

Polydopamine/PTFE Composite Coating for Large-Scale Journal Bearings in Next Generation Electric Machines

1467-1538

SurfTec, University of Arkansas, ABB

Period 2

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Overview

Timeline

- Award performance period:
- 04/01/2017 to 05/31/2019
- Project 50% complete
- Budget period 2 approved

Budget

	FY2017	FY2018
DOE Funded	\$ 562,376	\$ 637,622
Project Cost Share	\$ 140,594	\$ 159,405
Total Cost	\$ 702,970	\$ 797,027
Cost Share %	20	20

Partners

- **University of Arkansas Nanomechanics and Tribology Laboratory**
- **The ABB Group**

Project Goal

Explore the use of a low-friction polydopamine (PDA) /Polytetrafluoroethylene (PTFE) nanoparticle composite coating to replace traditional Babbitt liners in large-scale journal bearings enabling the DOE AMO's goal of reducing energy losses in high speed, megawatt class, MV electric motors and generator systems while simultaneously removing lead and bismuth.



Project Objective

Enabling the Replacement of Lead and Tin Babbitt in Large-scale Journal Bearings

Optimization of low-friction PDA/PTFE nanoparticle composite coating to reduce wear rate of PTFE.

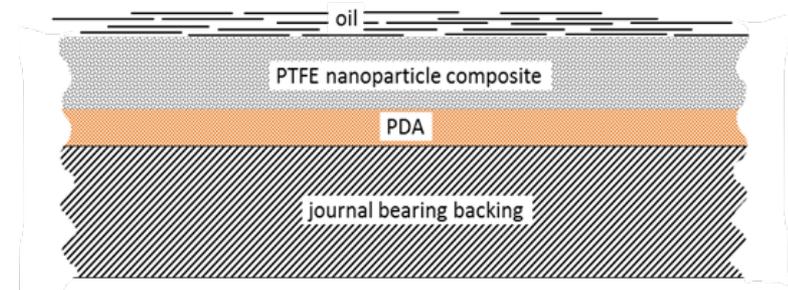
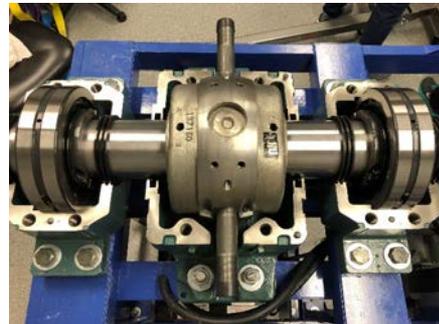
- Analysis of dopamine polymerization parameters and chemical composition allowing high strength bond to PTFE.
- Study of ceramic and metallic filler concentrations to improve mechanical properties of PTFE film.

Develop coating deposition process compatible with high through-put industrial processing lines.

- Characterization of surface topography and chemistry of **spray coated** PDA/PTFE nanoparticle coating. Study the tribological performance of spray coated films.
- Characterization and tribological testing of **dip coated** PDA/PTFE nanoparticle coating.

Evaluation of coating performance on large-scale journal bearings benchmarked against tin Babbitt.

- Design and assembly of bearing tester. Validation of test results with industry partner.
- Analysis of wear life, vibration, temperature torque loss, and current discharge in coated bearings.
- Benchmark against commercially available Babbitt bearings in boundary, mixed and hydrodynamic lubrication regimes.
- Testing in full-scale prototype.



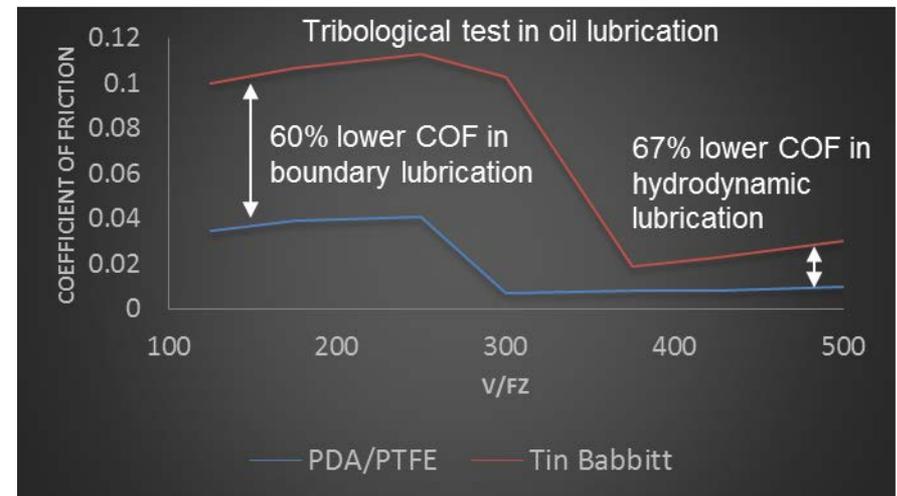
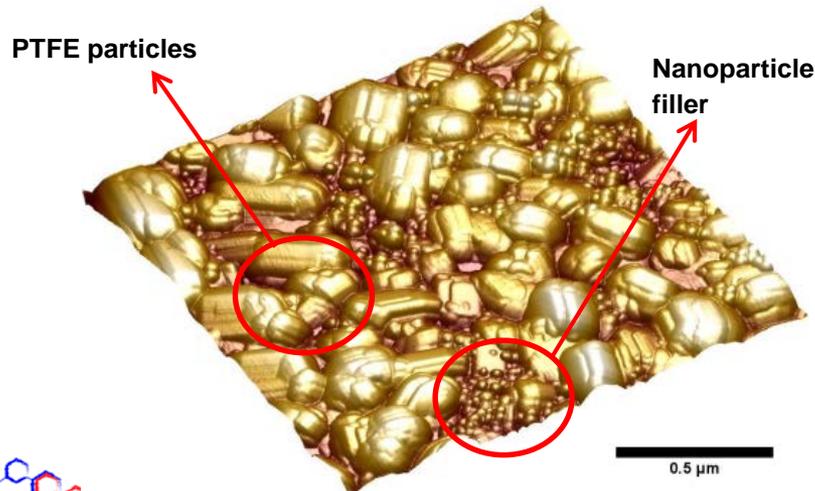
Technical Innovation

Traditional Tin/Lead Babbitt Journal Bearings Contain Appreciable Amounts of Lead

- Function well during hydrodynamic lubrication
- Are susceptible to high frictional losses during start/stop operation in electric motors.
- The price of tin is currently \$7.36/lb, significantly higher than other bearing materials. Cassiterite (tin) is considered a conflict mineral .
- In the fabrication of lead containing babbitt alloys, the disposal of waste materials produced during machining as well as the disposal of contaminated lubricants used in the machining process presents an environmental issue

Low-friction PDA/PTFE Nanoparticle Composite Coating is an Attractive Alternative

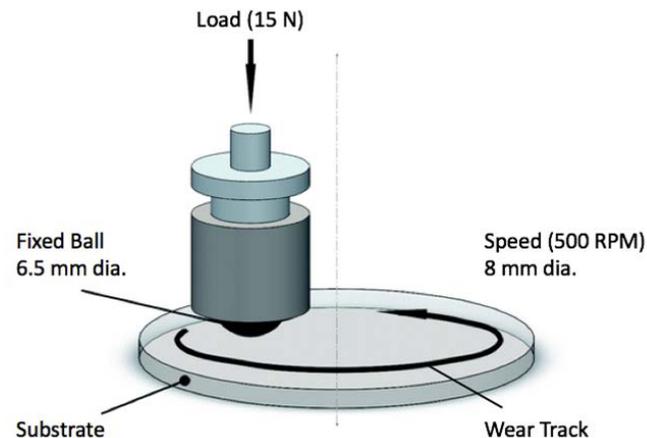
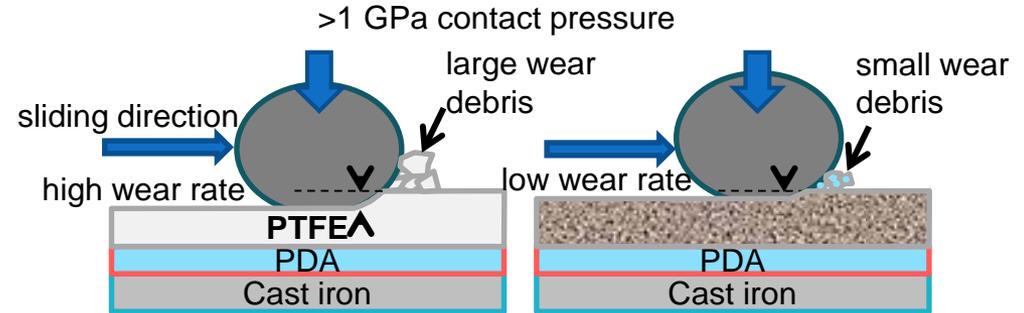
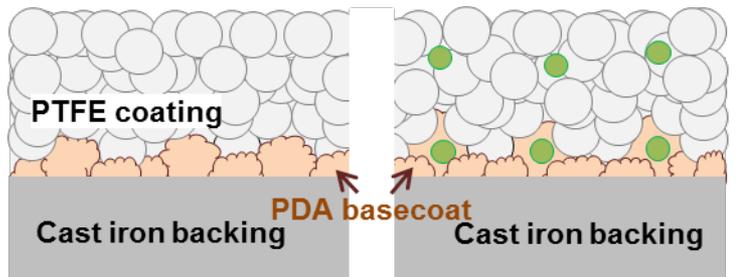
- Can reduce frictional losses by 60% and increase wear-life by 40%.
- Low cost ~ \$0.01/in² , Low weight – 2 g/cm³



Technical Innovation

Mechanism for Wear Resistance

- Dopamine used to promote adhesion and prevent coating delamination
- Nanoparticle filler used to deflect crack propagation and reduce wear debris size
- Testing under high contact pressures reveals we are performing far outside PTFE's pressure-velocity limit, outperforming PTFE coatings by 3 orders of magnitude and commercial fluoropolymer coatings by 20x.



Technical Approach

Budget Period 1 - Coating Synthesis and Optimization / Benchtop Tribological Testing

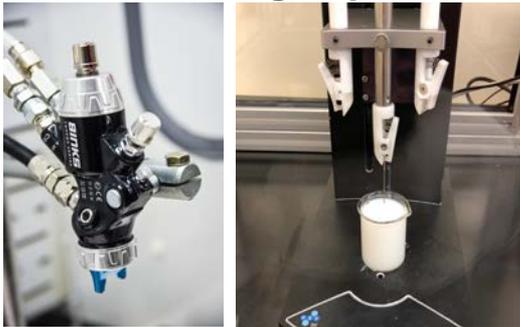
Task performed by SurfTec and University of Arkansas Nanomechanics and Tribology Laboratory

Bearing Tester Design/Assembly

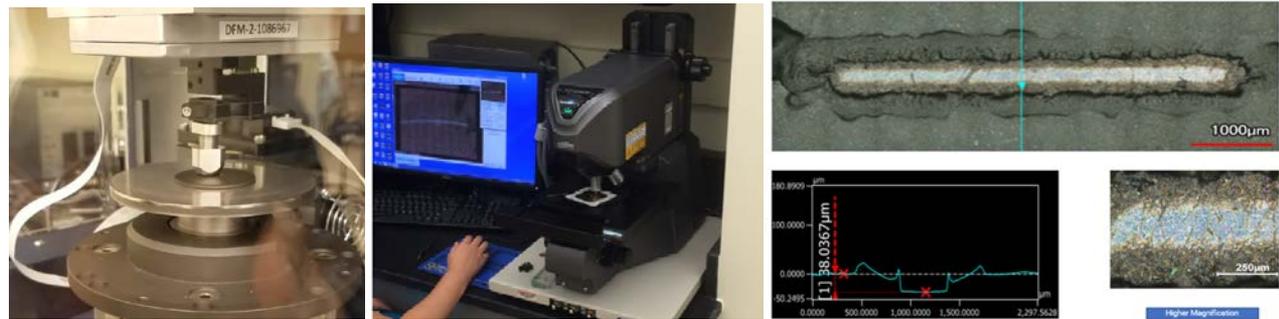


- RTD sensors to monitor bearing liner temperature
- Rotary torque sensor to measure frictional losses
- RTD sensors to monitor oil temperature
- Vibration sensor to determine metal on metal contact / wear life of coating or babbitt alloy.
- Oil recirculation system and oil analysis

Facile Coating Deposition



Benchtop friction and wear testing



Technical Approach

Budget Period 2 - Verification of coating performance in journal bearings and demonstration with a full scale prototype

Task led by SurfTec and ABB

1. Key Technical Risks

- a. PTFE's non-wetting property may cause slip at the oil/PTFE interface and pose potential challenges in establishing fluid film lubrication.
- b. We have structured the proposed plan so that early tribological testing provides a go/no-go decision point based on overcoming these key risks.

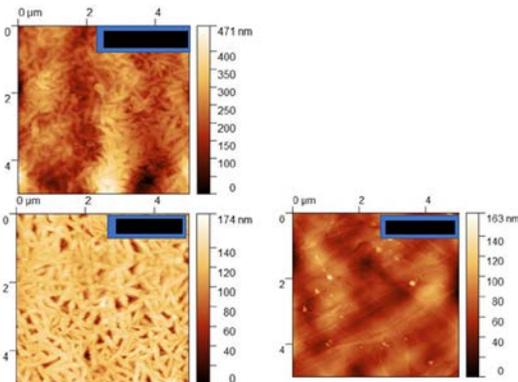
2. Execution Attributes

- a. University of Arkansas Nanomechanics and Tribology lab has extensive experience in surface engineering and developing low-friction coatings, and is a key partner during the synthesis and optimization of the proposed coating.
- b. ABB is a world leader in power distribution, generation and transmission products and is a key partner to validate our technology in a full-scale prototype system. ABB also manufactures large-scale journal bearings and will serve as an entry point into the market.
- c. SurfTec founders have been developing the proposed technology for the past 7 years and have made significant progress in its performance.

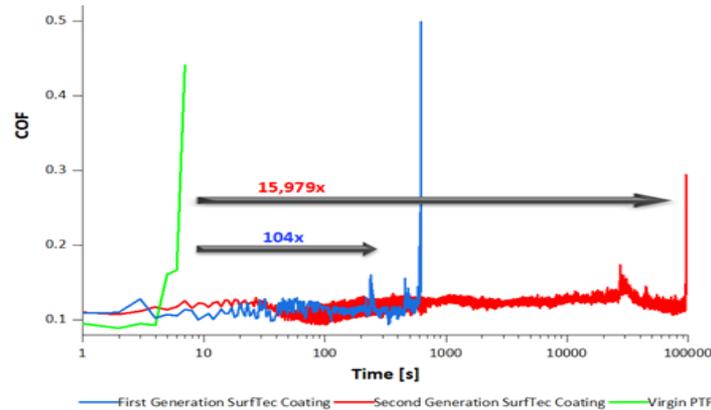
Results and Accomplishments

Tasks completed in Budget Period 1

Milestone 1.1	Design and BOM generation for journal bearing tester
Milestone 1.2	Assembly and validation of journal bearing tester
Milestone 2.1	Deposition 1-50um PDA/PTFE coating on cast iron and stainless steel
Milestone 2.2	Reduce porosity in coating below 250 nm length voids
Milestone 2.3	Produce coating with a dynamic COF <0.20 and wear life 100x greater than PTFE.
Milestone 3.1	Oil wetting and wear surface morphology characterization of coated cast iron. Coated cast iron exhibiting full hydrodynamic lubrication.
Milestone 4.1	Analysis and selection of optimal deposition method for large scale journal bearing geometries exhibiting controlled thickness up to 500µm, 100% surface coverage, >4N scratch adhesion critical load, and spray coating deposition duration under 5 min



AFM images showing reduction of porosity

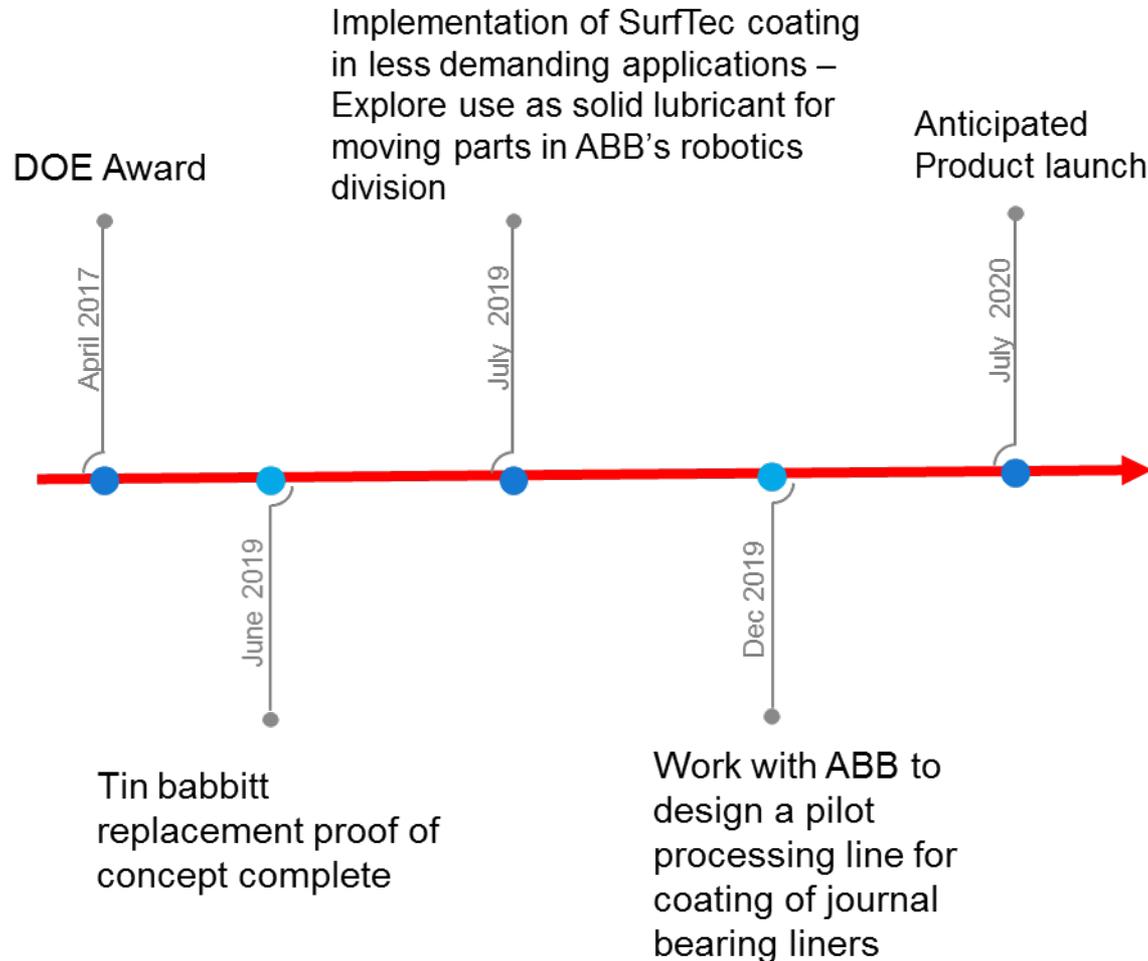


Coating performance		
Metric	Projection	Achieved
Dry COF	0.20	0.12
Wear life increase over pure PTFE	100x	15900x
Dielectric strength	20 MV/m	70 MV/m
Void length of pores	250 nm	<10nm

Tasks to be completed in Budget Period 2

*Testing of coating on journal bearings, build full scale prototype, study effect of filler

Transition (beyond DOE assistance)



Measure of success:

1. Reduce oil consumption in bearings
2. Extend service life in bearings and as a result in motors
3. Reduce maintenance costs related to bearing failures
4. Reduce energy consumption in electric motors
5. Eliminate environmental issues related to lead content in babbitt bearings

Questions?
