Development of a Cutter Bar Driver for Reduction of Vibration for a Rice Combine Harvester

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Abstract

The objective of this study was to develop cutter bar driver for reduction of vibration for a rice combine harvester. 3 types of new cutter bar drivers were developed: stir type, perpendicular axis type driven by chain, and perpendicular axis type driven by belt. Comparative vibration and header loss of the 4 types were tested. Results of the test indicated that the 4 type tested similarly in the header loss. The vibration of the header tended to be lowest when using the perpendicular axis type driven by chain.

Keywords: Rice Combine Harvester, Cutter Bar Driver, Vibration

Introduction

Rice combine harvesters play an important role in rice harvesting in Thailand, where there were more than 10,000 rice combine harvesters operated (Chinsuwan et al., 2010). They are machines with the reaping and threshing systems in one, which have been developed to fit the harvesting conditions in Thailand.

A rice combine harvester consists of different sets of equipments, one of the most important is the header which involves cutting, combining, and conveying rice to be screened and separated from straws in the threshing chamber. In the cutting process, a cutter bar driver, shown in Figure. 1, is an equipment driving cutter bars to cut rice stem. It consists of header's drive axial transmit power via connecting rod which drives the cutter bar to move in a swaying motion. Cutter bar drivers in rice combine harvesters are currently designed to move perpendicular to the rice combine harvester's moving direction. This is causing great vibration in the combine head and threshing drum, whereas more vibration was also caused when operating with reel and front auger. The equipment, in a rice combine harvester, creating strongest vibration is the cutter bar driver. On the other hand, the reel, the front auger, and chain conveyer are moving along the rice combine harvester's moving direction, causing relatively low vibration compared to that caused by the cutter bar driver (Chuan-Udom et al., 2009).

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Vibration in rice combine harvester causes the equipments and parts in it to worn out earlier than they should be, especially in the frame under the conveyer and header, which bear the machine weight. The machine manufacturer was, thus, required to increase the size of metals in such machine structure to reduce damages caused by vibration. Consequently, there is an increase in manufacturing cost as well as the machine weight. Vibration can also increase harvesting loss especially when harvesting local rice varieties, whose rice paddies fall easily (Chinsuwan et al., 2003), since the vibration in the header might shake the rice stem during harvesting. Therefore, this study aims to reduce vibration in the header and the rice combine harvester by developing new cutter bar driver to replace the existing one.

Equipments & Methodology

This study was conducted using the axial flow rice combine harvester, provided by the Agricultural Machinery and Postharvest Technology Research Center, Khon Kaen University. The harvester cutting width was 3 meters, the engine power was 194 kilowatts (260 horsepower), diameter of the auger was 600 millimeters, 6 pickup bars with 26 pickup teethes/bar, as shown in Figure 1. The study was done in 3 steps as follow:

The Development of Cutter Bar Driver

The development of cutter bar driver is supposed to reduce vibration in the header by changing the cutter bar driving mechanism to stir type and perpendicular-axle type.

Comparative Analysis of Vibration in Cutter Bar Driver

Vibration in the cutter bar driver was measured in the study at the header's drive axial speed between 250 to 400 revolutions per minute. The experimental speed was divided into 7 levels with 25 revolutions per minute intervals. There were 9 replications for each level. The revolution speeds used in the study were commonly used because speed lower than 250 revolutions per minute could be too slow leading to a jam in cutter bar, reel, and the front auger. On the contrary, 400 revolutions per minute would be too fast, leading to too much vibration on the header, causing the reel index to be too high which could increase header loss (Chinsuwan et al., 2004).

A vibration meter, VM-120, was used to measure vibration in 2 directions: horizontal and vertical, shown in Figure. 1. The measured location was done where the arm extended farthest from the header, Figure 2. Vibration measurement was done by measuring amplitude or the swaying distance of the header from the balancing ling, measured in Root Mean Square (RMS).

Figure 1. Horizontal and vertical vibration

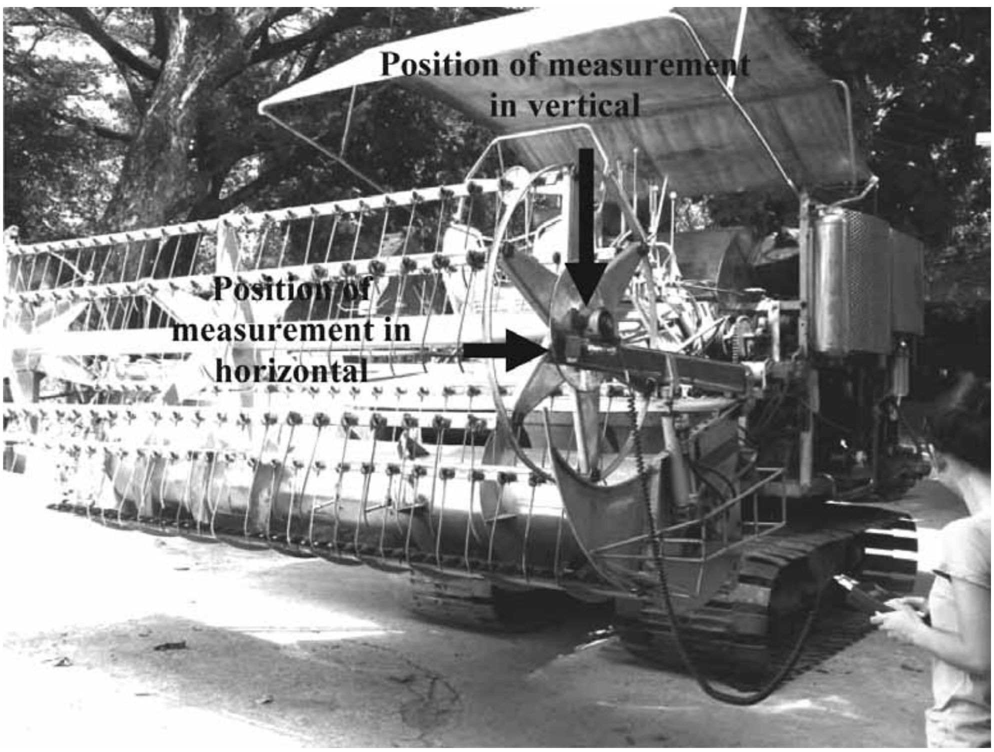

Figure 2. Area where horizontal and vertical vibration were measured

Comparative Analysis of Header Loss in Cutter Bar Driver

The study was conducted on Hom Mali 105 rice variety in the Khon Kaen irrigation area, at grain and straw moisture content of 21.01% and 61.37% wet basis, respectively. The average rice density was 241,920 plant per rai, average stem length was 88 centimeters, average inclined angle of crop plant was 40.2 degrees. The cutter bar speed was at 0.45 meters per second, while the reel index was at 3 and driving speed was 2.5 kilometers per hour. Clearance between the fingers and cutter bar was 50 millimeter and header's drive axial speed was 325 revolutions per minute.

For each type of cutter bar driver tested, three replications were done. In each replication, a rice combine harvester was designed to run at least 15 meters to ensure steady operating condition before collecting header loss data. Fallen grains were collected from the area where header loss data was to be measured. Afterwards, the rice combine harvester was run through the designated area then stopped without stepping into the area. The loss was collected by operating cutting width.

Results & Discussion

The Development of Cutter Bar Driver

1) Stir Type

This type of equipment uses the rotating movement of the axle to drive the header to stir the cam, which drives the cutter bar to stir along the axis. This type may cause less vertical vibration (Figure 3).

Figure 3. Cutter Bar Driver (Stir Type)

2) Perpendicular-Axis Type (Driven by Chain)

This type of equipment uses the drive from header axle by chain and gear. The advantage of this type is that there is no slip in the power transmission and there is low tension between front and back axle, which could affect vibration. However, it is costly and high-maintenance, compared to the belt type. The cutter bar uses the movement of perpendicular axis and is driven by the bevel gear in the gear chamber. The axle, then, drives the stir-type cutter bar driver. This type may cause less vertical and perpendicular vibration (Figure 4).

Figure 4. Cutter Bar Driver (Perpendicular Axle, Driven by Chain)

3) Perpendicular-Axis Type (Driven by Belt)

Most of the mechanics in this type of equipment is identical to the type driven by chain. The only difference is that the header was driven by pulley and belt. The advantage of this type was that it is low in cost and maintenance. However, there maybe some slippery during power transmission and some tension between the front and back axle, possibly causing horizontal vibration (Figure 5).

Figure 5. Cutter Bar Driver (Perpendicular Axle, Driven by Chain)

Comparative Analysis of Vibration in Cutter Bar Driver

The resulting RMS of horizontal vibration amplitudes in the header, while using different cutter bar driver at various speed, were compared and displayed in Table 1, while the vertical vibration amplitudes were displayed in Table 2.

Table 1. RMS of horizontal vibration amplitude in the header when using different types of cutter bar driver at various header's drive axial speed (mm.)

Header's drive axial speed (rpm)	Types of cutter bar driver			
	Original	Stir	Perpendicular Axle	
			Driven by chain	Driven by belt
250	2.05	2.45	2.14	3.19
275	2.78	2.88	2.27	3.40
300	4.06	3.18	3.01	4.04
325	5.05	3.72	3.42	4.12
350	6.19	5.01	3.78	4.51
375	10.07	9.47	5.40	5.46
400	13.44	12.01	8.04	6.70

Talbe 2. RMS of vertical vibration amplitude in the header when using different types of cutter bar driver at various header's drive axial speed (mm.)

Header's drive axial speed (rpm)	Types of cutter bar driver			
	Original	Stir	Perpendicular Axle	
			Driven by chain	Driven by belt
250	3.77	3.14	3.28	4.09
275	4.30	3.44	3.59	4.37
300	5.88	3.78	3.95	4.49
325	7.54	4.38	4.12	5.20
350	12.03	6.39	4.60	6.23
375	15.62	11.35	7.03	7.03
400	18.65	15.65	10.69	9.01

Figure 6. shows correlations between header's drive axial speed and RMS of horizontal vibration in the header, according to data in Table 1. It was found that as the header's drive axial speed was increased from 250 to 350 revolutions per minute, all 4 types of cutter bar drivers yielded linearly increasing RMS's of horizontal vibration. On the contrary, once the speed exceeded 350 revolutions per minute, RMS's dramatically increased. At speed lower than 300 revolutions per minute, all 4 types of cutter bar drivers yielded similar RMS's. However, when the speed was increased to be more than 300 revolutions per minute, RMS of the existing cutter bar driver tended to be increased the most, followed by the stir type, while the chain and belt type yielded similar RMS's.

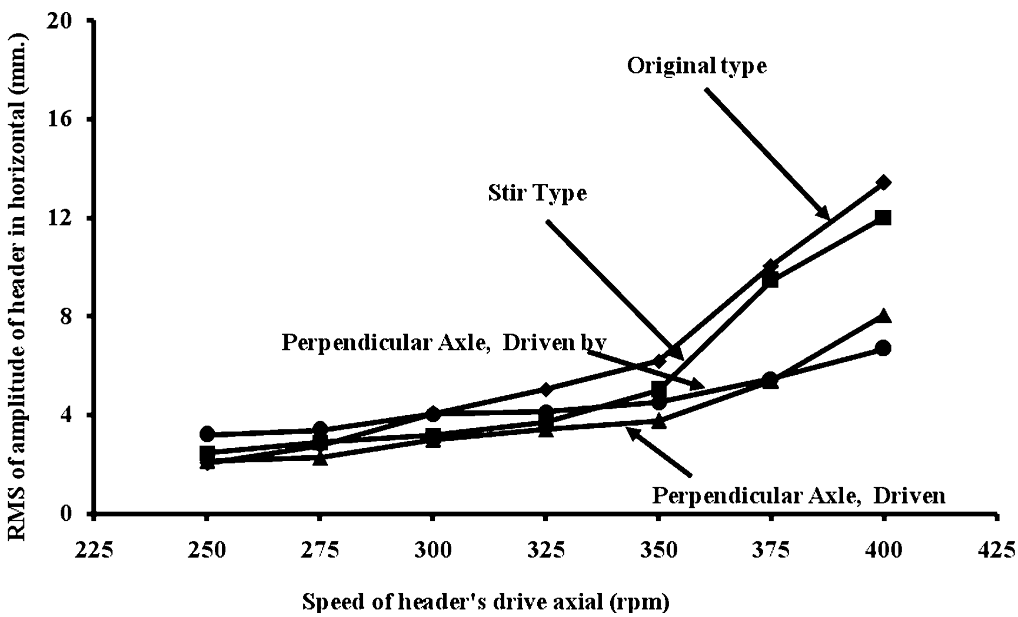

Figure 6. Correlations between header's drive axial speed and RMS of horizontal vibration, when using different cutter bar driver

The correlations between header's drive axial speed and RMS of vertical vibration in the header are shown in Figure 7. When the speed was increased from 250 to 275 revolutions per minute, the 4 types of cutter bar drivers yielded no significant differences in RMS of vertical vibration. However, once the speed exceeded 275 revolutions per minute, the existing cutter bar driver tended to yield the highest RMS, followed by the stir type whose RMS increase dramatically when the speed exceeded 325 revolutions per minute. On the other hand, those from the chain type and belt type increased linearly and were identical.

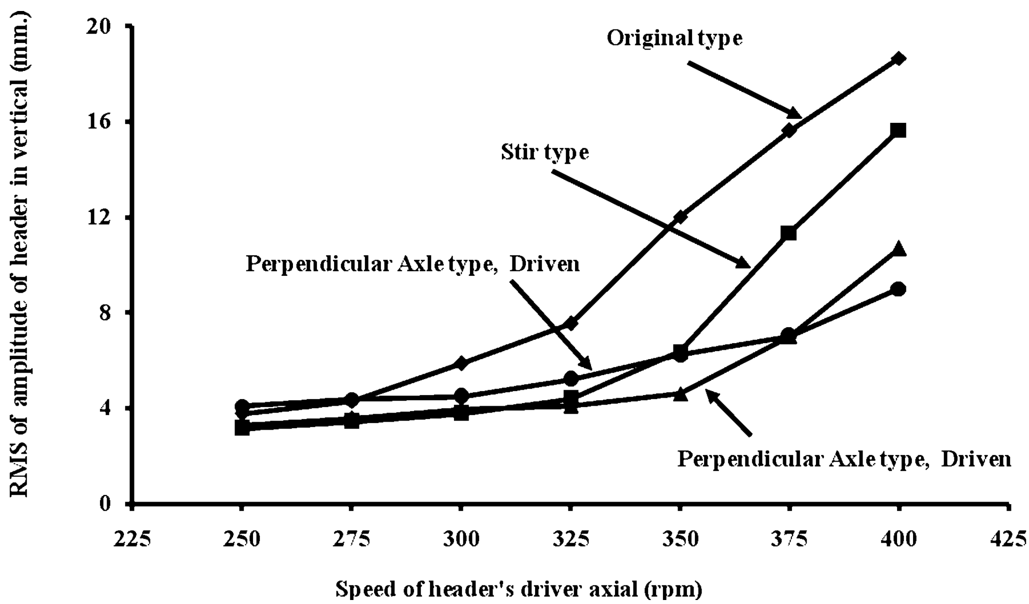

Figure 7. Correlations between header's drive axial speed and RMS of vertical vibration, when using different cutter bar driver

From analyzing the vibration in the header caused by the cutter bar drivers, both vertically and horizontally, it was found that cutter bar driver caused more vertical vibration then horizontal vibration. In fact, the cutter bar driver causing highest vibration, both vertically and horizontally, was the existing one, followed by the stir type. The perpendicular-axis, driven by chain, caused less vibration than the perpendicular-axis, driven by belt, when the speed was lower than 375 revolutions per minute. However, when exceeding 375 revolutions per minute, the belt type tended to cause less vibration than the chain type, both vertically and horizontally.

Comparative Analysis of Header Loss in Cutter Bar Driver

The header loss caused by each type of cutter bar driver when harvesting Dok Mali 105 rice variety is shown in Table 3. The results showed no statistical differences in header loss, indicating that the performance of the type of cutter bar driver had no influences on header loss.

Table 3. Header loss caused by different types of cutter bar driver

Types of cutter bar driver	Header loss (%)
Original	1.37 a
Stir	1.10 a
Perpendicular Axle, driven by chain	1.37 a
Perpendicular Axle, driven by belt	1.57 a

Note: same letters in the same column means insignificant difference, compared by using LSD at 5% significant level

Conclusion

This study tested the new cutter bar drivers against the existing one, in terms of vibration and header loss. The results indicated that the 4 types of cutter bar drivers had no influence on header loss. However, when vibration in the header was considered, the chain type tended to yield the least vibration. Thus, the chain type is suggested to be developed and modified to fit the manufacturing process of manufacturers in Thailand.

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