Effect of Running-in Conditions on Repeatability of Friction and Wear Testing Results

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Friction and Wear Testing

Testing on SRV and HFRR

- Both are high frequency reciprocating rigs
- Both are test rigs wit a ball-on-disc configuration
- SRV (schwingung, reibung, verschleis) main test rig we use for research
- SRV we investigate testing techniques and methods; different temperatures, varying frequencies and operating loads.
- HFRR focus on diesel lubricant related compositions

Friction and Wear Testing

- Majority of testing is conducted on **SRV** and **HFRR**

(http://kuala-lumpur.all.biz)

(http://www.antek.com.tr)

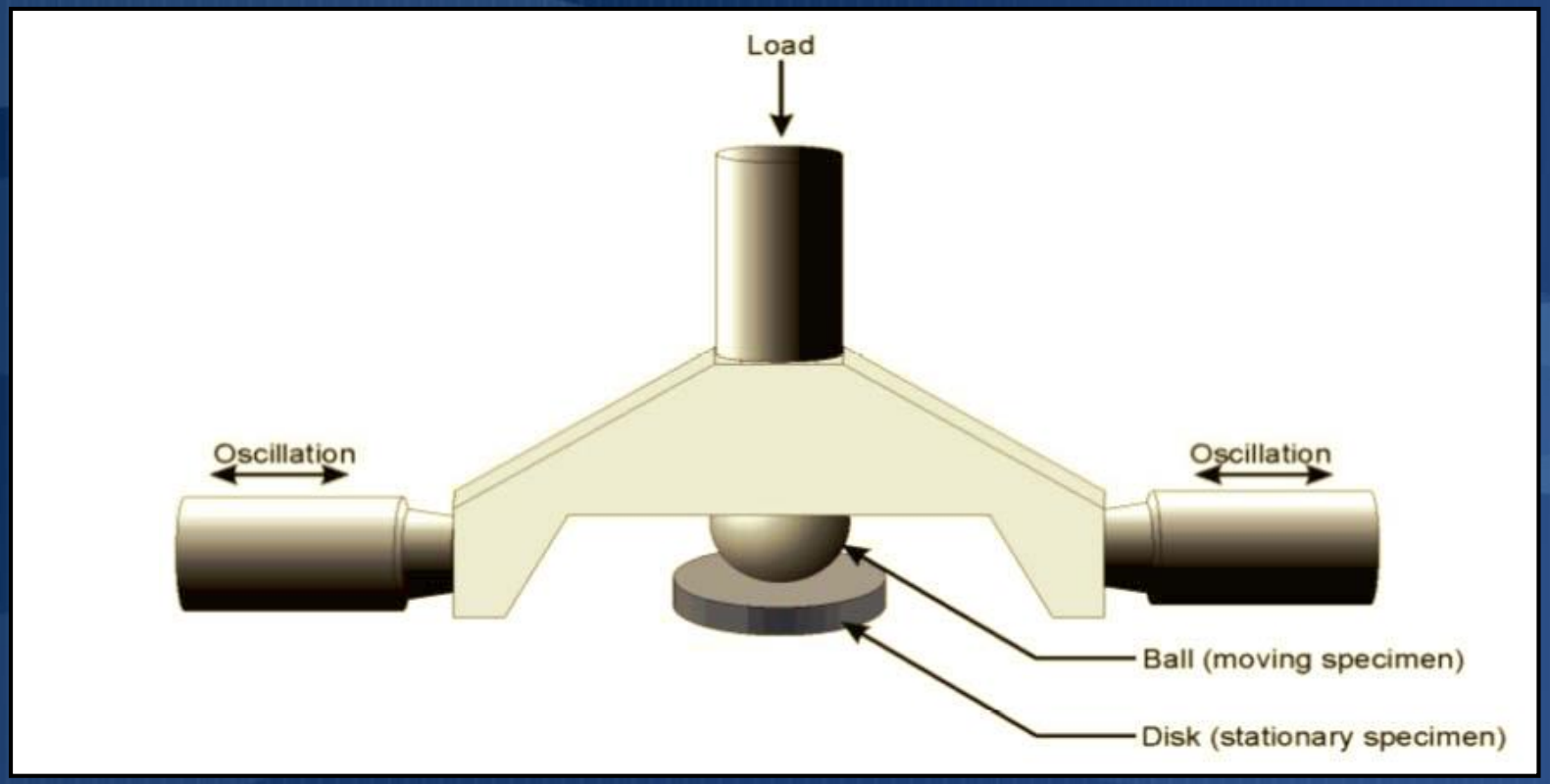
Friction and Wear testing: SRV

SRV more versatile than HFRR:

(http://kuala-lumpur.all.biz)

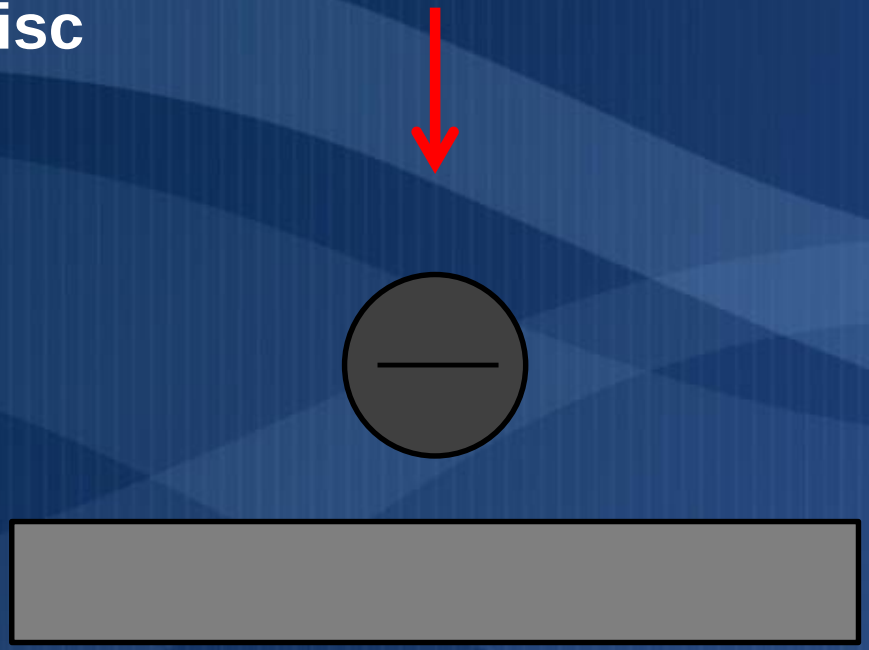
- Larger temperature range.
- Higher/varying operating load.
- Different contact configurations.
- Friction and wear testing as well as load carrying capacity (extreme pressure properties).

Friction and Wear testing: SRV



Friction and Wear Testing: HFRR & SRV

- **Ball-on-disc**



Standard Test Methods: SRV

- ASTM D 5707 & ASTM D 6425
  - ASTM D 5707: Lubricating Grease
  - ASTM D 6425: Extreme Pressure Lubricating Oils
- Similar to DIN 51834 part 2
- Combined with Chinese standards: ISO 19291-16

Standard Test Methods: SRV

Test Parameters			
Parameter	**ASTM D 5707**	**ASTM D 6425**	**In-house Test**
Load	**200 N**	**300 N**	**200N**
Block Temperature	**Ambient to 280 °C**	**Ambient to 280 °C**	**25 °C to 100 °C,**
Duration	**120 min. 30 sec.**	**120 min. 30 sec**	**65 min**
Running-in Procedure	**30 sec. at 50 N**	**30 sec. at 50 N**	**5 min. at 50 N**

Standard Test Methods: SRV

Test Parameters			
Parameter	**ASTM D 5707**	**ASTM D 6425**	**In-house Test**
Frequency	**50 Hz**		
Specimen Material	**AISI 52100 Steel**		
Hardness	**Ball: 60 ± 2 HRC / Disc: 62 ± 1 HRC**		
Surface Finish	**Ball: 0.025 ± 0.005-µm C.L.A. Disc: 0.035-µm < C.L.A. < 0.050 µm**		

Friction and Wear Testing: Results

1. Coefficient of friction
2. Wear Scar Diameter
3. Wear Volume
4. Wear Surface Appearance

Repeatability: ASTM Standards

ASTM D 5707 and ASTM D 6425

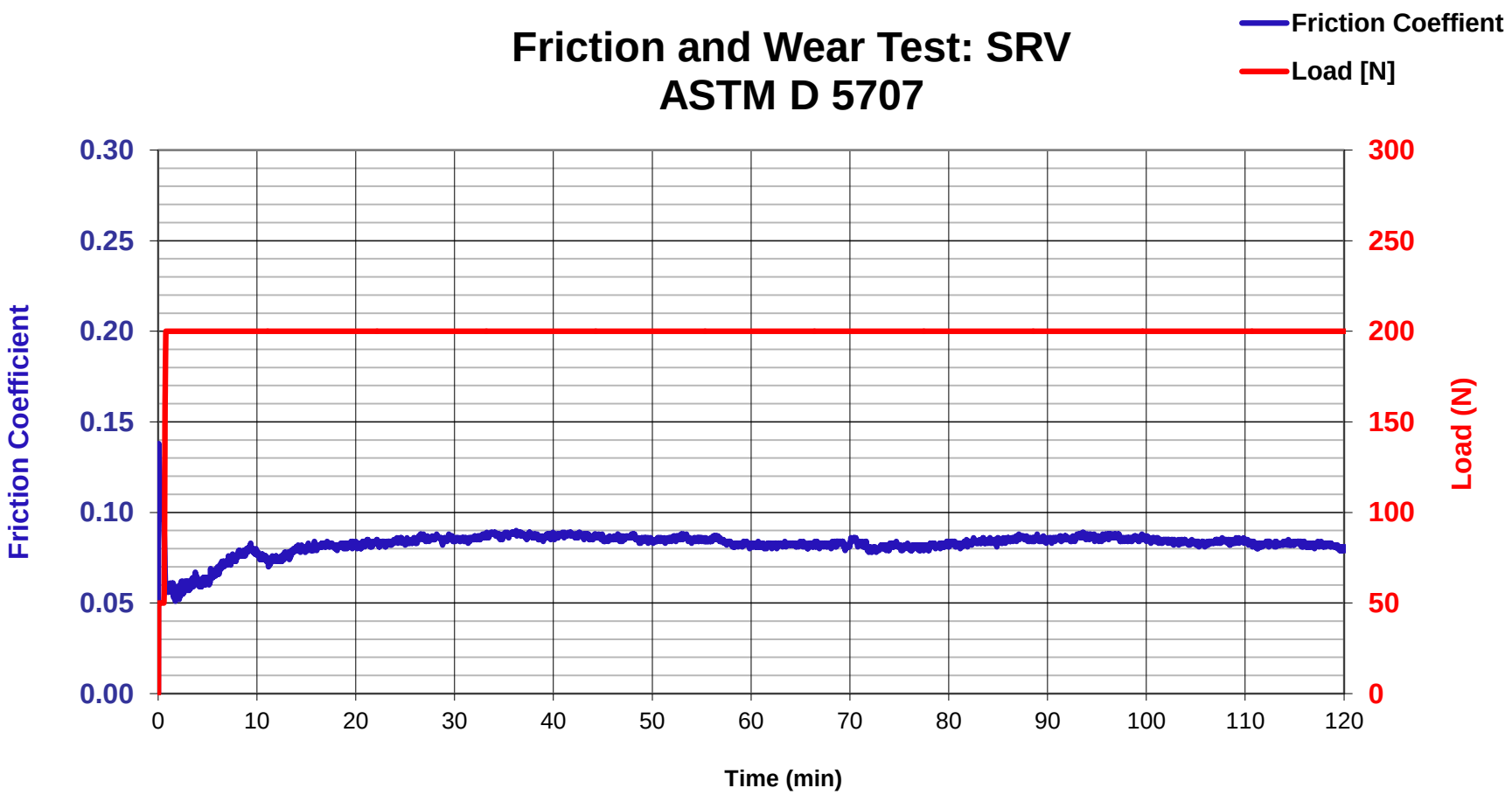
- Average Wear Scar Diameter:

  Not exceed 70 µm between two successive runs

- Friction Coefficient

  Not exceed 0.01 between two successive runs

Friction and Wear Testing: SRV

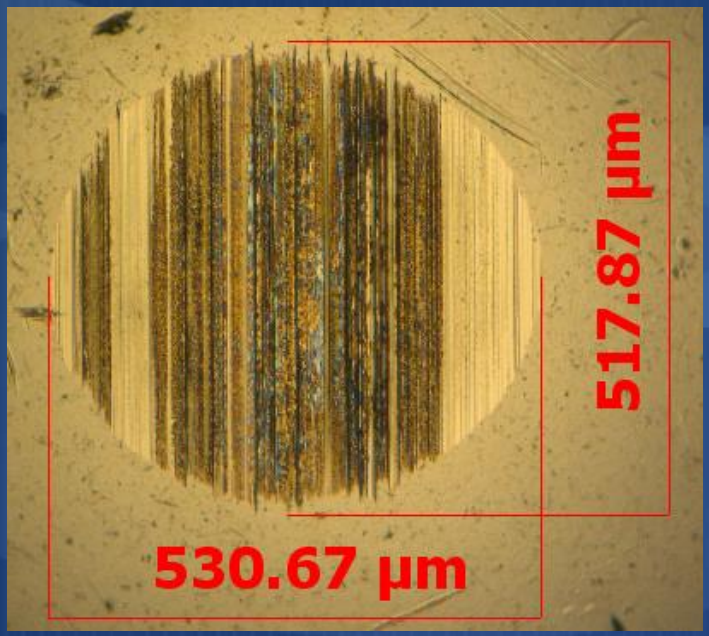


Amount of Wear: Wear Scar Diameter

- Average Wear Scar Diameter: amount of wear on the ball specimen.

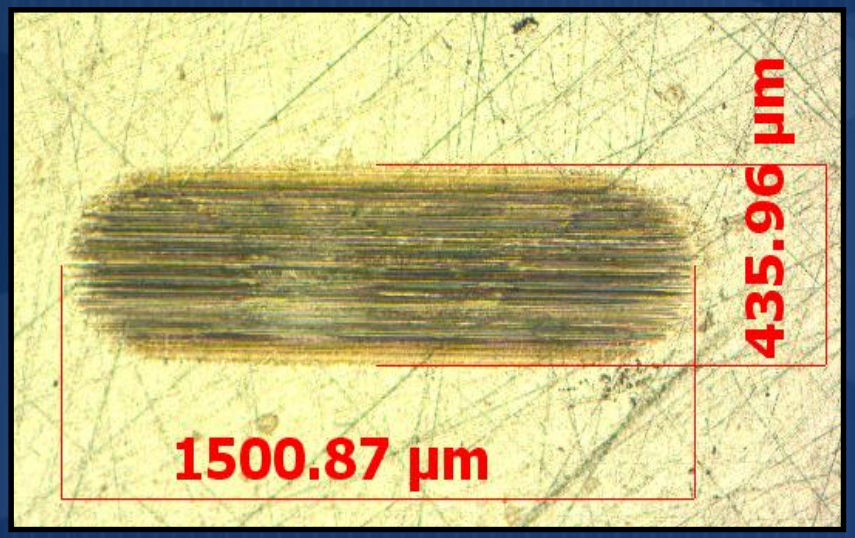
$$WSD = \frac{(530.67 + 517.87)}{2}$$

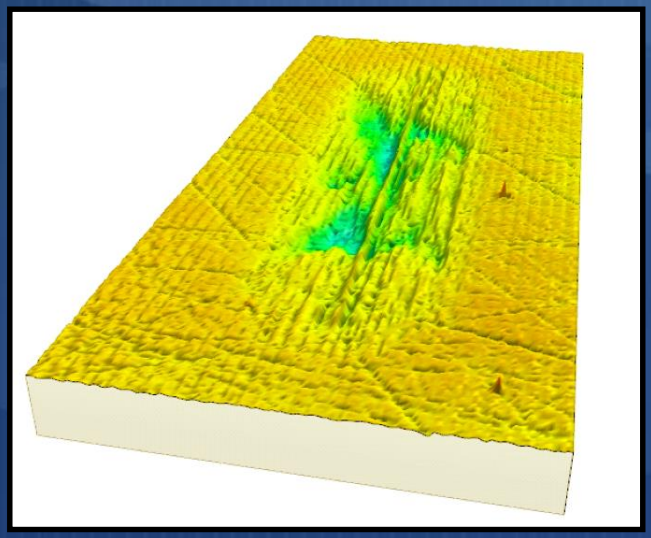
$$WSD = 524.17\ \mu m$$



Extent of Wear: Wear Volume

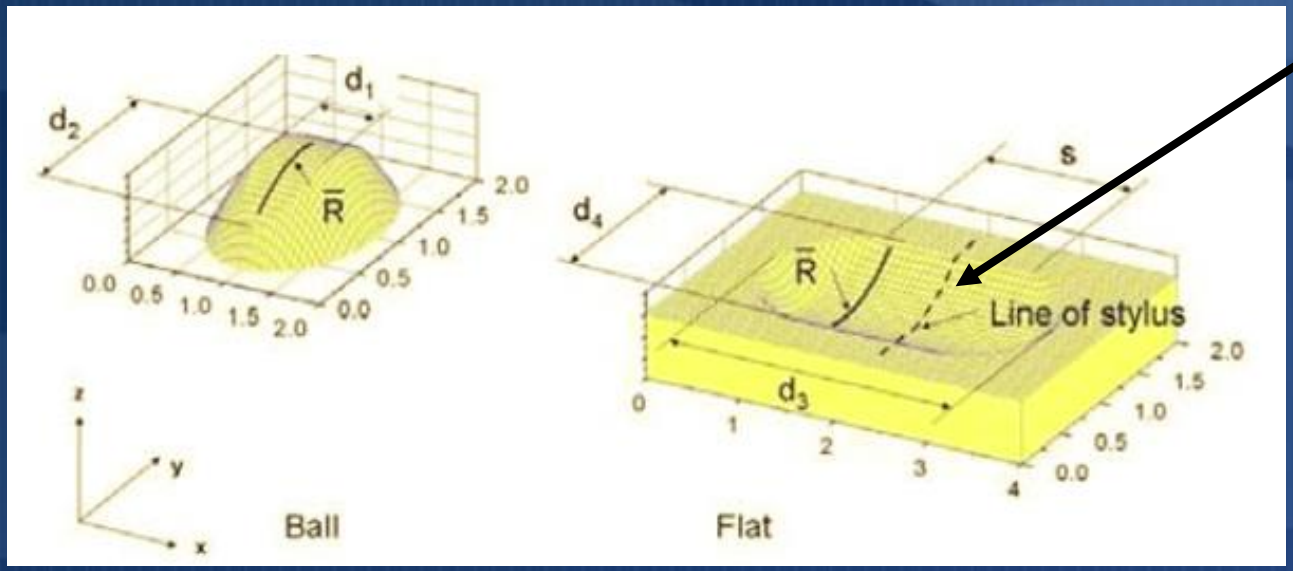
- ASTM D 7755
- Requires profile scan of the wear track – cross sectional area is used to calculate resulting “radius” of wear scar.





Amount of Wear: Wear Volume

- Wear Volume:
  - Volume of “cap” removed from ball
  - Volume material removed from disc

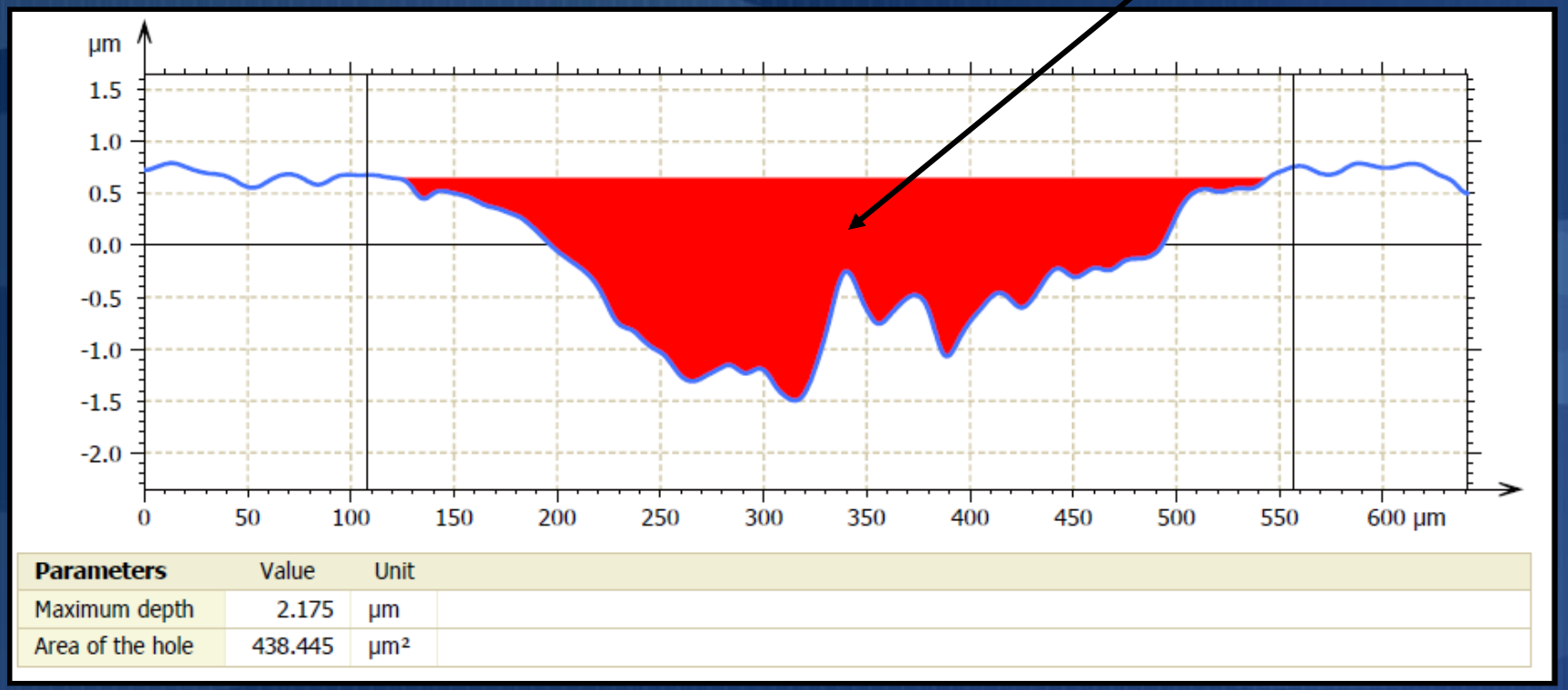


From profile analysis

(ASTM D 7755-11)

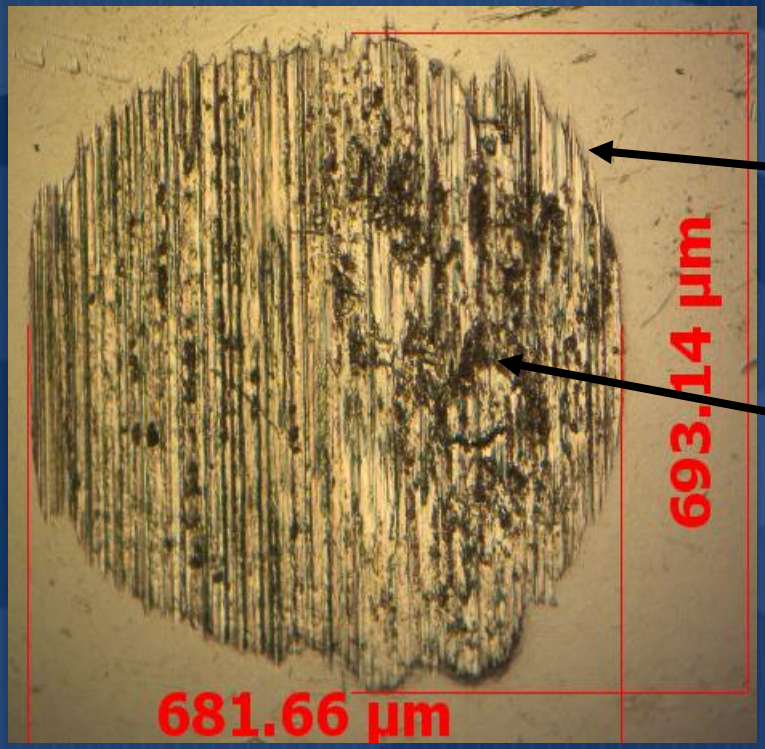
Amount of Wear: Wear Volume

Cross-sectional Area



Parameters	Value	Unit
Maximum depth	2.175	µm
Area of the hole	438.445	µm²

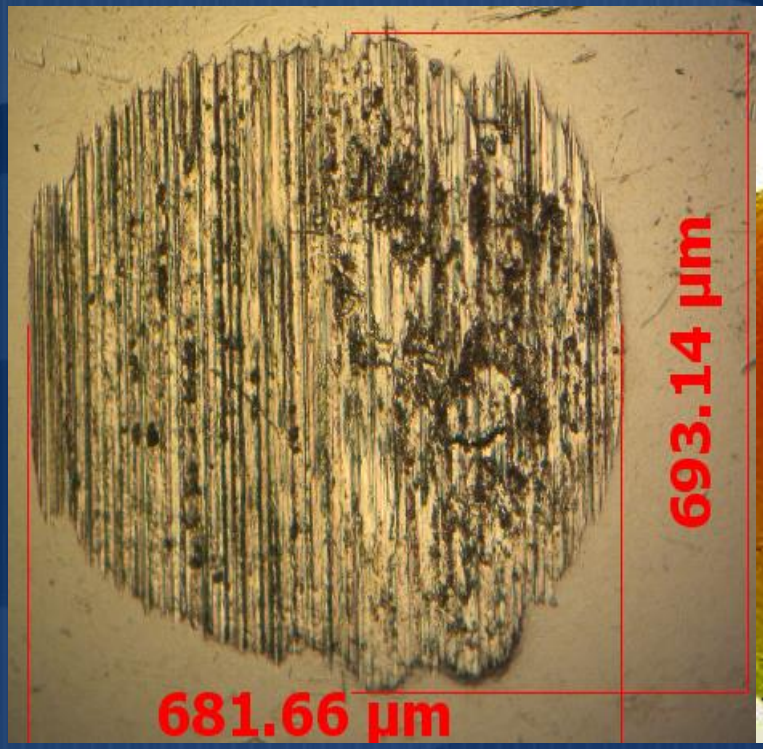
Surface Analysis: Wear Scar Image



Can't determine from image what surface profile looks like!

Possible corrosion layers

Surface Analysis: Wear Scar Image



Test Fluid Stability

Oxidation Reactions:

- Result in hydroperoxides (ROOH)
- Polymerization of ROOH groups
- Oxidation stability also affected by presence of metals

Hydrolysis:

- Reaction with water to from fatty acid
- Reactions affects performance of friction and wear testing

Mechanism of Oxidation
Initiation $RH + O_2 \rightarrow R^{\bullet} + HOO^{\bullet}$
Propagation $R^{\bullet} + O_2 \rightarrow ROO^{\bullet}$ $ROO^{\bullet} + RH \rightarrow ROOH + R^{\bullet}$ Peroxide decomposition $ROOH \rightarrow RO^{\bullet} + {}^{\bullet}OH$ $2ROOH \rightarrow RO^{\bullet} + ROO^{\bullet} + H_2O$ $RO^{\bullet} + ROOH \rightarrow$ Various comp.
Termination $ROO^{\bullet} + ROO^{\bullet} \rightarrow$ Inactive products $ROO^{\bullet} + IH \rightarrow ROOH + I^{\bullet}$

Factors Affecting Repeatability

Two Factors that affect repeatability:

1. Consistency of partial pressure of water vapour
2. Running-in procedure

Running-in Defined

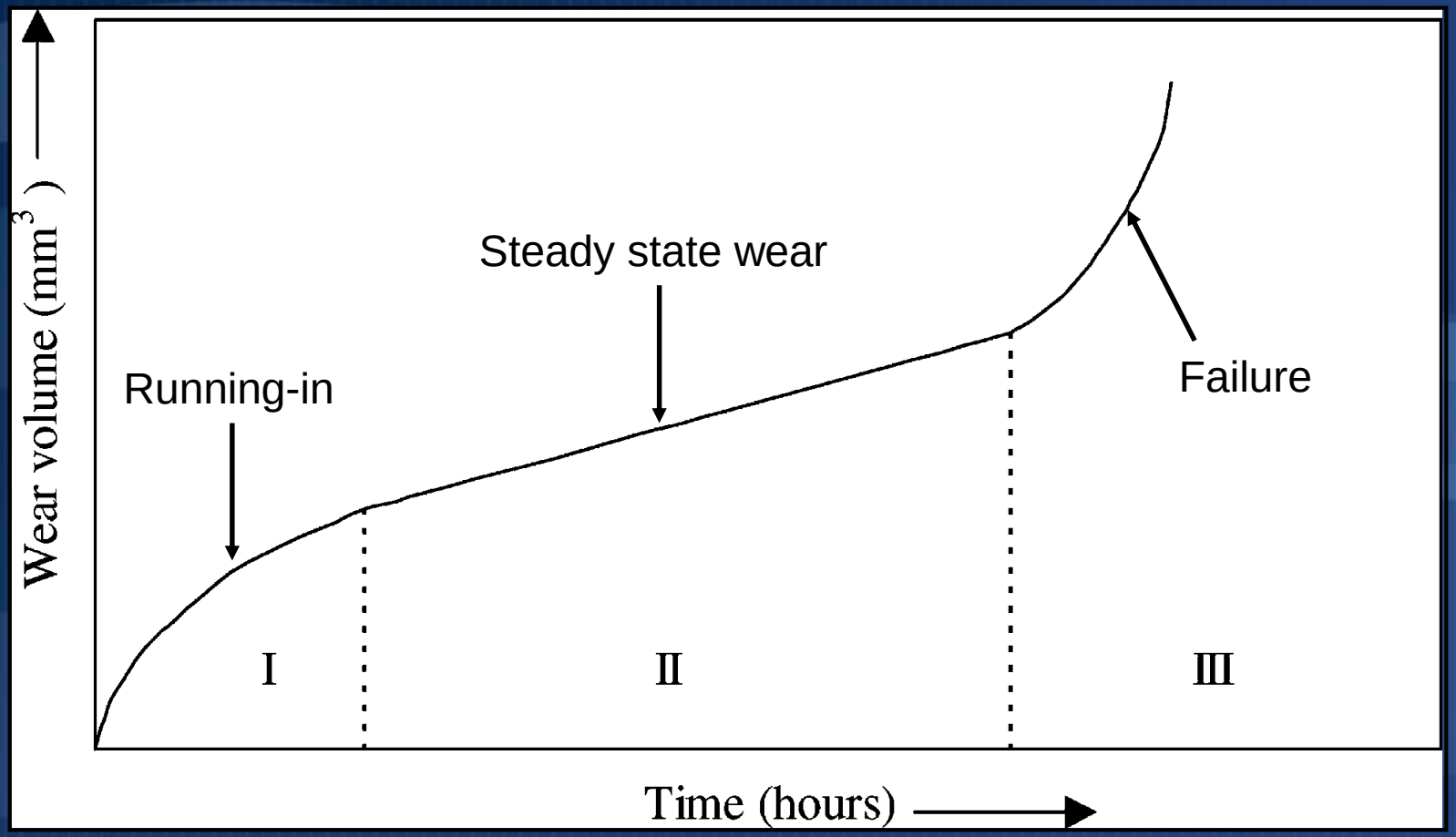
Peter J Blau, 1989

To impose a set of conditions on a tribosystem to reduce the time required to achieve a steady state, improve long-term performance, and/or to cause a steady state of geometric conformity to exist at the contact surfaces in that system. Run in for friction and wear.

ASTM test methods:

An initial transition process occurring in newly established wearing contacts, often accompanied by transients in coefficient of friction or wear rate, or both, which are uncharacteristic of the given tribological system's long-term behaviour.

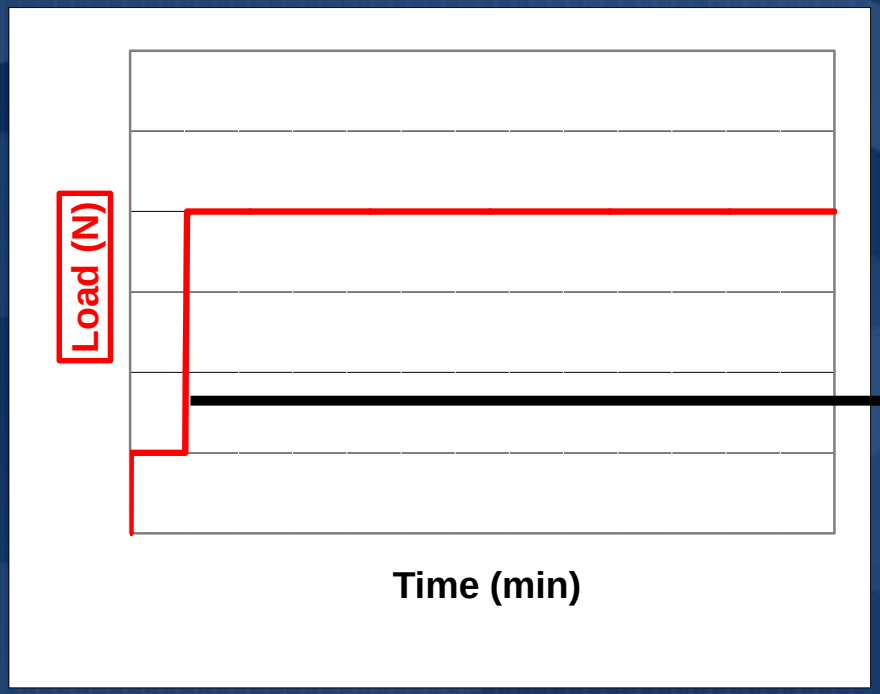
Running-in



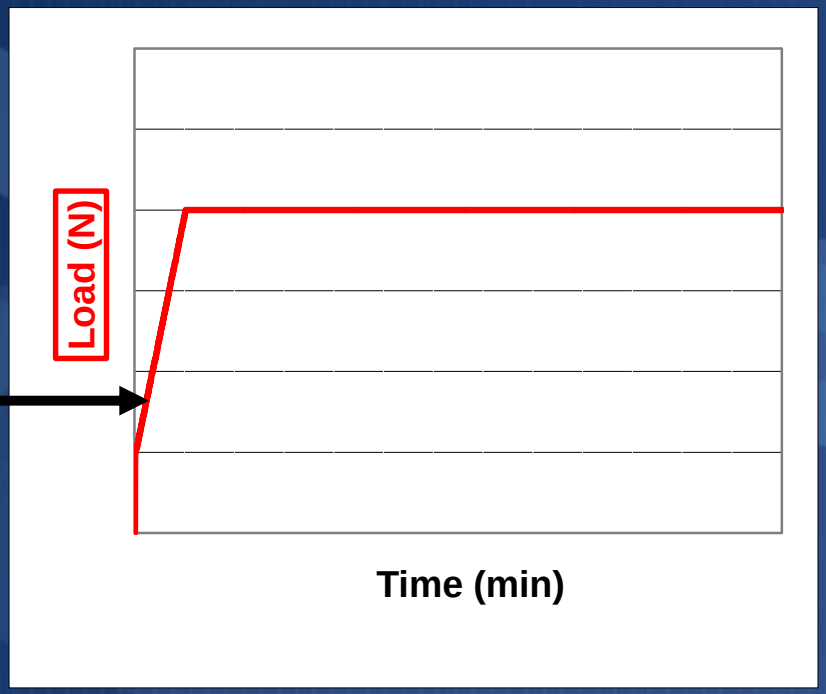
(Kumar et.al., 2002)

Modification to Running-in Procedure

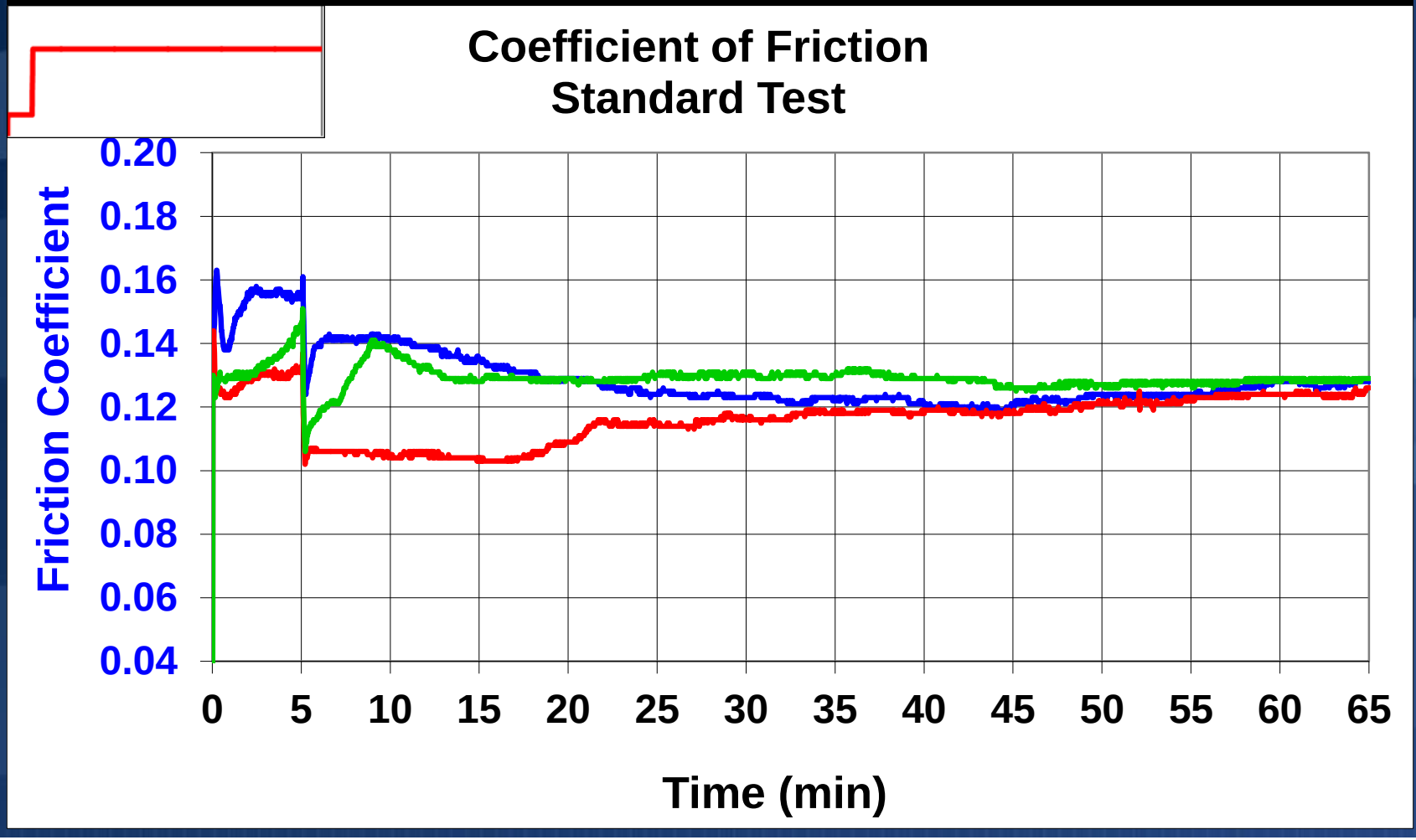
Standard Procedure



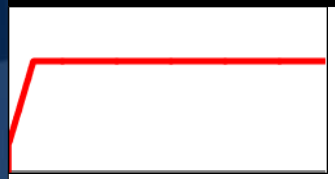
Modified Procedure

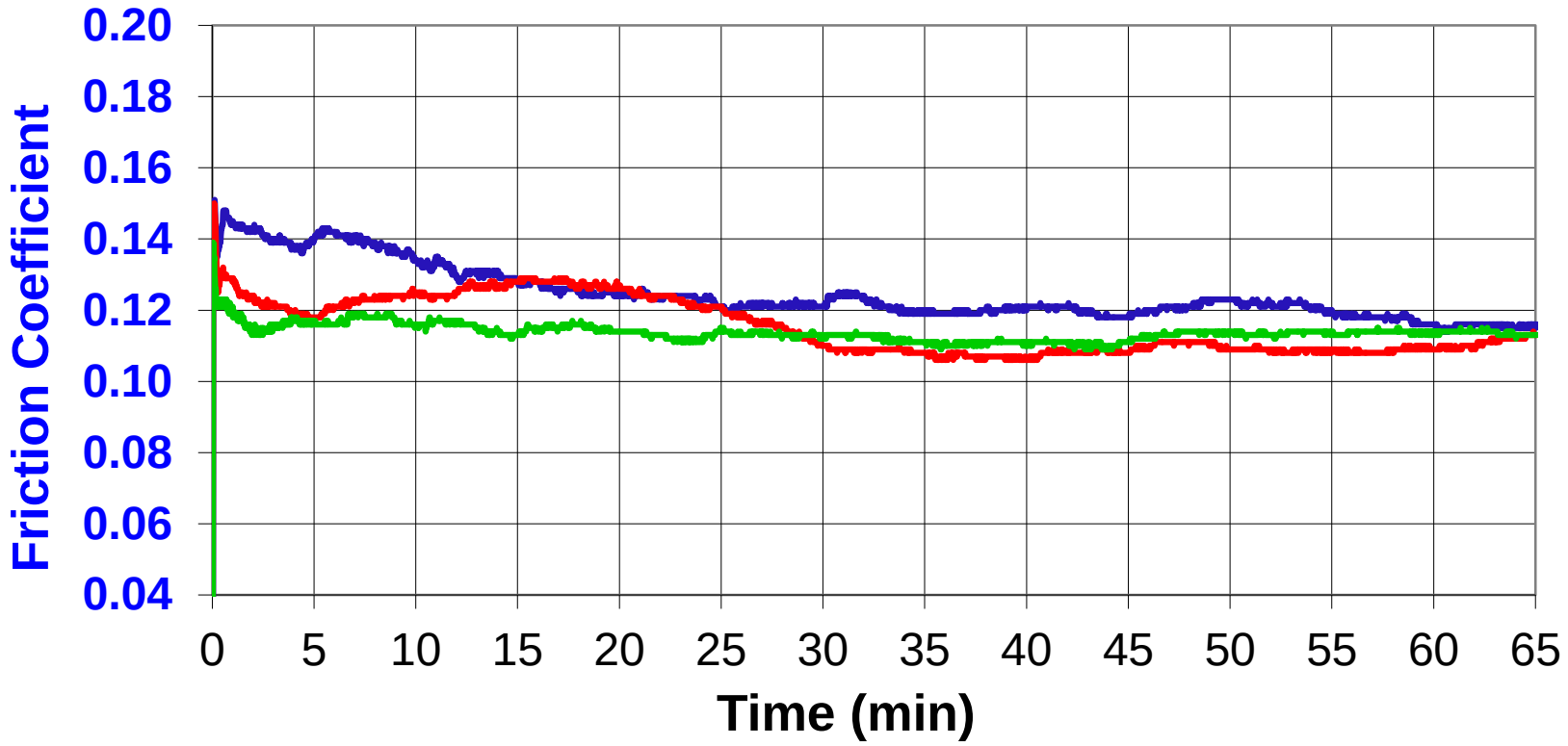


Friction Coefficient: Standard Test

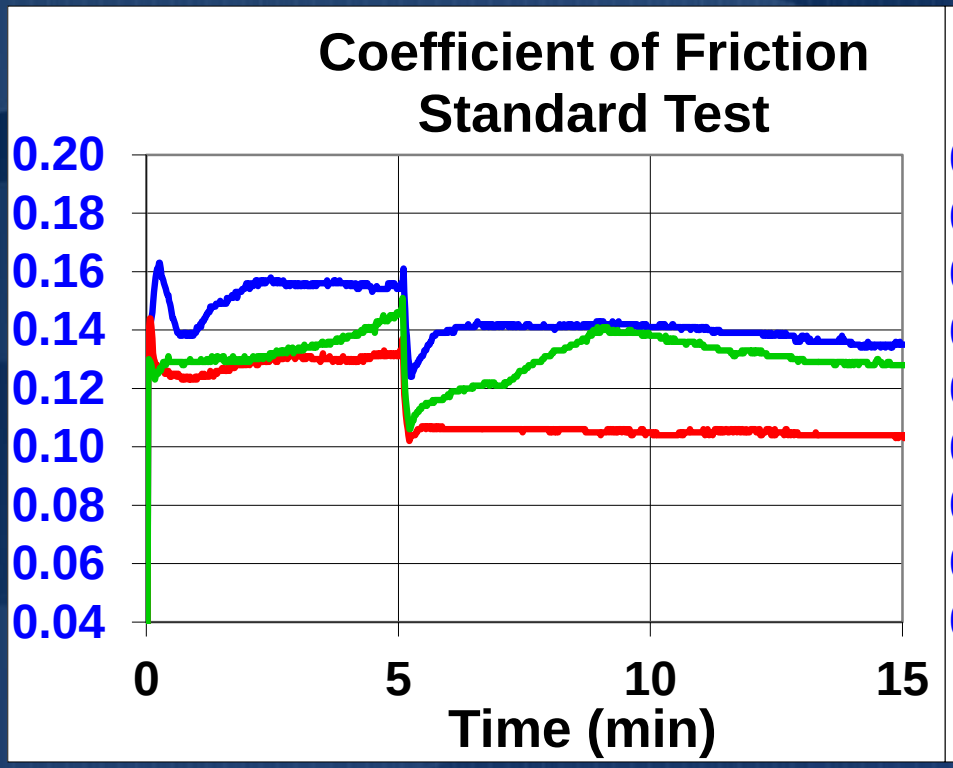


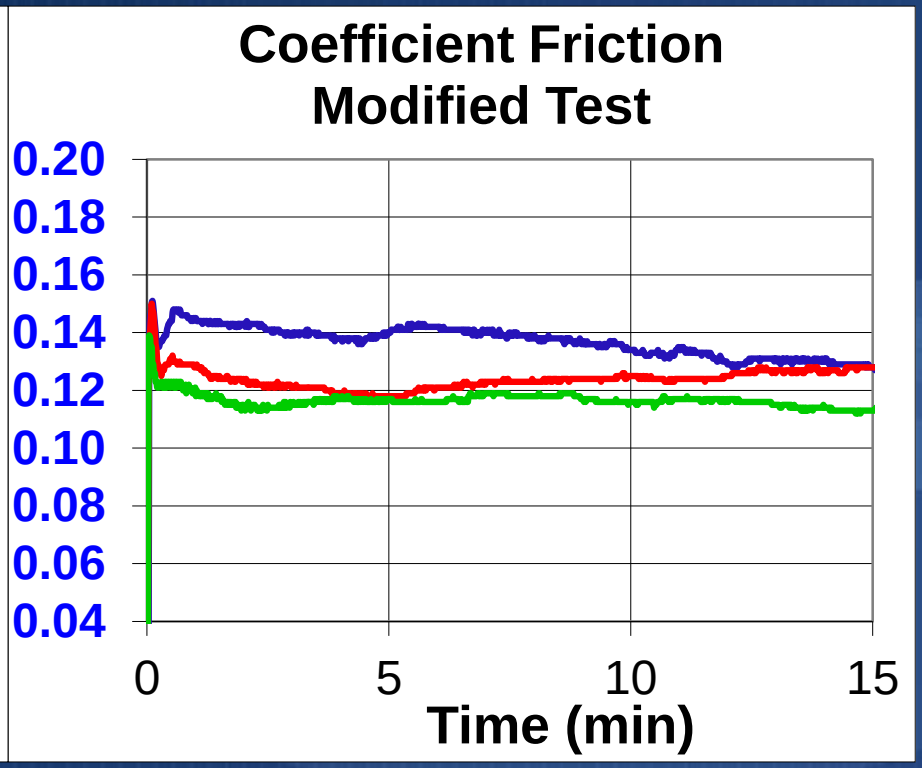
Friction Coefficient: Modified Test





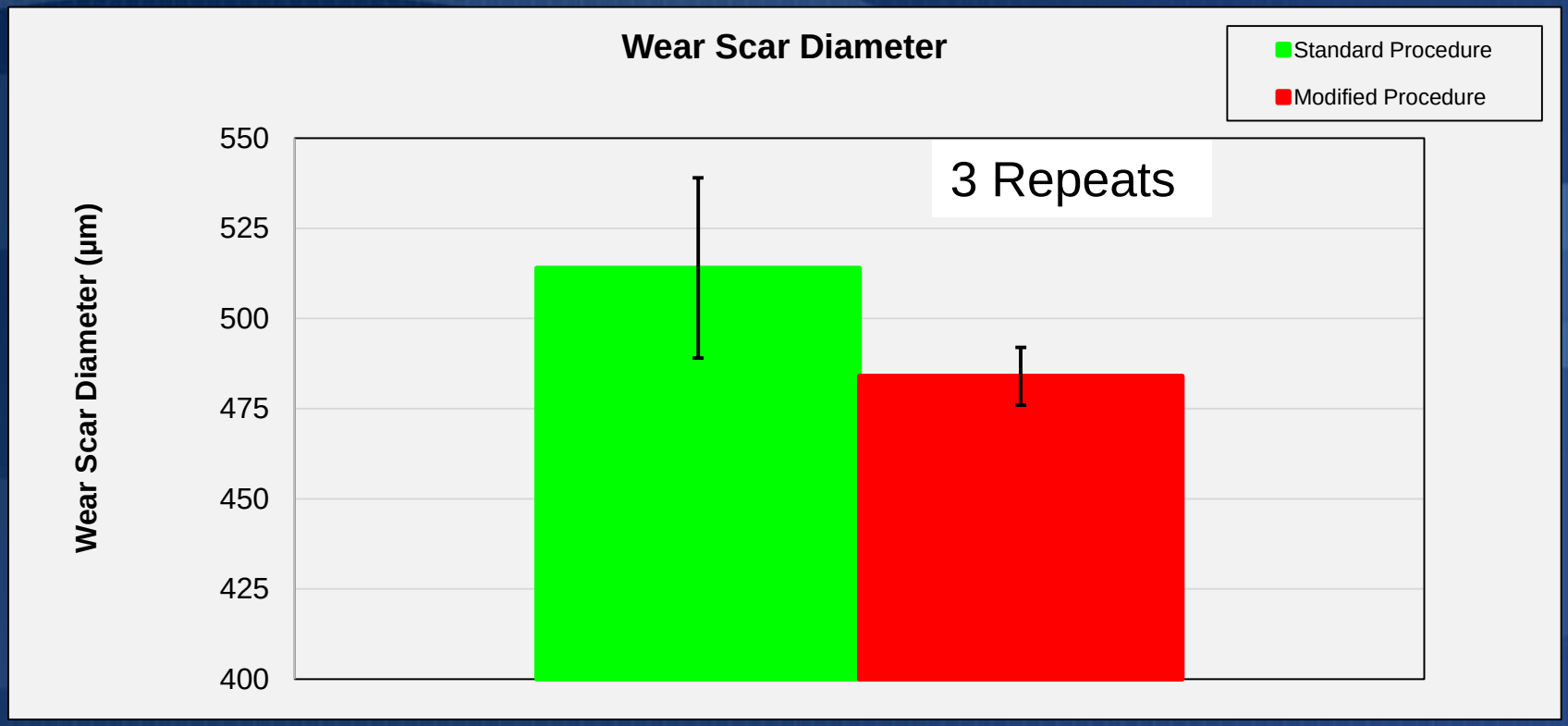
Friction Coefficient: First 15 min.



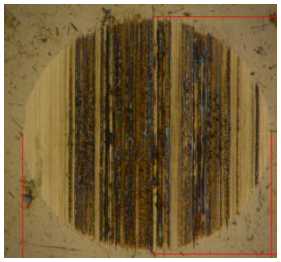
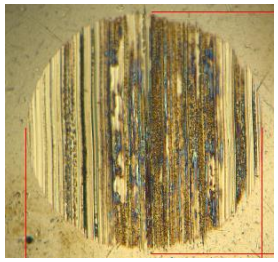
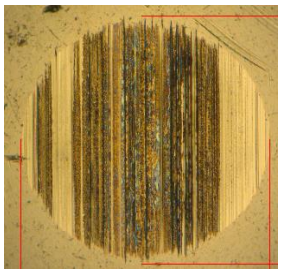
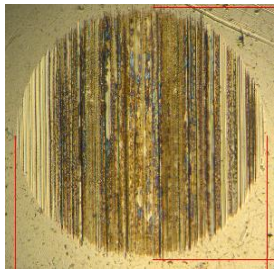
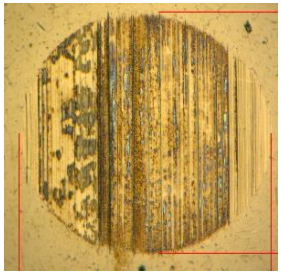
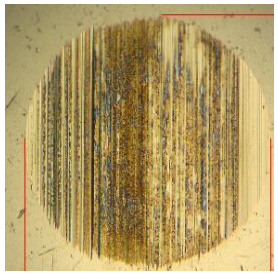


Wear Scar Diameter

Standard deviation decreased from 25 to 8 !



Wear Surface Appearance

	Standard Test	Modified Test
Run 1		
Run 2		
Run 3		

Summary

- Repeatability important to discern between good and poor lubricating fluids.
- Influence of the atmosphere on the test fluid should not be underestimated.
- Analysis of wear profile becomes more important; with calculation of wear volume and surface finish.
- More gradual load increase reduce uncertainty in the friction coefficient and improve repeatability of wear scar diameter and wear surface appearance.

Thank You!

References

- All biz (2010) “SRV 4 Test System” http://kuala-lumpur.all.biz [2017, May 6].
- Antek “HFRR (High Frequency Reciprocating Rig” *(http://www.antek.com.tr* [2017, May 6].
- ASTM D 5707 (2016) “Standard test method for measuring friction and wear properties of lubricating grease using a high-frequency, linear-oscillation (SRV) test machine” ASTM International.
- ASTM D 6425 (2011) “Standard test method for measuring friction and wear properties of extreme pressure (EP) lubricating oils using SRV test machine” ASTM International.
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- Kumar, R, Prakash, B and Sethuramiah, A (2002) “A systematic methodology to characterise the running-in and steady state wear process” Wear 252, 445-453.