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Identifying preventive maintenance guideline for a combine harvester with application of failure mode and effect analysis technique

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Abstract. The objective of this research was to study a risk assessment of the rice combine harvester using FMEA technique implementation and suggested the procedures to maintain the parts of the rice combine harvester by analyzing the causes of risk assessment of FMEA. The FMEA was also applied to specify failure causes and effects that occurred in the rice harvester. The obtained data were calculated for a risk priority number (RPN) and then sorted to be a descending order. The high RPN part was analyzed for the causes and effects and then suggested a preventive maintenance in near future. The results revealed that the highest RPN of 576 was found when a chain surface was considered and also showed the maximum risk among the considered parts in the rice combine harvester. While, the lowest RPN of 144 was found when a rice sieve part was considered but this RPN was still higher than that of 100 RPN which was required to specify the preventive maintenance.

1 Introduction

In order to increase income, rice farmers tried to increase productivity of rice cultivation. This was the main reason of replacing human labor with agricultural machine such as combine harvester. Using the combine harvester, the time spending on harvesting rice was reduced to less than 10 minutes, whereas manual harvesting required up to 1-2 weeks. However, the efficiency of the combine harvester was decreased after time as some parts of the rice combine harvester were depreciated and needed replacement [1, 2]. Therefore, it was necessary to perform a risk assessment of the rice combine harvester and suggested the procedures to maintain the parts of the rice combine in order to sustain the productivity of rice production.

Risk management was the processes including Risk identification, Risk assessment, Risk response, and Risk documentation and control. In previous study, risk management was used in reduction of error in engineering design of project management [3], reduction of downtime loss in concrete production [4], improving of preventive maintenance planning of an automobile shaft manufacturing [5], assessing risks in container terminals [6], reducing breakdowns of a sub system in the life care product manufacturing [7], assessing risks for wind turbine systems [8], assessing risks for rotary switches [9], analyzing risks of a biomass combustion process [10], and evaluating boiler tube [11]. These studies used an application of Failure Mode and Effect Analysis (FMEA) technique to implement on production process for risk management and productivity improvement, which could be lead to develop preventive maintenance guideline.

FMEA was an effective risk management technique for preventive maintenance in order to reduce waste, increase productivity, and reduce cost of production. Therefore, this research was aimed to study on problems, threats, and risks occurring in rice harvesting by the combine harvester. The obtained data were analyzed and then sorted to be a descending order. The high rated part was analyzed for the causes and effects and then suggested a preventive maintenance. This preventive maintenance guideline would help rice farmer maintaining the machinery parts effectively, which was leading to increase productivity and improve competitive advantage.

2 Experimental Procedure

In this research, there were three main steps to study on risks occurring in the rice combine harvester: (1) Risk identification, (2) Risk assessment, and (3) Risk response.

In Risk identification, two questionnaire had been designed to investigate risks from experienced farmers. First questionnaire was to investigate risks occurring while using the combine harvester. The questionnaire started with brand, model, engine size, and parts that farmers experienced risks. After obtaining the

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preliminary list of risks from first questionnaire, second questionnaire was generated into two section. First section aimed for general information such as gender, age, experience, and life of combine harvester. Second section asked for opinion on each risk.

In Risk assessment, using FMEA technique, Risk priority number (RPN) of each risk were calculated according to three main factors: Severity (SEV), Occurrence (OCC), and Detection (DET). Each risk was analyzed, compared, and prioritized based on RPN.

In Risk response, the risks, which had RPN higher than 100, would be categorized into 3 levels: High risk (H), Medium risk (M), and Low risk (L). The high risks then were analyzed for the causes and effects and then suggested a preventive maintenance.

3 Experimental Procedure

After collecting 30 responded questionnaire, the assessment of risks using FMEA had been performed. There were 19 types of risk which had RPN higher than 100. The RPN were used to prioritize risk and then catagorized into 3 levels: High risk (H), Medium risk (M), and Low risk (L) as shown in Table 1.

High risk were the part that user could not fix or replace by himself if it was damaged. These would halt the harvesting and damage both the combine harvester and quality of produced grain. Medium risk were the part that user could fix the problem temporarily by himself if it was damaged. The harvesting could be continued after taking care of problem, however, it might damage both the combine harvester and quality of produced grain. Low risk were the part that user could fix the problem immediately by himself if it was damaged. The harvesting could be continued without any damage.

Why-why analysis had been performed on the five highest RPN risks in high level for the causes and effects and then suggested a preventive maintenance.

1) Wear on surface of chain was caused by friction between chain and roller. It made the surface thinner and wavy as shown in Fig. 1. The risk could be detected by eye or surface measurement. Also, if the feeding system was operated inconveniently, this could be the signal that there was wear on surface of chain joint. Farmer could lubricate the chain joint and bring the part for surface hardening to strengthen the metal structure.

Fig. 1. Wear on chain surface.

2) Damage on oil seal for roller was the rupture and the hardener of rubber material. This would lead to oil spilling from roller and then damaged other parts of the combine harvester as shown in Fig. 2. Farmer could detect this problem by noticing the trace of oil from oil seal for roller. If it was occurring, the immediate corrective action for farmer to take would be filling enough amount of oil.

Fig. 2. Damage on oil seal for roller.

3) Wear on surface of roller was happening because of the friction between chain and roller. The surface of roller would be thinner and notched as shown in Fig. 3. If the size of roller was too small, the chain could fall off the roller. This led to unusual movement which could damage the combine harvester. The detection method was measuring the size of roller and checking the surface condition frequently. This problem could be solved by lubricating between chain and roller and bringing the roller for surface hardening.

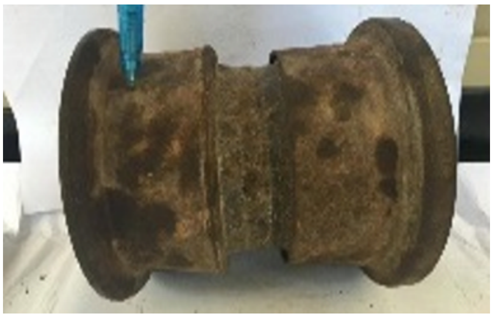

Fig. 3. Wear on surface of roller.

4) Damage found on sprocket was spiked and thinner cog as shown in Fig. 4. This would make the sprocket's pitch wider. The feeding system of the combine harvester would not work in full capability. Farmer could detect this problem by noticing the size of sprocket's cog and take preventive maintenance by lubricating and setting alignment of sprocket frequently and surface hardening for the sprocket.

Table 1. The result of Failure Mode and Effect Analysis.

Failure Mode and Effect Analysis on the Combine Harvester									Risk Level
Part	**Potential Risk**	**Potential Effect**	**SEV**	**Potential Cause**	**OCC**	**Responded Action**	**DET**	**RPN**	
Chain surface	Thinner and wavy	Machine vibration	8	Friction between chain and roller	9	None	8	576	H
Oil seal for roller	Flatten and harden	Oil spilling	9	Compression from oil and friction from seal group	8	None	8	576	H
Surface of roller	Reduce in size and has notch on surface	Unusual movement	7	Friction between chain and roller	8	None	9	504	H
Sprocket	Spiked and thin cog	Wear on bush	7	Friction between bush and chain	8	None	8	448	H
Wheel guide	Smaller ridge of wheel guide	Chain derailment	7	Friction between wheel guide and chain	8	None	8	448	H
Shaft bush	Loosen shaft bush	Not fitting with bearing	7	Breaking bearing or shaft bush	8	None	8	448	H
Plug Roller	Wear and broken	Not fitting with seal group	7	Vibration from harvesting	7	None	8	392	M
Screw conveyor	Smaller blade	Hard to move withered grain	6	Friction with grain	7	Replace screw conveyor	8	336	M
Bush	Thinner surface	Broken bush	8	Not enough lubrication or oil expiration	8	Lubricating frequently	5	320	M
Seal group	Thinner contact space	Oil spilling	8	Not enough lubrication or oil expiration	8	Lubricating frequently	5	320	M
Seal	Flatten and harden	Could not operate properly	8	Heat accumulation from chain or seal expiration	8	None	5	320	M
Knife guard	Wider guard	Could not cut rice properly	7	Friction with cutting blade and rice	8	Lubricating	5	280	L
Cutting blade	Less sharp	Could not cut rice properly	7	Friction with rice	8	Lubricating on blade set	5	280	L
Roller shaft	Notch on surface	Oil spilling	7	Not enough lubrication or oil expiration	7	Changing oil frequently	5	245	L
Chain bush	Thinner surface	Chain loosen and derailment	7	Friction with pin	7	Greasing before assembly	5	245	L
Bezel	Smaller in size	Could not thresh completely	5	Friction with rice	4	None	9	180	L
Chain pin shaft	Smaller pin	Broken chain	6	Impact from body	6	Greasing before assembly	5	180	L
Rice sieve	Broken sieve	Uncleaned grain	4	Vibration of sieve	4	None	9	144	L
Feeder shaft	Smaller in size	Inefficient guiding rice	4	Friction with rubber bolster	4	None	5	80	L
Screw conveyor for ears of rice	Smaller blade	Hard to move withered grain	2	Friction with rice	2	None	10	40	L
Tine	Smaller tip	Hard to remove grain	2	Friction between tine and ears of rice	2	None	9	36	L
Blade bar	Loosen bush	Noisy and Vibration	2	Friction between metal parts	2	Lubrication	9	36	L
Track	Thinner and bended	Machine vibration	2	Stepping on rock or unsmooth surface	2	Operating with attention	7	28	L

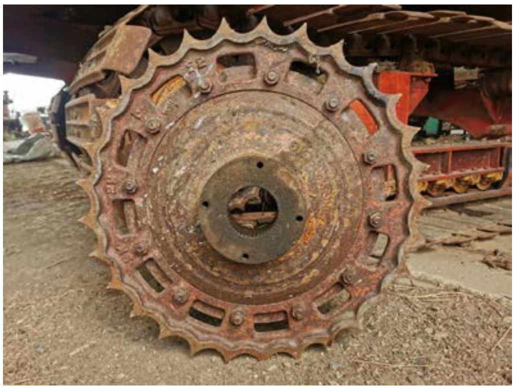

Fig. 4. Damage on sprocket.

5) Damage on wheel guide was occurring at the ridge of wheel guide from the friction between wheel guide and chain. If the ridge was getting smaller, the chain would derail more easily as shown in Fig. 5. To observe this problem, farmer could monitor the surface of wheel guide and observe the alignment of wheel guide. The maintenance must be performed immediately. If not, it would affect other parts of the combine harvester. The actions included lubrication, setting alignment, and surface hardening of wheel guide.

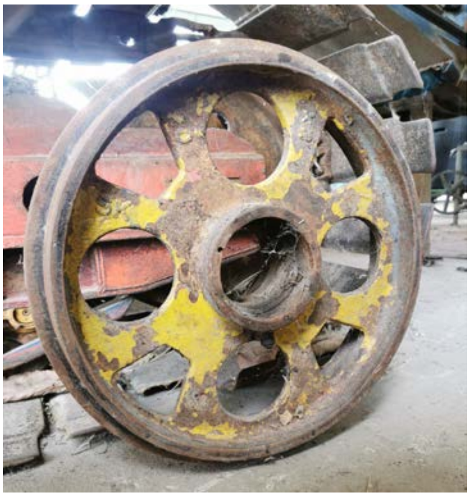

Fig. 5. Damage on wheel guide.

4 Summary

The FMEA technique was applied on parts of the rice combine harvester to study the potential risk, potential effect, and potential causes. The RPN then were calculated and used to prioritize risk level. The risk in high level were analyzed for the causes and effects and then suggested a preventive maintenance

The results revealed that the highest RPN of 576 was found when a chain surface was considered and also showed the maximum risk among the considered parts in the rice combine harvester. While, the lowest RPN of 144 was found when a rice sieve part was considered but this RPN was still higher than that of 100 RPN which was required to specify the preventive maintenance.

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