Continuation Research Proposal

Advanced Materials for Preventing Tribological Failures in Submersible Pumps and Other Turbomachinery

Dr. Andreas A. Polycarpou, apolycarpou@tamu.edu and Graduate Student Pixiang Lan, May 2016

Subject Categories: 4 (performance), 6 (pumps), 8 (tribology), 9 (bearings & coupling)

Objective: Recommend advanced materials, including high bearing polymeric and hard coatings, for ESP bearing system to prevent tribological failures. Polymeric coating materials are for tilting pad bearings, sleeve and washer; hard coating materials are for hard textured journal bearing and shaft. Work in developing these materials as well as testing them under harsh ESP conditions.

Background: In Electrical Submersible Pump (ESP), because of severe working conditions such as high load, high temperature, and sand contamination, the bearing systems are prone to wear and seizure. The main thrust bearing's seizure could cause stopping of ESP; the wear of washer/seal between the impeller and diffuser results in internal leakage that can significantly affect stage pressure rise, efficiency, power consumption, vibration, pump life and running cost [1]. State-of-the-art materials used include advanced materials, primarily in bulk form, such as, polymer or ceramic faced pad for thrust tilting pad bearing for higher load and higher temperature; and also apply ceramic journal bearings for ESP pumps to reduce sand abrasive wear. However, bulk polymers have poor thermal conduction and large thermal expansion under high temperature; and ceramic material is very brittle and easily fractured if loaded at one point or on a line [2]. Recent advances in subsea and deep exploration, requires the development of next generation of interface materials, under aggressive operating conditions.

Equipment: The Texas A&M tribology laboratory has several specialized tribometers: High Pressure Tribometer (HPT), Ultra High Pressure Tribometer (UHPT, in fig.1, 13.8MPa and up to 250°C with high temperature stage), High Temperature Tribometer (HTT, in fig.2 with cryogenic stage and high temperature furnace, -195 to 1000°C), and a Falex four ball machine. This variety equipment enables us to do tribological test under specific operating conditions, simulating specific devices such as pumps and compressors.

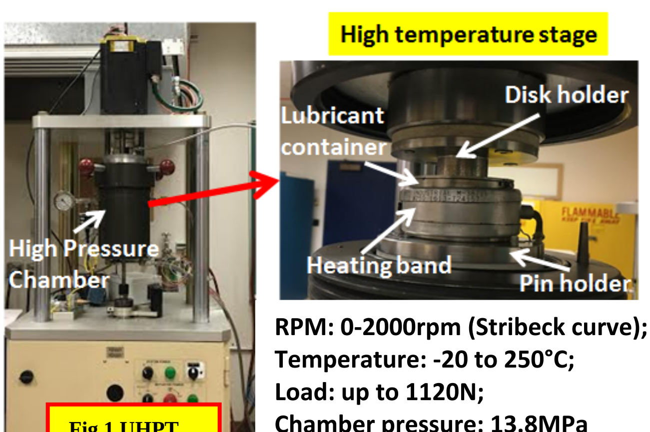

Fig.1 UHPT

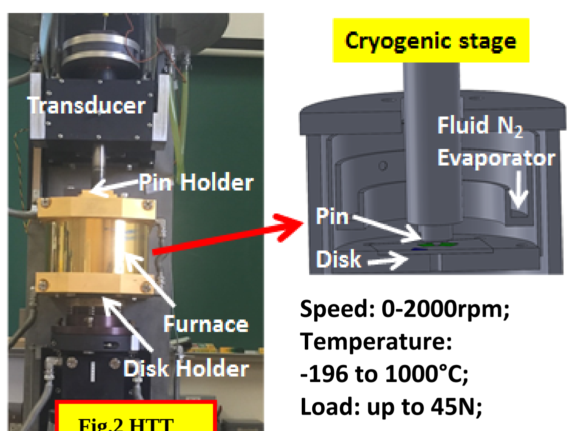

Fig.2 HTT

Summary of work 2014-2016 (Years 1&2): Results using the different tribometers and testing several advanced polymeric coatings (PEEK, PTFE and ATSP-based) and hard coatings (CrC and boronizing surface) have shown excellent performance compared to bare substrate materials without coatings. Based on aggressive scuffing (or seizure) and wear-type/durability experiments (boundary lubrication, high temperature, sand abrasive) simulating the tilting pad (3.5MPa, flooded lubrication), and hard textured bearings we found that:

- **Step load to failure:** both polymer and hard coatings improved the scuffing resistance compared to the substrate materials, such as ATSP and boriding improved 304SS scuffing pressure from 5MPa to 63.4 and 16.3MPa.

- **Boundary lubrication:** ATSP showed extremely low wear rate of 4.15x10^{-8} mm^3/Nm for 155.5 Km sliding, as shown in fig 3.
- **Sand abrasive:** both ATSP and hard coatings showed good sand abrasive wear resistance, as shown in fig.4.
- **UHPT high temperature:** ATSP showed working ability up to 220°C in submerged condition.
- **HTT ball-on-disk:** both ATSP and hard coatings have good high temperature and wear resistance.

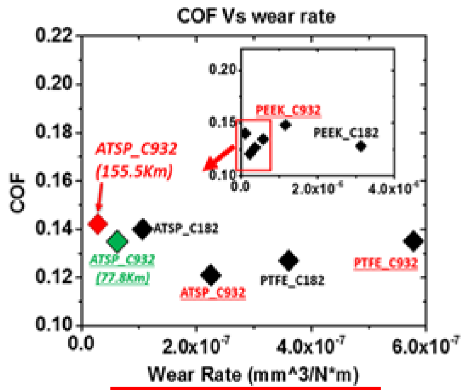

Fig.3 COF vs. wear rate

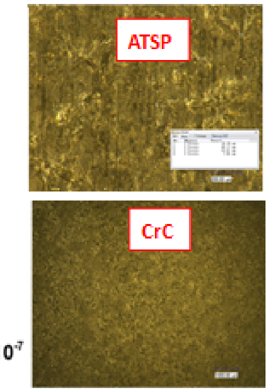

Fig.4 2h abrasive

<u>Proposed work 2016-2017:</u> Previous work showed excellent tribological performance of ATSP, CrC and boriding coatings in harsh conditions. Note that the hard coatings we tested had high roughness; the smoother surface can improve the tribological performance and should be explored. And polymer coatings such as PTFE, PEEK and ATSP have the potential to work in cryogenic conditions. Also, micro-texturing on polymer is very promising to improve tribological performance. Specifically, we propose:

- Perform experiments under **cryogenic conditions** (as low as -196°C) for PTFE, PEEK and ASPT based coatings; also ATSP composite in bulk format.
- Research smoother **CrC and boriding** coatings (with IBC Coatings Technologies, Inc.).
- Experiment on super hard **HfB$_2$** coatings (with collaborator J Abelson, Illinois).
- Work with Ionbond (already have existing collaboration) and investigate **WC+DLC** (as shown in fig.5) coatings' tribology performance under ESP working conditions. These hard coatings had unmeasurable wear under constant load experiments by HPT [3].
- Develop and optimize the two **polymer surface texturing** methods. **Hydrodynamic** experiment (Stribek curve) for the textured surfaces (a metal textured pin is shown in fig. 6 [4]).

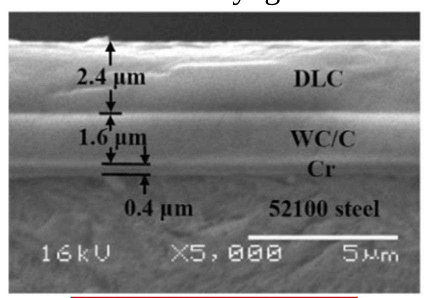

Fig. 5 WC/C+DLC coating

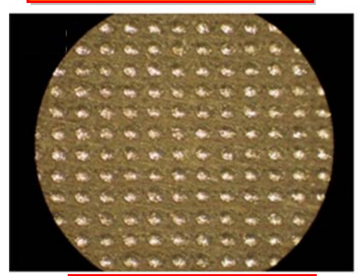

Fig. 6 textured surface

<u>Budget:</u> Support for graduate student	$ 26,400
Graduate student tuition and fees, and undergraduate student help	$ 9,600
Travel to conference(s), sponsors	$ 1,500
Machining parts and holders, shared facilities	$ 3,500
Consumables, Supplies, coatings	$ 4,000
Total Cost:	**$45,000**

<u>References:</u>

[1] Saleh, Ramy Moaness M (2013). Experimental Testing of an Electrical Submersible Pump Undergoing Abrasive Slurry Erosion.Master's thesis, Texas A&M University.

[2] Gabor Takacs, Electrical Submersible Pumps Manual, Gulf Professional Publishing, Boston, 2009

[3] Solzak, T. A., and A. A. Polycarpou, "Tribology of Hard Protective Coatings under Realistic Operating Conditions for use in Oil-less Piston-type and Swashplate Compressors," STLE Tribology Transactions, 53, 319-328, 2010

[4] Mishra, S.P. and Polycarpou, A.A., Tribological studies of unpolished laser surface textures under starved lubrication conditions for use in air-conditioning and refrigeration compressors. Tribology International, 44(12), pp.1890-1901.2011