The Functional Attributes and Utilization of Borates in Lubrication Nanotechnology

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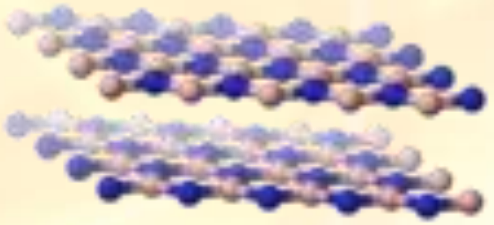
Boron

- Discovered in 1808 by Sir Humphrey Davy
- Brittle, black, semimetallic substance
- Tends to form planar compounds

The Use of Boron in Lubricant Formulations



- Boron Nitride (BN)
  - Planar hexagonal structure
  - Similar to graphite
  - Works well as a solid lubricant
  - Ceramic
    - Exceptional thermal stability
    - Stable in acids

The Use of Boron in Lubricant Formulations

- Boron Nitride
  - Steel on steel
    - BN actually increases coefficient of friction
    - BN is oxidized
  - Steel on cast iron
    - Coefficient of friction somewhat reduced
    - Diminished wear reduction
    - BN is not oxidized

    - Kimura et al. *Wear* Volume 232, Issue 2, October 1999

The Use of Boron in Lubricant Formulations

- Oil-soluble boric acid esters
  - Lubrizol Corp. 1986
  - Used as anti-wear additive in engine oil formulations
  - Exhibit some rust inhibition properties
  - Poor hydrolytic stability

The Use of Boron in Lubricant Formulations

- Oil-soluble borated amines
  - Watts et al., Infineum, late 1990's
  - Friction modifier and anti-wear additives for engine oils
  - Useful in automatic transmission fluids
  - High treat rates

The Use of Boron in Lubricant Formulations

- Borated amine and borate ester
  - Compared to traditional phosphorus additives
  - Tested for engine exhaust emissions
  - Determined that tailpipe emissions are reduced using boron additives
  - No reduction in catalytic converter performance

    - Morris et al. SAE International June 2004

The Use of Boron in Lubricant Formulations

- Boric acid nanoparticles
  - Used to improve diesel fuel lubricity
  - Dispersion of particles
  - Substantial friction reduction
  - Problems related to suspension
  - Does not tolerate water

- Argonne National Lab *Transforum* Vol. 7 No.2 August 2007
- Ali Erdemir, Nanolubricants, 2008 John Wiley & Sons

New Technology

- Combines the best of existing technology
- Borate nanoparticles
  - Produced using unique manufacturing process
  - Create planar structures on metal surfaces
  - Stable suspension
  - Tolerate water

- Canter, N. Tribology and Lubrication Technology, August 2009

New Technology

- The rest of the story:
  - Borate nanoparticles performance established
    - Difficulties lie in delivering nanoparticles to active site where friction is occurring
    - Improved hydrolytic stability can lead to more environmentally friendly applications
  - Improved delivery system
    - Transports nanoparticles to where they are needed
    - Keeps particles in suspension

New Technology

- Delivery system is special synthetic ester
  - Made from natural, renewable ingredients
  - Highly surface active
  - Forms strong lubricating film
    - Film is self-healing
  - Improves anti-wear performance
  - Tolerant of water
    - Soluble in oil and other hydrocarbons

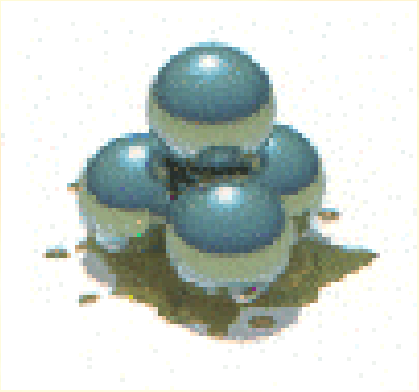
New Technology

- Contact between surfaces occurs at points
- Additive must be able to interact with metal points at contact
  - Certain level of adhesion required
    - Chelation
    - Ester carrier has polar interaction with metal surface

New Technology

- Combination of borate nanoparticles and ester carrier:
  - Gives improved stability and performance
  - Offers the opportunity to formulate water-based lubricants
    - Replace oil as carrier with water
    - Ester/nanoparticulate borate combined with emulsifer forms emulsion lubricant when blended into water

Performance

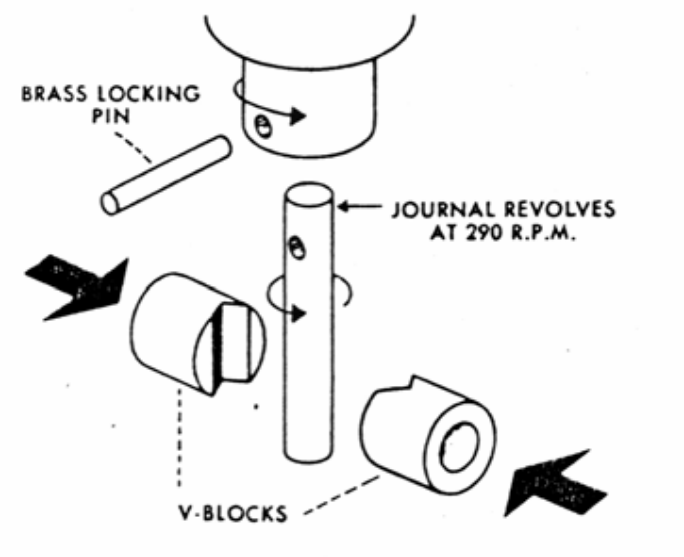


4-Ball Wear Test

Performance

- 4-Ball Wear
  - 0.35 mm scar vs 0.40 mm scar for traditional motor oil anti-wear additive package
    - Base oil alone had scar of 0.80 mm
- 4-ball Load
  - Standard lithium-complex grease held a load of 700 kg

Performance



Falex Pin-and Vee Test

Performance

- Load carrying capacity:
  - Oil alone: 500 lbs
  - Oil with boron nitride: 1250 lbs
  - Oil with PTFE: 2500 lbs
  - Oil with ester/nanoparticulate borate: 4000 lbs
  - Water-based emulsion with nanoparticulate borate: 4000 lbs

Emulsion Lubricant

- Easy to spray
- No VOC
- Excellent lubricity
- Very little odor
- Non-toxic
- Non-flammable
- Biodegradable
- Made from renewable resources

New Technology

- Allows formulation of environmentally friendly lubricants
- Proven performance
- Cost effective

Thank you!

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