Multi-component Nanoparticle Based Lubricant Additive to Improve Efficiency And Durability in Engines

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“This presentation does not contain any proprietary or confidential information”
Outline

- Objectives
- Technical Challenges
- Approach
- Nano-lubrication mechanism
- Performance measures and key results
- Concluding remarks
Project Objectives (P1)

- Design and optimize process for nanoparticle synthesis
- Analyze shape, size, and surface properties
- Understand agglomeration and improve suspension of hybrid nanoparticles
- Lubrication mechanism and tribological behavior
Technical Challenges

- Prevent progressive wear, lower friction and improve efficiency and durability in engine components
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- Additive system for lubricants that will minimize sulfur and phosphorus content and lower ash forming elements (Low SAPS).
- Advanced lubrication technology for cleaner emission.
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Technical landscape for SAPS

SAPS – Sulphated Ash, Phosphorus and Sulfur

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Leading OEMs and oil companies surveyed – Low- /no SAPS oil topped the list of emerging technologies (in next 5-10 yrs)
Different lines of defense

Coatings *(Good Antiwear agent and Friction modifier)*
- Get worn away with sharp asperities
- Inert to additives
- No easy replenishment possible

ZDDP *(Good Antiwear agent)*
- Needs activation so inadequate for cold start-up periods.
- It forms hard antiwear protective films but increases friction.
- New environment regulation is forcing low or no P molecules.

Solid lubricant as particles *(Good Antiwear and Friction modifier)*
- Micro particles settle in the oil.
- Nanoparticles available agglomerate, do not disperse.

Organic agents *(Good Friction modifier)*
- Lack in required AW properties.
- Excess might cause undesirable acid formation.
Approach

Conventional nanomaterials
Approach

*Top down particle architecture*

*Multi-component*

*Surface stabilization and dispersion*

**Conventional nanomaterials**

- MS$_2$ nano tube
- IF-MS$_2$ (fullerene structure)
Chemo-mechanical Process

Dry Process

Fractured small particles are aggregated due to increase in surface energy

Wet Process

Exfoliates planar layers
No size reduction
Surface passivation
The hybrid milling process is a combination of dry milling and wet milling process. TEM graphs of hybrid milled MoS₂ with dry milling step followed by oil milling step will result in monodispersed particles.

Combination of high energy milling to decrease the particle size and use oil to prevent particles from fusing - will result in monodispersed particles.
Technical Advantages

- Nanometric size: allows them to easily enter the surface asperity contact area
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- Weak inter-planner bonds: delamination under high contact stress

Particles are not depleted in low load environment

Transfer layer on asperity contact
Pressure sensitive architecture

Exfoliation of external lamellar sheet

Transfer of lamellar sheet (active component) to the contact zone

Lubrication Mechanism

Undeformed (Hydrodynamic)  Deformed (Mixed)  Fractured (Boundary)
Tribology of nano-lubricants
20 - 40% reduction in friction in BL regime

Evidence of MoS$_2$ transfer layer on surface
BOR wear test; unidirectional

- Nano materials highly effective in reducing friction & wear
Nanomaterials Effective from the 1st cycle

Block on Ring COF and Wear Volume

50% reduction in COF w/ nanomaterials
Industry specified test
ASTM D 4172

Base stock
Load = 239.3 Nm
Scuffed

Base stock w/nano particle
Load = 304 Nm
No scuffing

Cat FZG Gear scuffing test with nano-technology
Key Elements of nano-lubrication Technology Leadership

Control the Business Where it Counts
- Engine
- Aftertreatment
- Transmission
- Hydraulics
- Undercarriage

Control Core Competencies
- Efficiency
- Durability
- Combustion/Emissions
- Cooling
How will we win?

- Success through an integrated approach to lower SAPS and improve AT performance for engine systems solution

- Deliver high efficiency lubrication with more power density and increase component life

- Long term success through energy efficient nano-lubrication technology
Concluding Remarks

**Technology Potential** - Advanced lubrication for engine with potential to reduce friction and wear characteristics and low SAPS

**Approach to Research** - Novel nanomaterial technology with active particle architecture

**Technical Accomplishments** –

- A manufacture friendly process
- Understand transfer layer lubrication mechanism
- Particle stabilization process
- Reduction in friction and wear (20 – 40%), Low SAPS

**Tech Transfer** - Offers a nanomaterial technology for low friction / wear in engine with cost and scale-up analysis
Acknowlegdement

DOE Support: DE-FC26-07NT43277

University of Arkansas
  – Prof. Ajay Malshe
  – Dr. Demytro Dimyдов
  – Arpana Verma

NanoMech LLC
  – Dr. Wenping Ziang

Argonne National Lab
  – Dr. Ali Erdemir
  – Dr. Osman Eryilmaz
Thank you