Use of 3D Optical Profilometry to Differentiate Between Additive Chemistry

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Nye Lubricants

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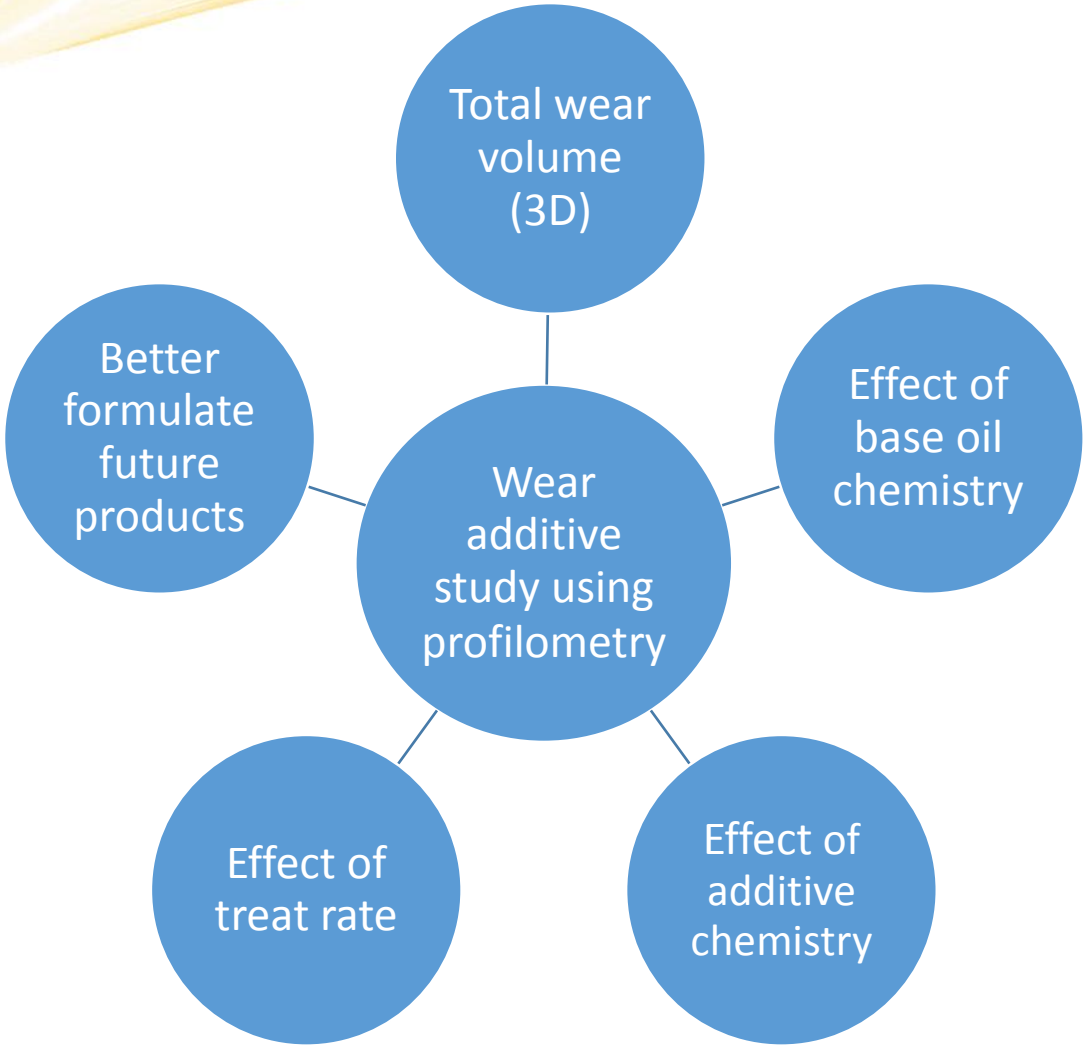
Project Goals

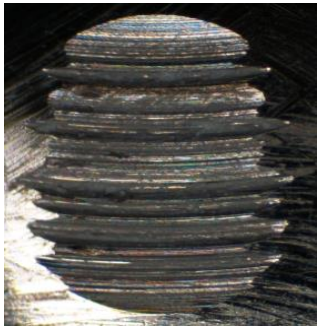


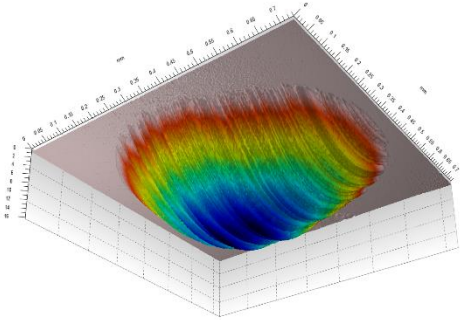
Test Matrix

Base Oils	• Polyalphaolefin (PAO) • Di-ester • Polyol ester
Additives	• Phosphate ester • Amine Phosphate • Zinc Dialkyldithiophosphate (ZDDP) • Methylene bis(dibutyldithiocarbamate) • Molybdenum di(2-ethylhexyl) phosphorodithioate
Treat Rate	• High (3%) • Low (1%)

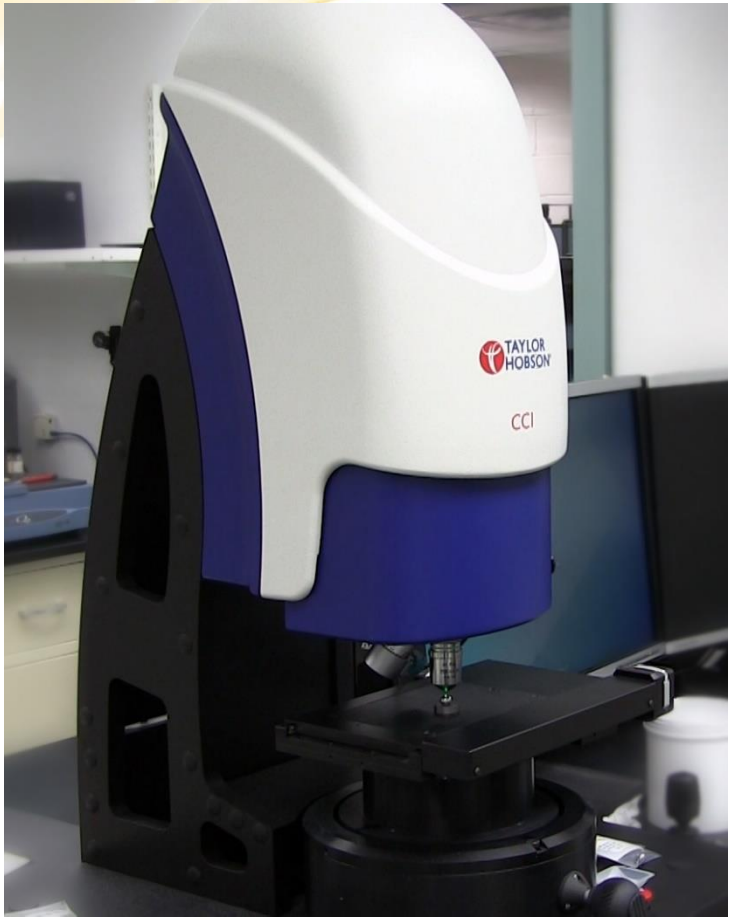
Testing Procedures

4-Ball Wear (ASTM D-4172)	SRV Coefficient of Friction (ASTM D-5707)	Optical Profilometry
• 40 kg load • 1200 rpm • 75°C • 1 hour	• 200 N load • 50 Hertz • 50°C • 2 hour • 1.0 mm stroke	• 3D surface profiler • Measures surface roughness and allows for volume calculations • Differentiates of similar size scars





Optical Profilometry

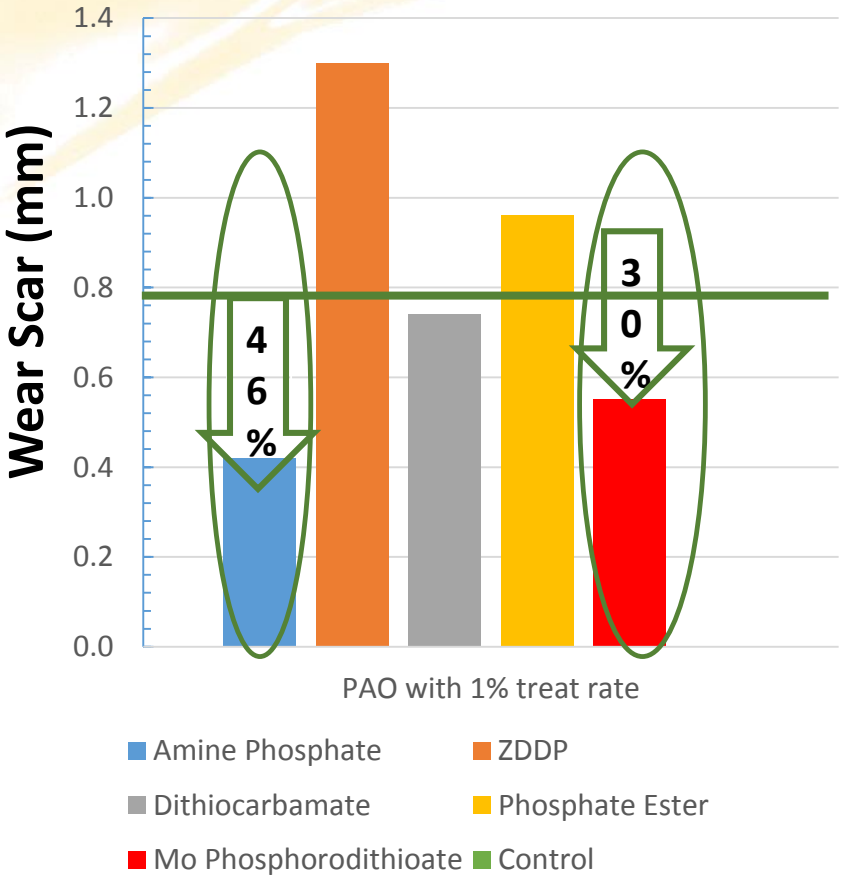


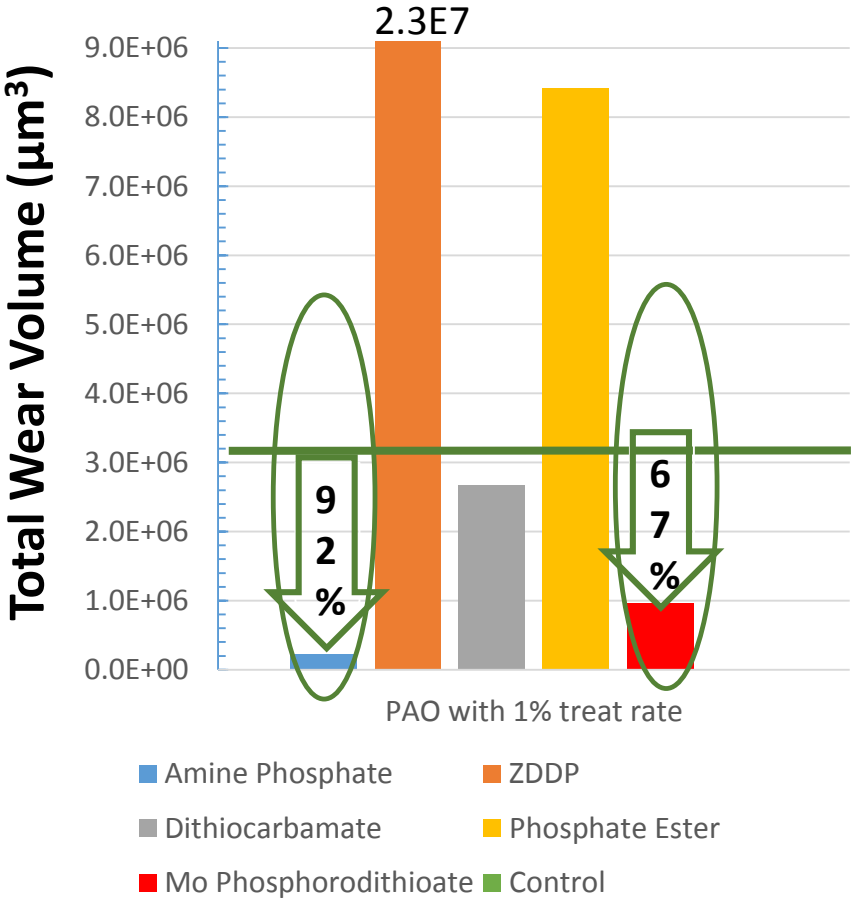
- **3D surface information in high definition**
- **High speed, non-contact measurement**
- **High resolution, accuracy, and repeatability**
- **Easy to use, automatic measurements**

DOE Test Result Analysis

- Performed data analysis using Minitab software
  - Identified interaction significance for each variable
  - Identified significant multi-variate interactions for each test
  - Identified main effects for each test
- 4 Ball Wear testing
  - R^2 = 87% for wear scar
  - R^2 = 72% for total wear volume
- SRV CoF testing
  - R^2 = 87% for total disc volume
  - R^2 = 71% for total ball volume

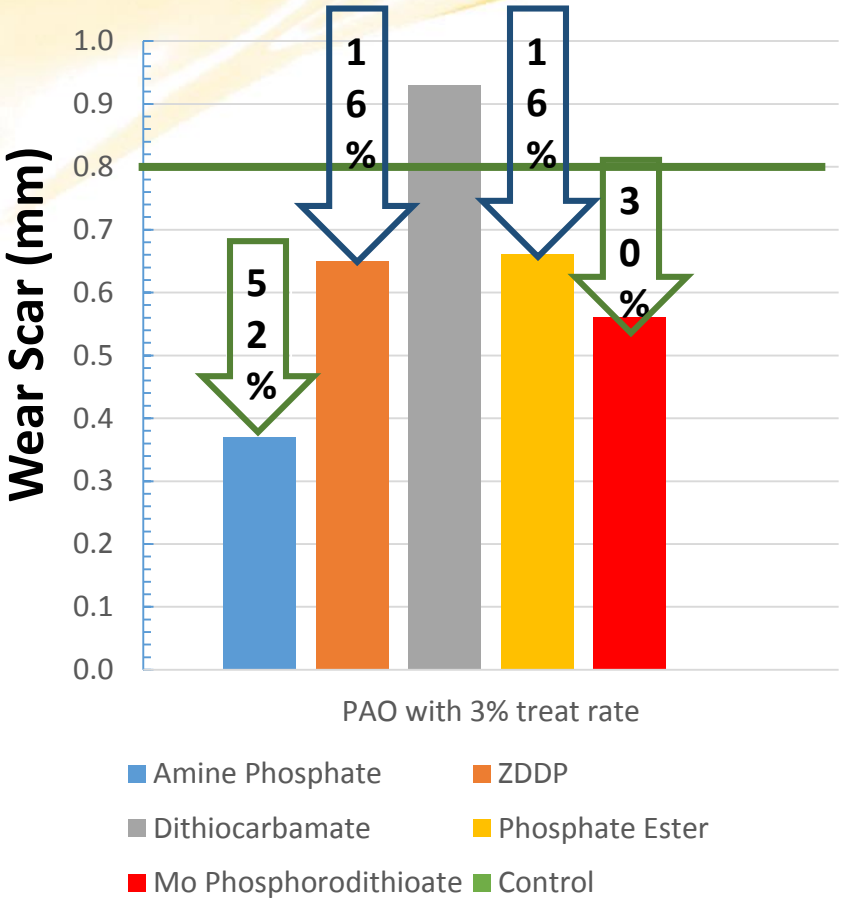
4-Ball Wear 2D and 3D Results for PAO Samples

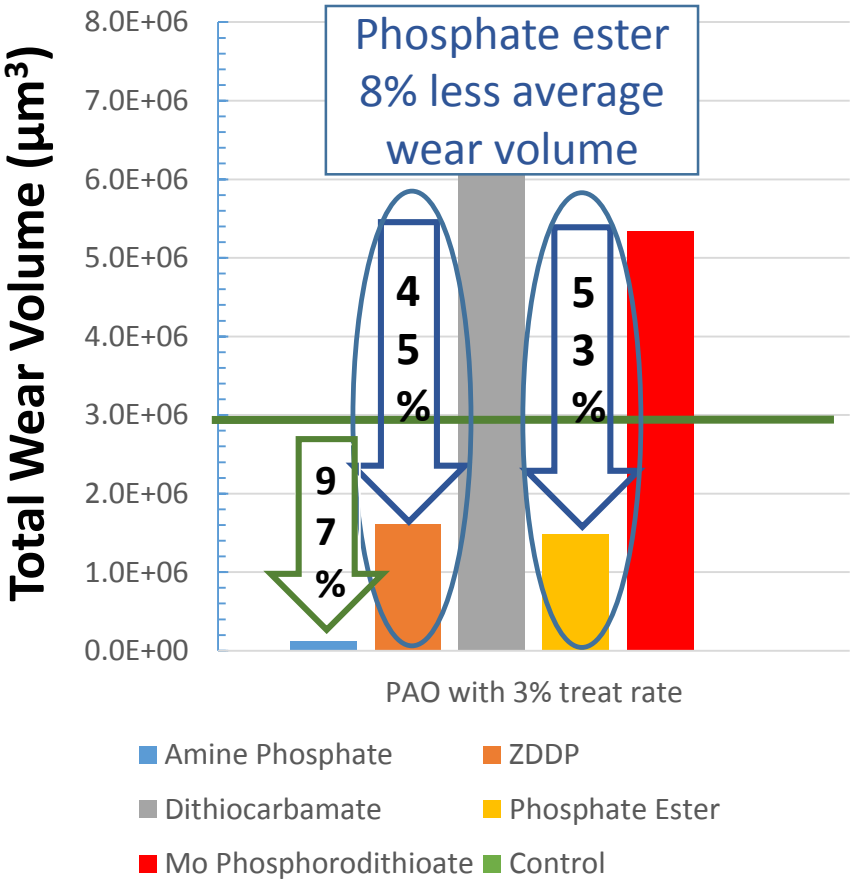




Amine Phosphate and Mo phosphorodithioate significantly reduce wear

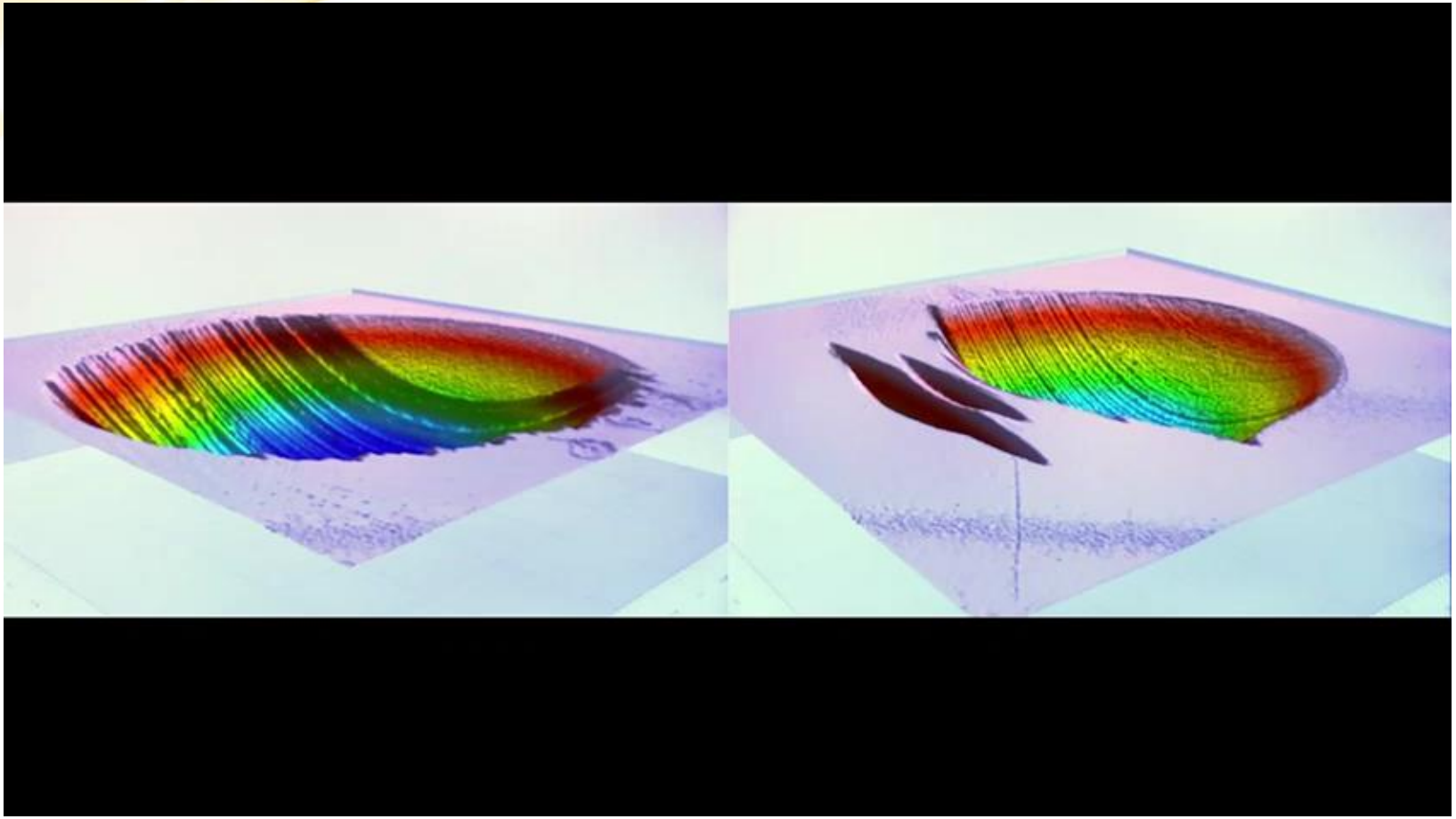
4-Ball Wear 2D and 3D Results for PAO Samples



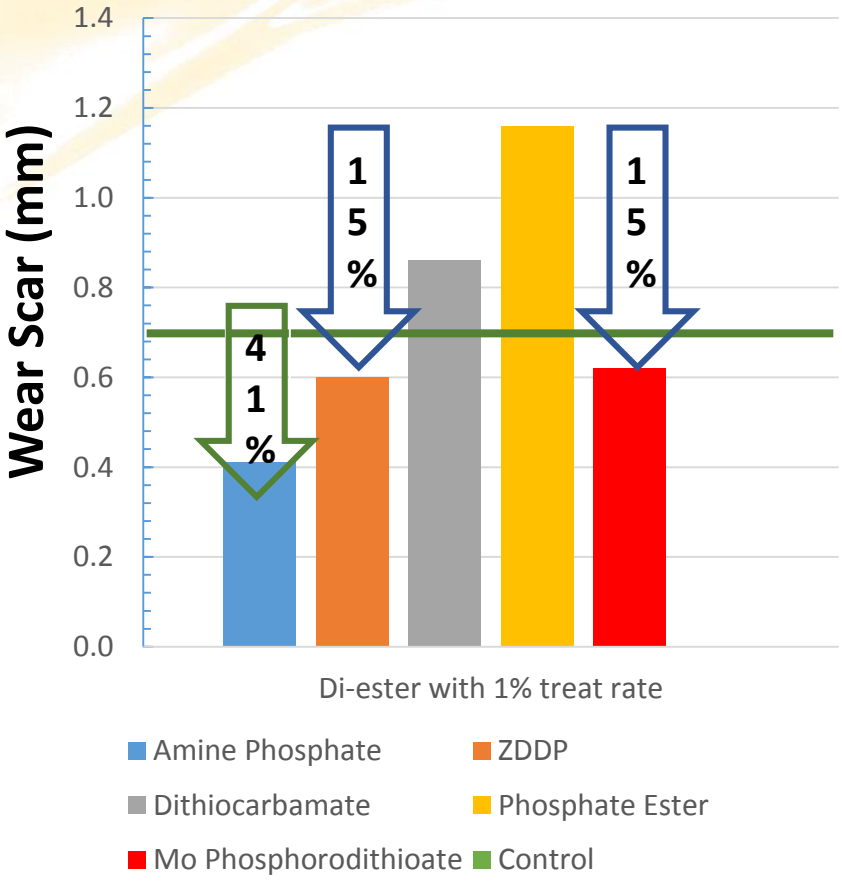


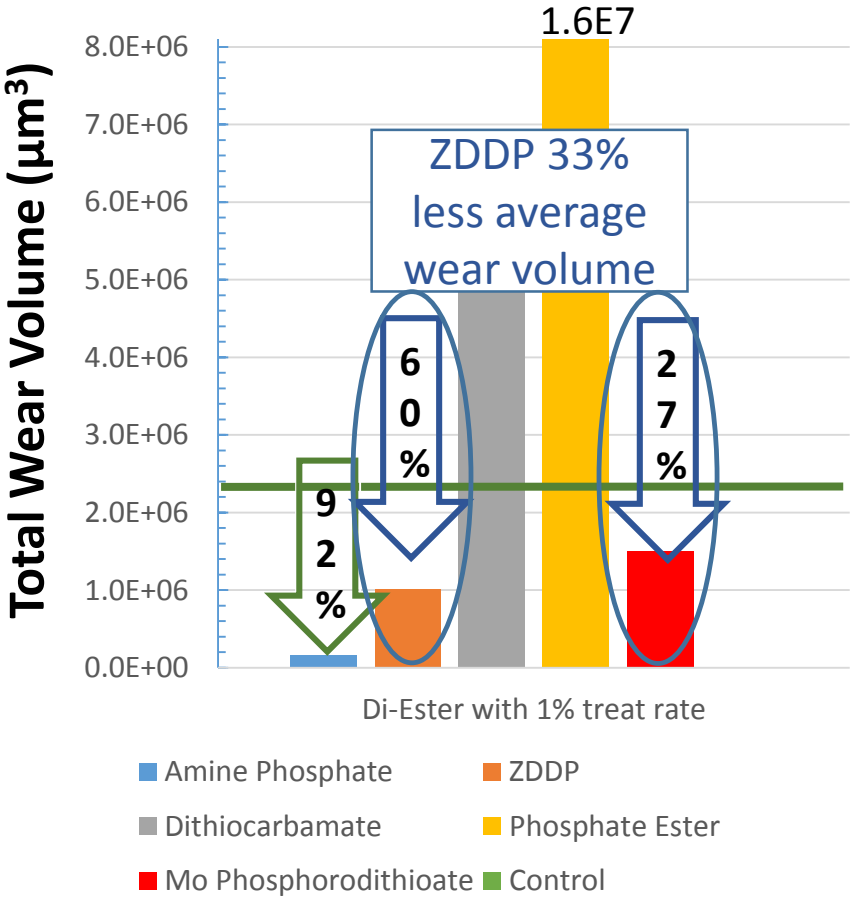
Optical profilometry distinguished differences between additives that have equivalent 2D wear scars

Profilometer Image of Additives in PAO



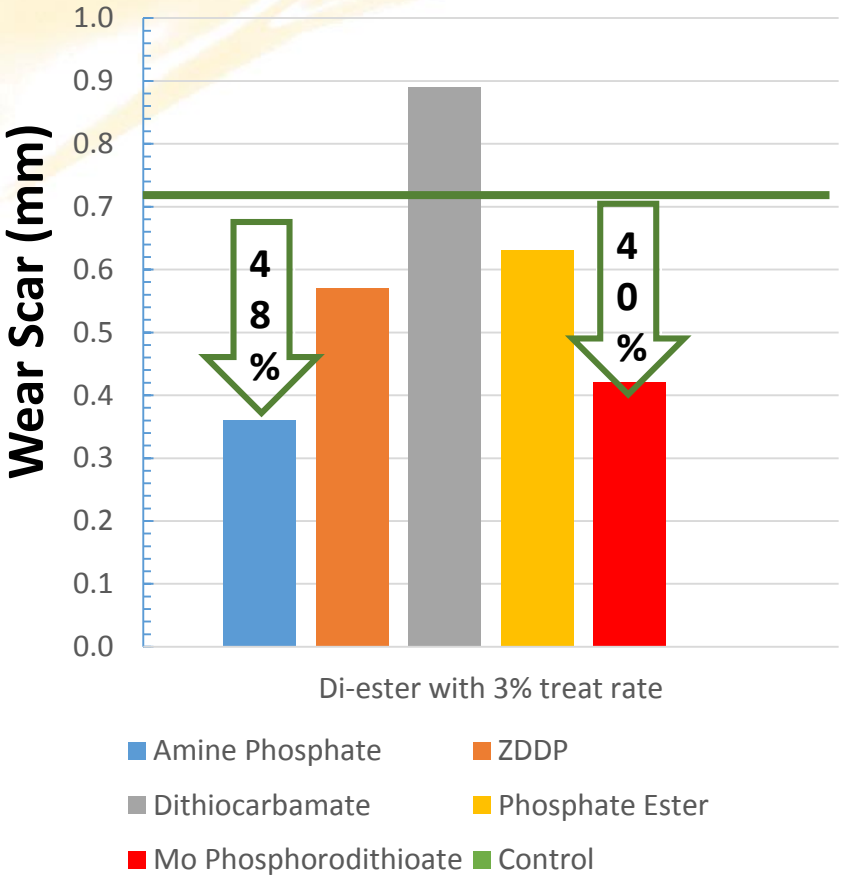
4-Ball Wear 2D and 3D Results for Di-ester Samples

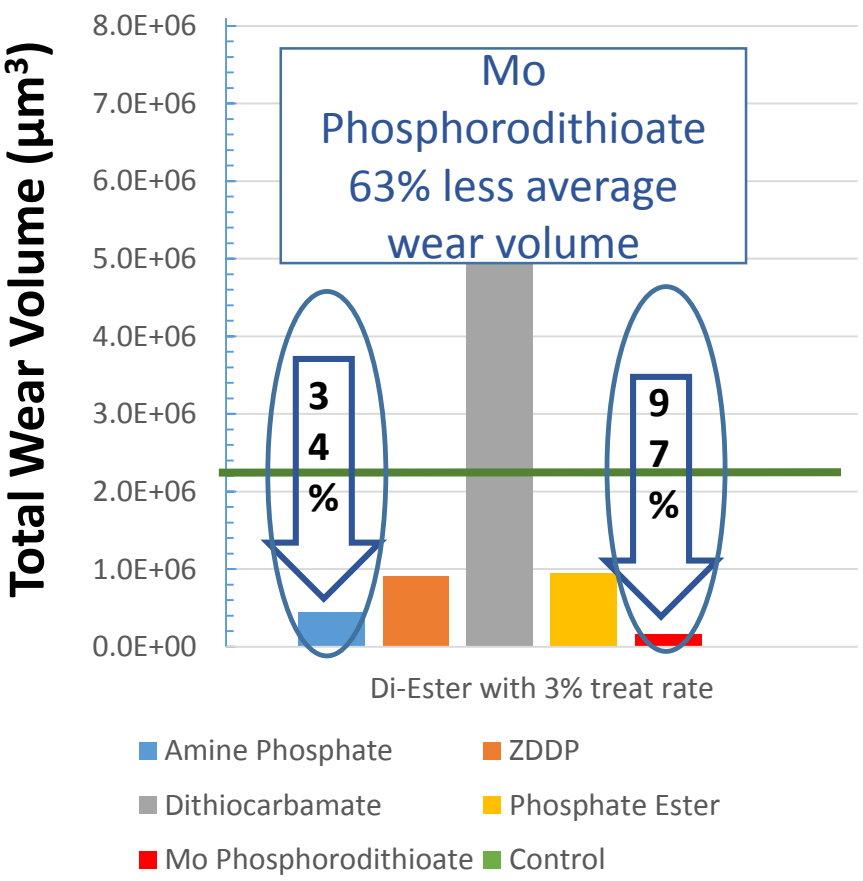




Optical profilometry distinguished significant differences in average wear volume between additives that have similar 2D wear scars

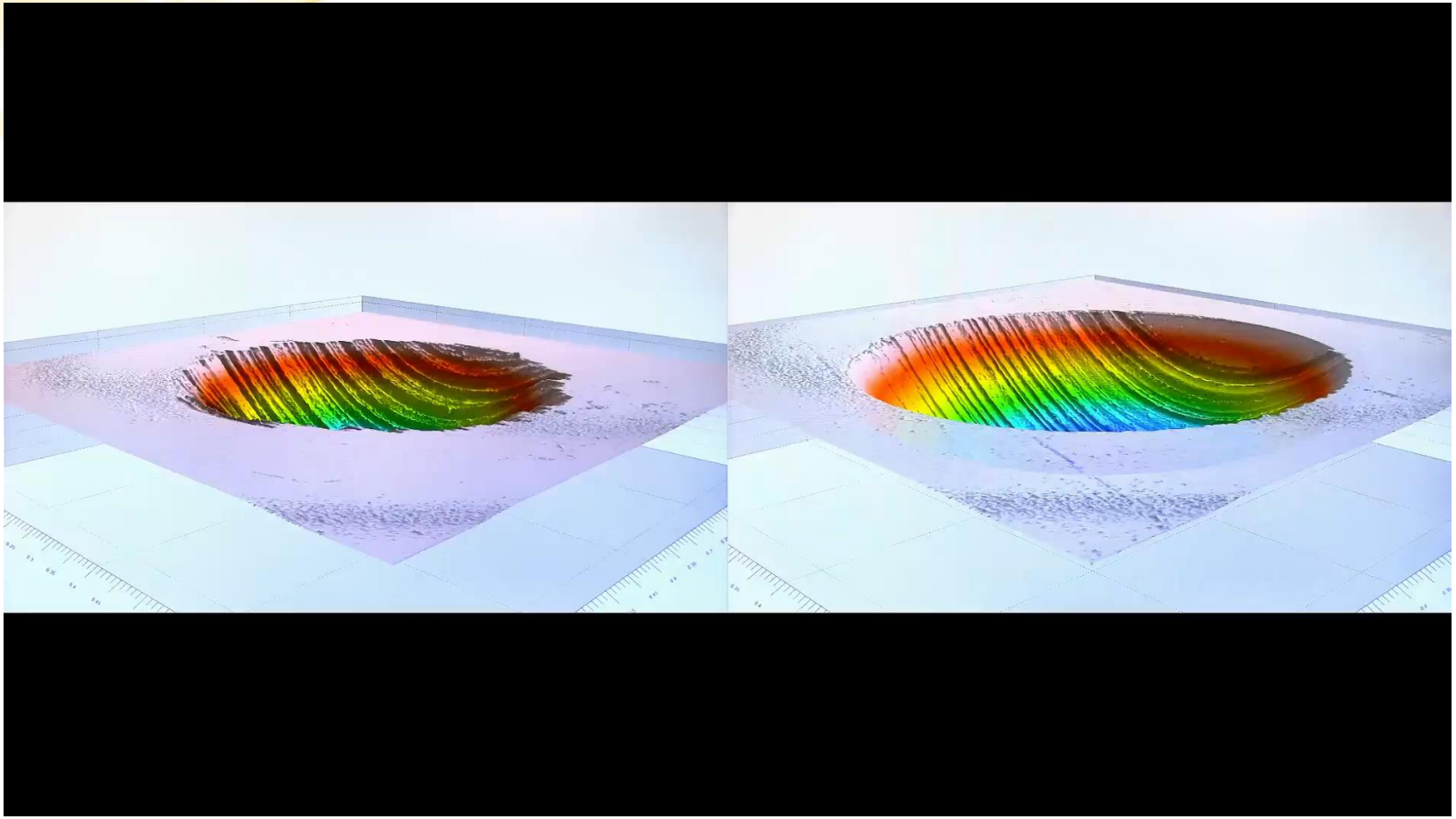
4-Ball Wear 2D and 3D Results for Di-ester Samples



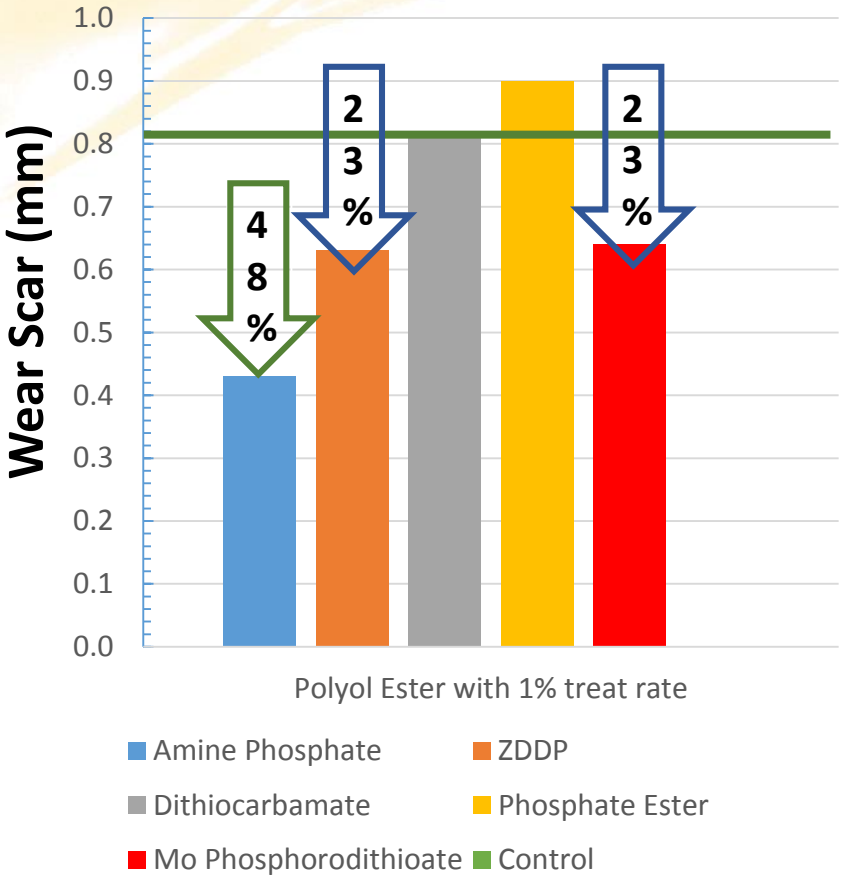


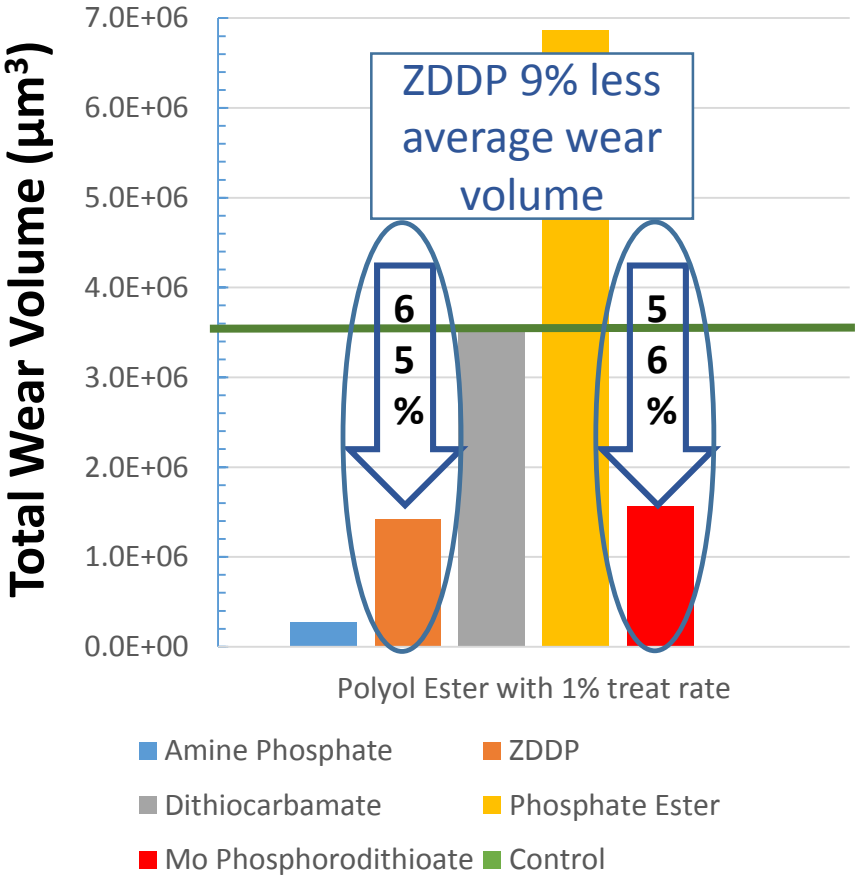
Optical profilometry distinguished significant differences in average wear volume between additives that have similar 2D wear scars

Profilometer Images of Additives in Di-ester



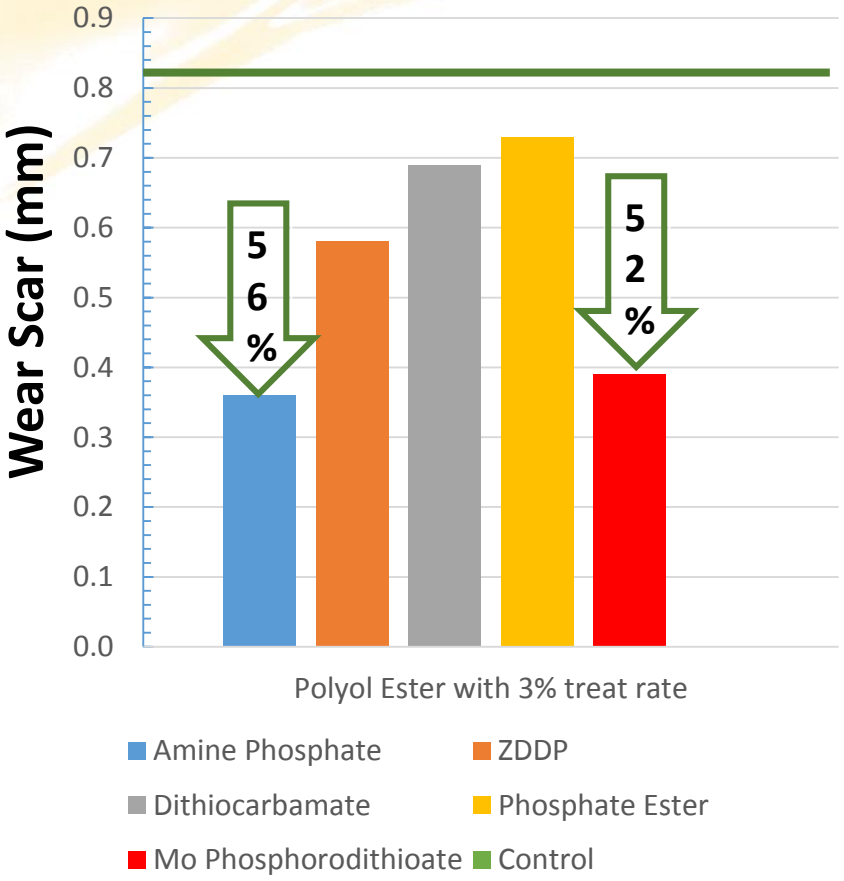
4-Ball Wear 2D and 3D Results for Polyol Ester Samples

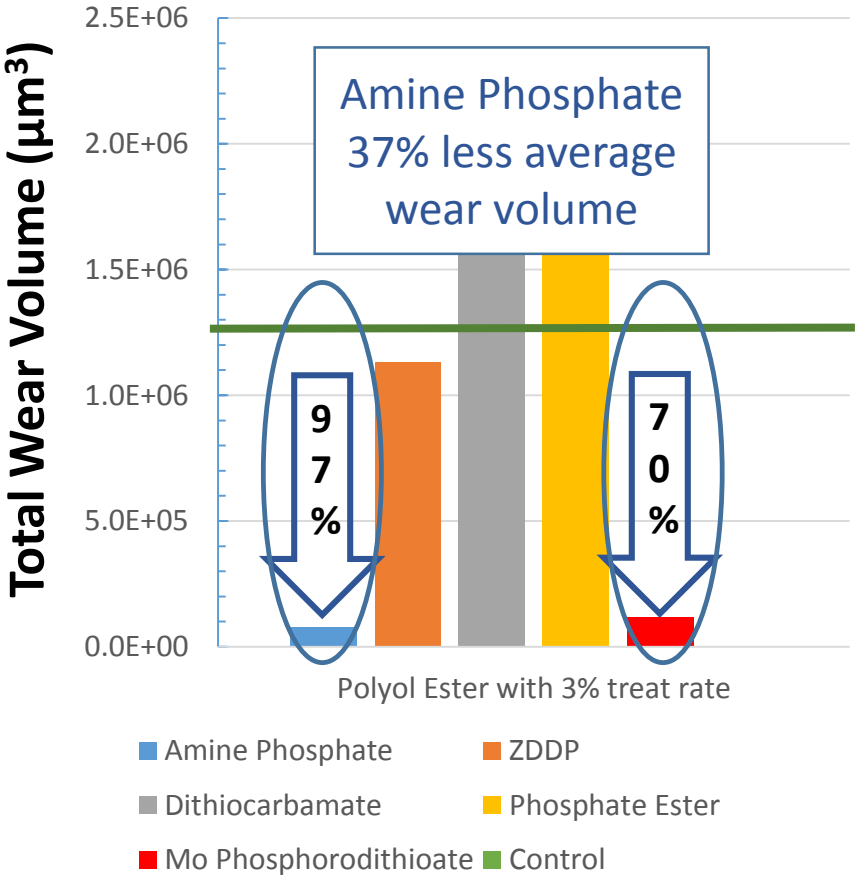




Optical profilometry distinguished differences in average wear volume between additives that have similar 2D wear scars

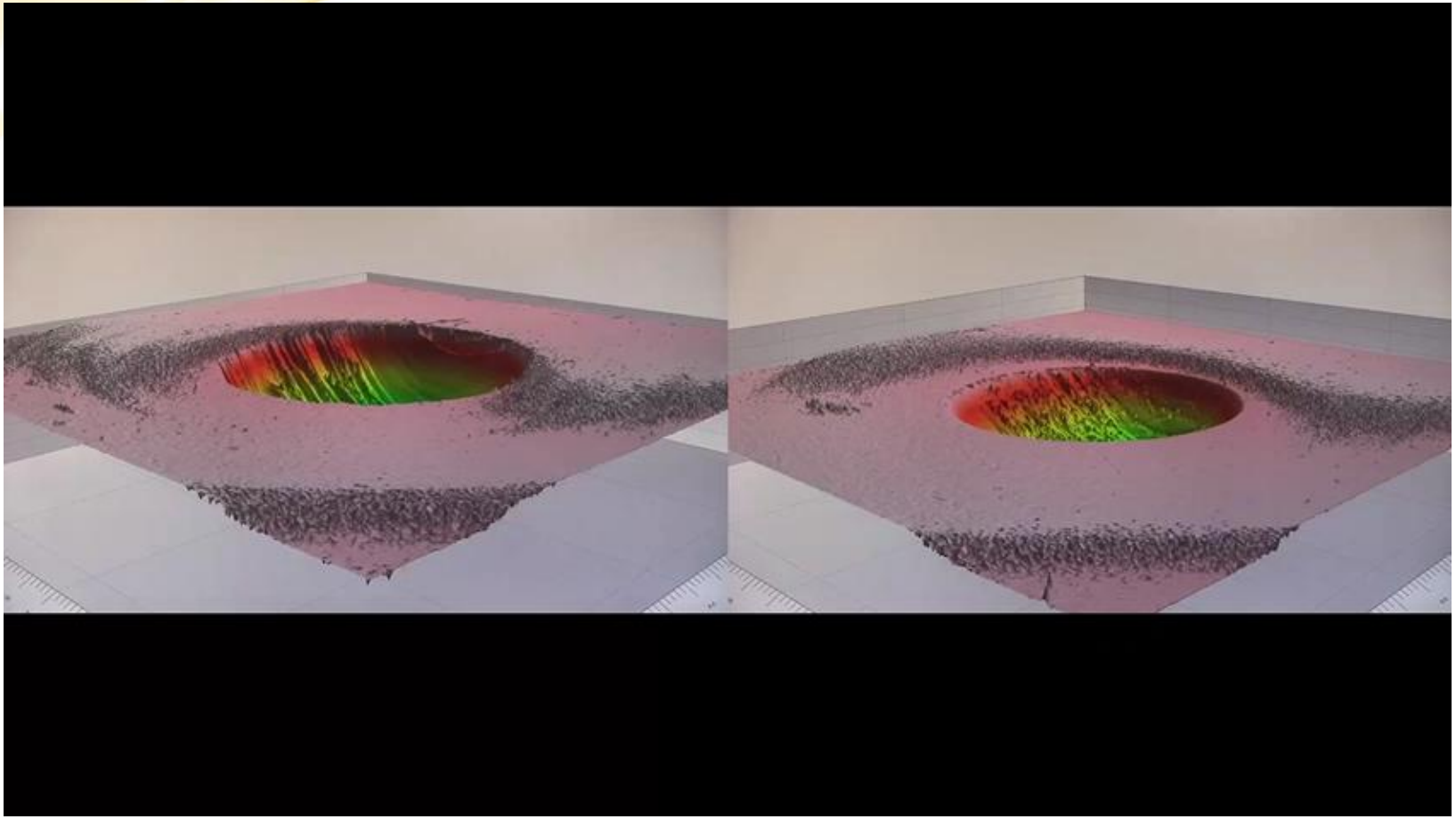
4-Ball Wear 2D and 3D Results for Polyol Ester Samples



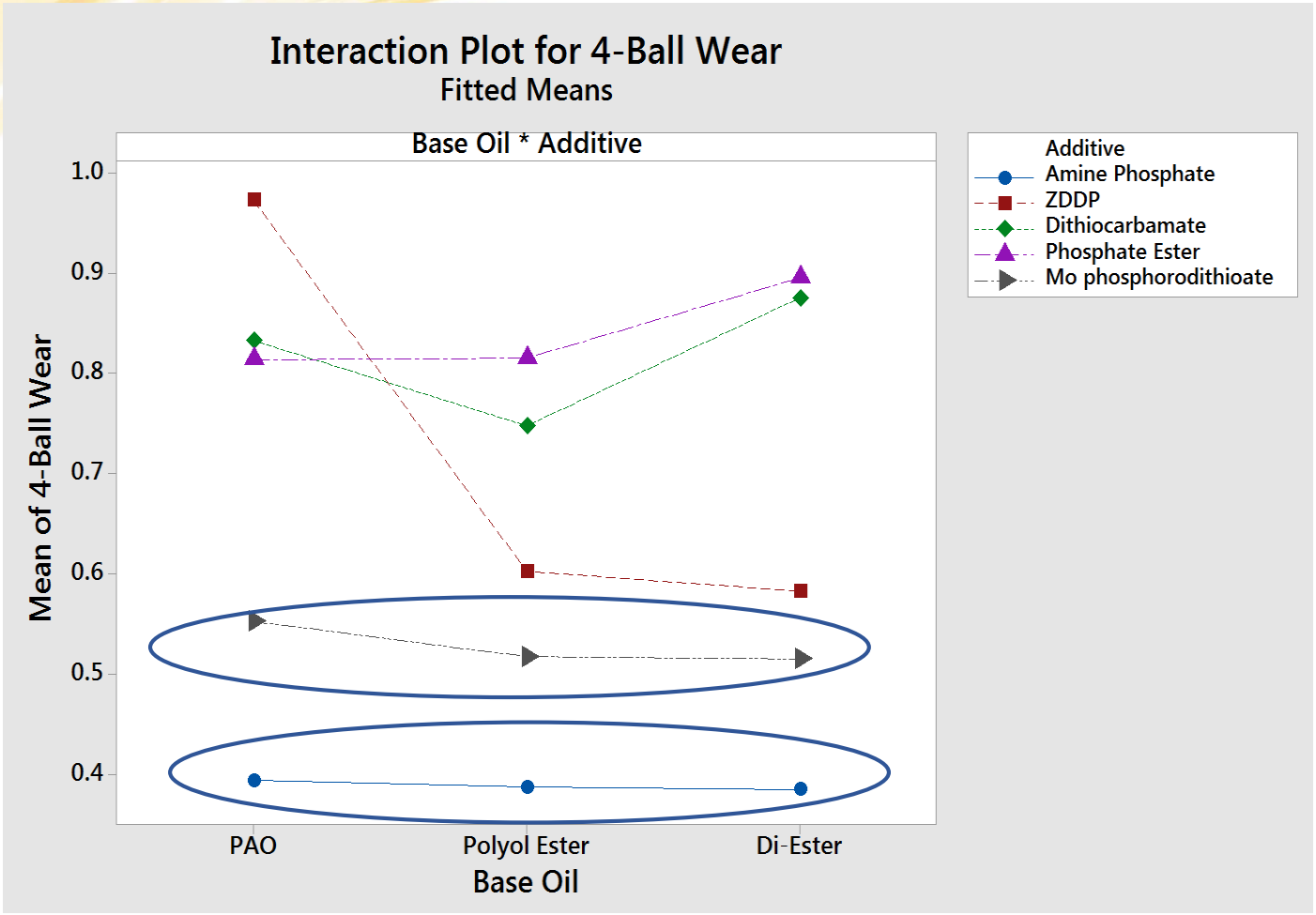


Optical profilometry distinguished significant differences in average wear volume between additives that have similar 2D wear scars

Profilometer Images of Additives in Polyol Ester



2-Way Interactions: Base Oil & Additive

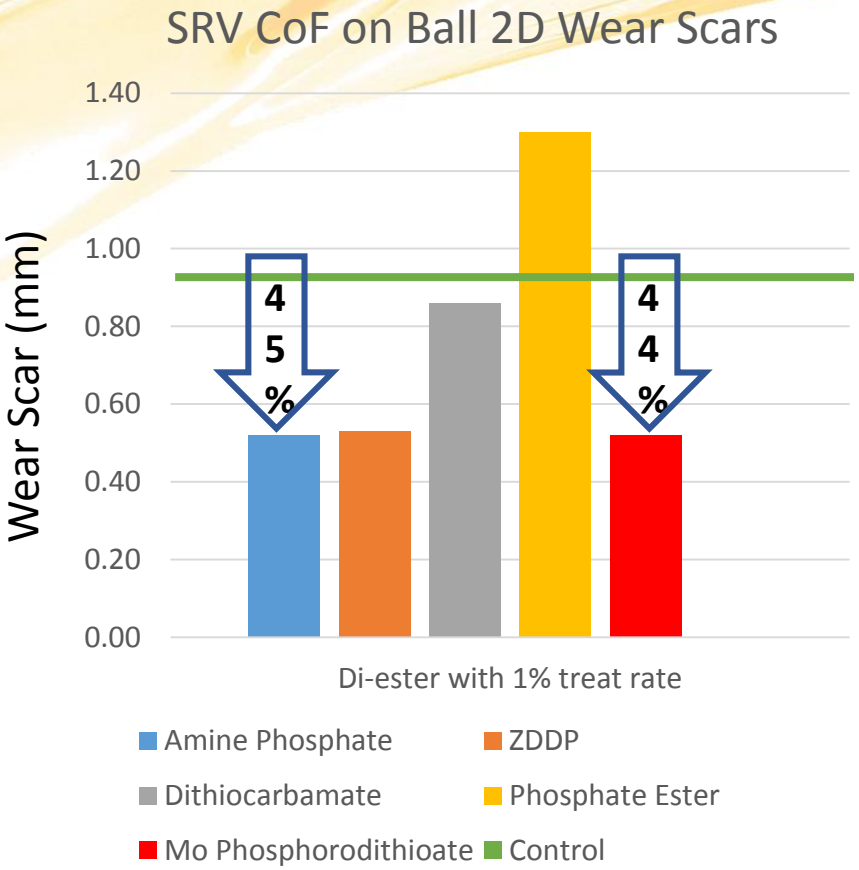


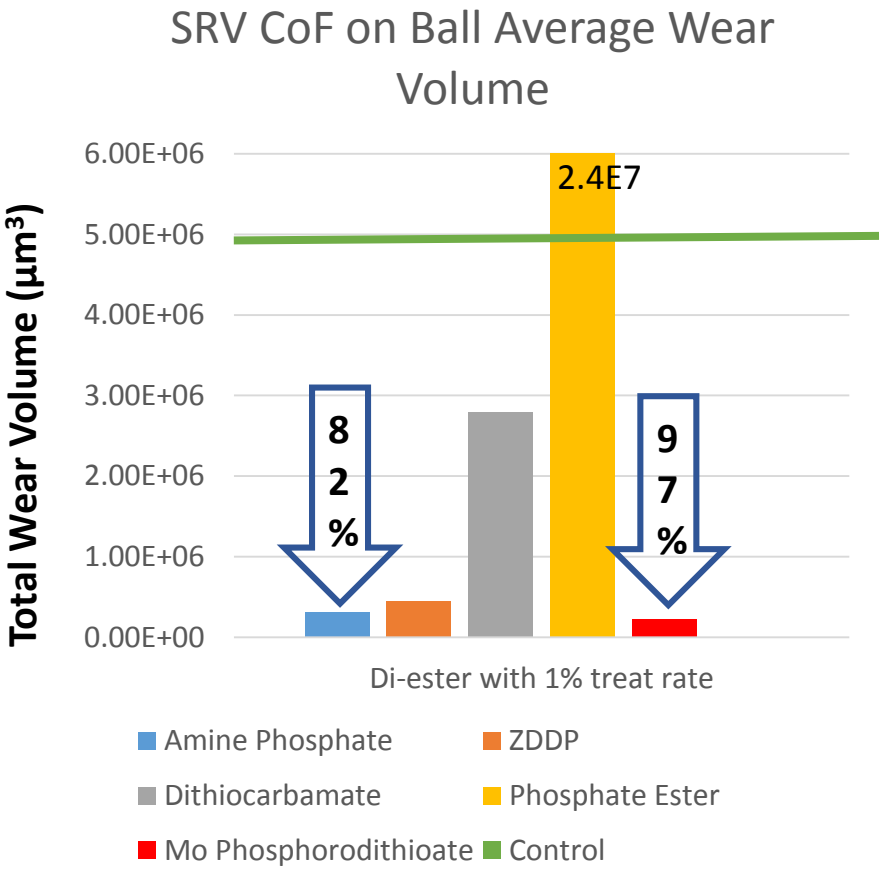
Amine phosphate and Mo phosphorodithioate had a positive effect on reducing wear

Conclusions: 4-Ball Wear

- **Average wear volume analysis showed major differences between some additive chemistries not seen with 2D analysis**
- **Amine phosphate additive was the most effective reducing the total wear volume in all 3 base oils**
- **Treatment level for all additives was significant**
- **2-way interactions were significant**
  - Treat level & additive
  - Base oil & additive
- **Profilometry is critical to consider when selecting wear additives as it will allow for further differentiation in wear performance**

SRV CoF Results





Shows similar trends as 4-Ball Wear data but slightly lower percent reductions in average wear volume for SRV testing on both the disk and balls specimens

Next Steps

- **Evaluate additional wear additive chemistries**
- **Expand to other base oil chemistries**
- **Study effect of blending wear additive chemistries**
- **Study impact of having other additive chemistries in the formulation**
  - Friction modifiers, extreme pressure, and corrosion additives
- **Look at grease formulations**

Acknowledgements

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- **Lab staff for performing all of the testing**
  - Jayna DeMedeiros
  - Brian Candido
- **Marketing staff**

Thank you

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