International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 8 Issue 9 September - 2024, Pages: 1-7

Experimental Assessment of 15w-40 Lube Oil Properties and Failure Effects on Performance and Availability of Heavy-Duty Machineries

S. L. Bani[1*]., S. E. Jack[2]., H. U. Nwosu[3]

[1*,2,3]Department of Mechanical Engineering, Rivers State University, Port Harcourt, Nigeria
[*]Correspondence Author: saturday.bani@ust.edu.ng

***Abstract**: Lubricants plays crucial roles in critical sectors of the economy, which helps in promoting national development. The performance of this oil is based on the properties, which varies with changes in temperature and other variables. This study, assessed the properties of used and fresh 15w-40 lube oil through experimentation. The effect of oil failure on the functionality and availability of machineries was also checked using reliability indices. Different oil samples were collected for laboratory tests. Investigation show that total acid number for A-oil category reduced by 21% compared to fresh oil, but that of B-oil, C-oil, D-oil and E-oil increased by 30%, 47%, 9.8% and 55.6%, respectively. The total base number reduced for A-oil, B-oil, C-oil, D-oil, and E-il by 57.0%, 120%, 82.0%, 73.7% and 51.1%, respectively. It was also, revealed that viscosity of all oil samples tested reduced with length of operations of the construction machineries compared to the virgin oil. Investigation also indicate that mean time between failures of A-oil, B-oil, C-oil, D-oil, and E-oil was 128hours and availability of the trucks was 91.6%. The gradual failure of the oil has no significant impact on the failure and availability of the construction trucks.*

Keywords: Failure effect**,** Lubrication oil, Heavy-duty machineries, 15w-40, Experimental assessment

1.0 INTRODUCTION

The basic function of lube oil is to keep engine and mechanical parts clean and free from rust and corrosion. In some cases, this oil also acts as coolant and sealant; provides an oil film cushion that keeps metal-to-metal contact barest minimum, hence reduce friction and wear of components. It helps to seal the engine, especially pistons and cylinders, and protect it against any contaminants that can damage the engine and cause severe damage. Though, this is only basic function of oil; It is the particular demands of a given application and the special conditions under which an oil is used that largely determine the numerous additional functions an oil perform. Diesel engines, for instance, normally operate at lower speeds but higher temperatures compared to gasoline engines, which is exceptionally conducive to oil oxidation, deposit formation and corrosion of bearing metals. The quality of the lubricating oil is always influenced by the types of additives used during production as well as the nature of the feed known as base oil. However, base oil is obtained as the finished lubricant which is achieved from the processing of the heavy crude through the medium of temperature variation (Edward *et al*., 2018). Yan *et al.* (2022) examined change interval based on oil physicochemical properties derived from oil analysis data. Iron debris, viscosity, and total acid number were considered indicators of lubricating oil. The Wiener-based stochastic process was used to described first hitting time and increasing trends of the selected oil change indicator. The result showed that oil change interval increased by about 50 percent as against planned maintenance interval. Compared with the planned maintenance time, the proposed method was observed reasonable based on dynamic property of oil degradation.
Hanifuddin *et al.* (2020) examined the use of biodiesel (B20) as fuel in light-and heavy-diesel engine vehicles to ascertain the effects of lubricant performance. The machineries were heavy-duty and light-duty for 10,000km journey. Results indicated that biodiesel dilutions were less than 2 percent in both engines. Kinematic viscosities of four samples of used lubricants in light-duty diesel engine studied decreased by 0.58–7.5 percent, and 4.66-16.4 for heavy-duty diesel engines from the initial values. The decreased of TBNs was less than 14 percent in light-duty diesel engine and fewer than 16 percent in heavy-duty diesel engine. Meanwhile, the acidity of used engine oil increased by 73 % for light-duty diesel engine and 63 percent heavy-duty diesel engine compared to base values. In all, the lubricants exhibit good performances in both light-and heavy-duty diesel engines fueled by B20. Tarar (2014) studied reliability centered maintenance for rotating machines through predictive maintenance. It was shown that full implementation of reliability centered maintenance in industry can ensure improved performance. Kupareva *et al.* (2013) experimentally compared chemical composition of used and fresh lube oils using elemental analysis. Results showed only slight changes between chemical properties of fresh and used oil.

Heredia-Cancino *et al.* (2021) experimentally characterized chemical properties of engine oil. The standard ASTM E2412 and FT-IR were adopted for analysis. Investigation showed that plasmonic sensor can detect changes in permittivity of oil caused by modification of chemical properties of lubricant. Result showed good correlation between both methods. Bani & Obi (2024) carried out availability analysis of roofing sheet corrugating system in a case manufacturing firm. Statistical method was employed for data analysis. Result showed 36.79% mean reliability of roller. Reliability of all investigated components decreased with year of service, from results. Bani & Nwosu (2024) used reliability centered maintenance to assessed the reliability of aluminium sheet making equipment. It was found that reliability of machines decreased with period of operation.

Although, lubricant finds applications across measure sectors of economy worldwide, because of the crucial roles undertaken. No matter the quality of the oil, slight changes do occur after being used over a long duration and this has to do with the physical and chemical properties, which determine the workability of the oil. Therefore, in this study, density, viscosity, viscosity index, TBN (Mg KOH/g), and TAN (mg KOH/g) of virgin and used 15w-40 oil samples was examined. The effect of gradual failure of the used oil on the functionality and availability of heavy-duty machineries was also checked.

2.0 Materials and Methods

2.1 Data Collection and Source

The data for this study was obtained through experimentation. Samples of used and unused oils were collected for laboratory analysis.

2.2 Theoretical Equations

Reliability

The reliability of the construction machineries can be obtained according to Owunna & Bani (2024) by Equation (1).

$$\cup_e\ (t) = \text{Exp}\left(-\frac{T_S}{\varphi}\right) \quad (1)$$

where $\cup_e\ (t)$ is the reliability of the construction equipment, Ts stands for the period reviewed and φ represents is mean time between failures of construction machinery.

Mean Time Between Failures

The relation of mean time between failures and number of failures can be obtained using Equation (2).

$$\varphi = \frac{\aleph}{\aleph_f} \quad (2)$$

where φ is mean time between failures, $\aleph$ is the operating durations and $\aleph_f$ represent number of failures within an estimated period.

Estimate of Failure Rate

Failure rate is the reciprocal of the mean time between failures stated according to Equation (3).

$$\omega = \frac{1}{\varphi} \quad (3)$$

where ω represents the failure rate.

Corrective Time Per Failure and Lost Time per Year

The lost time per year as a result of failure truck caused by expired lubricating oil in the engine mostly occurred by filter blockage. The corrective time per failure lost time per year due to failure are given in Equations (4 and 5).

$$C^{tf} = \frac{F_{y-1} \times C_E}{T_C} \quad (4)$$

$$T_{y-1} = F_{y-1} \times C_E \quad (5)$$

where C^{tf} is the corrective time per failure, C_E employed for corrective time of each component, T_C taken for the total failures per year, F_{y-1} represents the failure of each component per year.

and T_{y-1} is the lost time per year.

Unreliability of the System

The unreliability of the system can be obtained using Equation (6).

$$U_u(t) = 1 - \text{Exp}\left(-\frac{T_S}{\varphi}\right) \quad (6)$$

where $U_u(t)$ represents unreliability.

Determination of Availability

The application of availability concept can be expressed in Equation (7).

$$\forall = \frac{\varphi - T_{y-1}}{\varphi} \quad (7)$$

where ∀ is the availability of the construction equipment during the period.

3.0 RESULTS AND DISCUSSION

Samples of fresh and used lube oil obtained from various machineries were collected and analyzed in a standard laboratory. The result is presented in the following subsections.

3.1 Analysis of Total Base Number of 15w-40 Oil

Samples of fresh and used lube oil was analyzed for total base number and the result depicted in Figure 1.

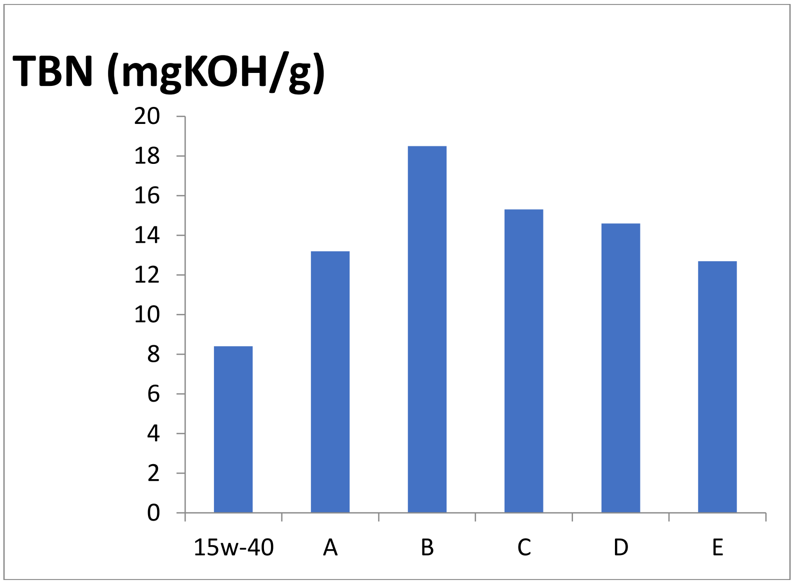

Figure 1: Variations of Total Base Number in 15w-40 Oil

From Figure1, it was found that total base number of the unused oil remain unchanged, while the value for other unused oil samples increased, with truck B-oil having the highest value of 18.5 mgKOH/g. A higher total base number implies that the oil has more reserved alkalinity available which can be used to reduce the corrosive effects of acids built up in the oil samples. Besides, low total base number can result in the formation of harmful deposits and sludge within the engine to cause wear of vital engine components and is not desirable.

3.2 Analysis of Total Acid Number of 15w-40 Oil

The result of oil samples analyzed for total acid number using standard approach reported in Figure 2.

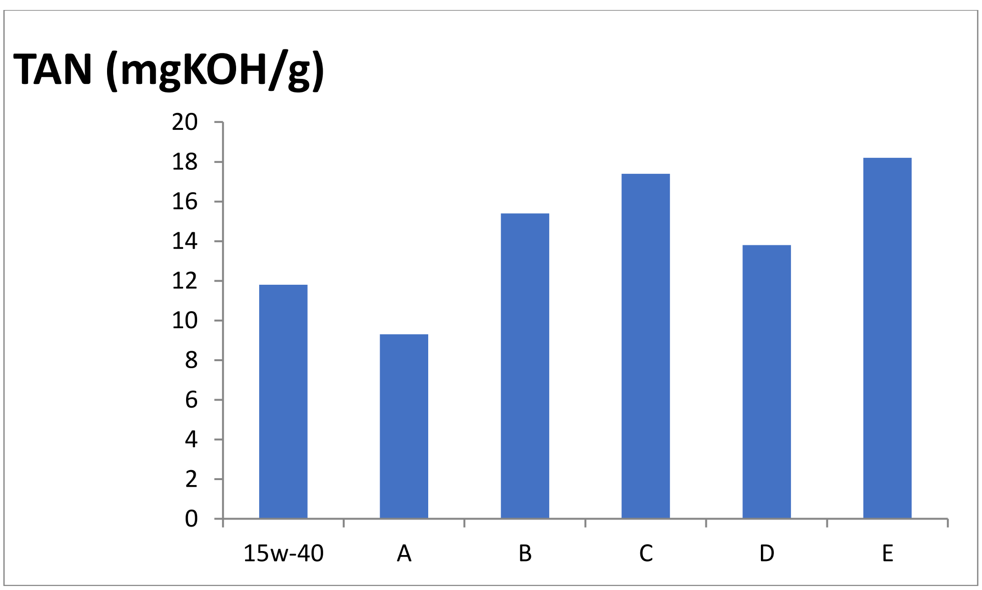

Figure 2: Variations of Total Acid Number in 15w-40 Virgin and used Oil

Result illustrate in Figure 2 indicates that total acid number of virgin oil is lower compared to used oil samples, except A-oil. The increase total acid number of used oils may be due to oxidation that occurred during operation of the construction machineries. An increase in total acid number may be due to oxidation as oil reacted, additive depletion or other properties of oil in relation to increase temperature.

3.3 Flash point Analysis

Flash point of oil is the minimum temperature at which the vapour of the oil start to catch fire. In this study, flash point was determined and the output is presented in Figure 3.

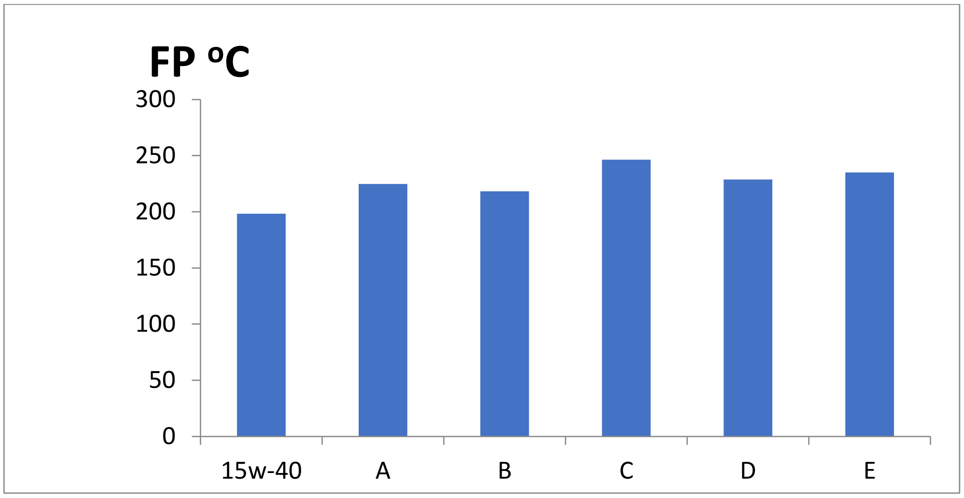

Figure 3: Variations of Flash Point of Oil Samples Versus Temperature

From variations of flash point against temperature shown in Figure 3, flash point of unused 15w-40 oil is lower compared to oil from A-oil, B-oil, C-oil, D-oil, D-oil. Investigation defined that average flash point of fresh oil is 198.4^0C and that of used oil is 224.8^0C.

3.4 Estimation of Viscosity Index of Fresh and Used Oils

Viscosity index describe the tendency with which viscosity of oil changes with temperature. From analysis, the viscosity of oil samples is presented in Figure 4.

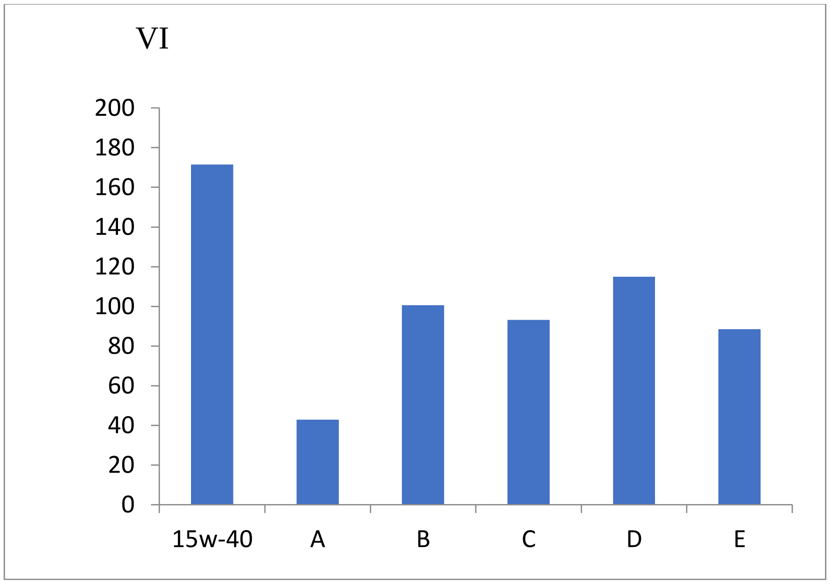

Figure 4: Variations of Viscosity Index with Temperature

From Figure 4, fresh oil tested has higher viscosity index compared to used oil from all the trucks. Truck D has higher index than used oil from the rest of the trucks. Higher viscosity index is more desirable to provide more stable lubricating film over a wider temperature range. On the average, result indicates that viscosity changes with temperature is low. hence the used oil samples have very low residual life.

3.5 Kinematic Viscosity of Used oil Samples

The samples of fresh lube oil and used oils collected were analyzed to determine viscosity at 100^{0}C and 40^{0}C and the results are presented in Figures (5 and 6).

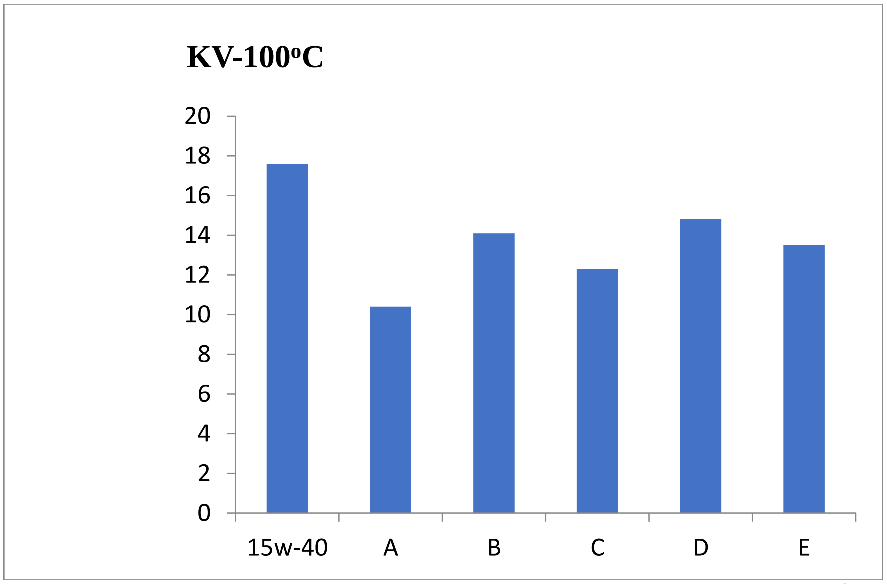

Figure 5: Variations of Kinematic Viscosity Against Temperature at 100^{0}C

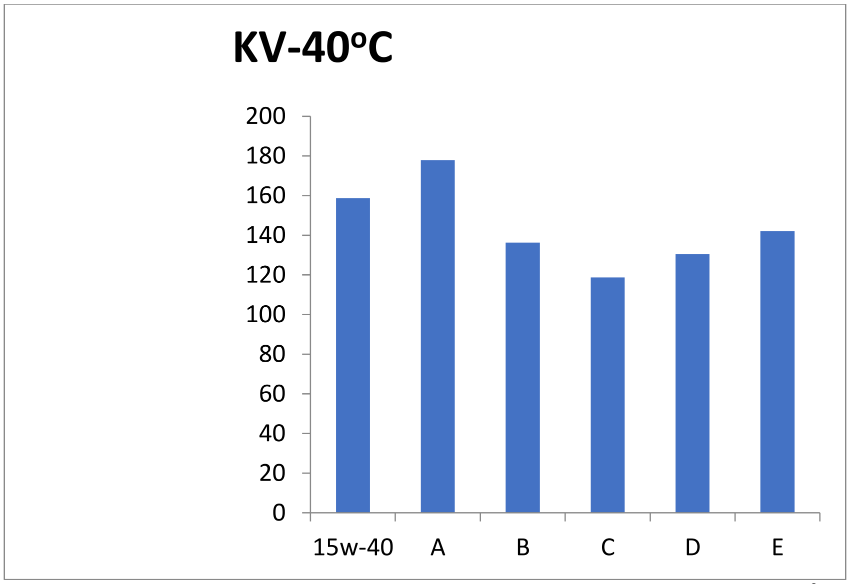

Figure 6: Variations of Kinematic Viscosity against Temperature at 40^{0}C.

Investigation presented in Figures (5 and 6) show that viscosity of the used oils decreased with time and distances covered. This implies that the oil becomes more lighter with very low resistance to deform or flow. At temperature of 100^{0}C, significant different exist between viscosity of virgin oil and used oil. The case is not the same for viscosity at 40^{0}C, where the viscosity fell only slightly with increased temperature.

3.6 Analysis of Reliability of Trucks

The failure of construction trucks was investigated using company maintenance records. The trucks were considered to have failed when they were withdrawn from operation for possible repair or replacement of part (s). Reliability of system was analyzed and reported in Figure 7.

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 8 Issue 9 September - 2024, Pages: 1-7

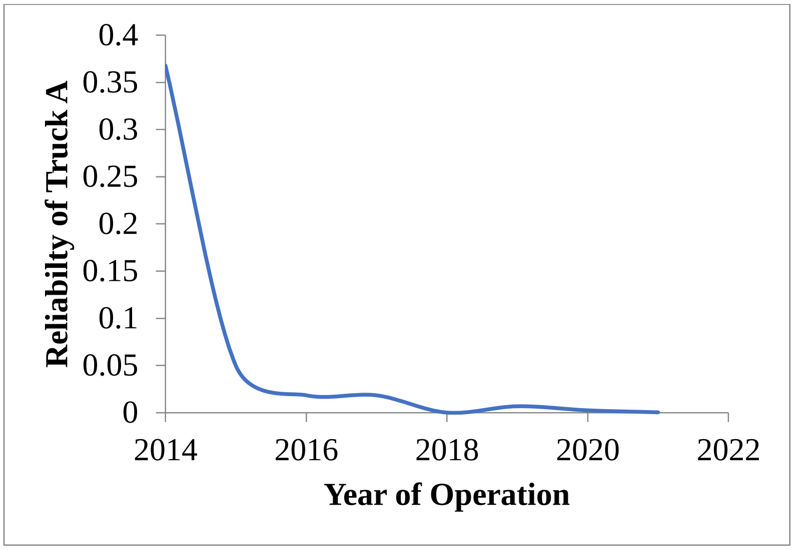

Figure 7: Reliability of Truck A against Operation Period

From Figure 7, it was found that reliability decreased rapidly from 0.3678 in 2014 to 0.0489 in 2015. Then, from 2015 reliability of truck gradually depreciated to zero, and continue at this level till 2021.

3.7 Evaluating Mean Time Between Failures of Truck A

The mean time between failures was evaluated and presented in Figure 8.

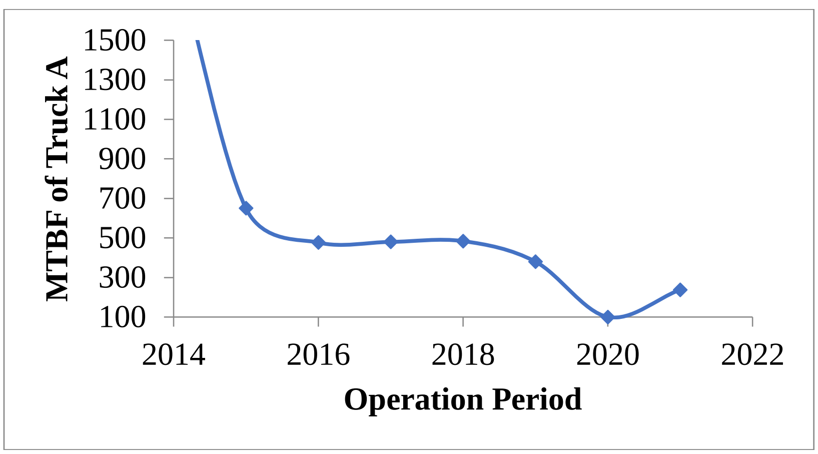

Figure 8: Mean Time Between Failures of Truck A

From Figure 8, mean time between failures of Truck A decreases from 1484 hours in 2014 to 700 hours in 2015. It then remained approximately constant from 2016 to 2018. Further observation indicates that mean time between failures decelerated to approximately zero in 2020, but later rise steadily to a terminal point of 285 hours in 2021. This implies that there should be regular servicing of truck A at interval of 120 hours to avoid breakdown and corresponding impact on construction activities in the company.

Conclusion

The properties of used and fresh 15w-40 lube oil and effect of oil failure on the functionality and availability of machineries was investigated and arrived thus:

i. Flash point of the unused 15w-40 oil is lower than the used oil samples from truck A, truck B, truck C, truck D and truck E.
ii. Viscosity index at 40^0C is higher compared to the condition at 100^0C.
iii. There is significant different between kinematic viscosity of virgin oil and used oil at 100^0C, but kinematic viscosity reduced slightly at 40^0C.
iv. Reliability of trucks depreciated with increased period of service

iv. The mean time between failures (1484 hours) of trucks occurred in 2014, while the least, 120 hours occurred in 2020. Trucks should be maintained less than 120 hours interval, regularly for sustainability.

REFERENCES

Bani, S. L. & Nwosu, H. U. (2024). Assessing the Sustainability of an Aluminium Roofing Sheet Corrugating Machine by Reliability Centered Maintenance and Cost Reduction Technique. *International Journal of Scientific Research and Engineering Development*, 7 (1), 933-942.

Bani, S. L. & Obi, M. (2024). Availability Analysis of Roofing Sheet Corrugating Equipment using Statistical Technique. *Journal of Modern Thermodynamics in Mechanical System*, 6 (1), 16-23.

Edward, N.B., Ukpaka, C.P. & Nkoi, B. (2018). Reliability analysis of an automobile brake system to enhance performance. *International Journal of Production Engineering*, 4(2), 17-27.

Hanifuddin, H., Fibria, M., Respatiningsih, C. Y., Widodo, S., & Maymuchar, M. (2020). The Evaluation of Lubricants Performances in Light- and Heavy-Duty Diesel Engines in The Application of Biodiesel (B20). *Scientific Contributions*, Oil & Gas

Heredia-Cancino, A. J., Carrillo-Torres, R. C., Félix-Domínguez, F., & Álvarez-Ramos, M. E. (2021). Experimental Characterization of Chemical Properties of Engine Oil Using Localized Surface Plasmon Resonance Sensing" *Applied Sciences*, 11(18),

Kupareva, A., Mäki-Arvela, P., Grénman, H., Eränen, K., Sjöholm, R., Reunanen, M. & Murzin, D. Y. (2013). Chemical Characterization of Lube Oils. *Energy Fuels*, 27 (1), 27–34.

Owunna, C. & Bani, S. L. (2024). Evaluation of Lube Oil Characteristics from Heavy-Duty Truck Failures: A Case Study. Journal of Fluid Mechanics and Mechanical Design, 6 (2), 27-33.

Tarar, M. A. (2014). Reliability Centered Maintenance of Rotating Equipment through Predictive Maintenance. Proceedings of the 2nd International Conference on Research in Science, Engineering and Technology, 21 – 22, March, 2 – 7, 2014.

Yan, S., Kong, Z., Liu, H., Li, B., Fan, M., & Zhang, X. (2022). Oil Change Interval Evaluation of Gearbox Used in Heavy-Duty Truck E-Axle with Oil Analysis Data. *Lubricants*, 10 (10), 252.