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Title: Engineered Surfaces for Inertial Confinement Fusion Experiments

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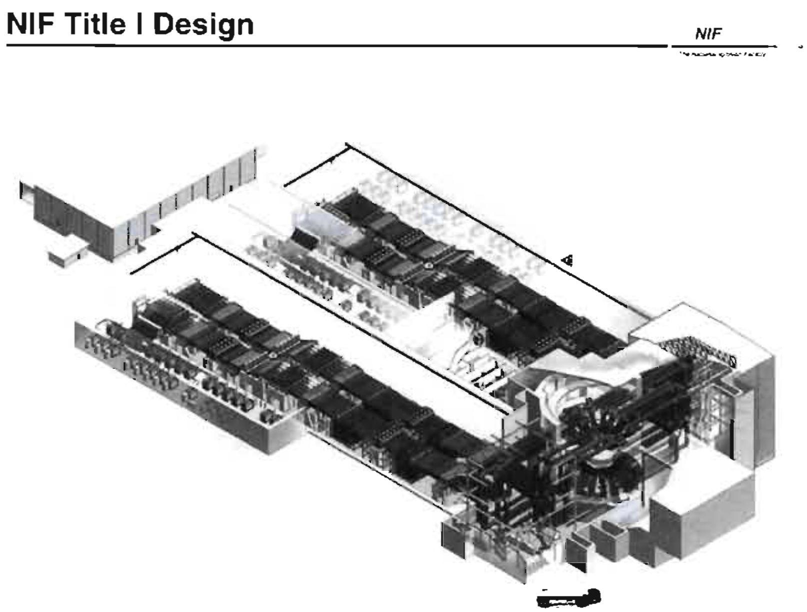
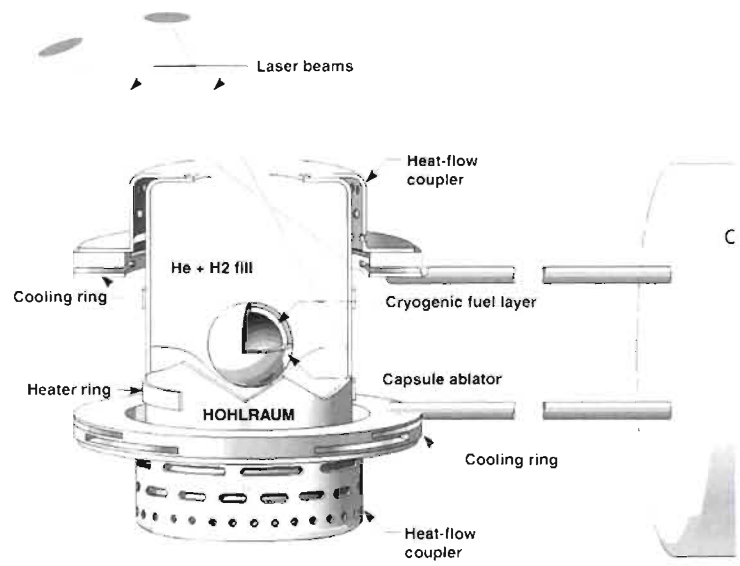
Engineered Surfaces for Inertial Confinement Fusion Experiments

R. D. Day, D. J. Hatch, G. Rivera

ASPE 2011 Spring Topical Meeting on Structured and Freeform Surfaces

High Energy Lasers Initiate Fusion



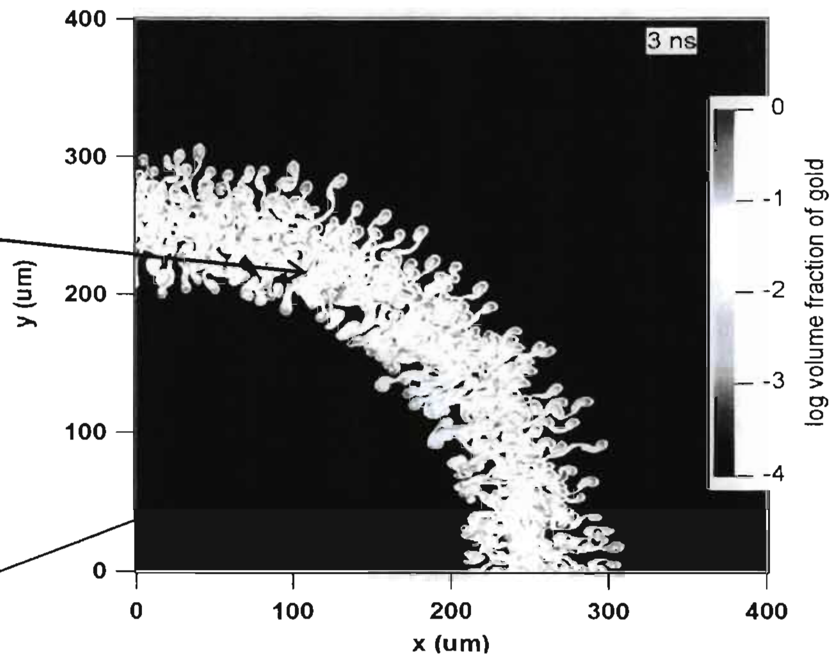


NIF Laser at LLNL

- Fusion Capsule

Mixing of Fuel and Non-fuel Can Stop the Fusion Reaction

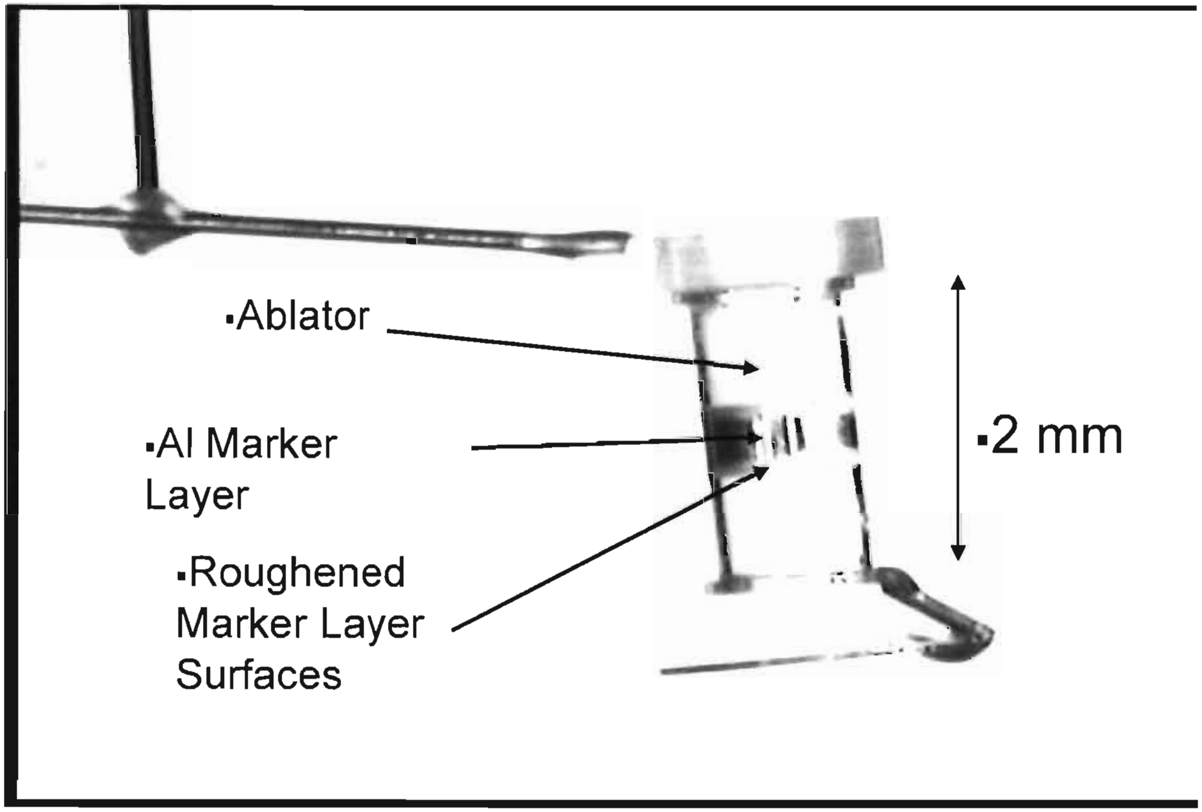
- R-Θ Mix at 3.0 ns



- Fuel Container
- Fuel Region

Simulation of Mixing of Fuel Container into Fuel

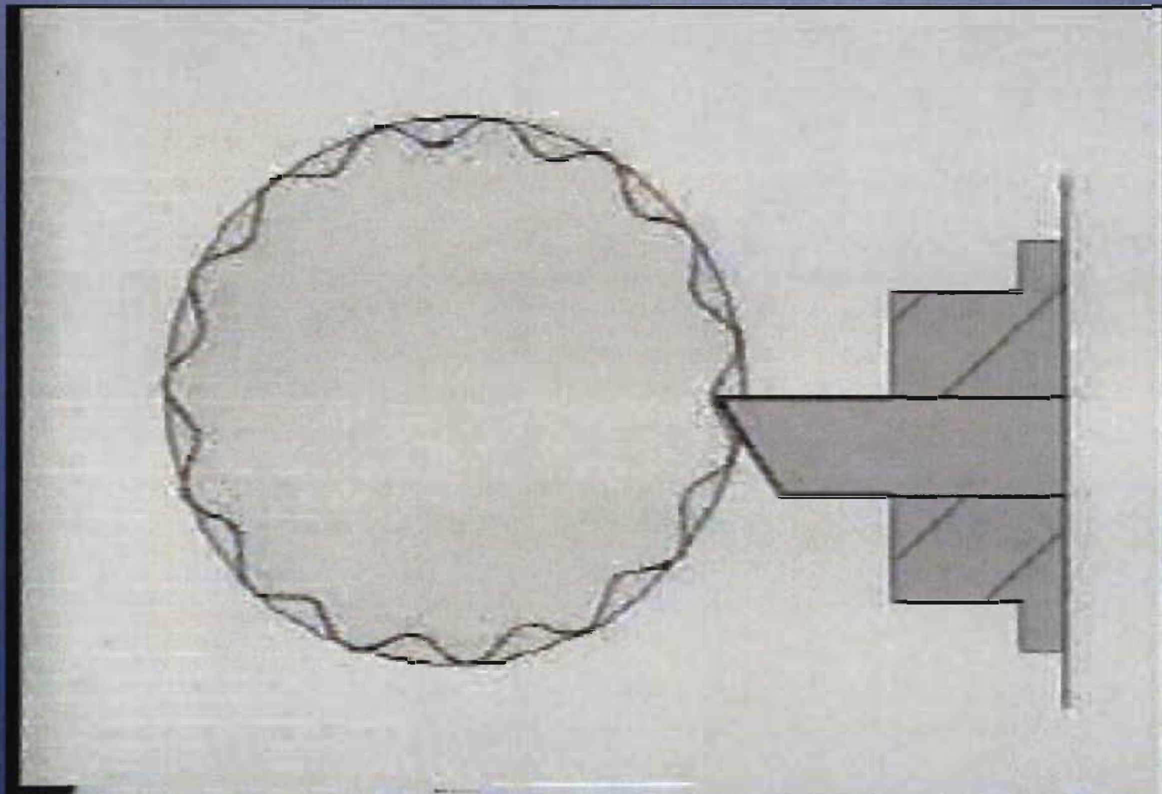
Experimental Package for Mixing Experiments



Three Types of Engineered Surfaces Needed

- Specific Frequency Peak, i.e. Sine Wave
- Flat Power Spectrum, Ra Specified
- Flat Power Spectrum and Peak at Certain Frequency, Ra Specified

Surfaces with Peak at Single Frequency (Sine Wave)



Fast Tool Servo, with Encoder Feedback on Spindle used to produce this Surface

Air Bearing LVDT Used to Measure Sine Wave Profiles

- 50 µm diameter sphere

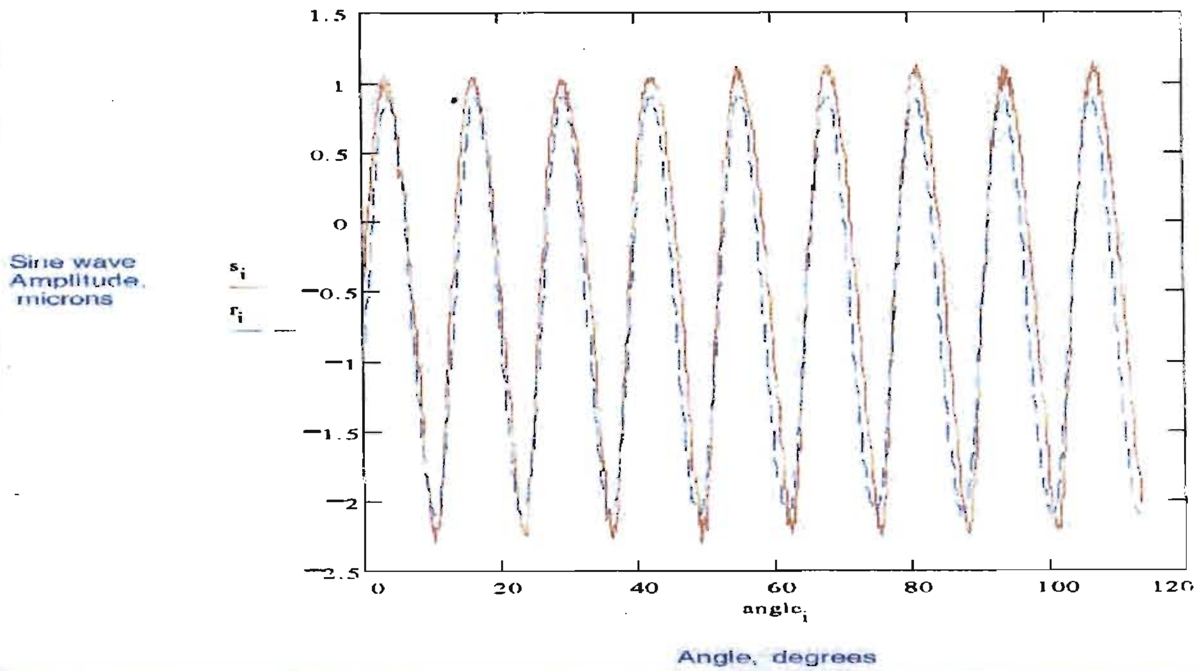
Air Bearing LVDT

Comparison of Measured and Theoretical Profiles

$s_i := y_i \cdot 13.61$ s is the sine wave amplitude in microns

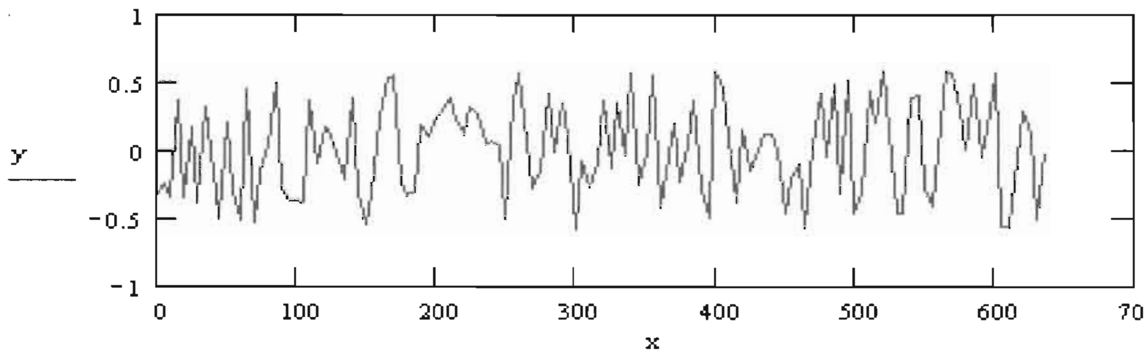
$$r_i := 1.5 \cdot \sin\left(\pi \cdot \frac{i \cdot 1}{42.5} + \frac{\pi \cdot 3.8}{2}\right) - 0.6$$

$angle_i := 0.151261 \cdot i$

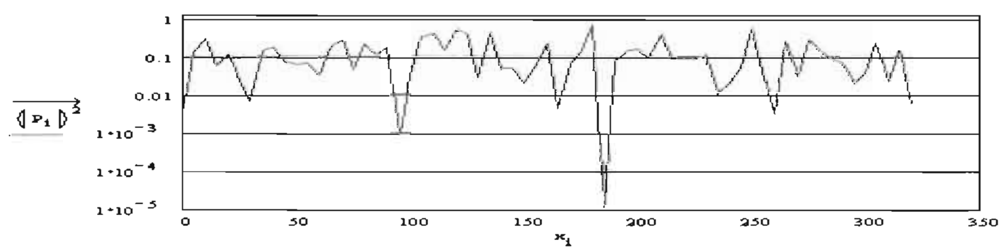


Surface with Flat Power Spectrum

- A simple model showed that a flat power spectrum can be generated by using a random number generator to drive the FTS tool bit position at 100 Hz.



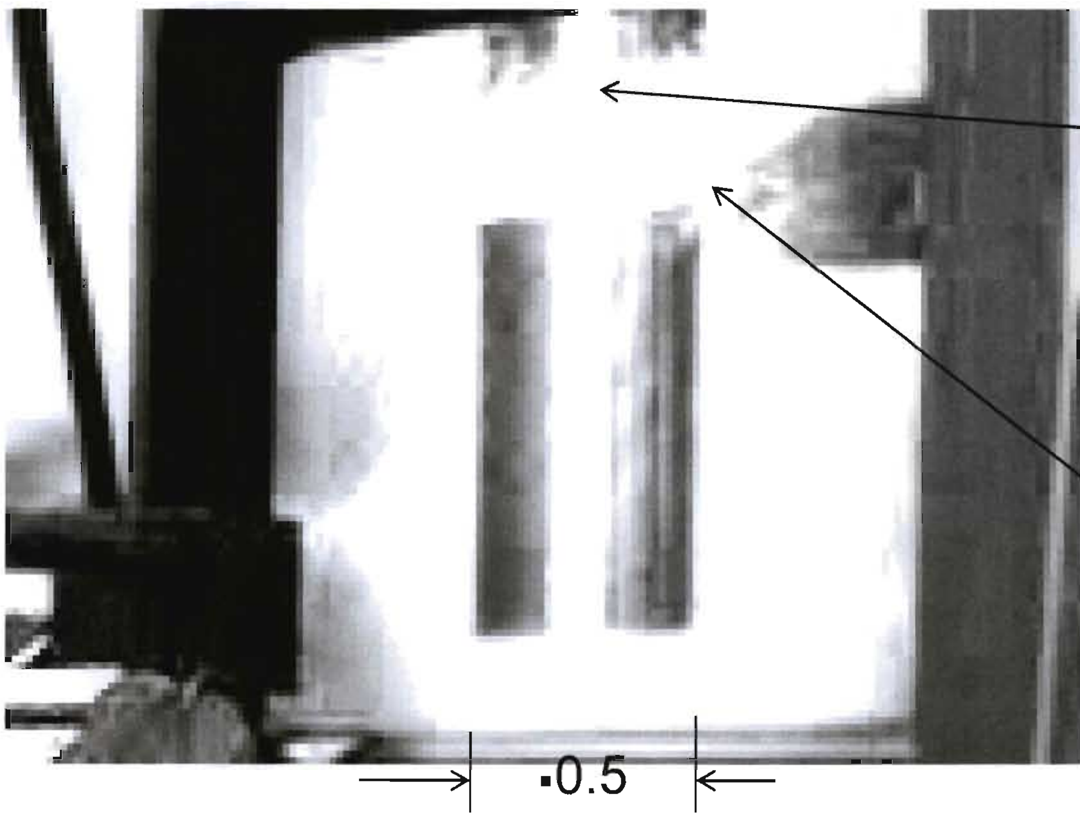
▪ *Random -number -generated tool position of FTS (calculated)*



▪ *Calculated surface power spectrum above tool position*

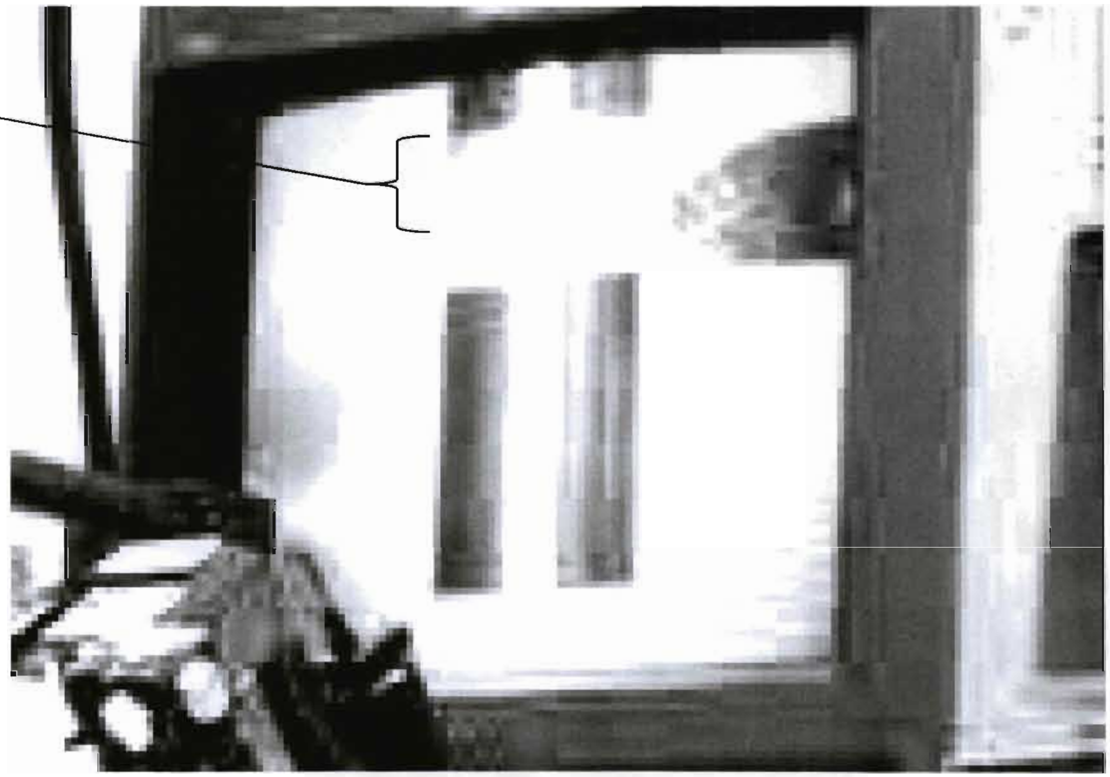
Fast Tool Servo with Diamond STM Tip used to Make Surface

Surface as it is Being Generated



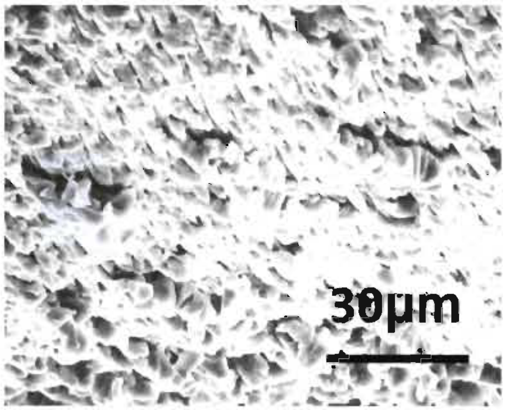
3.0 Volt Bias Applied Between Tip and Part to Remove Chips

- Region Where Chips Removed

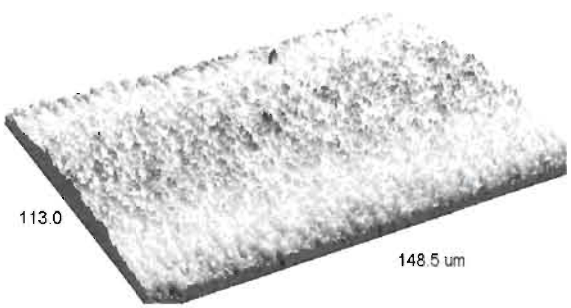


The Technique Successful Produced the Desired Surface

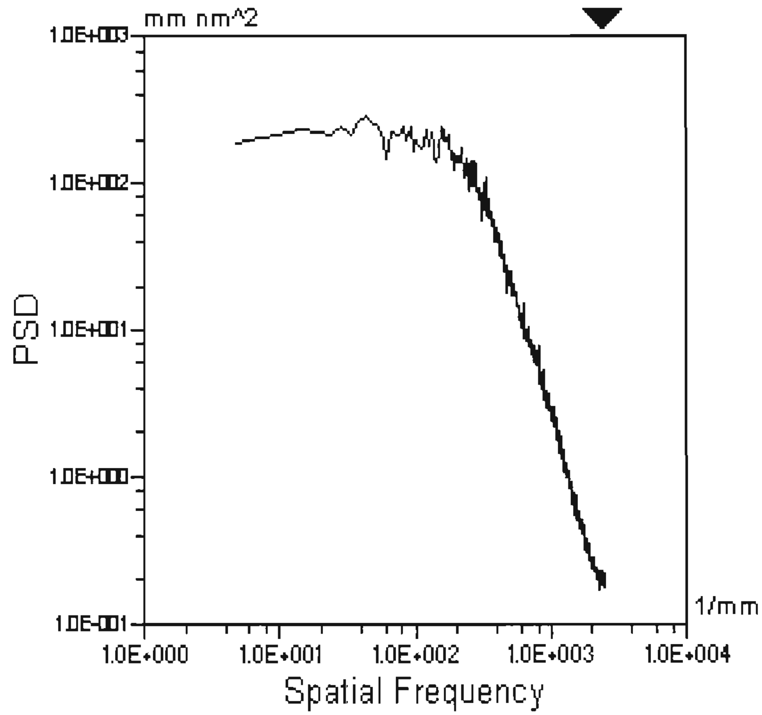
SEM micrograph of random surface



- Optical Profile Image of Surface



- Power Spectrum of Surface



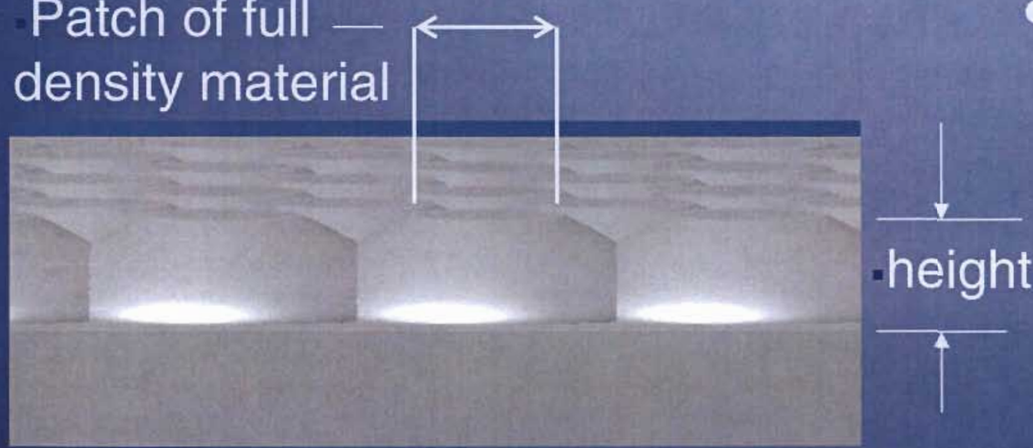
Band Thickness Measurement

- The band thickness was nominally 18 μm before roughening surface
- The Ra value could be as high as 2 μm
- Surface roughness region is significant fraction of band thickness
- So, band thickness measurement must be statistical

Density Varies from Full to Zero Density through Surface Roughness

- Region A is Full Density Region
- Region B is Surface Roughness Region

Bearing Area Ratio Plot Shows Density Variation through Surface Roughness



Circular regions are areas where material is present at this specific height through the roughness region

- Bearing Area Ratio is the ratio of the sum of full density patches to the total area of a surface at a specific height along the surface roughness

Bearing Area Ratio Plot of Generated Surface

Vecco

Mag:

Mode: VSI

Date: 09/15/2003

Time: 14:27:30

Statistics:

tp1: 0.0 %

tp2: 100.0 %

Htp: 20.77 um

Mr1: 10.76 %

Mr2: 89.38 %

RK: 4446.23 nm

Rpk: 1929.41 nm

Rvk: 1784.20 nm

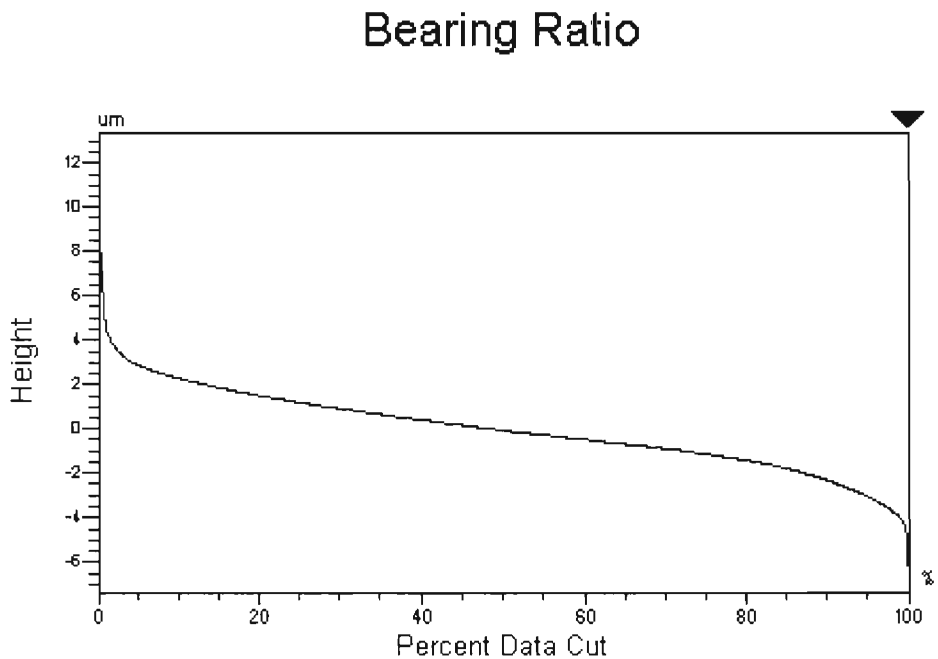
V1: 103.84 nm

V2: 94.77 nm

Ra: 1.42 um

Rq: 1.82 um

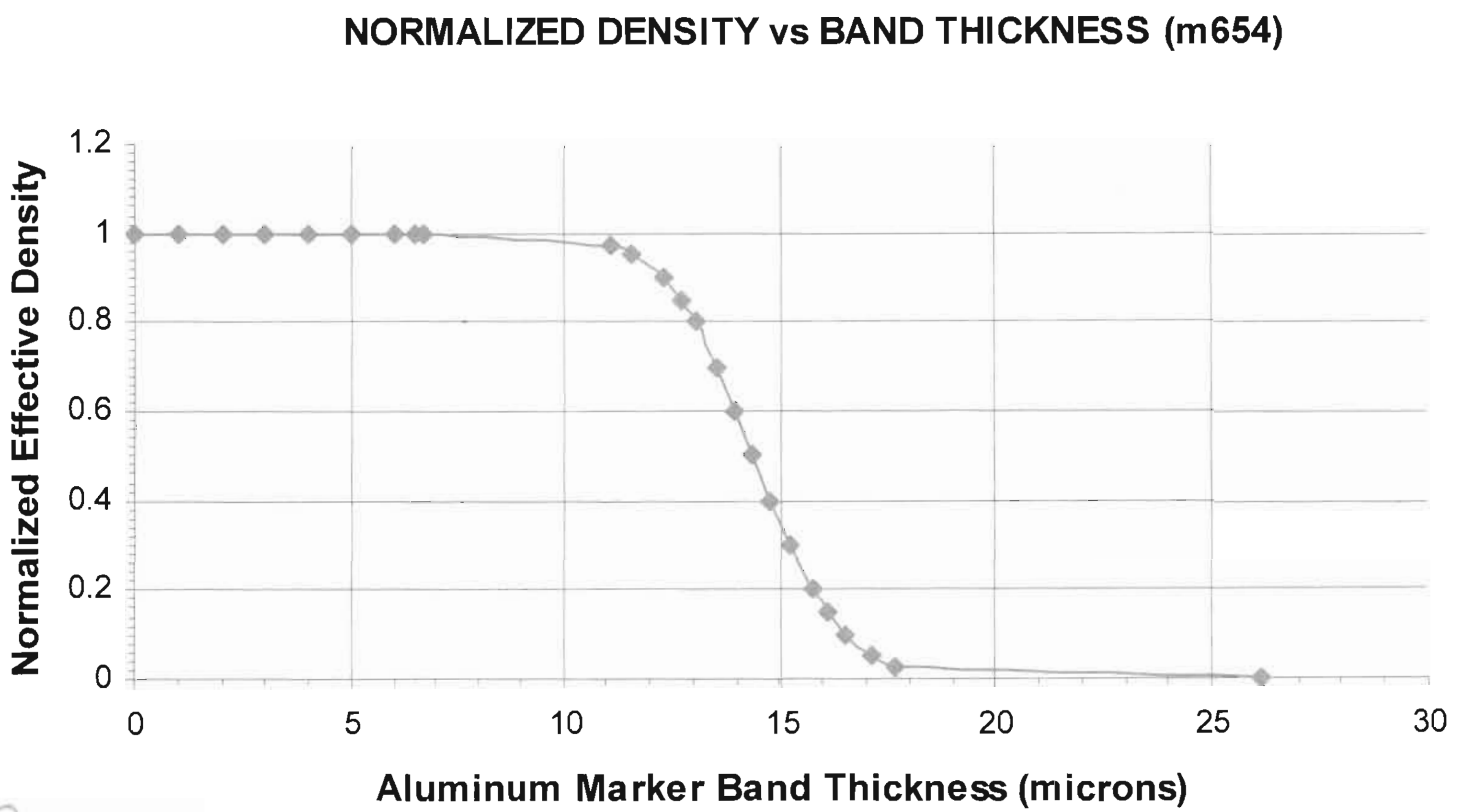
Rz: 18.34 um



Title: m654-3 rough

Note: mandrel 654 0 degrees

Final Band Thickness Measurement

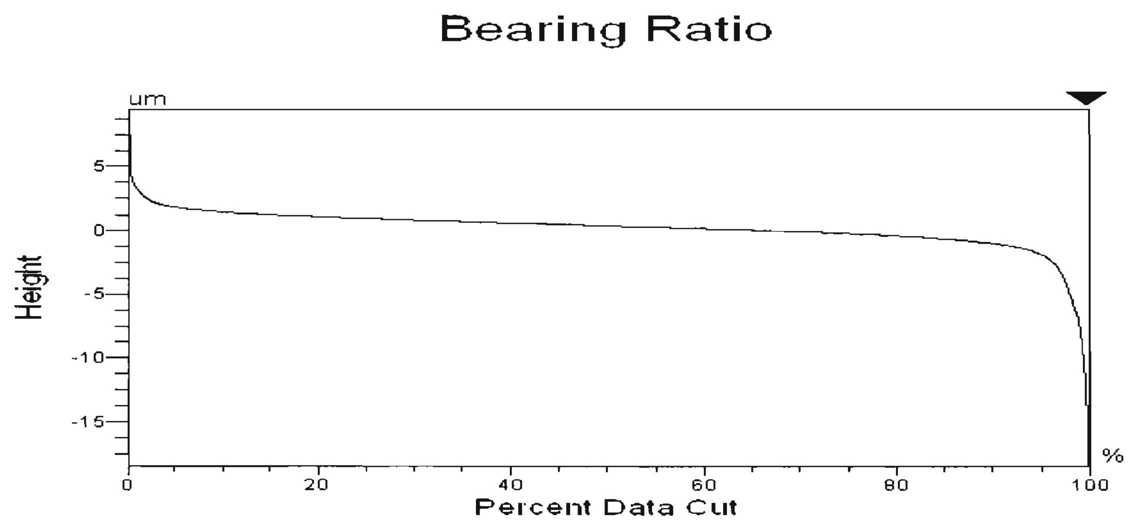


Effective Density Profile at Joints (two surfaces meet)

- Surface roughness causes an effective density variation across a joint
- Density profile difficult to measure because the gap is very small (x-ray techniques being investigated)
- Resort to simulations to estimate profile
- Bearing area ratio used to estimate profile

Simulated Surface - 1

- To simulate the density variation when two surfaces come into contact, a representative surface is simulated
- Must have a good simulation of the Bearing Area Ratio for the real surfaces of interest



Simulated Surface - 2

Surface of machined 60 mg/cc CH foam

Simulated surface

- Actual foam surfaces have a tendency to be somewhat random
- Consist of multiple peaks
- Simulated surface consists of modified paraboloids arranged in a close-packed configuration

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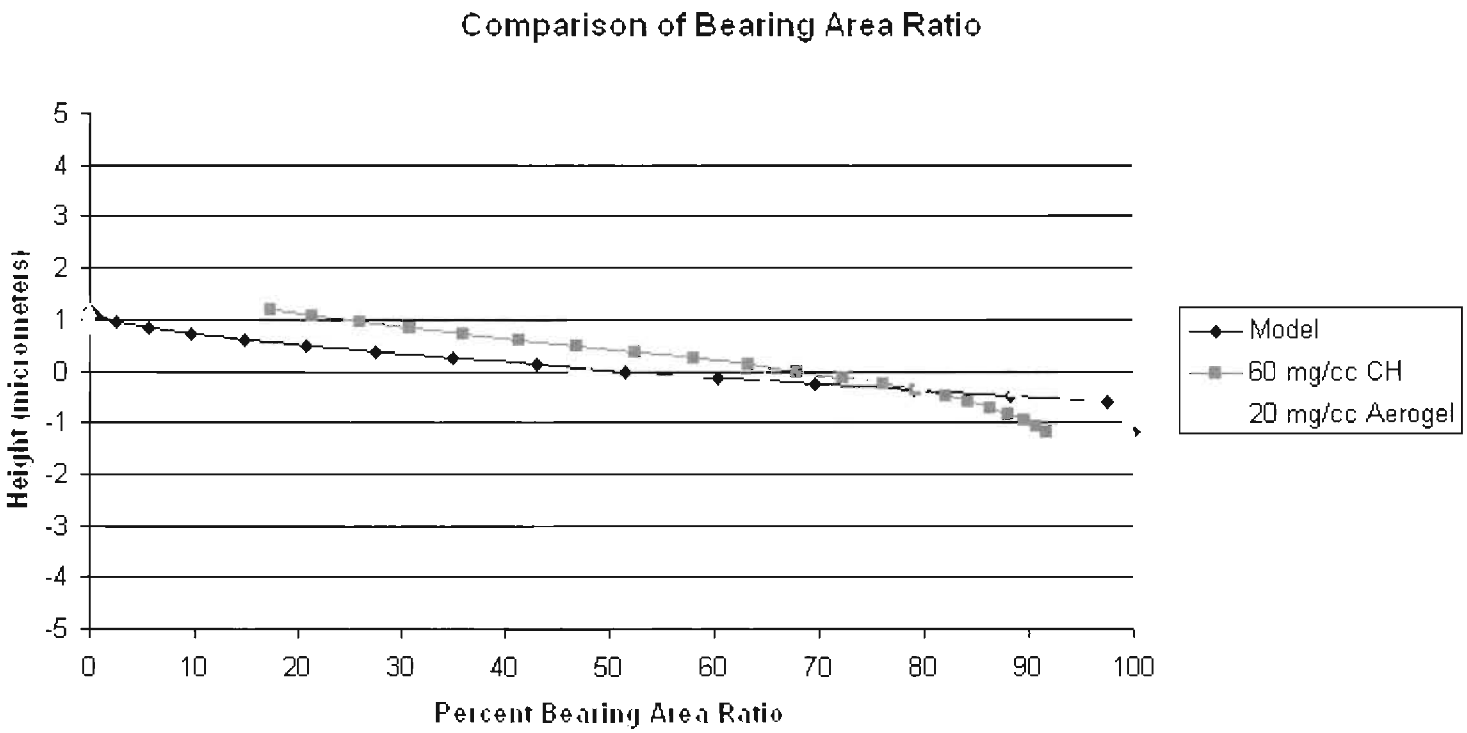
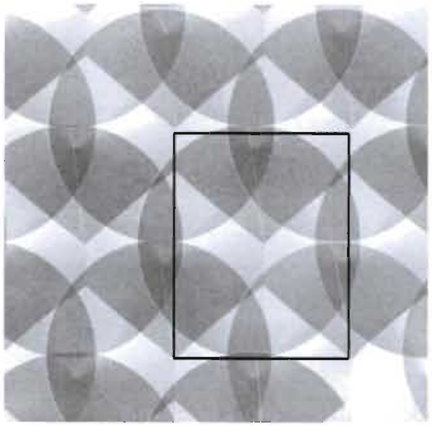
Simulated Surface Used to Model Bearing Area Ratio for Foam Surfaces



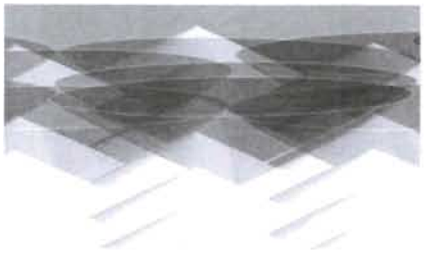
Contact of Two Surfaces - 1

- Assume both surfaces have same close-packed peak spacing
- Surfaces can have different surface roughness heights
- Surfaces nestle together in close-packed configuration

Contact of Two Surfaces - 2



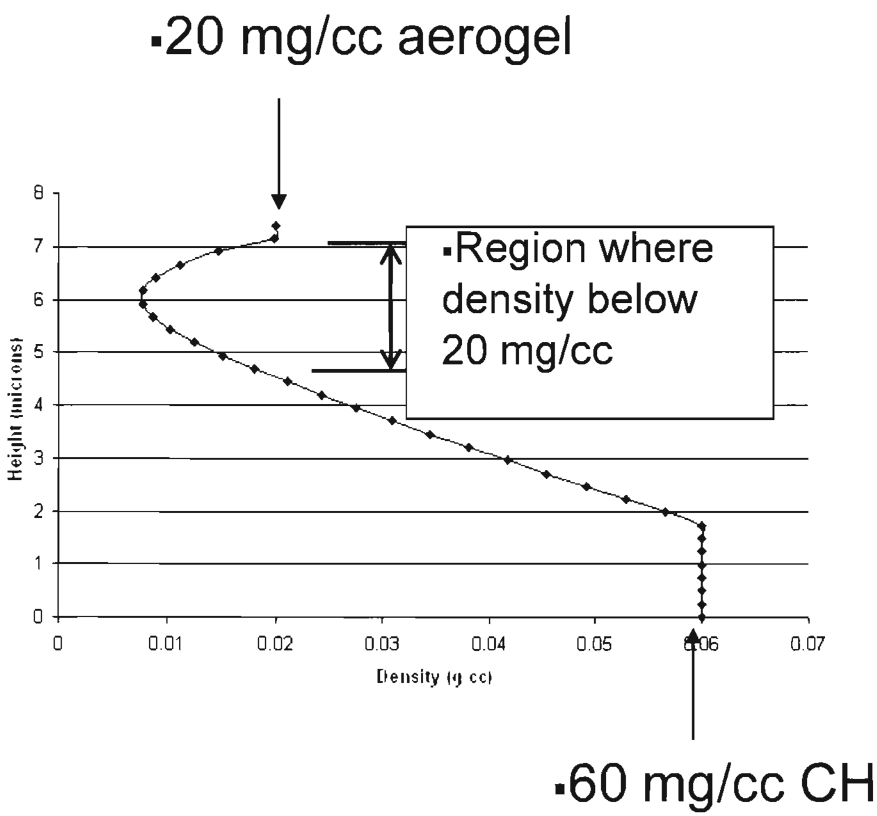
▪Nesting pattern of upper surface on lower surface



▪Tilted view of mating surfaces

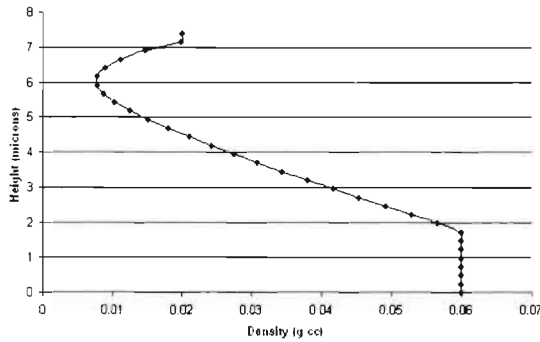
- Transparent grey paraboloids represent upper surface
- Surface can be broken into unit cells for doing the analyses
- The white rectangle is a unit cell

Calculated Density Profile for Aerogel and CH Foam Interface

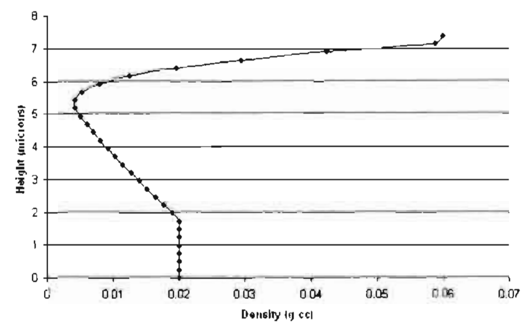


- 20 mg/cc aerogel with 275 nm Ra surface roughness
- 60 mg/cc CH foam with 800 nm surface roughness
- Calculation shows 2 μm region where density drops below 20 mg/cc

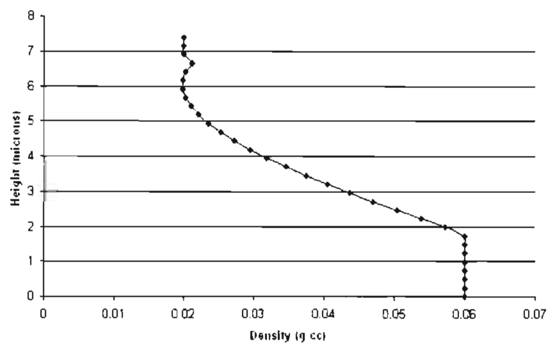
Model Useful for Exploring Effect of Surface Finish on Density Profile



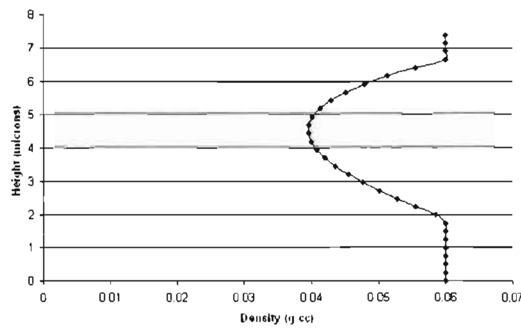
▪Low density smooth surface mating to high density rough surface



▪Low density rough surface mating to high density smooth surface



▪High and low density surfaces have same roughness



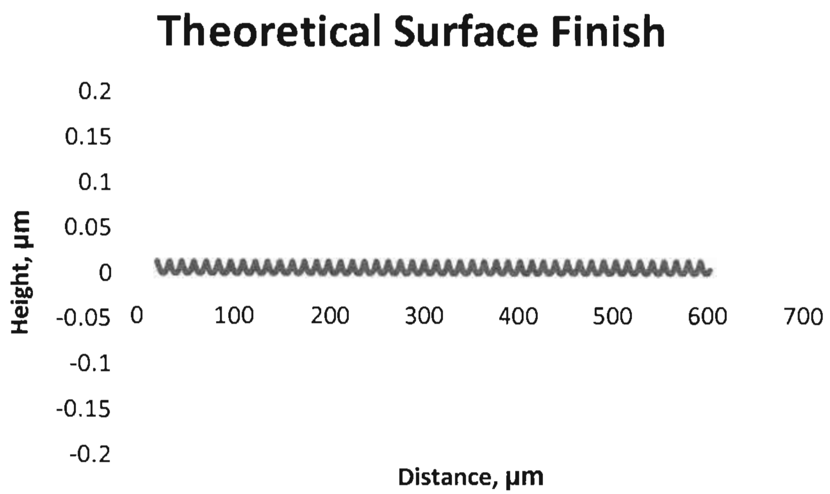
▪Same density and same roughness for both surfaces

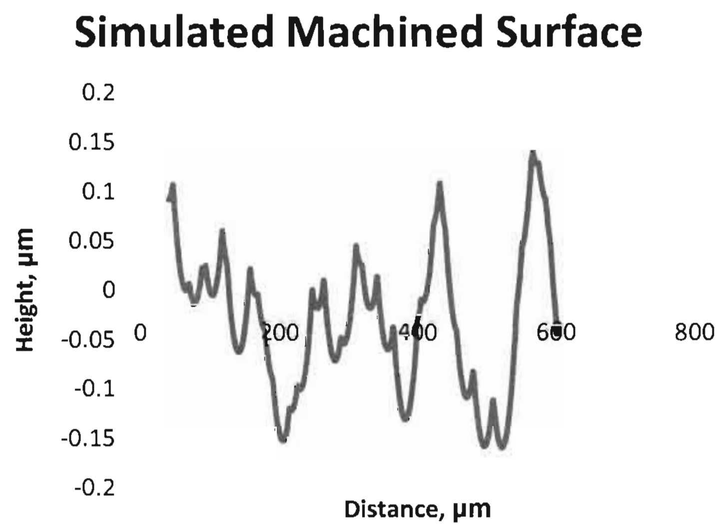
Better Surface Simulation

- Model surface as intersection of circles
  1. Radius of tool
  2. Center spacing equal to feed/revolution
- Add randomness about nominal position
  1. Effect of vibration
  2. Adds high frequency roughness
- Add randomness about last pass
  1. Effect of machine-tool errors
  2. Adds low frequency roughness

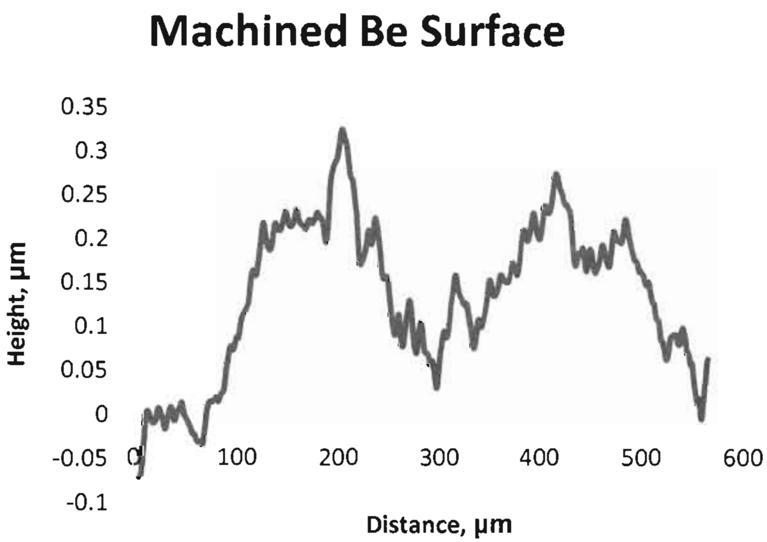
Simulated Theoretical and Noisy Machined Surfaces

Same feed/revolution and tool radius

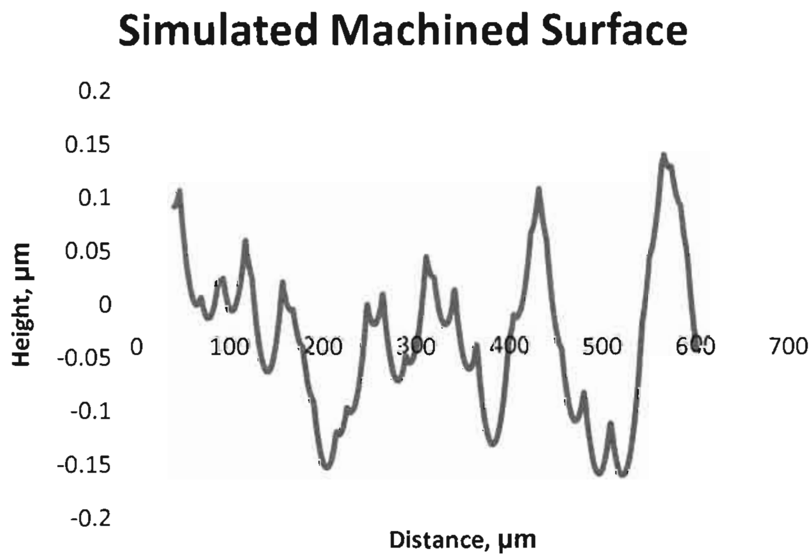




Real Machined Surface and Simulated Machined Surface

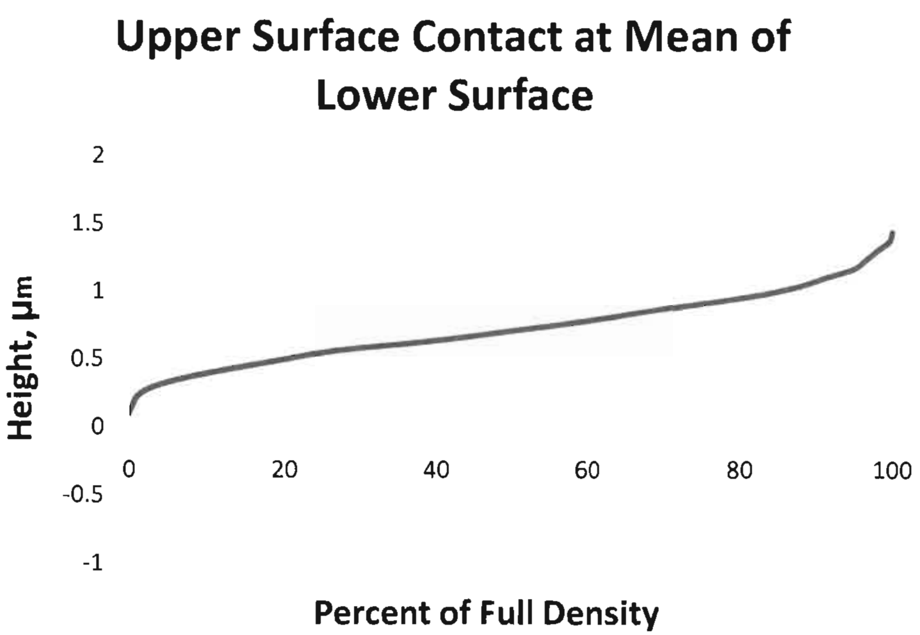


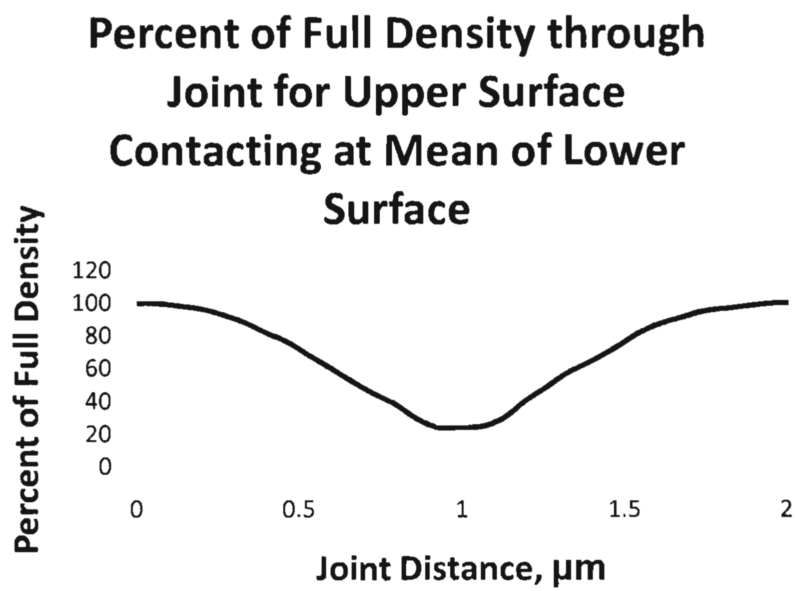
- Rms roughness = 110nm



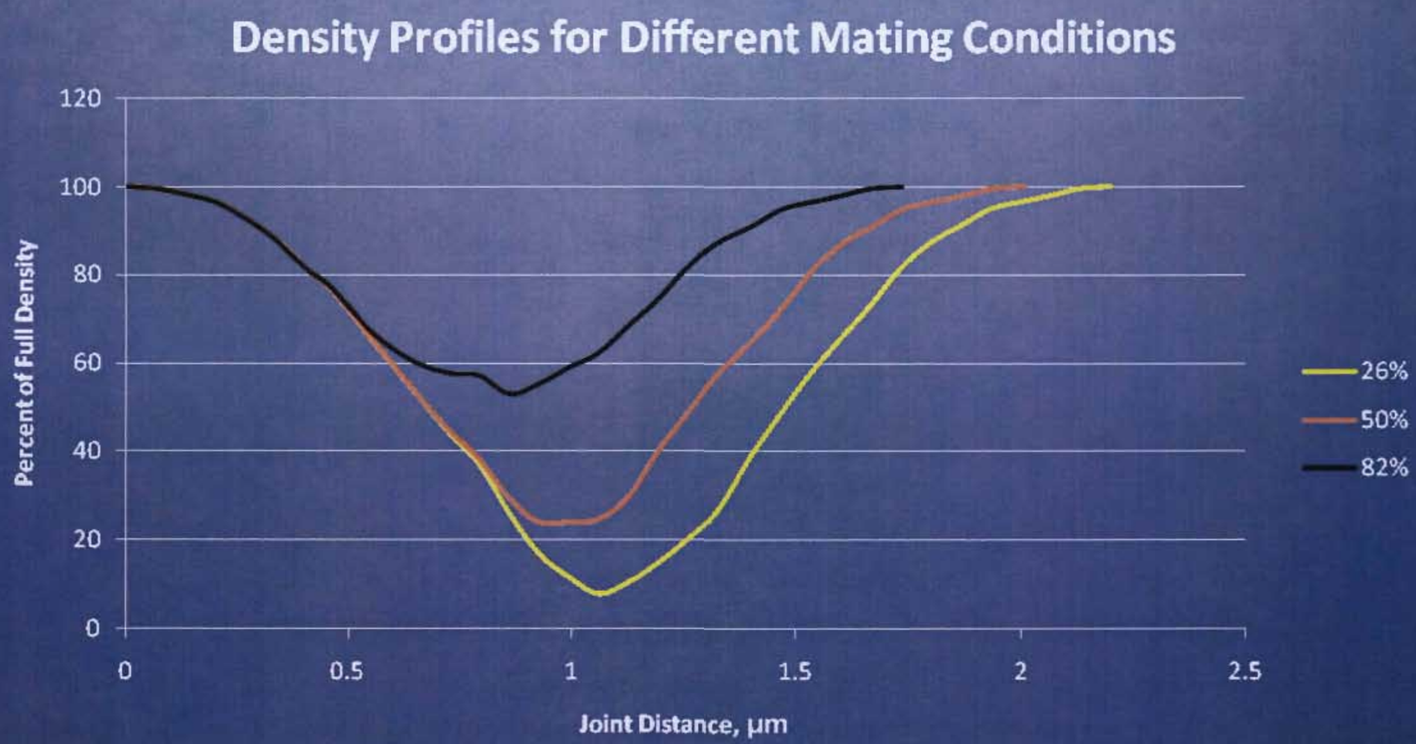
- Rms roughness = 91 nm

Bearing Area Ratios Combined to Estimate Density Profile





Density Profiles for Different Mating Conditions



Conclusions

- Produced surfaces with specific Power Spectra
- Bearing Area Ratio used to functionally characterize part thickness when surface roughness is significant portion of thickness
- Simulation of surfaces helped estimate effective density profile at joints
- Simulations useful to understand factors in producing surfaces
- Continue simulation development, and measurement of effective density profiles