International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 9, pp: 330-334 www.ijaem.net ISSN: 2395-5252

Service Lifespan Cost Analysis of a Marine Auxiliary Generator Using Manufacturer's Manual

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Date of Submission: 10-11-2020 Date of Acceptance: 24-11-2020

ABSTRACT: A review of service lifespan analysis (SLA) of an auxiliary generator generating 1250 kW as a case study is analysed. The aim of this research is to predict the cost estimation of using CAT-3512 for marine operations. Potential issues are identified regarding the way SLA is used for assessing manufacturer's maintenance manual. Additionally, a MATLAB codes is implemented for the algorithm and result obtained are shown in graphs. The initial purchase cost of CAT-3512 generator is ₦160,000,000. The maintenance and fuel consumption costs are₦107,500,000and ₦521,510,000 respectively for the first year. The cost of running this generator for 25 years which is estimated as the life span of a vessel is shown in this research work. This project analysed the cost implication of routine and major overhauling maintenance of CAT 3512 generator.

KEYWORDS: Marine Auxiliary Generator, Diesel Engine Operations, Service life Cost Analysis, Maintenance Cost, Fuel Consumption.

I. INTRODUCTION

[1].In 2005, Business Insights published a report called The Future of Power Generation, which looked at trends in the comparative costs of different types of power generating systems, with a particular focus on renewable energy technologies and traditional fossil (diesel) fuel power generating systems. The first report was updated and expanded in 2008 to reflect the changes that had taken place in the intervening years. This report is the third update and expansion. The report now represents a broad look at electricity generation costs and the various influencing factors.

One of the key trends of the previous reports was the progressive increase in the costs of maintenance of gen sets and the procurement of fossil fuels.Particularly, diesel fuel began to make power generation comparatively more expensive than other types. That trend accelerated into 2008 before the onset of the global financial crisis fed into a global recession and prices of fossil fuels slumped. In theory, this should adjust the economic balance in favour of the use of fossil fuel generators. However, at the beginning of 2010 there were signs that oil prices were beginning to rise sharply again as global economic activity grew.

[2].Maintenance, as one of the key trends in cost analysis of a diesel generator, is divided into two: Preventive and Corrective Maintenance. Preventive maintenance changed slightly in past revisions of NFPA 70B and NFPA 110. This is largely true based on studies conducted on diesel-electric generator sets in use between 1971 and 1998.

[3].In practice, recommendations for periodicity of maintenance and testing of emergency diesel generator systems differ significantly between organizations, publications, and manufacturers of similar technological systems. They also varyfor different manufacturingfranchises,and technical manuals for diverse models, and categories of generator sets. Undoubtedly, manufacturers are presumed to be the most knowledgeable about the design of their own equipment. However, their abilities to conduct robust long-term failure modeanalyses and effects analyses on fielded units have been limited: thus, manufacturer maintenance recommendations have often been highly speculate. Despite this shortfall, the maker's manual remains the only valid document for use, especially those on system maintenance.

Obviously, analysing SLA of a diesel generator used in marine operation is quite complex. The method used in this project is novel and simple. It uses elements of economics (e.g. inflation) and maintenance manual from the manufacturer to predict the total cost of operating a caterpillar 3512 generator either as an auxiliary or a main engine generator.

[4].Prompted by current problems of energy depletion and the implementation of

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commitments in climate change awareness, the world is searching for eco-friendly and renewable sources of energy. The power sector still remains an attractive area for investment, but investors are now more cautious than previously. Global warming continues to be a dominant theme but alongside that there is a new pragmatism about fossil fuel combustion technology.In addition, the economic advantages and reliability of these gen sets enable then to continuously dominate the power sector at least for next decade.

Meanwhile renewable sources of generation continue to advance due to its environmentally friendly operations, led principally by wind power but with solar capacity growing rapidly too, though from a small base. It is therefore paramount to undertake a project on the service lifespan cost analysis of a diesel engine generator set using caterpillar 3412 generator as a case study and to analyse its GHG effect.

II. RESEARCH GAP

[3,5].Márquez and Herguedas opined that extant data censoring usingpreventive maintenance statisticscould be implemented todetermine the significant failure modes and effects. Moubray stated that some managers allow equipment to work until they degenerate to the point of failure before repair actions are instituted. Both research teams used mathematical techniques and appropriate tolerances to analyse the censored data. Yet such techniques often require assumptions which are case specific. Thus, there is always the rigor of evolving the set of assumptions applicable to the individual case orparticular failure distribution.

[5,6,7].Examined different components of power plants using small sample sizes from portions susceptible to failure and the possible failure combinations as presented in their data sets. Sometimes data unavailability, presence of outliers and nonlinearity could impair the credibility of analysis results. The researcherschose to address this deficiency by analysingcases for which veritable data was available. Thus, Márquez and Herguedas only analysed cylinders which exhibited at least three failures within the fleet. Gat and Eisenbeis excluded data sets for which inadequate information was available. Márquez and Herguedas developed a data map, but neither Márquez and Herguedas nor Gat and Eisenbeis attempted any techniques to reconstruct missing data.

Despite the ubiquity of emergency diesel-electric generator sets in commercial and industrial facilities, there has been very little published research on the impact of maintenance and test data on the reliability of diesel-electric generator sets manufactured in the last twenty years. This research will analyse maintenance cost, specific fuel consumption and the amount of pollution caused by running a diesel generator, with caterpillar 3512 generator as a case study,during marine operation using the manufacturer manual

III. METHODOLOGY

MATLAB software is used to perform the diesel engine service lifespan cost analysis and thevarious unit costs for optimum operation using the manufacturer specifications. A power output of 1250kW is considered when CAT-3512 generator is operating at full capacity and its other parametersare shown in Appendix A.

Most importantly, when it comes to engine maintenance, it is recommended to do inspections regularly because preventive maintenance is better than reactive maintenance. Nevertheless, it is of utmost importance to follow the designated service procedure and intervals stipulated by the maker.

LUBRICATION SERVICE:

[8].The engine oil must be checked with a dipstick before starting the generator and with digital sensors at regular intervals while running it.The oil and filter must also be changed at regulated time intervals. Check with the engine manufacturer for procedures for draining the oil and replacing the oil filter. Their disposal should be done appropriately to avoid environmental damage or liability. A total of 2 drums of diesel oil are used in CAT 3512 maintenance. Equation 1 shows the cost of replacing lubricating oil during routine maintenance. where N_D is the number of drum, UC_D is the unit cost of drum and L_c is the total cost of the lubricating oil.

$$N_D * UC_D = L_o \qquad 1$$

COOLING SYSTEM:

[9].Check the coolant level during shutdown periods at the specified interval. Remove the radiator cap after allowing the engine to cool, and, if necessary, add coolant until the level is about 3/4 in. Equation 2 represents the cost analysis of the coolant used in CAT 3512 diesel generator. where N_C is the number of coolant, U_{CD} is the unit cost of the coolant used and L_c is the total cost of the coolant used.

$$N_C * U_{CD} = L_c \qquad 2$$

TESTING BATTERIES:

[10].Weak or undercharged starting batteries are a common cause of standby power

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system failures. The battery must be kept fully charged and well-maintained to avoid dwindling. By regular testing and inspection, the operator can determine the current status of the battery and avoid any start-up hitches of the generator. The batteries must be cleaned; and the electrolyte's specific gravity and levels checked frequently. Batteries should be changed at every 250 hours.

FUEL CONSUMPTION:

This is the singular most expensive item incurred in running a diesel engine. It constitutes over 80% of the operating cost. To maintain good performance, the fuel filters should be cleaned at the designated intervals. This is required to dislodge wear particles, soot, water, and other impurities that may clog them. Also, regular testing and fuel polishing may be required if the fuel is not used or replaced after three to six months. Preventive maintenance should include regular general inspection, the routine checking and maintenance of cooling system, lubricating oil system, fuel system, and starting system.

Fuel consumption of CAT 3512 is shown in equation .3. Where FCO is the fuel consumption, L is the fuel in Litres and Fl is the price of a unit litre. The rate of global inflation of crude products in Nigeria is 0.3% from the year 2000 to 2015. This can cause a significant increase in the price of diesel used in running the generator. Equation 4 is used to express the effect of inflation on the cost of fuel consumption per year.

$$FCO = L * Hr * Fl * nD * ni \quad 3$$

$$FC = FCO * (1 + r)^{ni-1} \quad 4$$

ROUTINE ENGINE MAINTENANCE

[6].Routine maintenance is typically done on schedule based upon engine hours and/or time periods. Maintenance is adapted to meet specific application needs. The more hours per year a unit operates, the more frequently it will require servicing.

Table 1 below shows the hours and the cost of running maintenance on CAT-3512 diesel generator. Routine servicing cost estimated is said to be about 5% of the initial cost of generator and complete overhauling is estimated to be around 8-10% of the initial cost of the diesel engine. Prices of parts and the interval of maintenance of routine servicing are considered in equations 5 and 6. The data is excerpt from CAT-3512 generator Maintenance guide book.

Table 1: The Maintenance Cost of Caterpillar 3512 Generator (see Appendix D)

Hours	Maintenance	Cost (₦)
250	Oil filter (3)	216,000
	Batteries	200,000
	Belts (4)	600,000
	Coolant (2)	110,000
	Engine oil (2)	710,000
	Water separator (2)	90,000
	fuel filter (5)	375,000
	Hoses and clamp (2)	190,000
	Air Filter (2)	300,000
	Total	₦2,791,000
10000	Overhauling cost	₦11,826,159.55

For n hours

$$M_{hr} = \frac{n * hr * nD}{hrm} \quad 5$$

$$\%M_{hr} = \frac{T_{M_{hr}}}{C_0} \quad 6$$

Where M_{hr} is the number of times that a maintenance hour will occur in the caterpillar engine, $\%M_{hr}$ is the percentage ratio of the engine to the running maintenance, while (T_{mhr}) is hour cost to the initial cost of the diesel engine.

IV. RESULT AND DISCUSSION

Caterpillar engines are widely known for their low cost of maintenance. A cost of ₦14,630,000 is the total cost of maintaining a CAT-3512 generator set.This generator is recommended for replacement after 25 years or 130,000 running hours as to avoid downtime due to equipment faults. Faulty parts, system break down andother issues caused by mechanical failure during operations can be averted.Typically, maintenance of the generator is divided into three categories (250 and 10000 running hours). The total of these categoriesis expressed as a fraction of the procurement cost of the diesel engine.

The maintenance cost of the first year is ₦215,050,000 for the two CAT-3512 engines used to generate 2.5MW, which were purchased at the cost of ₦160,000,000 as shown in Figure 1. This initial maintenance constitutes 9.14% of the overall maintenance cost of CAT-3512 generator.

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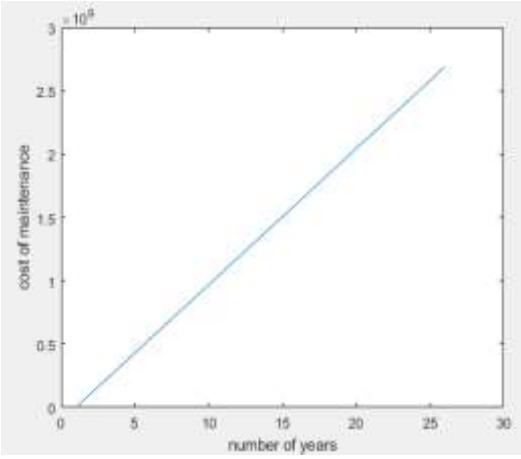

Fig. 1: Maintenance cost of diesel engine in 25 years

The initial fuel consumption cost is calculated as ₦521,510,000 for the first year and ₦13,038,000,000 for 25 years as shown in Figure 2. The sums of ₦107,500,000 and ₦2,688,100,000 are calculated as the maintenance costs of the diesel generators for their first and 25 years, respectively.

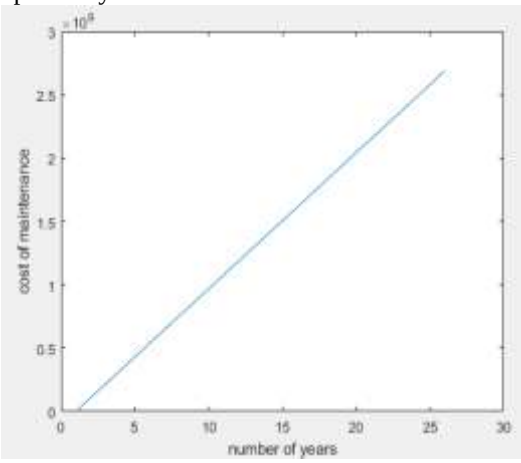

Fig**. 2:** Fuel Consumption Cost of running diesel engine in 25 years

The initial cost of fuel consumption, maintenance cost andthe procurement expenses are used in estimating the total cost of running the CAT-3512 diesel generators. Figure 3presents the running cost of diesel engine for 25 years. The slight change in the normal curve of the graph, as shown in Figure 3 at 15 years, is due to the replacement cost of the diesel generator after 130,000 hours. Costs of parts replaced, and routine maintenance are considered negligible, especially if the part is not listed during maintenance costing.

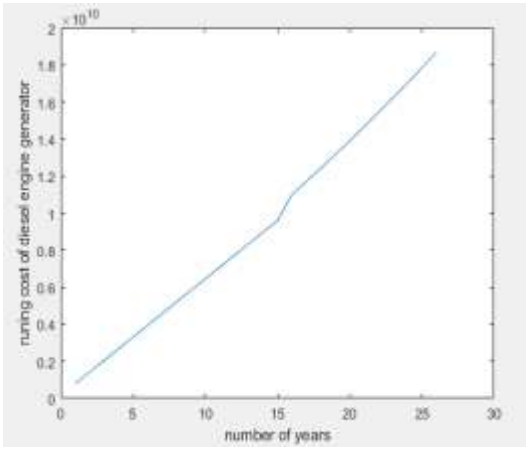

Fig. 3: Cost of running diesel engine in 25 years

V. CONCLUSION

A computer model has been formulated for service lifespan cost assessment of a diesel CAT 3512 generators. The results show that the procurement cost of the generators is high, but almost insignificant when compared to the cost of fuelling. The maintenance and fuel consumption cost of the diesel engine increases steadily..

Again, the analysis utilises service parameters of the diesel generator for the program as to obtain a realistic cost estimate. Since the manufacturer's manual is implemented for a service lifespan of 25 years which is the life span of a vessel, the predicted amounts are holistic and veritable, provided the economic indicators remain unchanged. This analysis procedure could be extended to other power plant such as gas and wind turbine plants.

VI. CONTRIBUTIONS TO KNOWLEDGE

The research is able to establish a simple but veritable procedure for estimating service lifespan cost of marine power plants. It is also demonstrated graphically that the generator set procurement cost is comparatively insignificant as compared to the running cost for which fuelling is a major. Finally, it develops a virtual tool for lifespan cost prediction of any power plant, considering procurement, maintenance, and fuelling.

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