Development of an Assembly Consistency End-of-Line Inspection System for Corn Harvester

Bingzhong Peng, Du Chen, Dong Sun, Shumao Wang
College of Engineering, China Agricultural University, Beijing 100083, China;
[1]Beijing Key Laboratory of Optimized Design for Modern Agricultural Equipment, Beijing 100083, China
bingzhong @cau.edu.cn, tchendu @cau.edu.cn

Keywords: Corn Harvester, Assembly Consistency, Vibration, Transmission.

Abstract: Nowadays, along with the application of intelligent equipment and new technology, automation degree of manufacturing becomes more and more advanced. While corn harvester, as one of the most important agricultural machineries, the assembly quality was still inspected by traditional method depending on workers' experience in China. Transmission is the core part of corn harvester, which is also the vibration source of whole machine. Detecting and keeping transmission assembly consistency can reduce the vibration degree and increase the mean time to failure, and improve the performance of whole machine. In this paper, a transmission assembly consistency inspection system was designed and a method for judging the assembly consistency was proposed. The proposed approach included two parts, the vibration signals analysis, which was processed based on six bands method to calculate the energy of six bands; and the consistency comparison, which was used to judge the assembly consistency intuitively through the chart. In the last we chose the corn harvester pulverizer as an analysis object. According to result, the third and the fifth are incongruous.

1 INTRODUCTION

Corn harvester, as one of the most complex agricultural machinery, is mainly embodied in the complexity of the transmission system. On the one hand, the transmission system of corn harvester consists of various transmission forms, including belt drive, chain drive, gear transmission, cam drive and so on. On the other hand, for the corn harvester, the harvest process requires long time, and the transmission system need to withstand interfere of dust, straw, clods and other debris while working, which increase the reliability and durability requirements of transmission system. Therefore it is necessary to inspect the assembly quality of corn harvester to ensure its reliability. At present, the inspection of assembly quality is still in a traditional way, without automation. Inspecting with an automated way can control assembly quality well.

At present, studies on assembly quality focus on process quality control strategies and techniques. Suzuki et al. (2001) aiming at the reliability of assembly workshop, put forward a method (AREM) of assembly reliability evaluation, in which, the assembly failure rate was quantitatively studied by designing factors and workshop factors. According to this study, it can improve the reliability level of assembly by controlling influence factors. Kurt et al. (2000) used the AQM and DFA to evaluate the assembly quality of the products, so as to improve the assembly quality in design stage. Milberg and Wisbacher (1992) analyzed noise of the assembled products and assembly process, and then controlling the assembly quality of products by using the noise spectrum diagram. Su S. developed a marine diesel engine assembly quality information management system based on management system model, which can extract diesel engine configuration information and generate assembly quality inspection cards suitable for specific diesel engines. Kong F. established the prediction model of assembly quality defect rate, it can be used as the monitoring means of assembly quality, and can also be used as the basis for product design and assembly process adjustment. According to the references, we know that most of the studies focused on design stage or components assembly. However, there is no end of line assembly quality evaluation method.

Specifically speaking, in order to ensure assembly reliability of corn harvester and raise automation degree of inspection, we proposed an end of line assembly quality evaluation method. The rest of the

Peng, B., Chen, D., Sun, D. and Wang, S.
Development of an Assembly Consistency End-of-Line Inspection System for Corn Harvester.
In *3rd International Conference on Electromechanical Control Technology and Transportation (ICECTT 2018)*, pages 652-656
ISBN: 978-989-758-312-4

paper is organized as follows: Section 2 provided method and materials in this work. Section 3 determined the proper sensor. In Section 4 the results and discussion are presented and Section 5 gave some conclusions.

2 METHOD AND MATERIALS

In the shop, the assembly quality of corn harvester is inspected in an artificial way (Yi and Wang, 2009). To make it automatic, we designed an inspection system, which can acquire vibration signal and analyze assembly quality with it. The inspection system includes velocity sensor, NI-9234 AD input module, NI cDAQ-9172 eight-slot USB chassis, and a signal analysis software. The specific composition and flow chart of measurement is shown in Figure 1.

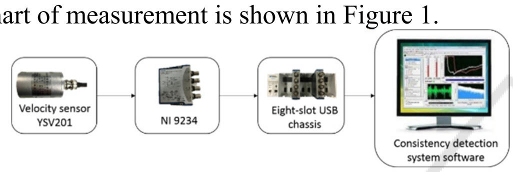

Figure 1: The specific composition and flow chart of measurement.

With the inspection system, to acquire vibration signal, we designed a set of experimental scheme and carried out in Tianjin Yongmeng Machinery Co. Ltd. The whole detection flow chart mainly included five steps, namely frequency pre-estimation, signal acquisition and processing, band division, data analysis, and results presentation. Type 4YZ4590 was selected as experiment object. And selecting four key vibration parts in a corn combine harvester, namely header, engine, pulverizer and rear bracket to test. Total 8 corn harvesters were tested. Each part tested 3 times. The sampling rate is set to 10 kHz. The harvester worked both in idle rotational or maximum rotational speed conditions. Figure 2 is the picture taken while we were doing experiment.

Figure 2: Doing experiments.

3 DETERMINATION OF THE PROPER SENSOR

In this paper, a preliminary experiment was carried out to determinate the proper sensor between velocity sensor and accelerometer, both using piezoelectric principles. Important parameters of the two sensors are shown in table 1.

Table 1: Main parameters of sensors.

Name	Performance index	Technical parameter
Type YSV201 Velocity sensor	range response frequency sensitivity	185mm/s 4~1000Hz 27mV(mm/s)
Type ULT2035V Accelerometer	range response frequency sensitivity	50g 1-12000Hz 98.24mV/g

All experiment materials comprised function generator, power amplifier, vibration exciter, velocity sensor, accelerometer, NI-9234 AD inputs module, NI cDAQ-9172 eight-slot USB chassis, and a computer with Signal Express software. Experiment installation is shown in figure 3.

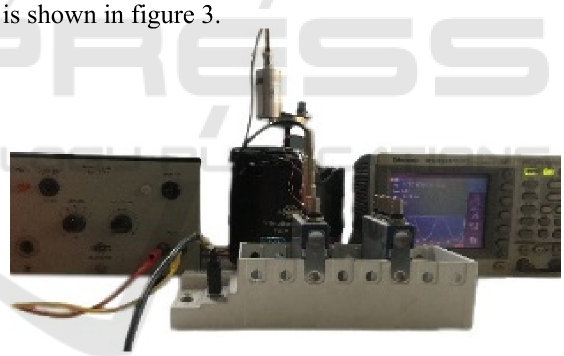

Figure 3: Experiment installation

In this experiment, according to the vibration frequency range of corn harvester, which belongs to low-frequency stage (Lin et al. 2015), it is better to use velocity to reflect vibration features based on vibration theoretical background. Therefore, velocity peak-peak value are measured to make a performance contrast. Data were acquired at the operational condition of sinusoidal signal from frequency 4Hz to 44Hz. And to get velocity values, the data acquired with accelerometer was processed in single integration algorithm. In Figure 4, measured data are shown.

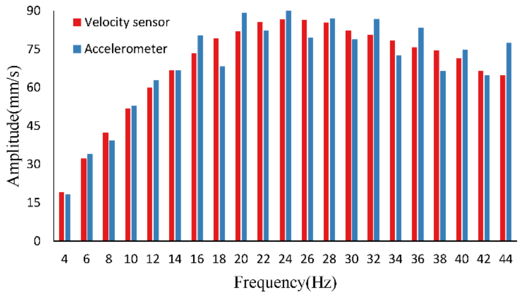

Figure 4: Peak-peak value contrast histogram between velocity sensor and accelerometer

From Figure 4, the two histograms are closed to each other from frequency 4Hz to 14Hz, when the frequency exceed 14Hz, they are alike in the tendency, but the result tested by accelerometer fluctuate tremendously. So the comparison leads to the conclusion that the velocity sensor is better while the frequency belongs to low-frequency stage. It is correspond to what we know that the accelerometer is suitable for frequency over 1000Hz. In a conclusion, from the stability perspective, measured with the velocity sensor is better.

4 RESULTS AND DISCUSSION

To judge assembly consistency, frequency band energy is a most commonly used parameter. The total energy generated by all the peaks in the band is calculated by the following formula:

$$E=\frac{\sqrt{\sum_{i=1}^{n} F_i^2}}{\sqrt{N_{BF}}} \quad (1)$$

Where the n is number of spectral lines in frequency band, F_i is the spectrum value, and N_{BF} is noise bandwidth of the selected window function.

According to the carried out experiment, corn harvest pulverizer was chose as analysis object. In order to analyze the test result, two kinds of data processed methods were used. One is statistical analysis. Total energy of corn harvester from frequency 0 to 500Hz was calculated in level and vertical directions. As we tested 3 times on each corn harvester, then made an average of total energy. Table 2 showed the sum of averaged level and vertical total energy. According to the data in table 2, first we verify that it obey the normal distribution. Because the sample is 8, we use the method of non-parametric test with the statistical analysis software SPSS. Result is shown in the following table 3:

Table 2: Total energy of frequency band.

No	1	2	3	4
Total power	290.43	305.61	1148.42	437.24
No	5	6	7	8
Total power	863.42	471.82	333.26	449.24

Table 3: Single sample Kolmogorov-Smirnov test.

parameters		energy
N		8
Normal parameter a, b	Mean value	537.4300
	Standard deviation	306.62526
Extreme difference	Absolute value	0.335
	Positive	0.335
	Negative	-0.210
Kolmogorov-Smirnov Z		0.947
Progressive significance(double side)		0.332

a. the distribution of test is normal distribution.

b. calculated according to the data.

The progressive significance is 0.332>0.05, so it obeys the normal distribution.

As it is verified obey the normal distribution, and the total mean value, variance are unknown, we can use T test and calculate the confidence interval of consistency, of which the confidence is 95%. The sample average, standard deviation and confidence interval are calculated with the following formulas:

$$\bar{X}=\frac{(x_1+\ldots+x_n)}{n} \quad (2)$$

$$S=\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1} \quad (3)$$

$$\left(\bar{X}-t_{\alpha/2}(n-1)\frac{S}{\sqrt{n}},\bar{X}+t_{\alpha/2}(n-1)\frac{S}{\sqrt{n}}\right) \quad (4)$$

Where the n is sample, $\bar{X}$ is sample average, S is variance, and α is significance level.

The calculated result is $\bar{X}$=537.43, S=306.63, and confidence interval is (281.58, 793.28). According to the confidence interval, the third and fifth corn harvests are incongruous. A reference index value K can be calculated. K=793.28/281.58=2.82. If the K value calculated less than 2.82, then the assembly is consistent, otherwise, it is incongruous. K value calculation formula:

$$K=\frac{P}{281.58} \quad (5)$$

Where the P is the total power.

Six bands spectrum is an effective way to analyze vibration signals by dividing the frequency domain signals into six frequency bands. On each band, it reflects correspond faults. Usually the first frequency band is less than 1 times working frequency, second, third, fourth and fifth frequency band contain 1times, 2 times, 3 times and 4 times, sixth band contains 4 to 12 frequency doubling (James, 1990). As the engine speed of tested corn harvesters is 2400rpm, so for the corn harvest pulverizer, its major energy focuses on the frequency from 0 to 500Hz, we divide it into 6 frequency band, first is from 0 to 35Hz, second is 35 to 75, and the increment is 40 from the second to the fourth, the last frequency band is from 195 to 500Hz. On each band, energy was calculated and made an average with 3 times. Figure 5 and figure 6 show the frequency band of 8 corn harvesters in level and vertical directions, respectively.

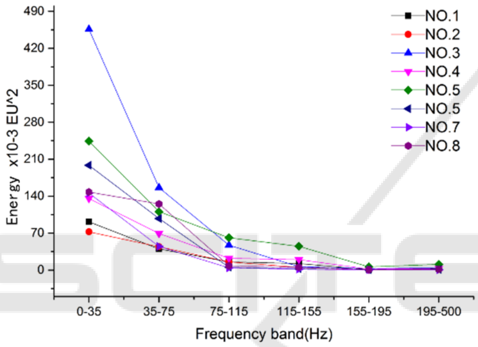

Figure 5: The energy of line chart in level direction.

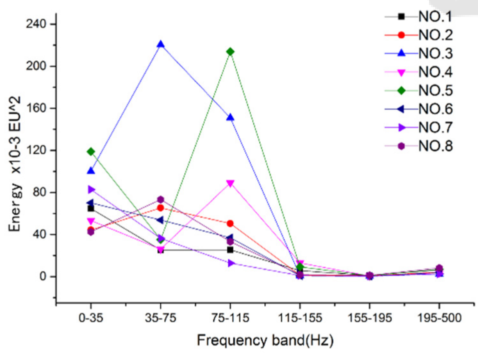

Figure 6: The energy of line chart in vertical direction.

From the line chart, it is easy to discern the third corn harvest and the fifth is incongruous with the others both in level and vertical direction. According to the knowledge of mechanical vibration fault diagnosis, we know rotary machine exist rotor unbalance if it is abnormal in working frequency, and if it is unusual in 2 times working frequency indicates rotor misalignment. The pulverizer is a kind of rotating machine, from figure 4 and figure 5, we can judge the third one with fault of unbalance and the fifth one exist misalignment.

Statistical analysis and six bands can judge assembly congruous of corn harvester both well. The statistical analysis makes a judgment quantitatively, while six bands judges more intuitionistic, which can also reflect specific fault.

5 CONCLUSIONS

In this work, it demonstrates an assembly consistency inspection system and a method of consistency judgment about corn harvest transmission system. The result using vibration signals corroborate its efficiency. The use of frequency bands energy help to separate the energy of different corn harvests in different bands, which make the corn harvest, whose assembly is incongruous, remarkable and easy to distinguish form the chart. It gives us an intuitionistic judgment.

This method proves to be extremely useful in cases where the vibration signals are the most important information for the complicated corn harvests. And it make the inspection of consistency more scientific, efficient and automatic, which can guarantee the whole performance of corn harvests well before they start working.

ACKNOWLEDGMENTS

This work was financially supported by National Science & Technology Pillar Program during the thirteenth Five-year Plan Period (2017YFD0700204). The corresponding author is Du Chen.

REFERENCES

Suzuki, T. et al. 2001. Assembly Reliability Evaluation Method. International Symposium on Assembly and Task Planning Soft Research Park, Fukuoka, Japan May 28-29, 2001.

Kurt, A. et al. 2000. Assembly quality method: a tool in aid of product strategy, design, and process improvements. Design Engineering Technical Conferences Baltimore, MD September 10-13, 2000.

Milberg, J. & Wisbacher, J. 1992. Acoustic Test Procedures —A Powerful Method for Quality Assurance and Process Monitoring in Assembly [J] CIRP Annals - *Manufacturing Technology*. 41(1):25-28

Yi, K. & WANG, M. 2009. Analysis and countermeasures for Chinese agricultural machinery product quality [J]. *Chinese Agricultural Mechanization*, (5): 07~10
Lin, J. et al. 2015. Status of Maize Harvesting Machinery and Its Development Trend in China [J]. *Agricultural Science & Technology and Equipment*(6)
James, E, Berry. 1990. How to Specify Machinery Vibration Spectral Alarm Bands. *Sound and Vibration*.