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HARVEY MUDD COLLEGE

Modification of Abrasiveness of Additive Manufacturing (SLA) Produced Components through Resin Formulation

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Clarification of Today's Talk

Modifying **Friction and Wear Resistance** of Additive Manufacturing Produced **Ceramic** Components Printed Using DLP Methods

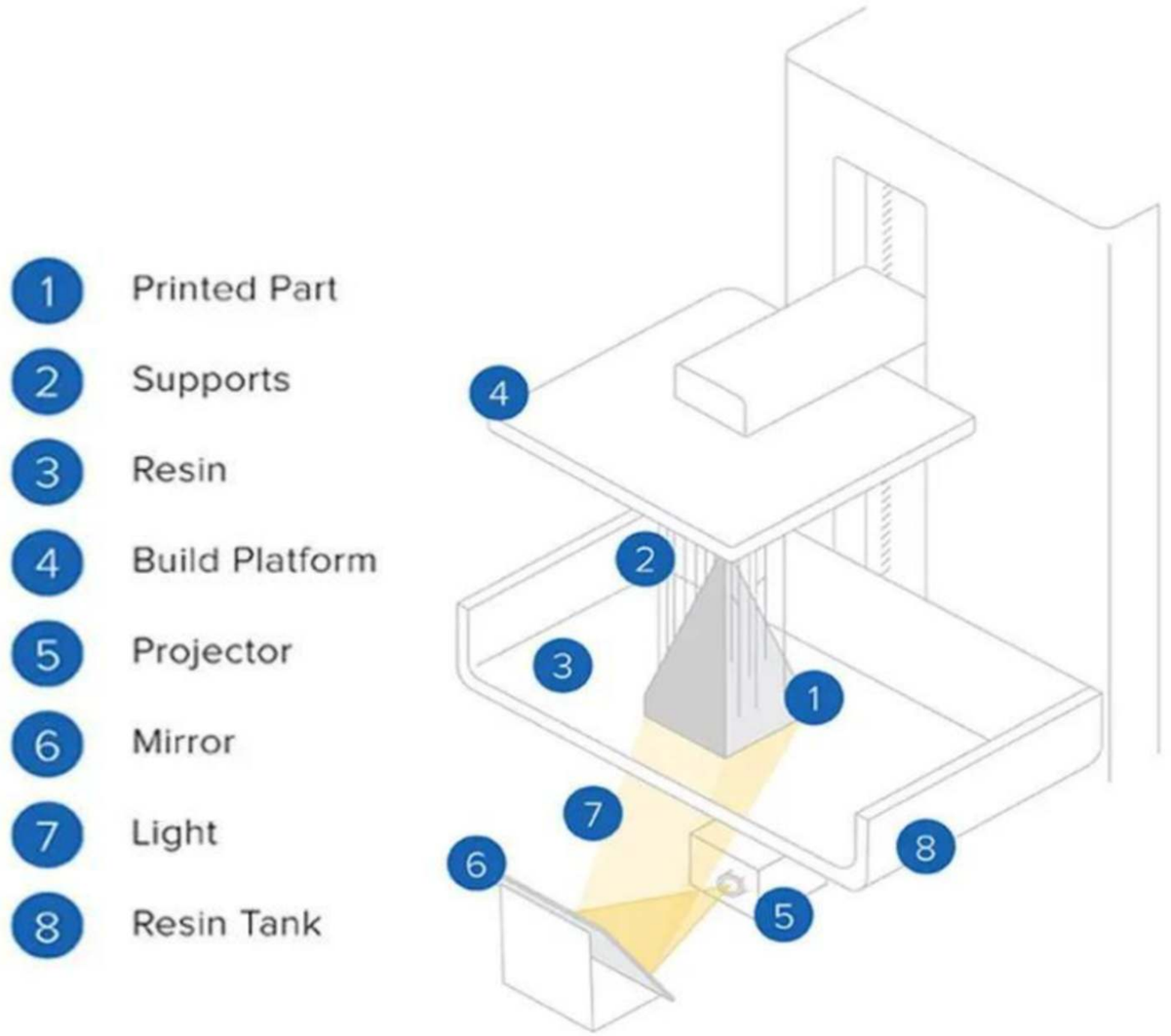
Agenda

1. About SLA Resin Printing
2. Ceramic 3D Printing
3. Challenges
4. Testing
5. Results
6. Next Steps

SLA-DLP

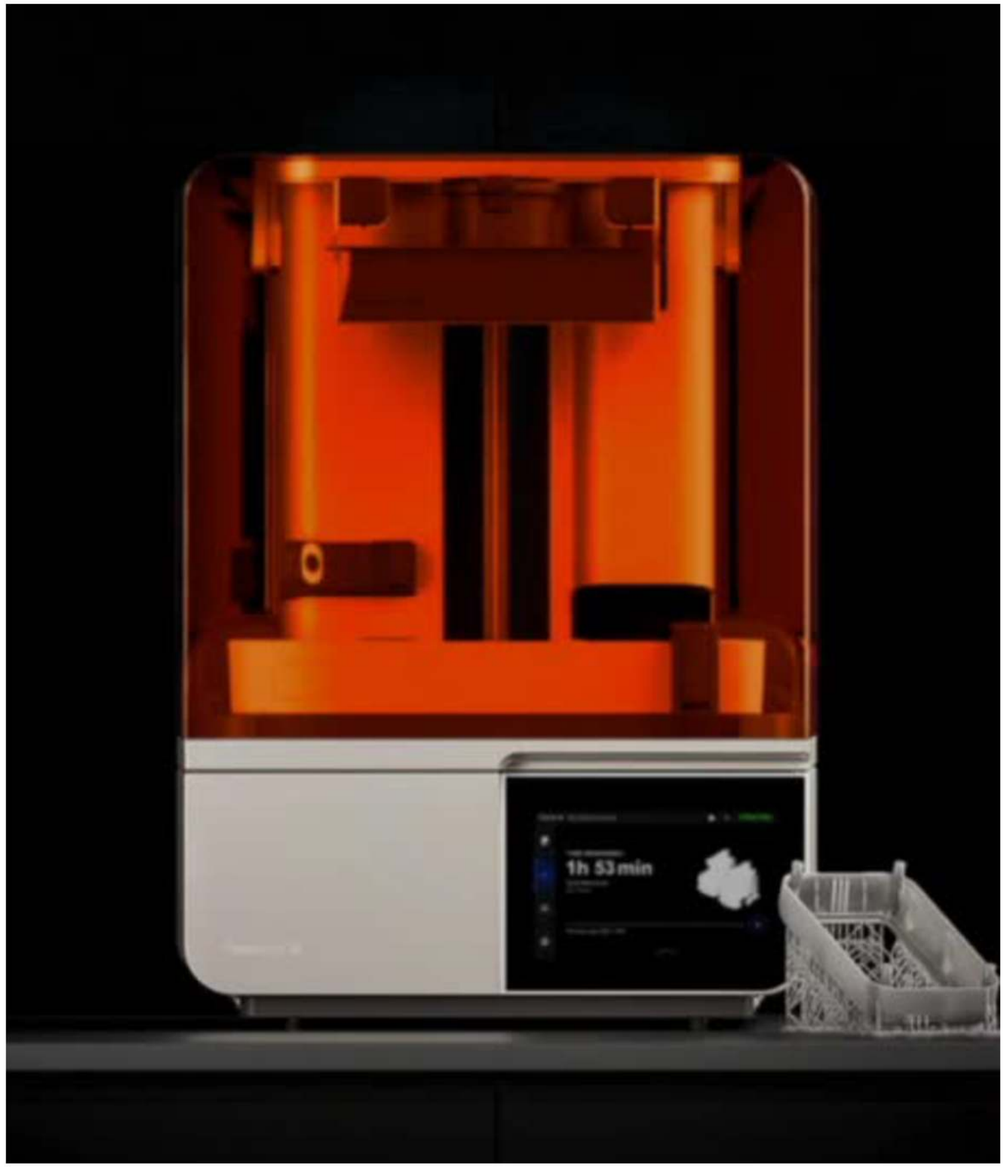
Stereolithography: 3D printing process that uses a UV laser to cure liquid resin.

Digital Light Processing: Uses a light projector rather than a laser to cure liquid resin one layer at a time



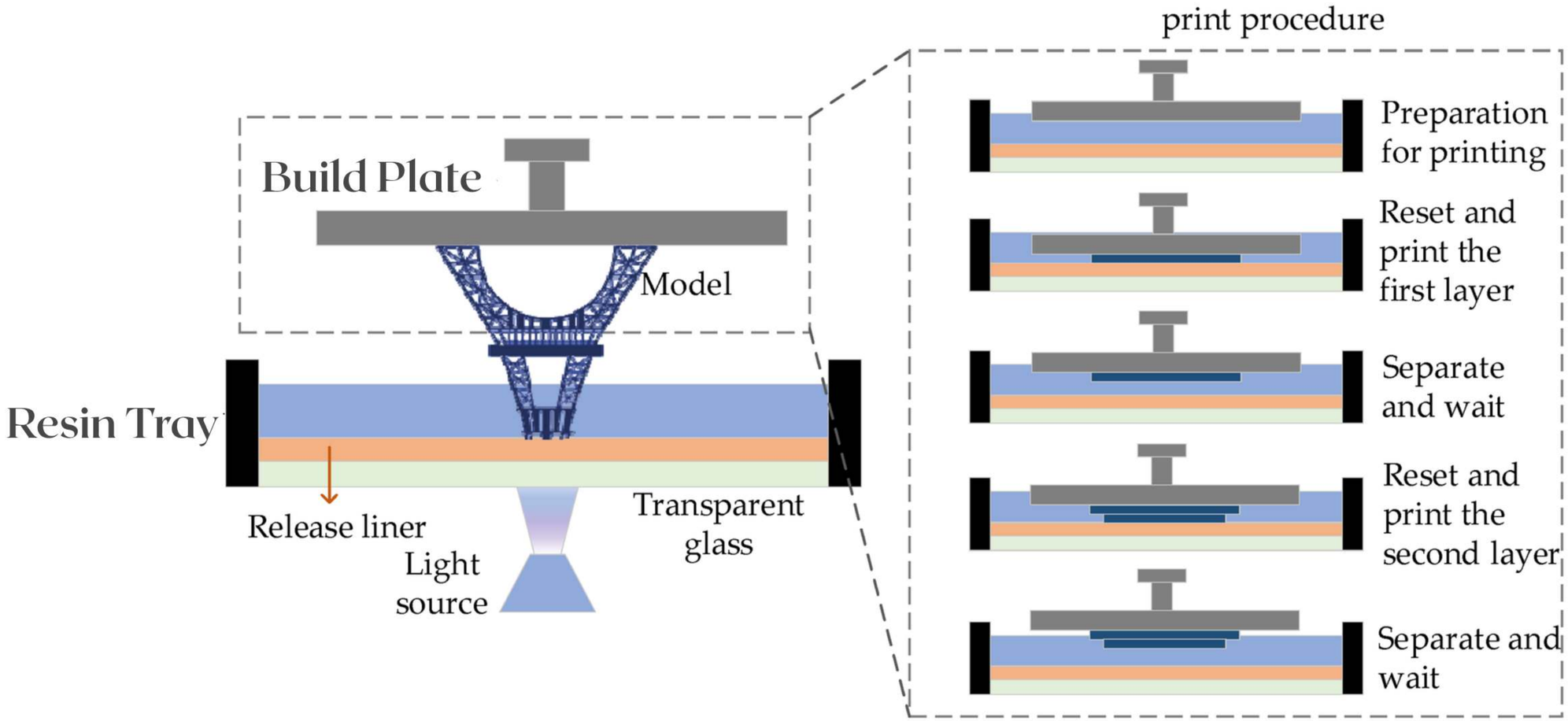
"SLA vs. DLP vs. MSLA vs. LCD: Guide to Resin 3D Printers," Formlabs. Accessed: Sep. 15, 2024. [Online]. Available: https://formlabs.com/blog/resin-3d-printer-comparison-sla-vs-dlp/

Mechanics



https://www.youtube.com/watch?v=v_3vLypJnNU

Mechanics



[Y. Wang, M. Zhang, Y. Li, and H. Liu, "Study of Forming Performance and Characterization of DLP 3D Printed Parts," Materials, vol. 16, no. 10, p. 3847, May 2023, doi: 10.3390/ma16103847.

Advantages of DLP Printing

Rapid Prototyping

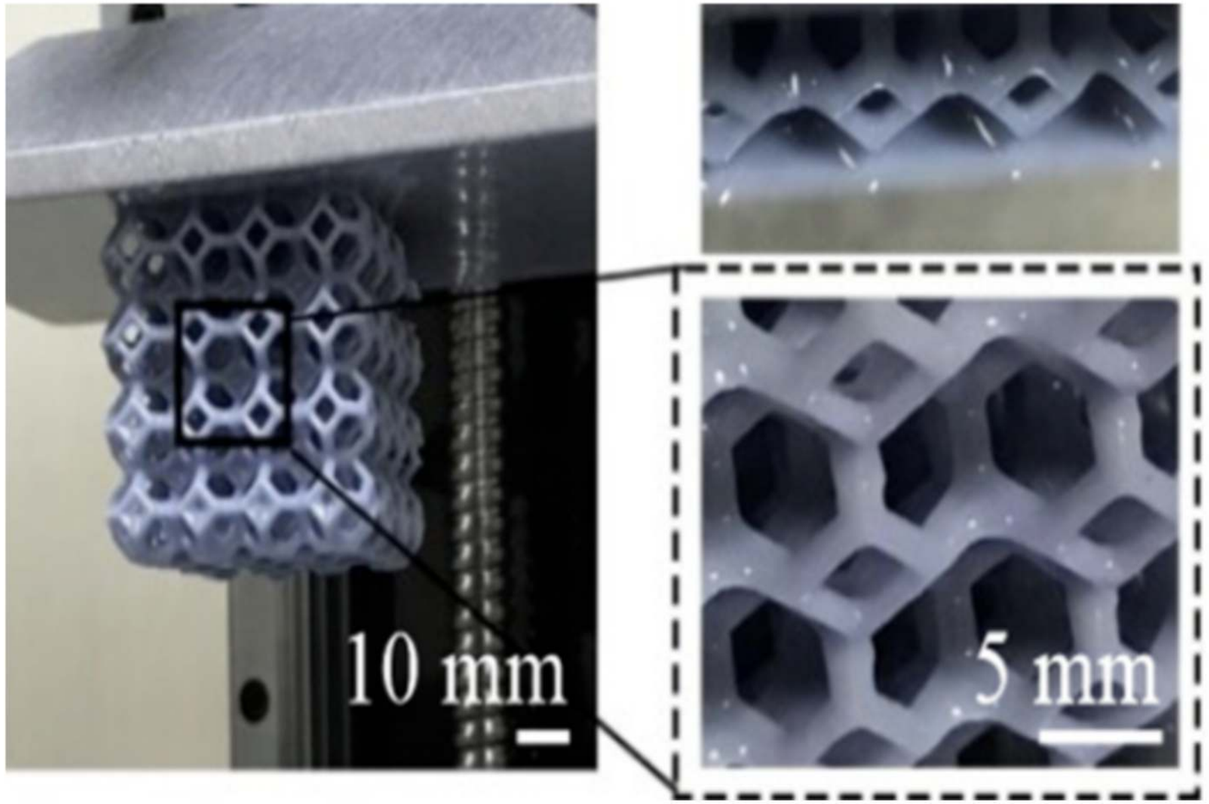
- Speed
- Complexity

Layering

- Solid vs Matrix

Feature Detail

- Minimum Layer Height 20 Microns
- Minimum Lateral Feature Size 100 Microns



Moayedi, Siavash & Zamani, Jamal & Salehi, Mohammad & Shayesteh, Mohammad. (2023). Investigating the Effect of Separation Speed and Image Cross-Section Geometry on The Separation Force in DLP Method using FEP and PP Polymer Membranes. 16. 9-17. 10.30486/admt.2023.1968925.1386.

Research Scope

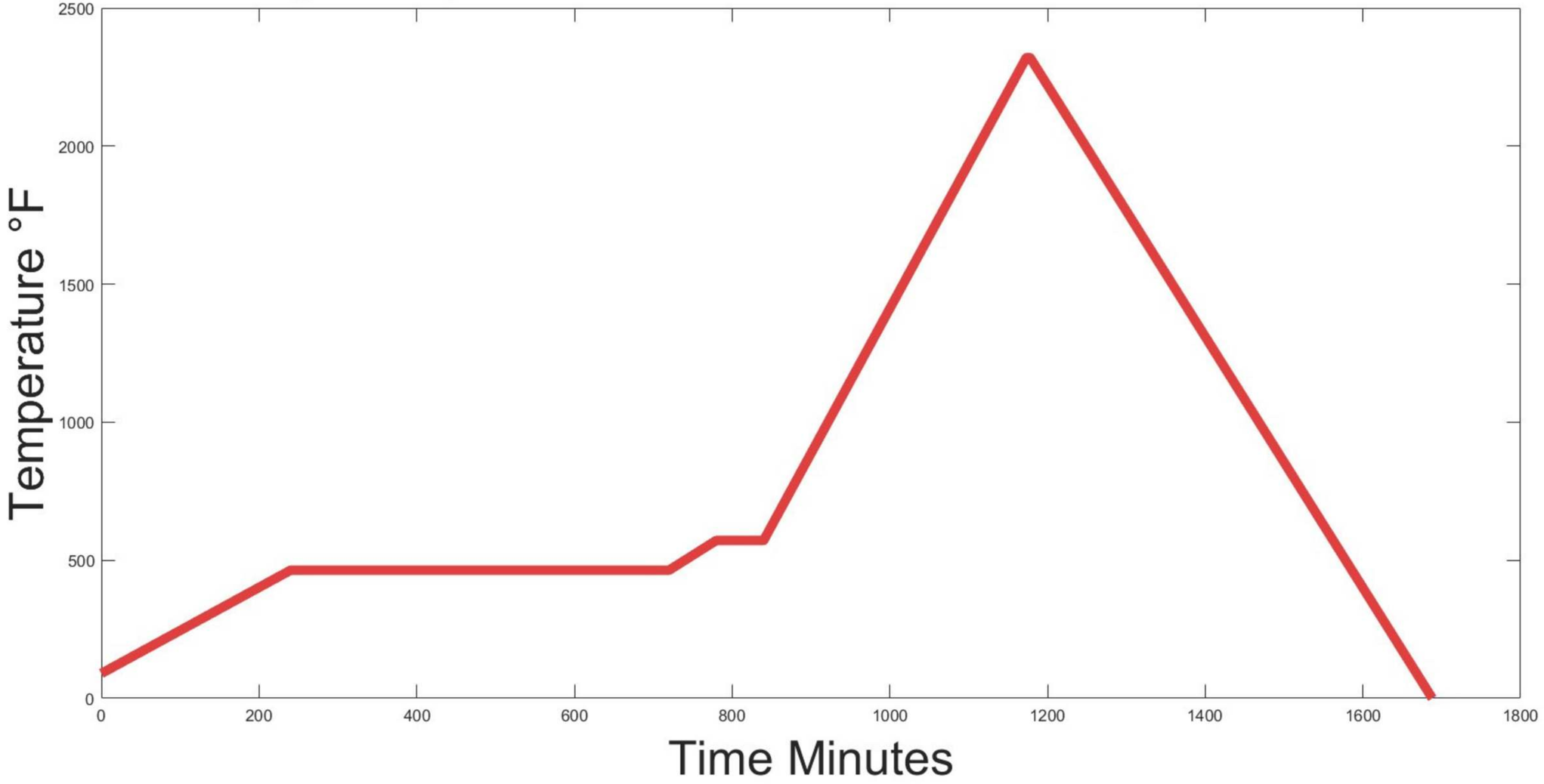
Investigate how the inclusion of SLA resin additives can alter ceramic surfaces' abrasiveness and wear resistance.

Hypothesis

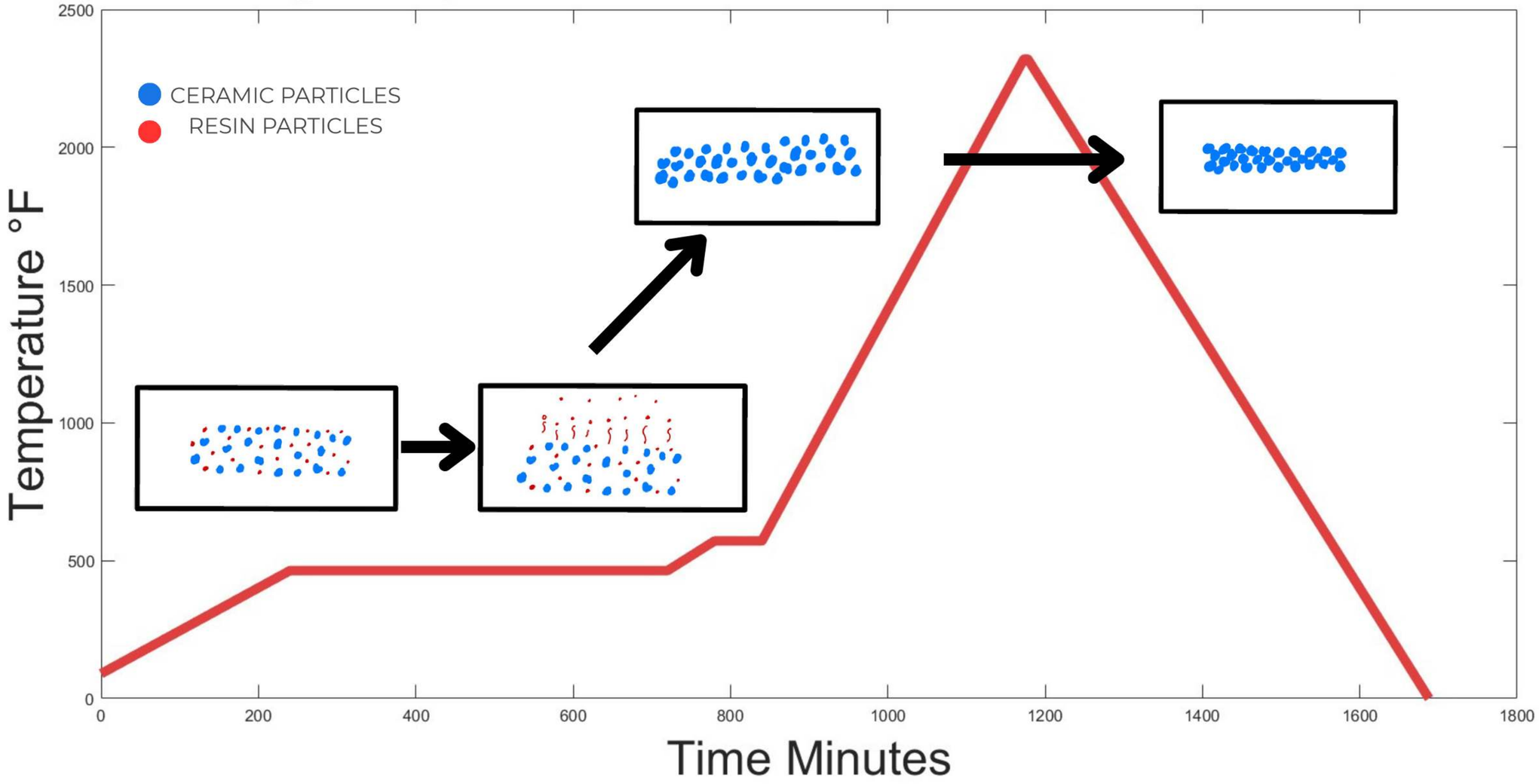
By adding a top layer of porcelain we will be able to alter ceramic surfaces' abrasiveness, friction, and wear resistance.

Ceramic Resin Printing

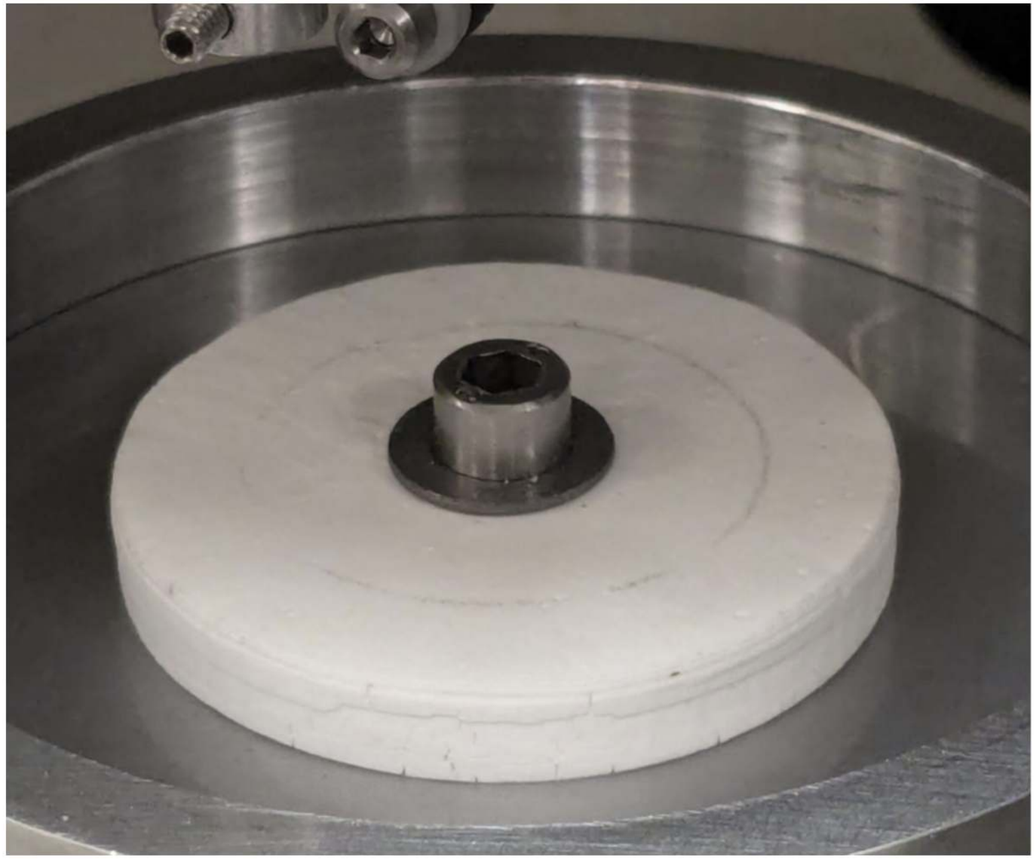
Firing Sequence for Alumina Ceramic Resin



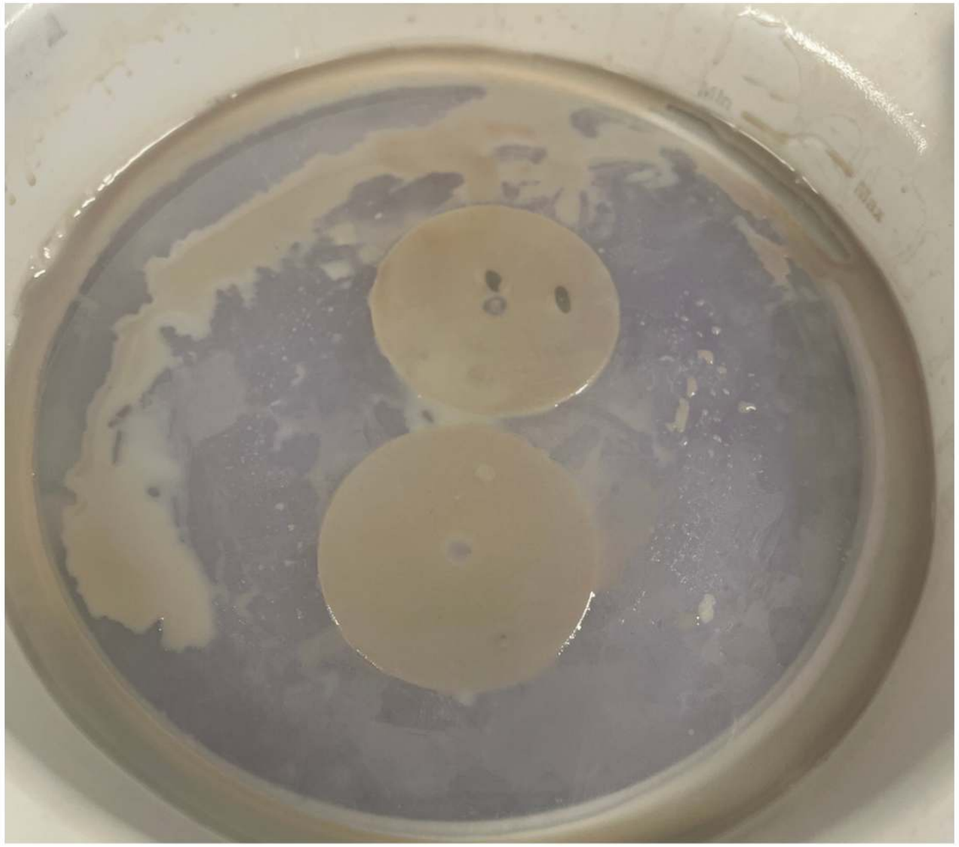
Firing Sequence for Alumina Ceramic Resin

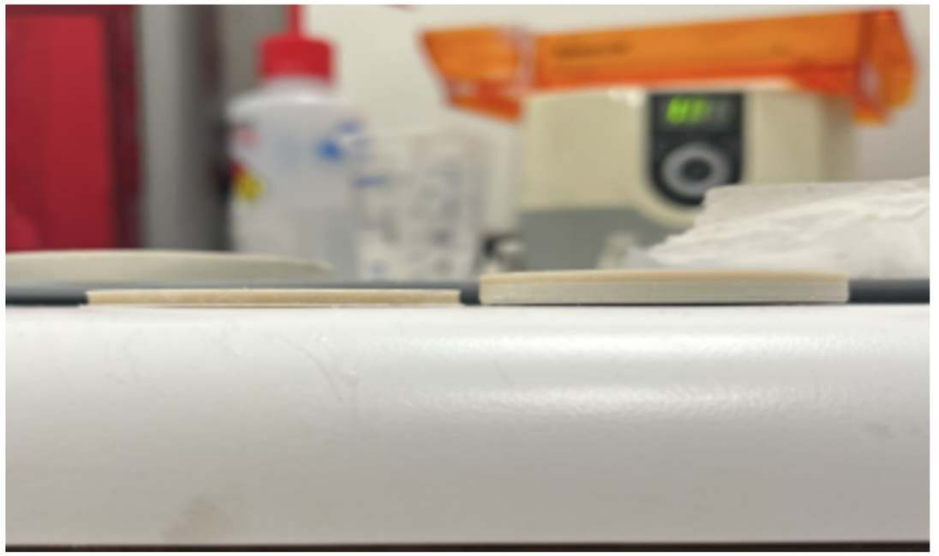


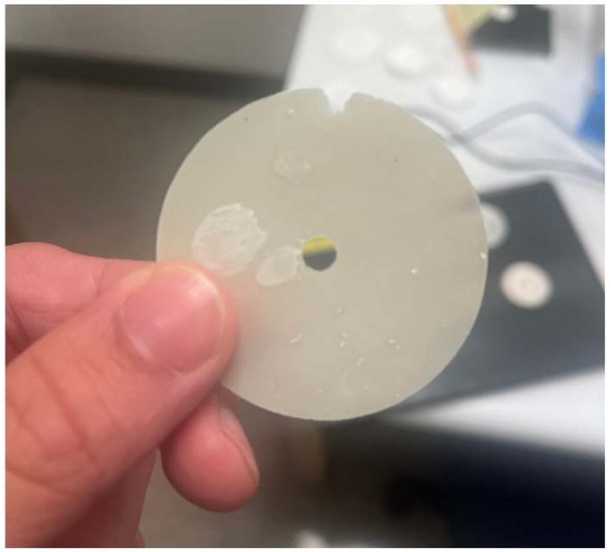
Finish Product



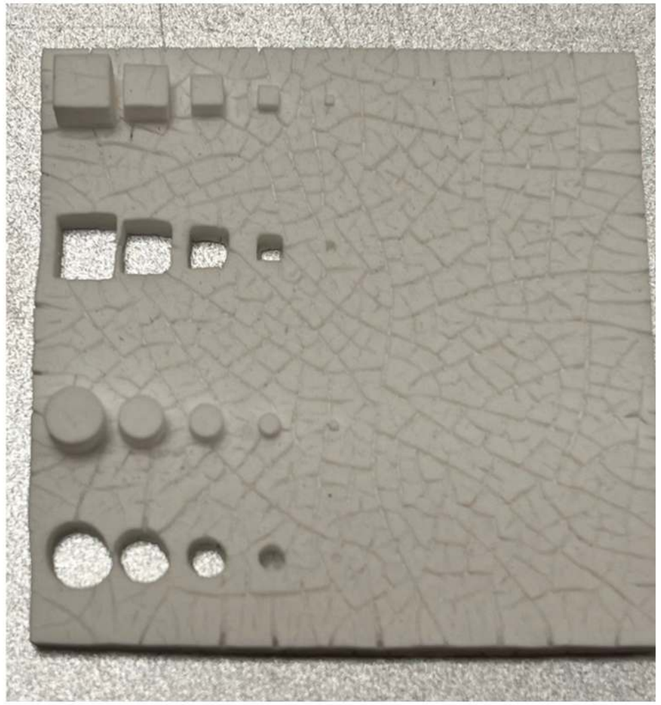
Challenges Printing







Challenges Firing



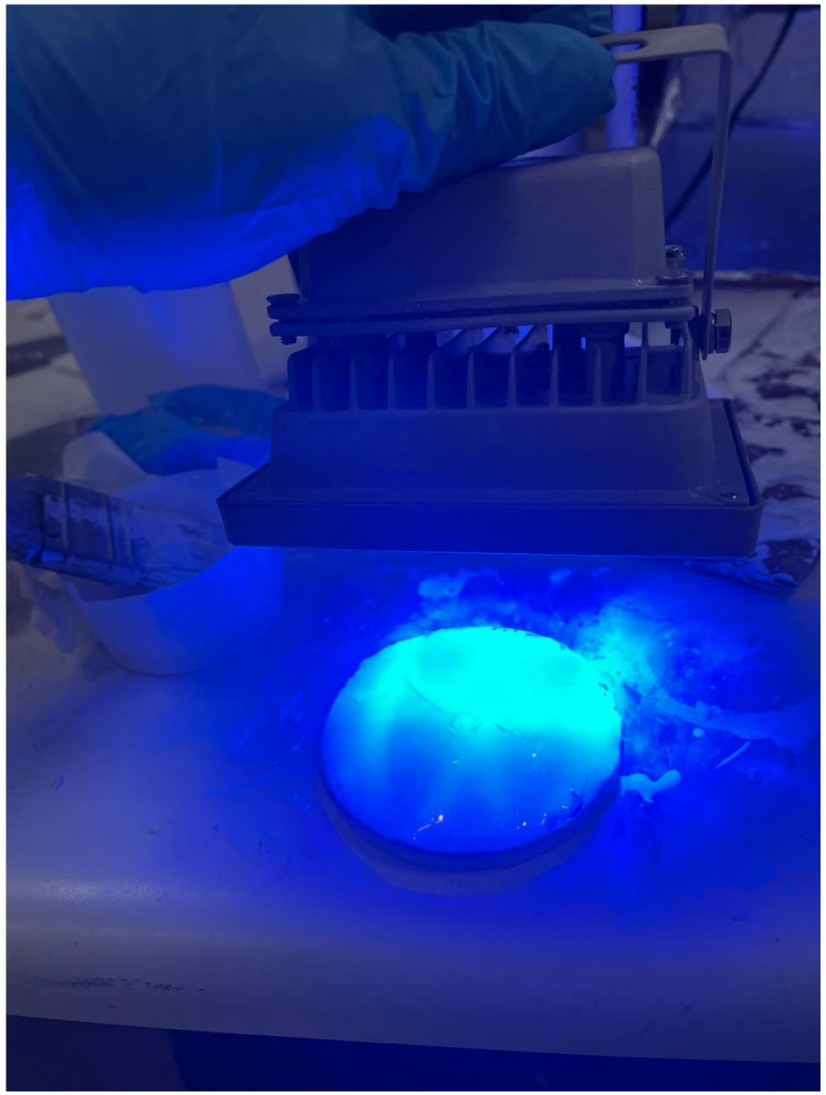
Limited Resolution

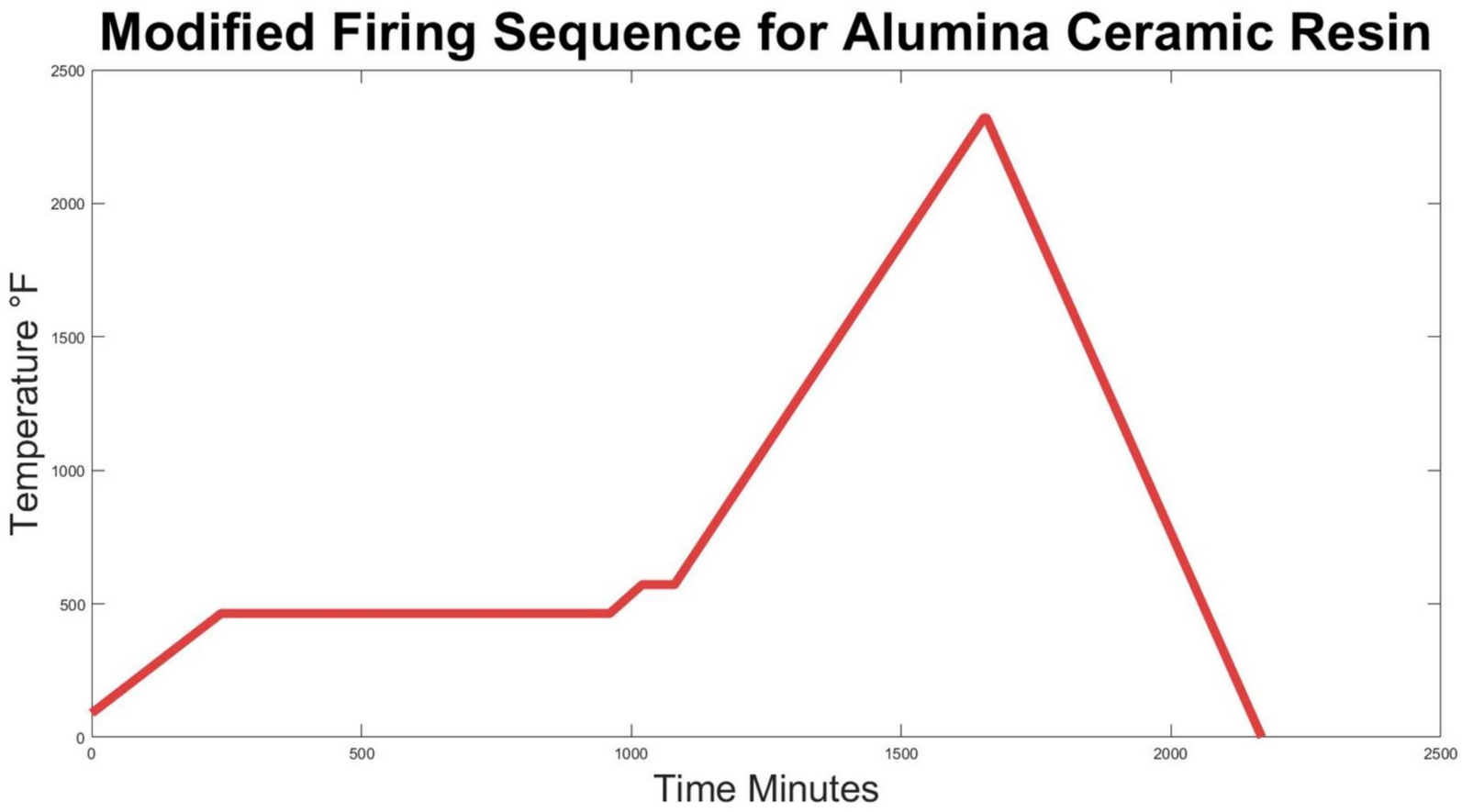
Flaking

Cracking

Bubbling

Interum Solution





Tested Disk

Al_2O_3 HRC(80-90)

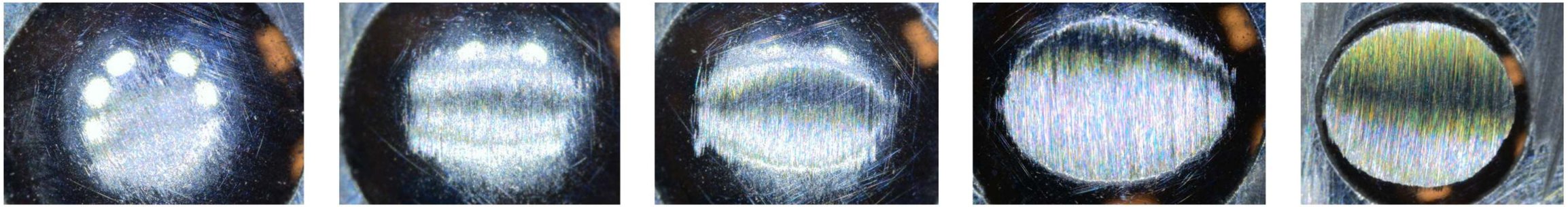
Al2Si2O5(OH)4 HRC(45-75)

Testing of Porcelain Coated and AluminaDisks

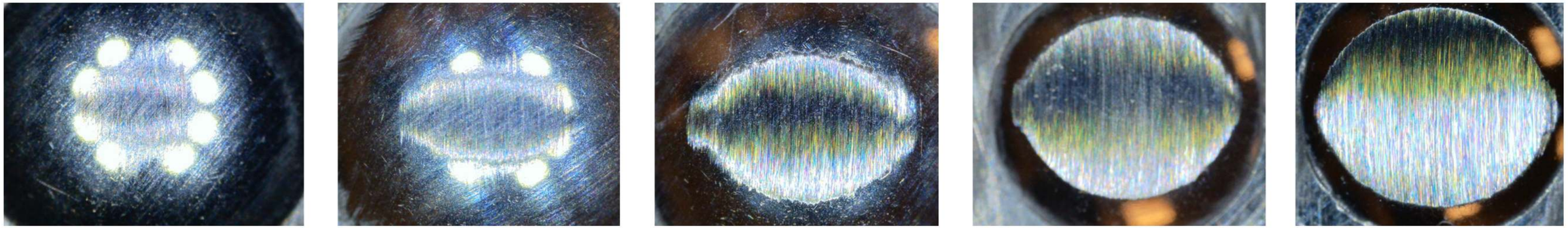
- UMT via pin-on-disk method
- Cycles in intervals of 1, 10, 100, 1k, 10k
- Tracks characterized by location and inspected through profilometers
- Steel Ball
  - Hardness: 62 HRC
  - Size: .25 inches
  - Force: 1N
  - Speed 75 mm/s
  - Dry Sliding
  - 30-40% humidity
  - 70° F

Scars

Uncoated



Coated



Wear Volume Calculations

Where R is the radius of the ball:

$$V = \pi * [\, h * R^2 - \frac{R^3}{3} + \frac{(R-h)^3}{3}]$$

h is the height of the scar given by the Pythagorean theorem:

$$h = R - \sqrt{R^2 - s^2}$$

s is the radius of the scar.

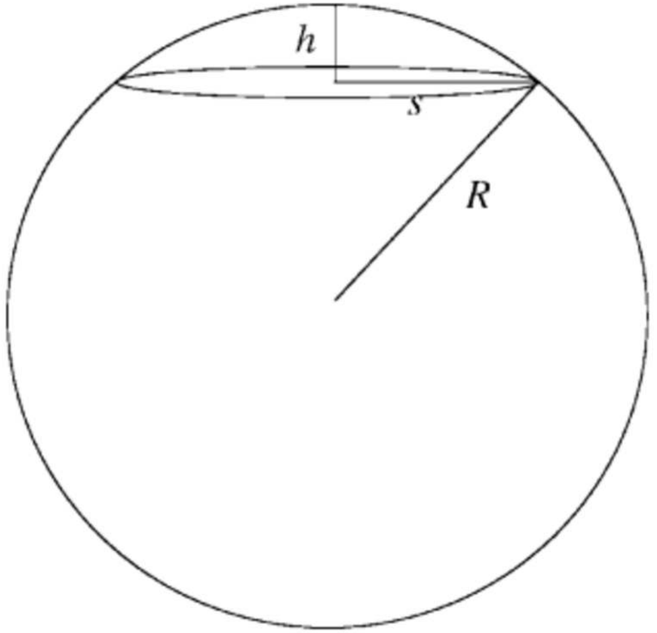
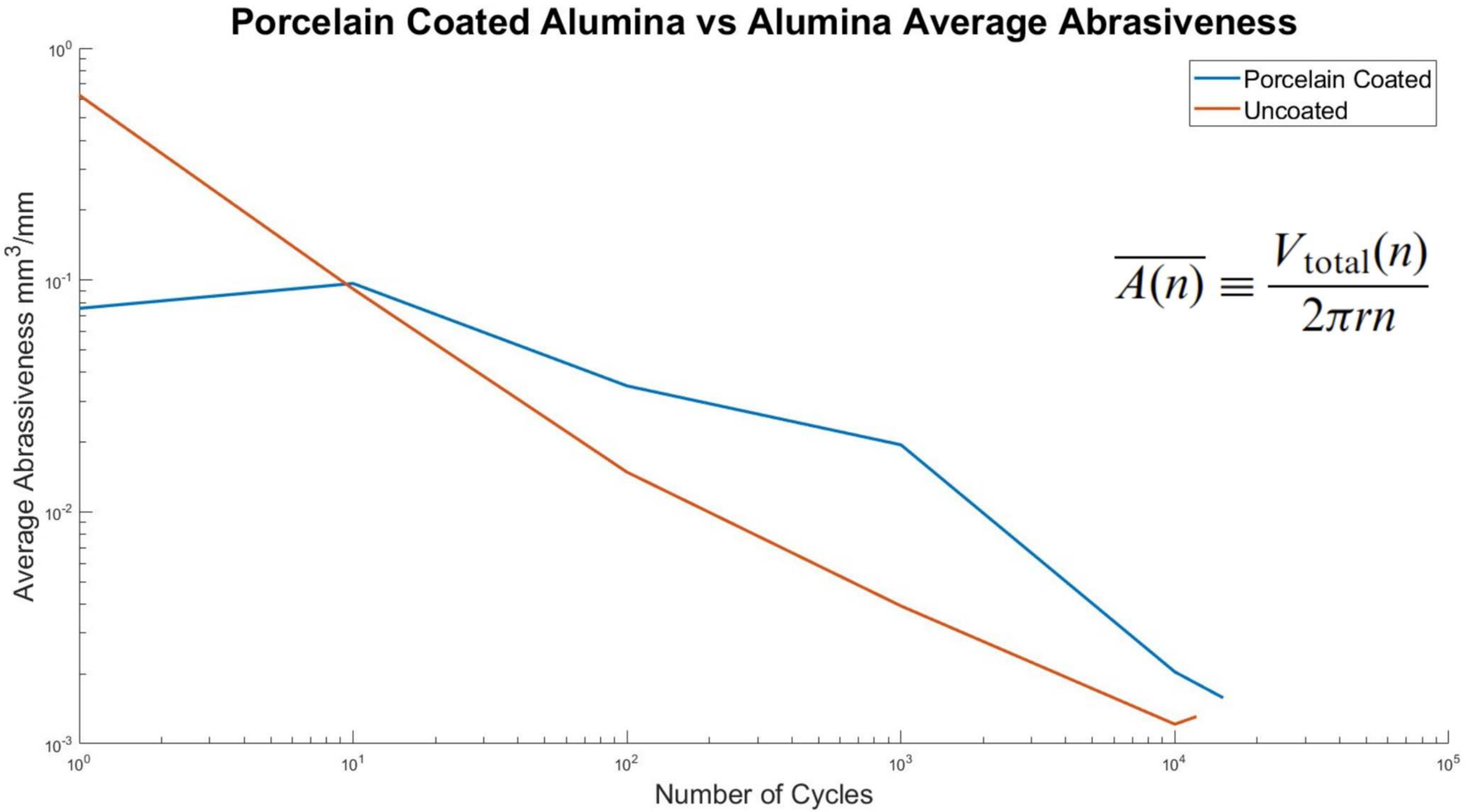


Figure 1. Schematic drawing of a ball with a missing "cap", corresponding to a wear scar.

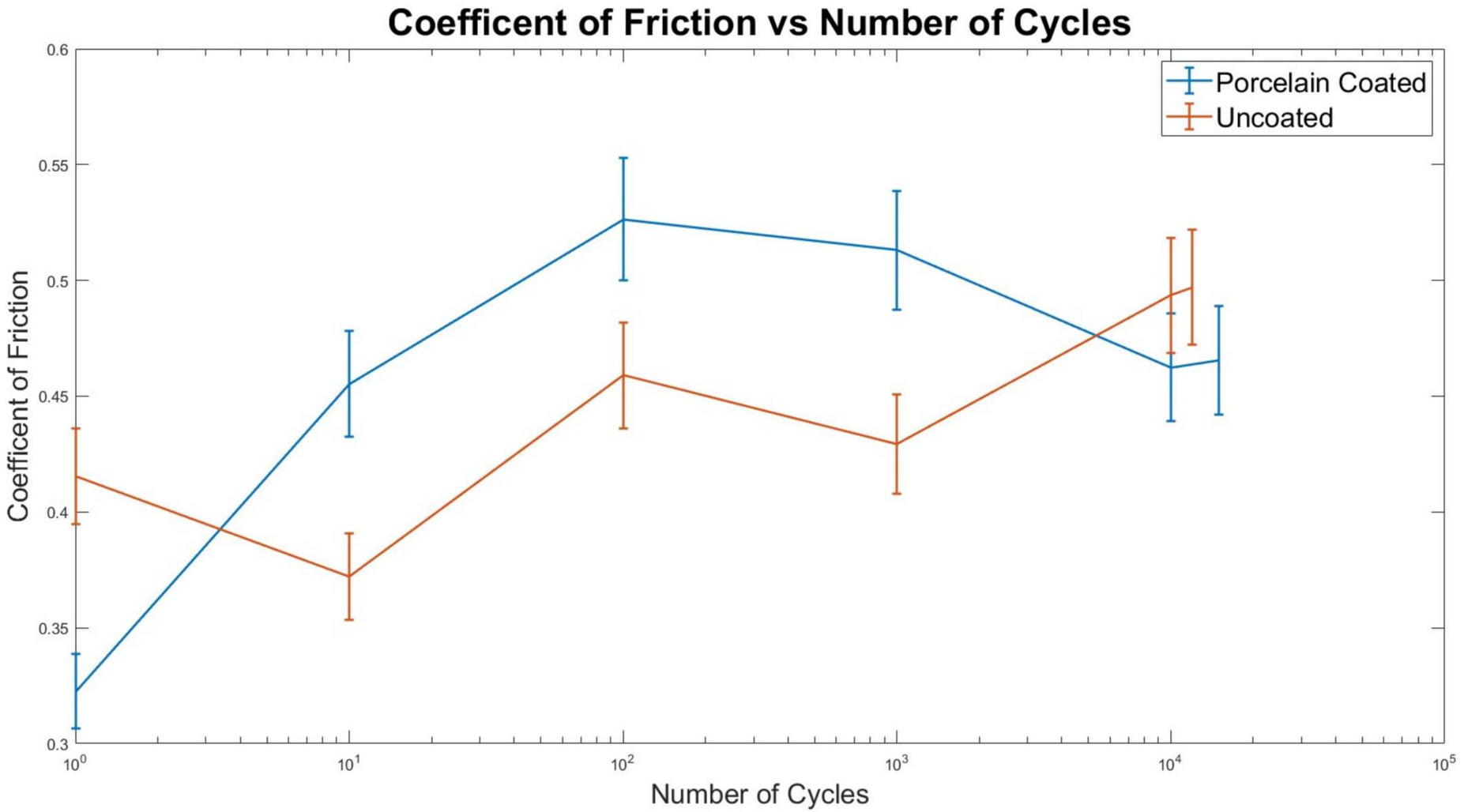
Figure from S. J. Harris and G. G. Krauss, "Improved technique for measuring the ball volume removed in a ball-on-disk test," Tribology Letters, vol. 10, no. 3, pp. 187–188, Apr. 2001, doi: 10.1023/A:1009014524815.

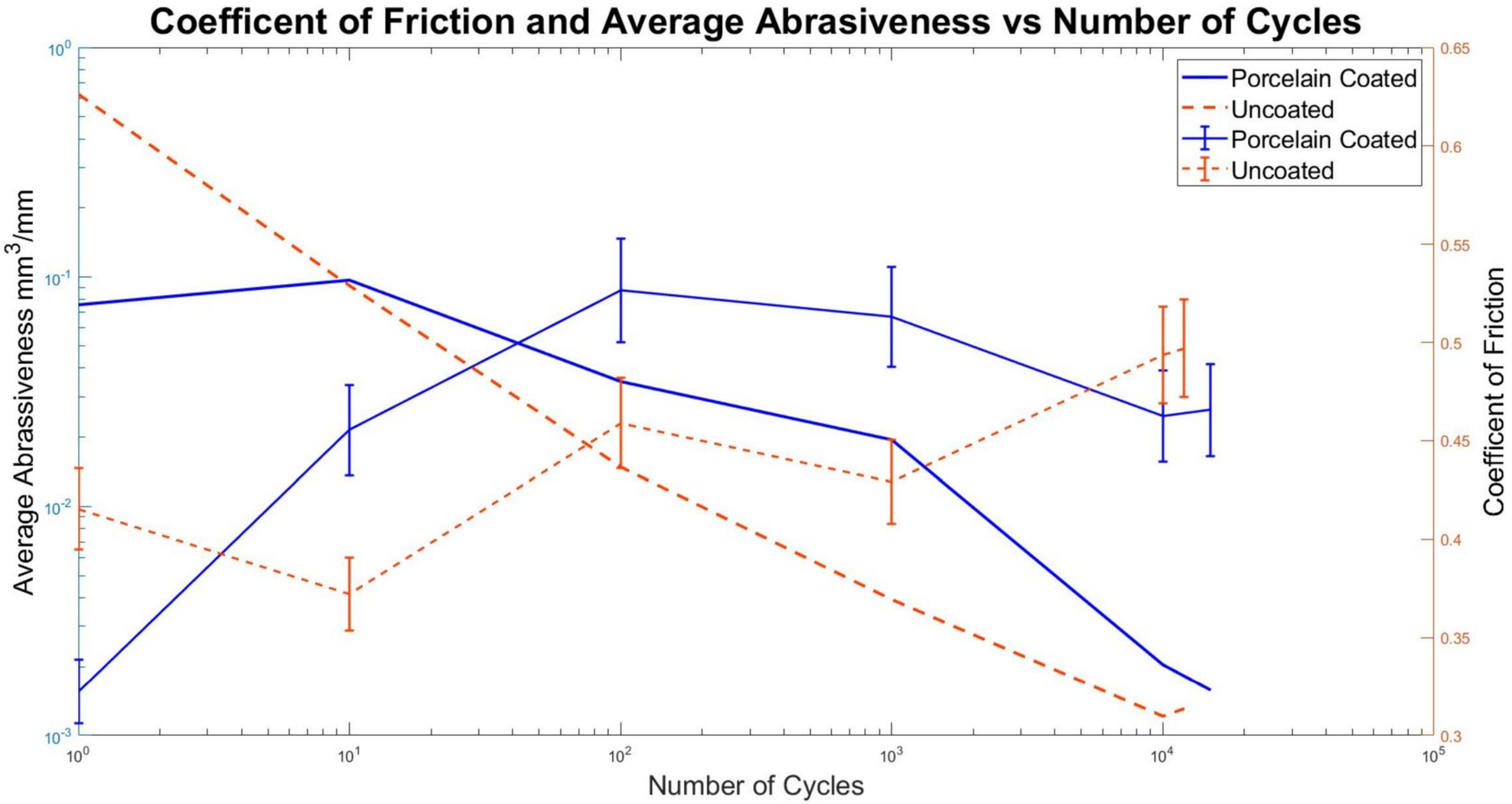
Results Average Abrasiveness



S. J. HARRIS, G. G. KRAUSS, S. J. SIMKO, T. J. POTTER, R. W. CARPICK, B. WELBES, AND M. GRISCHKE, "ABRASION OF STEEL BY CERAMIC COATINGS: COMPARISON OF RF-DLC TO SPUTTERED B4C," TRIBOLOGY LETTERS, VOL. 12, NO. 1, PP. 43–47, JAN. 2002.

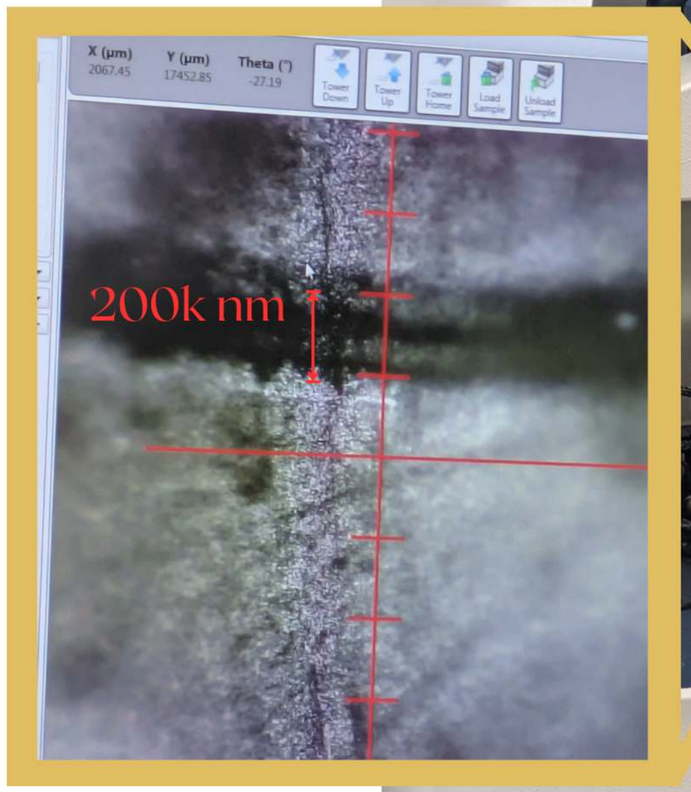
Results Coefficent of Friction

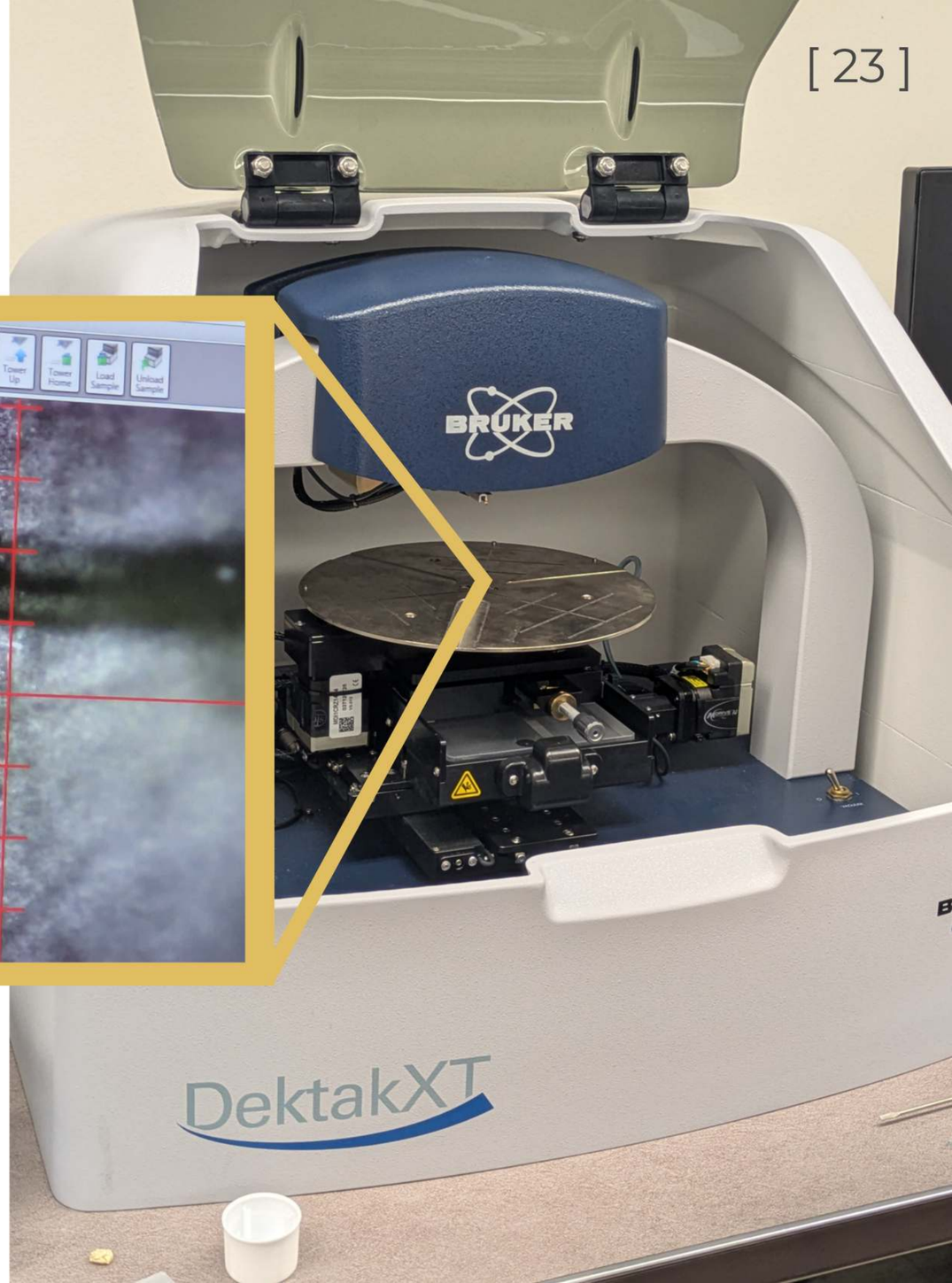



Coefficent of Friction and Average Abrasiveness vs Number of Cycles
Porcelain Coated
Uncoated
Porcelain Coated
Uncoated
Average Abrassiveness mm3/mm
Coefficent of Friction
Number of Cycles
10^0
10^-1
10^-2
10^-3
10^1
10^2
10^3
10^4
10^5
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3

Dektak About

- Profilometer that provides information on topography
  - Measures displacement as a function of position
  - Can create a height vs. 1D position graph
  - Sample moves with respect to the tip and traces a line forward
- Varied force and time across desired areas

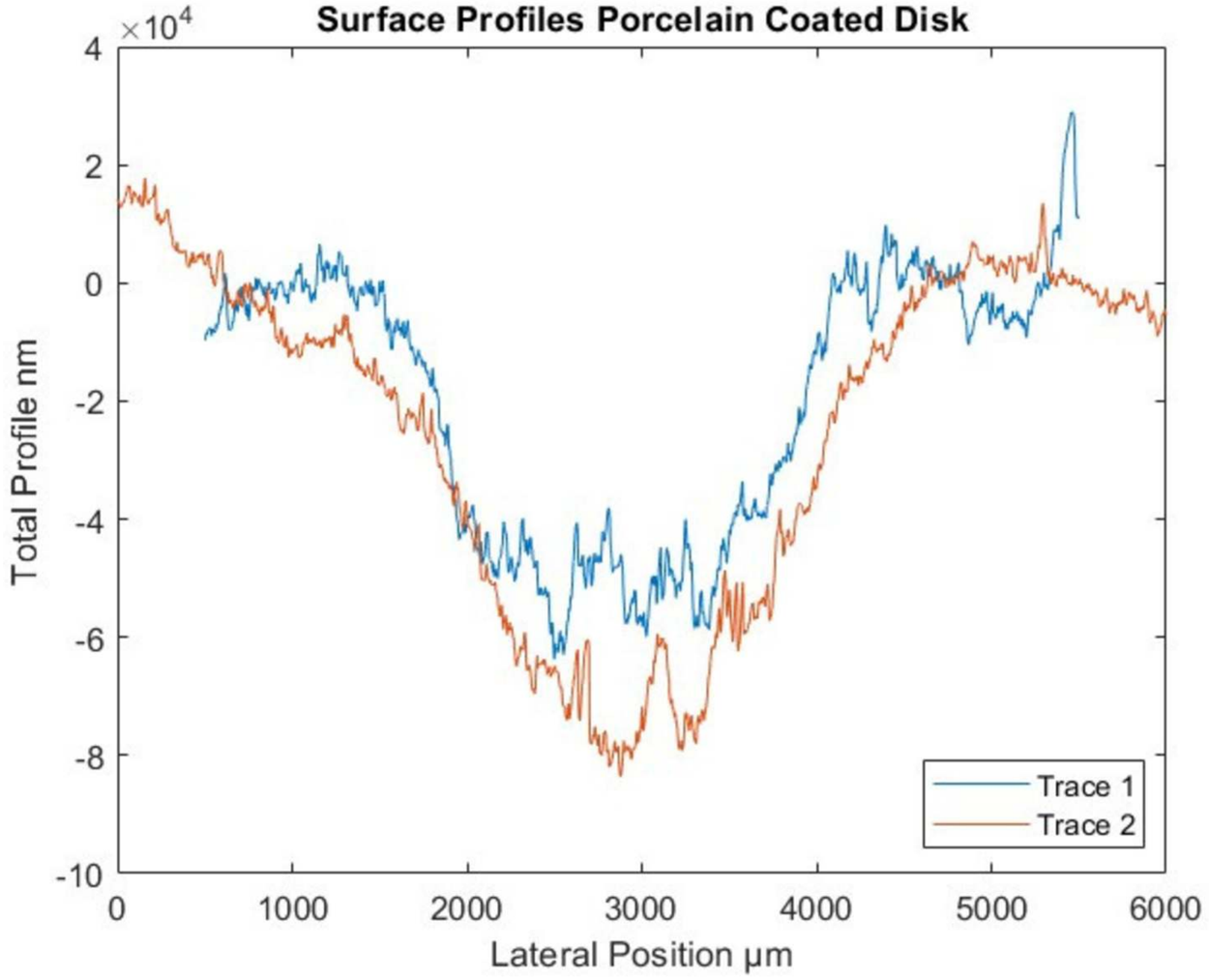




Dektak Measurements

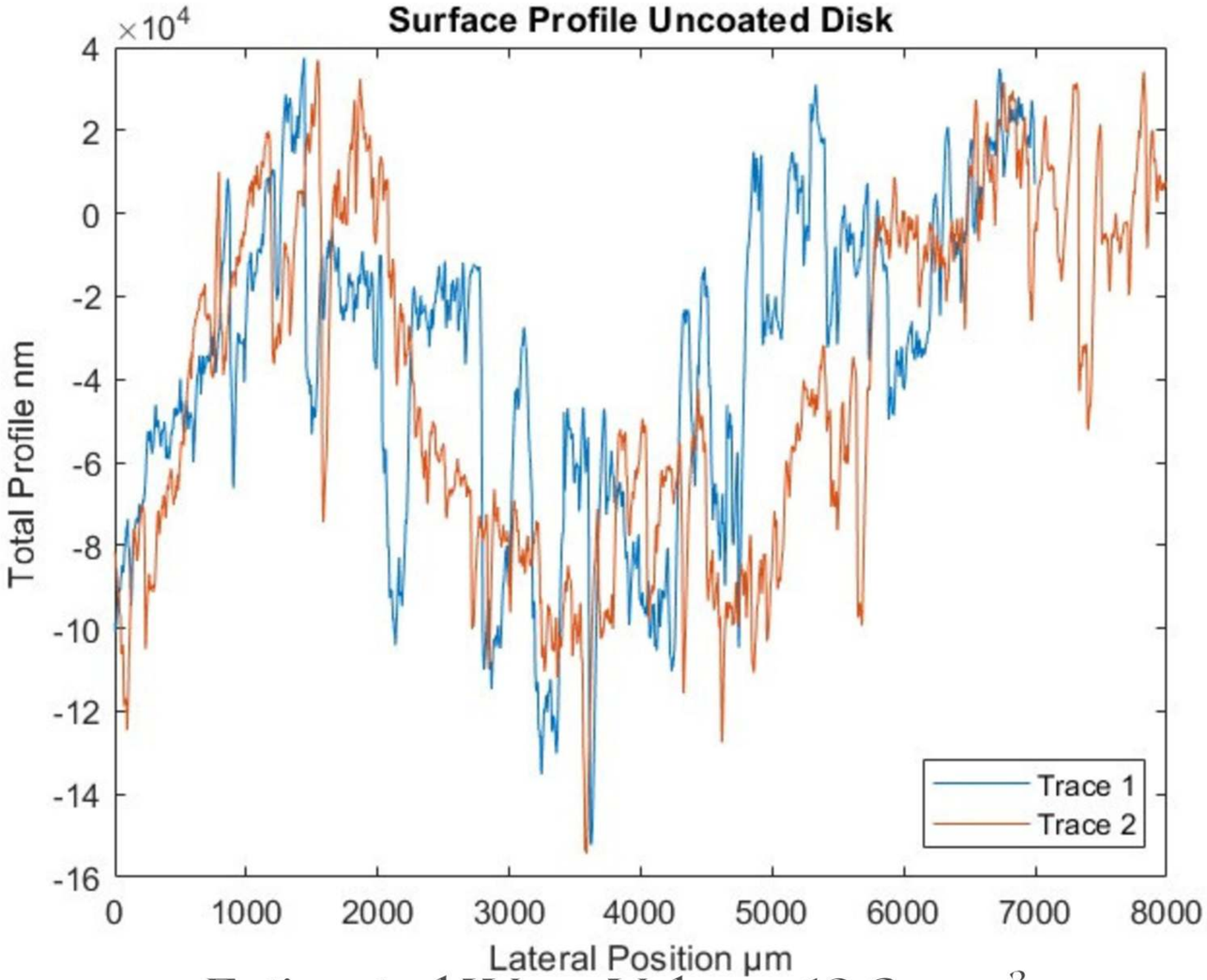
- Took two measurements of the track on the disk, separated by 180 degrees, which is characterized by motor rotation
- Track visually horizontal to the profilometer stylus path measurements to ensure accurate capture of the trench

Results Profilometer



Estimated Wear Volume 29.5 mm^3

Results Profilometer



Estimated Wear Volume 19.2 mm^3

Track Images

Uncoated

Porcelain Coated

Future Works

Improve Firing and Printing

- Continued modifications and improvements to produce smoother disks

Additives

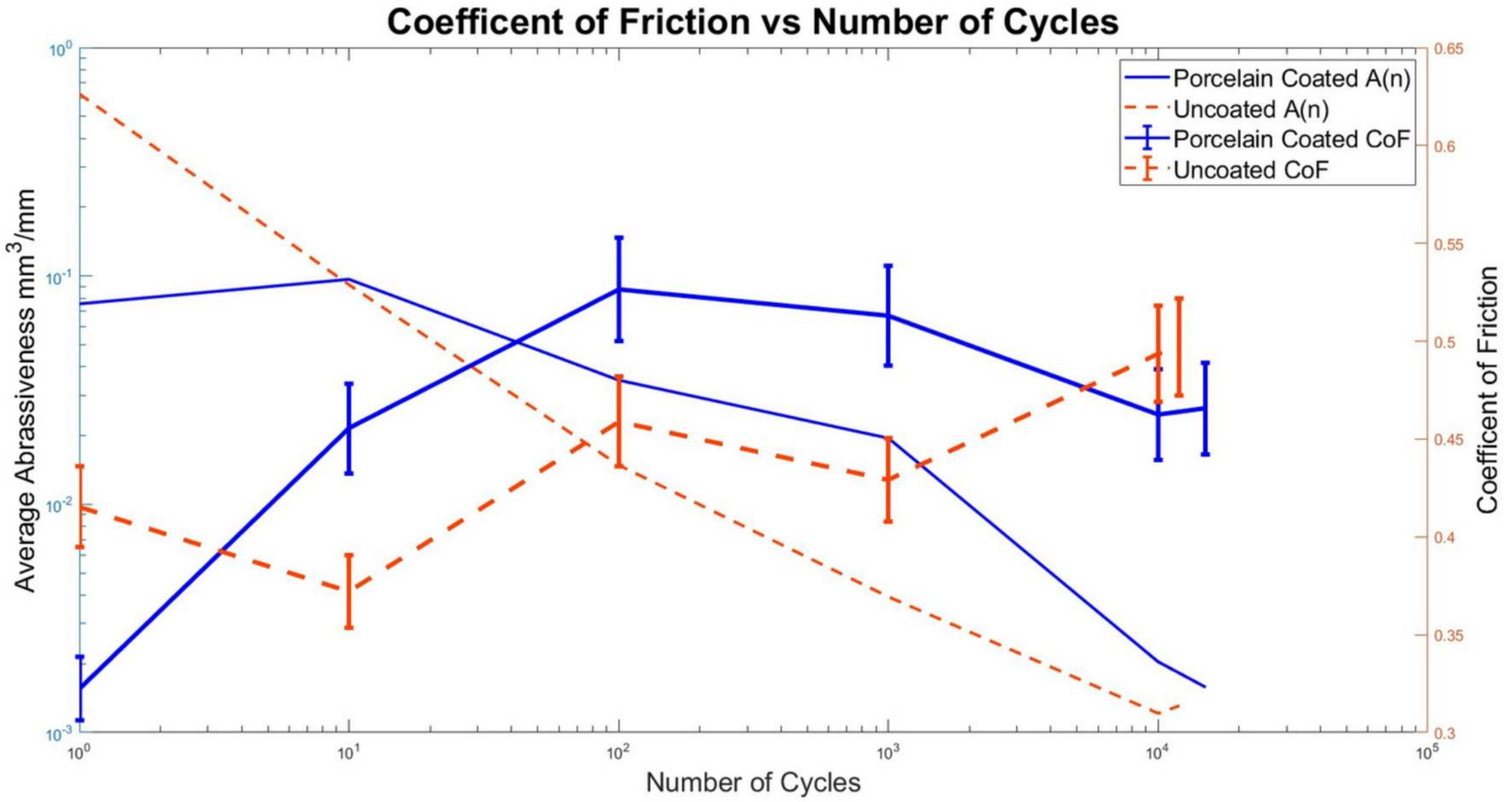
- Different Ceramic Types
- Different Particle Sizes

Testing

- Changing Ball Materials
- Higher Pressure
- Lower Speeds

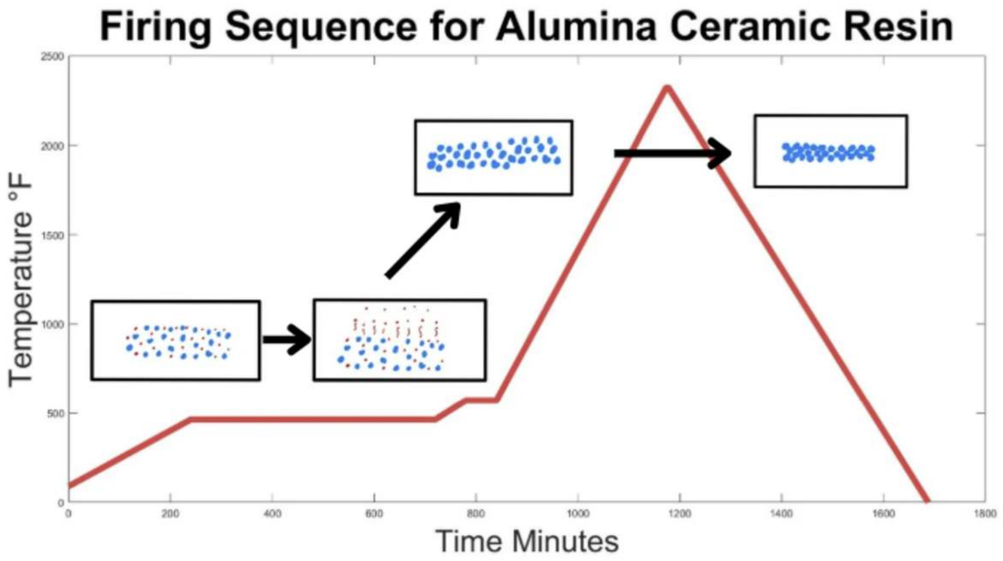
Conclusion

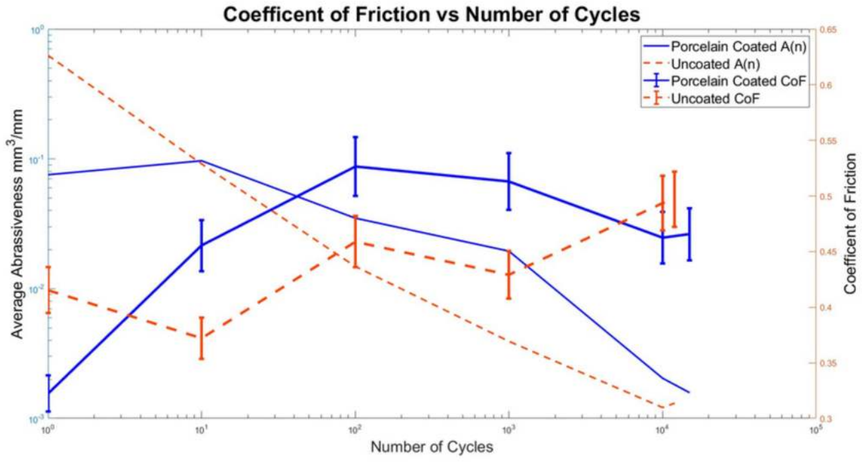
Porcelain coating temporarily increased friction and decrease the wear resistance of the disk.

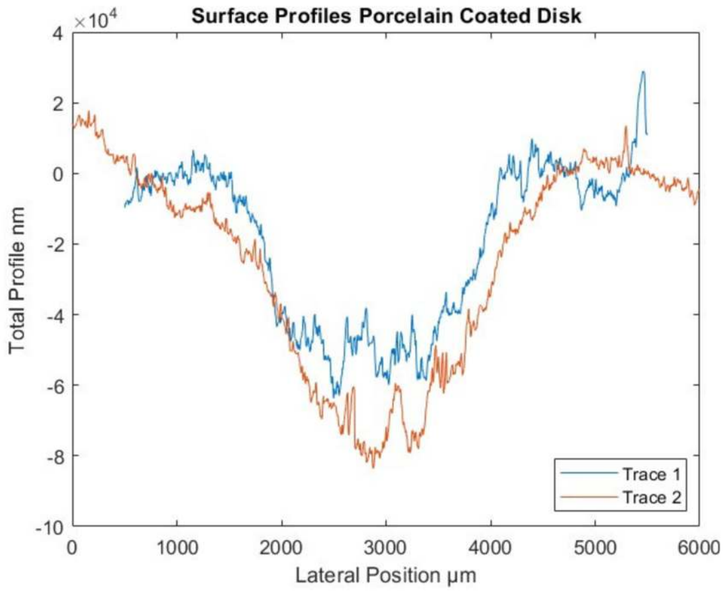


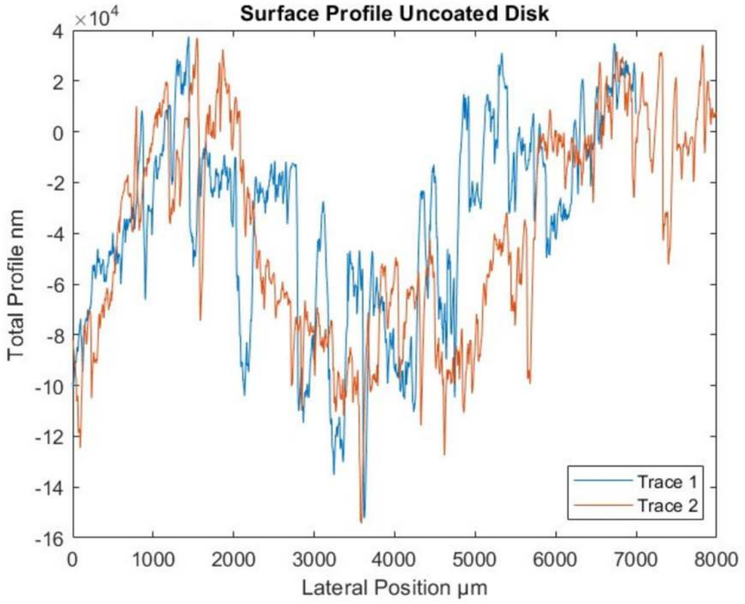
Summary

Thank you! Questions?









Acknowledgements

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- New Lab Members: Jack Van Der Reis, Rai Wandeler, Ellen Yu, & Julia Kolt.
- Alumni Hunter Whaples and Sophie Yu for donations of resin materials to the lab
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- Our Engineering Department Support Staff: Jacob Stampei and Xavier Walters