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A STUDY OF FARM TRACTORS RELIABILITY IN KWARA STATE OF NIGERIA



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ABSTRACT

A study of field reliability of farm machinery is highlighted. A field survey was conducted to assess the repair and maintenance facilities and reliability functions from the breakdown records of tractors. The workshop facilities for enhancing tractor reliability consist of technical staff and tools/equipment. The workshop staff consists of engineers, technicians and craftsmen/apprentices and in the ratio 1:2:6 respectively. The commonly owned tools are the basic hand tools. Comparison of the reliabilities of the various tractors revealed that the steering, traction and electrical systems are more prone to failure than the engine, cooling, transmission, fuel and hydraulic systems. The Massey Fergusson and Fiat tractors proved to be more reliable tractors in the state.

Keywords: Reliability, Repair, Maintenance.

1. INTRODUCTION

Farm tractor is a major element of farm mechanisation in Nigeria. Its versatility and high efficiency have made it suitable for most field and barnyard operations. However, the need for high management skills and susceptibility of tractors to breakdown have made its maintenance very imperative. Timeliness in farm operations is a crucial factor for successful agricultural operations. Farm tractors failure especially during the busiest part of the season cause delays which result in losses and inefficient labour utilisation. As more and more capital in the form of machinery replaces manual labour on the farm, the reliability of this equipment assumes greater importance. Indeed, deeper insight into failures and their prevention is to be gained by comparing and contrasting the reliability characteristics of systems that make up the tractor. Reliability is defined as the probability that the equipment or system will complete a specific task under specified conditions for a stated period of time (Amjad and Chaudhary, 1988). Hence, reliability is a mathematical expression of the likelihood of satisfactory operation. A failure may be referred to as any condition which prevents operation of a machine or which causes or results in a level of performance below expectation. The failure rate of a population of items for a period of time t_1 to t_2 is the number of items which fail per unit time in that period expressed as a fraction of the number of non-failed items at time t_1 . Hence, in reliability, the reciprocal of failure rate is the mean time between failures [MTBF] (Wingate-Hill, 1981). Amjad and Chaudhary (1988) reported that machine failures can be categorised into: early life failures, random failures and wear-out. Likewise, Lewis (1987) asserted that reliability considerations appear throughout the entire life cycle of a system. He claimed that data collection on field failures are particularly invaluable because they are likely to provide the only estimate of reliability that incorporates the loading, environmental effects and imperfect maintenance found in practice. At both component and system levels, such a database is invaluable for predicting the reliability of future design and for improving design. Owing to the importance of timeliness of operations in obtaining high yields, machinery breakdown especially at busy period such as sowing or harvest can lead to large losses of revenue quite apart from the cost of repairing the equipment. If estimates could be made of when equipment is likely to fail, this would assist in planning machinery purchases and spare parts inventories and reduce costs.

1.1 Objectives

- 1) To collate data on repair and maintenance facilities and failure of farm tractors.
- 2) To estimate reliability of farm tractors during its operating life.

This will help in assessing the suitability of imported tractors to Nigeria. Necessary steps can therefore be taken to make these imported tractors more reliable.

2. LITERATURE REVIEW

Farm tractors must be maintained and kept in good repair condition if they are to render efficient service (Beppler and Hummeida, 1985). An important design parameter which deals with minimization of repair time and which is often affected by the skills of the operator is machinery maintainability (Oni, 1987). Many of the establishment in Kwara state keep logbooks for repair and maintenance but little attempt has been made to collate the scattered and scanty data so as to further focus on repair and maintenance needs (Adigun, 1987). He also claimed that the failure in the farm tractors components could be classified into the following categories: Engine, Cooling, Fuel, Electrical, Transmission, Hydraulic, Steering and Traction. Archer (1963) described the problems of reliability prediction in terms of varying farm conditions under which a particular machine is designed to work. Hunt (1971) reported the results of a survey for the incidence of breakdown, lost time and repair costs experienced by farmers growing maize and soybeans. His study included the probabilities of breakdown for various machines depending on age and use, and concluded that an average farmer has less than a 50-50 chance of through the season without a breakdown that has timeliness cost associated with it. Hollenback (1977) applied reliability method to combine in both pre and post production operation. Wingate-Hill (1981) gave the exponential model for analysis of reliability data. It was assumed that the failure rate is constant over the entire life of equipment.

$$R(t) = \exp - (\lambda t) \quad (1)$$

Where $\exp$ = base of Naperian logarithm
 λ = failure rate (per month)
 t = time between successive failure (months).

However, Leitch (1988) gave the following disadvantages on the use of exponential model:

- 1) With only one parameter (i.e. λ) to vary, the data is not always a good fit to the model.
 - 2) It assumes that the equipment does not age i.e. the probability of failure in the interval from time 't' until $(t + x)$ depends only on x , the length of the interval and not on 't' the age of the equipment. In addition, Wingate-Hill (1981) disclosed that reliability data may not be exponentially distributed. As such, he recommended the use of the versatile three-parameter Weibull failure model in conjunction with median ranking for greater accuracy.
- Amjad and Chaudhary (1988) used Weibull failure model to apply reliability theory to farm machinery with special reference to mechanical reaper. It was claimed that the Weibull failure model is very basic and applicable to all farm machines such as combines, tractors etc. The Weibull cumulative density function (Cdf) or failure function was given as

(2)

Where $\exp$ = base of Naperian logarithm.
 α = scale parameter (months)..
 β = shape parameter or Weibull slope (ratio).
 γ = location parameter or lower bound of life (months)..
 t = time between successive failure (months)..

They disclosed that in the case of farm machinery, the first failure can be expected as soon as the machine is placed in service. Hence, the lower bound of the life or location parameter (γ) is zero. Thus $\gamma = 0$ and the Weibull cumulative density function becomes

$$F(t) = 1 - \exp - \left[\frac{t}{\alpha} \right]^{\beta} \quad (3)$$

The reliability function $R(t)$ was therefore given as

$$R(t) = 1 - F(t) \quad (4)$$

$$R(t) = \exp - \left[\frac{t}{\alpha} \right]^{\beta} \quad (5)$$

Therefore, the time between failures is:

$$t = \alpha \left[- \ln R(t) \right]^{\frac{1}{\beta}} \quad (6)$$

For the estimation of α and β (Weibull parameters) simple regression analysis was used. This method is based on the fact that the reliability function of Weibull distribution can be transformed into a linear function of $\ln t$ by means of double logarithmic transformation. Taking the natural logarithm twice of both sides of equation (3) gives:

$$\ln \left[\ln \frac{1}{1 - F(t)} \right] = \beta \left[\ln t - \ln \alpha \right] \quad (7)$$

$$\Rightarrow \ln t = \frac{1}{\beta} \left[\ln \left[\ln \frac{1}{1 - F(t)} \right] \right] + \ln \alpha \quad (8)$$

This is of the form $Y = Mx + C$

Where $M = 1/\beta$ (Slope of the linear equation)

$C = \ln \alpha$ (Intercept of the linear equation)

It was claimed that the Weibull model provide considerable flexibility in describing failure distribution. That is, upon setting $\beta = 1$, equation (3) becomes exponential distribution with a delay (which can be thought of as a guarantee period within which no failure can occur or a minimum life). Thus, the assumption of a constant failure rate (exponential model) is also included as a special case in this Weibull failure model. Both Wingate-Hill (1981) and Amjad and Chaudhary (1988) pointed out that reliability of a machine is a product of the individual component's reliability. If the engine, transmission, tyre and steering have reliabilities of 0.85, 0.95, 0.98, & 0.95 respectively for a specified condition, then the reliability of the tractor as a whole is $0.85 \times 0.95 \times 0.98 \times 0.95 = 0.75$.

The reliability studies done so far on farm tractor have not been concentrated on reliability of farm tractor during usage. Also, statistical analysis approach has not been applied on farm tractor reliability. It is however necessary to do thorough reliability study of farm tractors which will assist in setting standards for the farm tractors that are suitable and reliable.

3. MATERIALS AND METHODS

A questionnaire was designed to collect data on such items as: technical staff strength, available tools and equipment of repair and maintenance workshops, time between successive failures of each of the systems of the tractor. The tractor systems considered were engine, transmission, hydraulic, steering, electrical, traction, cooling and fuel. A total of twenty-six organizations responded to the questionnaire (Table 1). The organizations were well spread all over Kwara state. Forty-five tractors were surveyed and they were all still serviceable. They had covered a period of operation ranging from thirty to one hundred and thirty-six months. They were used for tillage, haulage and stationary barn yard operations. The data obtained from time measurement was compiled and used to quantify reliability. This data was grouped into class intervals analysed by using median rank equation and

regression analysis equation in conjunction with Weibull model. The time between successive failures data for each system of each tractor make was analysed to obtain the Weibull parameters (α and β) and the time between successive failures at a set reliability of each system. Also, the data for each system of all tractors irrespective of the make was analysed to obtain the overall Weibull parameters and the overall time between successive failures at a set reliability of each system. Likewise, the Weibull parameters and the time at a set reliability of each tractor as a whole were obtained.

4. RESULTS AND DISCUSSIONS

A total of thirty establishments comprising government, privately owned repair workshops were visited (Table 1). The results of the survey on the facilities of repair and maintenance are presented on Tables 2, 3 and 4. The data collected was analysed to obtain the average relative percentage of the workshop technical staff and tools/equipment. Table 3 indicates that the bulk of the workshop technical staff are the craftsmen and the technicians consisting of 36.2 % and 25.4 % respectively. They form a total of 61.6 % of the workforce and they are the main skilled workers that are physically engaged in the repair work in the workshops. Their figure is closely followed by 27.5 % for the apprentices. The engineers form 10.9 % and the least percentage of the workforce. Although, craftsmen form the highest percentage of the technical staff strength, their competence and proficiency are still questionable because not all of them have procured the final stage certificate of the recognised national trade test. The apprentices who are still under training form the second highest percentage of the workforce. Table 4 presents the relative percentages of the workshop tools/equipment. It reveals that the largest percentages of the tools are the spanners, hand files, chisel and pliers which are the basic hand tools. However, the special tools like hydraulic press, tap and die, torque wrench, pulley extractor etc which facilitates precision and accuracy of the work are lacking. The few ones are mostly available in the government establishments. Hence, most of the skilled workers in the private workshops lack the knowledge of usage of these special tools. It was also gathered that the high cost of purchasing the special tools has contributed to their non-availability. This situation could no doubt have affected the reliability of tractors. Despite the fact that there are comparatively enough skilled workers in the repair workshops, they lack the requisite special tools and genuine spare parts to enhance the repair and maintenance of the tractors. All the workshops visited complained of lack of genuine spare parts for repair and maintenance of the farm tractors. According to them, they are sometime forced to buy fairly used spare parts which tend to further affect the reliability of farm tractors. The time record collated from both breakdown and repair logbooks were analysed to obtain the Weibull scale parameter, α and shape parameter, β . These α and β are the basic parameters in the reliability function given by equation 5. Since reliability can assume values between 0 and 1 (i.e. 0 % and 100 %), the time between failures at which a system will have a reliability value of 50 % or 0.5 was calculated using the Weibull parameters in the Weibull model. Thus, the time between failure at 50 % reliability its general function

Table 1. List of the Establishments that responded to the questionnaire.

<i>S/n</i>	<i>Government owned Organizations</i>
1	Ministry of Agriculture and Natural Resources, Ilorin.
2	National Centre for Agricultural Mechanisation, Idofian.
3	National Agricultural Land Development Authority, Ilorin.
4	National Youth Service Corps Headquarters, Ilorin.
5	Lower Niger River basin Development Authority, Ilorin, Oke-Oyi, Tsonga, Omu-Aran and Erin-Ile stations.
Commercial / Privately owned Organizations	
1	Babarinsa Farms, Ilaga Village, Ilorin.
2	Diskabog Farms, Oko-Olowo, Ilorin.
3	Kinsley farms, Bakasse via Ilorin.
4	Paraclete Agric Services, Ilorin.
5	Akande Farms, Idofian.
6	Gari Okin Farms, Ilorin.
7	Oladele Farms, Shao.
8	Koshoni-Ola Farms, Oro.
9	Young Farmers Club, Patigi.
10	Buky Agro-allied Services, Ilorin.
11	Darols Farms, Ltd, Ilorin.
12	Deltroit Farms, Ilorin.
Repair Workshops	
1	Lower Niger River basin Development Authority, Ilorin, Oke-Oyi, Tsonga, Omu-Aran and Erin-Ile stations.
2	Ministry of Agriculture and Natural Resources, Ilorin.
3	National Centre for Agricultural Mechanisation, Idofian.
4	Jossy Auto-plant Engineering Works, Ilorin.
5	Aalco General Auto-plant Engineering Works, Ilorin.
6	In God We Trust Engineering Works, Ilorin.
7	Yabo Amana Engineering Workshop, Ilorin.
8	Koshoni-Ola Farms Workshop, Oro.
9	Nda Tractor Repair Workshop, Patigi.

Table 2. Frequency table of time between failure of systems of selected tractor makes.

Massey Fergusson			Fiat			Steyr			Ford			Overall		
CI	CM	Fr	CI	CM	Fr	CI	CM	Fr	CI	CM	Fr	CI	CM	Fr
E N G I N E														
40-44	42	5	30-34	32	18	20-24	22	10	14-16	15	19	10-14	12	10
45-49	47	3	35-39	37	13	25-29	27	8	17-19	18	8	15-19	17	17
50-54	52	2	40-44	42	5	30-34	32	2	20-22	21	3	20-24	22	13
												25-29	27	8
												30-34	32	20
												35-39	37	13
												40-44	42	10
												45-49	47	3
												50-54	52	2
H Y D R A U L I C														
20-24	22	7	19-23	21	23	16-20	18	10	15-19	17	11	15-19	17	30
25-29	27	5	24-28	26	18	21-25	23	7	20-24	22	7	20-24	22	41
30-34	32	6	29-33	31	8	26-30	28	3	25-29	27	2	25-29	27	25
35-39	37	2	34-38	36	3							30-34	32	14
												35-39	37	2
S T E E R I N G														
9-13	11	11	13-17	15	21	9-13	11	19	9-13	11	15	9-13	11	50
14-18	16	9	18-22	20	18	14-18	16	14	14-18	16	13	14-18	16	57
19-23	21	6	23-27	25	15	19-23	21	3	19-23	21	3	19-23	21	28
24-28	26	7	28-32	30	7							24-28	26	20
29-33	31	4										29-33	31	10
T R A N S M I S S I O N														
15-19	17	7	16-20	18	20	11-15	13	17	11-15	13	17	11-15	13	36
20-24	22	5	21-25	23	18	16-20	18	9	16-20	18	10	16-20	18	47
25-29	27	5	26-30	28	14	21-25	23	4	21-25	23	3	21-25	23	27
30-34	32	3	31-35	33	2							26-30	28	21
35-39	37	2										31-35	33	4
40-44	42	1										36-40	38	1
45-49	47	1										41-45	43	2
F U E L														
39-43	41	5	35-39	37	11	31-35	33	6	16-20	18	10	16-20	18	10
44-48	46	3	40-44	42	9	36-40	38	3	21-25	23	8	21-25	23	8
49-53	51	2	45-49	47	6	41-45	43	1	26-30	28	2	26-30	28	2
			50-54	52	2							31-35	33	8
												36-40	38	15
												41-45	43	13
												46-50	48	8
												51-55	53	4
C O O L I N G														
25-29	27	8	19-23	21	23	10-14	12	17	15-19	17	9	16-20	18	10
30-34	32	6	24-28	26	14	15-19	17	11	20-24	22	8	21-25	23	8
35-39	37	1	29-33	31	11	20-24	22	4	25-29	27	3	26-30	28	2
			34-38	36	3							31-35	33	8
												36-40	38	15
												41-45	43	13
												46-50	48	8

												51-55	53	4
T R A C T I O N														
NOT AVAILABLE	11-15	13	25	10-14	12	17	10-14	12	16	10-14	12	51		
	16-20	18	18	15-19	17	9	15-19	17	9	15-19	17	40		
	21-25	23	16	20-24	22	4	20-24	22	5	20-24	22	23		
	26-30	28	10							25-29	27	15		
E L E C T R I C A L														
11-15	13	16	11-15	13	28	10-14	12	17	10-14	12	17	10-14	12	72
16-20	18	10	16-20	18	24	15-19	17	11	15-19	17	11	15-19	17	57
21-25	23	7	21-25	23	13	20-24	22	2	20-24	22	2	20-24	22	26
26-30	28	4	26-30	28	7							25-29	27	14
CI = Class Interval (months)			CM = Class Mark (months)			Fr = Frequency								

Table 3. Technical Staff Distribution

Staff Category	Qualification	Total	Average per Establishment	Percentage
Engineer	B.Eng./ HND	15	1.2	10.9
Technician/ Technologist	OND/ C & G	35	2.7	25.4
Craftsmen	Trade Test	50	3.8	36.2
Apprentices	Pry/Sec. Sch.Cert.	38	2.9	27.5
Total		138	10.6	100.0

Table 4. Workshop Tools Available

	Tools	Total	Average per Establishment	Percentage
1	Set of Spanners	114	8.8	21.1
2	Set of Screwdrivers	46	3.5	8.5
3	Hammer	35	2.9	6.5
4	Torque Wrench	22	1.7	4.1
5	Chisel/ Punches	56	4.3	10.4
6	Pliers	45	3.5	8.3
7	Cranes	21	1.6	3.9
8	Hydraulic Press	7	0.5	1.3
9	Tap & Die (Set)	11	0.8	2.0
10	Ring Compressor	35	2.7	6.5
11	Grinder	13	1.0	2.4
12	Drills	18	1.4	3.3
13	Hydraulic Jack	38	2.9	7.0
14	Files	64	4.9	11.8
15	Pulley Extractor	16	1.2	3.0
	Total	541		100.0

$$t = \alpha \left[-\ln R(t) \right]^{\frac{1}{\beta}} \quad \text{becomes} \quad t_{50} = \alpha \left[-\ln (0.5) \right]^{\frac{1}{\beta}} \quad (9)$$

The significance of the time between failure 50 % reliability (t_{50}) is that it is the time between failure at which a system has a 50 - 50 chance of failure. The various Weibull parameters and the time between failures at 50 % reliability are shown in Table 5. From Table 5, it can be deduced that the engine of Massey Fergusson tractor is the most reliable with a 50 % reliability of 46.57 months. The least reliable is that of Ford tractor with a 50 % reliability time between failures of 16.54 months. The steering system of Fiat tractor showed the highest t_{50} value of 20.86 months. Generally, on all the tractor systems pulled together, fuel system showed the least tendency to failure because it has the highest t_{50} value of 35.28 months compared to other systems. It is closely followed by the engine with t_{50} value of 27.96 months. The steering, electrical and traction systems are the least reliable systems with average t_{50} value of 16.96 months. Taking the tractor as a whole, Massey Fergusson and Fiat tractors are relatively more reliable than the Steyr and Ford tractors. This is in agreement with the reports of Adigun (1987), that Fiat and Massey Fergusson tractors show low incidence of breakdown in Kwara State. Figure 1 shows the reliability function of the tractor makes. It can be deduced from the figure that Massey Fergusson tractor is the most reliable tractor. It has the smallest slope on the reliability curve. It is followed by Fiat tractor. Then Steyr tractor while the least reliable is the Ford tractor.

5. CONCLUSION

The study conducted an investigation to assess the repair and maintenance facilities and reliability functions from the breakdown records of tractors. It revealed that the workshop staff consists of engineers, technicians and craftsmen/apprentices and in the ratio 1 : 2 : 6 respectively. The commonly owned tools are the basic hand tools. Some of the problems of repair and maintenance of tractors in the state are unavailability of genuine spare parts, few or lack of special repair and maintenance tools and improper record keeping habits etc. Also, comparison of the reliability of the tractors showed that traction, steering and electrical systems have higher tendency to failure than the cooling, transmission, engine, fuel and hydraulic systems. The Massey Fergusson and Fiat tractors were found to be comparatively more reliable tractors in the state.

Table 5. Weibull Parameters and * t_{50} of Tractor makes

Tractor System	Massey Fergusson			Fiat			Steyr			Ford			Overall		
	α	β	t_{50}	α	β	t_{50}	α	β	t_{50}	α	β	t_{50}	α	β	t_{50}
Engine	48.35	9.78	46.57	37.26	8.18	35.62	27.16	6.12	25.58	17.57	6.08	16.54	31.75	2.88	27.96
Hydraulic	30.59	5.15	28.49	27.50	4.88	25.51	23.41	4.93	21.73	21.83	4.71	20.19	25.87	4.36	23.78

Steering	21.61	2.70	18.86	22.93	3.88	20.86	15.46	3.56	13.94	15.82	3.62	14.30	19.79	2.91	17.45
Trans- mission	30.21	3.00	26.74	25.04	4.74	23.17	17.68	3.64	15.98	17.47	3.78	15.86	23.36	2.98	20.66
Fuel	47.35	9.56	45.57	44.65	7.86	42.61	38.22	7.75	36.45	22.77	5.01	21.16	39.31	3.39	35.28
Cooling	32.01	7.24	30.43	27.74	4.74	25.67	16.78	3.58	15.14	22.64	4.97	21.03	24.99	3.51	22.51
Traction	NOT AVAILABLE			21.03	3.31	18.83	16.65	3.42	14.96	14.04	3.42	15.30	19.12	3.14	17.01
Electrical	20.17	3.18	17.97	20.08	3.42	18.04	16.24	3.70	14.71	16.24	3.70	14.71	18.41	3.19	16.41
Whole Tractor	29.35	2.82	25.78	27.56	2.96	24.36	21.61	3.36	19.38	18.66	4.94	17.33	26.13	3.31	23.39

* t_{50} : Time between failures at 50 % reliability

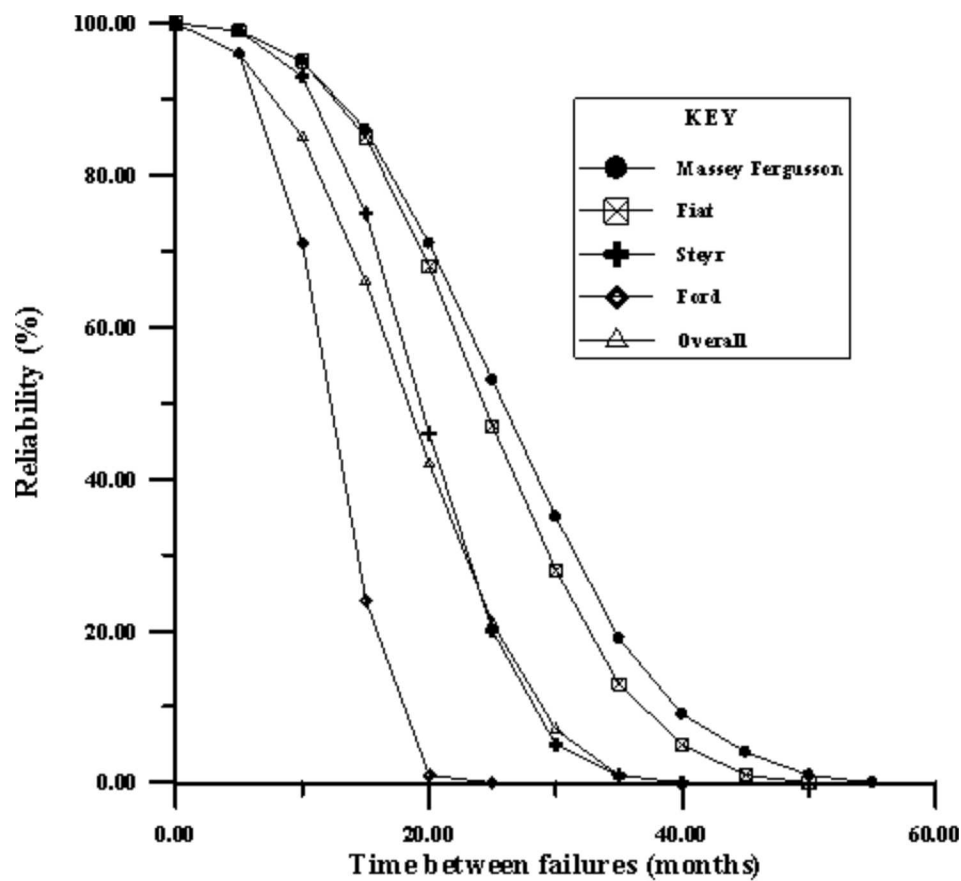


Figure 1. Reliability function of selected tractor makes

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