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Research Article

Case Study on Preventive Maintenance Strategy of Off-Highway Truck

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Abstract: Present study developed the preventive maintenance strategy of the articulated off-highway truck to minimize the total maintenance cost, and maximize the utilization rate. After analyzed the field data, the original maintenance manual, the scope of preventive maintenance, and other related priorities, the preventive maintenance mechanism is initial established. After that, the interview of experts was collected to confirm the key preventive maintenance items. After six months implemented, the empirical data identify the key preventive maintenance strategy which developed in present study is reliable.
Keywords: Preventive maintenance strategy; Off-highway trucks; Key preventive maintenance items

INTRODUCTION

The off-highway trucks are the indispensable equipment on earthmoving tasks. Dumpers and articulated are the most two important types of the off-highway trucks. The dumpers trucks are applied to the operations on the normal road situation. The articulated trucks (Figure 1) are suitable for the harsh terrain situation. Due to the climatic characteristics (rainy in Spring, typhoon in Summer, and northeast monsoon in Winter) caused the harsh construction environment in Taiwan. Therefore, the articulated off-highway trucks are generally used for the reservoir earthwork project operations. Case company J is one of the major construction contractors of the Hushan reservoir.

The maintenance of the articulated off-highway truck is costly. For example, there are has six transmission axles (3 coaxial). The replacement cost was about NT$ 1.5 million when a failure occurs for each transmission axle. Further, when a transmission axle was wear, generally the synchronization coaxial must be replaced. Therefore, the maintenance cost was about NT$ 3 million for each replacement. This highly replacement cost significant affected the project expenditure.

Morad et al. [2] employed Monte Carlo simulation for assessment of the dynamic behavior of the equipment for Sungun copper mine to improve of the equipment performance and reduce operation cost. The importance analysis is used to identify the items which have critical impact on reliability and availability of overall equipment for prioritizing the decision for improvements. Martins et al. [3] described the relation between measurable variables and economic parameters obtained in one important large scale Brazilian mine and how they interact and relate to each other in order to facilitate the decision making process. Unfortunately, empirical researches about the preventive maintenance of the articulated off-highway trucks are lack. Therefore, there is needed to empirical investigate the preventive maintenance strategy of the articulated off-highway truck minimize the total maintenance cost, and to maximize the utilization rate.

Fig-1: The exterior of articulated off-highway trucks in present study [1]

RESEARCH PROCEDURE

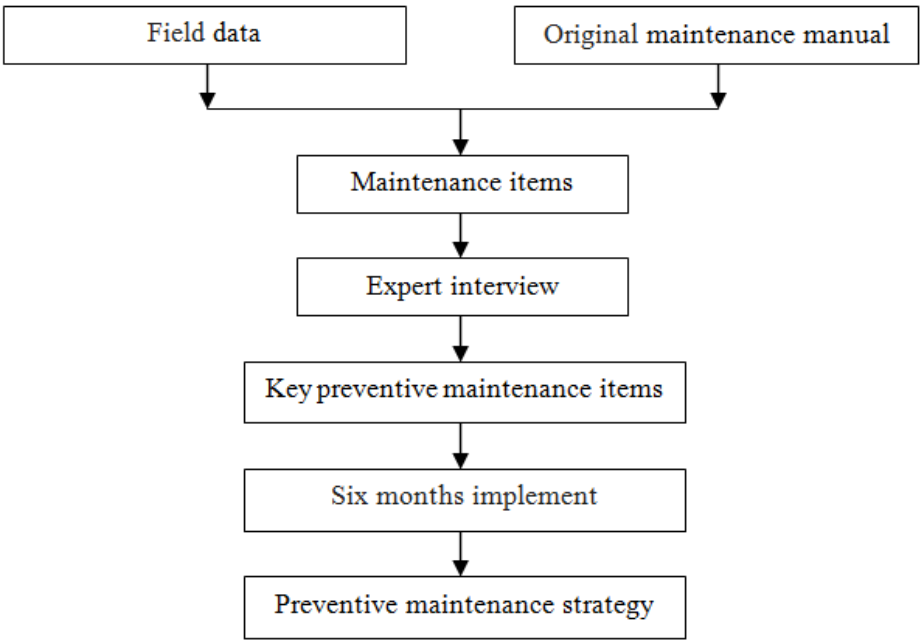

Fig-2: Research flowchart

Field data

The present study collected the field data (include maintenance items, maintenance expenditure, and utilization rate) of company J. The data collected period was from Sep 2012 to Aug 2013. Therefore, there are 12 months of field data. Preliminary statistics obtained the 12 months maintenance costs and the utilization rate. The engine failure analysis, fuel supply fault analysis, transmission structure lock, power system fault, and oil analysis were also conducted. Furthermore, the oil analysis was conducted. Table 1 shows the oil sampling data. There are 193 oil samples. Figure 2 shows the oil sampling and analysis instrument.

Table 1. Numbers of oil sampling

2013	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
numbers	30	22	30	40	32	13	26	193

(a) Oil sampling

(b) Oil analysis instrument (Atomic absorption spectrometer)

Fig- 2. Oil sampling and analysis instrument

Table 2 shows the summary of the possible source of the debris in the oil. According to the analyze results of the possible sources. The engineers could judge the debris' possible source, and then check the wear situation of the possible source.

Table 2. Summary of the possible source of the debris in the oil

Contain	Possible source		Judgment criterion
Cu	1. From lubricant additives 2. Bushing or bearing 3. Turbocharger 4. Governor	5. Piston pin 6. Valve rocker 7. Oil cooler core 8. High pressure fuel pump	Higher than the set value
Fe	1. Cylinder liner wear 2. Gear 3. Crankshaft or camshaft	4. Piston pin 5. Oil pump 6. Valve	Higher than the set value
Pb	1. Bearing 2. Piston ring	3. Exhaust valve 4. Crankshaft	Higher than the set value
Cr	1. Crankshaft main bearing or rod bearing coatings	2. Camshaft bearing coating 3. Turbo charger bearings	Higher than the set value
Al	1. Connecting rod bearing 2. Camshaft bearing 3. Balance shaft bearing	4. Rocker shelf 5. Oil pump bearing 6. Piston 7. Fuel injection pump plunge	Higher than the set value
Si	1. Lubricants anti-foam additives 2. Coolant	3. Outside dirt 4. Siliceous lubricating oil 5. Liquid gasket	Higher than the set value

Original maintenance manual:

The articulated off-highway truck of present study was CAT 740. Therefore, the present study referred the operation and maintenance manual of the Caterpillar. The streamline of the operation and maintenance manual as following:

(1). Maintenance items of every 10 service hours or daily.
(2). Maintenance items of every 10 service hours.
(3). Maintenance items of every 50 service hours.
(4). Maintenance items of initial 500 service hours.
(5). Maintenance items of every 500 service hours.
(6). Maintenance items of every 1000 service hours.
(7). Maintenance items of every 2000 service hours.
(8). Maintenance items of every 2000 service hours or 1 year.
(9). Maintenance items of every year.
(10). Maintenance items of every 3000 service hours.
(11). Maintenance items of every 3 years.
(12). Maintenance items of every 4000 service hours.
(13). Maintenance items of every 5000 service hours.
(14). Maintenance items of every 5000 service hours or 3 years.
(15). Maintenance items of every 6000 service hours.
(16). Maintenance items of every 12000 service hours or six years.

Maintenance items

The present study combined the field data and the original maintenance manual. And then develop the maintenance items of experts' interview.

Expert interview:

The present study interviewed 12 experts (Table 3) to confirm the maintenance items. Table 4 shows the sample items of the experts' interview. The experts using Likert 5 point scale to evaluate the frequency of failure and the preventive maintenance effects based on their experience. Table 5 shows the portion results of the experts' interview of maintenance items of every 500 service hours.

Key preventive maintenance items:

After interviewed the 12 experts. The key preventive maintenance items were obtained (Table 6).

Six months implement:

Company J implement the key preventive maintenance items six months (Nov 2013 to Apr 2014).

Preventive maintenance strategy:

After six months implement, the key preventive maintenance items was confirmed.

Table 3. Portion items of the preventive maintenance

Item	Preventive maintenance item	Acts
Initial 500 hours		
1	Engine compression brake valve lash	Check
2	Engine valve lash	Check
3	Oscillating hitch	Adjust
4	Cooling system coolant sample	
Every 500 service hours		
5	Drive belts	Inspect / Adjust / Replace
6	Braking system	Test
7	Differential and final drive oil level	Check
8	Differential and final drive oil sample	Obtain
9	Engine crankcase breather	Clean
10	Engine oil sample	Obtain
11	Engine oil and filter	Change
12	Fuel system	Prime
13	Fuel system prime filter	Clean / Inspect / Replace
14	Fuel system secondary filter	Replace
15	Fuel tank cap and strainer	Clean
16	Hoist system and braking system oil sample	Obtain
17	Hoist system and braking system strainer	Clean
18	Secondary steering	Test
19	Steering system oil sample	Obtain
20	Steering system strainer	Clean
21	Torque converter and transmission oil filter	Replace
22	Torque converter and transmission oil sample	Obtain
23	Transfer gear oil sample	Obtain

Table 3. Experts' profile

Expert type	**Project manager**	**Project engineer**	**Project design**	**Project client**
numbers	4	4	2	2
Average experience	18 years	8 years	17 years	26 years

Table 4. Sample items of the experts' interview

Frequency of failure	**Items**	**Preventive effects**
Almost did not happen	Braking system	Almost impossible to prevent
Rarely happen		Difficult to prevent
General happen		General to prevent
Usually happen		Easy to prevent
Always happen		Very easy to prevent

Table 5. Portion results of the experts' interview of maintenance items of every 500 service hours

Items	Frequency of failure	Preventive effects
Engine compression brake valve lash	2.93	3.47
Engine valve lash	2.90	3.03
Oscillating hitch	3.63	3.17
Drive belts	3.50	3.40
Braking system	3.33	3.37
Differential and final drive oil level	3.17	2.73
Engine crankcase breather	2.17	3.47
Engine oil and filter	3.50	3.37

Table 6. Portion results of the key preventive maintenance items

Item	Importance of the item	Normal maintenance costs estimated	Fault repair costs estimated
Engine	The engine is the most important core of the off-highway truck. If the engine failure the off-highway truck will shot down Immediately.	NT$ 40,000 / 500 hr	NT$ 800,000 / Overhaul
Pump	The pump is the main component to convert the engine power. Therefore, if the pump failure then the off-highway truck also failure too.	NT$ 20,000 / 500 hr	NT$ 500,000 / Overhaul
Axle	Type 740 off-highway truck has 6 axles. Any axle fault will not bear the load, due to the symmetric systems. The main function will also disappear. Therefore, axle maintenance is also the focal point of this type off-highway truck.	NT$ 100,000 / 500 hr	NT$ 1,500,000 / Overhaul

CONCLUSION

The purpose of present study is to develop preventive maintenance strategy to minimize the total maintenance cost (preventive cost and replacement cost), and to maximize the utilization rate.

After analyzed the existing maintenance status, the scope of preventive maintenance, technical capacity, and other related priorities of company J, the preventive maintenance mechanism is initial established. After that, the interview of experts was collected and analyzed to confirm the key preventive maintenance items. After six months implement, the empirical data verify the preventive maintenance strategy can minimize the total maintenance costs. According to the data of the case company, the total maintenance cost was reduced about 15% per month and kept the high utilization rate (higher than 80%). These results confirm that the proposed preventive maintenance strategy is reliable.

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