AN INNOVATIVE INSTRUMENT TO TEST LUBRICITY IN FUELS : BALL-ON-CYLINDER LUBRICITY EVALUATOR (BOCLE)

When working with lubricants, it may seem that all the oil and fuel lubricants are the same, but different oils have different lubrication properties that can change with time and use. The necessity for having the proper oil for lubrication is an automotive engine. In many vehicle engines, for example, the distance between contacting components, or the tolerance can be around 0.0001 to 0.00022 inches [1]. With such high tolerances and constant movement at high speeds, it is important to keep these parts lubricated as best as possible because the surfaces, if not properly lubricated, will start to wear away over time leading to overheating and wear on the parts ultimately resulting in engine damage or premature failure [2]. The same idea applies to jet engines and other places where there is metal-on-metal contact in constant motion. One way to prevent excessive wear and overheating is to use a lubricating oil or fuel. Understanding the properties of oil or fuel before it is used in an industrial application is important as it allows for informed and adequate lubrication to specialized parts of machinery at predetermined conditions, including high speed or pressured environments. Comprehensive knowledge on the applicability and effectiveness of a wide variety of fuel lubricants ultimately allows for the prolonging of machinery lifespan in addition to a reduction in diagnostic and replacement costs.

When an automotive engine is not properly lubricated, the metal-on-metal contact surfaces will start to scrape on each other resulting in parts wearing down and grinding causing the point of contact to heat up resulting in overheating issues [7]. One prominent type of issue that is common in automotive engines is known as a spun out bearing. The bearing that is being referenced here is the connecting rod bearing. This bearing is used to transfer the energy from the piston to the crankshaft [8]. When that bearing spins out, that is a direct result of not being properly lubricated. When not properly lubricated, the connecting rod bearing, piston rod and crankshaft all begin to grind on each other. When this happens, the bearing will start to wear down. This will result in damage to the crankshaft and a possibility for the connecting rod to break. If the not properly addressed, the main bore in the engine could get damaged also, which could mean that the engine could have to be sent off to get machined [7]. When any wear happens on any part of the engine block, the life span of the engine is severely decreased and the cost of fixing those issues are expensive or in some cases having to replace the engine.

This problem does not only exist in automotive engines. This issue exists in other engines or in areas with parts that are in constant motion that are in need of lubrication. Grease is not the best choice of a lubricant for some of these areas, so oil or fuel are used to lubricate instead. High speed and temperature applications, for example, often require oil or fuel lubrication over the use of grease. In these applications, heat generated from friction must be transferred from the surface or it will result in wear. While the engine is running, the oil is pumped through the engine. Other than lubricating the engine, the oil will be absorbing the heat from the friction resulting in cooling down the high friction areas [10]. Another advantage of using oil over grease is that it can capture contaminants that get into the machine and move them to filters to be filtered out [9]. One reason to consider oil over grease, is that grease is very viscous, so it stays in the environment in which it was applied on. Also, if the environment is likely to have a buildup of heat or has a buildup of contaminants, the grease will not be able to move it away from the environment because grease stays in the location where it was applied. With this information, there are a few advantages of using oil and fuel over grease in some lubrication cases. Both properties of oil can change with the different oils available on the market. Studying the different types of oils available on the market can help increase the lifespan of the engine.

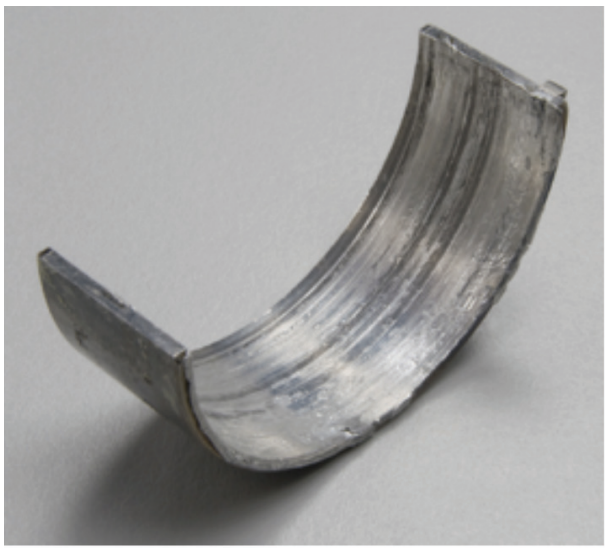

Figure 1. A spun-out connecting bearing from an automotive engine not being properly lubricated.

On the market there are various types of oils and fuels to choose from, each with differing properties and applicability ranges. These properties change with time as the engine runs through multiple cycles or when the oil is heated up to its operating temperature. In some cases, the lubrication properties can change for the better or worse. If not noticed ahead of time, the poor lubricating oils could have a negative effect on the engine. This will result in parts in the engine grinding and overheating, leading to the decreasing of the lifespan of the engine. When designing a new engine or trying to find a new lubricating oil, it is important to consider these factors before it gets used in the engine. Something to consider also, is the use of biofuels as a new lubricating fuel as the world moves away from using petroleum as a source for fuel. There are many ways to test relevant oil and fuel lubricant properties. One of the test methods that are commonly used to test the lubrication properties of jet fuel is the Ball-on-Cylinder Lubricity Evaluator (BOCLE), standardized as ASTM D5001.

The test consists of a fixed steel ball and a rotating metal cylinder that is submerged in a sample oil or fuel. The ball used in the test is composed of a chrome alloy steel that is AISI standard steel No. E-52100 and has a diameter of 12.7 mm. The metal cylinder is

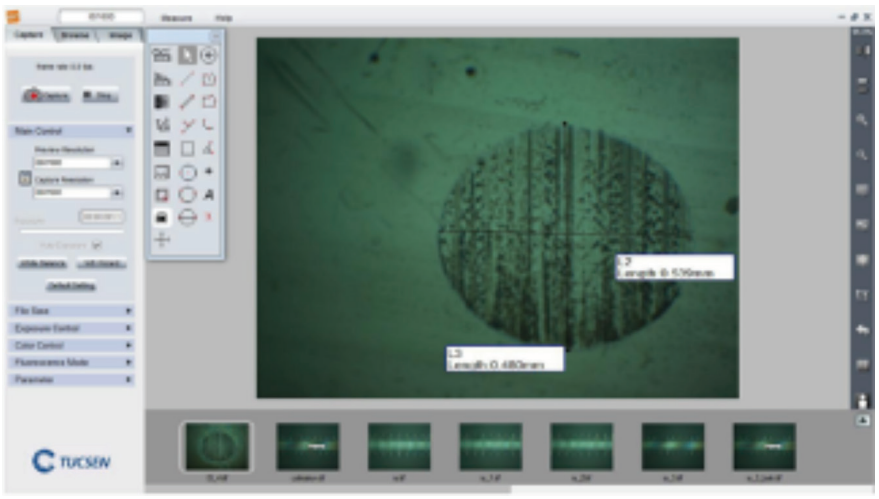

Figure 2: SEM imaging of wear scar after operation using K94190 BOCLE Lubricity Test rig.

comprised of SAE 8720 steel. In the test the steel ball is pressed on a metal cylinder with an applied load of 1000 g which remains constant throughout the test [3]. The metal cylinder is mounted to a motor which rotates the metal cylinder at a fixed velocity of 240 rotations per minute (RPM) for thirty minutes. The instrument essentially simulates the metal-metal contact to assess the effect of the sample oil or fuel lubricant. The presence of wear scars on the ball enables researchers and field experts to evaluate lubrication properties at the control speeds and contacting loads. Once the test has been completed, the apparatus is disassembled, and the ball is placed under a microscope with 100x zoom to exam the wear scar depth formed during operation. Figure 2 represents the scanning electron microscopy (SEM) imaging of the worn metallic surface after a test was conducted on a BOCLE testing instrument.

To quantify the results of the test, the wear scar diameter (WSD) was calculated as followed [3]:

$$WSD = \frac{M + N}{2}$$

The terms M and N are the length of the scarring on the ball on the major and minor axis of the ball. The M term is defined as the major axis of the scarring, while the N term is defined as the minor axis of the results viewed under the microscope. The precision of the test should be compared to that from multiple different laboratories. The repeatability and reproducibility of this test method to produce results that exceed expectations is one out of every twenty tests. The result of the test is to give an insight into the lubrication properties of fuel on areas of motile metal-on-metal surfaces [3].

In 2002 the Institute for Interlaboratory Studies Dordrecht conducted a proficiency evaluation of the BOCLE testing method with jet fuel. In the evaluation, 15 different laboratories participated in assessing the proficiency of the BOCLE method. Specifically, ten liters of jet fuel was purchased from a local refinery and subsequently homogenized. The fuel was then measured for its density and divided up into separate bottles which were sent to each of the testing sites. Each of the labs conducted the BOCLE method with a ring speed of 240 revolutions per minute for 30 minutes using approximately 50 mL of the fuel that was provided. The Z score term in the report was used to evaluate the results from all the participating labs. The way the Z score was calculated using this equation:

$$Z_{Target} = \frac{individual\ result - average\ of\ the\ proficiency\ test}{target\ standard\ deviation}$$

The target standard deviation for the test was 2.8, and it was discovered that Z_{Target} was less than 2 for each of the labs that conducted the BOCLE test. The organizers concluded that the test was within compliance to standards, as Z_{Target} less than one proved good results and a Z_{Target} of less than two proved satisfactory results. Of course, further evaluations with more laboratories participating are needed to better measure reproducibility [5].

The K94190 Lubricity Test Rig (BOCLE) by Koehler Instrument Co. is one of the few instruments on the market which performs this testing method [4]. The instrument provides everything required to perform the test as well as additional features. Some of those features include the ability to control the humidity of the testing chamber, PC control of the motor speed and the data logging of the motor speed, temperature of the air and oil and humidity of the test while running the experiment. Once the test has been completed, the K94190 comes with a digital microscope with 100x optical zoom that can connect to the built-in software with characteristic image acquisition software to measure the size of the wear scar left from the test [4].

In conclusion, the importance of

Figure 3: Image of the K94190 Lubricity Test Rig (BOCLE) by Koehler Instrument Co.

understandings the lubrication properties of oil or fuel can have an impact on the lifespan of the engine. Currently in the market, there are many kinds of fuels that can be used for lubrication. Testing methods like BOCLE will help researchers and field experts gain a good understanding for the properties of the oils that are being considered to be used in certain applications. The test can provide information that if the oil performs poorly in the controlled environment, it is very likely to perform just as poorly or even worse in industrial environments with the presence of numerous other uncontrollable variables. Knowing this information ahead of time could save money in terms of maintenance and repair costs by extending the life of the engine or the parts that are in motion for as long as possible.

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