

Tribological features of ATSP: With Lubricant and Refrigerant

ATSP Innovations

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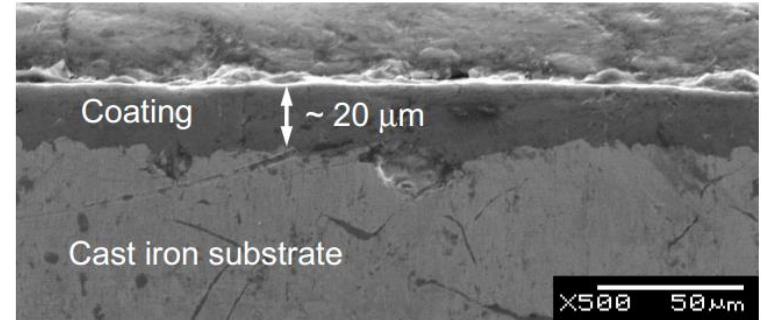
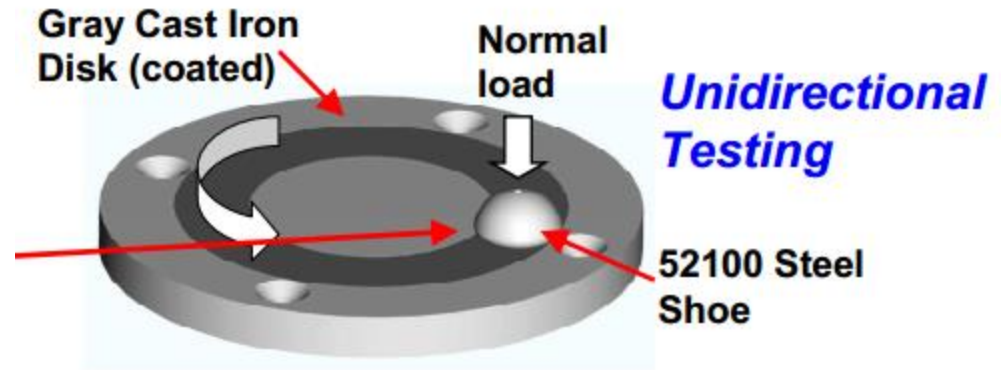
Company Synopsis

- ATSP Innovations is a rapidly growing small business that is developing innovative materials technologies for commercialization
- Location: Champaign, Illinois
 - University of Illinois Research Park
- Capitalization: Private
- Total number of employees: 9
- Key Personnel
 - Dr. James Economy (President), Dr. Andreas Polycarpou (VP), Dr. Gaetan Bonhomme (CFO), Dr. Chris Mangun (Senior Scientist), Ms. Bitia Vaezian (Production Manager), Mr. Jacob Meyer (Laboratory Manager), and Dr. David Carroll (COO)
- Principal Customers
 - NSF, Refrigeration Manufacturers, and Coatings Manufacturers

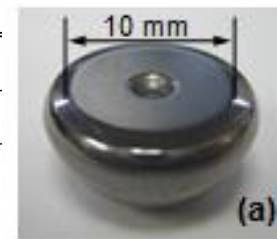


Experimental Method (Samples)

- Shoe-disk configuration
- Commonly found in swash-plate type automotive air-conditioning compressor system.



SEM cross section of the coating thickness



Shoe: 52100 hardened steel (actual compressor part)

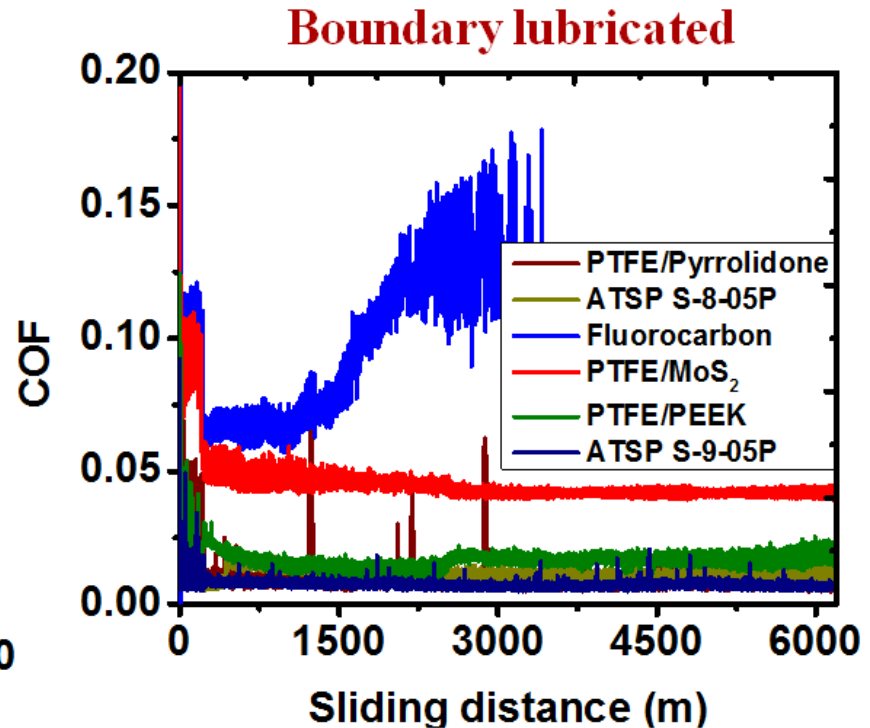
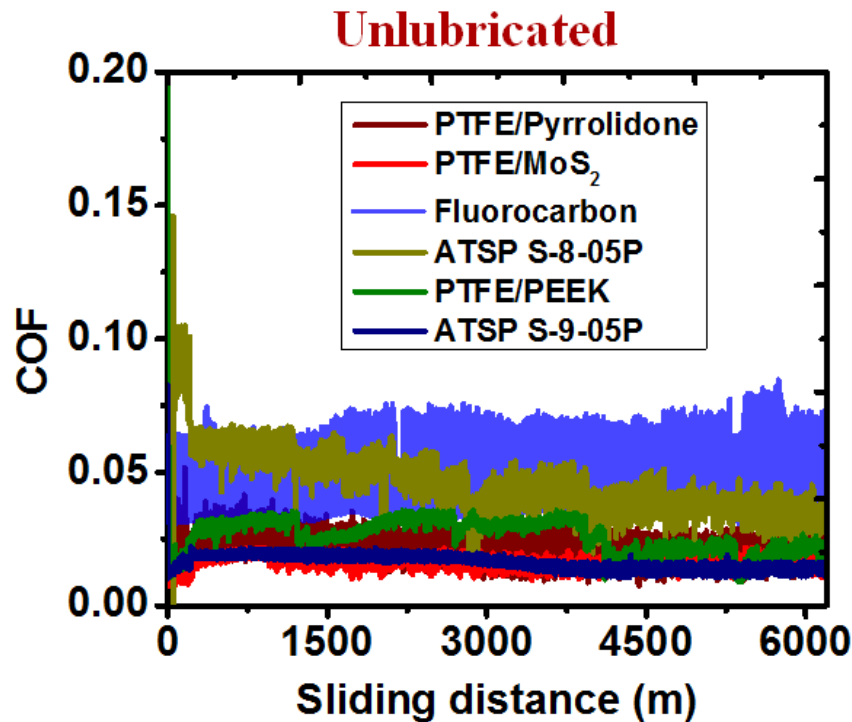
Coatings	House Name	Roughness	Thickness
		μm	μm
Dupont 958-414	PTFE/Pyrrolidone	2.28	20-25
Fluorolon 315	PTFE/MoS2	1.14	20-30
1704 PEEK/PTFE	PTFE/PEEK	1	20-30
Impreglon 218	Fluorocarbon	1.53	20-30
ATSP S-8-05P	ATSP S-8-05P	1.7	20-25
ATSP S-9-05P	ATSP S-9-05P	1.7	20-25
Cast Iron		1.2	-
52100 Steel shoe		0.035	-

Experimental Method (Conditions)

Parameters	Unidirectional	Oscillatory
Normal Load	445 N	445 N
Rotational speed	1500 rpm (3.6 m/s)	-
Amplitude	-	60°
Frequency	-	4.5 Hz
Lubricant	Dry and PAG	Dry and PAG
Viscosity of Lubricant	300 SUS	300 SUS
Operating Temperature	90 °C	90 °C
Refrigerant	HFO-1234yf	HFO-1234yf
Chamber Pressure	0.3 MPa	0.3 MPa
Duration	30 min	30 min

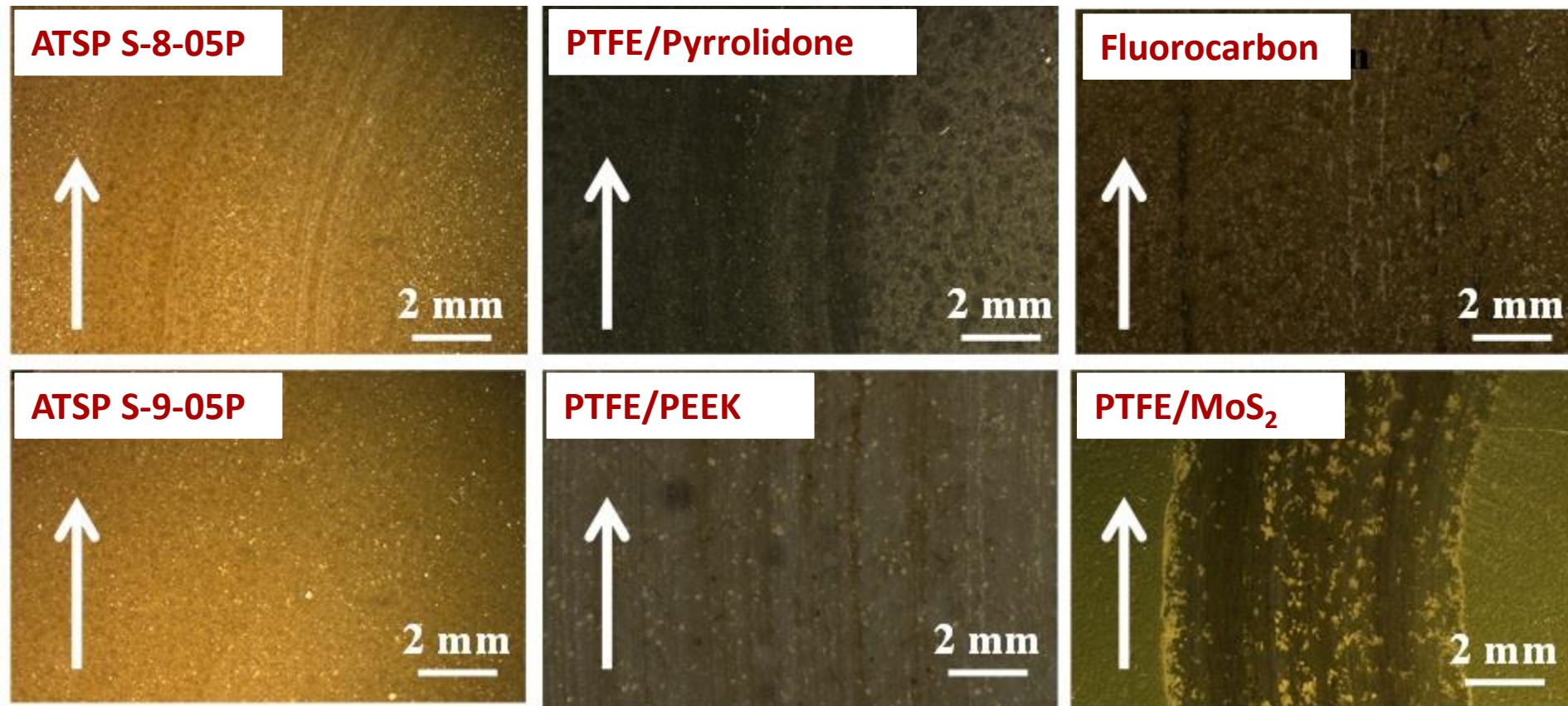
- All the experiments were performed at least twice to confirm the repeatability.
- The grade of the PAG was Idemitsu NS-D1 (viscosity 300 SUS at 40°C)
- About 46mg of lubricant was directly applied on the interface to develop boundary conditions.

Tribological Results (Unidirectional)



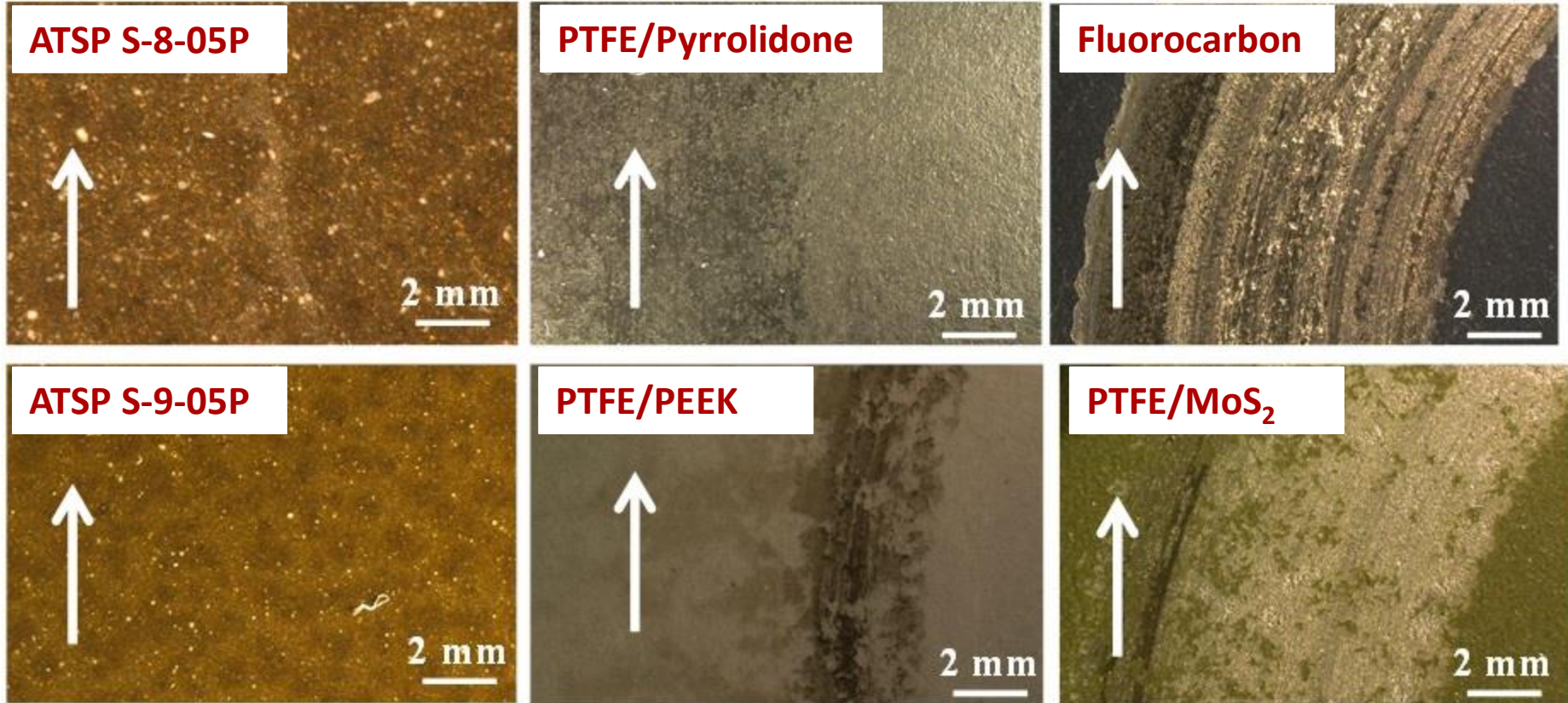
- **ATSP S-9-05P** exhibited the **lowest friction coefficient** under both dry and lubricated conditions.
- PTFE/MoS₂ performed similar to ATSP S-9-05P under dry condition. However, COF increased significantly with interaction of boundary lubricants.
- PTFE/Pyrrolidone showed almost similar behavior under both conditions.

Optical Microscopic Analysis (Unlubricated)



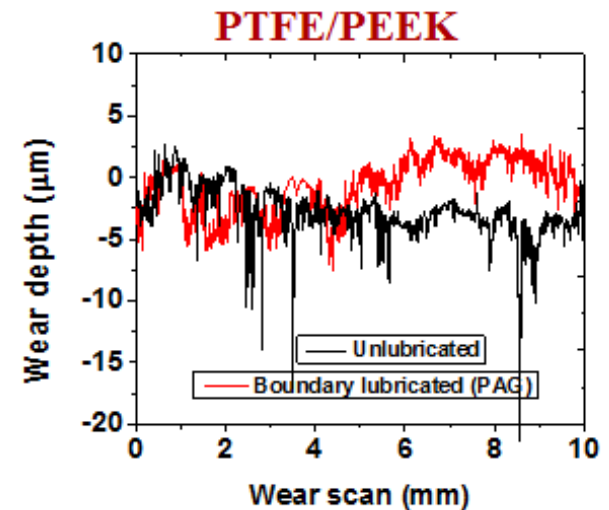
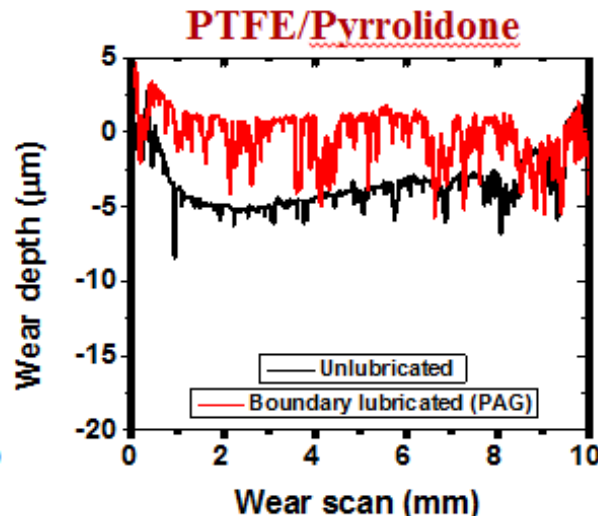
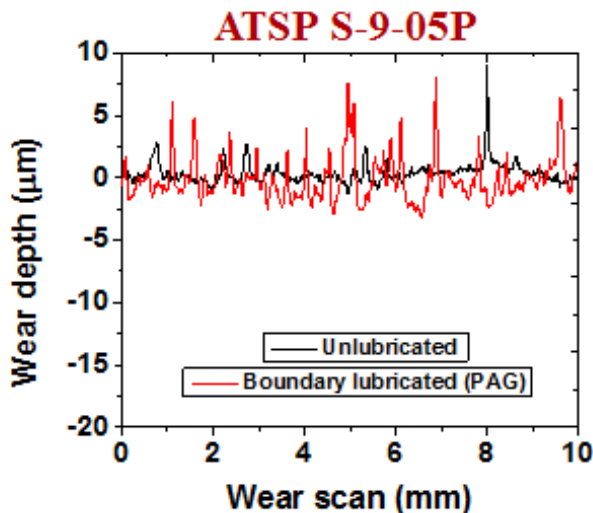
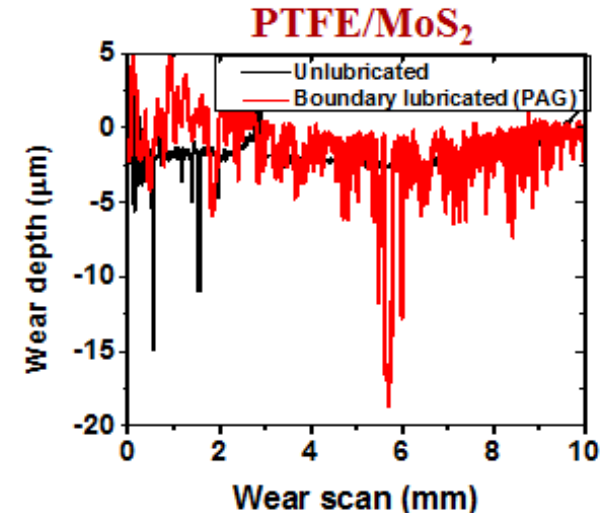
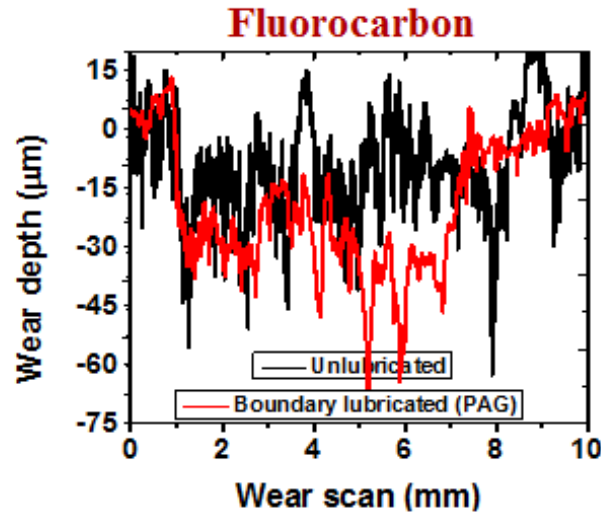
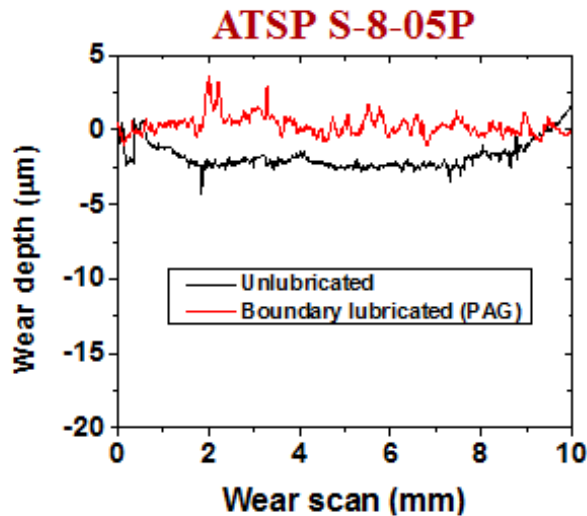
- **Better surface integrity** was found for ATSP based coatings.
- PTFE/Pyrrolidone showed some burnishing on the disk surface.
- Moderate wear was seen for PTFE/MoS₂.
- Wear scratches were found on Fluorocarbon and PTFE/PEEK surface.

Optical Microscopic Analysis (Lubricated)



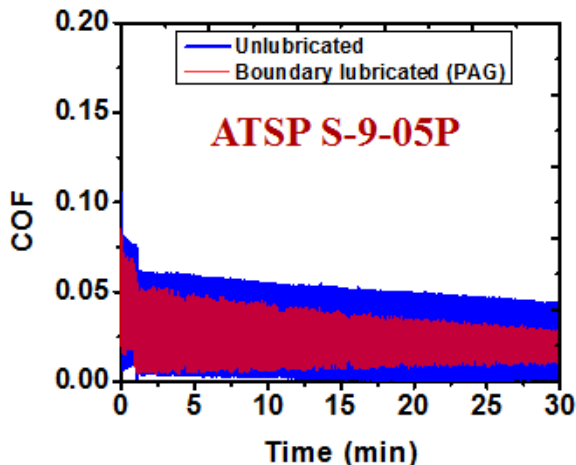
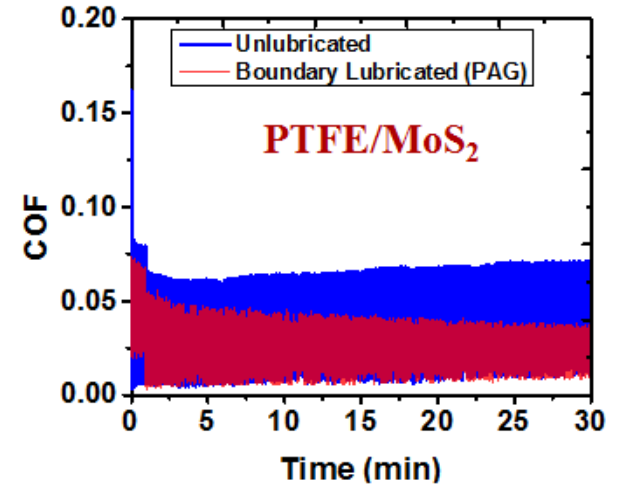
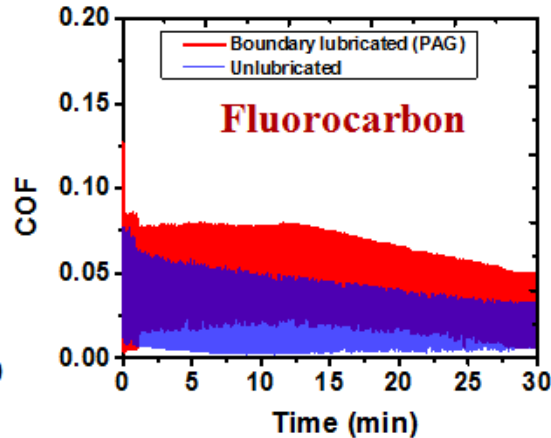
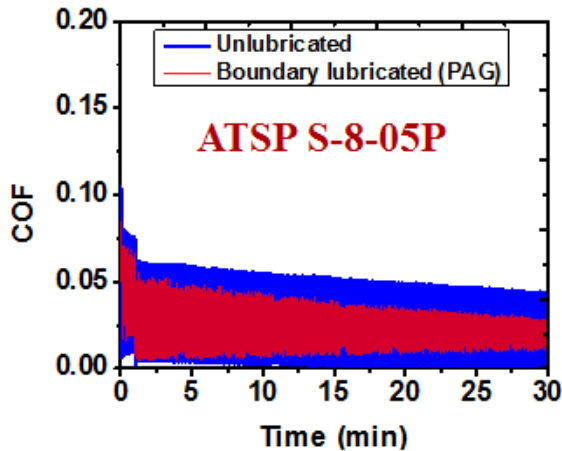
- Like the unlubricated conditions, **ATSP-based coatings exhibited better resistance to wear**. No significant wear mark was seen.
- Fluorocarbon and PTFE/PEEK showed the worst performance compared to dry condition.
- Almost similar surface topography was found for PTFE/Pyrrolidone.

Wear Profile

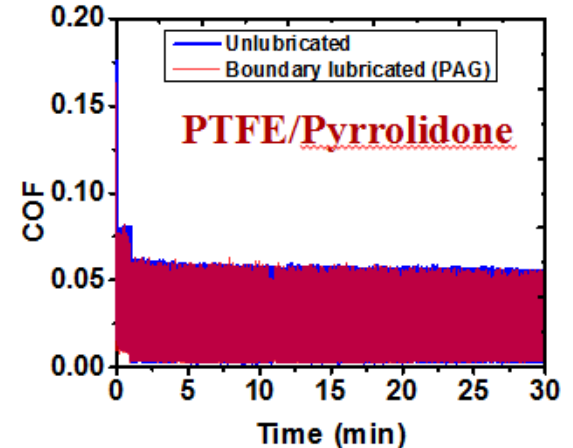


- Profilometric analysis showed almost **zero wear for ATSP-based coatings**.
- **Higher wear resistance** was observed compared to other coatings.

Tribological Results (Oscillatory)

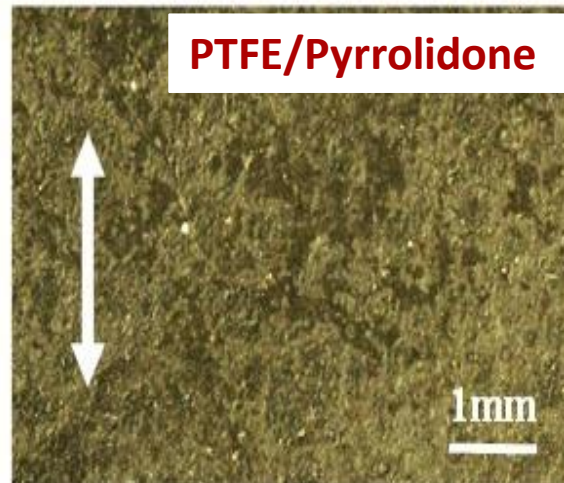
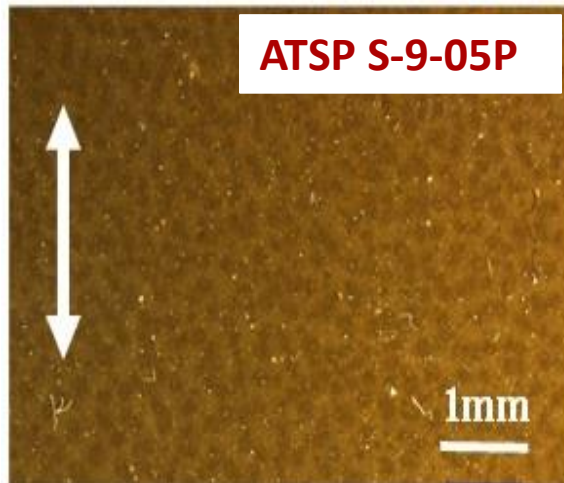
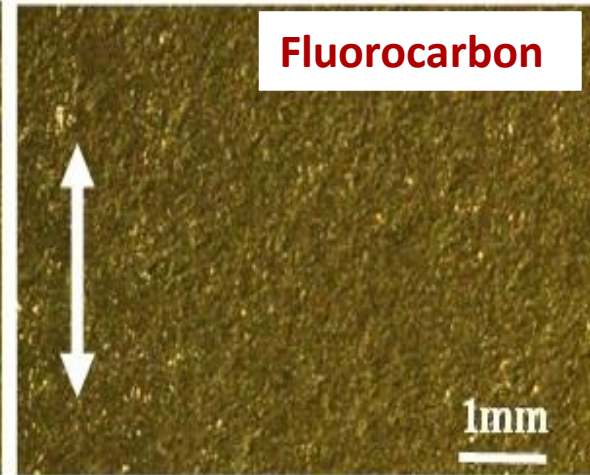
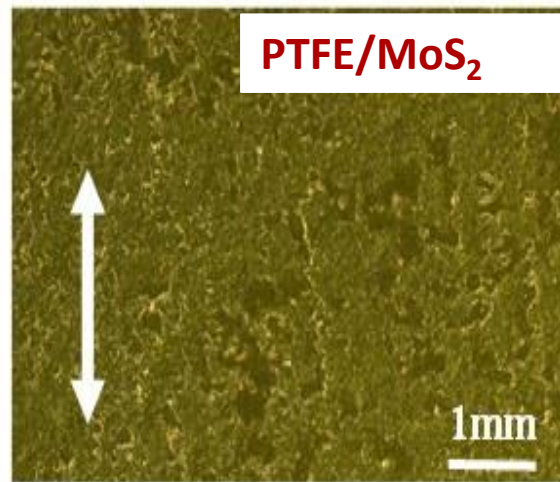
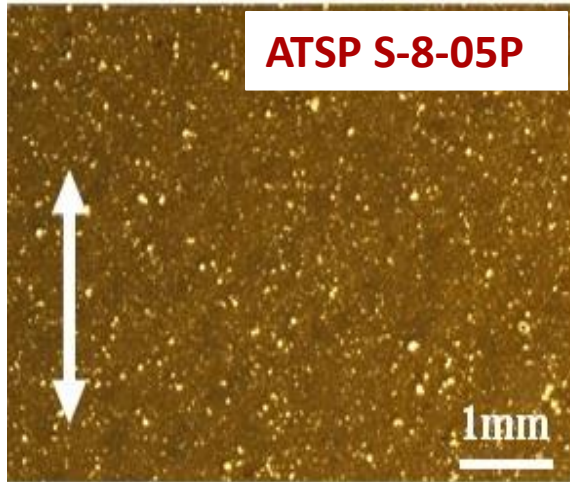


A significant reduction of friction was found (both in average and standard deviation) for **ATSP-based coatings**. This suggested a **synergistic** effect of lubricant and coatings for these cases.



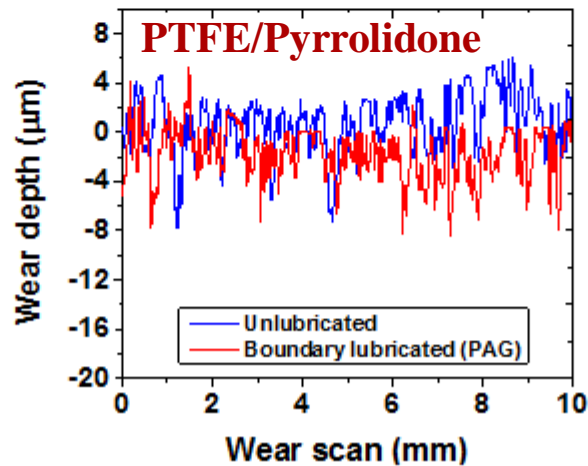
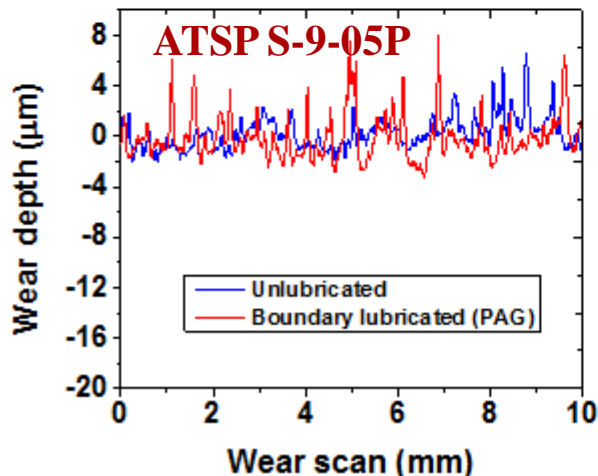
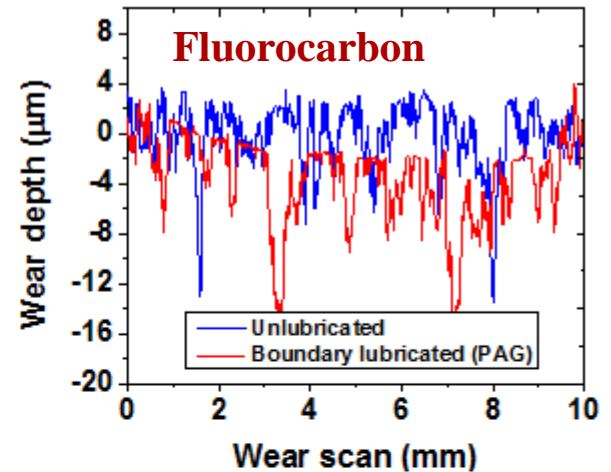
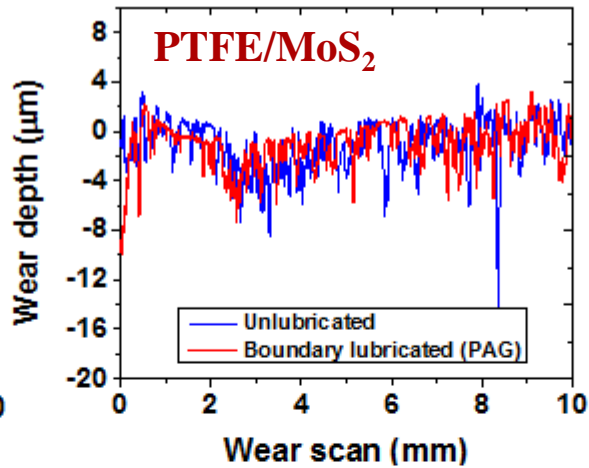
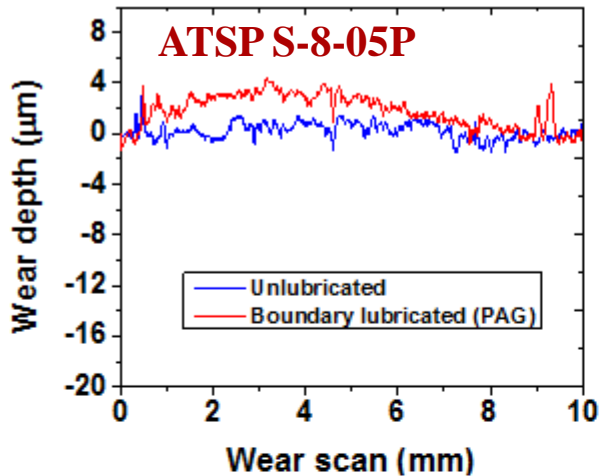
- PTFE/Pyrrolidone performed **almost identically** between unlubricated and lubricated conditions meaning no positive effect from boundary lubrication.
- COF increased for PTFE/MoS₂ and PTFE/PEEK coatings.
- Other polymeric coatings tended to form sludge of lubricant and wear debris.

Optical Microscopic Analysis



- **No surface damage** associated with wear or scratch was seen for **ATSP-based coatings**.
- Moderate wear was revealed on PTFE/MoS₂ and PTFE/Pyrrolidone surface.

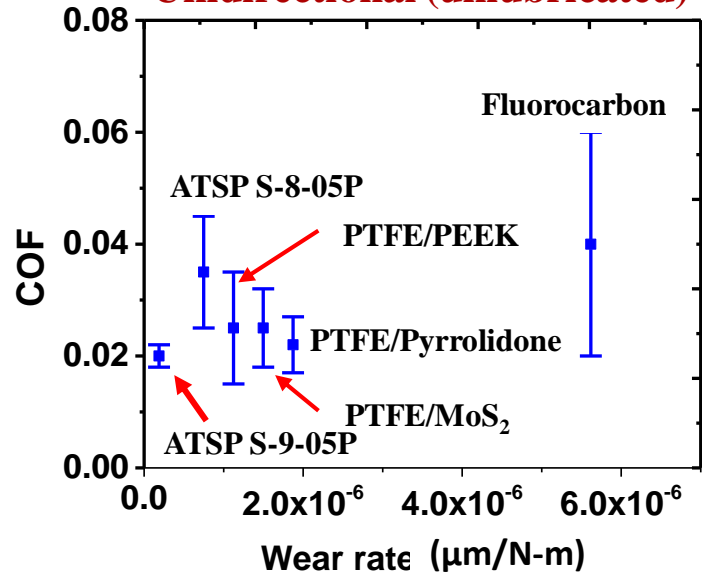
Wear Profile (Oscillatory)



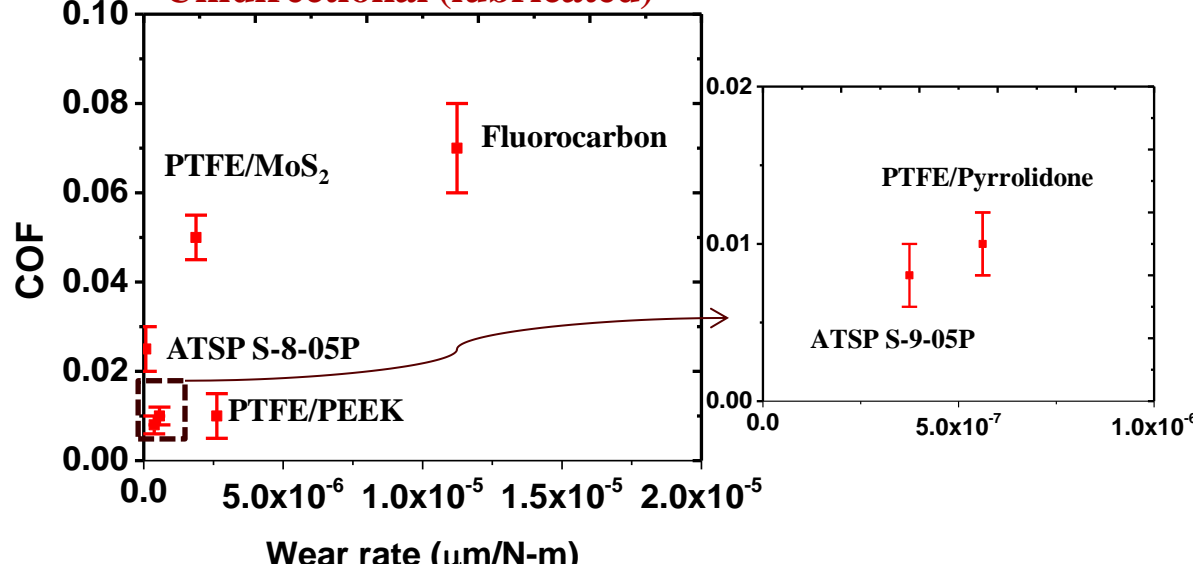
- Under dry conditions, all coatings exhibited better wear resistance under oscillatory conditions compared unidirectional conditions.
- **ATSP based coatings performed better** compared to other coatings.

Summary (Coatings Experiment)

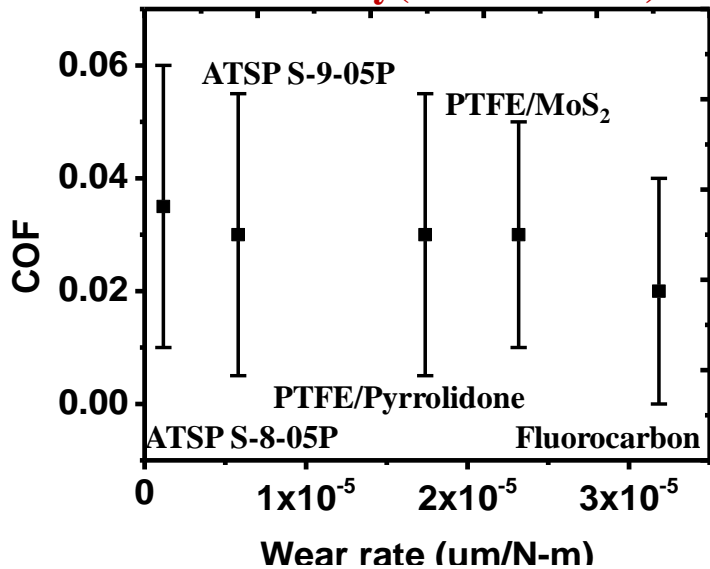
Unidirectional (unlubricated)



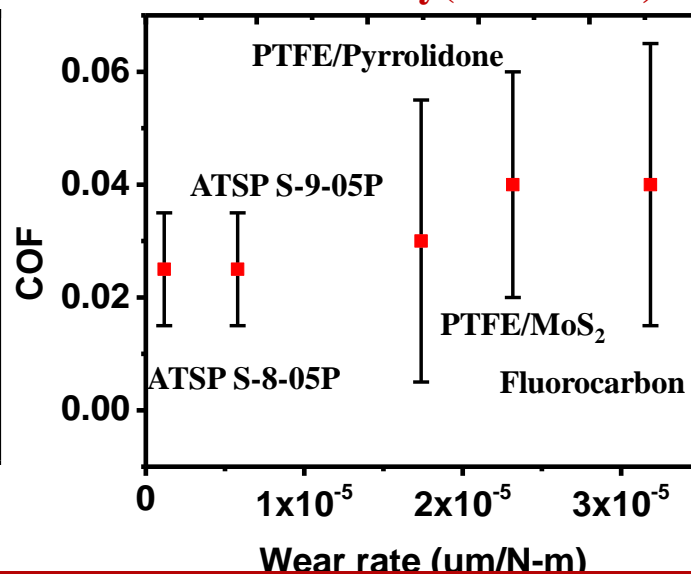
Unidirectional (lubricated)



Oscillatory (unlubricated)



Oscillatory (lubricated)



Summary

- ATSP-based polymeric coatings exhibited superior tribological performance compared to state-of-art coatings (used in this study).
- Morphological analysis revealed better surface integrity for ATSP-based coatings under both unidirectional and oscillatory conditions.
- Better synergistic effect was achieved for ATSP-based coatings. Specifically, ATSP S-9-05P offered about 30% improvement of tribological performance over state-of-art coatings.
- Other polymeric coatings tended to form sludge of lubricant and wear debris, inhibiting positive effects from lubrication.