Micro-Scale Surface Texturing for Friction Reduction Leading to Improved Energy Efficiency

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Motivation

Increasing concern for the future need of clean and reliable energy sources has led to advancements in improving the efficiency of our current energy utilization. One area where there is significant opportunity for energy savings is through technology that is focused on reducing friction in lubricated mechanical systems.

Financial & Environmental Impact

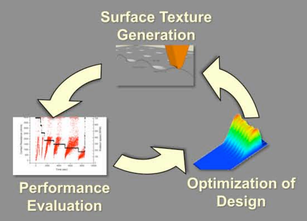
UK Financial Study, 1966 [1]
- Defined *Tribology*: the scientific study of friction, wear, and lubrication of contacting surfaces in relative motion.
- Estimated 1% of GNP of industrialized nation can be saved through tribology improvements

US Tribology Study, 1977 & 1981 [2]
- Estimated energy savings of 5.3% with tribology improvements

Engine Efficiency Study, 1994 [3]
- 40% of energy used in an internal combustion engine is consumed to overcome frictional losses in the engine.

Objective

- Develop an industrial ready texturing process
- Utilize simulation tools to study influence of dimple design
- Verify friction performance of optimized texture design
- Develop a texture design methodology for implementing treatment process



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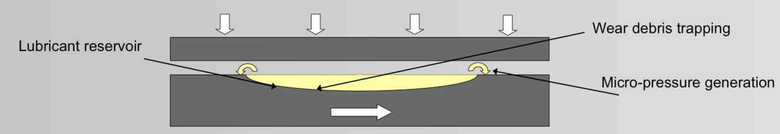
Principles of Surface Texture

The formation of well-designed dimples or pits in the surface of a substrate can drastically improve tribological properties of certain bearing components

Mechanisms:
- Micro-reservoirs that effectively retain an interfacial medium, reducing leakage
- Trapping wear particles and debris, eliminating potential plowing of the substrate surface
- Boosting hydrodynamic pressure, enhancing lubricating action



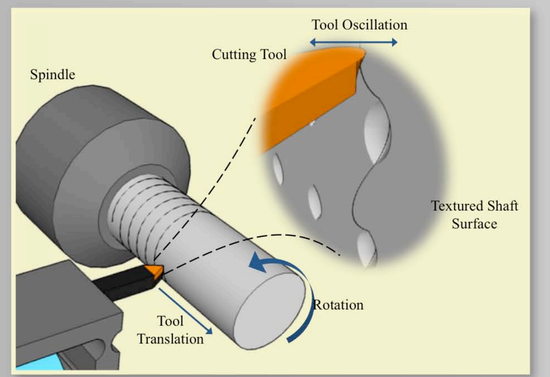
Micro-Texturing Technology

Vibro-Mechanical Texturing (VMT)

- Advanced positioning system used to oscillate cutting tool during turning [4]
- Dimple dimensions are controlled using machining parameters
- Closed-loop control system developed to improve accuracy to >90%

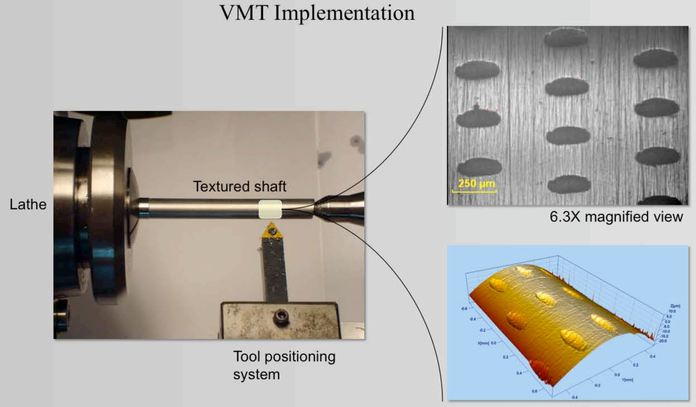
Advantages:
- Easily integrated into existing tooling
- Cost effective treatment (90% savings over current methods)
- Clean and safe processing
- Versatile texturing on multiple workpiece geometries and materials

VMT Concept



- Designed to be retrofitted to a standard lathe
- Machining parameters are used to derive equations to predict dimple design

VMT Implementation



- VMT system is developed and optimized to >90% texture accuracy

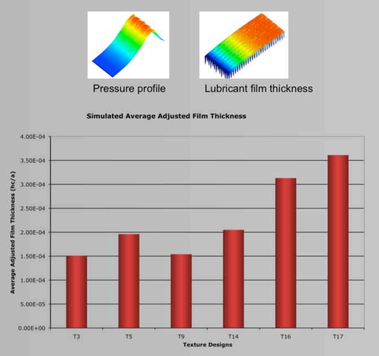
Textured Bearing Performance Testing

Journal-Bearing Friction Testing:

- Surface texture design is experimentally evaluated on a journal-bearing test rig
- Numerical simulation tools are used for comparison
- Dimple design is studied for optimal low speed performance

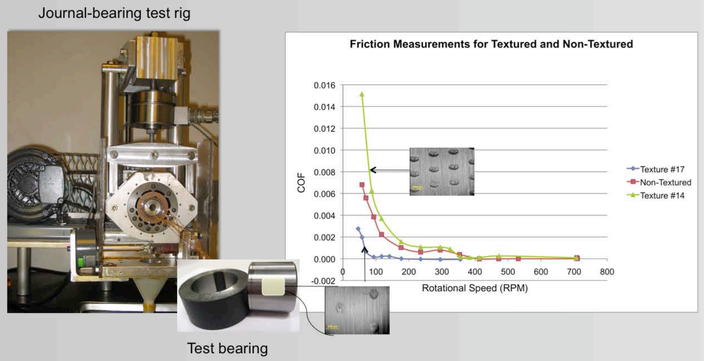
Results:
- Dimple design is critical to journal-bearing performance
- Dimple design is optimized to achieve a 70% friction reduction
- Numerical simulations verify experimental results and give insight to dimple design methodology

Surface Texture Modeling



- Simulation tools are used to calculate the film thickness for each texture design

Experimental Friction Evaluation



- Optimized texture design demonstrates 70% friction reduction
- Poor texture design shows friction increase

Conclusion

- VMT process is developed as a cost effective industrial ready treatment process
- VMT is optimized to increase accuracy to > 90%
- Surface texturing is studied and optimized for a journal-bearing application resulting in a 70% friction reduction
- A texture design methodology is established utilizing simulation and experimental tools

References:

[1] Jost, P., *Lubrication (Tribology) - A Report on the Present Position and Industry's Needs*, E.a. Science, Editor. 1966, H.M. Stationary Office.
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[3] Nakada, M., *Trends in engine technology and tribology.* Tribology International, 1994. **27**(1): p. 3-8.
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