

HIGH PERFORMING SOLIDS FOR DEMANDING APPLICATIONS.

Comparative Study of IF-WS₂ MoS₂ and hBN

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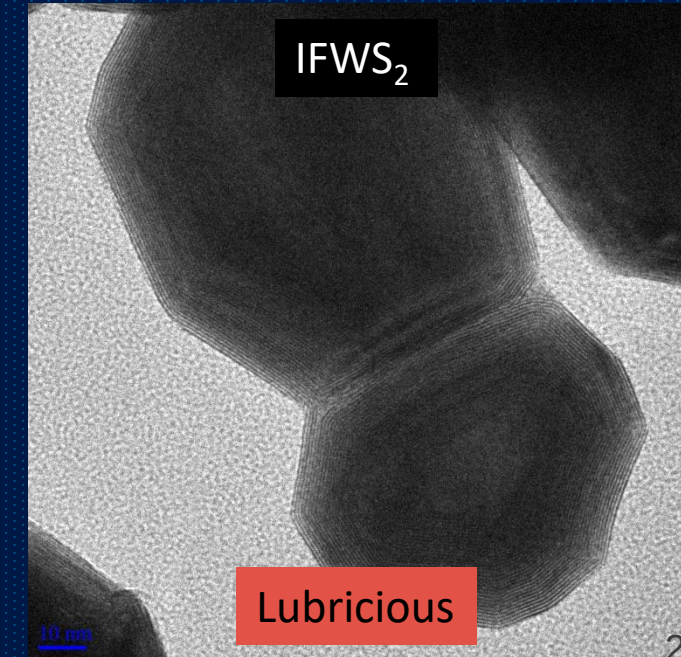
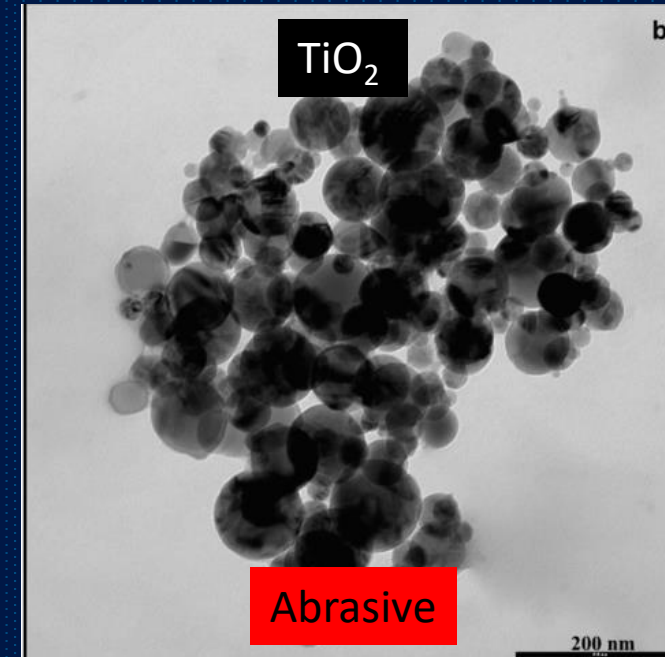
Essen Germany 2022

NanoTechnology; what does it mean?

✓ Claiming "NANO" is Good for Your Appliation = Oil is Good for Your Car!

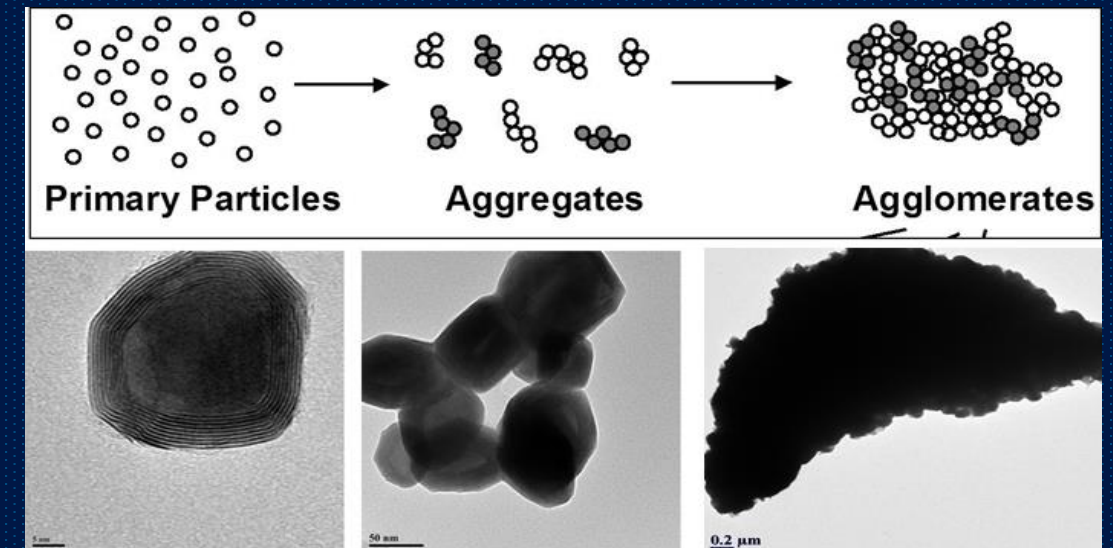


✓ Not Every Oil / Neither Every "NANO"



NanoTechnology; what does it mean?

- ✓ Small Size = High Surface Area = Lower Treat Rates
- ✓ Nano is definition of Size, hence everything can be measured in Nano
- ✓ Shape is as important as Size
- ✓ Dispersability & Stability in Dispersion
- ✓ Agglomeration / Aggregation
- ✓ Health & Safety
- ✓ Supply





COMPARATIVE STUDY BETWEEN IF-WS₂ & MOS₂ IN GREASES



Traditionally speaking, MoS₂ is well known as an Anti-wear and Extreme pressure additive for high performance greases. Hence, it is relevant to compare it with IF-WS₂ in lubricating greases.

MoS₂ Powder vs. IF-WS₂ Dispersion

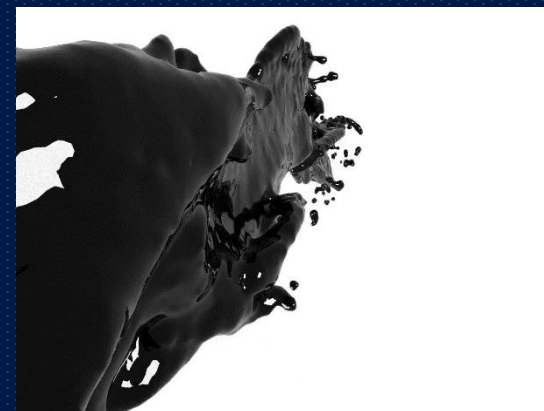
MoS₂

- Supplied as Powder
- Solids in Powder form are Difficult to Handle;
Hazardous Airborne Particles
- Powder Can Be Used Only in a Limited Number of Applications.



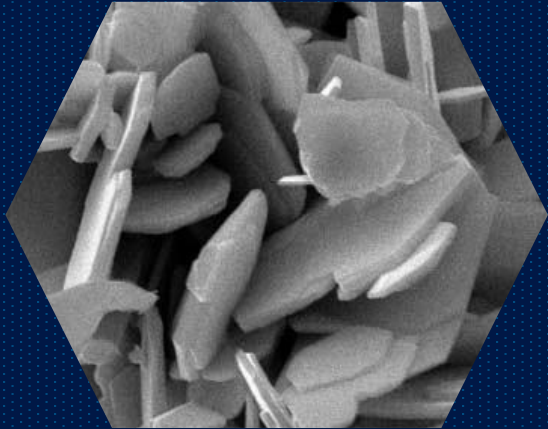
IF-WS₂

- Supplied as Dispersion
- Dispersions are Easy and Safe to Handle
- Liquid IF-WS₂ has Various Industrial Applications
- Easier to Mix Homogeneously in Various Type of Carriers such as Greases

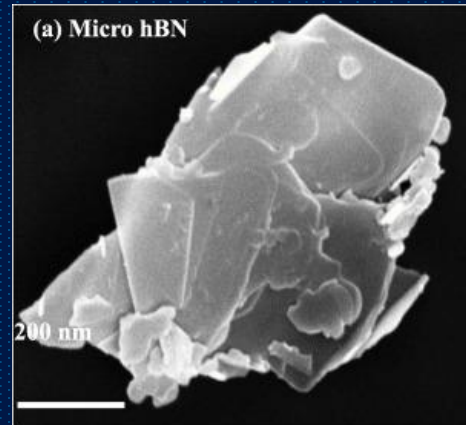


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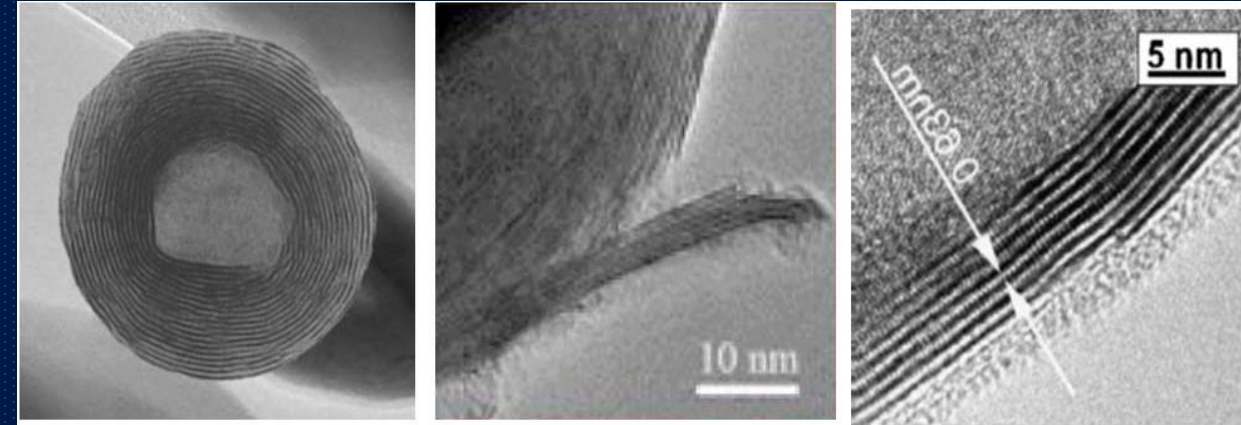
IF-WS₂ VS. MOS₂ and hBN



MoS₂ platelet type particles do not absorb shock forces and do not protect metal surfaces from pitting and micro cracks. Shows moderate EP but high wear under high speed

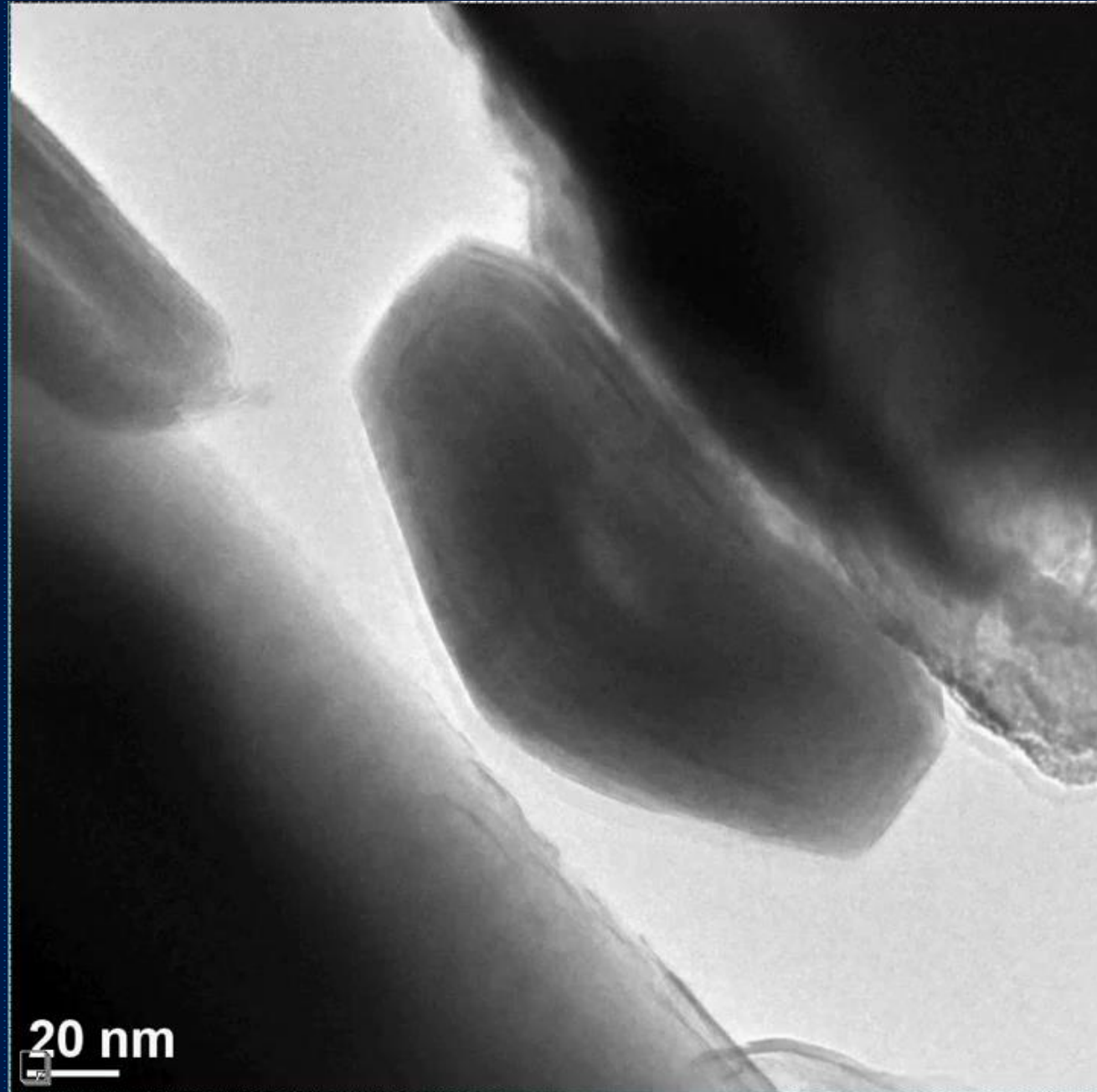


hBN platelet type particles do not absorb shock forces and do not protect metal surfaces from pitting and micro cracks. Shows AW/AF properties but no EP



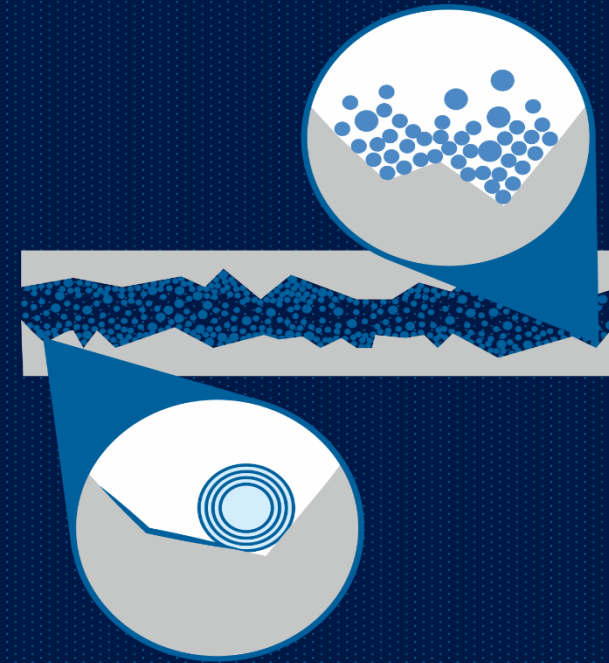
IF-WS₂ particles absorb shock forces, protect and recondition metal surfaces. Show excellent EP, AW and AF properties. Synergistic with MoS₂ and hBN

HRTEM VIDEO (PROF. F. DASSENNOY LAB)



IF-WS₂ Performs as a Lubricant

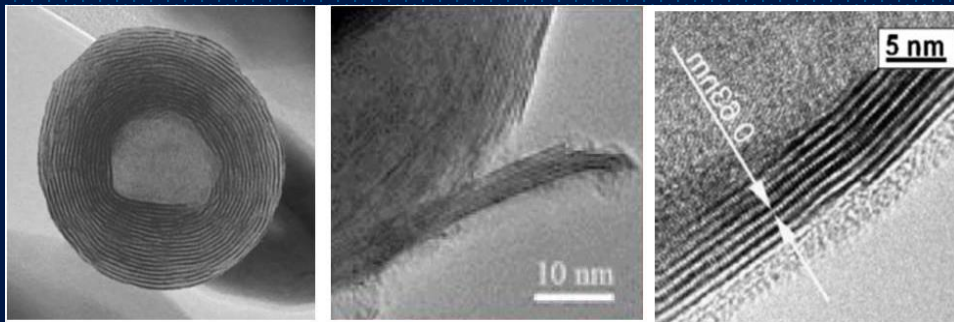
- Because of their **size and shape**, IF-WS₂ particles can fill in the asperities and cracks (to prevent further crack propagation and growth) on contacting surfaces.
- Because of their **onion-like structure**, IF-WS₂ exfoliate to produce single and multi layer tribofilm on the surface.



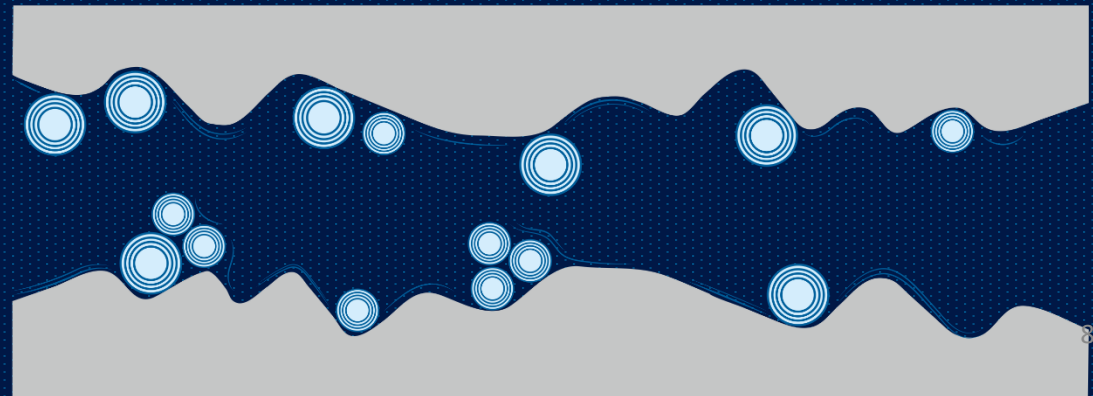
FILL IN CRACKS

P. U. Aldanaab, F. Dassenoya, B. Vachera, T. Le Mognea, B. Thiebautb and A. Bouffetb,
Tribology Transactions, 59, 2015

**16 – 20
Layers**



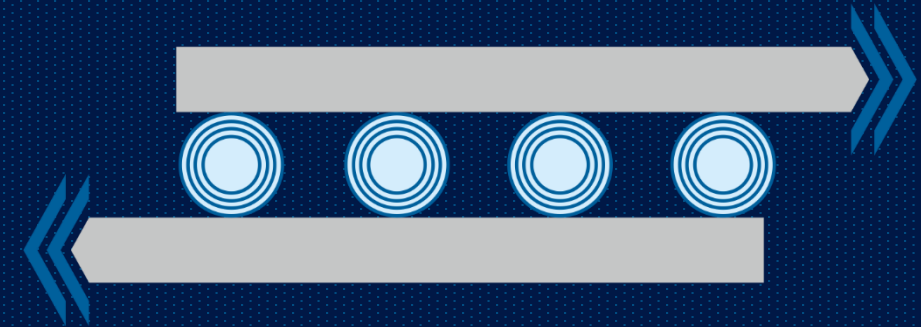
Pre-exfoliated IF-WS₂ layers TEM images



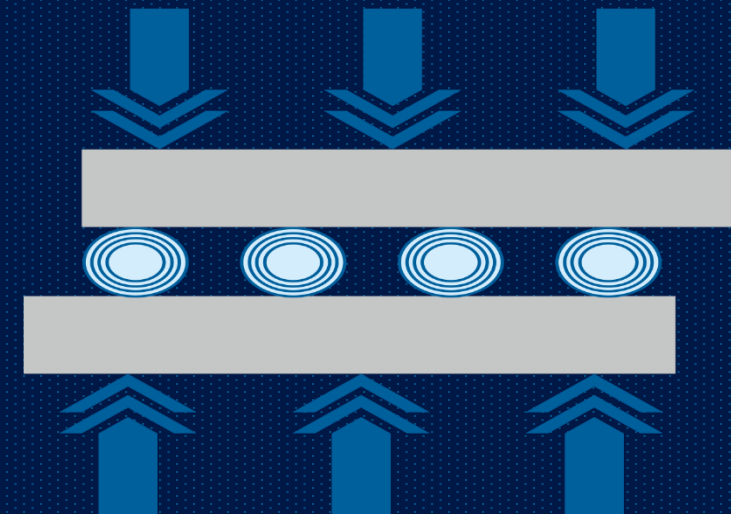
IF-WS₂ Performs as a Lubricant

- Thanks to IF-WS₂'s nearly spherical shape, the particles act as nano roller ball bearings, creating an antifriction effect; eventually, it results in a smooth conditioning effect, thus healing previously damaged surfaces.
- IF-WS₂ nearly spherical particles also have a **hollow cage structure**, which provide **Extreme Pressure resistance**, **high load bearing capacity**, and **high elasticity**. IF-WS₂ particles protect surfaces under extreme dynamic and static loads, as well as shear and shock conditions.

ROLLING EFFECT



WITHSTAND EXTREME PRESSURE



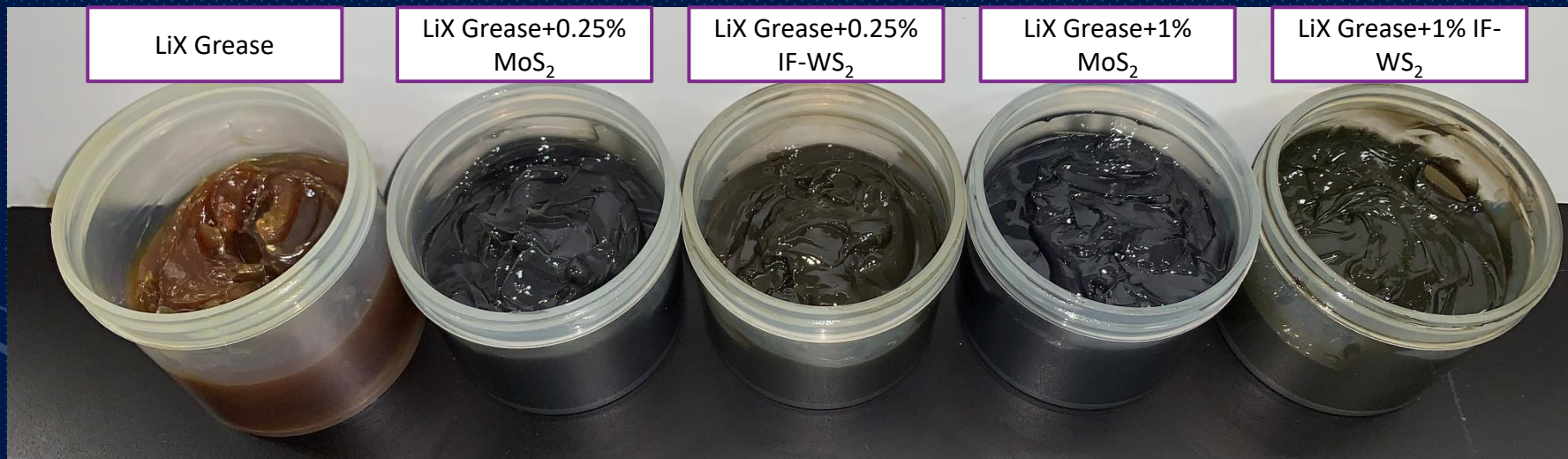
Mixing Process of IF-WS₂ & MoS₂ Greases

Neat greases

IFWS₂ solids 25% Concentration dispersion

MoS₂ solids 25% Concentration dispersion

Sample preparation All samples were prepared by mixing and homogenizing in speed mixer. Mixing time 8 min @ 3200 rpm

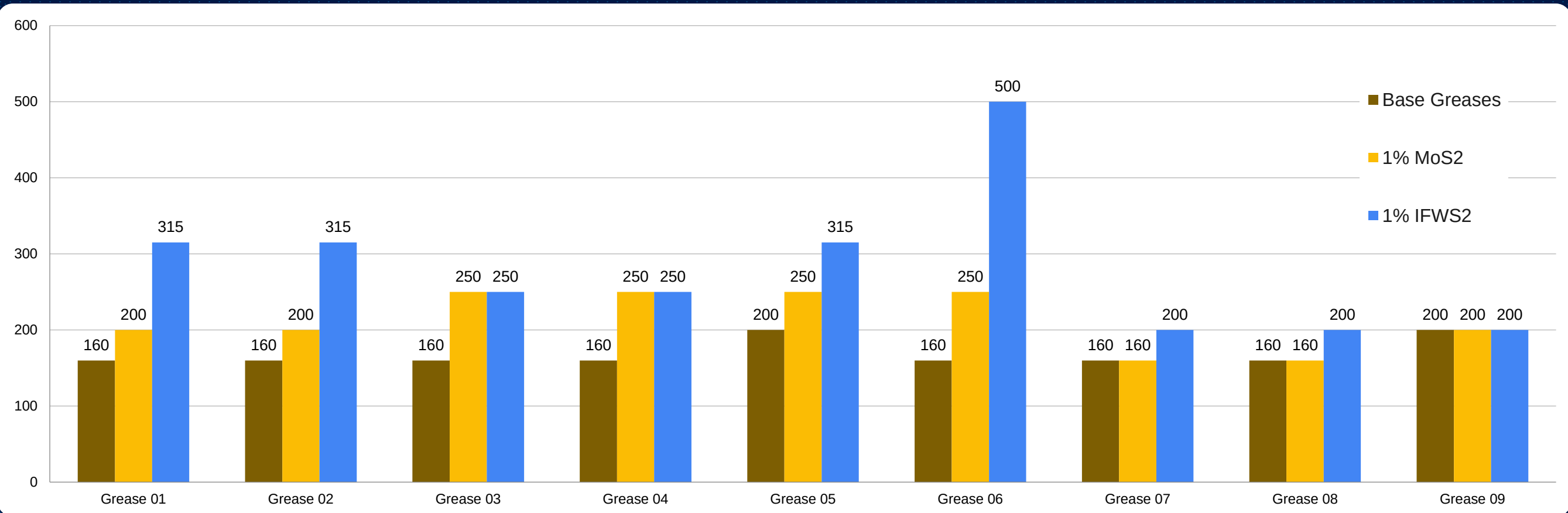


TRIBOLOGICAL STUDY



IF-WS₂, MoS₂ in NLGI 2 Greases

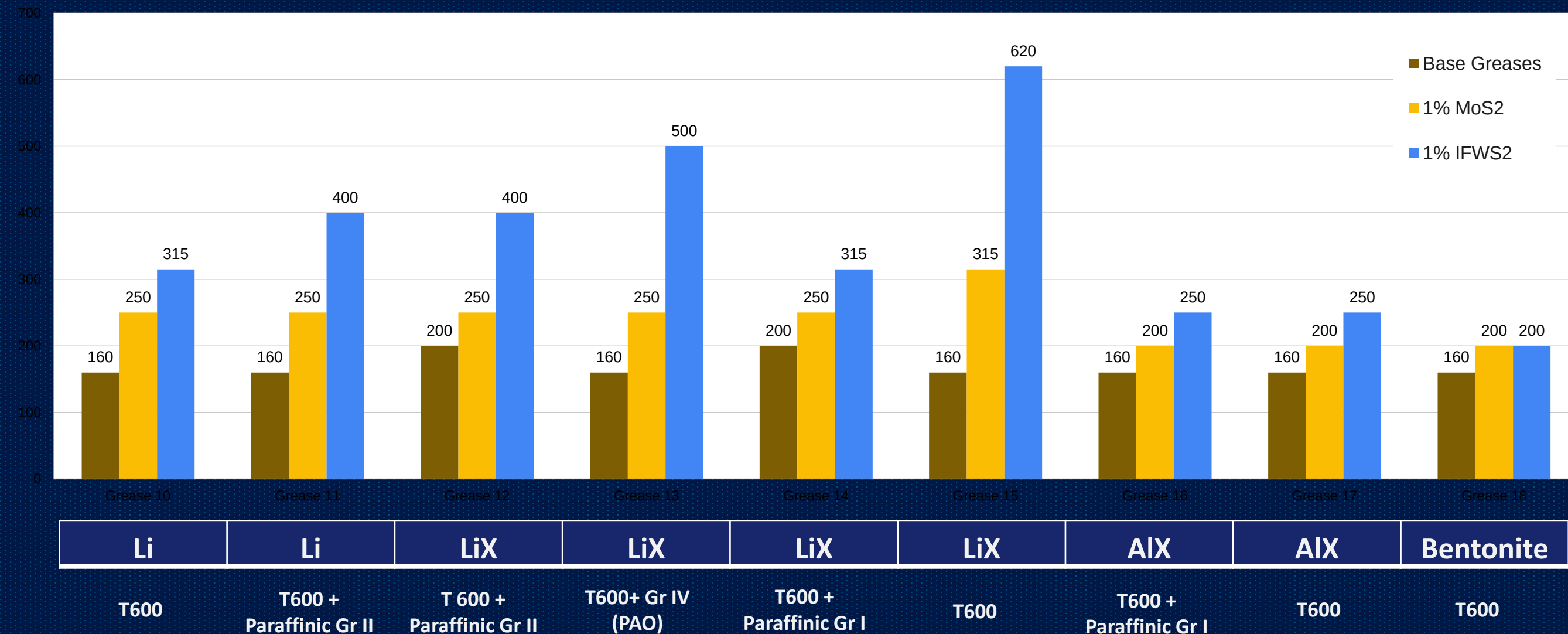
ASTM D2596 – Weld Load (kgf)



Li	Li	LiX	LiX	LiX	LiX	AlX	AlX	Bentonite
T600	T600 + Paraffinic Gr II	T 600 + Paraffinic Gr II	T600+ Gr IV (PAO)	T600 + Paraffinic Gr I	T600	T600 + Paraffinic Gr I	T600	T600

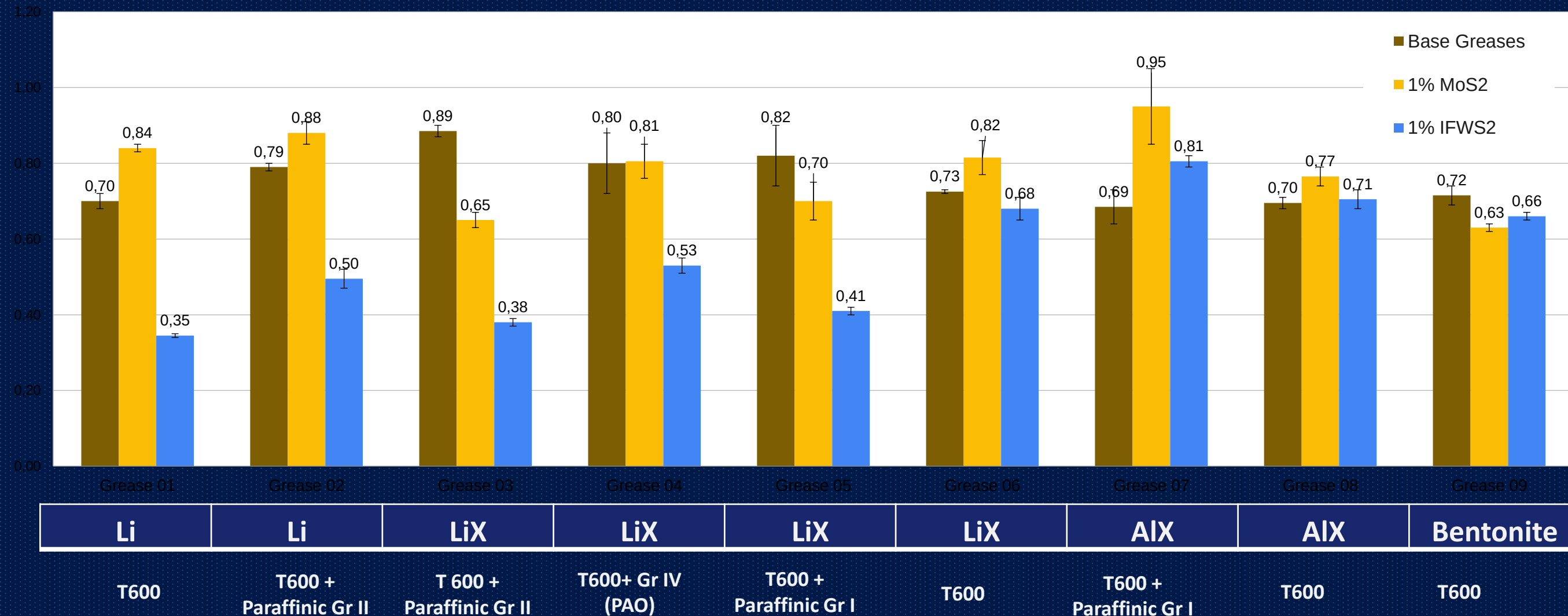
IF-WS₂, MoS₂ in NLGI 1 Greases

ASTM D2596 – *Weld Load (kgf)*



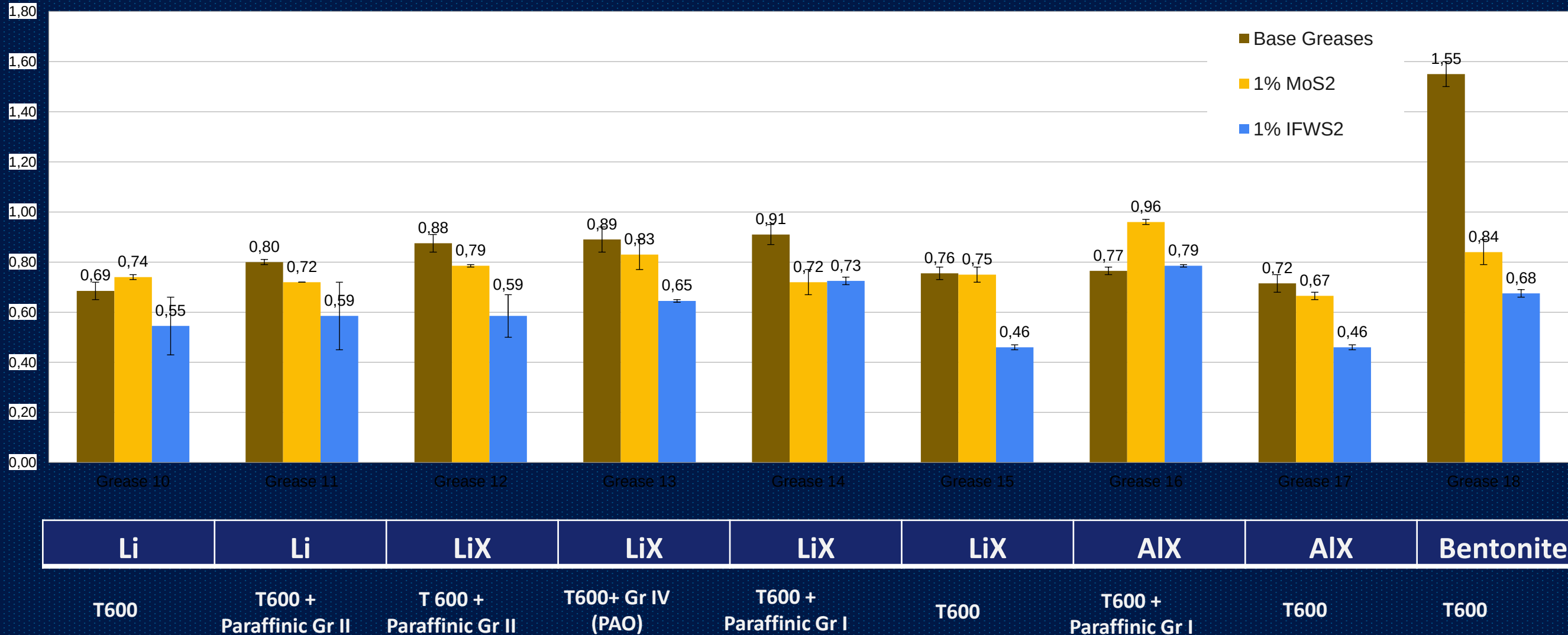
IF-WS₂, MoS₂ in NLGI 2 Greases

ASTM 2266 – *Wear scar (mm)*



IF-WS₂, MoS₂ in NLGI 1 Greases

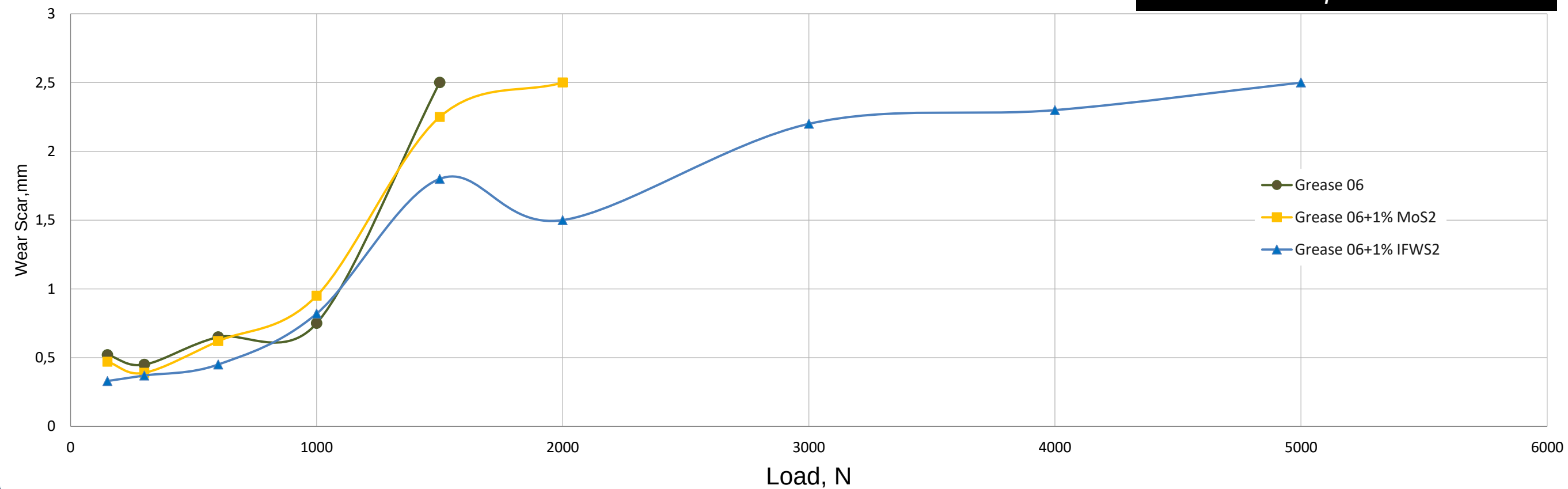
ASTM 2266 – *Wear scar (mm)*



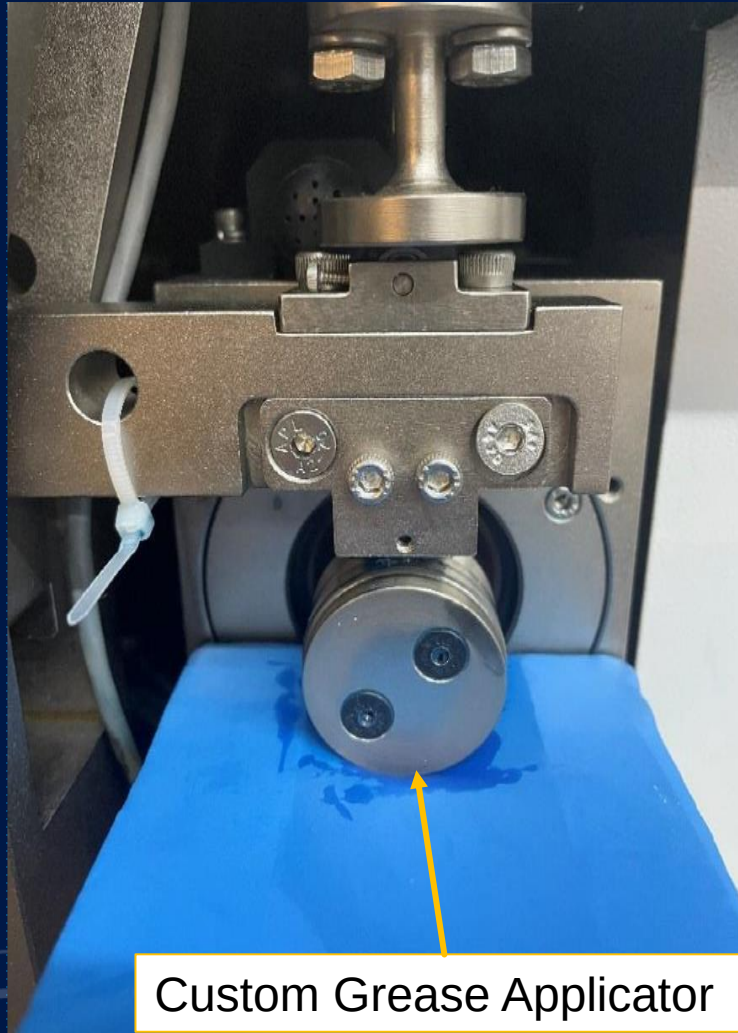
Wear as a Function of Load (DIN 51350-5)

Anti-Wear Characteristics Load -Wear
(DIN 51350-5)

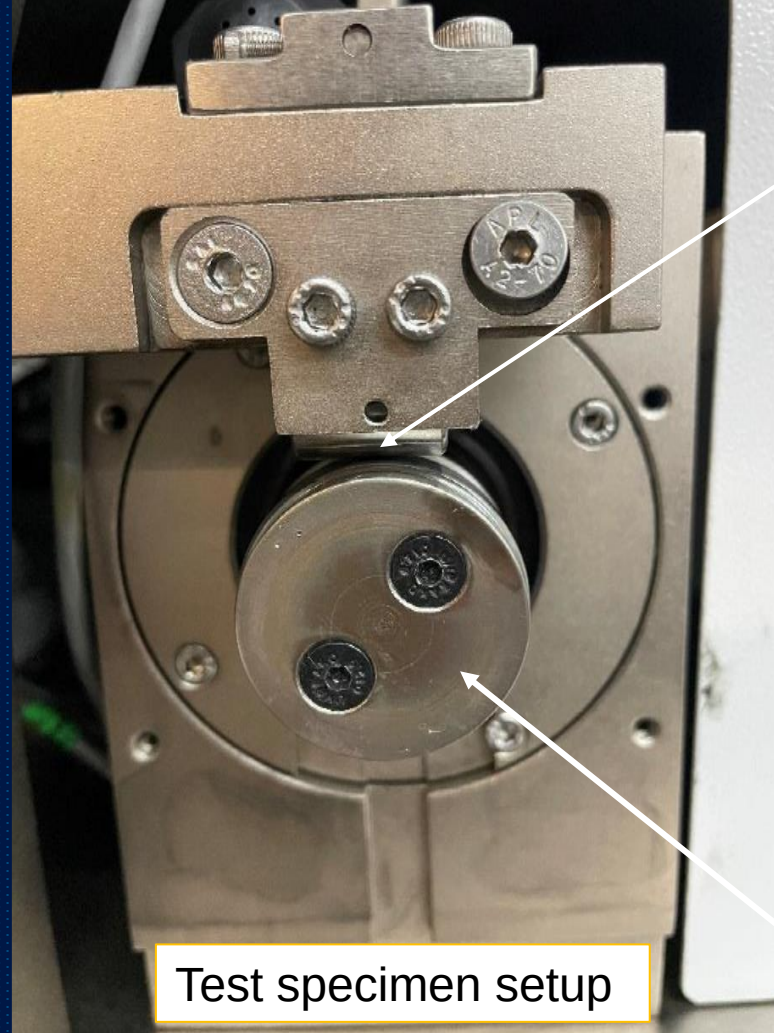
LiX NLGI 2 Naphthenic Oil T600



Ring On Cylinder Test



Custom Grease Applicator



Test specimen setup

Cylinder specimen

In an ideal situation of a rolling-sliding contact, the grease operates in full-fluid film lubrication condition to reduce the friction and wear.

However, in most cases, many contacts operate under starved lubrication conditions. Starved lubrication conditions lead to thinner films and eventually wear and failure.

The purpose of this study is to determine the friction behavior of greases under a thin film of lubricating grease using a cylinder on ring test configuration.

Rotational Ring

Test Specifications



- **Rotation Speed:** 100 rpm
- **Load:** 100 N
- **Test duration** 10 mins
- **Contact:** Sliding contact
- **Geometry:** Cylinder on Ring (also called crossed cylinder)
- **Contact evolution:** Point to area
- **Grease volume:** 0.5 ml

Following greases have been tested as is,
with 1% MoS₂ & with 1% IFWS₂

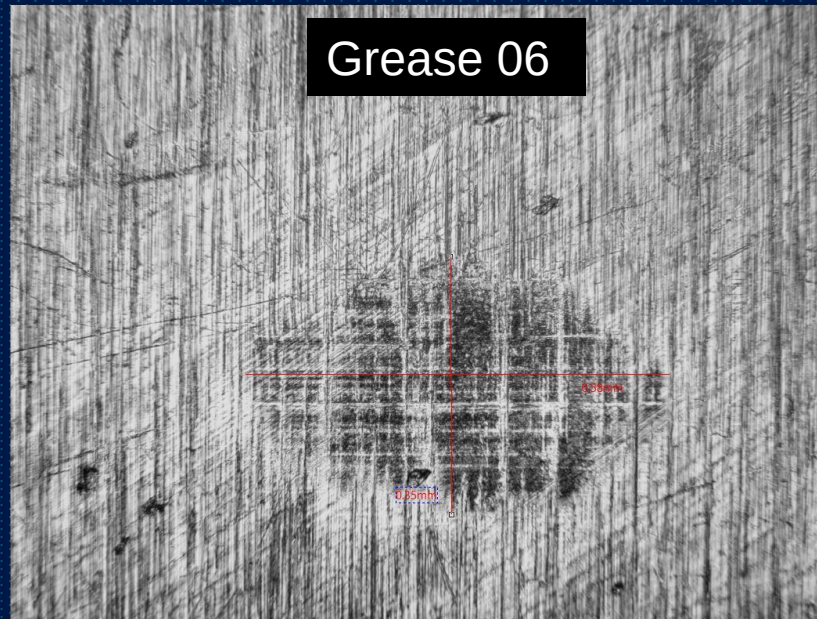
Grease 06 (Lix NLGI 2) ; Grease 08 (Alx NLGI 2)

Grease 13 (Lix NLGI 1) ; Grease 15 (Lix NLGI 1)

WEAR RESULTS

Grease	Wear X axis, mm	Wear Y axis, mm	StDev	
Grease 06	0.57	0.36	0.04	LiX NLGI 2 Naphthenic Oil
Grease 06+ 1% MoS ₂	0.86	0.425	0.05	
Grease 06+ 1% IFWS ₂ Test 1	No visible scar	No visible scar		
Grease 06+ 1% IFWS ₂ Test 2	No visible scar	No visible scar		
Grease 08	0.7	0.43	0.13	AIX NLGI 2 Naphthenic Oil
Grease 08+ 1% MoS ₂	0.84	0.435	0.02	
Grease 08+ 1% IFWS ₂	0.58	0.29	0.02	
Grease 13	0.65	0.39	0.03	LiX NLGI 1 Naphthenic Oil + Gr IV (PAO)
Grease 13+ 1% MoS ₂	0.77	0.43	0.01	
Grease 13+ 1% IFWS ₂	0.77	0.48	0.04	
Grease 15	0.72	0.40	0.15	LiX NLGI 1 Naphthenic Oil
Grease 15+ 1% MoS ₂	0.72	0.39	0.00	
Grease 15+ 1% IFWS ₂ Test 1	0.61	0.34		
Grease 15+ 1% IFWS ₂ Test 2	No visible scar	No visible scar		

Grease 06



Grease 06 + 1% MoS₂

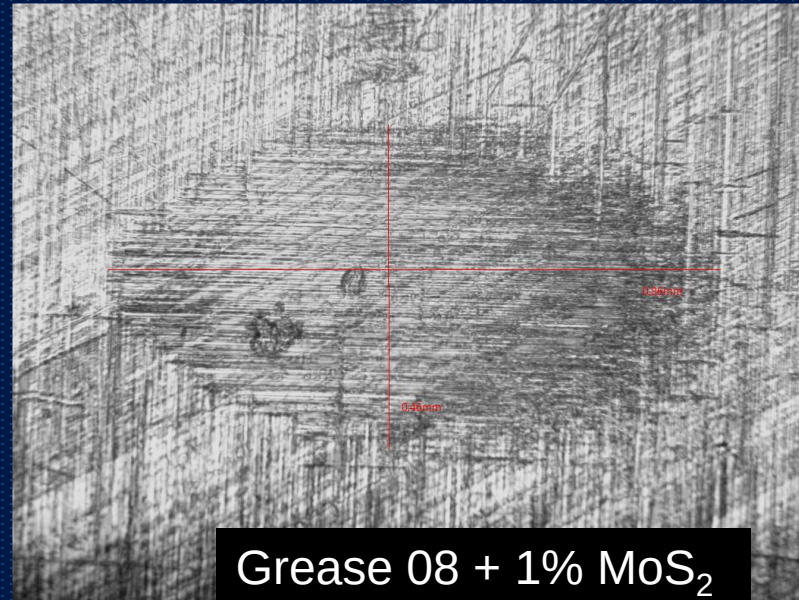


No Visible Scar!

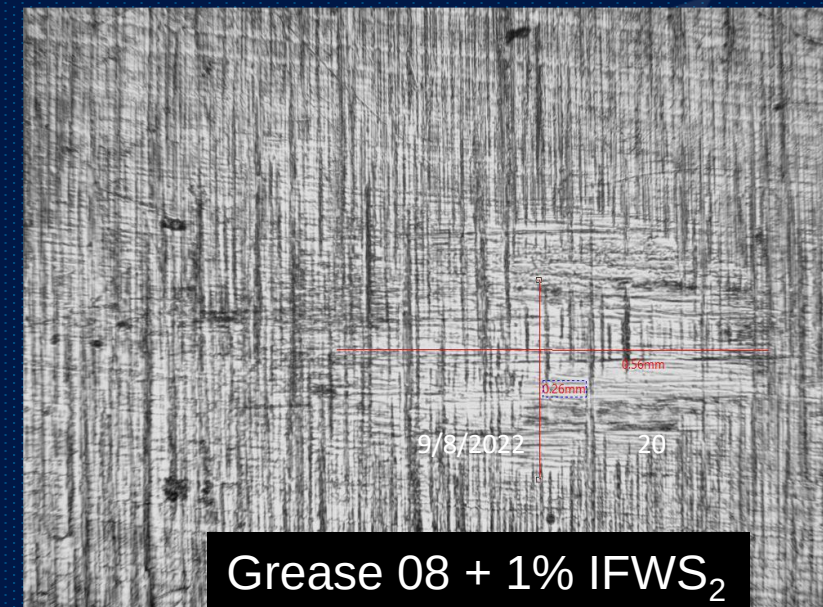
Grease 8



Grease 08 + 1% MoS₂



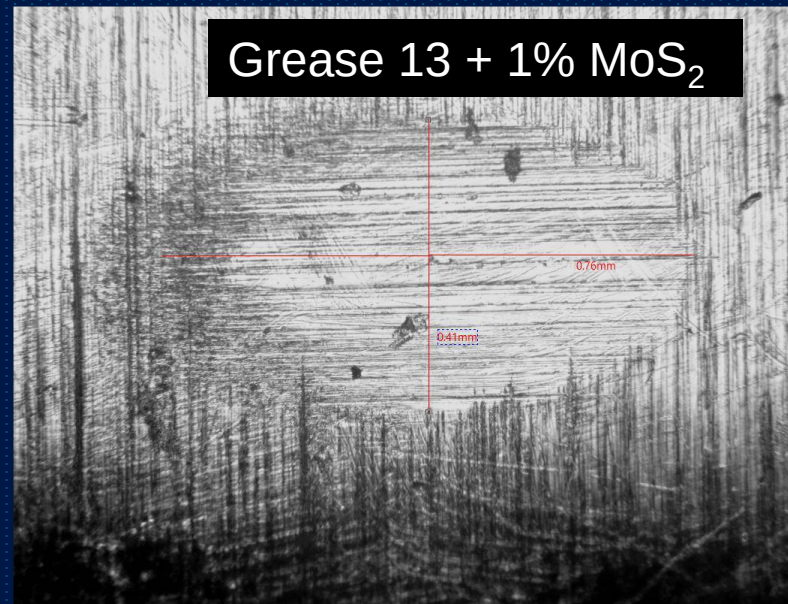
Grease 08 + 1% IFWS₂



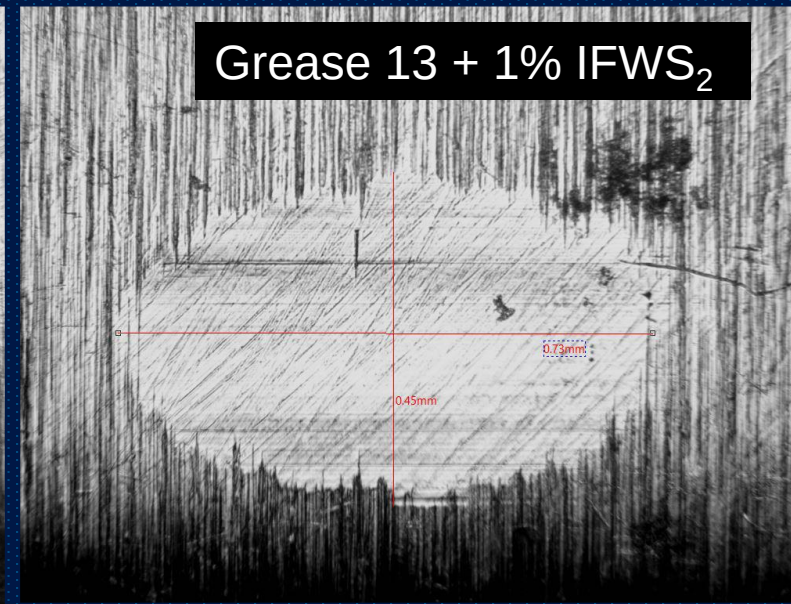
Grease 13



Grease 13 + 1% MoS₂



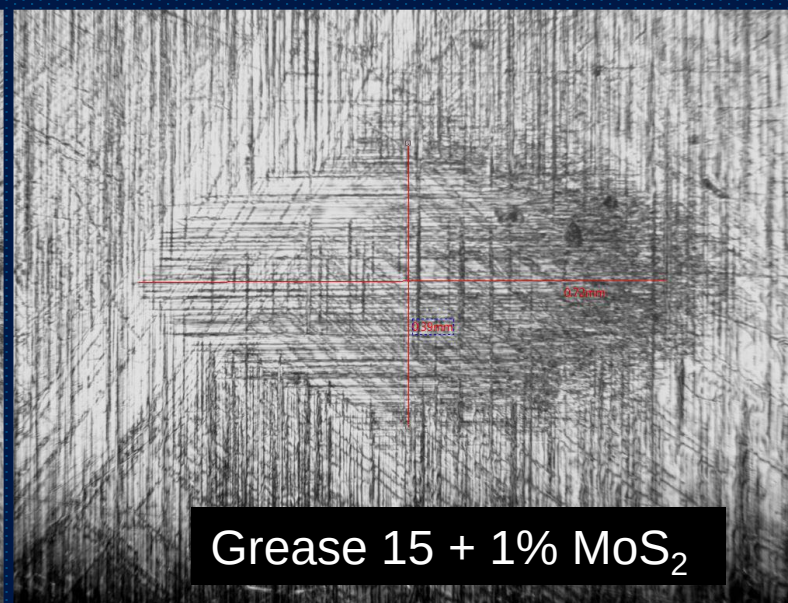
Grease 13 + 1% IFWS₂



Grease 15



Grease 15 + 1% MoS₂



Grease 15 + 1% IFWS₂



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COMPARATIVE STUDY BETWEEN IF-WS₂ & hBN

SAMPLE DESCRIPTION

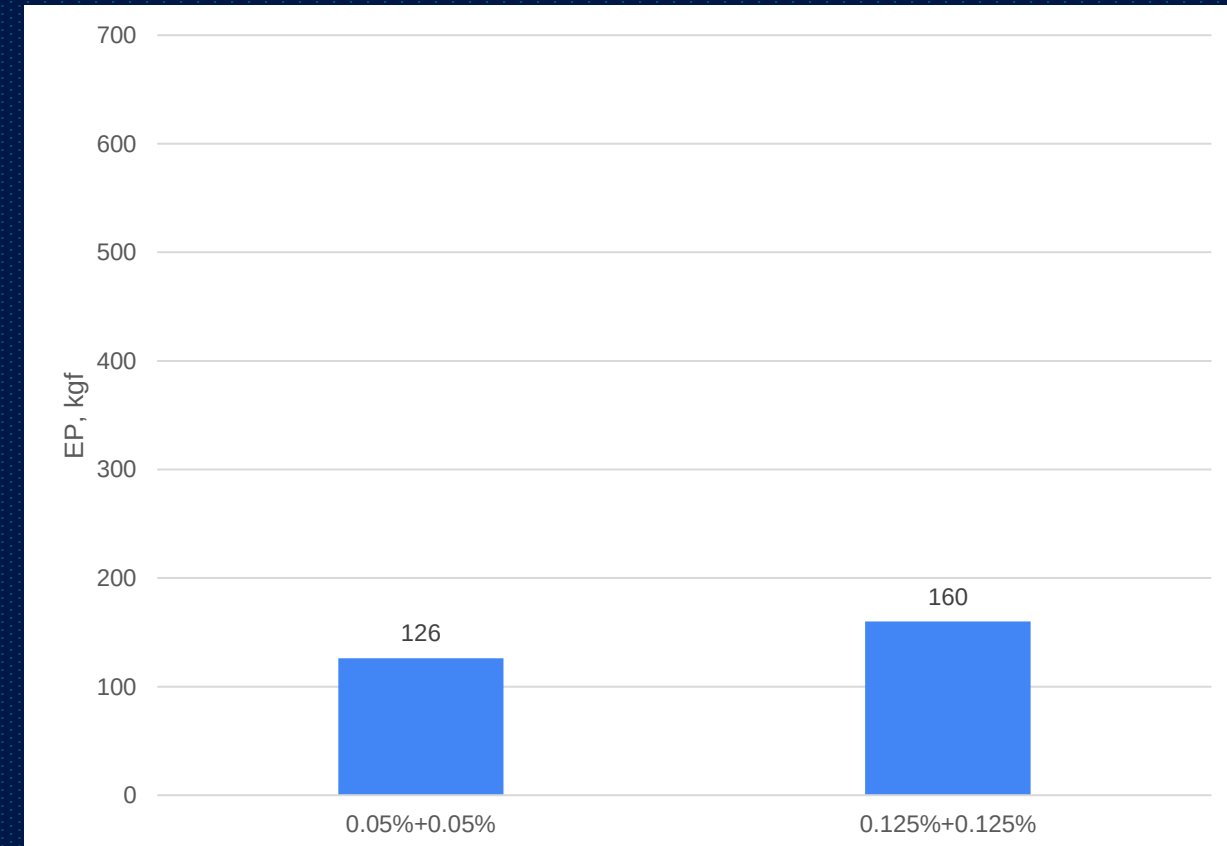
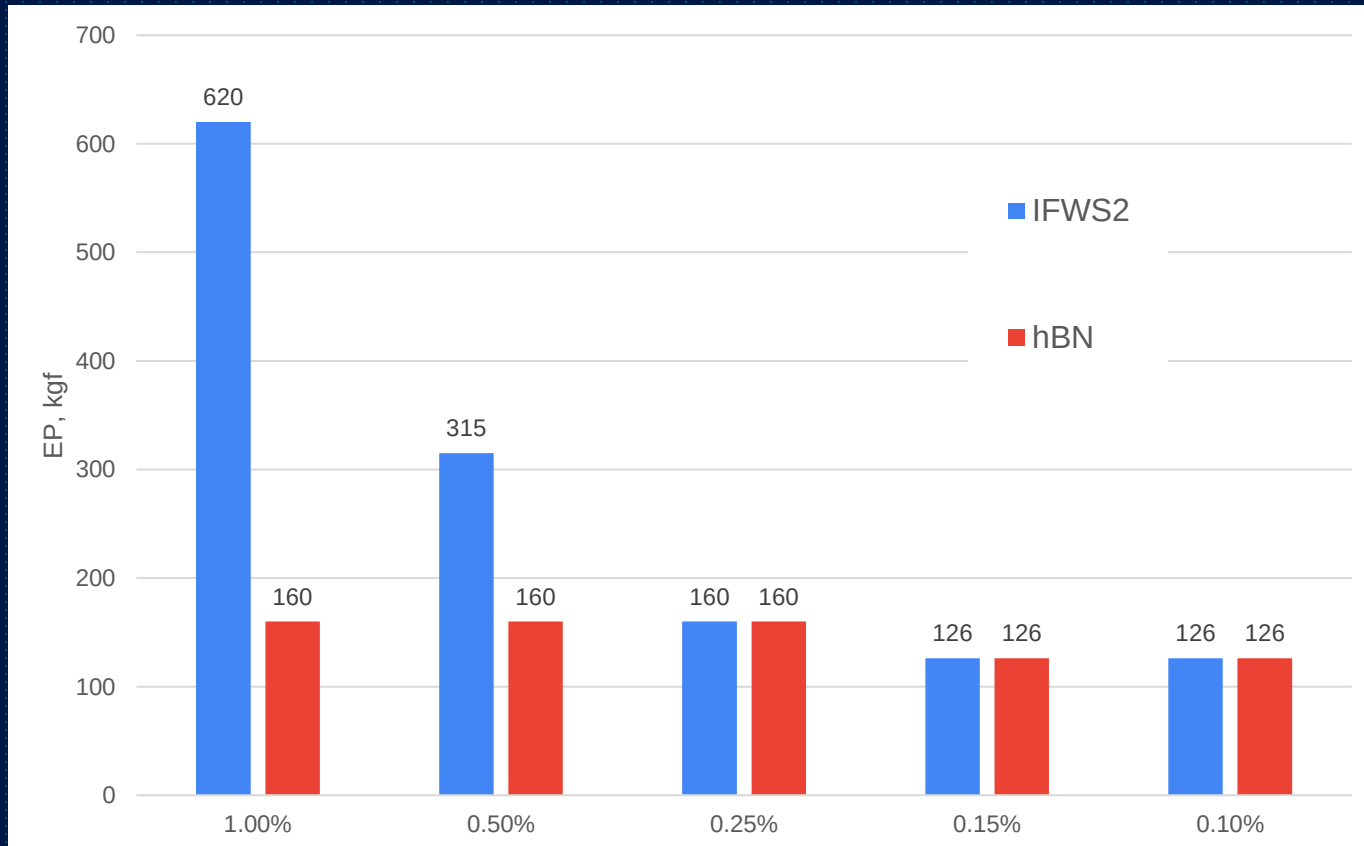
IFWS2 particles as well as hBN been dispersed in distilled water

Solid concentration in each dispersion was 50% by weight



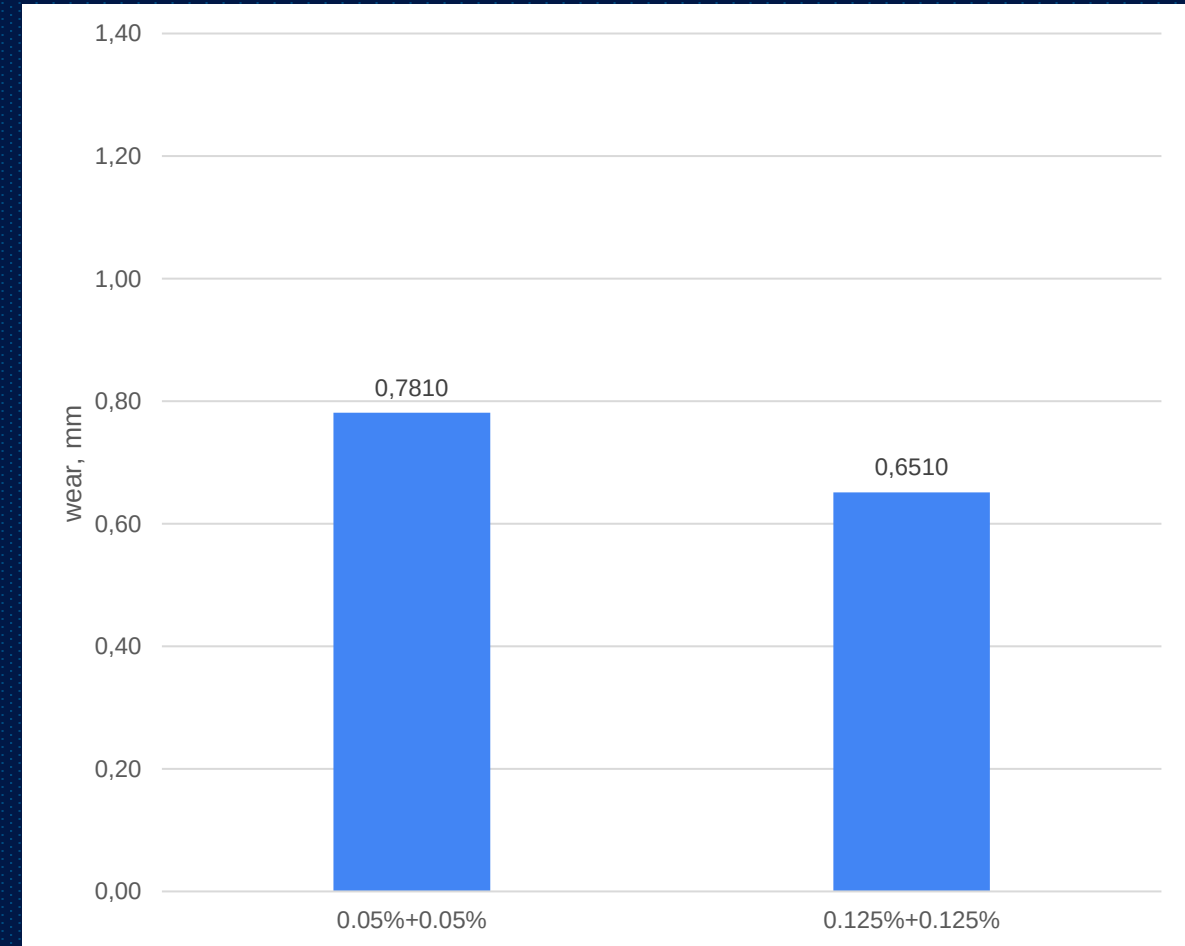
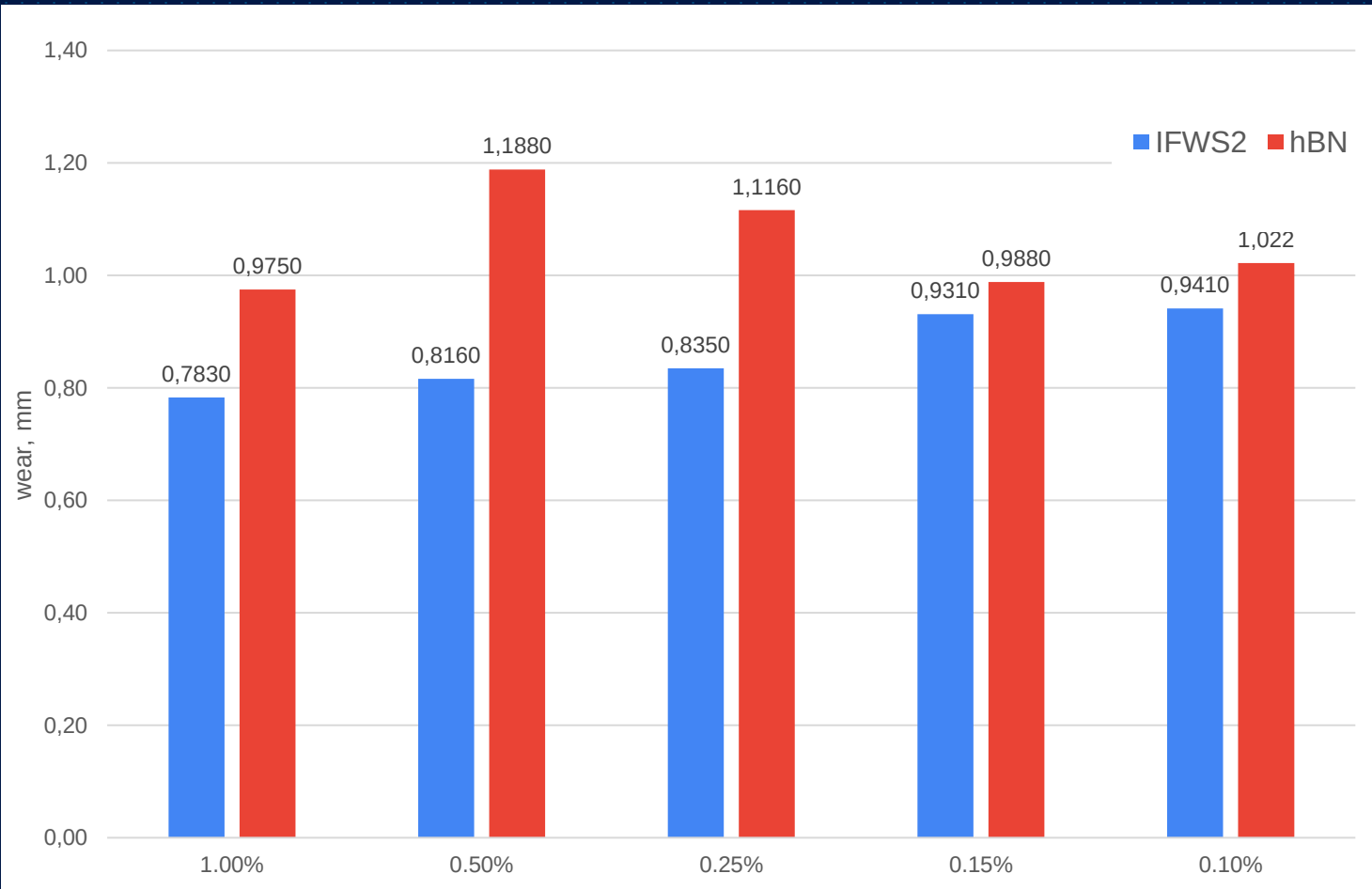
Sample #	Solid concentration
Sample 01	1% IFWS2
Sample 02	1% hBN
Sample 03	0.5% IFWS2
Sample 04	0.5% hBN
Sample 05	0.25% IFWS2
Sample 06	0.25% hBN
Sample 07	0.15% IFWS2
Sample 08	0.15% hBN
Sample 09	0.1% IFWS2
Sample 10	0.1% hBN
Sample 11	0.05%IFWS2 + 0.05% hBN
Sample 12	0.125%IFWS2+0.125%hBN

IF-WS2 VS hBN 4 BALL EP ASTM D2783



IF-WS₂ VS hBN

4 BALL WEAR ASTM D4172



Summary

High Viscosity Naphthenic Oils with **High Degree of Solvency Power** (Low Aniline Point) such as **T 600** can be use in various type of greases, resulting to **Low Thickener Content** and **Good Tribological Performance**

IF-WS₂ in **Li & LiX** greases based on **T 600** (Naphthenic Oil) offers an **Excellent Platform** for grease formulators developing **High Performance Greases** with **Fewer Components** and subsequently overall **Lower Cost**.

IF-WS₂ and hBN in water show synergistic effect on AW and AF properties. IFWS2 shows excellent EP properties.

THANK YOU FOR YOUR ATTENTION!

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***Thanks to DUCOM instruments for
support and technical assistance***