Using Condition Monitoring to Estimate Repair and Maintenance Costs of Tractors in Iran

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Abstract: One of the most aspects of managing of agricultural machinery is control and estimating of repair and maintenance costs. So, this is necessary to introduce mathematical methods to define repair time and machine condition. It reduces repair costs and increases the chance of machine service. In this research, condition monitoring was established to introduce this mathematical model for tractors in Iran. The study was done on MF285 and MF399 as the most conventional tractors in Iran. 120 tractors were selected randomly and their repairing and maintenance costs as well as working time were recorded. The costs for usual methods and control monitoring methods were compared by F test in SPSS software. Results show that the effects of CM can reduce costs in comparison with usual method significantly (Sig=0.002). Finally by assuming cumulative working time (X) as independence and cumulative costs based on definite percent of initial price (Y) as dependence variable a mathematical model was introduced. Powered regression introduced this model as $Y=0.0028\ X^{0.981}$ which can used to estimate repairing and maintenance costs for selected tractors.
[Ahmad Mohammadi, Morteza Almasi, Alireza Masoudi, Saeed Minaei, Hamid Mashhadi Meighani. Using Condition Monitoring to Estimate Repair and Maintenance Costs of Tractors in Iran. Journal of American Science 2011;7(5):227-231]. (ISSN: 1545-1003). http://www.americanscience.org.

Key words: Condition monitoring, Tractor, Repair and maintenance, Model

1. INTRODUCTION

With regard to the importance of technical and economical management in agriculture sector and control costs in the production fields, our knowledge about the present situation in different parts of these sections plays a major role. Using of agricultural machinery is of the most important parts in this section and investment in this field causes the highest cost of production processes (Ward, Nulty & Cunney, 1985). Therefore machinery management including control of the amount of expenditures related to maintenance and repair machinery is one of the most important parameter that a manager must make do with it.

Today, tractor is one of the most important power sources in agriculture. Effect of tractor power on agriculture is considerable (Rotz, 1987). Good machinery management yields 25% less machinery repair cost .poor machinery management yields 25% greater repair costs. (Singh, 2006). Machinery costs fit into two broad categories:

Fixed costs - Those costs associated with how long a machine is owned, rather than how much it is used. Fixed costs represent more than one-half of the total cost of owning a piece of machinery.

Operating costs - Those costs associated with the amount of machine use (Rotz & Bowers, 1991). Precise information and close to the reality about the time and the type of ravages for agricultural machines plays an important role in programming to do preventive repairs and increases the reliability of machines and implements. There are three types of maintenance tasks: breakdown, corrective and preventive. The principal difference in these occurs at the point when the repair or maintenance task is implemented. In BM[1], repairs do not occur until the machine fails to function. Preventive and corrective maintenance tasks are implemented before a problem is evident (Mobley, 2008). The difference between them is that in corrective maintenance a problem must be existing then repair it. The main activities which help programming of corrective and preventive maintenance is the CM[2] of

[1] breakdown maintenance
[2] condition monitoring

machine systems. It means that checking machine parameters can help to inform machine condition. It may lead to activities which reduce needed repair. Oil analysis is the main CM technique for reciprocating machinery maintenance and fault diagnosis (Lindley, Higgins, Darrin & Mobley, 2008).

In 1974, Hunt gathered the information about repair and maintenance cost for 745 agriculture machinery working in corn fields of Illinois for 8 years. He suggested a practical model based on power formula to calculate accumulated repair and maintenance cost by working hours (Hunt, 2001). In 1986, Morris studied about repair and maintenance cost for some agriculture tractors in England. The cost was calculated by type of the machines and annual working hours in his method. This manner expressed the cost using percentage of primary purchase cost (Morris, 1986). In 1999, a same studding was done by fuel in 8 area of South Africa. Repair and maintenance costs for 282 tractors were gathered and analyzed by him. At the end, a power formula as same as the previous equations was suggested. This recently advancing formula includes management and operation factors (Fuls, 1999).

Improved reliability results in lower maintenance costs. If the assets are not breaking down, a greater percentage of maintenance work can be performed in a planned and scheduled manner, which enables the workforce to be at least twice as efficient. Reducing these losses will also result in requirement of

- Fewer spare parts
- Less overtime
- Fewer contractors (Massoudi, 1994).

Oil analysis is the main CM technique for reciprocating machinery maintenance and fault diagnosis. The object of this research was to choose and to investigate the best oil for Dump Truck HD325-5, used for transportation of minerals, by OCM method (Oil condition monitoring). The results from this article have enhanced understanding on the dependent and independent roles of oil analyses in predicting which oil is more suitable for a machine in working condition (Mollazade & Ahmadi, 2008).

2. MATERIAL AND METHOD

Reduction of repair and maintenance cost using CM method was the main goal of this research. The cost for two types of conventional tractors in Iran called MF285 and MF399 were investigated by analyzing their engines and gearboxes oil for 3 years. Lubricating oil analysis, as the name implies, is an analysis technique that determines the condition of lubricating oils used in machine. In this case viscosity, contamination, fuel dilution, solid content, fuel soot, oxidation, nitration, total acid and bases number and particle content were checked during tests. The costs were compared with costs calculated by breakdown maintenance (BM) method to determine the effect of CM method on reduction of costs. For this comparison the costs were determined by CM and BM methods using annual working hours. The tractors were classified according to their age in unit year into 15 groups from 1 to 15. Also, for per class, the mean annual repair &maintenance costs and Accumulated working hours were calculated. The information about random annual working hours and costs were gathered by using face to face questionnaire. The costs for CM and BM were compared together by F-test. With regard to this goal, SPSS15 computer software was used. By the way, the software provided a regression analysis to determine relationship existed between the costs (based on percentage of primary purchase price) and the annual working hours for each method.

The amount of fixed costs that affected by the life and the purchase price with regard to the fact that elective systems for two years with equal method has been chosen for every two methods of the amount of the weekend.

3. RESULTS

The costs of spare parts, repairman vague, oil, filters and timeliness were investigated for BM and CM methods separately for MF285 and MF 399, respectively as shown in table 1.

Table 1. The mean annual repair and maintenance costs for MF285 and MF399 tractors

	Type of maintenance	Repayment cost ($/hr)	Oil and fuel ($/hr)	Filters ($/hr)	Total ($/hr)
MF285	BM	0.33	0.35	0.07	0.75
	CM	0.13	0.3	0.02	0.45
MF399	BM	0.35	0.39	0.15	0.89
	CM	0.13	0.36	0.10	0.59

Table 2 includes variable costs, fixed costs, incomes, benefits and benefits per costs. According to the results shown in table 3, there is a significant difference between costs in CM and BM method similar to the significant difference existed between their incomes.

Table 2. The mean annual fix and variable costs and Income for MF285and MF399

	Type of maintenance	Variable costs ($/hr)	Fix cost ($/hr)	Income of trait ($/hr)	Profit of trait ($/hr)	Profit per cost ratio
MF285	BM	3	1.5	15	10.5	2.33
	CM	2.72	1.5	17.22	13	3.08
MF399	BM	3.5	2.7	19	12.8	2.00
	CM	3	2.7	20.18	14.48	2.54

Table 3 present the obtained data from 60 sample tractors MF285 and MF399, including annual use and cost were used to calculate the accumulated working Hours and repair and maintenance cost. The presented data in these tables were used to comparison repair and maintenance costs, predicted between BM and CM and determine the repair and maintenance cost model. According to the tables 3 and 4 by using F-test deference between the amounts accumulated R&M in methods BM and CM at the level of 5 %(table 4).

ANOVA table a show that the cost of repair and maintenance cost in two methods has been mentioned in the 5% signification difference exists (Table4). With regard to the average cost in two method can be said that the amount of in method BM more than the method of CM.

To determine the relationship between accumulated costs and accumulated working hours, some mathematical formula including liner, power, exponential and logarithmic equations were used. The power formula shown in table 6 for kind of tractors in type of maintenance. Formula is available for estimating repair costs realizing that repair/maintenance cost have a variable structure as the machine ages.

$Y=aX^b$

Where X is the accumulated working hours for the tractors and Y is accumulated repair and maintenance costs.

Table 3. The accumulated repair and maintenance costs and working time of MF285 & MF399

	MF 285				F399			
	BM		CM		BM		CM	
Age	Ac.W.T[4] (hr)	Ac.R&M[3] costs ($)	Ac.W.T (hr)	Ac.R&M costs ($)	Ac.W.T (hr)	Ac.R&M costs ($)	Ac.W.T (hr)	Ac.R&M costs ($)
1	1212	7.458	1500	4.017	1230	4.479683	1480	3.874032
2	2292	15.032	3040	8.097	2550	10.97468	3000	7.715272
3	3452	23.587	4590	12.185	3820	18.03473	4550	11.58028
4	4708	33.183	6190	16.393	5085	25.63217	6030	15.23938
5	6028	43.55	7720	20.409	6325	33.51639	7560	18.99839
6	7660	56.68	9330	24.629	7663	42.43068	9170	22.93338
7	9164	69.038	10910	28.763	8943	51.30111	10670	26.58388
8	10708	81.936	12440	32.763	10376	61.58213	12163	30.20457
9	12292	95.36	14070	37.019	11740	71.67636	13793	34.14486
10	13868	108.89	15650	41.141	13230	83.01392	15286	37.74371
11	15116	119.72	17180	45.130	14582	93.55889	16816	41.42263
12	16436	131.27	18760	49.24	15912	104.1534	18396	45.213
13	17860	143.83	20240	53.09	17142	114.1341	19876	48.75608
14	19460	158.07	21760	57.05	18462	125.0289	21396	52.38806
15	21084	172.642	23310	61.08	19732	135.681	22946	56.08508

Table4.ANOVA table for cost of tractors in type of maintenance (BM&CM)

	Sum of square	df	Mean Square	F	Sig.
Between groups	2375.781	1	2375.781	16.115	0.002
Within groups	17396.444	118	147.427		
Total	19772.226	119			

[3] Accumulated repair and maintenance costs
[4] Accumulated working time

Table 5.The equations for types of tractor in type of maintenance

Type of tractors	Type of maintenance	R2	Equation
MF285	BM	0.98	Y=0.205(x/100)1.229
	CM	0.98	Y=0.208(x/100)0.975
MF399	BM	0.98	Y=0.586(x/120)1.1
	CM	0.98	Y=0.328(X/120)0.992
Generally	BM	0.98	$Y=0.285(X/100)^{1.22}$
	CM	0.98	$Y=0.28(X/100)^{0.981}$

Table 6. Developed models for tractors in type of maintenance

Researcher	Types of maintenance	Cumulative repair and Maintenance costs*		Developed models
		5000 hours	10000 hours	
Bowers	BM	43	86	$Y = 0.\ 0\ 76(X/120)^{1.26}$
Ward	BM	49	183	$Y=0.042(X/120)^{1.895}$
ASAE	BM	30	120	$Y=1.2(X/1000)^{2}$
This research	CM	44	87	$Y=0.1088(X/120)^{0.9766}$

*based on percent of list price

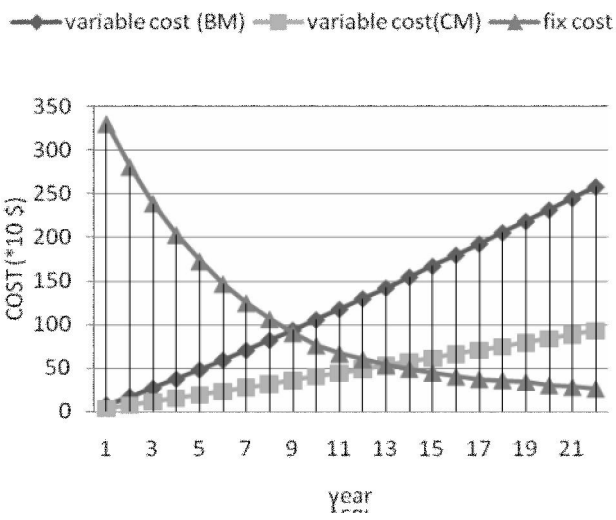

Figure1. Rapier and maintenance cost of tractors BM and CM method in Iran

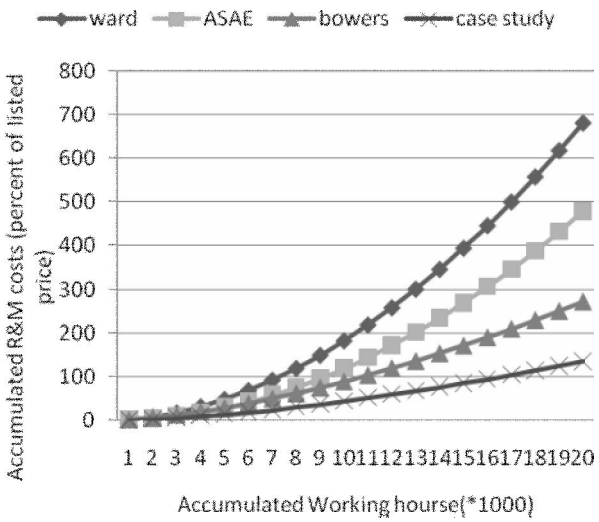

Figure2. Comparison of results with other researchers

The figure 1 shown increased of R&M cost in BM and cm method. With regard to the chart, the trend of increase cost of CM method much less than BM method. According to figure 2, repair and maintenance cost is increased with a lower gradient in the CM method than the BM methods suggested by other researchers. So, CM can reduce the repair and maintenance costs to an acceptable level. By the way, it increases the reliability of machines and decreases the timeliness costs using reduction of the breakdown times for machines.

The relations with relations which have already been achieved by the researchers compared the formula get the method of condition monitoring of the amount of increasing the costs of buildings with sloping shows less. The rate is increasing the costs of buildings in this method is very much lower than breakdown maintenance method.

Therefore it can be concluded by the use of that supervision and using the situation can take care of the cost of repairs in an acceptable level and reduced the other side regarding the number of casualties happened during research, which is very much lower than usual method is can be said that this method can be the amount of reliability machine to take higher and the expense of stopping the decrease.

4. DISCUSSION

Using CM, reduced maintenance costs amount to very much.these results are in harmony with data have been published by Massoudi (1994).

The obtained results showed that amount of costs in two ways CM and BM were observed, the average cost in BM method, much larger than average cost in CM method is. the obtained results seem to be in accordance with the published data by Mollazade & Ahmadi (2008).

ANOVA table a show that the cost of repair and maintenance cost in two methods has been mentioned in the 5% signification difference exists (Table 5).

Trend of increasing costs in the way CM, much slower method is BM method. the obtained results deference to be in accordance with the published data by ward (1985); bowers (2005); ASAE (2000).

5. Conclusion

Therefore it can be concluded by the use of that supervision and using the situation can take care of the cost of repairs in an acceptable level and reduced the other side regarding the number of casualties happened during research, which is very much lower than usual method is can be said that this method can be the amount of reliability machine to take higher and the expense of stopping the decrease.

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4/1/2011