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Predicting Failure Rate in Different Maintenance Conditions for MF 399 Tractor, a case study in southern parts of Iran

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ABSTRACT

The use of tractors for agricultural works showed an important role to mechanized agricultural sector. A repairable mechanical system (as agricultural tractor) is subject to deterioration or repeated failure. In this study, the regression model was used to predict the failure rate of MF399 tractor. The machine failure pattern was carefully studied and key factors affecting the failure rate were identified in five regions of Khouzestan province. Results showed that different annual use hours (AUH) and maintenance policies affected failure rate. According to the data, the MF399 tractors included in 300-1000 AUH were commonly in a randomized breakdown period during their useful life but these tractors tend to enter the wear out period in the 1200-2000 AUH.

Introduction

Today, Tractor is one of the most important power sources in agriculture and represents a major component of farm fixed costs with its main share in planting, retaining and harvesting operations and then in mechanization sector (Sonekar and Jaju, 2011 and Asadi et al., 2011). For modern farming, for example, it makes up as much as 40% of the total investment (Henderson and Guericke, 1985). The success of the investment depends greatly on operating costs, which, in turn, are influenced greatly by the quality of repair and maintenance. Rahmoo et al. (1979) stated that the economic benefits from a tractor depend upon the efficient manner of its use. Therefore, tractor should be maintained correctly to ensure effectively working for a long period without any breakdown and thus provide a much benefit to its owners. A tractor that breaks down and must be prematurely replaced incurs large expenses and wastes the investment. From an economic point of view, idleness due to machinery breakdowns can be very costly as a result of lost working time (Jacobs et al, 1983). Repairs of broken down machines are also expensive (Hunt, 1971), because the breakdowns consume resources; manpower, spare parts, and even lose of production (Dodson, 1994). Consequently, the repair costs become an important component of the total machine ownership costs (Ward, 1985). As an example, in developing countries approximately 53% of total machine expenses have gone to repair machine breakdown as compared to 8% in developed countries (Inns, 1978), that these costs could be decreased up to 50% by establishing the effective repair and maintenance program (Khodabakhshian kargar et al., 2008). Since, in this paper failure rate versus accumulated use hours of tractor were modeled according to the exponential relationship of regression in four groups using AUH and maintenance program.

Material and Methods

The experiment was conducted in Khouzestan province, one of the arid and semiarid agricultural region in southwest of Iran. Khouzestan province located at latitude of 29° 58′ to 33° 4′ N, and longitude of 47° 31′ to 50° 39′ S. Data was collected from agricultural mechanization service enterprises in 2012. The five regions including Andimeshk, Dezful, Shush, Ahwaz and Behbahan were selected for this research. These locations were selected specifically to represent the main tractor operational conditions faced in Khouzestan province. Sixty seven tractors and their owners were selected for sample. The corrective maintenance (CM) and preventive maintenance (PM) were considered in different grouping. All tractors were used in the same operating environment. Since, the repair – maintenance policies of the machinery during the year was selected as an effective factor. The relationship between failure rate and accumulated use hours of tractor were graphed and analyzed in regression analysis according to the following subgroups:

1) 300 to 1000 AUH / PM (14 machines)
2) 300 to 1000 AUH / CM (19 machines)
3) 1200 to 2000 AUH / PM (12 machines)
4) 1200 to 2000 AUH / CM (25 machines)

Failure rate (λ) was equal to the reciprocal of the mean time between failures (MTBF) defined in hours, and its equation was as follows (Tufts, 1985; Billinton and Allan, 1992):

$$\lambda = \frac{1}{\text{MTBF}}$$

Where: λ: failure rate

MTBF: Mean time between failures

The exponential function which is one of the most common distributions in the evaluation of failure rates was applied for analyzing data (Kumar and Gross, 1977; Billinton and Allan, 1992). For this reason, this distribution applied.

Failures, in general, can be categorized into three basic types, though there may be more than one contributing cause for a particular failure. The three types are 1) early failures 2) random failures and 3) wear out failures. Early failures are those that occur due to some defect in the part or the assembly resulting from a design, manufacturing, or inspection deficiency. During the random failure period, the failure rate is usually a constant failure rate. The failures are due to a random

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occurrence of environmental stress levels sufficiently severe enough to cause component failures. This period in the life of components is also known as “useful life period.” The wear out period is characterized by an increase in failure rate due to the degradation of parts with age. The relationship of these three failure classes is shown in Figure 1 (Kumar and Gross, 1977).

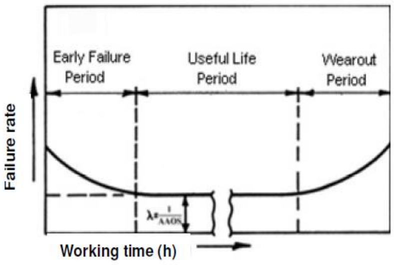

Figure 1. Failure rate curve (bath tube) for an ideal machine or machine part

Results and Discussion

Table 1 presents failure types and their distribution in different systems of the MF399 tractors included engine, hydraulic, transmission, electrical, brakes, steering, fuel, cooling, etc (tyre, ring, ball bearing and operator seat) as a percentage of total failures data derived from farm records. As indicated, the electrical system caused the majority of recorded failures, 20.3%. Also, the electrical system failures made up the majority in each machine sub-group. The reasons for the electrical system failures generally were due to short life of the battery and dynamo in this type of tractor.

The average annual use hours and average age are presented in Table 2. As depicted in the table, the average AUH for 300-1000 and 1200-2000 main groups were 753.03 and 1445.73, respectively. The average age for all sub-groups was almost near each other. The machine number in the CM sub-groups in the both main groups were higher than that of the PM. That it was due to most operators in the province, kept their tractors in the CM conditions. Some descriptive statistics of failures data in given sub-groups are summarized in Table 3. Average failure numbers calculated in the CM groups and also for 1200-2000 groups were higher than the PM and 300-1000 groups, respectively. The maximum and the minimum values of the failure numbers for the 1200-2000 CM sub-group were most. The average failure rates calculated in Table 4 specified the effects of the annual working hours and maintenance conditions. As indicated, the average failure rate values in the 1200-2000 sub-groups were higher than the 300-1000 sub-groups. Additionally, these values in the CM sub-groups were most of the PM sub-groups. Therefor, it seems that the PM conditions of the machinery decreased the failure occurrence frequency. Failure rates versus accumulated use hours of tractors were modeled according to the exponential relationship of regression. Because of, this modeling gave the highest R^2 by comparisons of each sub-group to other regression models. The relationship between the calculated failure rate and the accumulated use hours of tractor for each sub-group with their equations are given in figures 2, 3, 4 and 5. Predicted failure rate in the 1200-2000 and CM sub-groups were higher than that the 300-1000 and PM sub-groups, respectively. It showed the AUH and type of maintenance conditions slightly affected MF399 tractor failure rate.

According to the Figure 2 pattern, MF399 tractors in the 300 to 1000_{PM} sub-group were mostly in the useful life period. The randomized failure period, with a mean time between failures value of 132.21 h, is valid due to a proper maintenance conditions and a slightly decreased accumulated use hours comparison to the 300-1000_{CM} sub-group. As Figure 3 indicates, there is a general trend that fits the exponential relationship towards the wearing out period of machine life for the 300 to 1000_{CM} sub-group. Additionally, MF399 tractors working under given conditions at 14000 accumulated use hours were almost in the beginning of wear-out period with a mean time between failures value of 100.93 h. In the 1200-2000_{PM} sub-group with a mean time between failures value of 87.48 provides an obvious indication of wear-out period entrance based on the exponential regression model (Figure 4). Lastly, the relationship between failure rates versus accumulated use hours for the 300 to 1000_{CM} sub-group was depicted in Figure 5. It shows that MF399 tractors in this sub-group tend to enter the wear-out period with a mean time between failures value of 78.37 h. Machines in the 1200 to 2000 AUH main group were obviously in a nearer position to the wear-out period, than that of the 300 to 1000 AUH main group, since increased AUH have an effect on failure frequency increase. Timely preventative maintenance and inspection will not only help reduce major problems and downtime, it will also help identify problems when they can be corrected with relatively minor repairs (Grisso and Pitman, 2009). Aneke (1994) and Amari et al. (2006) reported that poor maintenance caused the major failures.

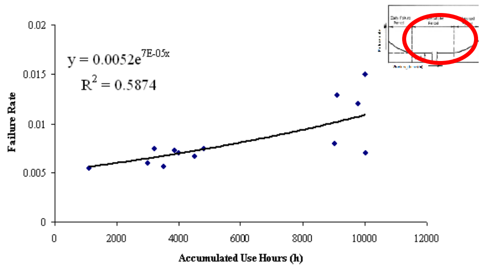

Figure 1. Calculated failure rate vs accumulated use hours of tractor for 300-1000_{PM} subgroup

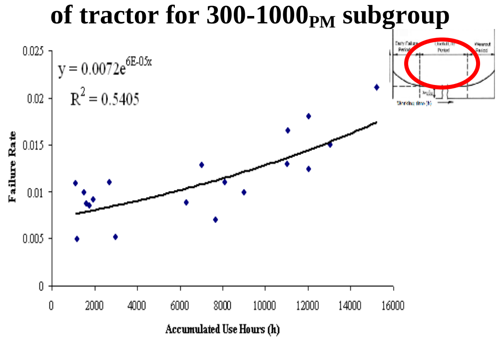

Figure 2. Calculated failure rate vs accumulated use hours of tractor for 300-1000_{CM} subgroup

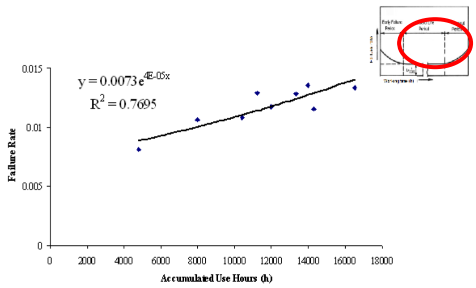

Figure 3. Calculated failure rate vs accumulated use hours of tractor for 1200-2000_{PM} subgroup

Table 1. Failure types and their distribution

Failure types	Failure numbers				Total	%
	1	2	3	4		
Engine	10	22	12	61	105	11.64
Hydraulic	19	18	10	59	106	11.75
Transmission	9	17	25	62	113	12.52
Electric	24	40	27	92	183	20.3
Brake	2	6	11	22	41	4.54
Steering	4	9	10	24	47	5.21
Fuel	4	16	16	32	68	7.54
Cooling	6	19	20	84	129	14.3
etc	8	27	18	57	110	12.2
Total	86	174	149	493	902	100

Table 2. Some descriptive data related use hours for given sub-groups

Sub group	Average AUH (h)	Average age (year)	Number of machines
1	721.428±59	7.64±0.85	14
2	776.31±47.35	8.47±1.32	19
Average/ Total	753.03±36.73	7.81±0.7	33
3	1420.22±49.08	8.33±0.91	9
4	1465.2±41.01	8.96±0.57	25
Average/ Total	1453.42±32.65	8.79±0.48	34

Table 3. Some descriptive statistics of failures encountered in given sub groups

Sub group	Number of failures			
	Min	Max	Average	Total
1	3	15	6.14±0.9	86
2	3	20	9.16±1.14	174
Average/ Total	3	17.5	7.87±0.79	260
3	13	21	16.55±0.93	149
4	13	32	19.72±1.18	493
Average/ Total	13	26.5	18.88±0.93	642

Table 4. Average failure rates and mean time between failures for sub-groups

Sub group	Average failure rate	Mean time between failures (h)
1	0.0082±0.00077	132.21±9.34
2	0.0113±0.00094	100.93±9.23
Average/ Total	0.0093±0.00056	114.2±7.08
3	0.0117±0.0006	87.48±5.08
4	0.0134±0.00064	78.37±3.36
Average/ Total	0.013±0.0005	80.78±2.86

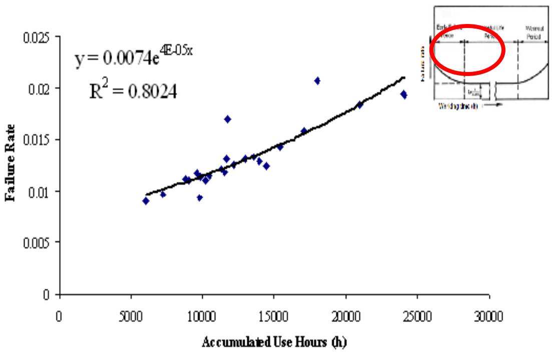

Figure 4. Calculated failure rate vs accumulated use hours of tractor for 1200-2000$_{CM}$ subgroup

Conclusion

The highest profit is the ultimate goal of any farming firm. The effective management of agricultural machinery (specifically tractor) is one of the most critical factors for achieving this goal. Appraisal of failure rate models for farm machinery is important to decide for accurate estimating the required spare parts and to decrease extra repair and maintenance costs caused by delaying during the repair time. In accordance with the data obtained from this study and as the coefficients in the calculated equations shows, it can be emphasized that increase in AUH and CM conditions increased the failure rate values. But, the effect of AUH on the failure rate values was more obvious than the maintenance conditions. The results of this paper give a new approach for all tractor operators and farmers.

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