Surface Metrology 101: Corrosion and Wear Monitoring

Atomic Force Microscopy
3D Optical Microscopy
Fluorescence Microscopy
Tribology
Stylus Profilometry
Nanoindentation

Innovation with Integrity
Outline

• Introductions
  • Overview of 3D Microscopes based on WLI
    • General technology description
    • Benefits and general applications
  • Specific Application Examples
    • Corrosion Measurement/Monitoring
    • Wear Metrology
• Summary
• **Founded 1961, Karlsruhe, Germany**
• **Headquarters today – Billerica, Massachusetts, USA**
• **6000+ Employees, $2 Billion Revenue, 90 Sites, Global Presence**
• **3D Optical Microscopy**

• **Stylus Profilometry**

• **Tribology and Mechanical Testing**

• **Scanning Probe Microscopy**
Bruker
Stylus and Optical Metrology

• Technology Leadership
  • 60+ Patents
  • 3 R&D 100 Awards
  • 6 Photonics Circle of Excellence Awards

• Manufacturing Excellence
  • Lean, six sigma-based processes
  • Rapid production ramp capability
  • Focus on industry partnership

Bruker NSD SOM is part of Bruker Materials (BMAT), a division of Bruker
Introductions

Speaker

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Stylus and Optical Metrology
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- Joined Bruker 2011 (~3.5 years)

- Industry experience (~17 years)
  optical engineering, fabrication and metrology

- Earned Ph.D. working in private sector metrology capital equipment
  (instrument design/assembly/test)
Who Will Benefit?

*Intended Webinar Audience*

- People interested fast, non-contact method for looking at corrosion, pitting, wear on metal or other parts (vs. gravimetric or SEM type studies)

- Those unfamiliar with 3D microscopes based on WLI will gain understanding of this technique for quantitative surface measurements and imaging capabilities

- Those already familiar with 3D microscopes based on WLI — introduced to some example applications where the technique may be new
Outline

- Introductions

- **Overview of 3D Microscopes based on WLI**
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- Specific Application Examples
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  - Wear Metrology

- Summary
3D Optical Microscope
*Bruker - White Light Interference (3D WLIM)*

- Scan special objective in a predefined fashion through focus
- CCD camera captures intensity changes over multiple frames
- Best focus determined from multiple images of captured intensity via mathematical algorithms
- Technique based on *interferometry* which provides excellent resolving power along the scan axis
Demonstration of 3D Optical Scan

Step Height Measurement

Step Height Sample

Live Video
3D Microscope Surface Imaging

What do the Images Look Like?

Images can be displayed as a color look up table (e.g., red high, blue low)

...or displayed in greyscales to look like SEM as well
Benefits and Applications
Why?

3D Optical Microscopes provide...

- Fast, accurate, GR&R capable metrology
- Non-contact, non-destructive
- Vast array of analyses
- Stable, operator independent data

Electronics
Orthopedics
MEMS
Functional surface + texture metrology
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Costs of Corrosion
Areas of Impact – Major Costs

Corrosion important in...

- **Structural Infrastructure Management**
  - Buildings, Bridges, Railways, etc...
- **Large Commercial Asset Management**
  - Trucks, Excavation equipment, Mining, etc.
- **Automotive, Aerospace, Military**
- **Turbines**
  - Wind, Jet
- **Pipelines**
  - Oil and gas, refining
  - Natural Gas Condensate
  - Liquid Petroleum, water
- Monitoring to understand prevention – surface metrology can help!

2002 NACE Costs of Corrosion Study – Still relevant today

Direct Corrosion Costs: $276 billion (3.1% of U.S. GDP)

NACE 2013 Information

1998 U.S. GDP ($8.70 trillion)
The impact of corrosion on the U.S. economy.

NACE 2013 Information

Corrosion Costs the Refining Industry $7.68 Billion Annually.
We can help you change that.

Corrosion Control in the Refining Industry Course
Pipeline Coupons

- A “coupon” is placed through (or could be) a section of pipe that is removed to establish service requirements
- Coupons placed in pipeline (using ‘hot-taps’) and measured for corrosion
- Conservative estimates approximately ~5000 of these pulled every day to be measured (global basis)
Pitting Corrosion Monitoring

**Current Methods**

**Currently using**

- Weight loss – for global corrosion, slow (need to remove large material to get accuracy)

- SEM – for quantifying corrosion pits, time consuming, small area sample

**Industry Challenge**

- Need rapid and sensitive measure general/global corrosion
- High precision corrosion pit measurement
- Automated throughput of multiple sample measurements
**Corrosion Metrology**

*Example Corrosion Study – 3D WLIM*

- Experiments range from salt water baths for petrochemical industry to slight atmospheric contamination in MEMS

- To accelerate experiments, expose surfaces to dilute Sulfuric Acid

- Aluminum coupon and 22 different surface texture regions on a GAR strip were examined

Four of the 22 surface regions studied for corrosion

*GAR strip is a Precision Reference Standard, rectangular in shape, (2 1/2” x 3 3/4”), made of electroformed nickel and is rhodium plated for superior abrasion resistance. It is a calibration block (on the market) with actual patch mean values of low and high micro-inch surfaces and certified by the National Institute of Standards and Technology (N.I.S.T.).*
Corrosion Metrology
Example Corrosion Study – 3D WLIM

RMS roughness changes from 1.3 to 3.5 µm
Corrosion with different starting surface finish type and level examined

Overall rougher surfaces did not corrode significantly more in static environment

Some initial defects seen to foster pitting and corrosion
Various surface finishes examined for rate of corrosion over longer time period

Similar trends on increasing roughness and randomness of the surface

Rougher surfaces corroded to greater degree
Corrosion Study
Results Correlate to Weight Loss

• Automated analysis finds corrosion pits to quantify size, volume

Image of flat coupon with corrosion pits

Results can correlate to gravimetric techniques

“Optical measurement of uniform and localized corrosion of C1018, SS 410, and Inconel 825 alloys using white light interferometry”
Tribology and Wear
Accurate Quantitative Metrology is Key

• Science of mechanisms of friction, lubrication, and wear of interacting surfaces that in relative motion
  • A very old science, historically quantified using Gravimetric methods (weight changes determine material loss)
  • Literally, “the study or science of rubbing”

• Quantification of these processes is essential for many industries
  Automotive, Aerospace, robotics, data storage, Petroleum, MEMS, Biomedical, Chemical, Materials, precision machining, Microelectronics and more

• Current development studies and process/quality control goals require higher performance as manufacturing demands increase
Tribological Study: Drills
Examination of Wear of Drilling Bits
Tribological Study: Drills
3D Images Allow Study of Drilling Process

- Examine surface properties of bits of varying material/coatings drilling the same surface
- High speed steel, TiCN, SiC, TiN bits used to drill into 6mm anodized aluminum plate
- Head, inside surface, and forward surfaces examined throughout the process
- Many parameters examined to obtain meaningful data
Tribological Study: Drills

3D Images Allow Study of Drilling Process

- 30 holes drilled with each type of bit, using same machine, plate, and setup
- SiC bit showed least amount of material re-deposition, HSS the most
- Edge chipping, radius of curvature changes overall insignificant for this number of uses

- TiCN
- HSS
- TiN
- SiC
Further Example, Induced Wear

Wear on PEEK Material
Further Example, Induced Wear
Wear on Carbon-PEEK Material
Summary

- Introduced Bruker BNS-SOM, 3D Microscopes based on WLI
- Gave general benefits of technology and brief overview of applications
- Discussed specific applications for corrosion and wear metrology

Questions?
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