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Operational reliability analysis of lube oil and load utilization effect on the efficiency

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A B S T R A C T

Evaluation of the comparison of reliability and unreliability of lube oil in the generator on the effect of load utilization was studied using reliability analysis. The continuous running of the generator set and the load utilization reduces the quality of the lube oil which influences the operational performance. The results obtained on evaluating the performance of lube oil in the generator using reliability analysis reveals that constant failure was observed as the characteristics of the lube oil decreases and the available load utilization reduces as well. Finally, this research work is found useful in monitoring, predicting and simulating the effect of load utilization and output running hours on the reliability and unreliability of the generator set. However, the reliability value decreases as the lubricating losses the integrity in terms of quality to perform the primary assignment. The cost of unreliability increases as continuous shut down will be experience as load input increases.

Capsule Summary: Reliability of lube oil in the generator and load utilization effect was studied and it was observed that characteristics of the oil has significant effect on the performance.

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INTRODUCTION

In Nigeria today, electricity is one of the most common challenges faced by businessmen in the smooth running of their industries. So, many businessmen result to the use of generator set to generate power and to run their businesses. Some of these businesses run these generator sets without recourse to maintenance. This continuous usage without maintenance affects the characteristics of the lubricating oil which can lead to components failure and business breakdown (White et al. 2009., Gano, 2003). Further study revealed that component failure of a plant influences any business operation negatively (Dekker, 2006., Owen, 2006). For instance, loss of value in the characteristics of the lubricating oil can influence the engine performance, which in turn can cause generator set to shut down unexpectedly or malfunction (Saurin et al. 2010., Meel et al., 2007., Law and Kelton, 2000).

To ensure high reliability, efficiency and quality output production by the generator set, improvement is required in the continuous servicing of the generator sets as recommended by the manufacturer. In this research, reliability analysis of the lubricating oil was examined as a function of time dependent and was monitored with respect to load utilization (Shaeda and Bury, 2008).

The quality of component materials used in repairing and servicing the generator set also influence the output performance and have effect on the lubricating oil as well as other components (Shaeda and Bury, 2011). The use of substandard materials in repairing and servicing generator set increases the unreliability and reduced the reliability value of the generator set. However, this dissertation covers the reliability analysis of lubricating oil characteristics on the influence of running time cover and deliverability of load output to the end users (Hauptmanns, 2004).

The aim of this research work is to examine the characteristics of lubricating oil concentration of a generator set over a running time with load utilization using reliability analysis concepts. The objectives of this study are to: Examine the concentration of the lubricating oil before utilization, examine the concentration of the lubricating oil after load utilization per unit time covered, identify the number of failures as constant load utilization was applied with increase in running hours, identify the available load utilization as the lubricating oil lost its value with increase in running hours and determine the reliability and unreliability values.

MATERIAL AND METHODS

The model of unreliability, reliability and availability

The model development of unreliability, reliability, and availability for the various operational conditions of 11KVA, 20KVA and 40KVA was examined upon the influence of time and their impact on the characteristics of the lube oil performance output in load utilization.

Model development of unreliability

The model development for unreliability in terms of load utilization and their impact on the generator set was studied. The mathematical expression for the evaluation of unreliability of the process plant can be expressed as;

$$U_N = 1 - {}^{e-}\left(\frac{1}{OSLI/ALF}\right)t \quad (1)$$

$$U_N = 1 - {}^{e-}\left(\frac{1}{y/x}\right)t \quad (2)$$

$$U_N = 1 - {}^{e-}\left(\frac{1}{MTBT}\right)t \quad (3)$$

$$U_N = 1 - {}^{e-}\left(\frac{1}{\lambda}\right)t \quad (4)$$

Model development of reliability

The reliability model of the operational system can be expressed mathematically as;

$$R_m = e^{-}\left(\frac{1}{OSLI/ALF}\right)t \quad (4)$$

$$R_m = e^{-}\left(\frac{1}{y/x}\right)t \quad (5)$$

$$R_m = e^{-}\left(\frac{1}{MTBF}\right)t \quad (6)$$

$$R_m = e^{-}\left(\frac{1}{\lambda}\right)t \quad (7)$$

The reliability of the process can be grouped in terms of the lube oil characteristic upon the influence of number of Times (Hours) and their load utilization. The reliability of process from 0 h to 400 h can be summed to represent them through the scenario of the process for each generator product capacity, thus:

$$^{20KVA}R_m = e^{-}\left(\frac{1}{\lambda}\right)_{50rpm} + e^{-}\left(\frac{1}{\lambda}\right)_{100rpm} + e^{-}\left(\frac{1}{\lambda}\right)_{150rpm} + e^{-}\left(\frac{1}{\lambda}\right)_{200rpm} + e^{-}\left(\frac{1}{\lambda}\right)_{250rpm} + e^{-}\left(\frac{1}{\lambda}\right)_{300rpm} + e^{-}\left(\frac{1}{\lambda}\right)_{350rpm} + e^{-}\left(\frac{1}{\lambda}\right)_{400rpm} \quad (8)$$

Model development of availability

The model for availability can be developed by considering the mean time between failures with the lost time per year. Therefore, the mathematical expression for availability can be expressed as;

$$Av = \frac{Mean\,time\,between\,failure - lost\,time\,per\,year}{Mean\,time\,between\,failure} \quad (9)$$

Also, the model development of availability can be written as;

$$Av = \frac{MTBF - LTPY}{MTBF} \quad (10)$$

$$Av = \frac{(OSLI/ALF) - LTPY}{OSLI/ALF} \quad (11)$$

$$Av = \frac{(y/x) - LTPY}{y/x} \quad (12)$$

$$Av = \frac{\lambda - LTPY}{\lambda} \quad (13)$$

Event description

Table 1: Description of data collection of 20 KVA generator sets in terms of hours contributing to failure on load Utilization

Time (Hours)	50 h	100 h	150 h	200 h	250 h	300 h	350 h	400 h
Failure	8	12	15	10	18	22	30	35

While examining the performance of the generator set, there was an unexpected interruption or failures as loads were being increased and after obtaining the bases set point, i.e., the optimum loads set point for the investigation. The unexpected interruptions experienced were because of overloading with the significance of lube oil degradation in characteristics value and physicochemical properties or parameters of their values, causing the generator set to stop unexpectedly. In some cases, such immediate shutdowns influence the generator performance, resulting in faults and failure of components.

These failures required the user to repower the generator after reducing the load utilization to enable the generator output load to be utilized by the household. The total number of the appliance was identified and isolated as failures at different incremental number of hours. The events described above are the approach adopted for this investigation and failure of the generator set was attributed to the degradation of the lube oil.

Root causes analysis

The generator set under investigation was produced by Mikano International Nigeria Limited and the aging period is with one to two years utilization with several numbers of times less than 1052 h. In the root cause analysis techniques, various approaches were applied to investigate failure of any given component/plant and project. The research work conducted by Gano (2003) revealed the solution of a root cause analysis using the concept of Apollo Associated Services (AAS) which was described in terms of techniques involved.

RESULTS AND DISCUSSION

The data used in the evaluation the cost of reliability and unreliability is presented in Table 1 as shown in the appendix as well as the computation evaluation.

Reliability and Unreliability Analysis against time

Analysis on the individual characteristics of the reliability and unreliability of a 20 KVA generator sets operation of the various hours on the influence of the load utilization on reliability and unreliability were analyzed as shown in Figure 1–8, respectively. Monitoring the characteristics of reliability and unreliability of 20 KVA generator set on the effect of increment in time reveals a decrease in reliability and increase in unreliability at a set point load utilization as presented in Figure 1. The variation in the reliability and unreliability in time could be attributed to the variable in time as well as the available load distribution and utilization. Results obtained revealed an increase in unreliability and a decrease in reliability values as reported in Figure 1. The equation established by the curve is given as $y = 0.0062x + 64.865$ with R^2 which the square root of the best fit given as $R^2 = 06505$ indicating the intercept as 64.865 with the slope of 0.0062. The variation in the unreliability value for 50 h attained by the generator set after introducing the lubricating oil into the system revealed variation upon the influence of time of operation as shown in Figure 1. Similarly, the equation of curve for reliability was established as $y = 0.0062x + 35.313$ with $R^2 = 0.6566$ which defines the square root of the best fit. The slope of the curve was obtained as -0.00062 with the intercept value of 34313. In this case, the variation in the characteristics of the reliability can be attributed to the effect of the physiochemical properties of the lubricating oil which is influenced by the variation of time of operation.

Figure 2 showcase the individual behavior of the unreliability and reliability of 20KVA Gen sets operation at 100 h on the influence on the physiochemical properties of the lubricating oil which influence the available load utilization by the household. The result demonstrates the significance of the loss of value on the quality of the lubricating oil in terms of reliability and unreliability characteristics and performance of the generator set when in use. The result in Figure 2 indicates an increase in unreliability with a decrease in reliability. The unreliability equation of the curve is $y = 0.0039x + 78.518$ and $R^2 = 0.5186$ as well as the slope of the curve given as 0.0039 and intercept given as 78.568, whereas for reliability we have the equation of curve as $y = -0.0039x + 21.434$ and $R^2 = 0.5186$ with the slope of the curve as -0.0039 and intercept as 21.343. The unreliability variation in value can be attributed to the characteristics of the physiochemical properties of the lubricating oil used on the influence of utilization of the 20 KVA Gen sets and the available load upon the variation of time. Similarly, in terms of reliability variation in value one can hence attribute the degree of reliability concept in the 20 KVA Gen set to the characteristics of the physiochemical properties as well as the influence of heat and temperature on the degradation of the lubricating oil in the engine system which influence the load utilization by the household on the variation of time for 100 h. Figure 3 demonstrates the characteristics of reliability and unreliability of 20 KVA Gen sets load utilization on the influence of the lubricating oil physicochemical properties. The result illustrates the variation in unreliability and reliability upon the influence on the composition of the lubricating oil in the engine system of the Gen sets, which was attributed to the characteristics of the lubricating oil load utilization and available load 'on' for the utilization by the household as well as the influence of time for 150 h attained. The unreliability curve equation is y = 0.0025x + 84.655 with the square root R^2 = 0.4513 which defines the slop and the intercept value of 0.0028 (slope) and 84.655 (intercept) whereas for the reliability the equation of the curve is y = -0.0025x + 14.445 with the square root of R^2 = 0.3582 and the slope as well as the intercept given as -00025 (slope) and 14.445 (intercept) as shown in Figure 3.

Figure 4 demonstrates the importance of unreliability at 200 h on the influence of load utilization

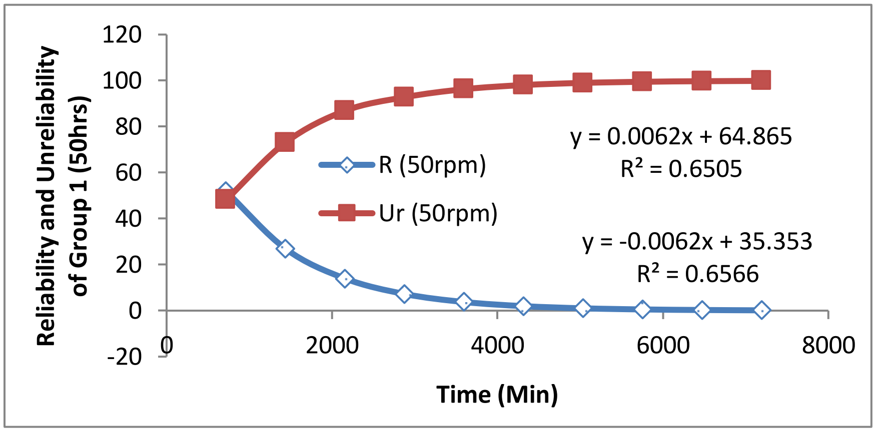

Fig. 1: Graph of reliability and unreliability against time for 50 h

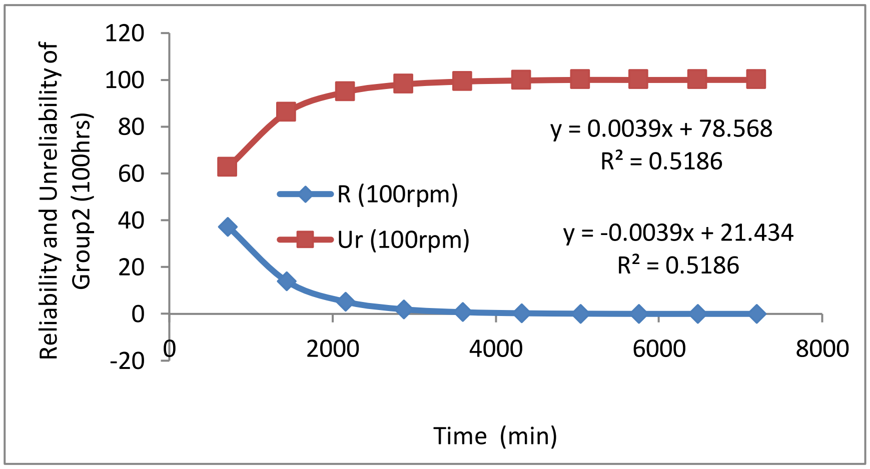

Fig. 2: Graph of reliability and unreliability against time for 100 h

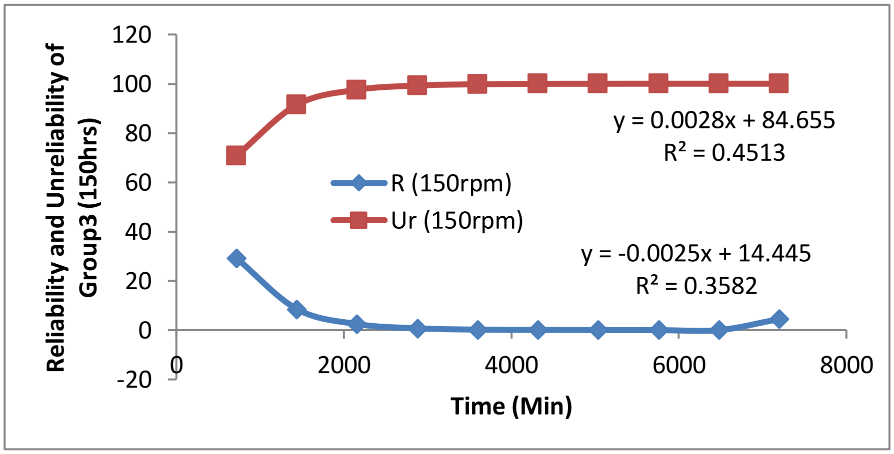

Fig. 3: Graph of reliability and unreliability against time for 150 h

which is dependent on time. The relationship of reliability, unreliability, and time on 20 KVA Gen set showcase the significance of load utilization on the characteristics of the lubricating oil performance in a household. This research work as presented in Figure 4 showcase the variation of the unreliability of the Gen sets load utilization by a household with the variation of the operating time, which from the result obtained revealed a significant effect on the lubricating oil characteristics. The equation of the curve for unreliability is given as y = 0.0049x + 72.572 and the square root of best fit for unreliability given as R^2 = 0.5793 indicate the slope as 0.0049 and intercept as 72.672.

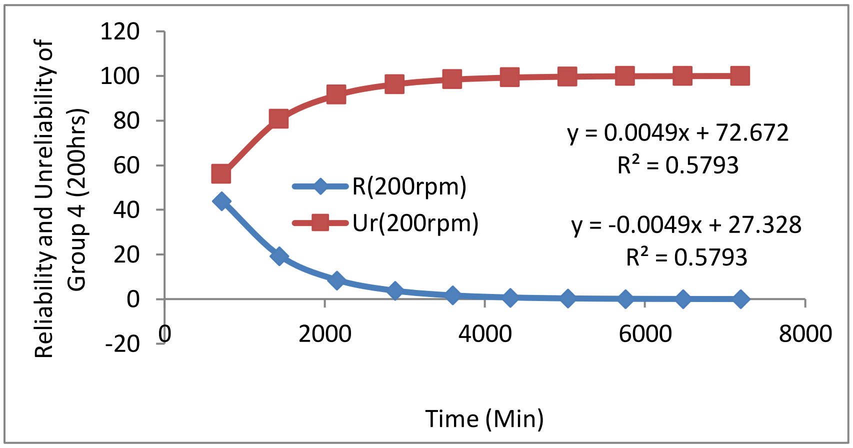

Fig. 4: Graph of reliability and unreliability against time for 200 h

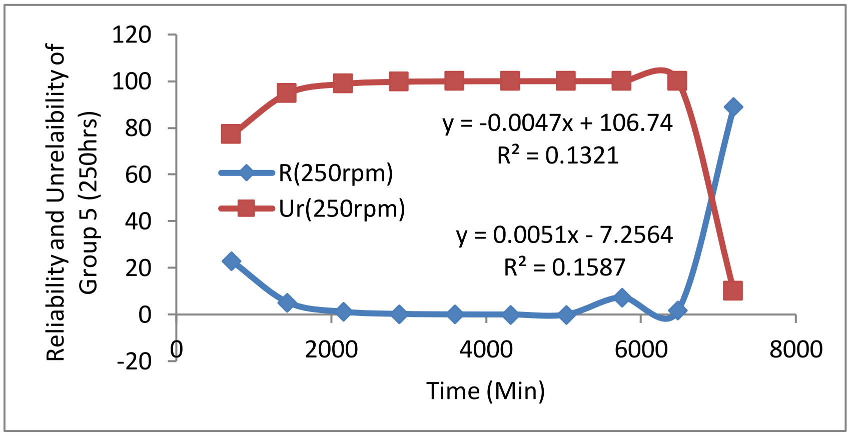

Fig. 5: Graph of reliability and unreliability against time for 250 h

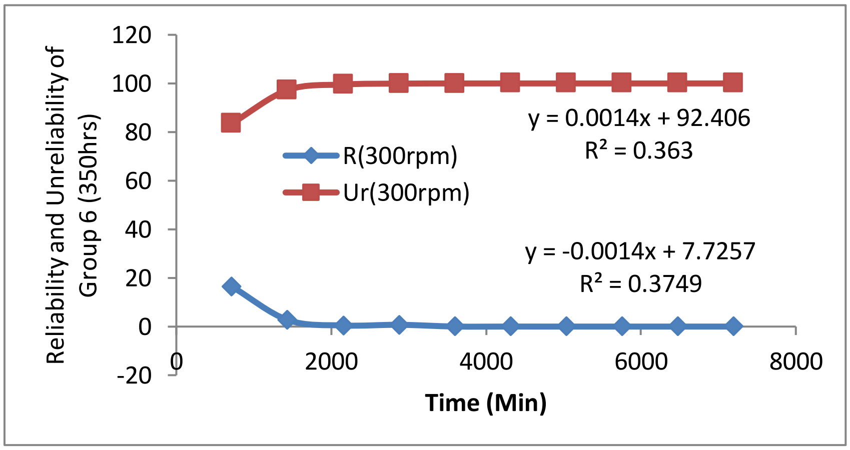

Fig. 6: Graph of reliability and unreliability against time for 300 h

Similarly, considering the reliability curve of the equation, we have y = -0.0049x + 27.328 with the square root of the curve of reliability as R^2 = 0.5793 indicates slope as -00049 and intercept as 27.328 as shown in Figure 4. The reliability variation in value can be attributed to variation in load utilization operating time and lube oil characteristics.

Figure 5 demonstrates the variation in reliability in reliability and unreliability for 250 h run off of the generator set. A decrease in reliability was observed as well as an increase in unreliability as the run off time increased until a sudden decrease in unreliability and increase in reliability was experienced at 7000 minutes as seen in Figure 5. The variation in the reliability and unreliability could be attributed to variable in run off time as well as the available load utilization and the efficiency of the lube oil in the operational engine. The result obtained showcase the equation of the curve as y = -0.0047x + 106.74 with the square root of the fit as R^2 = 0.1321 as well as the slope of the curve and intercept value of the graph as -0.0047 and 106.74 for unreliability value at 250 h and intercept of reliability we have y = 0.0051x – 7.2564 with square root of the curve fit given as 0.1487 in which the slope and intercept of the graph were established as 0.0051 and 7.2564 respectively for 205 h. The variation on the unreliability and reliability value of the Gen sets at 250 h can be attributed to the variation in the physicochemical properties of the lubricating oil available load utilization, operating time, loss in Gen sets out pressure value.

The graph of unreliability and reliability versus time for 300 h was demonstrated in Figure 6 and the results obtained showcase an increase in unreliability with a decrease in reliability value. The variation in reliability and unreliability value of Gen sets at 300 h upon the influence of load utilization is shown in Figure 6. The variation in the value of unreliability and reliability on the Gen sets performance in terms of load utilization can be

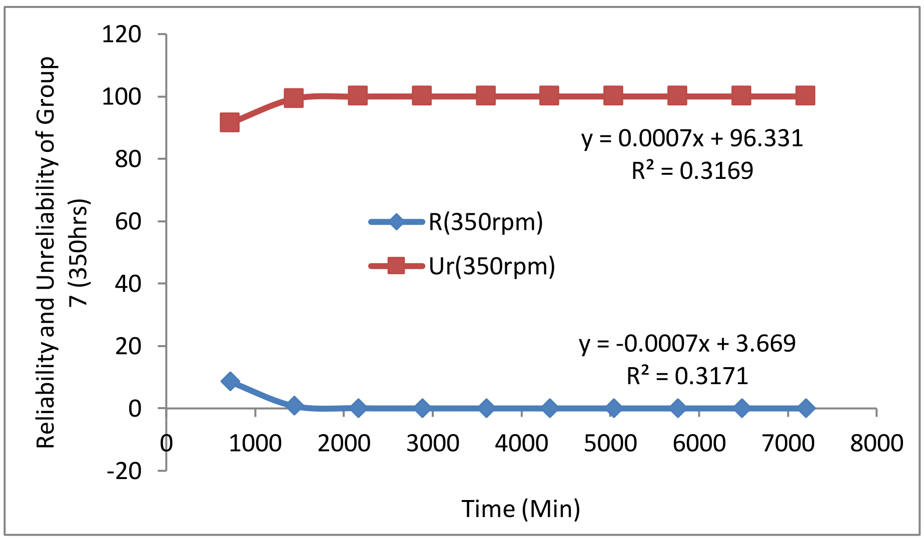

Fig. 7: Graph of reliability and unreliability against time for 350 h

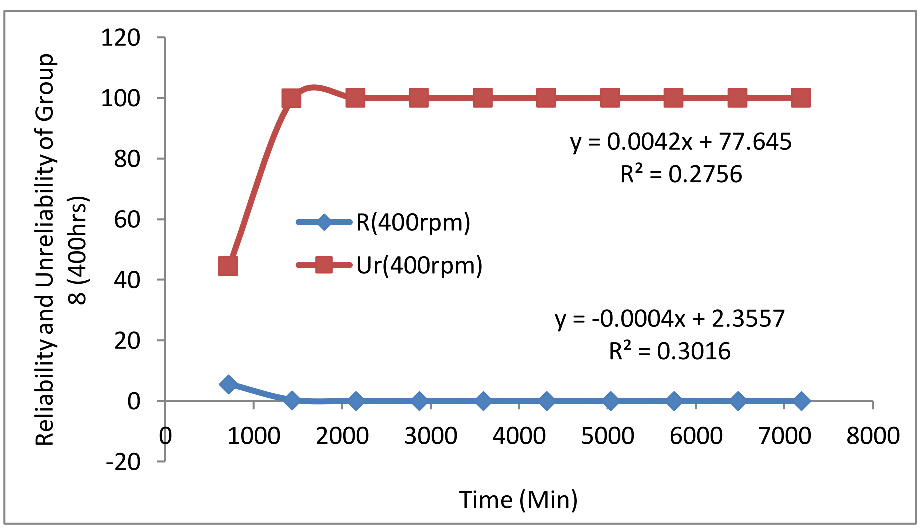

Fig. 8: Graph of reliability and unreliability against time for 400 h

attributed to the variation on the lubricating oil characteristics that is, high level of lubricating oil degradation in concentration or loss of value in terms of the concentration, which yielded low performance in pressure output discharge in the system as well as the variation can be attributed to the operational time. The equation of the curve of unreliability for 300 h is given as y = 0.0014x + 82.401 with the square root of the best fit R^2 = 0.363 and the slope as well as the intercept value is given as 0.0014 and 92.406 respectively. In the reliability the equation of the curve is given as y = 10.0014x + 7.7257 with the square root of the curve as R^2 = 0.3749 and intercept and slope of reliability value for 300 h is given as 7.7257 and 0.0014, respectively.

Figure 7 demonstrates the effect of 350 h of the Gen sets on the reliability and unreliability value on load utilization and on the characteristics of the lubricating oil physiochemical value. The equation of y = 0.0007x + 96.331 with the square root value of R^2 = 0.3169 define the unreliability curve with the slope and intercept value for 350 h as 0.0007 and 96.331, whereas the equation for reliability is y = -0.007 + 3.669 with the square root for 350 h of the reliability value as R^2 0.3171 with intercept and slope value for 350 h as 3.669 and –0.0007 respectively, the variation in the unreliability and reliability value for 350 h can be attributed to the variation on the effect of load utilization, physiochemical properties of the lubricating oil, operational time and other environmental factors. Result obtained in this research indicate the significance of the warm out value on the lubricating oil leading to low performance or efficiency in output pressure discharge by the Gent sets.

Figure 8 illustrates the reliability at 400 h and unreliability at 400 h of the generator sets on the influence of load utilization. High load utilization influences the performance of the Gen set at this stage because of high loss in value in terms of the characteristics of the physiochemical properties of the lubricating oil in the Gen sets system. The variation in the unreliability and reliability value of 400 h can be attributed to the variation in load utilization, the warm out value of the lubricating oil and operating time through the lubricating oil has loss it value. The equation of the unreliability is given as y = 0.0042x + 77.645 with R^2 = 0.2756 as well as the slope and intercept determined as 0.0042 and 77.645 whereas for reliability at 400 h the equation of the curve was given as y = -0.0004x + 2.3557 with the square root of best fit for 400 h as R^2 = 0.3016. However, the slope and the intercept were determined as shown in Figure 8 as -0.004 and 2.3557 respectively.

CONCLUSIONS

The following conclusions were drawn from this comparison of reliability and unreliability of lube oil differentiation on effect of load utilization:

i. The aging characteristics of the lube oil in the generator sets influence the performance as well as reduce the service time.
ii. It is observed that constant failure of the generator set occurs when the time exceeds 200 h.
iii. It is also observed that above 200 h the available load utilization on the household appliance reduces tremendously due to loss in lubricating oil value.
iv. The cost of unreliability is very high when the time exceed 200 h.

In conclusion this research work addresses the significance of changing lubricating oil in the generator sets once the time attains 200 h. If this culture is maintained, it shown that high culture in safety and safe practice of the generator sets are maintained as well as its service time.

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