

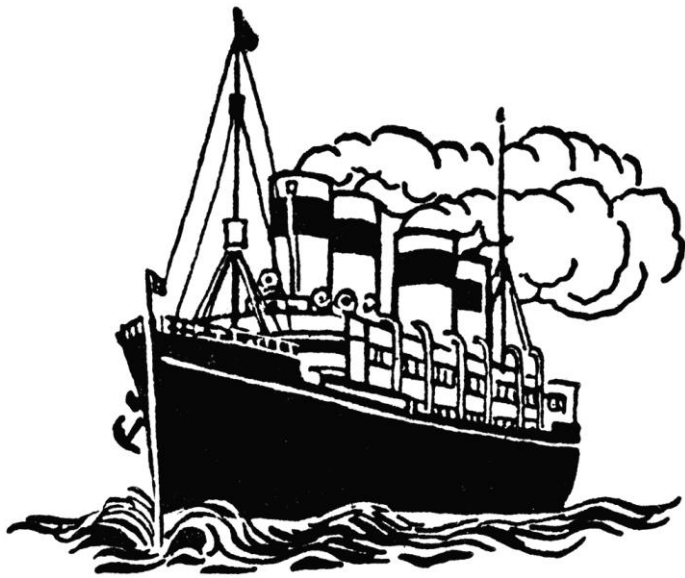
NanoLub[®]

SURFACE RECONDITIONING NANO-LUBRICANTS



NanoMaterials
Active Protection NANOMaterials APNANO

10/06/2015



Ener. Co Castrol TLX Plus Range Diesel
Engine oil
Client: Carnival Cruise
Ref. No.:



Castrol TLX Plus Range Diesel Marine Engine Oil

- In this document is consolidated 4-ball AW and Roller-on-Block performed on following samples :
- Castrol TLX Plus oil
- Castrol TLX Plus formulated with NanoLub DE-M6000

4 Ball AW description:

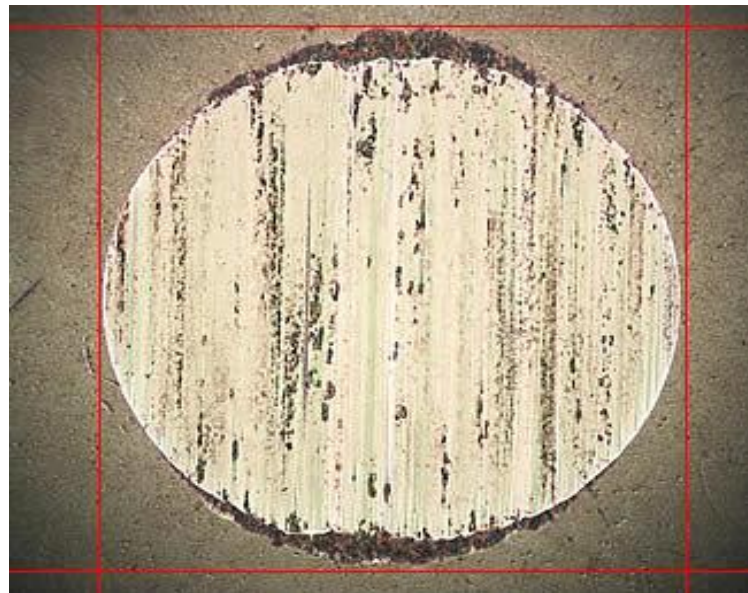
- To compare the anti-wear performances of Castrol TLX Plus as is vs. Castrol TLX Plus formulated with NanoLub DE-M6000 additive. The 4 Ball ASTM D-ASTM 2266 is used at 75°C.
- This test method covers the determination of the wear preventive characteristics of oil and greases in sliding steel-on-steel applications. It is not intended to predict wear characteristics with metal combinations other than steel-on-steel or to evaluate the extreme pressure characteristics of the lubricants.
- Three 1/2 inch (12.7 mm) diameter AISI 52100 steel balls are clamped together and covered with the lubricant to be evaluated. A fourth 1/2 inch diameter steel ball, referred to as the top ball, is pressed with a force of 40 kg (392 N) into the cavity formed by the three clamped balls for three-point contact. The top ball is rotated at 1200 rpm for 60 min. Lubricants are compared by using the average size of the scar diameters worn on the three lower clamped balls.

4-ball machine



Measuring:

- After testing, scar diameters are measured on each of the three clamped balls. Figure illustrates a typical wear scar on a ball. The measurements are made thanks to a binocular microscope associated with a numerical video camera that allows precise measurements through adequate software and calibration.
- The mean value of the three scar diameters is reported and gives the anti-wear characteristic of the tested fluid as described in ASTM D 4172. Because of repeatability questions, each lubricant is tested three times following the same procedure.



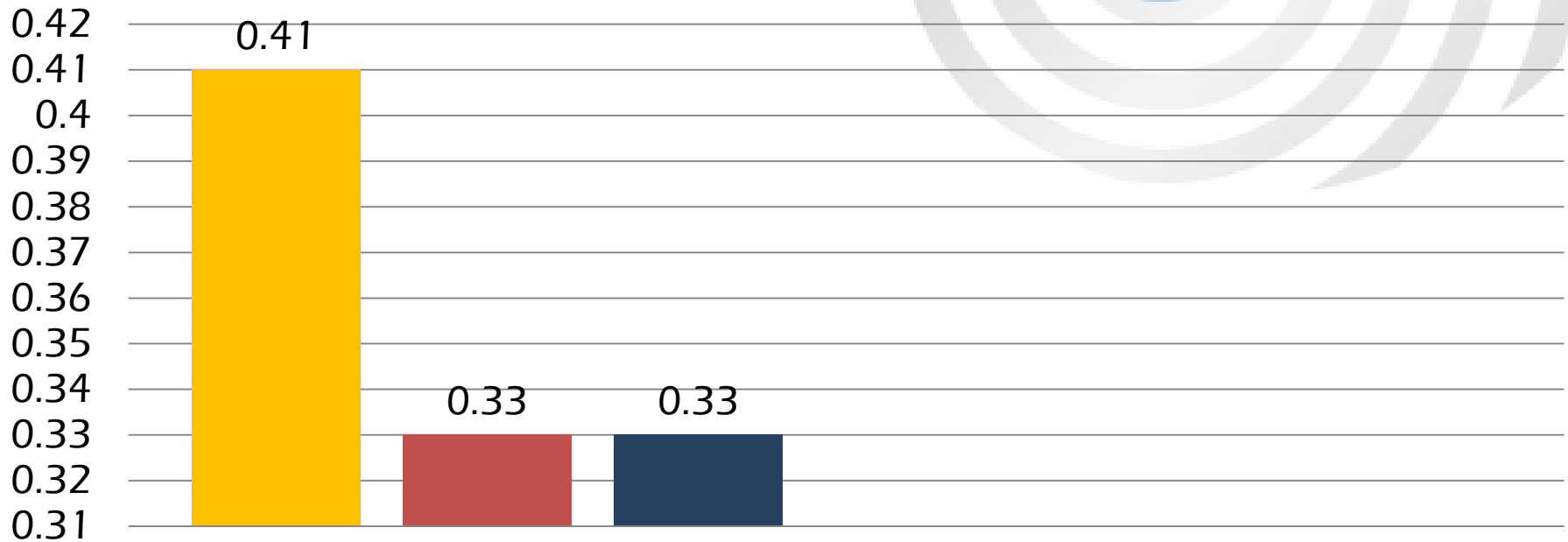
Wear Scar Diameter Test Results:

	Castrol TLX Plus as is	Castrol TLX Plus +3% DE-M6000	Castrol TLX Plus +4% DE-M6000
WSD, mm	0.41	0.33	0.33

Wear Scar Diameter test results:

Castrol TLX Plus as is vs. Castrol TLX Plus Formulated with Nanolub DE-M6000 products

Wear Scar Diameter, mm

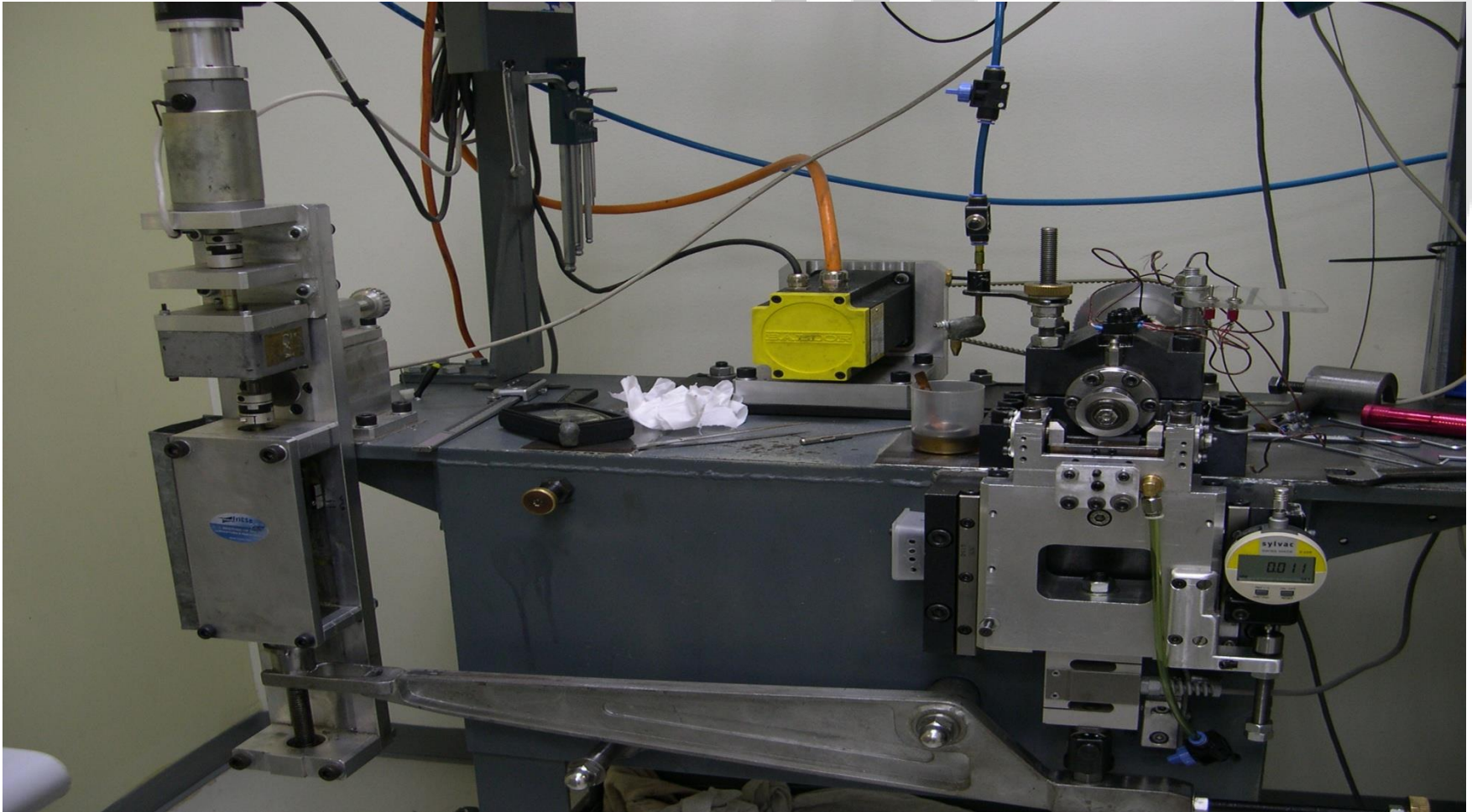


■ Castrol TLX as is ■ Castrol TLX+3% DE-M6000 ■ Castrol TLX +4% DE-M6000

Roller-on-Block Tribotesting Machine

- Roller-on-Block
- Coefficient of friction and wear rate (WR) measures were performed using a roller -on- block test machine, approaching guidelines to the international standard ASTM G-77.
- Vertical load on the steel block (SAE 4340) , roller is rubs on the surface of the block with the constant speed .
- The tests was done under boundary lubrication conditions.
- The measurements were performed according to the parameters given below:
- Load was increased by stepwise from 50 N to 300 N
- Speed 0.6 m/s
- Roller diameter 38 mm, width 10 mm
- Block width 10 mm
- Way 1000 meter

Roller-On-Block Tribotesting Machine



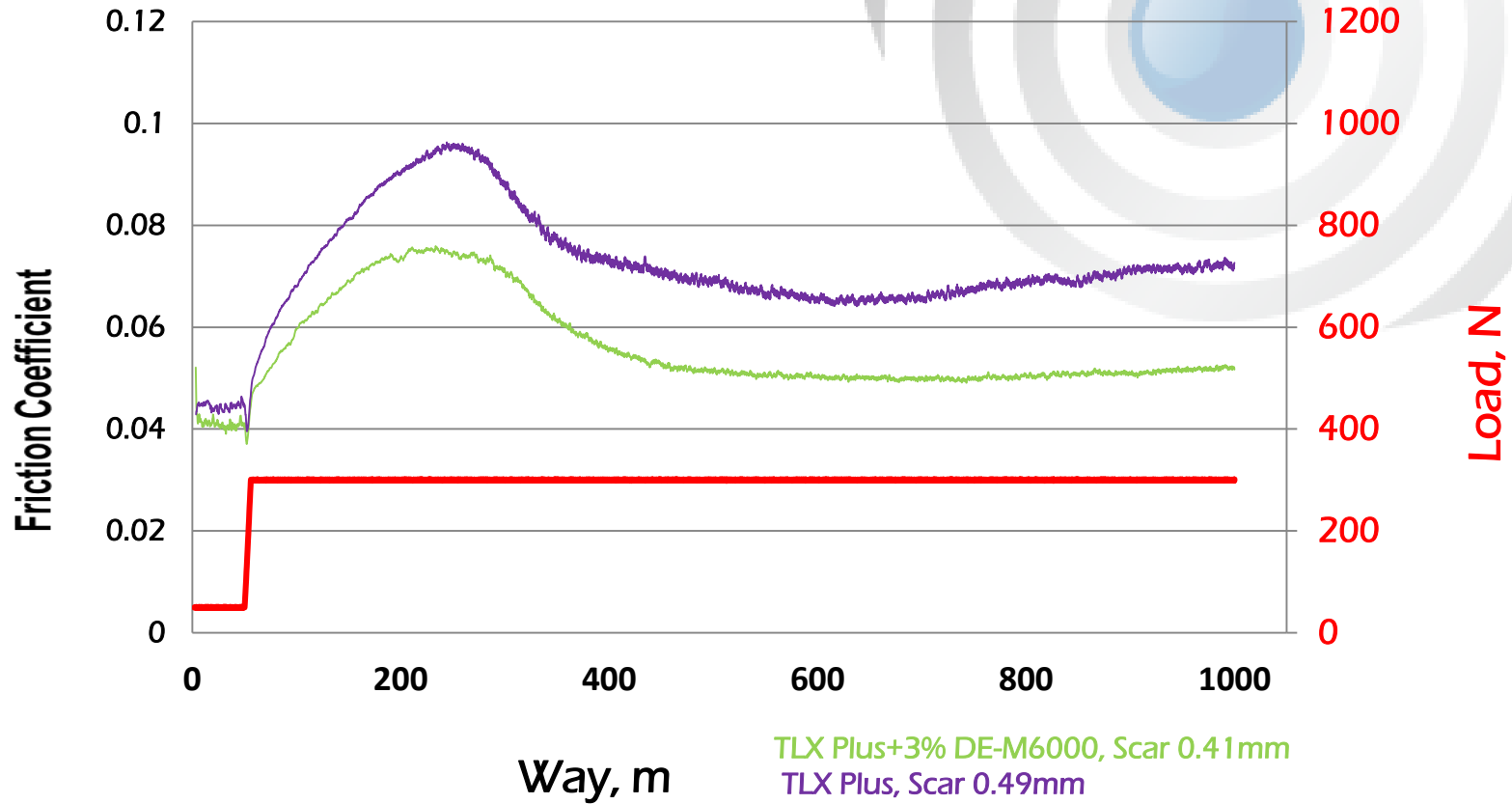
Test "Roller-on-Block"

Friction Coefficient

Castrol TLX Plus vs. Castrol TLX Plus +3% DE-M6000

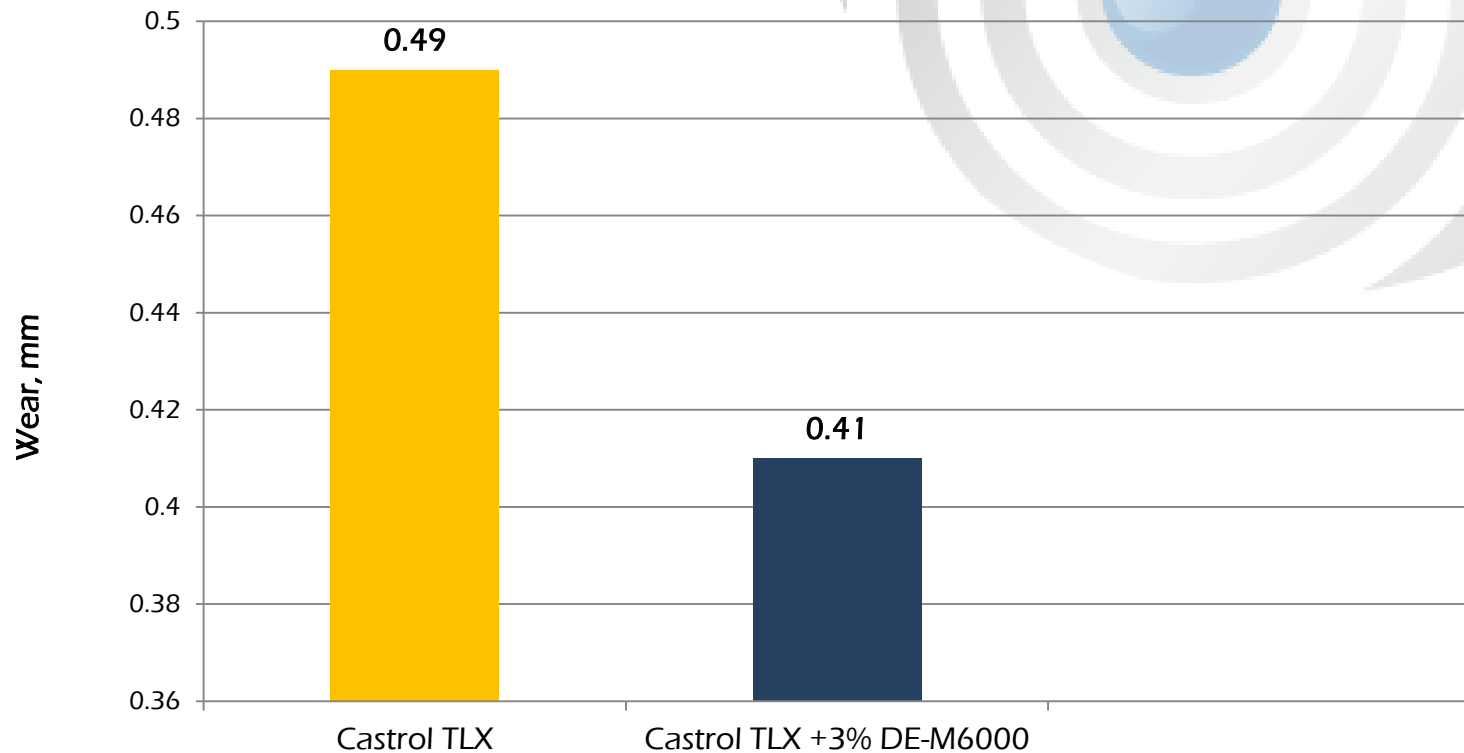
Way 600 meters

400 N, velocity 0.6 m/sec



Roller-on-Block test results: Wear Data

Castrol TLX Plus vs. Castrol TLX Plus Formulated with 3% DE-M6000



Conclusions:

According to the 4-ball and Roller-on-Block test results we found significant improvement of the tribological properties of Castrol TLX Diesel Engine oil formulated with NanoLub products.

4-ball test – Wear scar diameter was decreased by 20%.

Roller-on-Block test – Wear scar rate was decreased by 16%.

According to these findings, the recommended treat rate is 3%.