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PREDICTING REPAIR AND MAINTENANCE COSTS OF AGRICULTURAL TRACTORS IN NIGERIA.

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Abstract

Repair and maintenance cost of some agricultural tractors were investigated using the Enugu State Agricultural Development Programme (ENADEP) as case study. The study was limited to two most available tractor models namely – Massey Fergusson (MF) and Fiat tractors. Investigations were focused on determining the relationship between the accumulated hours of usage and total accumulated repair and maintenance costs as well as the general fixed and operating costs of the tractors under government owned management system.

Data obtained from the study were subjected to statistical analysis using knowledge based software analytical tool,, MATLAB (2014 version) generating regression models useful to predict repair and maintenance costs of tractors in Nigeria.

Results obtained indicate that the relationship between total accumulated repair and maintenance cost (ARM) and total accumulated working hours (AWH) of the tractor models were developed and could be expressed as $ARM = 5.097e-7\,(AWH)^{2.017}$ and $ARM = 4.17e-8\,(AWH)^{2.303}$ for MF and Fiat tractors respectively with a service life of 12000 h. The results of this finding will be very useful in farm machinery management with regards to prediction of repairs and maintenance costs of agricultural tractors in Nigeria.

Keywords: Prediction, Repair, Maintenance, costs, Tractors, Accumulated-use, Nigeria.

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1. INTRODUCTION

When agricultural farm machinery first became widely used in the 1920s and 1930s, much attention was given to costs of owning and operating these machines. Then repair costs were normally reported as a percentage of the new cost of the machine with no attempt made in relating this cost to machine age.

Repair and maintenance cost is a very important portion of the total cost of operating farm machinery and account for about 10 to 15% of their total cost of ownership. However, this tends to increase with machine age, making repair costs very important factor that influences the optimal time for farm machinery replacement. Repair and maintenance costs of farm machinery are those expenditures necessary to restore technical soundness and reliability of the machine [12]. According to [7], Purchasing and maintaining agricultural machines are two of the most considerable costs in the agricultural production sector of the economy.

In Nigeria, it has been the policy of the federal government to import some agricultural machinery in order to boost agricultural mechanization aimed at increasing food production in the country [9]. Maintenance of these machines is paramount in order to get the expected results of increasing the productivity of the Farmer leading to increase in food production. Accurate prediction of repair & maintenance cost trends is critical in determining the optimum economical life of agricultural machines as well as making appropriate decisions for machinery replacements and general farm management purposes [4].

[2], in their research on the coefficients of repair and maintenance costs of self-propelled combine harvesters in Italy, noticed that the repair and maintenance cost incidence on the list price of Italian self-propelled combine harvester at 3000 working hours was 23.1% as compared with 40.2% calculated through the most recent U.S. model.

[6], in their work on modelling of repair and maintenance cost of John Deere 4955 tractors in Iran, showed that average repair and maintenance (R&M) costs per hour increased with tractor age.

In Nigeria, very limited studies have been done on repair and maintenance cost of tractors and farm machinery. One of such is the study by [1] which determined the repair and maintenance cost for MF375 tractor based on accumulated operating hours as the major determining factor of the repair and maintenance cost: a case study in Kano metropolis, Nigeria. [5] also conducted a study on applications and case studies appraisal of farm tractor maintenance practices and costs in Nigeria based on cumulative hours of use.

Also there is a great variation in repair and maintenance costs between different tractor models, tractors and their operating conditions, making it difficult to obtain general models. As Massey Fergussson (MF) and Fiat tractors are widely used by Nigerian farmers and agro-companies, this study therefore aims to carry out an investigative research survey on MF and Fiat tractor models with a view to developing a mathematical model for their repair and maintenance costs in the country using the statistical analytical tools.

2. MATERIALS AND METHODS

Primary and secondary data were collected from Enugu state agricultural development program and some agro based companies in some States of Nigeria using structured questionnaires, existing records and oral interview.

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Information gathered such as total hours of usage, fuel cost, purchase price of tractor, year of purchase of tractor as well as tractor operators' salary, etc.were for the period covering 2004 to 2013.

The data so collected were analysed statistically using MATLAB 2014 version. The following cost components of repair and maintenance of a tractor were determined:

2.1. Lubricating Cost

The lubricating cost was calculated using 15% of the fuel cost in line with the approach employed by [10].

$$Lc = 0.15Fc \quad \text{..... 1}$$

Where, $Lc = lubricating\ cost$

$Fc = fuel\ cost$

2.2. Depreciation Cost

Depreciation costs were determined by using the straight line method as used by [8].

$$D = \frac{PL}{N} \quad \text{..... 2}$$

Where, D = depreciation

P = purchase price of tractor (₦)

L = salvage value of the tractor

N = useful or economical life of tractor (years)

The useful life of 10 years and a salvage value of 5% were assumed in line with the American society of agricultural engineers' specification [3].

2.3. Interest Rate

Interest rate depends on the prevailing situations in the banking sector of the economy. In this study, the interest rate of 21% of the investment was used based on the current interest rate of the country.

$$\mathrm{I} = \frac{\mathrm{R(C+L)}}{100} \quad \text{..... 3}$$

Where, I = annual interest

R = interest rate %

C = initial cost

L = salvage value

2.4. Shelter

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Shelter of 0.5% of the purchase price of the machine was used to calculate the cost of housing tractors as used by [8].

2.5. Repair and Maintenance Costs

Repair and maintenance costs of the agricultural machinery studied were determined by adapting repair and maintenance percentage approximation as applied by [8]. The cost percentage approximation schedule suggests that the repair and maintenance costs for any agricultural machinery could be averaged to 6% of the purchase price a year for 10 years of 6000 hours life. Thus, a schedule of repair and maintenance cost as a percentage of purchase price were developed with the assumption that overhauls were done when needed. The schedule is as follows:

1st year = 0%	2nd year = 1%
3rd year = 3.75%	4th year = 8.5%
5th year = 2.5%	6th year = 10%
7th year = 4.5%	8th year = 5.75%
9th year = 11.25%	10th year = 6.5%

2.6. Prediction of the Repair and Maintenance Costs of the Tractors studied.

The predictive models as shown in equations 4 and 5 developed to predict repair and maintenance costs of the tractors studied were based on the principles of an earlier study by [13]. In doing that the accumulated working hours (AWH) for each year were added up to the previous working hours and the sum was considered to be independent variable of the models. Also, the accumulated repair and maintenance (ARM) cost as percentage of the initial purchase price which was considered as a dependent variable was obtained through dividing the total accumulated repair and maintenance cost by initial purchase price of tractor multiplied by 100. A and B are the model parameters.

In other to determine the appropriate mathematical model for tractors, regression analysis was performed on the data using MATLAB 2014. Power and polynomial regression types were applied as follows; The regression model having the highest coefficient of determination (R^2) was selected as the best model(s) for predicting actual R & M costs trend.:

$$ARM = A\,(AWH)^{B} \quad \text{..... 4 (power)}$$

$$ARM = A\,(AWH)^{2} + B\,(AWH) + C \quad \text{..... 5 (polynomial)}$$

3. Results and Discussion

Table 1 shows the mean annual repair and maintenance cost of the tractors studied. It could be seen that spare parts procurement incurred the highest percentage cost compared to the percentage of other items in both Fiat

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and MF 375 tractors. This high percentage could be due to the substandard spare parts available and frequently used in the repair and maintenance industry.

The workmanship component is next, with percentage of 18.95% and 15.42% for MF375 and Fiat tractors respectively, showing that MF375 tractor's is 3.53% higher. The least percentage is seen in the oil & fuel filter of 2.87% and 2.35% for MF375 and Fiat tractor respectively.

Table 1: Mean Annual Repair and Maintenance Cost of MF375 and Fiat Tractor

Tractor name	Parameter	Cost (N)	Percentage (%)
MF375	Spare parts	448282.11	54.9
	Workmanship	154734.89	18.95
	Oil&fuel filter	23434.78	2.87
	Lubricant	24822.91	3.04
	Fuel	165268.3	20.24
	Total	816543	100
Fiat	Spareparts	528603.74	62.95
	Workmanship	129484.82	15.42
	Oil & fuel filter	19733.42	2.35
	Lubricant	29810.06	3.55
	Fuel	132087.96	15.73
	Total	839720	100

Table 2. The Accumulated Working Hours and Accumulated Repair and Maintenance Cost Percentage for MF375 and Fiat Tractors

	MF375	Fiat

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Age (Years)	Accumulated working hours (h)	Accumulated repair and maintenance cost as a percentage of initial purchase price (%)	Accumulated working hours (h)	Accumulated repair and maintenance cost as a percentage of initial purchase price (%)
1	1339	0.43	1450.8	0.57
2	2529.8	1.46	2851.38	1.58
3	3651.9	5.21	4146.38	6.25
4	4547.88	13.71	4929.58	15.35
5	5481.63	16.21	5835.98	18.6
6	6237.87	26.21	6520.54	28.64
7	7136.11	30.71	7366.29	34.06
8	8003.32	36.46	8166.27	40.31
9	8843.5	47.71	8789.97	51.74
10	9644.65	54.21	9442.02	59.19

Table 2 presents the result of the calculated accumulated working hours and accumulated repair and maintenance cost as percentage of initial purchase price per unit for MF375 and Fiat tractors for their different ages and were used as base data for the development of their mathematical model.

Figures 1 and 2 represents the graph of the accumulated repair and maintenance cost as percentage of initial purchase price versus accumulated working hours for the two tractor models considered (MF375 and Fiat Models).

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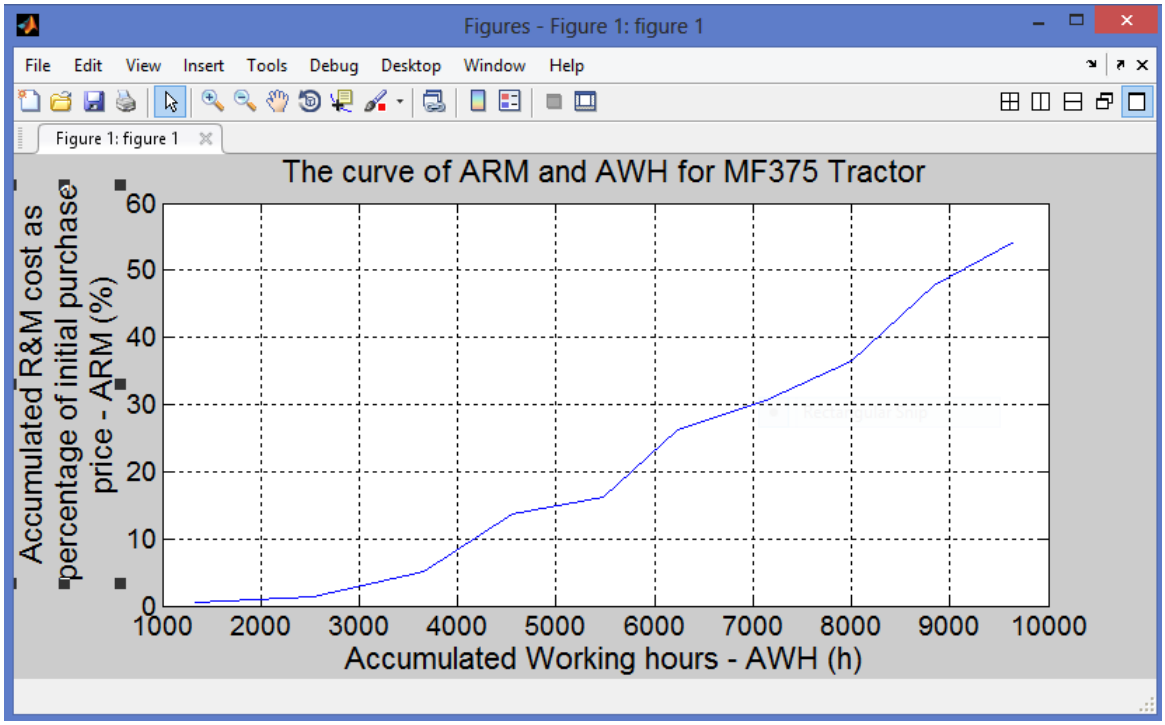

Figure 1: The curve depicting the actual data of the accumulated repair and maintenance cost (ARM) and accumulated working hours (AWH) for MF375 Tractor

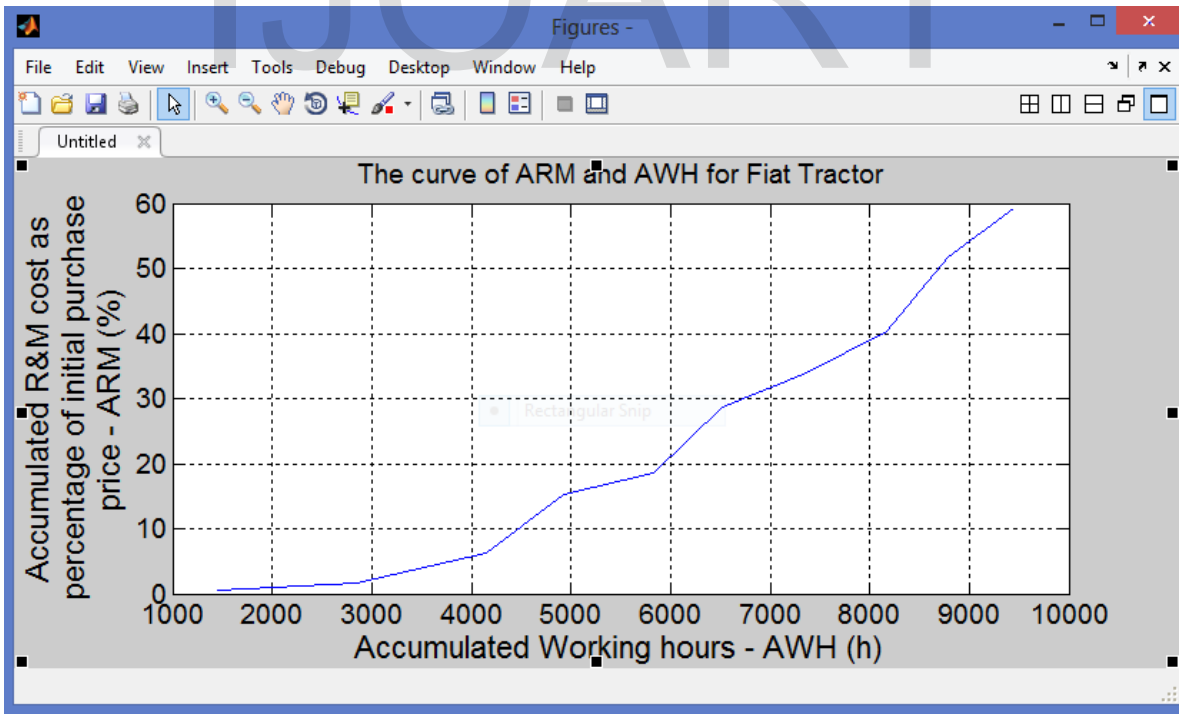

Figure 2: The curve depicting the actual data of the accumulated repair and maintenance cost (ARM) and accumulated working hours (AWH) for Fiat Tractor

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A curve fitting analysis (or regression analysis) performed using a knowledge based software and analytical tool, MATLAB (2014 version) produced a very strong correlation coefficient of determination of R^2= 0.9899 (with parameters A= 5.097e-7 & B= 2.017) and R^2= 0.9916 (with parameters A= 5.26e-7, B= 0.0009494 & C= -3.119) respectively for power and polynomial options for the MF375 tractor model. Thus giving rise to equations 6 and 7, together with table 3 and figure 3.

$$ARM = 5.097e\text{-}7\ (AWH)^{2.017} \quad \text{.....6}$$

$$ARM = 5.26e\text{-}7\ (AWH)^2 + 0.0009494\ (AWH) + (-3.119) \quad \text{.....7}$$

Considering equations 6 & 7, it could be seen that the polynomial model has the highest value of correlation coefficient of determination. It follows, therefore that the polynomial model is more likely to give a more accurate prediction of the repair and maintenance costs for the MF375 tractor model considered.

Table 3: The accumulated repair and maintenance cost (ARM) and accumulated working hours (AWH) as predicted from the developed Mathematical Model for MF375 Tractor Model.

	MF375		
Age (Years)	**Accumulated working hours (h)**	**Predicted repair and maintenance cost as a percentage of initial purchase price (%) using power option**	**Predicted repair and maintenance cost as a percentage of initial purchase price (%) using polynomial option**
1	1339	1.03	0.90
2	2529.8	3.72	2.65
3	3651.9	7.81	7.36
4	4547.88	12.16	12.08
5	5481.63	17.72	17.89
6	6237.87	23.00	23.27
7	7136.11	30.18	30.44
8	8003.32	38.03	38.17
9	8843.5	46.52	46.41
10	9644.65	55.41	54.97

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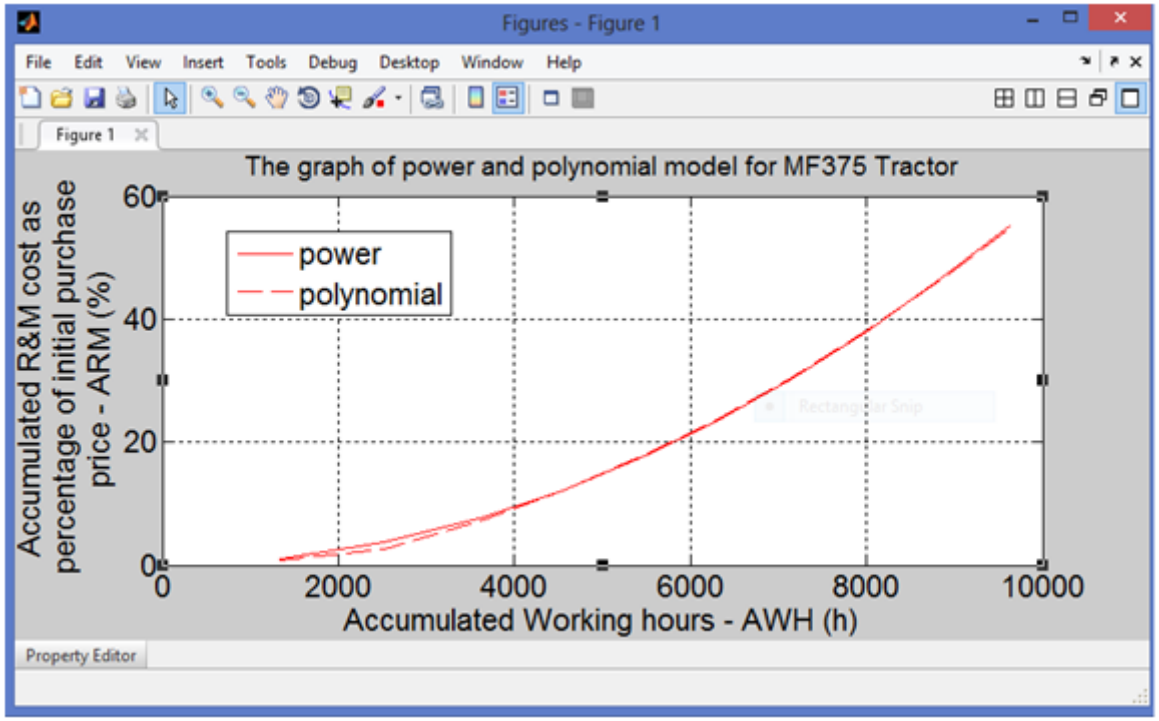

Figure 3: The Curve of Power and Polynomial Model for MF375 Tractor

From figure 3, it could be seen that the little difference in the correlation coefficient of determination between the polynomial and power model is infinitesimal as both have almost the same curve thereby, justifying the wide acceptance of the power model by other researchers.

Similarly, a very strong correlation coefficient of determination of R^2= 0.9899 (with parameters A= 4.17e-8 & B= 2.017) and R^2= 0.9916 (with parameters A= 5.26e-7, B= 0.0009494 & C= -3.119) for power and polynomial options respectively were produced for the case of Fiat tractor model. Thus giving rise to equation 8 and 9, together with table 4 and figure 4.

$$ARM = 4.17e\text{-}8\ (AWH)^{2.303} \quad \ldots\ldots 8$$

$$ARM = 7.917e\text{-}7(AWH)^2 + (-0.00116)(AWH) + (-0.3762) \quad \ldots\ldots 9$$

Then considering equations 8 & 9, it could be seen that the polynomial model has the highest value of correlation coefficient of determination. Which implies that the polynomial model is more likely to give a more accurate prediction of the repair and maintenance costs for the Fiat tractor model also considered.

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Table 4: The accumulated repair and maintenance cost (ARM) and accumulated working hours (AWH) as predicted from the developed Mathematical Model for Fiat Tractor Model.

	Fiat		
Age (Years)	**Accumulated working hours (h)**	**Predicted repair and maintenance cost as a percentage of initial purchase price (%) using power option**	**Predicted repair and maintenance cost as a percentage of initial purchase price (%) using polynomial option**
1	1450.8	0.79	0.39
2	2851.38	3.77	2.75
3	4146.38	8.94	8.43
4	4929.58	13.32	13.14
5	5835.98	19.65	19.81
6	6520.54	25.37	25.72
7	7366.29	33.60	34.04
8	8166.27	42.61	42.95
9	8789.97	50.48	50.60
10	9442.02	59.53	59.25

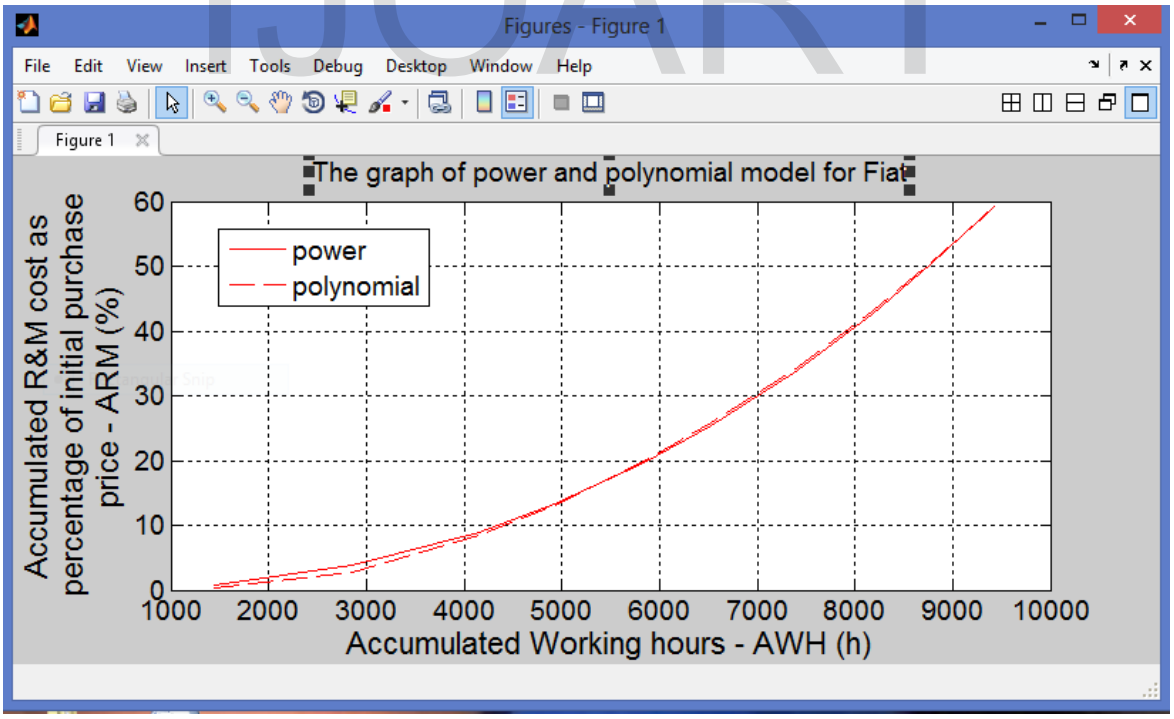

Figure 4: The Graph Showing Power and Polynomial Model for Fiat Tractor

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Similarly, it could be seen from figure 4 that the little difference in the correlation coefficient of determination between the polynomial and power model is not all that significant as both have almost the same curve, thereby justifying the wide acceptance of the power model by other researchers, mostly on the ground of easy determination.

3.1. Comparision of the Actual Data and data obtained the predictive Models for the Tractors Studied

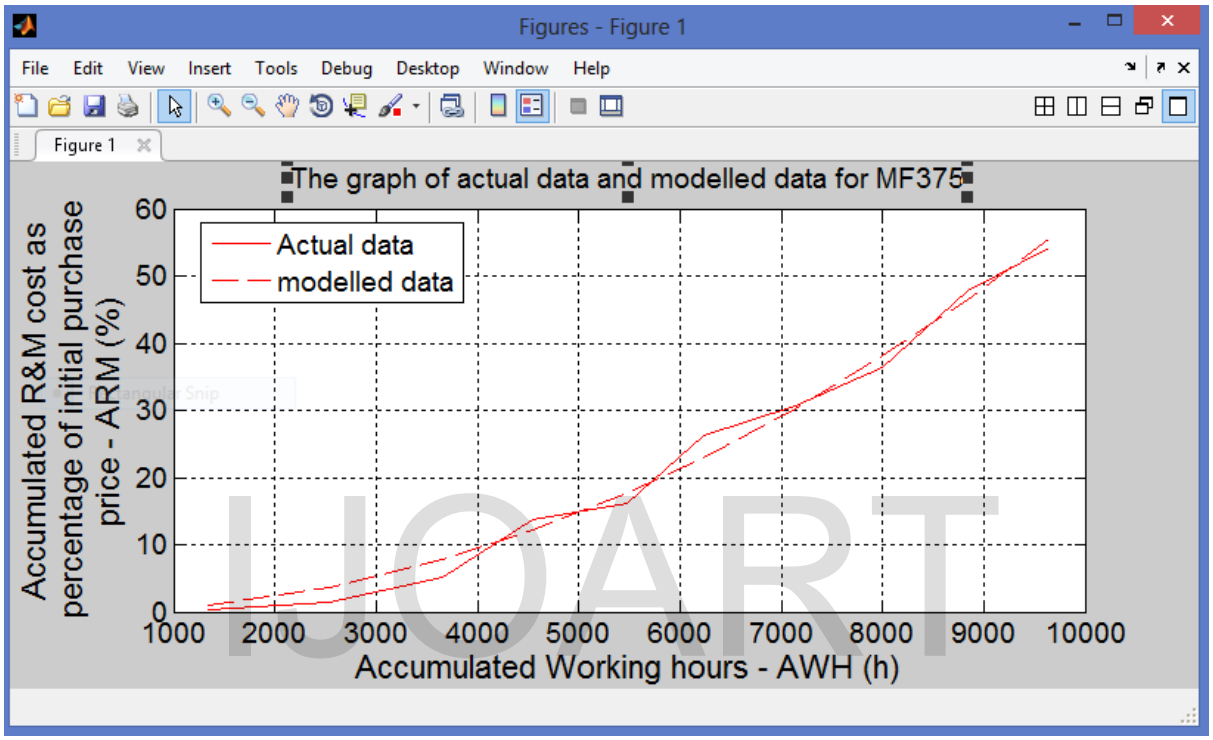

Figure 5: Comparison of Actual Data and Modelled Data for MF375 Tractor

The accumulated repair and maintenance cost of MF375 as percentage of initial purchase price versus accumulated working hours for the actual data and data obtained from the developed models were compared as shown in figure 5. It could be seen that actual data curve and modeled data curve gave almost the same trend. Also, it was observed that the rate of accumulated repair and maintenance costs at earlier life time of MF375 tractors was low and was increasing gradually. However, the increasing rate of repair and maintenance costs may be attributed to quality in the design and manufacturing as well as higher cost of spare parts.

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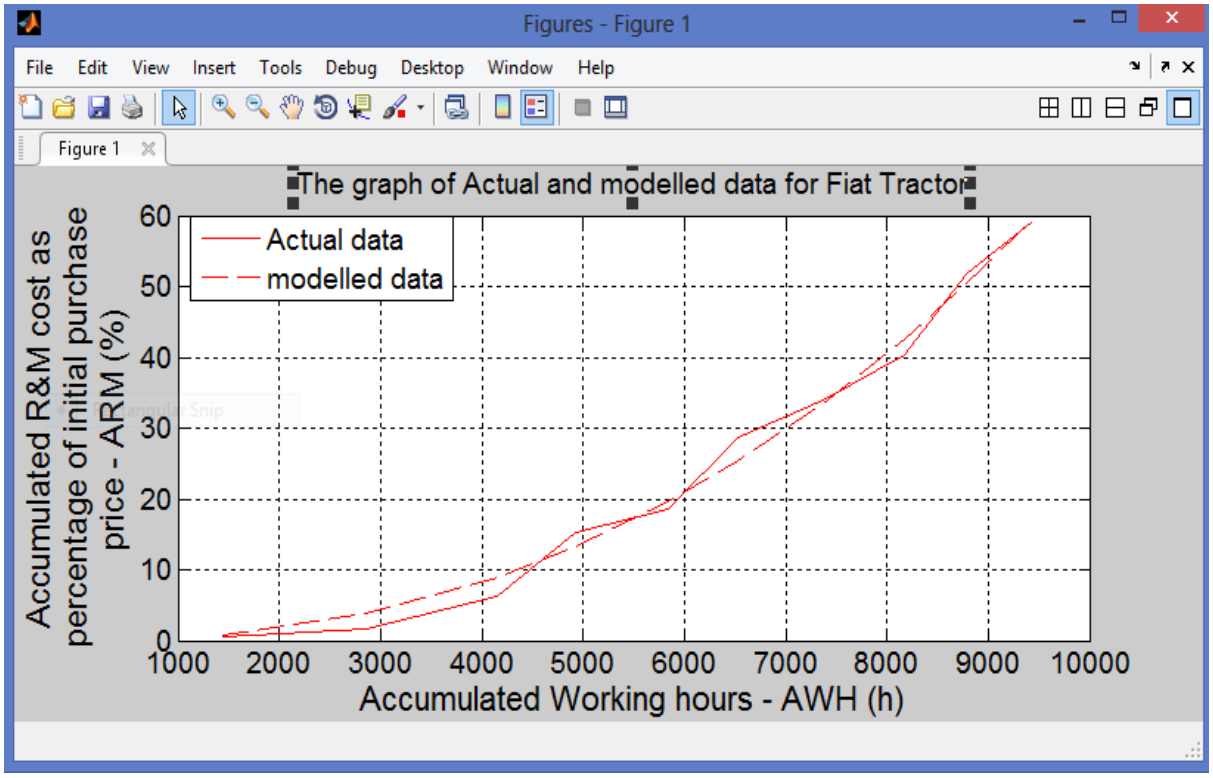

Figure 6: Curve Showing Actual Data and data obtained from the developed Models for Fiat Tractor

Figure 6 show that the actual data and modelled data have very little differences in their curve. It can also be observed that the rate of accumulated R & M cost at earlier life time of tractors was fairly low. The accumulated repair and maintenance cost was fairly low at working hours of 6000h, then increased moderately high above 6000h. The increasing rate of R&M costs could be related to frequent breakdown, inferior production technology and incompatible field operations to their power and efficiencies.

3.2. Percentage Error Determination

It's worthy of note that graphs produced from these developed models, are seen as depicting the ***more accurate*** accumulated repair and maintenance cost (ARM) and accumulated working hours (AWH) for the tractor models studied, when compared with that obtained from the data collected. The little difference as noticed among the two is likely to be as a result of errors inherent in the documentation of the data ranging from input error, biased information, etc.

The magnitude of the errors in terms of percentage was determined as follows:

1.) For MF375 Tractor

$$Error\ (E_M) = M_{acc} - M_{act} \quad \text{.....10}$$

Where, $M_{act} = actual\ data\ for\ MF375$ and $M_{acc} = modelled\ (accurate)\ data$

2.) For Fiat Tractor

$$Error(E_F) = F_{accf} - F_{actf} \quad \text{.....11}$$

Where, $F_{act} = actual\ data\ for\ Fiat$ and $F_{acc} = modelled\ (accurate) data$

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Table 5: Showing the error value obtained by comparing the repair and maintenance cost (ARM) and accumulated working hours (AWH) as a percentage of initial purchase price (%) given by the developed mathematical models and that obtained from the data collected for the studied MF 375 tractor models

Age (Years)	Predicted repair and maintenance cost as a percentage of initial purchase price (%) using power option of the actual data	Predicted repair and maintenance cost as a percentage of initial purchase price (%) using power option of the modelled (accurate) data.	Error (E_M)
1	0.43	1.03	0.6
2	1.46	3.72	2.26
3	5.21	7.81	2.8
4	13.71	12.16	-1.55
5	16.21	17.72	1.51
6	26.21	23.00	-3.21
7	30.71	30.18	-0.53
8	36.46	38.03	1.57
9	47.71	46.52	-1.19
10	54.21	55.41	1.2

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Table 6: Showing the error value obtained by comparing the repair and maintenance cost (ARM) and accumulated working hours (AWH) as a percentage of initial purchase price (%) given by the developed mathematical models and that obtained from the data collected for the studied Fiat tractor model

Age (Years)	Predicted repair and maintenance cost as a percentage of initial purchase price (%) using power option of the actual data.	Predicted repair and maintenance cost as a percentage of initial purchase price (%) using power option of the modelled (accurate) data.	Error (E_F)
1	0.57	0.79	0.22
2	1.58	3.77	2.19
3	6.25	8.94	2.69
4	15.35	13.32	-2.03
5	18.6	19.65	1.05
6	28.64	25.37	-3.27
7	34.06	33.60	-0.46
8	40.31	42.61	2.3
9	51.74	50.48	-1.26
10	59.19	59.53	0.34

From the tables 5 and 6 it can be concluded from the small error values that modelling curve and actual data are almost the same.

4. CONCLUSION

From the foregoing, the following conclusions were drawn:

- That the repair and maintenance cost of Fiat and MF375 tractors as a percentage of initial purchase price (%) in Enugu state can be accurately predicted using the following mathematical model:

$$ARM = 5.097e-7\ (AWH)^{2.017} \quad 12$$

$$ARM = 4.17e-8\ (AWH)^{2.303} \quad 13$$

Equations 12 and 13 for MF375 and Fiat tractors respectively.

- That Fiat and MF375 tractors have very strong positive correlation coefficient of determination.
- That the repair and maintenance cost increased with an increase in working hours for both Fiat and MF375 tractors.

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- That the major determining factor of the repair and maintenance costs of both Fiat and MF375 tractors is their accumulated working hours as could be noticed from its supposed power influence as depicted in the developed model.

- That MF375 tractors should be used more in Enugu state as it has less repair and maintenance cost than the Fiat model, which is confirmable from the recommended equations of 12 and 13.

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