objective

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- Design, Construct, and Evaluate a Miniaturized Machine Tool
- Machine Tool Specifications
  - Total Volume  $\sim 0.01\text{m}^3$
  - CNC Machine Functionality
  - Submicron Feature Size and Surface Finish



# Motivation

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- Demand for microscale components for biomedical, computer/consumer electronics, and aerospace applications
- Fewer material restrictions than chemical, energy beam, and silicon etching processes
- Ability to create true three dimensional features unlike layering methods

# Experimental Setup

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- Positioning Table
  - 4 Axis Table
  - Resolution:  
10nm x 10nm x  
4nm
- Machine Tool Frame
  - Solid Invar
- Video Microscope
  - 50x-200x



# Experimental Setup Cont'd

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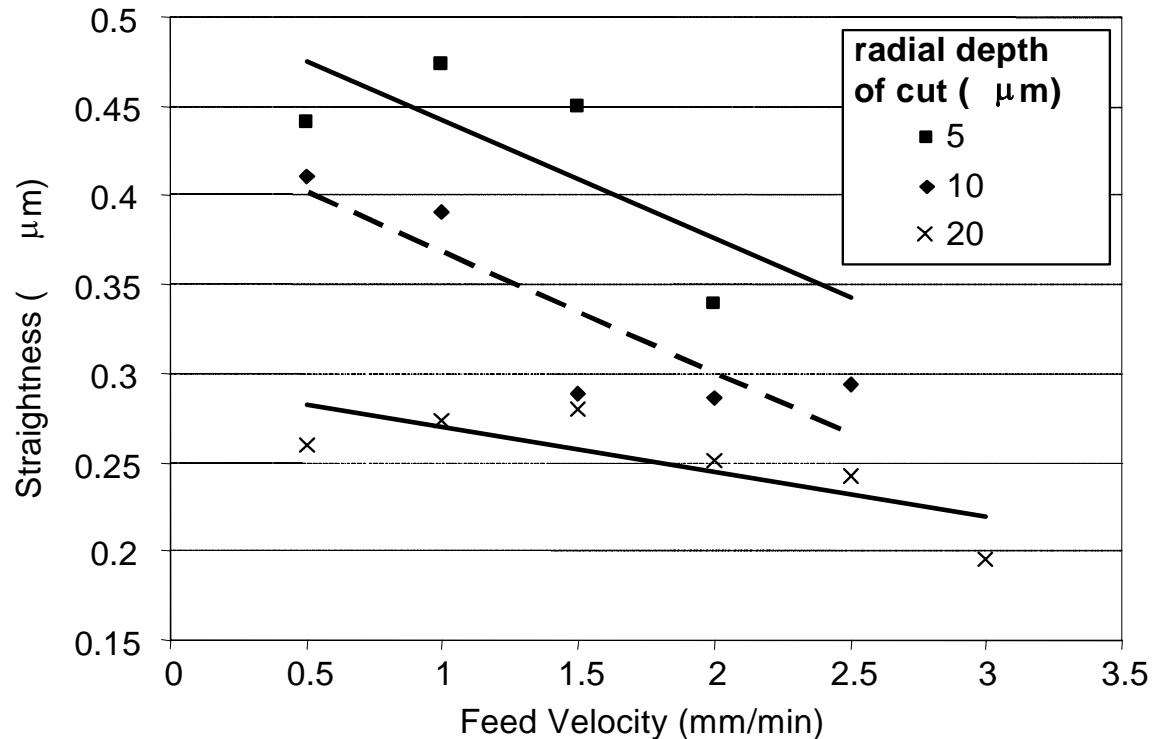
- Spindle
  - Electric DC Motor
  - Hybrid Bearings
  - 60,000 RPM
  - Runout < 1 $\mu$ m
- Cutting Tool
  - Solid Carbide
  - 2-Flute, Square End
  - Tip Diameter Size: 50-200 $\mu$ m



100 mm Diameter Tool

# Experimental Results

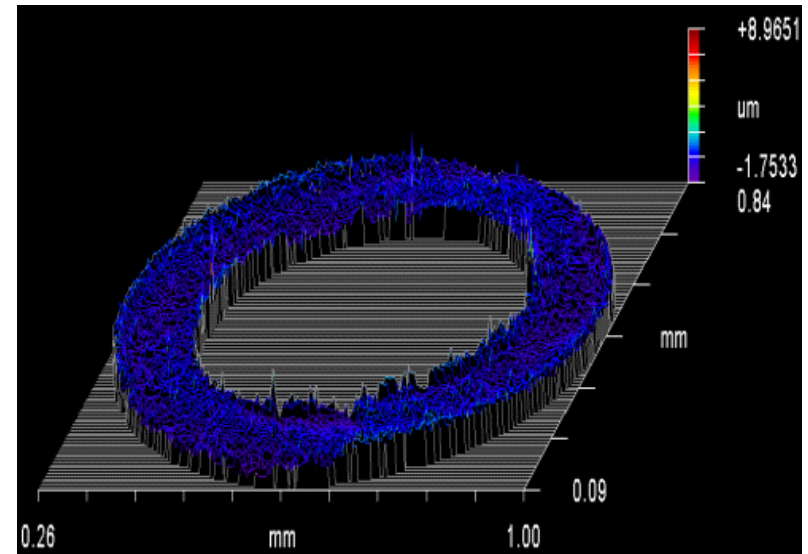
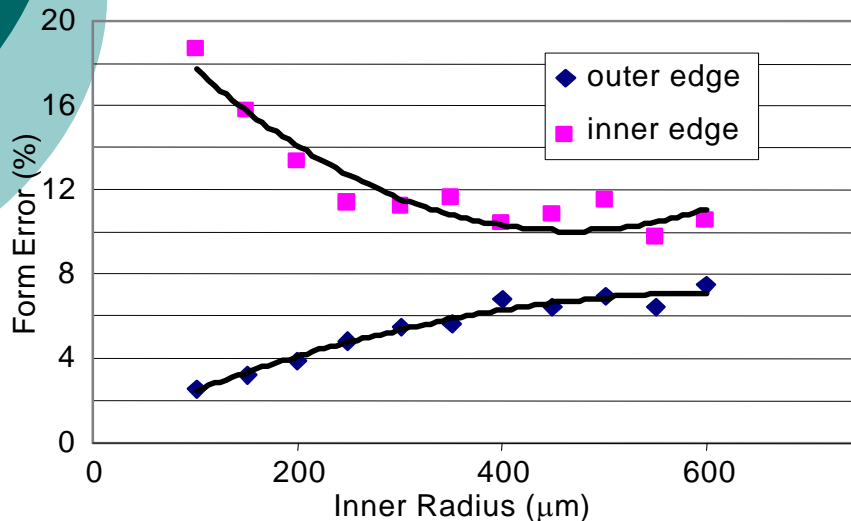
## One Dimensional Test: Straightness Error



Error vs. depth of cut and feed velocity

# Experimental Results Cont'd

## Two Dimensional Test: Circle Errors



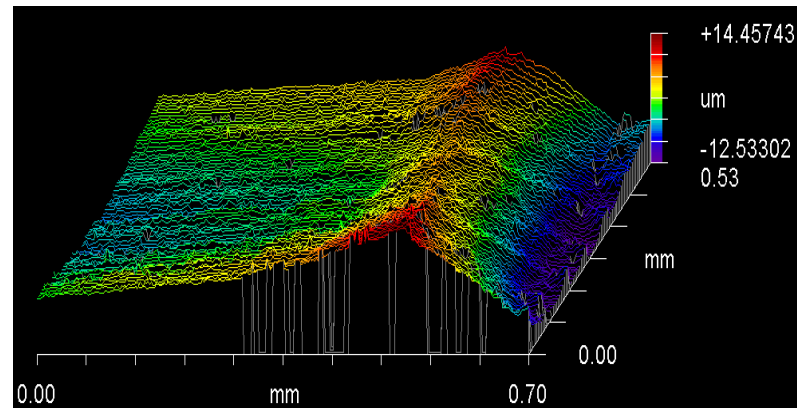
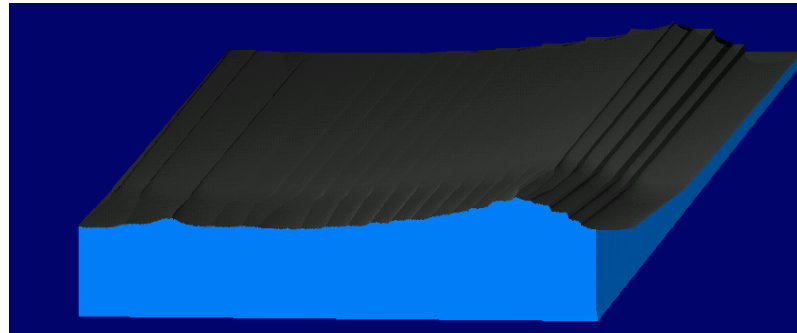
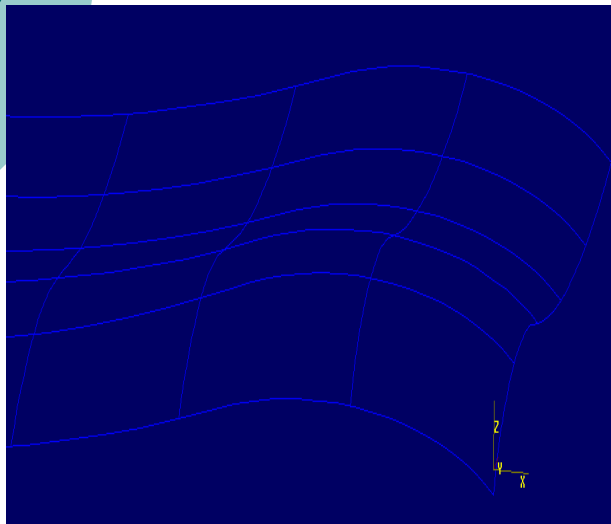
Percentage form error at 20 mm depth of cut and surface roughness plot



# Experimental Results Cont'd

## Three Dimensional Test: Sculptured Surface

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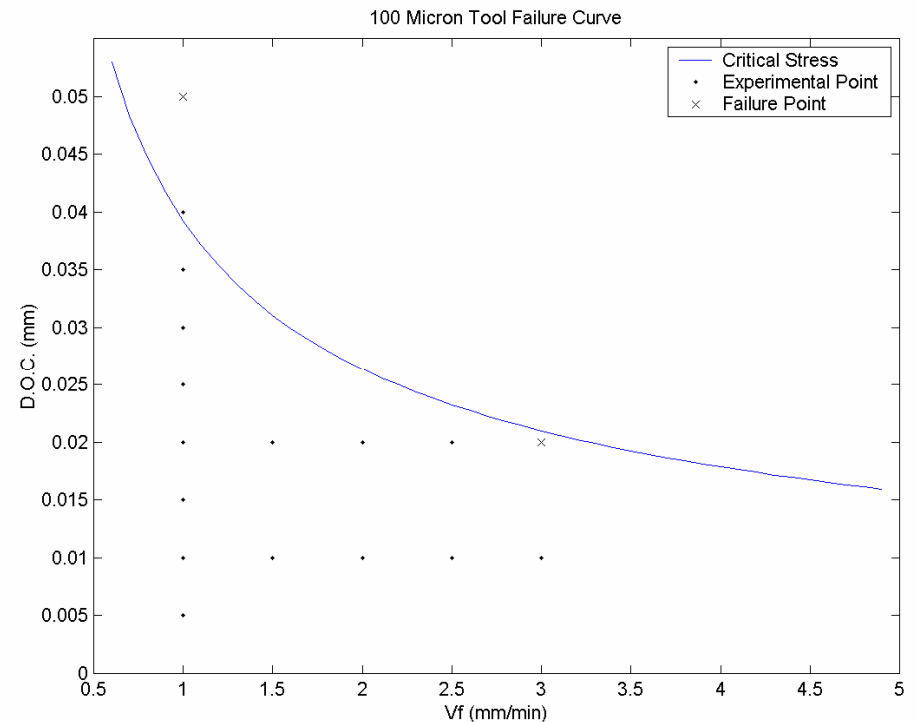


Computer generated model and machined part  
of the sculptured surface (1mm x 1.5mm)

Introduction – Motivation – Setup – Results – Calculations – Conclusion

# Theoretical Calculations

- Force Models
- Failure Curve
- Deflection Models

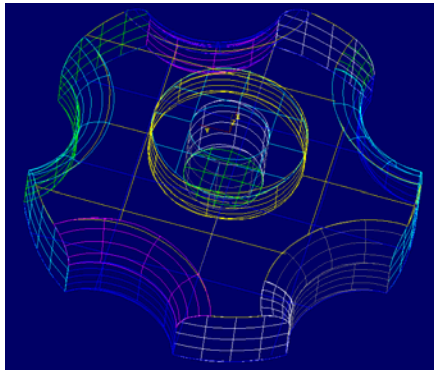


**Theoretical calculations for tool failure**

# Next Phase of Development

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- Redesigned Machine Tool
  - Smaller, Stiffer Frame
  - More accurate Positioning Table
  - Increased Measurement Ability
- Fabricate Micro Parts with Even Greater Precision



Computer generated model of a micro gear and the machined part

**Introduction – Motivation – Setup – Results – Calculations – Conclusion**

# Conclusion

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- Brief discussion of purpose for microscale machining
- Overview of current miniaturized machine tool
- Description of experimental results
- Sampling of theoretical results