The Canadian Society for Bioengineering
The Canadian society for engineering in agricultural, food, environmental, and biological systems.

CSBE | SCGAB

La Société Canadienne de Génie Agroalimentaire et de Bioingénierie
La société canadienne de génie agroalimentaire, de la bioingénierie et de l'environnement

Paper No. CSBE08-148

GRAIN HARVESTER REPAIR AND MAINTENANCE COSTS

Saleh A. Al-Suhaibani*
Mohammed F. Wahby*
*Agricultural Engineering Department
King Saud University
P.O.BOX 2460 Riyadh, Saudi Arabia

Written for presentation at the
CSBE/SCGAB 2008 Annual Conference
Vancouver, British Columbia
July 13 - 16, 2008

Abstract

Work-job orders for 15 combines with different cutting width were used in this study. Data for 352 work-job orders were classified as repair or maintenance into nine categories. These categories included, header unit, threshing unit, separation, cleaning shoe, engine, pre-harvest jobs, general and fabrication works, electrical and tires. Total annual cost for each category was determined, and the ratio of total cost to purchase price was calculated. Total costs were divided into labor and parts according to each work job orders. Correlations between repair and maintenance costs and some factors (such as: separation hours, engine hours, combine age, labor cost, and parts cost) were made. The relationship between repair and maintenance costs, combine age and cutting width on repair was investigated. Seventy-two percent of the work orders were classified as repair work while twenty-eight percent were maintenance. Repair mean total costs were significantly higher than maintenance costs. Furthermore, repair and maintenance mean total costs were directly related to grain harvesters working life (age) and some other factors.

INTRODUCTION

The good estimation of operating costs of farm machinery is an important indicator of good machinery management. The models of cost estimation should be developed on clearly justified bases. The degree of accuracy also depends on the accuracy of the input of accurate data, where there are no models better than that the data goes in it. The annual operating costs usually estimated based on operating hours or per unit area according the system in the area of study. The cost of R&M (repair and maintenance) for tractors in developing countries represents 53% of annual operating costs, in comparison to 8% in developed countries, Inns (1978).

Several studies on R&M costs for combines had been worked out in different parts of the world. Most of the studies resulted with exponential models as a function of engine operating hours, Bowers and Hunt (1970), Fairbanks et al (1971), Rotz and Bowers (1991), ASAE standards (1993).

A study done by Gliem et al (1989) compared the R&M costs by using the standard equations adapted by American society of agricultural engineers, ASAE (1989) which is based on the cumulative area covered by the machine and the actual costs of some farms. It was found that the calculated costs much higher than those of farm records and the variation between the actual and estimated reaches up to 700%. In another study by Abdulmotaleb (1993) about R&M costs of the rice harvester, where he compared a multi-Linear model developed under the Egyptian conditions which gone much higher estimation than those developed by American Society of Agricultural Engineers.

R&M cost models as well as the other cost component of operating farm machinery need to be checked to assure their suitability for the area to be used for. Also, more research studies needs to be done of the details of the cost components to improve the cost models for better estimate. The components of R&M costs for any machine could be classified according to the type of job performed for the machine.

Analysis of tractors R&M records (Al-Suhaibani and Wahby, 1999) classified data for more than 1670 work orders on R&M. 16 types of works (such as electrical, transmission, etc.) were defined as repair and 12 types (such as hour service, air system, etc.) were defined as maintenance. In this study 51% of the work orders were classified as repair work; while 49% were maintenance. The study concluded that the repair mean total costs were significantly higher than maintenance costs. Also it was found that mean total costs were directly related to tractor working life and tractor power.

Multi-Linear models developed for R&M costs for combines by Wahby (1995). The model included a relationship of the cumulative costs of combine R&M and machine power, price, and width of cut, cumulative engine working hours and separation hours. The comparison between the developed models and exponential models showed that the multi-linear models gave a very close estimate to the actual costs with difference up to 2%, while the exponential model had a difference up to 57%.

Two exponential models were developed for R&M costs for combines by Wahby and Al-Suhaibani (1995). The first model estimates the costs when some or all machines moving parts are operating, which when compared with other similar models developed by other studies gave the least cost with an acceptable accuracy. The second model developed estimates the cost when all parts are operating. However, the studies recommended that the use of R&M costs

mathematical models for combines be used in the areas they developed for, or in conditions similar in cost of spare parts and labor.

In the light of the above, it is clear that there is a need for further investigation of the grain harvester repair and maintenance cost components and identification of the frequency of each item. The objective of this research was to classify types of repair and maintenance event and study the effect of the combine age (working life) and cutting width on repair and maintenance costs.

MATERIALS AND METHODS

Repair and maintenance of grain harvesters collected by HADCO (Hail Agricultural Development Company), Saudi Arabia, were used in this study. The data of 15 harvesters out of 40 owned by the company were used. All data were listed in WJO (work-job orders) and stored in the company's computer. Each WJO included the following data: date of the job, harvester serial number, machine power, type of work done, number and cost of the parts used, total labor requirement and the related cost, and the total cost of the WJO. The data covered the period from 1988 to 1993.

Data for 352 WJO obtained from HADCO were sorted and classified as repair or maintenance according to the ASAE Standard, S495 (ASAE, 1993). The type of work was coded according to a description in the WJO. The job types were classified as follows: header, threshing unit, separation unit, cleaning shoe, engine, preharvest, general works, electrical, and tires.

The statistical package SAS was used in the analysis of the classified data, and the results were examined to get the significance between repair and maintenance cost. The analysis included sorting the data according to repair or maintenance codes and their related costs, cutting width, power, and age (in years).

RESULTS

Analysis of the 15 grain harvesters WJO's showed that harvesters age ranged from 5 to 10 years, while the power varied from 71.3 to 202.5 kW (95 to 270 hp) and the power was directly related to cutting width. Three harvesters groups were found in terms of model, cutting width, and power. Summary of grain harvester's characteristics is listed in table 1.

Analysis of the WJO's from 1988 to 1993 showed that 253 WJO's were classified as repair work and 99 were classified as maintenance (figure 1). The total costs of all work jobs were consisted of 88.6 % as parts cost and 11.4 % as labor cost.

Table 2 listed frequency and the distribution of WJO's of all grain harvesters for both repair and maintenance works during the period of the study. General repairs(general checkup) came on the top of repair works to grain harvesters under study, while threshing unit and cleaning shoe repairs showed the least repair works have been done to both units. This could be due to the effect of pre-harvest repairs(general check-up, fabrication of some parts, welding works, replace and rebuilt of parts: shafts, pulleys, and crop lifters.) which took care of all harvesters units before starting the harvesting season and therefore reducing the repairs of the above units to its lowest rate. Other repair works items could be directly related to the working hours of the harvester during the harvesting season and were kept to a low values, such as header, electrical, and tires repairs. On the other hand, only five items of maintenance have been done to all grain harvesters. General maintenance (regular or complete service) came as the highest percentage of

WJO's followed by engine, electrical, tires, and pre-harvest maintenance (general checkup).It was clearly shown in table 2 that the company took a great care of the maintenance work of the major harvesters units, i.e.; header, threshing, separation, and cleaning units, during the pre-harvest repairs in order to reducing the number of machine stopping during the harvesting season- because the weather getting very hot during the harvesting season and the pre-harvest grain losses go higher. This action reduced the mean total cost of maintenance of those four units into zero cost, but added it to repair costs. It was also found that separation unit in all harvesters didn't have any repair or maintenance costs, and it was the only unit did not need any repair or maintenance works (tables 2 and 3).
The annual mean total cost for both repair and maintenance according to the previous classification is listed in table 3. The costs were listed in US$ and cost per purchase price of the harvester (US$/p.price). It is shown in table 3 that the highest mean repair costs was for preharvest which reached 1341 US$, while the lowest mean total cost was for tires maintenance (38 US$).

The distribution of mean annual repair costs of the most repair items as related to harvesters age are shown in figure 2, while the distribution of mean annual maintenance costs for the same items are shown in figure 3. Both figures show that the costs of either repairs or maintenances were increasing gradually (engine, for example) for some years until reaching a maximum value, then started to decrease after a major repair or maintenance. It was noticed from figures 2 and 3 that there was a close relation between repair and maintenance in term of costs; for example, when the annual mean total costs of repairs were at high value, the annul mean total costs of maintenance went to a low or moderate value. This could be seen for most items of repair and maintenance lists. While some items went in decreasing trend and then jumped to a high amount (pre-harvest), other items of repair or maintenance were almost taken care inside the pre-harvest repairs and maintenance, so they didn't appear in the work job orders or they included in the pre-harvest jobs in order to reduce the recording items during the working years.

Effect of harvester age and cutting width

Using the SAS package and PROC CORR and PROC RE, the relationships between R&M mean total costs and harvester cutting width; harvester age (in years), engine working hours and some other parameters were tested. Pearson Correlation Coefficient between each two of the above parameters were calculated, and the analysis results showed that a significant correlation ($p<0.05$) existed between each of engine working hours, and the cutting width and repair and maintenance annual mean total costs.

While a highly significant correlation ($p<0.001$) was found between the harvester age and the repair and maintenance annual mean total cost. Figure 4 shows the annual repair and maintenance mean costs as affected by harvester cutting width and age. It was also found (as shown in table 4) that the number of work jobs and the repair and maintenance mean total costs per work job were directly related to the cutting width. As it was shown in figure 4, the mean annual R&M cost increased as increasing the harvester age and also by increasing the cutting width. This could be the results of the intensive use of harvesters with wider cutting width (i.e., 8.22 meter width) and as related to the mean engine working hours, as listed in table1. The correlation analysis showed a highly significant correlation between engine hours and separator hours.

Regression analysis (PROC REG) showed a highly significant relation ($p<0.001$) between harvester cutting width and R&M mean total costs, and the coefficient of variation (CV) was about 18%; which mean that 82% of the data could describe that relation. It was also shown in table 4 and figure 4 that the R&M mean total costs of the 8.22m cutting width was significantly higher than that of the 4.88 and 3.69m machines. The same relation was also existed between R&M mean total costs and harvester age (years), as described previously.

Conclusions

Classification of repair and maintenance in grain harvesters is very important for identifying the major causes of breakdowns. The results of this study lead to the following conclusions:

1. Of all work job orders received, about 72 % were for repairs and 28% for maintenance.
2. Repairs had the highest percentage of work orders, 72%, while the maintenance was 28%. Mean total costs were significantly higher than maintenance costs, and represented 83.8% of mean total costs. The most common repairs were pre-harvest followed by general and engine repairs. The most common maintenance was in the following order: engine, electrical, general, and pre-harvest maintenance.
3. Pre-harvest repairs were usually executed every year before harvesting season. The pre-harvest repairs reduced costs of most of other repair or maintenance jobs in the machines during the harvesting season.
4. R&M mean total costs were directly related to both cutting width and harvester age (in years). R&M mean total costs of the 8.22m(27 ft) harvesters (60% of mean total costs) were significantly higher than that of both 4.88m(16 ft) 15%; and 3.69m(13 ft) 25%; machines.

Acknowledgment. The authors wish to acknowledge HADCO (Hail Agricultural Development Company) for providing and use of their accurate and helpful data.

REFRENCES

Abdelmotaleb ,I .A. 1993. Repair and maintenance cost analysis of farm machines under Egyptian conditions. Misr. J. of Agr. Eng. Proceeding of the International Conference on Technological Techniques for Handling Agricultural Products. Faculty of Agriculture, Cairo University ,Egypt.

Al-Suhaibani, S. A. and M. F. Wahby. 1999. Tractor Repair and maintenance in Saudi Arabia. Applied engineering in agriculture, 15(6): 591-596.

ASAE Standards. 1993. ASAE EP 496.1: Agricultural machinery management. St. Joseph, MI. USA.

Bowers, W. and D.R Hunt 1970. Application of mathematical formulas to repair cost data. Transactions of the ASAE. 13(6): 806-809.

Fairbanks, G.E.,G H. Larson and O.S Chung. 1971. Cost of using farm machinery. Transaction of the ASAE 14(I): 98-101.

Gliem, J.A.., K.M. Persinger, T.G. Carpenter, RG. Holmes and H. E. Ozcan. 1989. A comparison of ASAE estimated tractor and combine repair and maintenance costs to actual repair and maintenance costs of selected farmers. ASAE paper No. 89-1024 ASAE. St. Joseph. MI. USA.

Inns, F.M. 1978. Operational aspects of tractor use in developing countries-A case for the small tractor. The Agricultural Engineer. summer 1978:52-54.

Rotz, C.A. and W. Bowers. 1991. Repair and maintenance cost data for agricultural equipment. ASAE paper No 91-1531 ASAE, St. Joseph, Ml, USA.

Wahby, M. F. and S. A. Al-Suhaibani. 1995. Repair and maintenance cost models for combines in Saudi Arabia. Arab Universities Journal of Agricultural Sciences. Ain Shams Univ. Cairo. 3(2): 59-69.

Wahby, M.F.1995. Multi-linear models for repair and maintenance costs for combines in Saudi Arabia. Bull. Fac. Agric., Univ. Cairo, 46(3):379-390

Table 1: Grain harvester's characteristics.

No. of combines	Model	Cutting width, m(ft)	Engine power, kW	Purchase date	Purchase price, US$	Mean working hours, h/yr	
						Engine	Separator
1	Gleaner N7	8.22(27)	202.5	Feb. 83	106493	305.4	98.3
6	Gleaner N7	8.22(27)	202.5	Apr. 84	104000	342.5	152.6
4	Gleaner N7	8.22(27)	202.5	May 84	101758	362.3	237.7
1	Gleaner F3	3.96(13)	71.3	May 84	56000	177.7	101.9
1	Gleaner N7	3.96(13)	71.3	Apr. 85	56000	188.4	106.1
1	Gleaner N7	3.96(13)	71.3	May 84	57867	197.1	126.6
1	Gleaner M3	4.88(16)	108.8	Apr. 85	69333	231.8	112.0

Table 2: Grain harvesters work orders and type of job.

Job type				
Repair			Maintenance	
No. of work job	Percent,%		No. of work job	Percent,%
5	1.97	Header	0	0
1	0.40	Threshing unit	0	0
0	0	Separation	0	0
1	0.40	Cleaning shoe	0	0
24	9.49	Engine	23	23.2
32	12.65	Pre-harvest	4	4.0
166	65.61	General	53	53.5
15	5.93	Electrical	13	13.1
9	3.55	Tires	6	6.2
253	100		99	100

Table 3: Grain harvesters repair and maintenance mean total cost*.

Type	Mean cost	Min. cost	Max. cost
Repair	US$		
Header	743(0.0094)**	21	1707
Threshing unit	89(0.0008)	89	89
Separation	0	0	0
Cleaning shoe	108(0.003)	108	108
Engine	927(0.0089)	27	5705
Pre-harvest	1341(0.0131)	3	9172
General	1320(0.0134)	0	8850
Electrical	385(0.0038)	10	1005
Tires	147(0.0014)	0	1269
Total Repair	1168(0.012)	0	9172
Maintenance			
Engine	347(0.0034)	5	2318
Pre-harvest	156(0.0015)	3	273
General	199(0.0021)	0	329
Electrical	220(0.0021)	51	95
Tires	38(0.0004)	3	197
Total Maintenance	225(0.002)	0	2318

** 1US$ = 3.75 SR*

*** Cost/ p. price.*

Table 4: Number of WJO's and mean total R&M cost per work job for different cutting width.

Cutting width	No. of WJO's	Mean total R&M costs/WJO
m (ft)		US$
3.69 (13)	27	427.5
4.88 (16)	29	249.1
8.22 (27)	296	1010.0

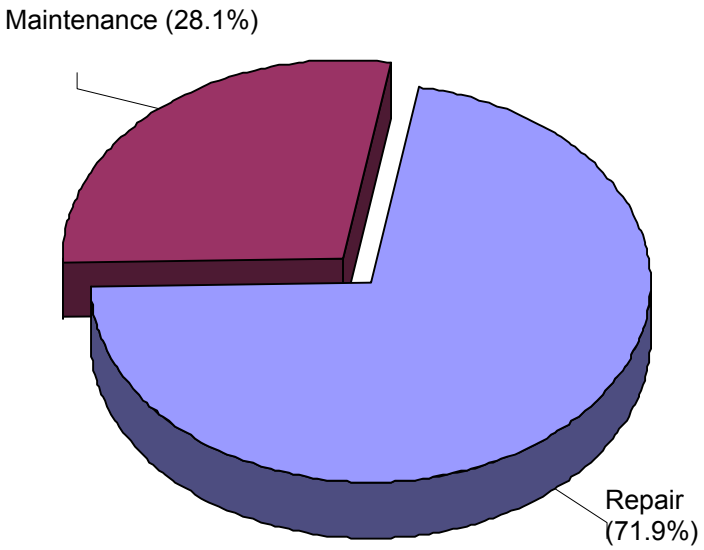

Figure 1: Grain harvesters repair and maintenance work orders ratios.

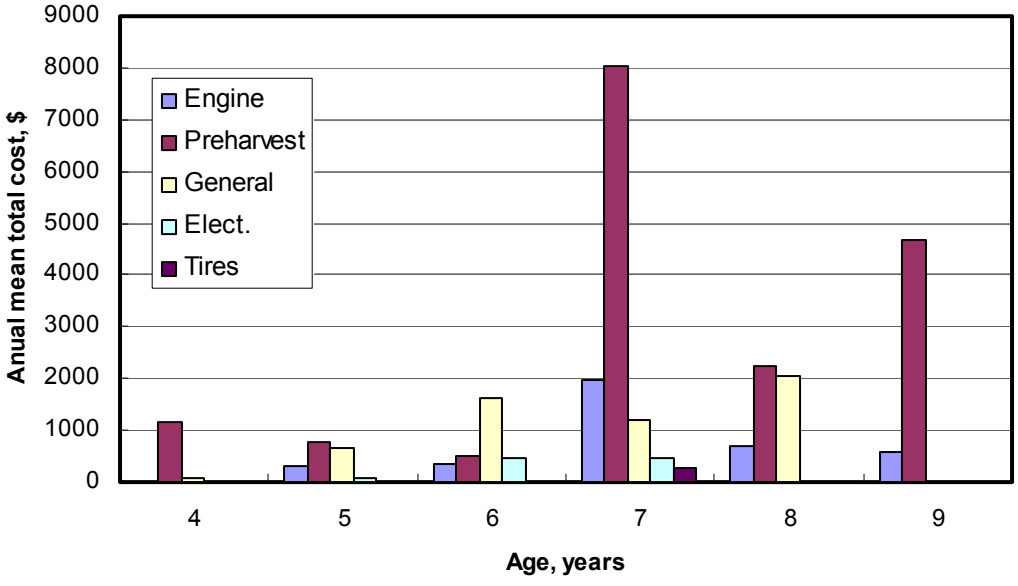

Figure 2: The distribution of mean annual repair costs as related to harvester's age.

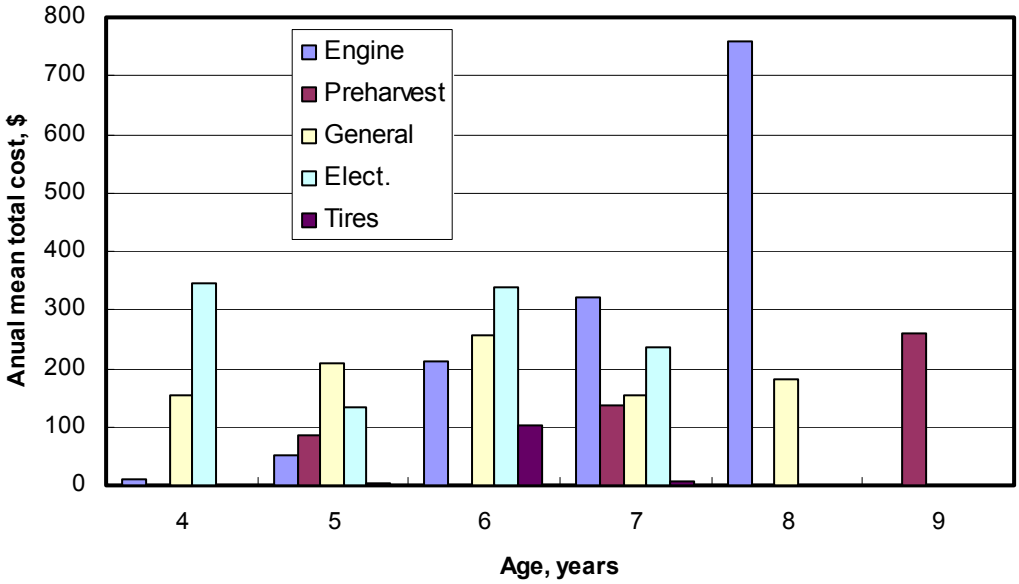

Figure 3: The distribution of mean annual maintenance costs through the harvester's age.

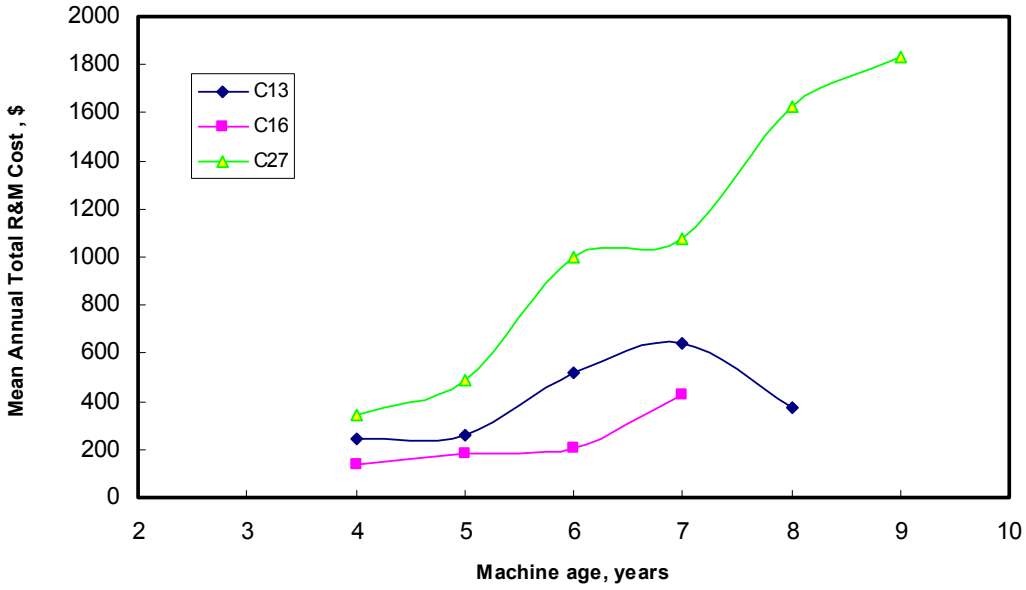

Figure 4: The relationship between harvester age, cutting width, and mean annual R&M costs.