Performance Analysis of Tellus68 Lubricating Oil on Hydro Power Turbo Generator

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Abstract: *Shiroro Power Station, Niger State, Nigeria had not been able to effectively generate its own quota of electricity to the Nigerian National grid because of frequent shut down of the turbo generators as a result overheating within the Upper guide bearing (UGB) with the use of Tellus 68 oil for lubrication of the generating units. This work involved laboratory evaluation of the performance characteristics of Tellus 68 to determine the effects on the temperature variation within the lower and upper guide bearing of the hydro unit. The procedures involved in the experiment were: determination of viscosity; flash point, pour point, neutralization number; water and ash contents. The equipment used for the tests consist of Chan U-Tube Viscometer; Pesky- Martens Closed Flash Tester; Brian Weigh Cylindrical Test Jar; Armfield Potentiometric Titrimeter; Pyrox Water Content Apparatus; Bausch and Loub Evaporating Crucible Electric and Muffle Furnace. Reagents used includes Alcohol, Potassium Hydroxide (KOH); Phenolphthalein Solution; Methyl Orange Solution; Alkali Blue Solution ; Ethyl Alcohol; Toluene; N-Xylene; Silicone Oil; Premium Motor Spirit; Chlorobenzene; Solid Carbon Dioxide; Ethanol; Pyrogallol and Zinc Oxide. The results experiments conducted through a series of ASTM/IP tests when compared with manufacturer's specification shows that Tellus 68 Oil is suitable for effective lubrication of hydro power turbo generators.*

Keywords— *UGB, Tellus 68 Oil, Pour point, Turbo Generator, Neutralization Number, Flash point*

I. INTRODUCTION

Frequent power outages in Nigeria have crippled manufacturing and production processes and been compelling industries to fold up. If this trend is not arrested there could be no meaningful industrial revolution required for national development. The Shiroro Power Station was built with an installed capacity of 600 MW generated from four hydro units. Unit 2 was shut down due to persistent problem of abnormal temperature rise within the UGB unit. The shutdown amounts to reduction in the power generated and hence the station now has an installed available capacity of 450 MW [1].

Turbo generators are vertical machines built with a thrust bearing load greater than 1500 tons (1,360,500kg) which is a bearing of the order of 10ft (3m) in diameter. The load includes the weight of the rotating parts and maximum hydraulic thrust on the turbine runner. The design, manufacture, and operation of such large bearing pose problems with regards to starting the machine [4]; [3]. The oil selected for bearing lubrication should be viscous enough to carry the load imposed within a reasonable margin of safety. Excess viscosity results in needless power losses. The optimum viscosity is difficult to determine because of the many variables involved [5]; [7]. Oil is usually the preferred lubricant at high speed, at load temperatures and under all other conditions where the housing permits. Viscosity recommendations for plain bearing compound lubrication problems thus extra film strength is required in service [8]; [16].

Comprehensive studies have been carried out for effective lubrication of anti- friction bearings. At speeds of 3,600 rpm only enough oil to maintain a film on moving parts is necessary. Below 3,600 rpm lubrication is often obtained by a spray of oil directed on the bearing by a stream of compressed air. Oil is pumped continuously through anti- friction bearing draining into the sump in the hydro-electric turbo generator. The oil is cooled with circulating water in a heat exchanger; [10]; [14]. Majority of works done have shown that the qualities that are inherent in good lubricating oil are: viscosity, viscosity index, fire and flash point, carbon residue content, emulsification and deterioration ability, acidity or neutralization number, colour, sulphur content and saponification. The properties that are most critical in hydropower turbo generator lubricating oil Tellus 68 are: viscosity, flash point, solidifying point, neutralization number, water content and ash content [13].

Viscosity is a measure of internal resistant to flow and an important physical property of lubricating oil. Industrial lubricants are usually measured at 40 °C and recorded in Centistokes (cSt). Most industrial lubricants are classified by their viscosity. Viscosity of oils decreases with increase in temperature. Lubricants oxidation and degradation are indication of contamination with higher grade oil either with fuel, engine oils, or industrial oils [12].

For installations that operate at low temperature, the pour point of lubricating oil is of prime importance. Pour point is an important property considered when selecting oil for turbo generator lubrication. It is a measure of oil quality used for evaluation of lubricant problem suspected in the system. The pour point is a vital flow characteristic of Tellus 68 oil at the lowest temperature of its utility for turbo generator [2].

Flash point is measure flammability of an industrial lubricant used to test if light-end hydrocarbons are entering into the oil through seal leaks or any other means. It is used for guide effective quality control of seal performance in light end hydro-carbon compressors. Low Flash Points pose a safety hazard in the event of component failure than can generate heat above the flash point of the oil, such as bearing failure [15].

Neutralization number is the most critical property that affects the temperature and quality of lubricating oil used in turbo generator because it measures the degree of protection in the lubricants residual to neutralize acids formed as a result of combustion. When the acid number of lubricating oil reaches a discarding limit, replacement or lubricant upgrading with viscosity index improvers and load carrying additives is best option. Neutralization point is used for evaluation of lubricant deterioration in service and eventual bearing failure. The neutralization number tells nothing unless it is compared with manufacturer's specification for fresh lubricating oil [14].

Water is the commonest contaminant found in lubricants that readily damage bearings and other lubricated components. Water corrodes the metal surfaces resulting lubricant deterioration with poor lubricating effects. Oil used is contaminated very quickly by dilution with water which enters the bearing of turbine as leakage. Oil readily picks up over 2% mixture from the atmosphere through the seals after a relatively short service period. Oil dissolved in water at 120° F with about 100 ppm (parts per million) is not hazardous and does not change the appearance or performance of the lubricant. Oil become milky and very harmful above 100ppm when mixed with water (emulsify) in tight bonds difficult to break. Oil becomes 'milky' at about 150 - 300 ppm depending on the base stock and additive in the lubricant [9].

Ash is the inorganic constituents in lubricating oil after oxidization to remove water and any organic material. Lubricants must be free from any ash forming matter and any phosphorous compound which are undesirable impurities that contaminate the oil [11]. This research is therefore essential to help reduce outages of hydro units as results of abnormal temperature rise to enable hydro stations effectively contribute their quota to the national grid. [13].

II. MATERIALS AND METHODS:

Performance test was conducted on lubricating oil using various ASTM/IP test methods. The experimental procedures involved the determination of Viscosity, Flash Point, Pour Point, Neutralization number, Water content and Ash content. Experiments were carried out at Power Holding Company of Nigeria (PHCN) laboratory, Ijora Lagos State, Nigeria on four samples of Tellus68 oil.

A. Instrumentation and Experimental Apparatus

The equipment used for the tests consist of Chan U-Tube Viscometer; Pesky- Martens Closed Flash Tester; Brian Weigh Cylindrical Test Jar; Armfield Potentiometer; Titrimeter; Pyrox Water Content Apparatus; Bausch and Loub Evaporating Crucible Electric and Muffle Furnace. Reagents / materials used includes TELLUS 68 oil; Alcohol Potassium Hydroxide (KOH); Phenolphthalein Solution; Methyl Orange Solution; Alkali Blue Solution ; Ethyl Alcohol; Toluene; N-Xylene; Silicone Oil; Premium Motor Spirit; Chlorobenzene; Solid Carbon Dioxide; Ethanol; Pyrogallol and Zinc Oxide**.**

B. *Experimental Procedure*:

1). Determination of Viscosity (IP 71/87 D-ASTM D 445-87)

A U-tube Viscometer was used to measure the viscosity of Tellus68 Oil (Tellus 68 is the viscosity value 68 cSt measured at 400 C for Tellus oil). A bath containing clear transparent paraffin was maintained at a test temperature (400C or 1000 C). A thermometer was held in an upright position under the same condition of immersion as when calibrated. The bath has provision for four viscometers. Four clean, dry calibrated viscometers having ranges covering the estimated kinematic viscosity were selected on the basis of their capillary tube. Each of this viscometer has a constant number written on it, which was used for calculation. The viscometers were cleaned with Premium Motor Spirit (PMS petrol and rinsed with small quantity of oil sample. The viscometer bath was then switched on to the temperature of 400 C. The test oil was introduced slowly into the viscometer via a filling tube and allowed 15 minutes to attain the bath temperature. The samples were then sucked up from point 'G' below a marked point 'E' on the tube. The oil was allowed to fall freely to the lower point 'G' and the time was noted with a stop watch. These procedures were repeated at an experimental temperature of 1000 C to determine the variation of viscosity with temperature with the four samples of Tellus 68 oil.

2) Flash Point Determination (IP 34/88 Designation ASTM D 80-93)

The flash point was measured with Perky-Martens Pesky- Martens Closed Flash Tester. The component support of the apparatus incorporated with a thermometer having a range of – 6 to 4000 C carries a test cup; a heating plate with a heater; and a test flame applicator. The test cup was filled with four samples of oil poured up to the marked point. The test cup was heated up until the temperature of the samples increased rapidly. This temperature was held for a slow constant heating rate to approach the flash point and the test flame was lighted. The test flame was then passed across the cup at every interval of 2 0C and the lowest temperature at which the oil vapour ignites was recorded as the flash point. This test carried out twice for all the four samples and recorded.

3) Pour Point Determination (IP 15/67D- ASTM D 66-97)

Four samples of oil were poured up to the marked point of a test jar closed firmly with a cork carrying a high cloud and pour thermometer (ranging from -38 ^{0}C to 50 ^{0}C). The thermometer bulbs were immersed in oil. The sample was cooled at a constant rate in an unsilvered vacuum flask containing solid carbon dioxide (CO_2). After the oil has cooled enough to form paraffin wax crystals, the test jar was carefully removed and tilted to ascertain whether there is movement of oil in the test jar. When oil cease to flow at -34 ^{0}C the solidifying point is reached. After 3 seconds the oil begins to flow when the test jar was tilted, the oil attains the pour point at -30 ^{0}C, the lowest temperature at which it starts to flow.

4) Determination of Neutralization Value (IP 1/74)

IP 1/74 method was used for the determination of the acidity of used and fresh lubricating oils. Acid content is the quantity of Potassium Hydroxide (KOH) required to titrate all acid or salt present in the sample, expressed in milligrams of KOH per 1 g of the sample of oil. Two methods have been reported for the determination of neutralization value namely: the indicator and the potentiometric methods. The potentiometric method was used for this experiment. 10 g of the samples of oil were weighed and poured into a washed and dried conical flask. 120 ml of equal mixture of 60ml alcohol and 60ml of toluene was added to the sample. It was then titrated with standardised KOH solution (phenolphthalein) as the indicator. The Acid value (AV) was determined using Equation 1 [6].

$$AV = \frac{56.1 \times N \times V}{M} \quad (1)$$

where;

56.1 is the Molecular weight of KOH; m is the mass of sample (g); V is the sample volume (ml); and N is the actual normality of KOH alcohol.

The procedure was repeated for the entire four samples and the results were recorded.

5) Determination of Water Content (IP 74/81)

50 ml of TELLUS 68 oil samples were mixed with 50 ml of N-Xylene in a water content analysis apparatus. The content of the flask was then heated for 55minutes. The water content of the test samples was separated into the calibrated side of the apparatus for measurement.

6) Determination of Ash Content (IP 4/81; ASTM 80-82)

The procedure involves evaluation of residual ash constituents in lubricating oil, fuels, crude oils and other petroleum products after oxidization to remove water and any organic material which are undesirable impurities that contaminates the oil. 100 g of oil samples were weighed in the crucible. The sample was then heated in a muffle furnace at 775^{0}C until the sample burn completely to remain only ash and carbonaceous residue. The residue was left until the next day to cool naturally in air and the samples weights were recorded and presented as a percentage of the original sample computed using the relationship in Equation 2.

$$Ash = \frac{w \times 100}{W}\% \quad (2)$$

Where: w (g) is the weight of ash in samples; and W (g) is the weight of sample.

III. RESULTS AND DISCUSSION

1) DESCRIPTION OF SAMPLES

Sample A: Upper Guide Bearing (UGB) used oil;

Sample B: Lower Combined Bearing (LCB) used oil;

Sample C: Clean Oil before purification; and

Sample D: Clean Oil after purification

The summary of the result of the experiment conducted on the four samples of Tellus 68 Oil is shown in Table 1.

Table 1: Result of Lubricating Oil Analysis (1st Experiment)

Property Unit	Visco sity at 40^{0}C (cSt)	Visco sity at 100^{0}C (cSt)	Flash Point (^{0}C)	Pour Point (^{0}C)	Acidity Mg/ KOH/g	Water Content %	Ash Content %
Test Method	IP 71	IP 71	IP 34	IP 15	IP 1	IP 74	IP 4
Sample A	66.58	9.2	200	-30.5	0.350	0.08	0.027

Sample B	65.85	9.9	200	-29.5	0.173	0.07	0.025
Sample C	71.72	10.5	210	-30.0	0.161	0.06	0.021
Sample D	68.57	10.0	210	-30.0	0.120	0.02	0.018

Another set of experiments were conducted to validate test results earlier performed and the results are presented in Table 2.

Table 2: Result of Lubricating Oil Analysis (2nd Experiment)

Property Unit	Viscosity at 40^0C (cSt)	Viscosity at 100^0C (cSt)	Flash Point (^{0}C)	Pour Point (^{0}C)	Acidity mg/ KOH/g	Water Content %	Ash Content %
Test Method	IP 71	IP 71	IP 34	IP 15	IP 1	IP 74	IP 4
Sample A	66.40	9.9	220	-31	0.361	0.07	0.025
Sample B	64.05	9.8	220	-30	0.254	0.06	0.022
Sample C	72.56	9.4	200	-28	0.236	0.03	0.019
Sample D	69.00	10.5	200	-28	0.203	0.02	0.018

From Tables 1 and 2, it could be seen that the flash point is a verifiable measurement rather than a basic physical quantity. The values measured vary with temperature ranges and the instruments used for scientific experimentation. The Flash point determined from experiments ranges from 200 ^{0}C to 220 ^{0}C which is satisfactory when compared with manufacturer's specification of 160 ^{0}C minimum.

The Pour point of ranging -30 ^{0}C to -28 ^{0}C is as well satisfactory when compared with manufacturer's specification of maximum of -20 ^{0}C.

Test analysis on the oil for various samples ranges from 0.120 to 0.361 mg/KOH/g neutralization number in tables 1 and 2. However the neutralization numbers for sample A show a significant deviation from the recommended manufacturer's specification of 0.3 mg/KOH/g. The values of neutralization number for sample D has the lowest value of neutralization numbers indicating that purified fresh TELLUS oil is satisfactory for lubrication of hydro turbo generator

The water content of range 0.02 to 0.08 % experimental values of is significantly low compared with manufacturer's specification of 0.1 % water content implying the good quality. Furthermore, the Ash content measured experimentally for a range of 0.018 to 0.022 % for samples which when compared with manufacturer's specification of 0.028 %. This implies that the ash content is perfectly okay for lubricating turbo generators.

The result of ASTM/IP tests in tables 1 and 2 were used for comparison with the manufacturer's specification presented in Table 3.

Table 3: Manufacturer's Oil Specification

1	Viscosity at 50^0 C	30-37 CSt
2	Flash Point	min -160^0C
3	Solidifying (Pour) Point	min - 20^0C
4	Neutralization Number	0.3 mg KOH/g
5	Water content by volume	0.1 %
6	Ash Content	0.02 %

The average of the result of the viscosity experiment conducted on four samples of Tellus68 Oil in Tables 1 and 2 is presented in Table 4.

Table 4 Result of Average Viscosity Test

SAMPLE	A	B	C	D
Viscosity at 40 ^{0}C (cSt)	65.49	64.95	72.14	68.79
Viscosity at 100 ^{0}C (cSt)	9.55	9.80	9.92	10.25

The viscosity in Table 4 was measured at 40 ^{0}C and 100 ^{0}C and converted to temperatures of 50 ^{0}C, 60 ^{0}C, 80 ^{0}C, 90 ^{0}C using Walther relationship in Equation 3.

$$\text{Log}\,[\log(v + 0.7)] = A + B \log T \qquad (3)$$

The coefficients A and B were computed to be 1. 279 and -0.633 and the kinematic viscosity at 50^0C determined to be

v = 36.07 cSt.

Where; A and B are Walther coefficients; v is the kinematic viscosity (cSt); and T is the Temperature (K).

These values were used to generate viscosity at other temperatures as presented in Table 5.

Table 5: Computed Viscosities with temperatures

Viscosity at Temps	40 ^{0}C	50 ^{0}C	60 ^{0}C	80 ^{0}C	90 ^{0}C	100 ^{0}C
Sample A	65.49	37.11	24.21	13.54	10.96	9.55
Sample B	64.95	37.05	24.96	14.26	11.64	9.80
Sample C	72.14	40.64	26.96	15.33	12.54	9.92
Sample D	68.79	38.92	25.74	14.64	11.93	10.3

From Table 5 it could be seen that viscosity is a function of temperature for Tellus oil viscosity decreases with temperature rise for all samples.

It was also revealed that viscosity decreases with increase in temperature for all the samples used during this experiment, this is shown in Figure 1. The closeness of the curves is as a result of approximately close viscosities of all the four samples of oil used during the experiment.

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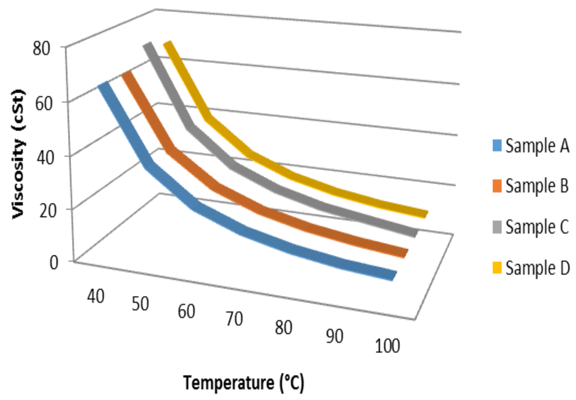

Figure 1: Experimental Viscosity and Temperature Relationship

IV. CONCLUSIONS

Performance analysis of Tellus 68 Lubricating Oil used in Hydro Power Turbo Generator was analysed using four various samples of oils collected from Shiroro Power Station Niger State, Nigeria. From the analysis, results obtained and their discussions, the following conclusions were drawn from the research carried out:

The viscosity of the oil samples fell within the range specified by manufacturer (i.e. viscosity at 50^0C should be 30-37 cSt), thus Tellus oil viscosity is good enough for lubricating the turbo generator

The Pour point determined experimentally ranges from -30 ^{0}C to -28^{0}C is quite satisfactory when compared with manufacturer's specification of maximum of -20 ^{0}C for lubricating the turbo generator.

The Flash point determined from experiments ranges from 200 ^{0}C to 220 ^{0}C which is satisfactory when compared with manufacturer's specification of 160 ^{0}C minimum.

The experimental measured values of water content ranges from 0.02 to 0.08 % and are significantly low compared with manufacturer's specification of 0.1% water content implying Tellus oil is of good quality for lubrication of turbo generator in operating condition.

The Ash content measured experimentally ranges from 0.018 to 0.022 % for samples which when compared with manufacturer's specification of 0.028 % is perfect for lubricating turbo generators.

When the neutralization number of regenerated oil was compared to that of fresh oil in this work, the average difference between the experimental and manufacturer's specified values were large enough to justify discarding spent oil for lubricating turbo generator. Changing or replacement of the oil is recommended for any deviation from the specified value. Depending on its source, additive content, refining procedure, or deterioration in service, lubricating oil may exhibit certain acidic or alkalinity characteristics which may be derived from the product's neutralization number.

The results of test analysis demonstrated that Tellus 68 oil is satisfactory for lubricating Shiroro Hydro Power Turbo Generators. However, the regenerated oil should be critically examined before reused in the hydro plant. There would be reduction in the quality of spent oil because of the chemical reaction between the machine parts and the bearing oil. For better cooling and lubricating effects, spent oil whose properties differ from the specified values should be discarded and the system refilled with purified fresh oil.

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