

Direct Metal Laser Melting

Analyzing Surface Roughness

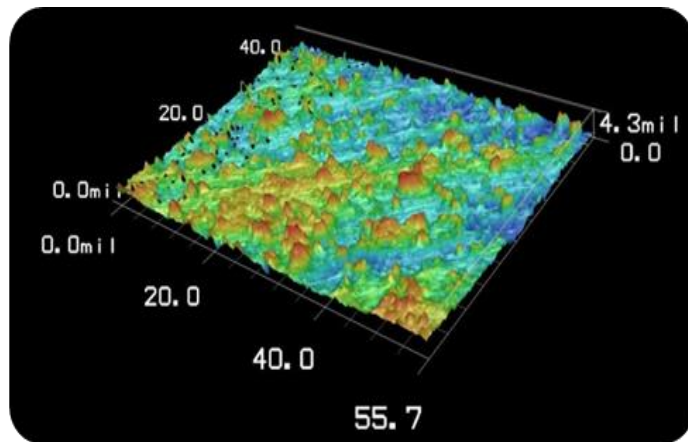


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Introduction

Laser Additive Manufacturing offers GE many opportunities for improvements in efficiency, cost, and time.

Roughness is a critical feature in metal 3D printing as it is related to a part's fatigue life.



Application to Turbine

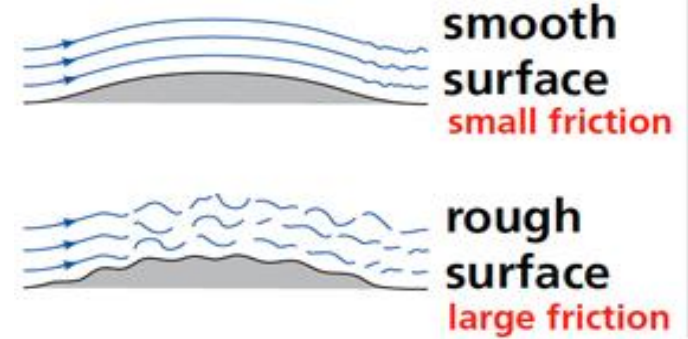


BUSINESS CASE FOR 3D PRINTING : VALUE ADDITION

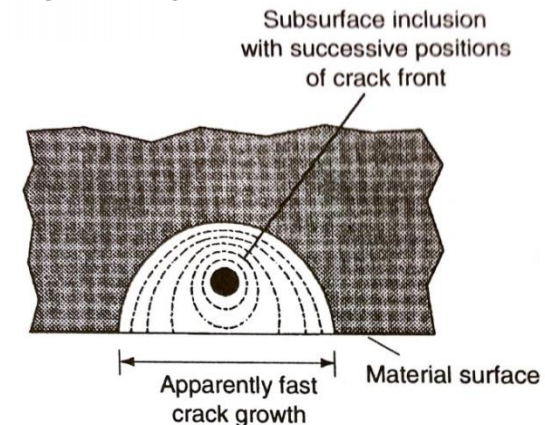
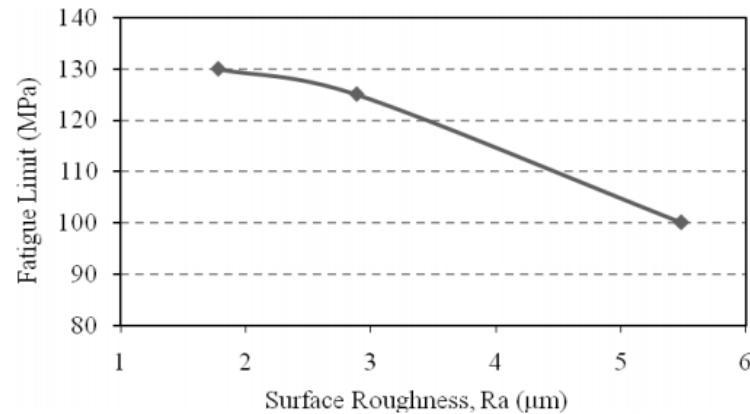
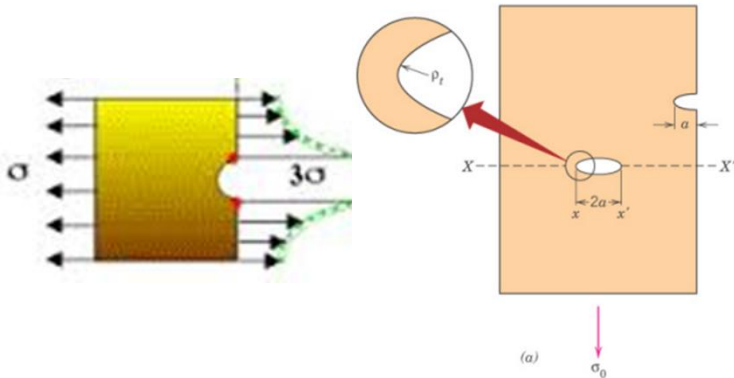
- Potential for advanced Heat Transfer and Fluid Dynamic features.
- Rig Test (Design & Test) – *NTI Speed*
- Production – *NPI Speed*

Why is Surface Analysis Important?

- **Airflow:**
 - Reynold's number – Turbulence
- **Failure:**
 - Stress Concentration -> Crack Propagation -> Fatigue

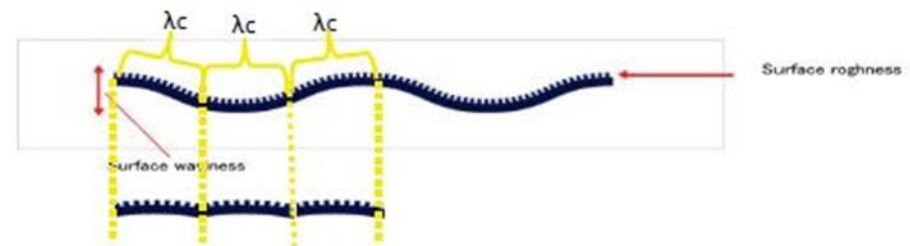
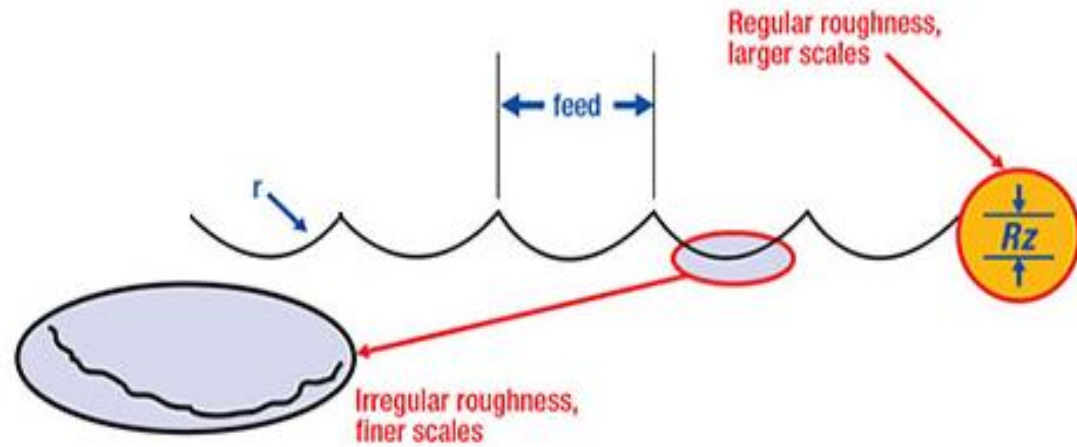


$$\sigma_m = 2\sigma_0 \left(\frac{a}{\rho_f} \right)^{1/2}$$



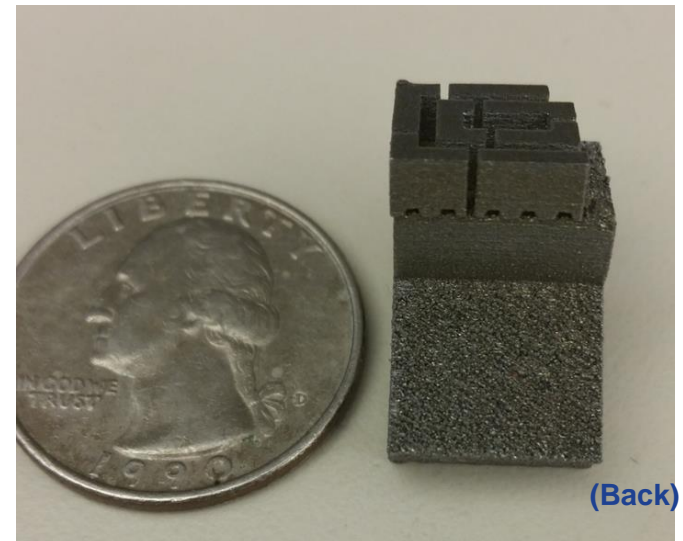
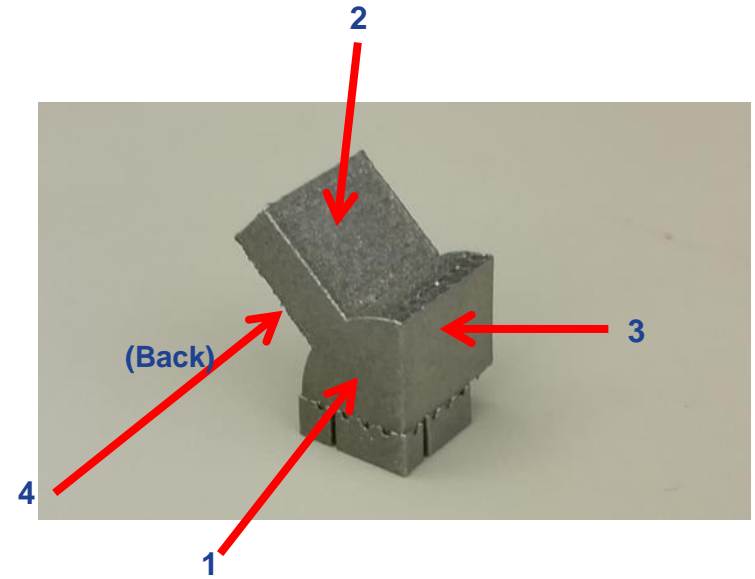
Reading Roughness

- Waviness = Macro-roughness
 - *Flow*
- Roughness = Micro-roughness
 - *Cracks*
- **Correct parameters must be employed based on application of interest**
 - Cut-off filters
 - Scan Length



Experiment:

- DMLM Co-Cr-Mo
- Printed with varying angle (30°-45°)
- 4 Surfaces
- Measured with Stylus and Laser
- Compilation of Vertical, Horizontal and Area scans.



Comparison of Laser to Stylus

Pros and Cons

Stylus Profiler

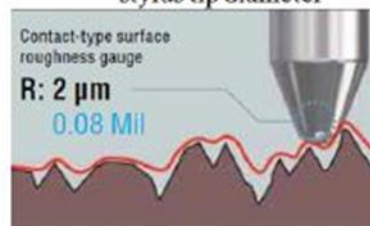
- Prone to directionality
- Tip does not get full detail
- Single Line Scan
- **Inconsistency** (Tip damages and damages sample)
- Price
- Ease of Use
- Quick (When comparing with single measurement)

Laser Profiler

- Affected by reflectivity
- Small Scan Area
- Software
- Calibrated from Stylus
- Too many parameters
- Detailed Information
- Multiple Simultaneous measurements
- Many Many features

Stylus Profilometer

3. Resolution is limited by stylus tip diameter

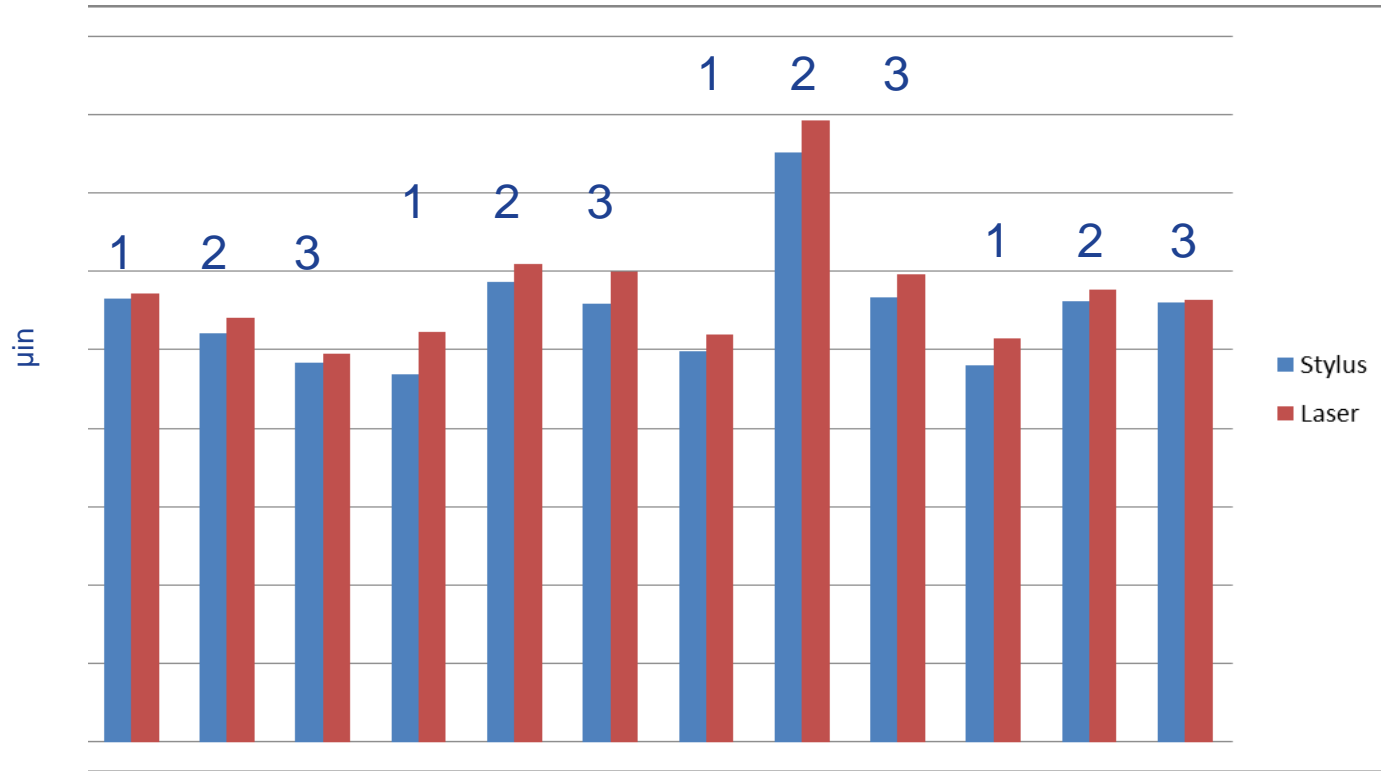


VK

3. Small beam-spot laser



Results and Comparison (X represents average of all results)



True Mean as Single Population (Surf: 1, 2, 3)

Laser: $(X + 12.2) \pm 21.7$ (95%)

Stylus: $X \pm 21.1$ (95%)

Back Side (4):

Unreadable with Stylus

Gage R&R

%R&R_{Laser}: 19.5%

%R&R_{Stylus}: 28.1%*

*Average of two runs and subtracting obvious Outliers

P-Test

(Does stylus mean meet target (laser) mean?)

$(X - 16.8) <$
 $(X + 12.2) <$
 $(X + 7.6)$
 (99%)

Conclusions

- Laser is more capable and more accurate
- Differences in methods for the range of roughness studied is not significant enough to account cost difference.
- Roughness of surfaces 1-3 are not significantly affected within the range of angles printed.
 - Surface 4 showed noticeable change with different angles.



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