Cylinder lubrication challenges when operating on low-sulphur fuel on two-stroke marine diesel engines

Changing the fuel, from heavy fuel oil to greener low-sulphur alternatives, is a necessary approach to fulfil the emission regulations in 2020. However, the changeover has shown to cause bore polishing and scuffing problems. In this review, Rathesan Ravendran (Ph.D., Postdoctoral researcher) from Aalborg University highlights the importance of cylinder oil distribution.

New and upcoming emission regulations for ships will push towards greener sea based transports. Changing the fuel, from heavy high sulphur fuel oil to low sulphur diesel oil or natural gas, is a necessary approach to fulfil these regulations, but tribological problems are expected to appear when the low sulphur diesel and sulphur-free gas replaces the sulphur-rich heavy fuel oil. Ironically, tribological problems are now instead expected when the sulphur level in the fuels becomes very low. Prolonged operation on these low sulphur fuels may lead to bore polished cylinder liner surfaces with a subsequent risk of cylinder liner scuffing as the consequence.

Experimental studies have shown that fuel with lower sulphur content has a lower lubricity and hence a lower scuffing resistance. In some studies, it has been shown that fuels containing sulphur have about 20% higher scuffing resistance than does fuels without sulphur [1], [2].

The general belief is that the sulphur in the fuel have a beneficial tribological effect due to build-up of a solid lubricating oil film and due to promoting a beneficial mild corrosive wear. This will be addressed in the following.

Figure 1 shows the "bath tub curve" or normal wear profile found in lubricated systems [3], [4]. After running-in an engine for a short time, a normally honed cylinder liner will exhibit a surface profile similar to a plateau honed cylinder liner. The initial wear of normally honed cylinder liners is high. The initial period is shown by the curve AB in Figure 1. After this period, the surface is relatively stable in terms of wear, curve BC. During this second period, the plateau honed surface continues to possess relatively large and smooth plateaus, which provide a large bearing area and also deep valleys that help to retain the cylinder oil for lubrication and provide relief pockets for wear particles. A smooth and stable plateau honed liner offers substantial improvement in oil consumption, piston ring wear and cylinder liner wear at the ring reversal zone. In the final phase of the wear rate curve, CD, the cylinder liner wear increases dramatically, which is due to the wear down of the plateaus and the smaller valleys on the surface. Thus, the surface will not be able to maintain the lubrication oil pockets nor pockets for wear particles. This naturally increases the risk of bore polishing and scuffing.

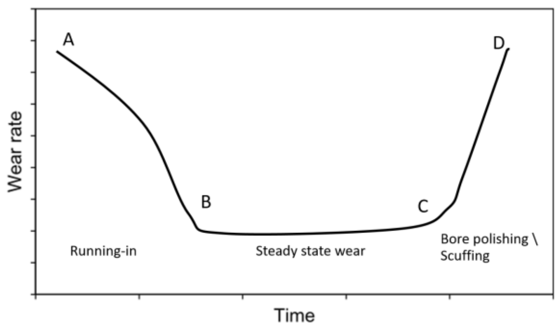

Figure 1: Normal wear profile for lubricated systems.

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Sulphur rich fuels will prolong the period of steady state wear, as its lubricating properties will reduce the wear down of the plateaus on the surface, and since mild corrosive wear from sulphuric acids produced during combustion will maintain an open cylinder liner material surface. Low-sulphur fuels will on the other hand have the opposite effect, meaning the period of steady state wear will be shorter. Thus, lead to earlier bore polishing and scuffing.

The lost lubricity of the low sulphur fuel must be replaced by conventional cylinder lubrication oil, its primary function is to provide a continuous stable hydrodynamic oil film between surfaces in relative motion to reduce friction and prevent wear and thereby prevent seizure of the mating parts. Ensuring a stable hydrodynamic oil film between the surfaces will prevent the wear down of the surface plateaus and thereby increase the period of steady state wear (as illustrated in Figure 2).

To overcome the challenges of operating with fuel with lower sulphur, the required amount of cylinder lubrication oil must be distributed correctly on the cylinder liner. This has been highly prioritized by Hans Jensen Lubricators. For this purpose, HJ SIP spray injection valves, placed at the liner circumference, direct the lubricating oil spray upwards and into the engines scavenging air swirl. Thus, the lubrication oil is evenly distributed at the upper part of the cylinder liner, where the oil film is exposed to a hazardous environment e.g. high pressure and temperature.

It is proven that a combination of HJ SIP valves and HJ Lubtronic lubricator ensures good cylinder liner condition, minimises wear and reduce the risk of bore polishing and scuffing [5]. The HJ Lubtronic lubricator operates with automated stepless stroke adjustment and timed lubrication. Cylinder lubrication oil injection at each piston stroke will refresh the oil film at each piston stroke, which ensures a stable oil film as well as minimises the stress level of the oil film on the cylinder liner [6].

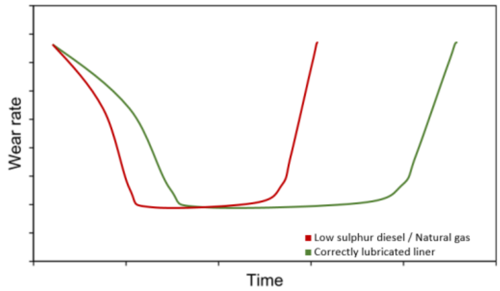

Figure 2: Correctly lubricated liner increases the steady state wear and prevent early bore polishing and scuffing.

References

[1] Ajayi, Alzoubi, Erdemir, and Fenske, "Effect of carbon coating on scuffing performance in diesel fuels," *Tribol. Trans.*, vol. 44, no. 2, pp. 298–304, Jan. 2001.

[2] P. Olander, P. Hollman, and S. Jacobson, "Piston ring and cylinder liner wear aggravation caused by transition to greener ship transports-Comparison of samples from test rig and field," *Wear*, vol. 302, no. 1–2, pp. 1345–1350, 2013.

[3] M. Winkler, "The use of tribology and wear metal analysis in two-stroke engines to optimize oil feed rates and reduce liner wear," *CIMAC Congr. 2010*, 2010.

[4] P. A. Lakshminarayanan and N. S. Nayak, *Critical Component Wear in Heavy Duty Engines*. John Wiley & Sons, 2011.

[5] P. Jensen, M. Bach, A. Salufas, D. Tsalapatis, and H. Rolsted, "Lubtronic SIP promise remarkably low wear rates with low CLO consumption," *CIMAC Congr. 2016*, 2016.

[6] R. Ravendran, *Cylinder Lubrication of Two-Stroke Diesel Engines : Investigation of Nozzle Flow and Spray Formation using Numerical Simulation and Experimental Visualisation*, 1st ed. Aalborg Universitetsforlag, 2018.

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