Graphene-Based Solid Lubricant for Automotive Applications

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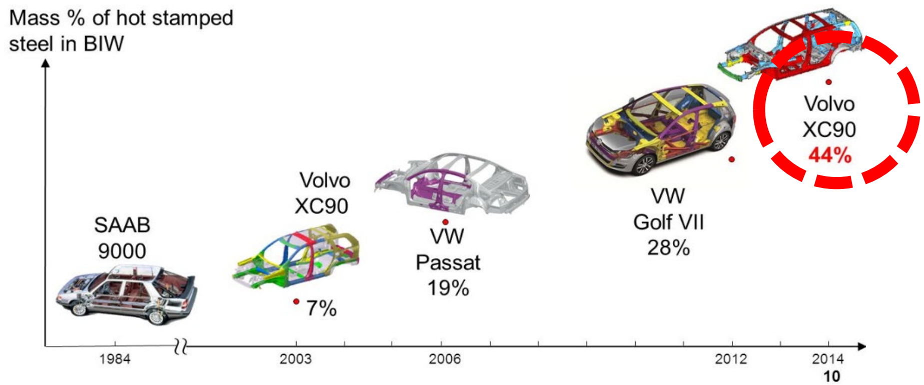
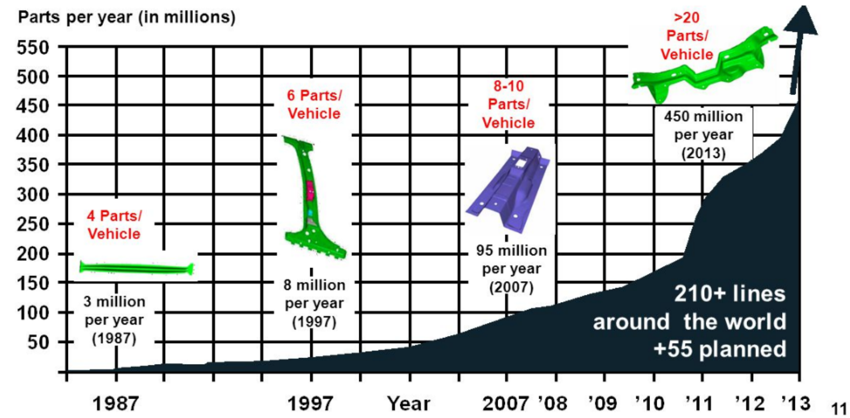
Overview



Ref: Lund 2009, Holzkamp 2011, Lindh 2011, Bielz 2012, Mattsson 2012, VW Media Services.



Ref: Oldenburg 2010, Hund 2011.

- Upwards of 44% of automobile parts are hot stamped
- The individual pieces are upwards of 450 million per year
- The projected growth was 180 Billion by 2022
- Urgent need for developing high temperature lubricants for stamping applications
- Oil-free, environment friendly lubricants are preferred
- Auxiliary effects include elimination of post-op cleaning procedures

Overview

Timeline

- Project start date: August 2018
- Project end date: August 2020
- Percent complete: 30%

Budget

- Total project funding
  - DOE share: $640,000
  - Contractor share:$10,000
- Funding for FY 2018: $315,340
- Funding for FY 2019: $267,681
- Funding for FY 2020: $66,979

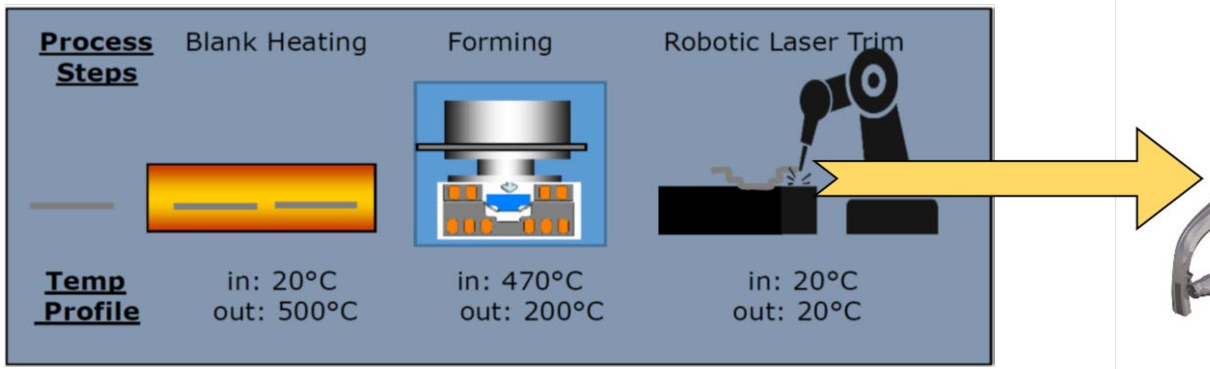
Barriers and Technical Targets

- Barriers addressed
  - Performance of graphene-based lubricants at elevated temperature.
  - Coating uniformity and adhesion to die steel.
  - Stability at elevated temperature.

Partners

- Magna International Inc.
  - Tim Skszek, PI
- University Waterloo

Relevance

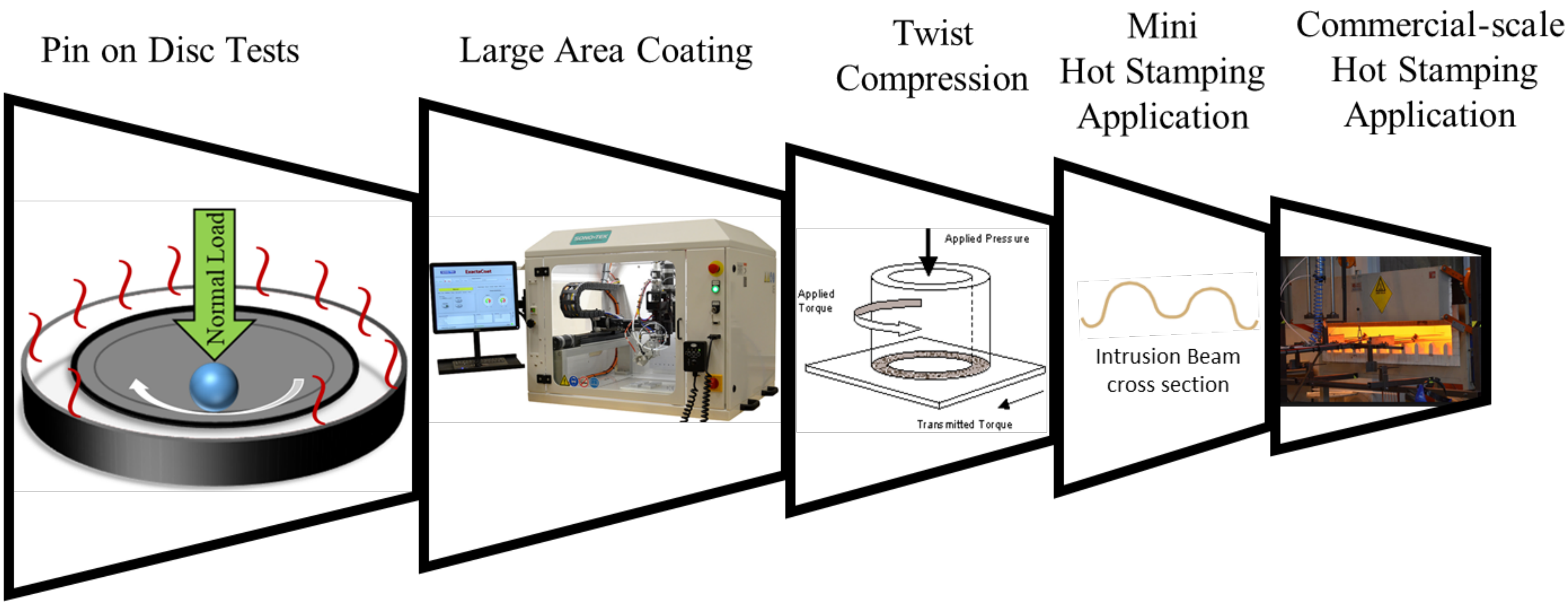


- Motivation: Expected market size **$180 billion** by 2022.
- Objective: Replacement of existing lubricants based on oil with graphene will significantly reduce emission of hazardous waste, reduction in cost and savings in energy
- Impact: A marginal reduction of friction in stamping process will translate into savings of **$100M** in manufacturing cost

Milestones

Task	Milestone	Deliverables	Timeframe
Complete Development and characterization of an optimized graphene-based die coating	**Determine best possible graphene-based solution** that can withstand elevated temperatures and **provide low friction and wear**	Optimized graphene-based lubricant to be used for the next phase **W**ater-based **H**igh **T**emperature **L**ubricants **(WHTL)**	Months 1 – 8
On Track Development and demonstration of a graphene die coating application process	Design and develop a large area graphene spray coating system	Large area graphene spray coating system with uniform coating over 1' x 1' area	Months 9 – 16
Planned Process validation and performance testing using production scale forming press and die to manufacture side door intrusion beam	Scale-up of graphene spray coating from prototype testing to real-world testing	Implementation of the graphene as a solid lubricant for metal forming process at industrial scale	Months 17 – 24

Approach

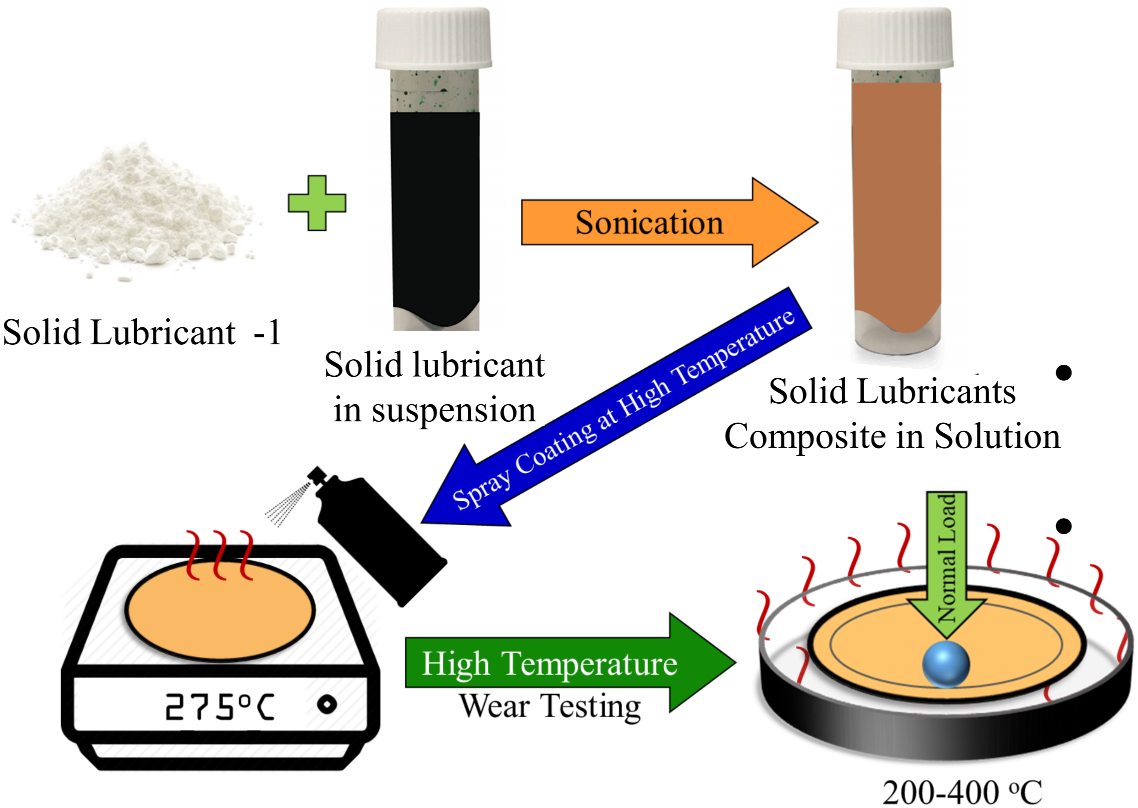


Months 1 – 8 (Phase-I) Months 9 – 16 (Phase-II) Months 17 – 24 (Phase-III)

- Conduct Pin-on-disc tribology measurements at elevated temperature to establish base-line friction metrics of steel-vs-steel and steel-vs-coated steel interfaces.
- Go/No-Go: Demonstrate reduction of friction coefficient relative to traditional lubricants.
- Develop and demonstrate large area (1 sqft) die coating system.
- Conduct twist compression tribology measurements at elevated temperature.

Technical Accomplishments

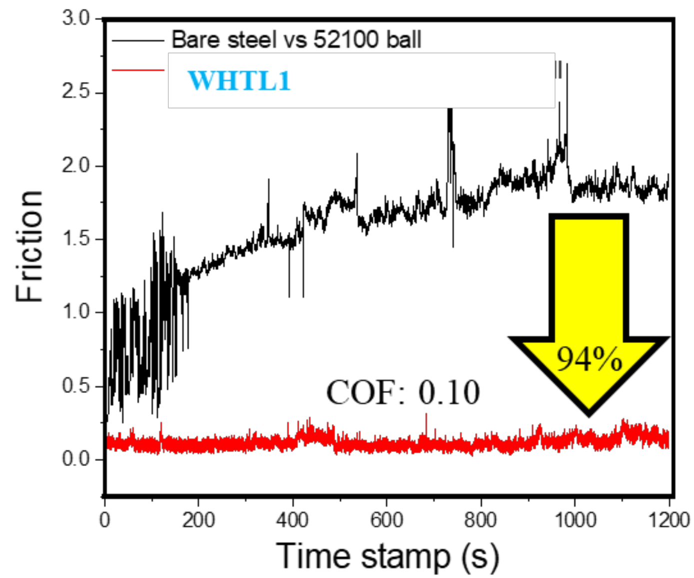
- Developed two classes of lubricants:
  - **WHTL1 and WHTL2**
- Developed new spray coating technique for applying lubricant at high temperature

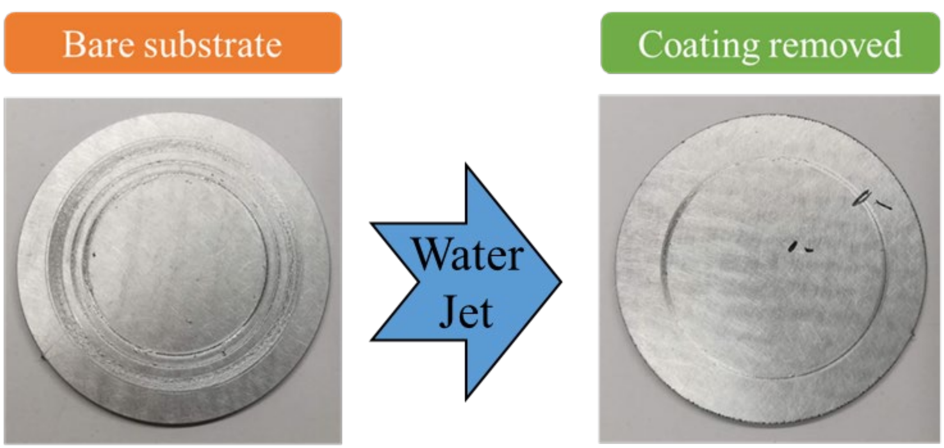


- Spray-coating technique developed for applying solid lubricants *at high temperatures* on the stamping die.
- Excellent adhesion on the die.
- High thermal stability

Technical Accomplishments

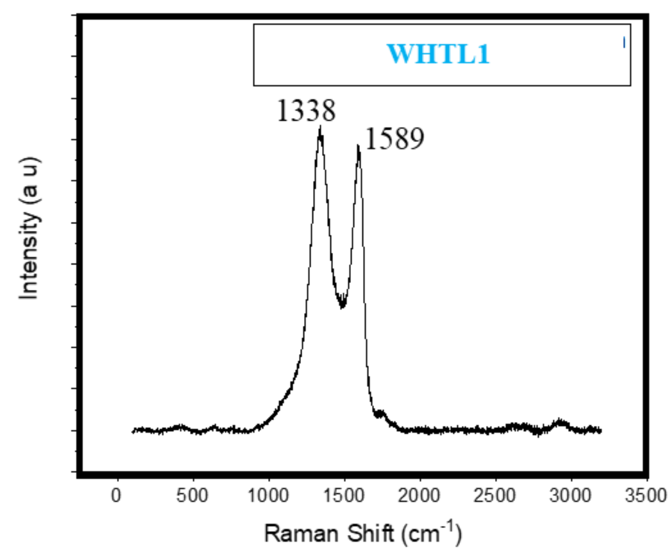
- WHTL1 reduced friction between 52100 and boron steel pair by 94.4%
- Lubricant composition remained unchanged after testing at 275°C
- Wear volume loss decreased from 0.613 mm³ to 0.465 mm³





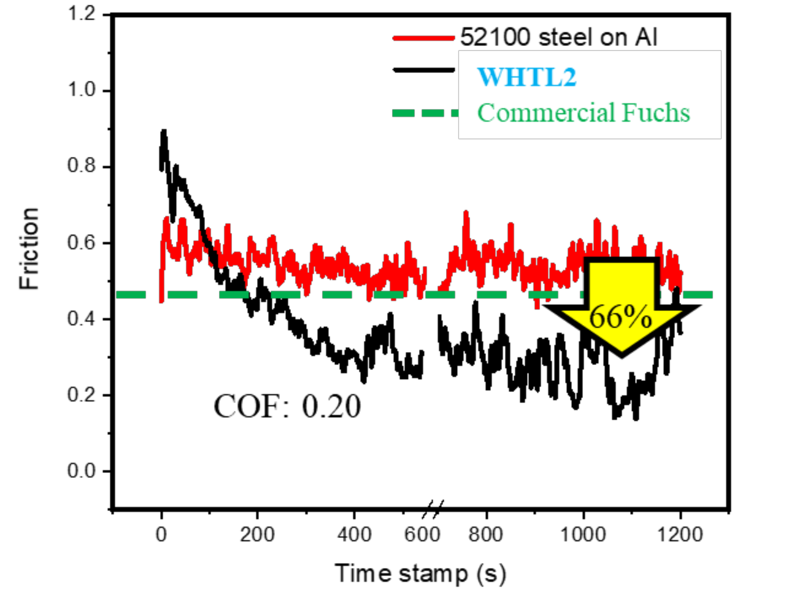
Wear Volume: 0.613 mm³

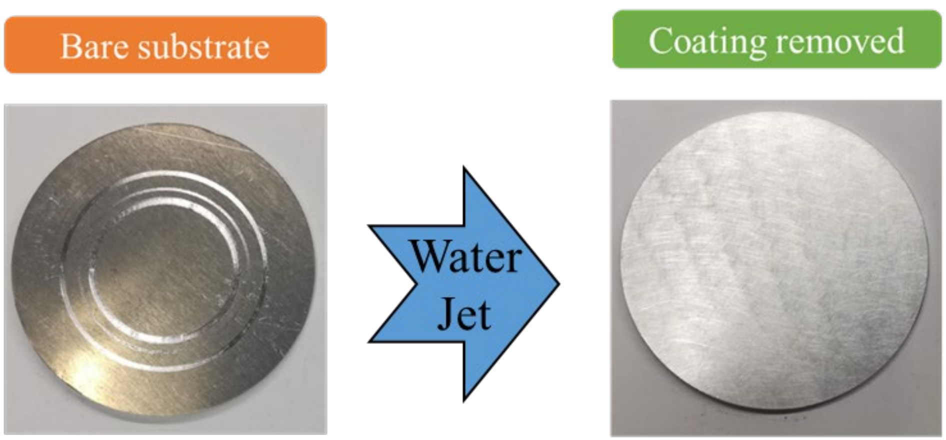
Wear Volume: 0.465 mm³



Technical accomplishments

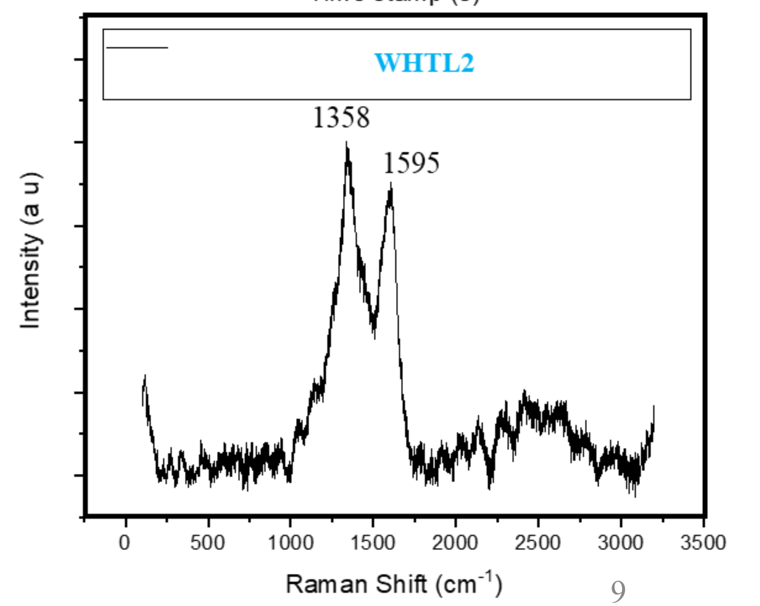
- WHTL2 reduced friction between 52100 and Aluminum steel pair by 66%
- Lubricant composition remained unchanged after testing at 275°C
- No calculable wear loss was observed after coating removal





Wear Volume: 1.115 mm^3

No Calculable Wear Loss



Collaboration with other institutions

- Team: Tim Skszek, Tim Reaburn and Ben Saltsman
- Relationship: Industrial Partner

- Team: Mike Worswick and Kaab Omer
- Relationship: University Partner

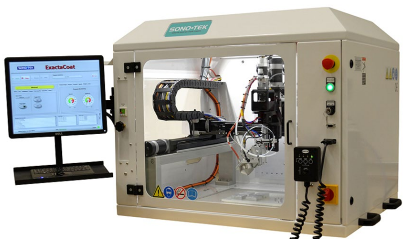
Remaining challenges

- Coating uniformity(Phase-II): Depositing graphene based lubricants on to large area (1'x1') followed by testing
  - Ensure coating uniformity
  - Maintain composition of the lubricant during delivery
- Ascertaining die-worthiness (Phase-II): Application of lubricant on to the die and determining the performance and longevity of coatings during stamping operation
- Production scale forming (Phase-III): Implementation of the graphene as a solid lubricant for metal forming process at industrial scale

Proposed future work

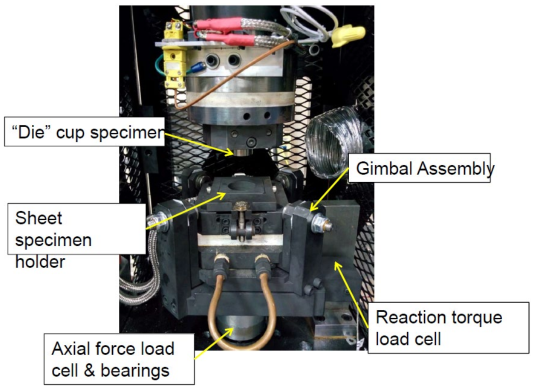
Addressing Major Challenges:

1. Large area coating:



Standardize lubricant and coating parameters using robotic ultrasonic spray coating tool to get uniform distribution of the solid lubricant coating on large area (1' x 1').

2. Twist-compression testing:



Test and optimize the performance of the lubricant under twist-compression test conditions at elevated temperature.

3. Ascertain commercial scale worthiness: Prototype to be used to establish the application technique and service interval of the graphene coating.
4. Scale-up coating process for forming: Scale-up of graphene spray coating process from prototype testing to real-world testing

Summary

1. Successful Lubricant Formulation:
   - Solid lubricant WHTL1 lowered friction on steel substrates by 94% and wear loss by 32%.
   - Solid lubricant WHTL2 lowered friction on Al alloys by 66% and nearly 100% reduction in wear loss.
2. High Temperature Stability:
   - In-situ Raman spectroscopy ascertains a high degree of thermal stability.
3. Scale-up and Lubricant Uniformity:
   - Scaling-up of the spray coating process over 1’ x 1’ area with better uniformity and validation of lubrication performance in the next step. Twist-compression tests are underway.