ICETAT 2024

2024 International Conference on Engineering Tribology and Applied Technology

Evaluation of tribosystems with water-based lubricant for sheet metal forming

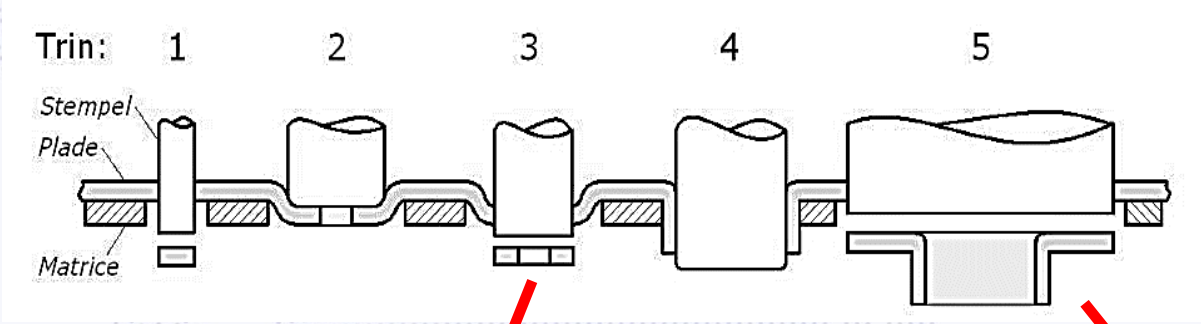
Mohd Hafis Sulaiman

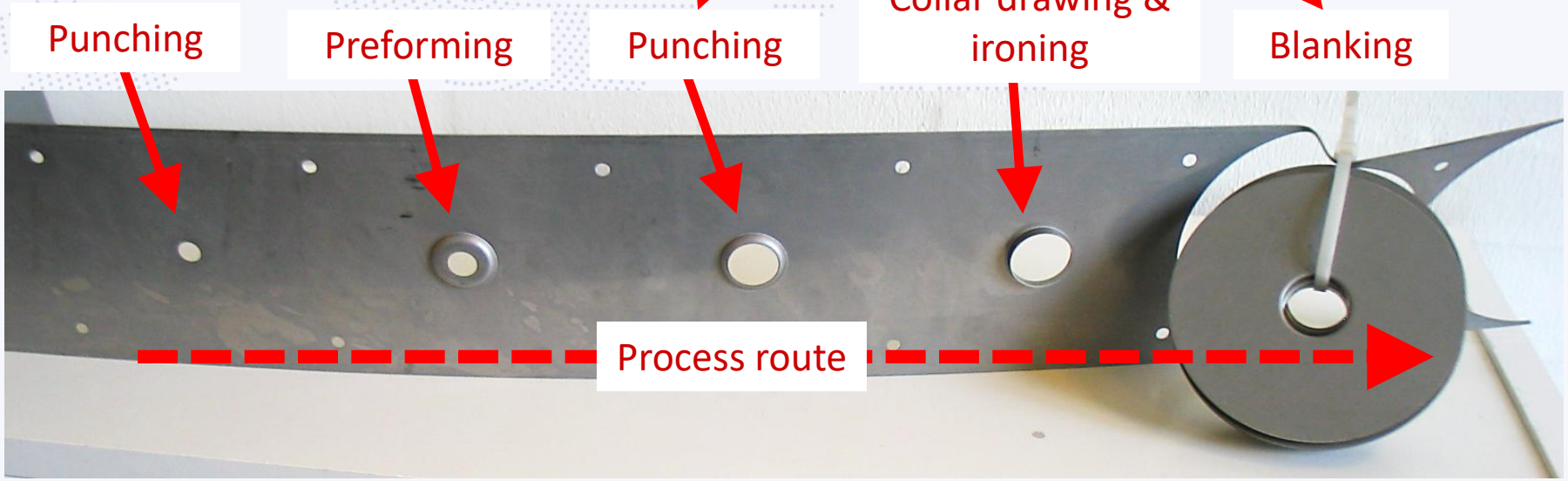
Department Of Mechanical And Manufacturing, Faculty Of Engineering, Universiti Putra Malaysia

Sheet-metal forming

- Sheet metal forming often uses blanking and punching, which are the primary methods of cutting.
- It is often integrated with additional forming procedures either as an intermediate or final step in production.

Production testing in progressive tool





Sheet-metal forming

Production testing in progressive tool

Varying tool material, lubricant and production speed

Measurement of back stroke force and tool temperature

- Punches experience severe contact conditions, including high contact pressures and loads.
- Increasing punch lifetime and improving produced product precision can be achieved through optimizing blanking tools to reduce stress and applied lubricants to reduce the friction between the tool and workpiece.

Lubrication in Punching and Blanking

The presence of active workpiece material presented a challenge in allowing the lubricant to adequately reach the tool-workpiece interface when the punch was retracted to its original position after the punching procedure.

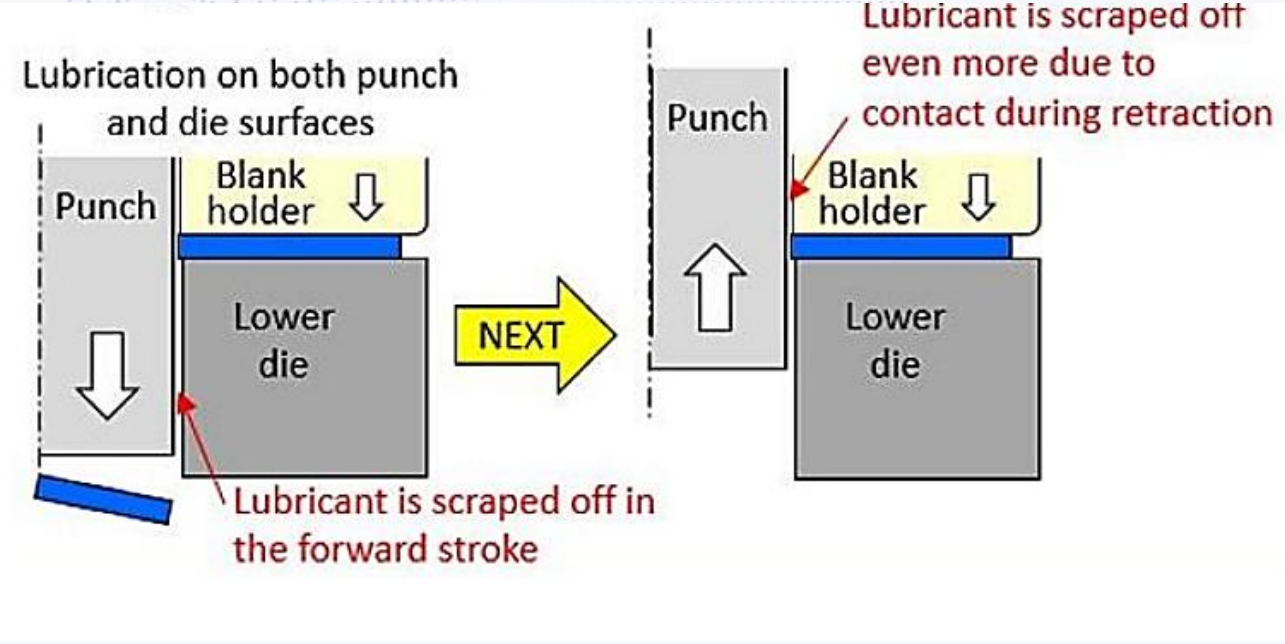


Illustration of the punching and blanking process.

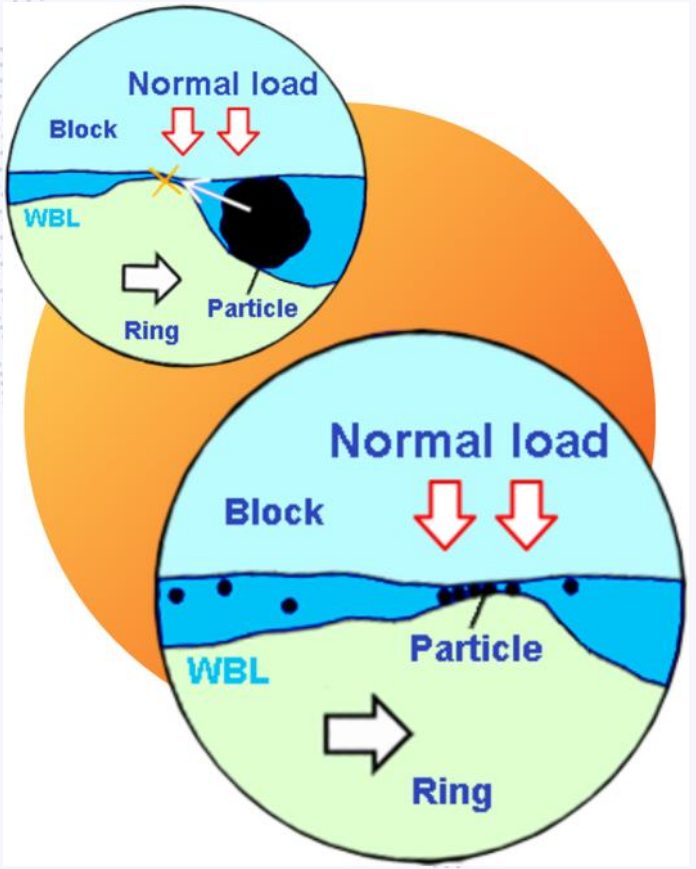
Problems with WBLs

Water-based lubricants (WBLs)

- Reduce **friction poorly**, have **low viscosity**, and **corrosive** properties
- Poorer performance under **high contact loadings and sliding speeds**

WBLs with nanoparticles

- Determining the **ideal nanoparticles** for WBLs remains a challenge
- More understanding on the **mechanisms and effects** of nanoadditives on the lubricants is required



Objectives

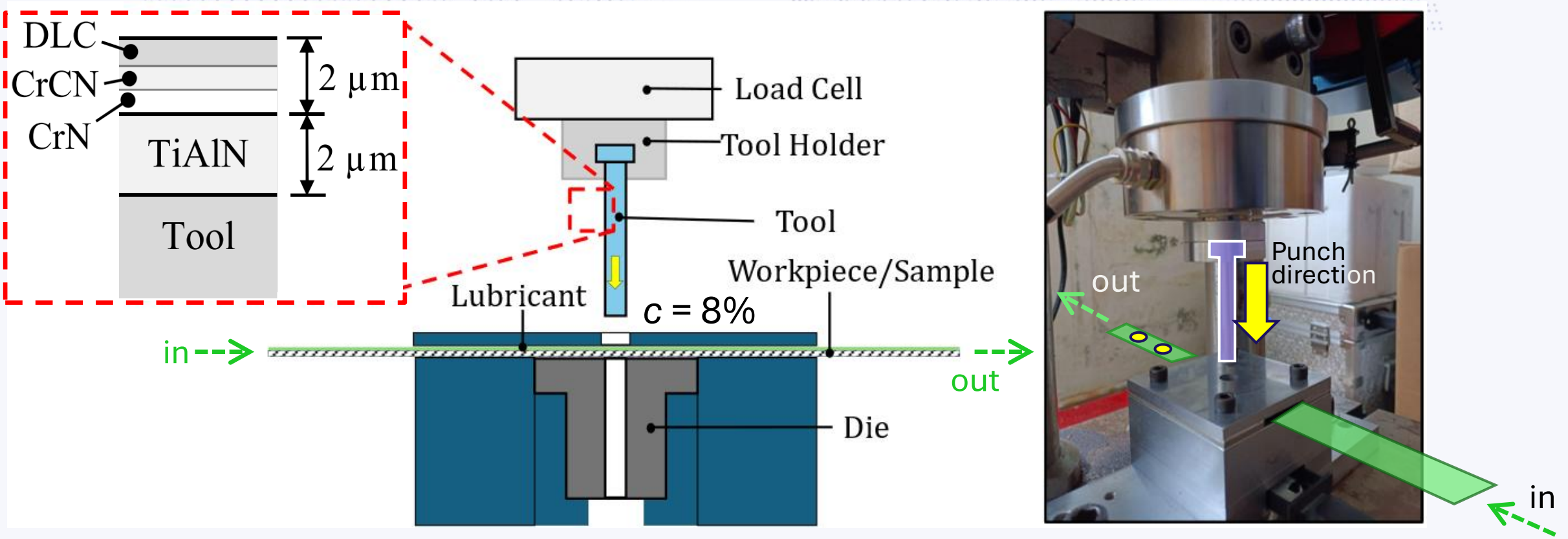
To reduce the large consumption of lubricants, which is harmful to human health and the environment.

This study presents an investigation of nanoadditives (MgO, SiC, TiO2, and MgO/SiC) added to WBLs:-

1. Properties of the formulated WBLs were studied.
2. Punching and blanking test of aluminum as well as the tribological test setup were used to understand the tribological performance of the formulated WBLs.

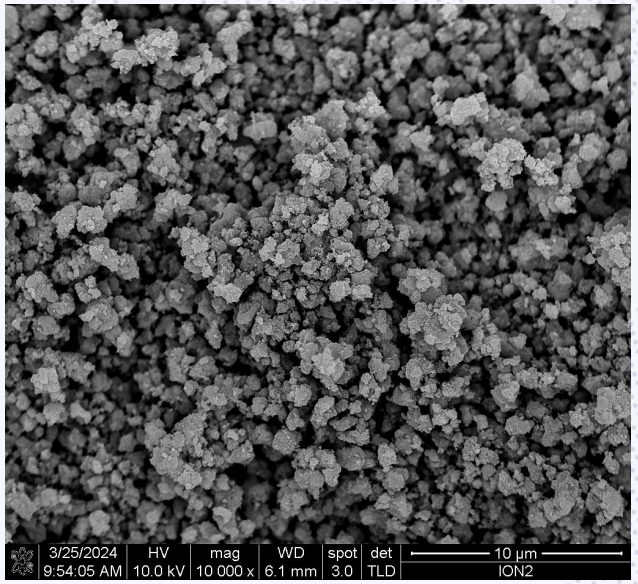
Experimental Setup of Punching and Blanking

Laboratory setup for testing lubricants in punching and blanking of aluminium

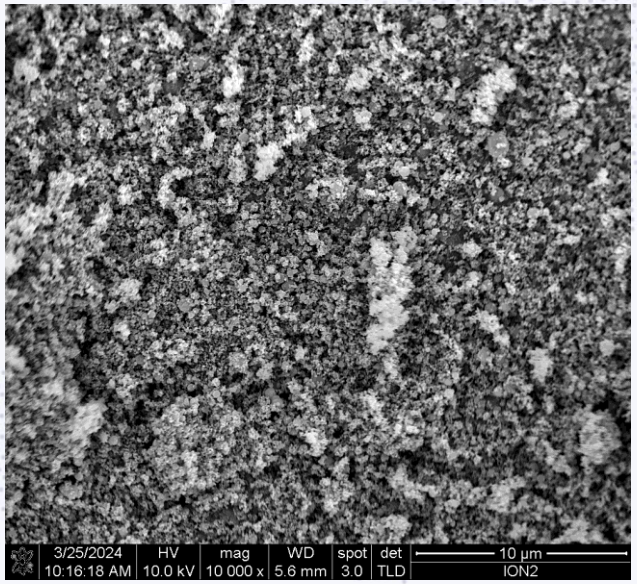


Nanoadditives

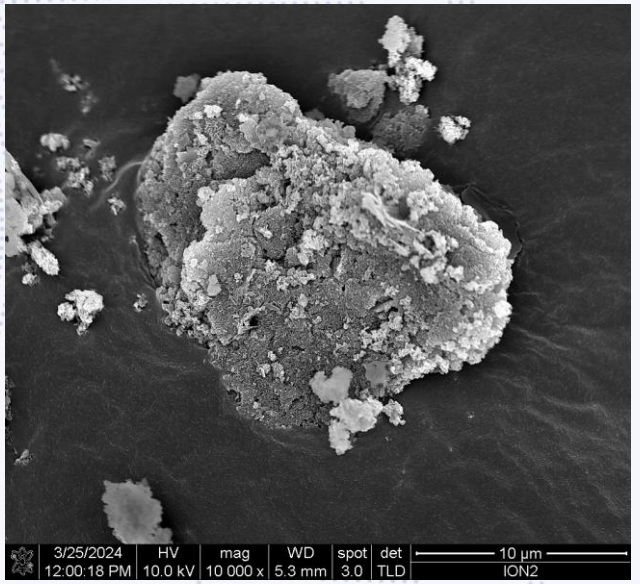
Nanoadditives used (Size: 10-40 nm)



MgO



SiC



TiO_2

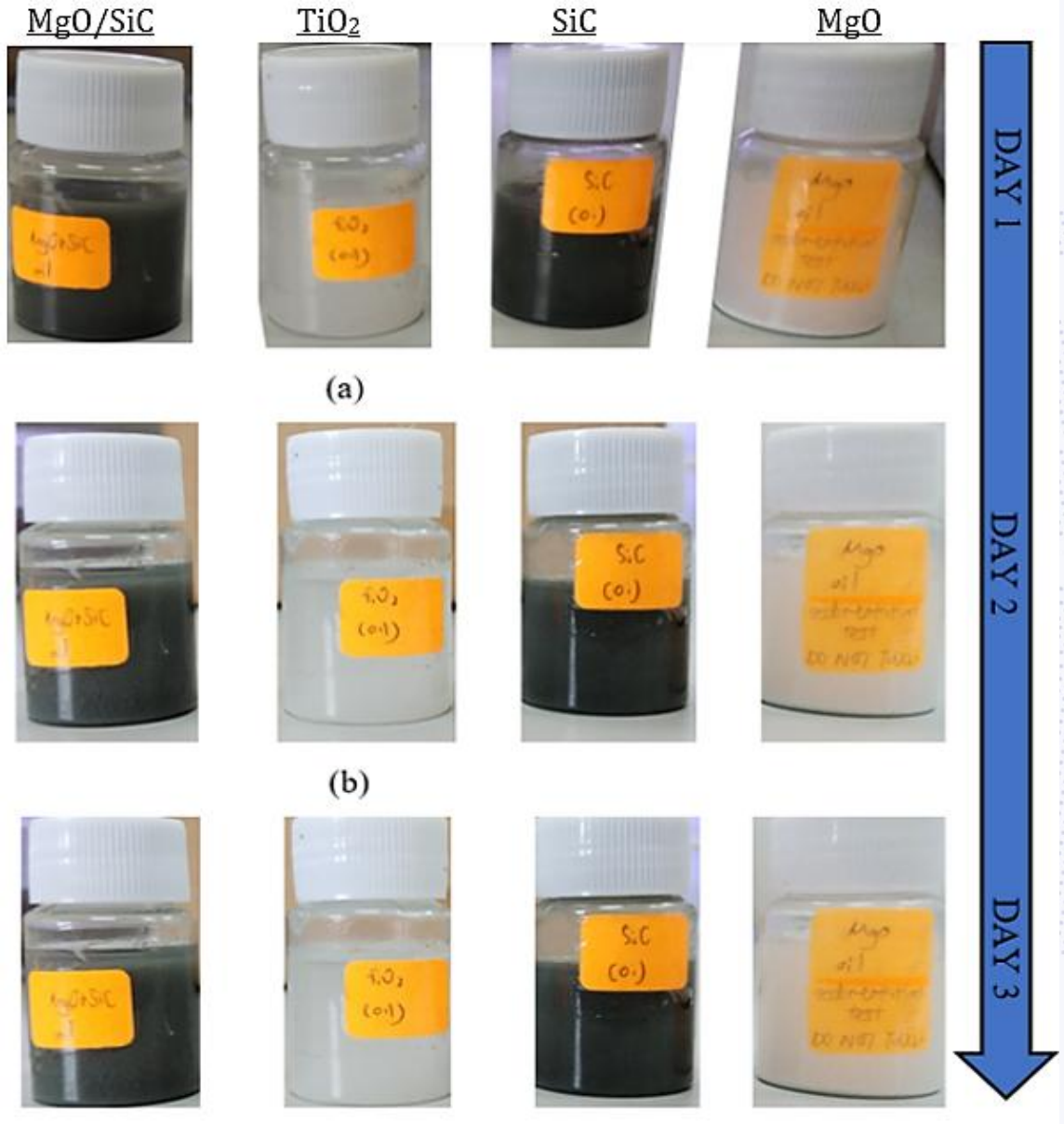
Test Lubricants

Additive concentrations in the test WBLs.

Sample	Content
Oil	Commercial mineral oil
MgO	0.2 wt% MgO nanoparticles + 2.0 wt% Glycerol + 0.05 wt% PVP + DI water
SiC	0.1 wt% SiC nanoparticles + 2.0 wt% Glycerol + 0.05 wt% PVP + DI water
MgO/SiC	0.2 wt% MgO nanoparticles + 0.1 wt% SiC nanoparticles + 2.0 wt% Glycerol + 0.05 wt% PVP + DI water
TiO_2	0.2 wt% TiO_2 nanoparticles + 2.0 wt% Glycerol + 0.05 wt% PVP + DI water

The formulated WBLs were prepared by dispersing nanoparticles by a two-step method:-

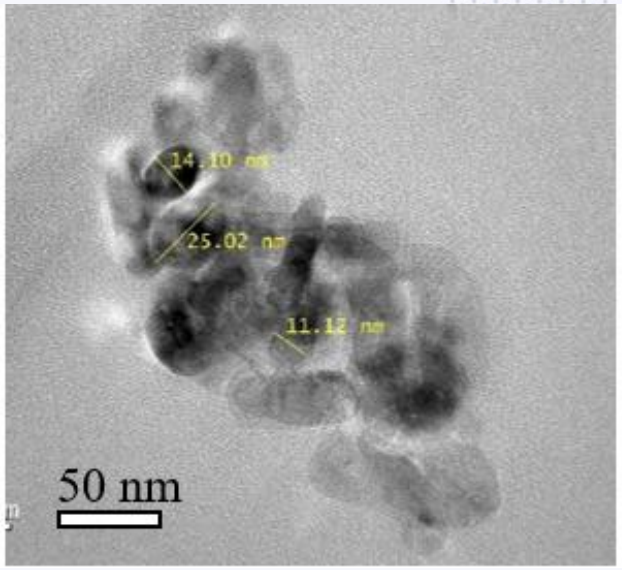
1. Glyerol and DI water were mixed using magnetic stirring (Speed 1,200 rpm & Duration 120 mins).
2. Polyvinylpyrrolidone (PVP) was gradually introduced into the WBLs while continuing magnetic stirring.
3. The solution was incrementally supplemented with nanoparticles.
4. Any remaining agglomeration was eliminated via ultrasonication (Speed 13,000 rpm & 45 mins).



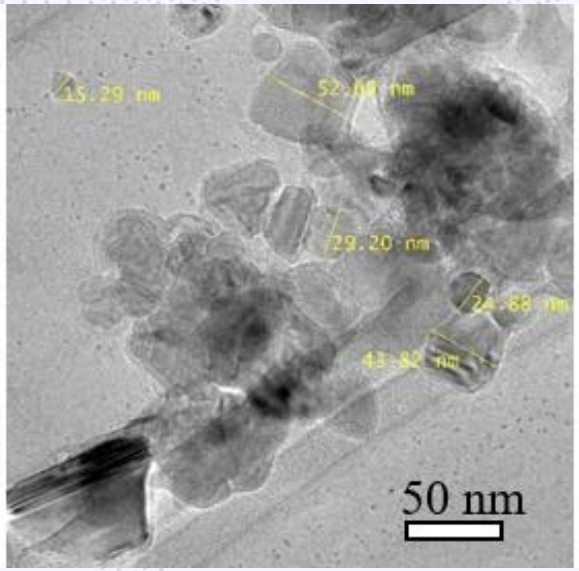
Sedimentation of formulated WBLs from Day 1 to Day 3

Test Lubricants

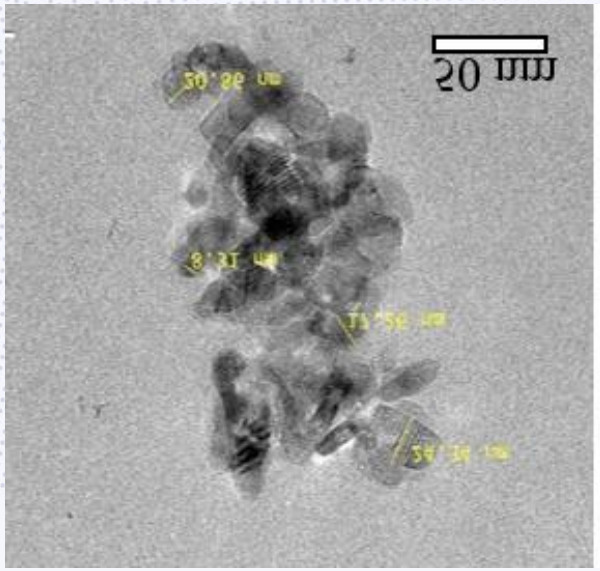
- TEM images of formulated WBLs.



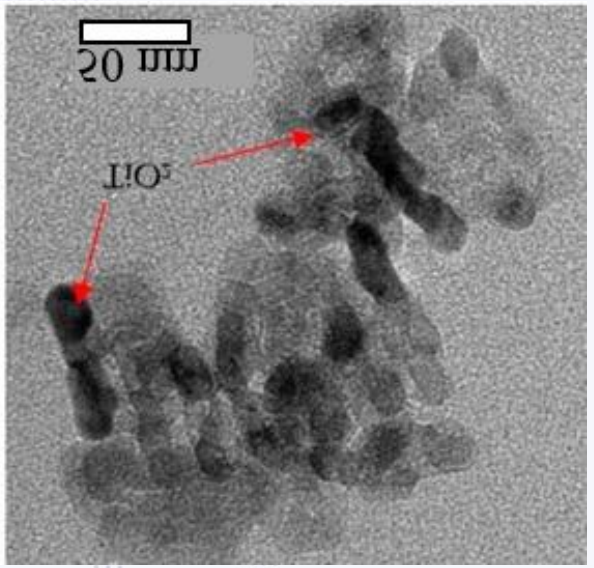
MgO



SiC



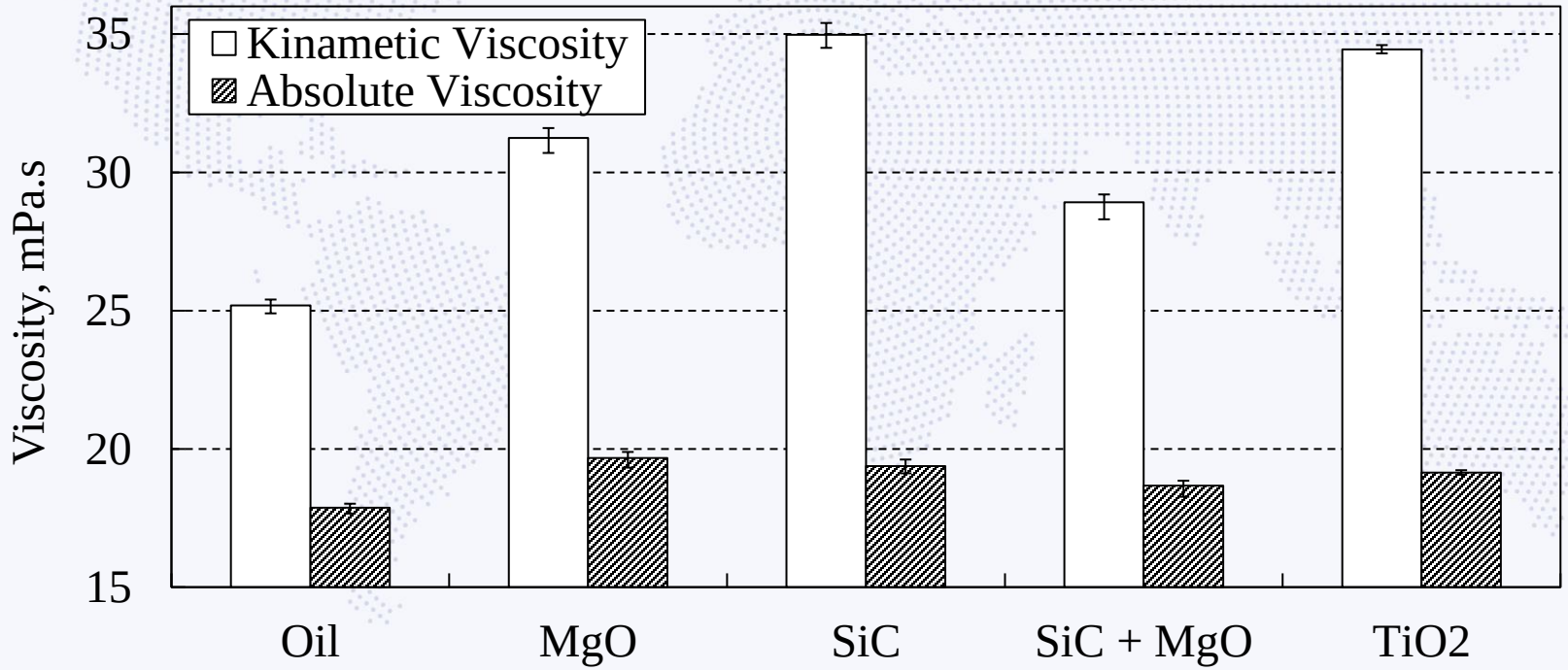
MgO/SiC



TiO_2

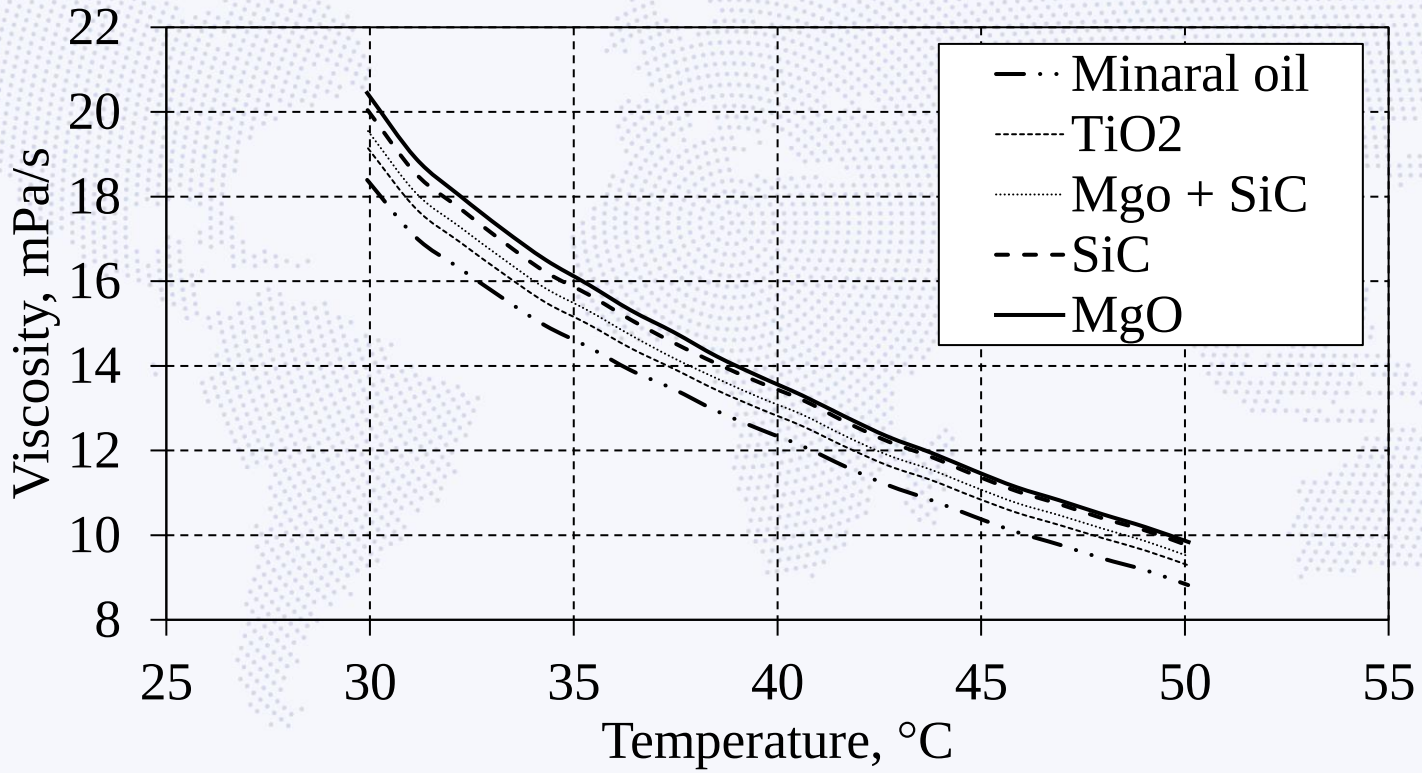
Viscosity at room temperature

The kinematic viscosity is the ratio of absolute viscosity to the density of a fluid. It is used to describe a fluid's resistance to flow in relation to its mass and is important in applications involving fluid motion and diffusion.



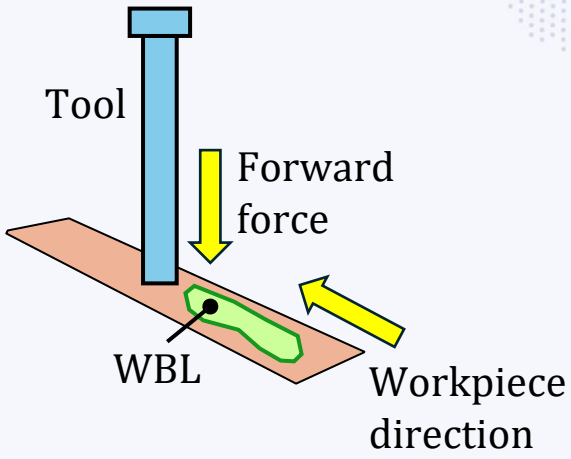
Viscosity at varying temperature

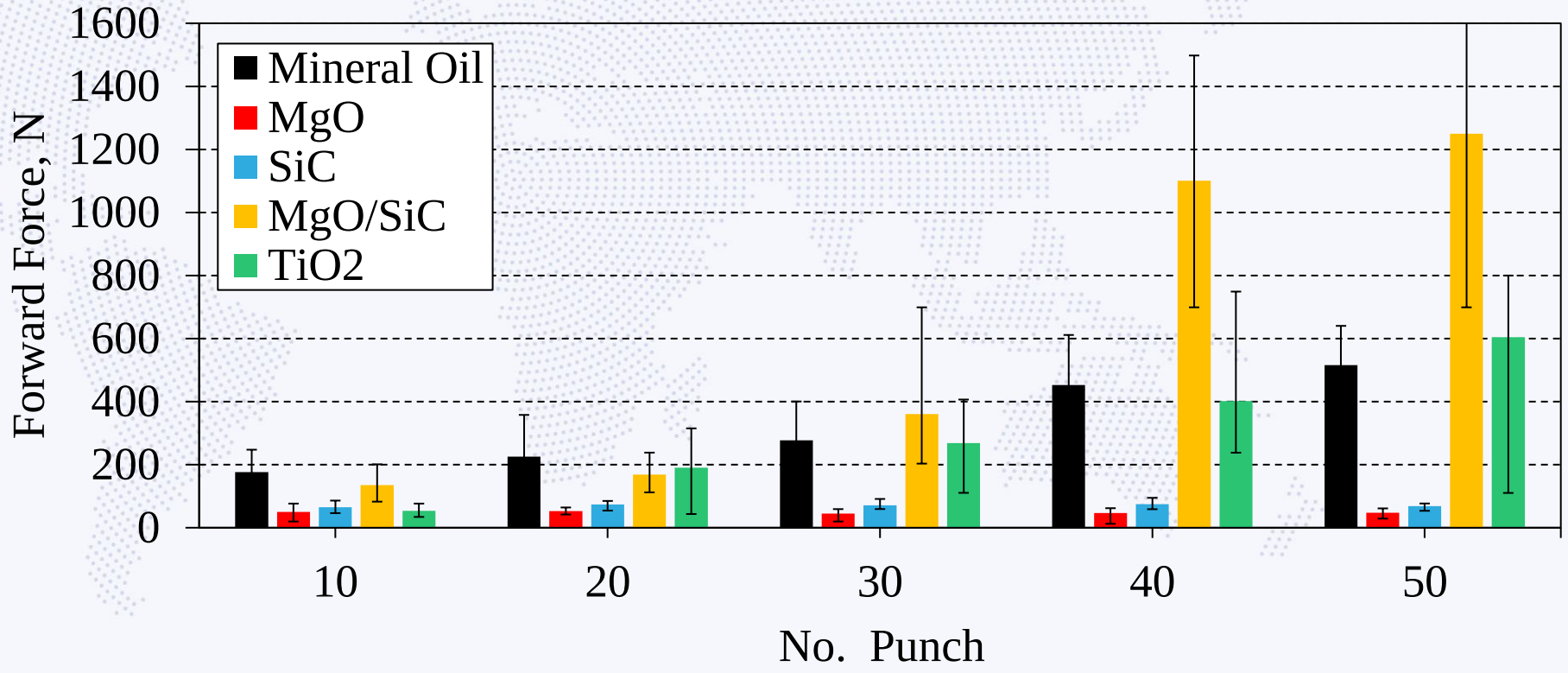
Viscosity and particle mobility are inversely proportional to each other, and particle mobility increases with temperature.



Lubricant Performance in Punching and Blanking

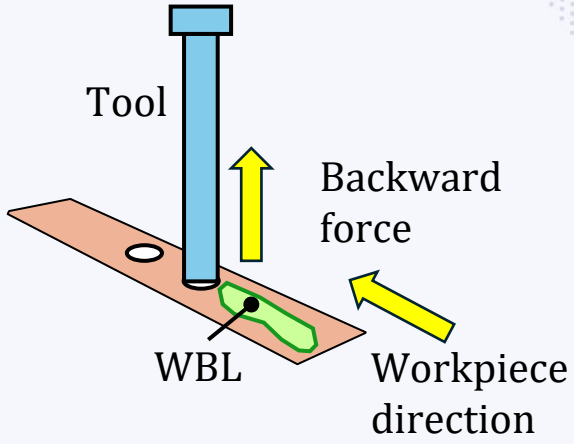
- Forward force: The punch moved down, penetrating the workpiece with lubrication.
- Creation of virgin surface causing highly stressing contact region.

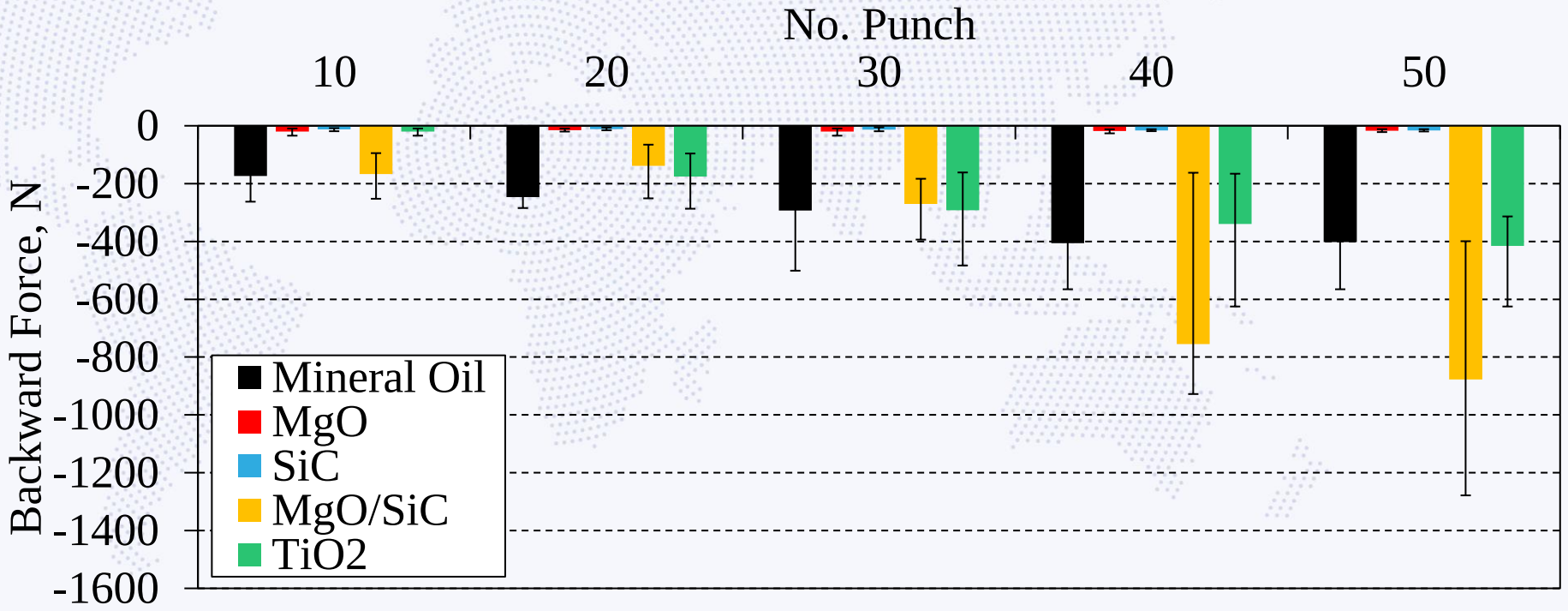




Lubricant Performance in Punching and Blanking

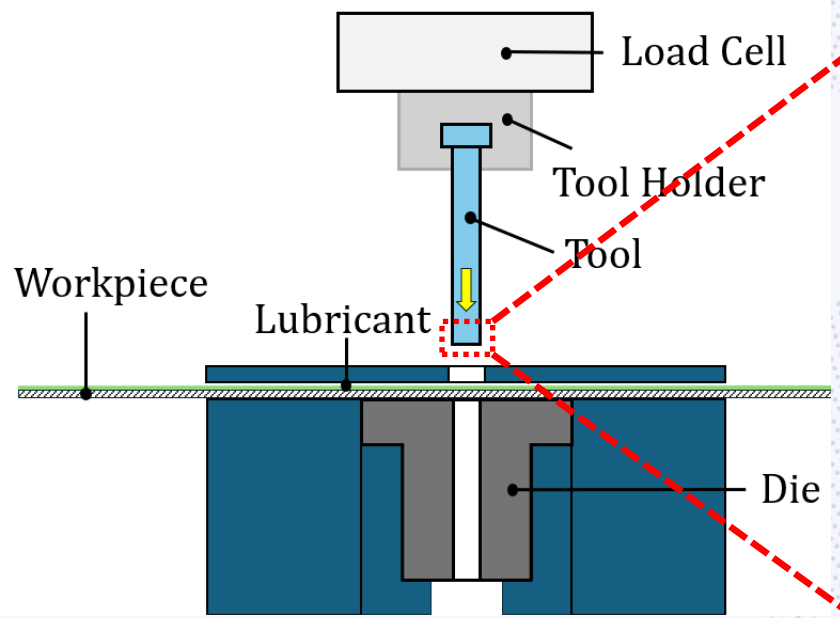
- Backward force: Punch moved upward with no additional lubrication.
- Additional contact caused by the workpiece during punch retraction removed the lubricant, resulting in severe wear on the tool surface.



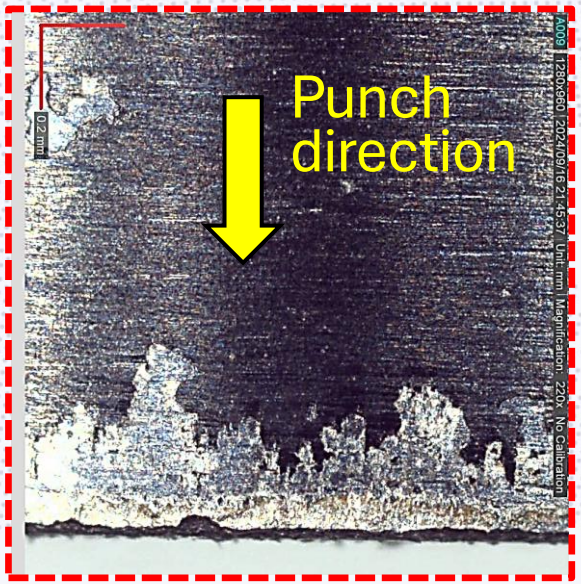


Tool wear

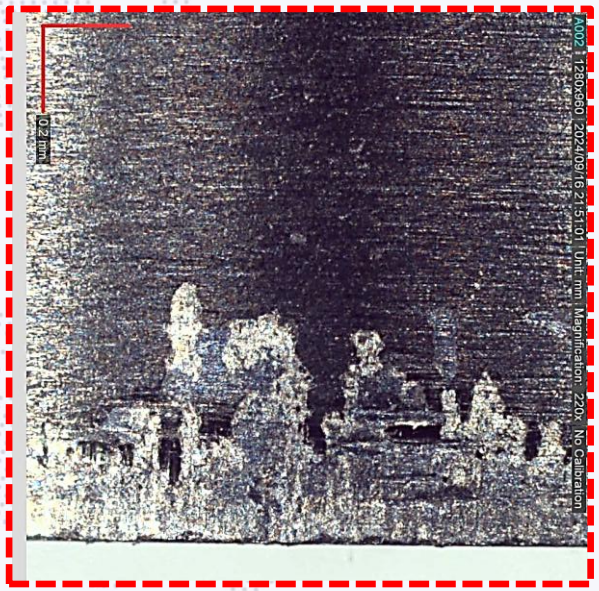
- Wear occurred to DLC/TiAlN-coated punches after the 50th punch holes.



Mineral oil



MgO



SiC

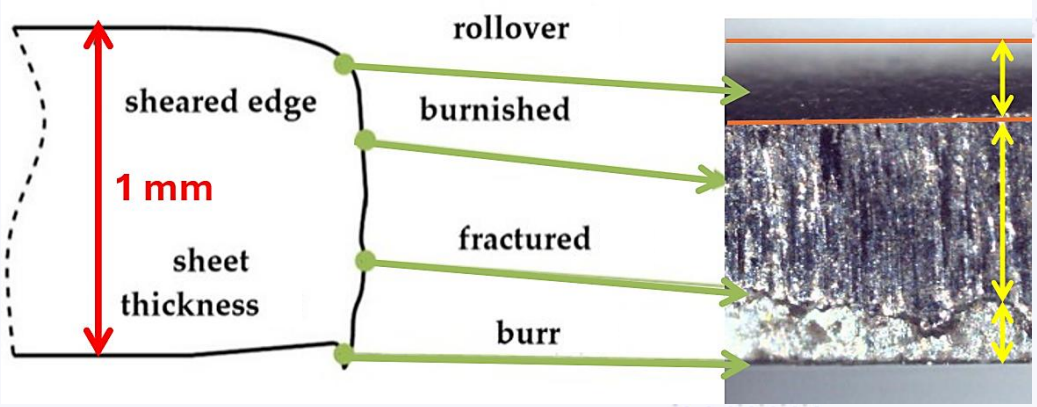
Test lubricants	10th Punch	20th Punch	30th Punch	40th punch	50th punch
Mineral Oil					
MgO					
SiC					
TiO2					
MgO/SiC					

Wear images on workpiece

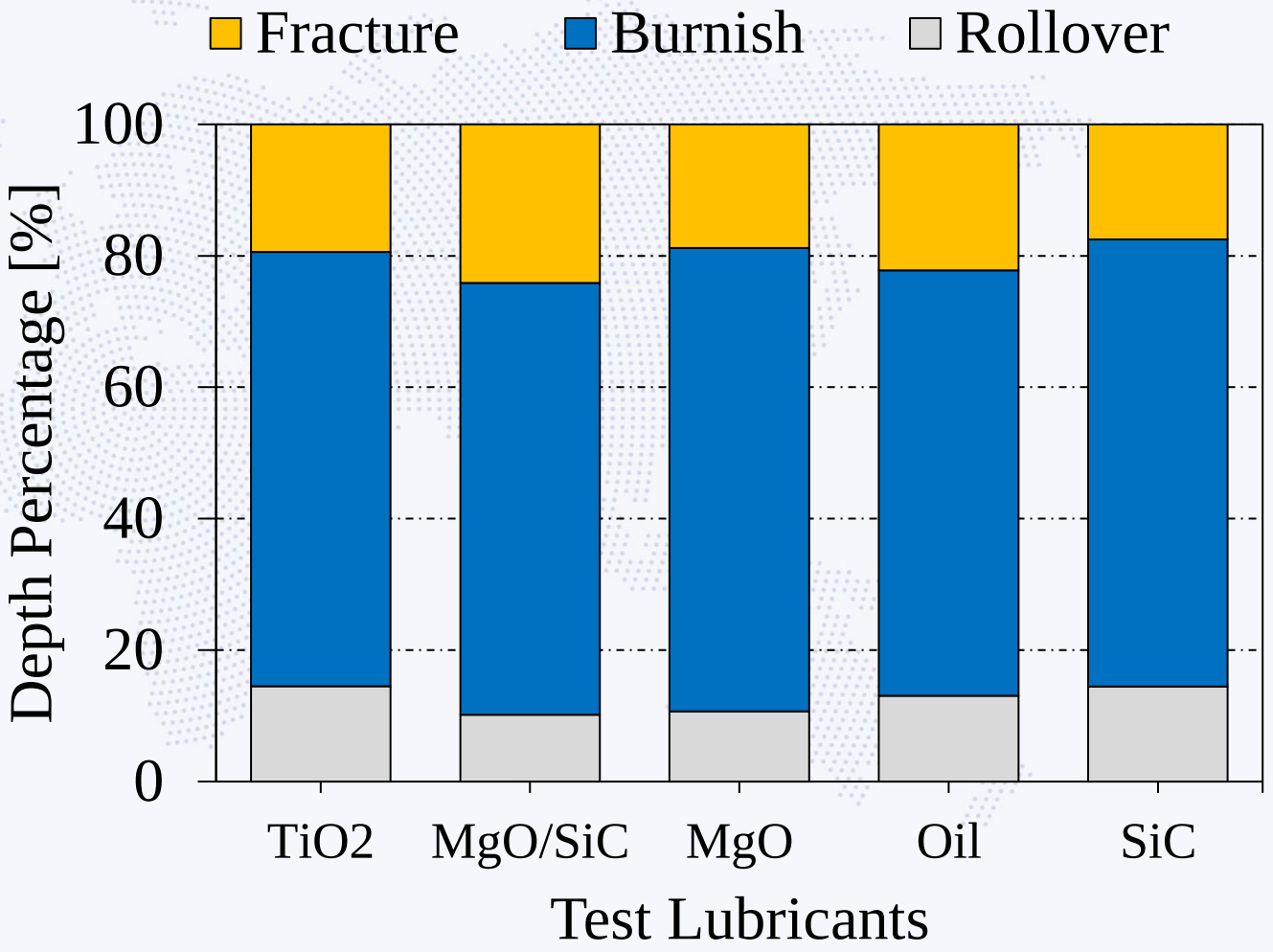
Adhesive wear caused by the aluminium being scrapped off and cold welding to the punches.

Wear Analysis on workpiece

Profile sheared edge scheme

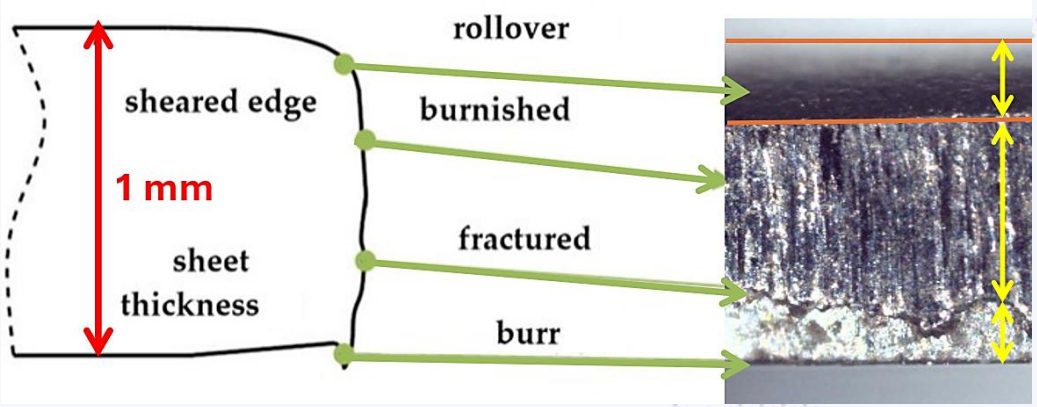


- MgO is the most promising lubricant additive enhances the burnish height.
- The choice of additive significantly affects the burnish height, which is critical in applications where surface finish and precision are important.

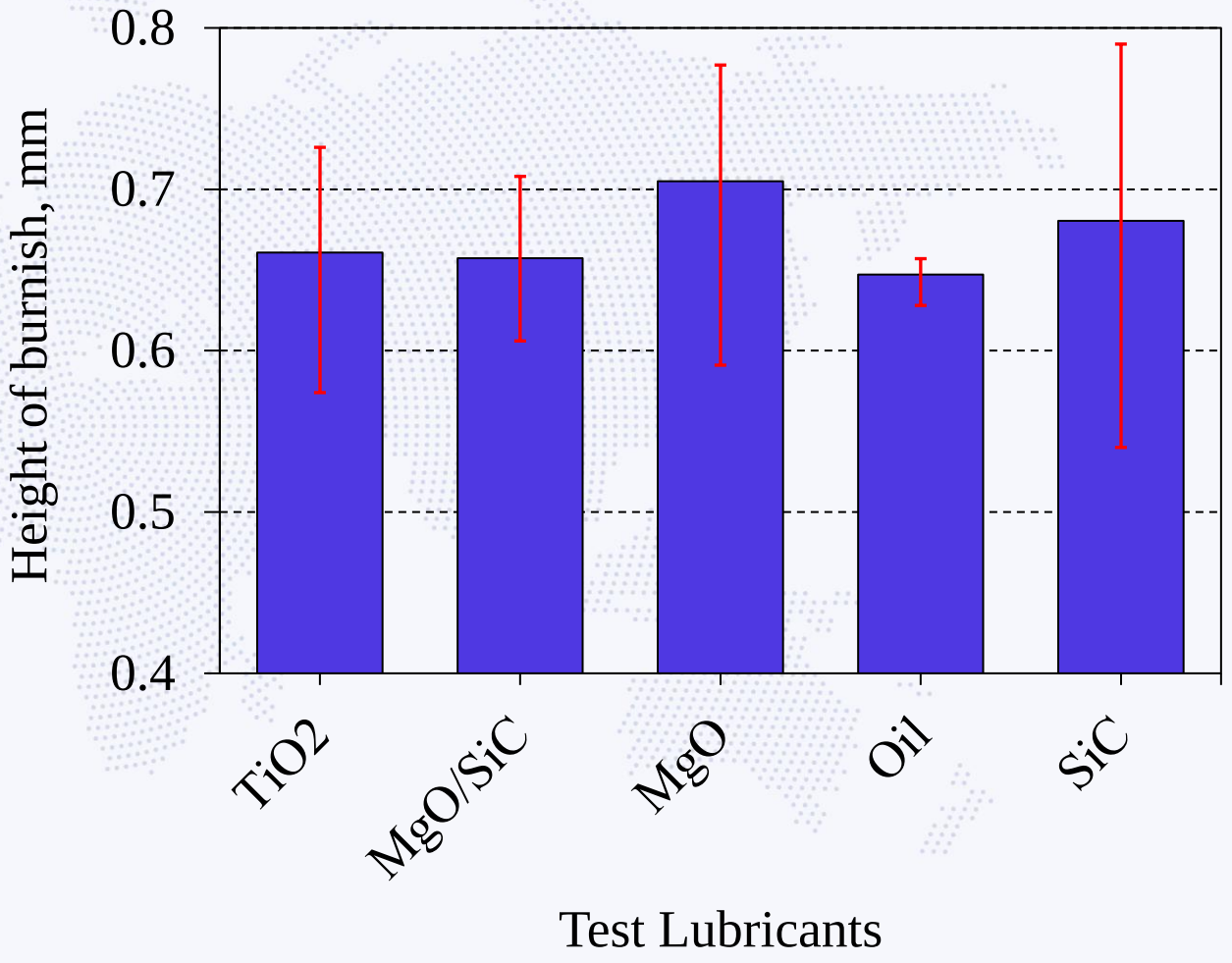


Wear Analysis on workpiece

Profile sheared edge scheme

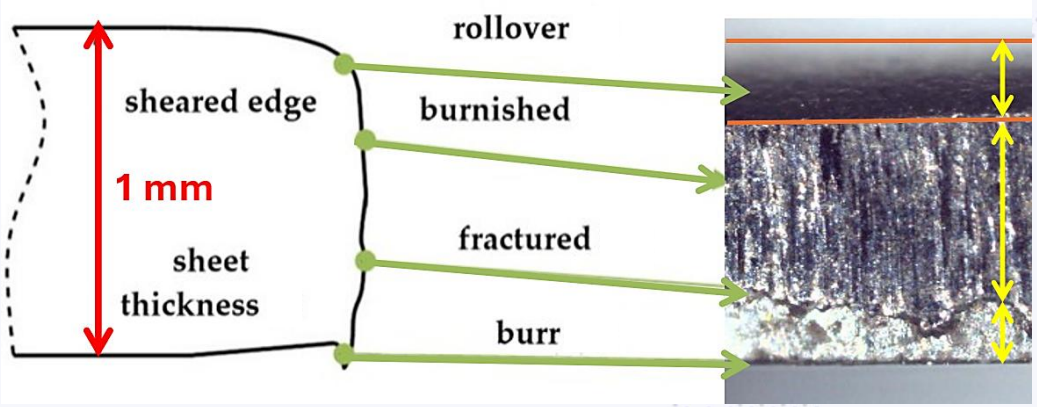


- MgO is the most promising lubricant additive enhances the burnish height.
- The choice of additive significantly affects the burnish height, which is critical in applications where surface finish and precision are important.

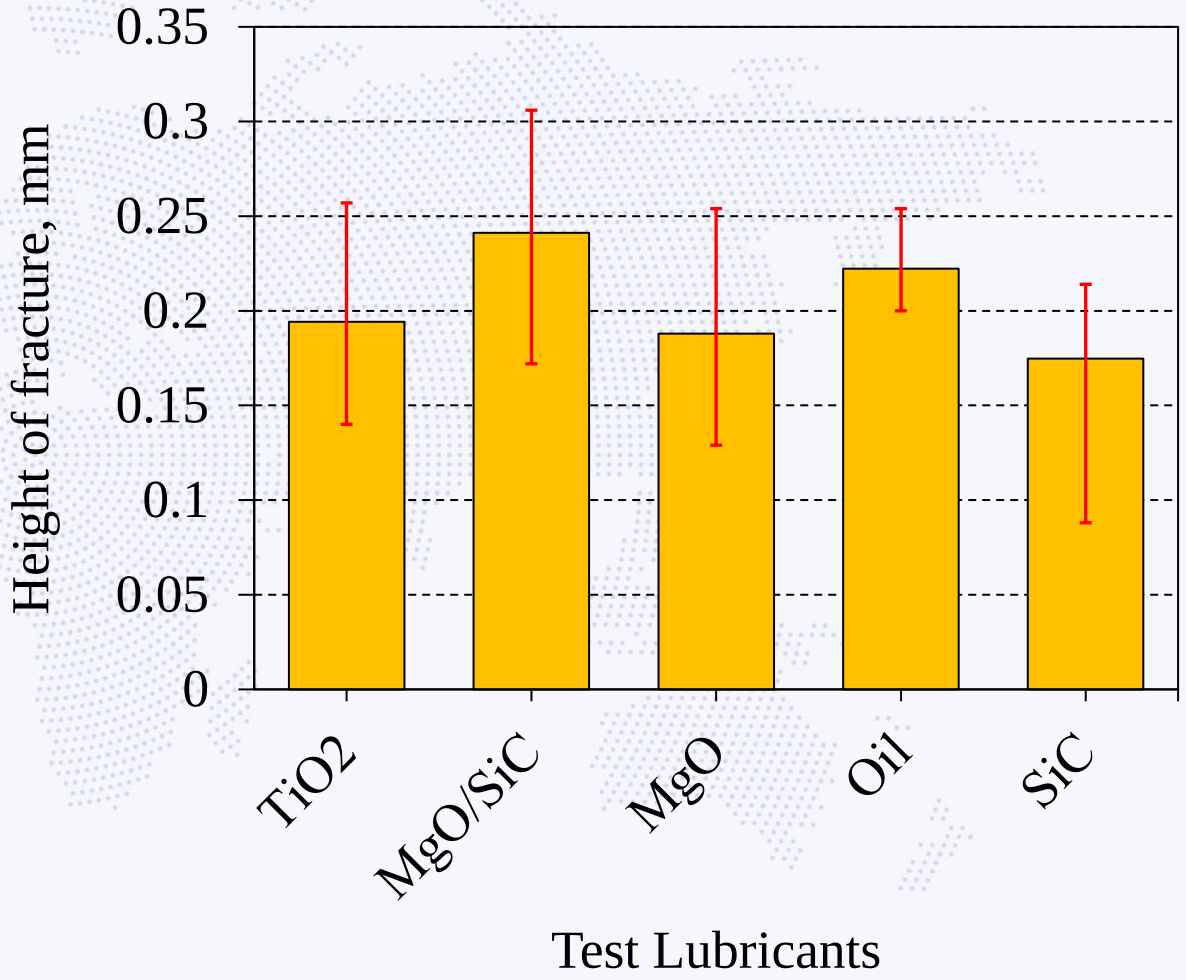


Wear Analysis on workpiece

Profile sheared edge scheme

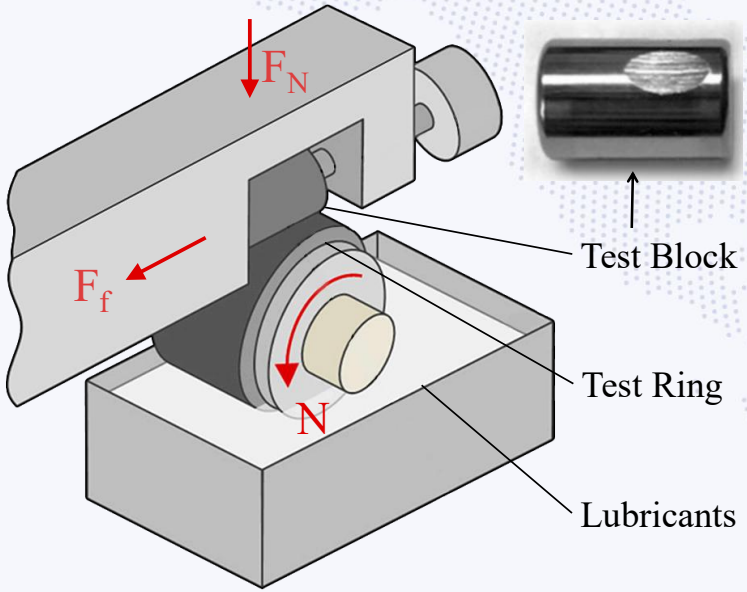


- MgO is the most promising lubricant additive enhances the burnish height.
- The choice of additive significantly affects the burnish height, which is critical in applications where surface finish and precision are important.



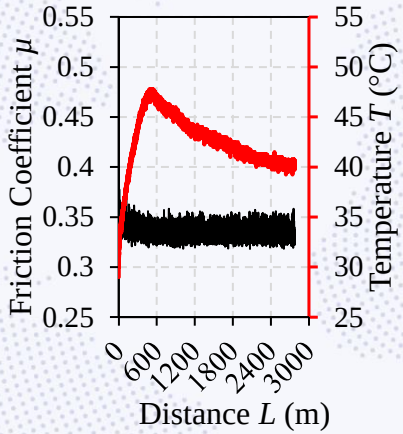
Lubricant Performance with tribological test

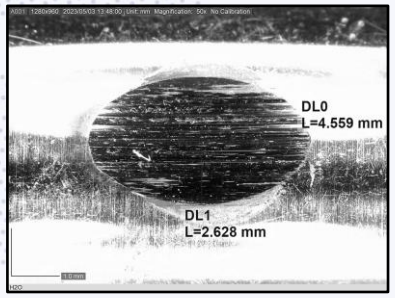
- Tribological experiment according to ASTM G77.



2 mm

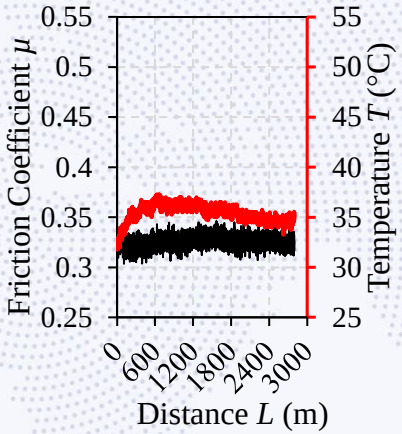
DI water

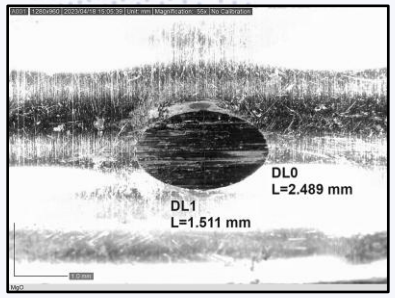




A=9.410mm^2

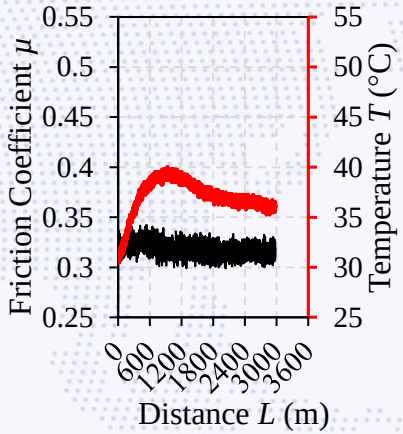
MgO

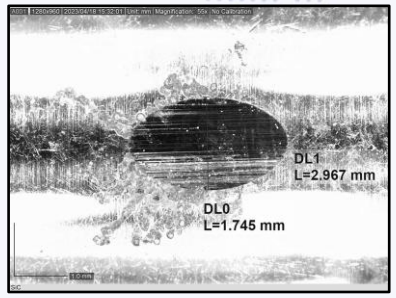




A=2.954mm^2

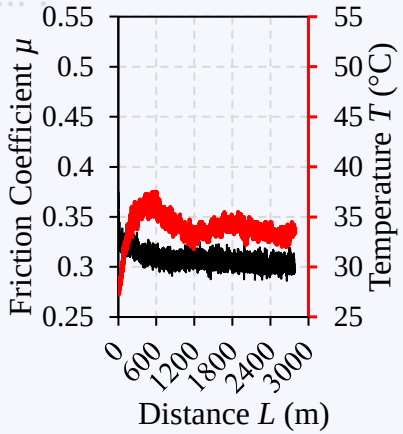
SiC

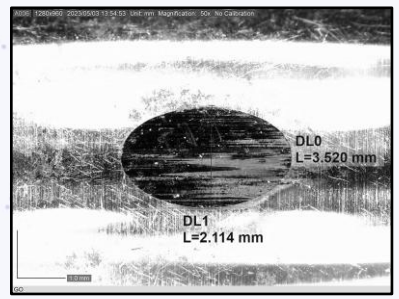




A=4.066mm^2

MgO/SiC



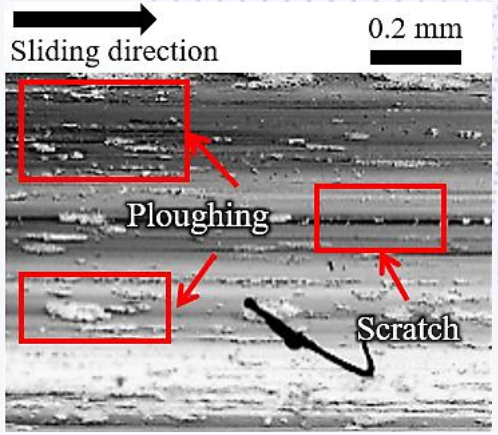


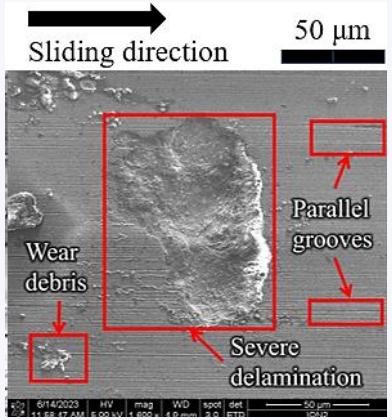
A=5.844mm^2

Lubricant Performance with tribological test

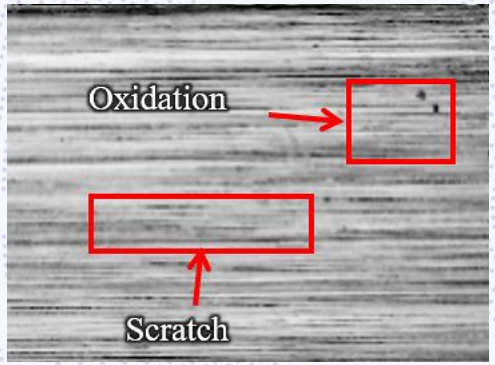
- Wear observation using FESEM.

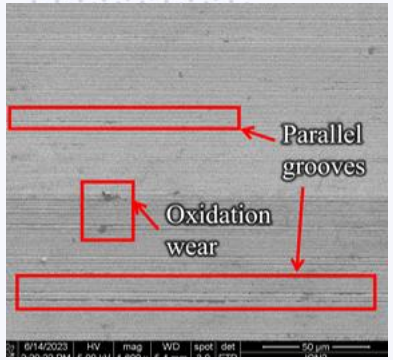
DI water



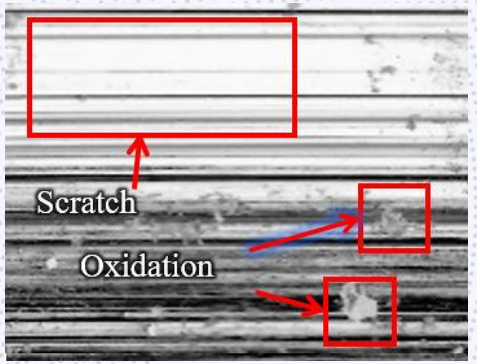


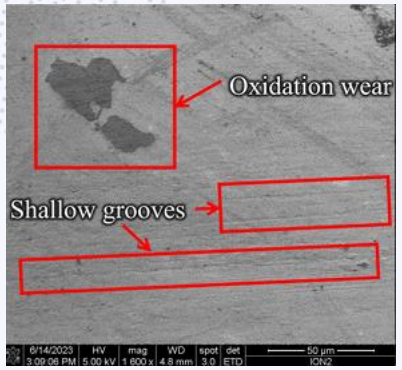
MgO



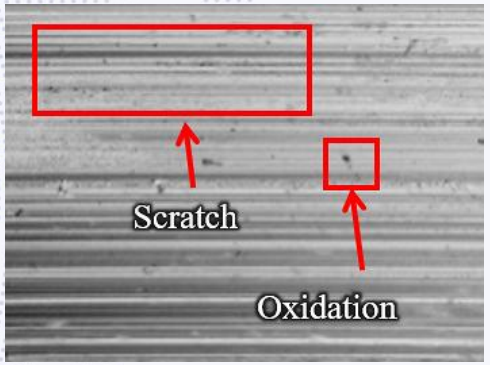


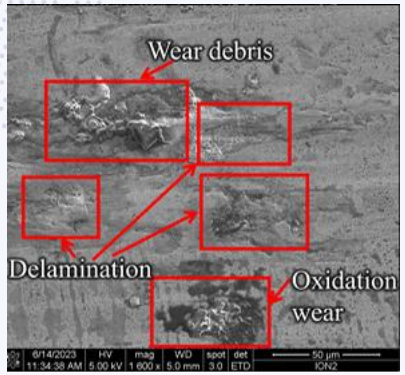
SiC





MgO/SiC

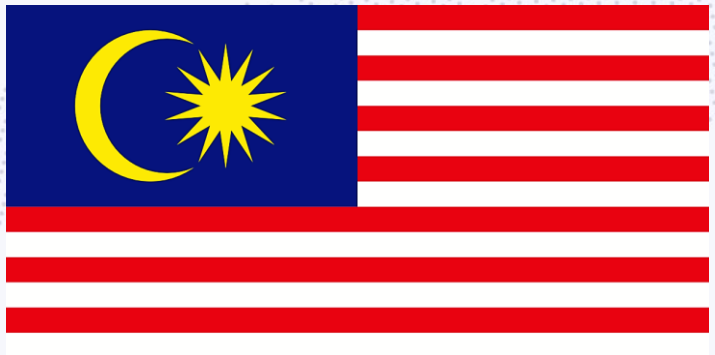




Conclusion

- The MgO additive can reduce up to 90 % when compared with commercial cutting oil at 50th shot of punch on the aluminium sheet during the punching and blanking operation.
- Nanoadditive can provide less fracture zone when the punch number increase, in which lower fracture zone on the workpiece is better.
- This study suggest single nanoadditives like MgO and SiC in WBLs serves better lubricant penetration through the highly stressing contact surface.

Acknowledgement



Malaysia Ministry of Higher Education for the primary financial support under the Fundamental Research Grant Scheme (FRGS/1/2022/TK10/UPM/02/9)

Universiti Putra Malaysia GP-IPM (UPM/GPIPM/2022/9717500) for providing additional financial assistance

- Special thanks are extended to the **Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia**, for their invaluable assistance and for making their facilities available at every stage of this research.

UPM
UNIVERSITI PUTRA MALAYSIA
BERILMU BERBAKTI

PUTRA
PERTANIAN UNTUK RAKYAT

Agriculture • Innovation • Life

With Knowledge We Serve

Thank you