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A Performance Evaluation Device for Vibration Absorption Unit of Grain Loss Monitoring Device of Combine Harvester

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Abstract: *In order to ensure proper operation of crop combine harvesters, the operation should be paused several times during the harvesting, so as to measure grain loss and determine its cause(s). Grain loss depends on combine configurations, material input rate, farm status, and the land conditions. When installed on the back of a combine, "grain loss monitoring" device can determine simultaneous indication of grain loss incurred by the grain separation and cleaning units, while allowing the user to set an optimum progress speed, when moving within the farm, while sticking with an acceptable level of grain loss. Used in this device are highly sensitive piezoelectric sensors. When operating, combine harvester generates such a great deal of vibration which may prevent the sensors from operating properly and reliably. In order to attenuate interferential effects of combine-derived vibrations on the performance of sensors, the vibrations are to be prevented from being transmitted to the grain loss monitoring device, making it necessary to install some vibration absorption mechanism on the combine harvester prior to have the grain loss monitoring device installed. In the present research, not only a vibration absorption mechanism is presented, but also a device is designed and manufactured to evaluate its performance; the complete system is then installed on a combine harvester where it is practically examined. It is observed that the proposed vibration absorption mechanism can absorb nearly all vibrations generated by the combine harvester body, so as to prevent them from reaching highly sensitive sensors with which the grain loss monitoring device is equipped.*

Keywords: *Combine, Grain Loss Monitor system, Absorber, Performance Evaluation Device.*

INTRODUCTION

About 11% of the lands covering Iranian territory are assigned to agriculture, so as to fulfil nutrient needs of about 75% of the Iranian population. Meanwhile, wheat production is seen to enjoy a highlighted position. Within the recent past, a great deal of discussion has been dedicated to the subject matter of wheat loss in the course of the chain from agricultural production to consumption, so as to find solutions for attenuating such a loss, especially in the course of harvesting the crop using combine harvester. Even though some reports indicated such losses to be as much as 20%, the corresponding figures to industrial countries typically range within 2–5%.

Beginning from about four decades ago, a great deal of efforts has been put on the development of grain loss measurement and monitoring devices for combine harvesters. Dahlquist and Klee(1972) designed a device to measure grain loss, which was composed of two helixes and a flow meter. Among other features provided by this device, one may refer to its simple structure and low cost. In this system, grains and other materials leaving the back of combine were guided, through the helixes, towards the flow meter which measured the flow of material using a signal generating instrument.

Liu and Leonard (1993) utilized 9 sonic impact sensors arranged in triples below the combine separating unit to build up a combine grain fall

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measurement device which was able to measure the grain loss simultaneously. Each sensor had its own signal processing and amplification circuits connected to a computer equipped with a microprocessor. The data from different sensors was used to develop a curve describing the way grains were separated in the separating unit; this curve, in turn, was used to infer an exponential loss separation curve in the separating unit. Actual grain loss was then predicted on the basis of this curve. The required hardware and software should be installed on combine harvester.

Bernhardt and Hubner (2003)presented a novel method, as of that time, together with its implementation, for determining combine harvester grain loss. They equipped different components of separating unit with sonic sensors which generated a signal proportional to the amount of separated crop. The signal was then sent to evaluation unit where it was further processed. Next, a separation curve was established for minimum separation in different units; it was then converted into quantitative properties. Based on the measured quantitative properties, determined grain loss according to the curve was obtained by the evaluation unit. In this approach, since the grain loss was indirectly measured, it was associated with significantly reduced adverse effects of crop changes on grain loss.

Attempting to develop a grain loss monitoring device for combine harvesters, Karimi *et al.* (2009) used a load cell to measure grain loss, and aiming to prevent long straws from being fallen on the load cell, they incorporated a mesh into the device. The system design was composed of two parts, namely hardware design and software design. The device was of a high sensitivity which was adjustable in the same time, so that it could identify any loss of down to 50 mg weight. However, due to the large deal of noise signals produced at such a high sensitivity, and also the fact that grain loss was measured in percentages of total crop (i.e. there was no need to such a high sensitivity), the initial sensitivity of the device was set to 0.1 g, with a LCD panel used to display load cell output data. Once manufactured, the device was calibrated and then tested in the laboratory. The results indicated the optimum angle for the installation of the device to be 37°.

Although the combine vibrations have an effective and useful role in the performance of the combine and grain separation process, transition of these vibrations from combine body to the device, is one of the factors causing malfunction in the performance of the sensitive sensors used in the grain loss monitoring device and detection of grain impact signal from vibration noise is difficult. So it's necessary to prevent the transfer of the vibration to the device.

Theoretically, it is possible to remove the vibration completely, but the cost of preparing and implementing the vibration removal equipment may be very high. Therefore, the designer should create a balance between the acceptable vibration intensity and the cost of removing them. Sometimes the unbalancing force resulted from the vibration, originates from the inherent characteristics or working condition of the device. Even if this force is little, in the resonance frequency the response could be undesirably high (especially if the damping of the system is low). In these cases, the unwanted response could be reduced by the use of vibration absorber. In recent years, numerous and diverse researches have been done on various vibration absorbers. The researches indicates that the dynamic vibration absorber, which has been known as tuned mass dampers, are one of the effective and low cost methods for controlling and reducing the mechanical vibrations of the systems (Hunt and Nissen, 1982; Jeong *et al.,* 2014). The first vibration absorber which has been used in 1991 was a spring-mass system (Frahm, 1911).

The existing restrictions in the field of frequency range control, led to the use of damping element along with spring in absorber system. Therefore, the design elements of dynamic vibration absorber systems are mass, spring, and damper. For these systems, the optimal values of these parameters are very important for researchers (Berardengo, *et al.,* 2014; Marian and Giaralis, 2014).

Huang and Lin (2014) investigated the new vibration absorber system consisted of two little beams connected to each other by a spring. The results indicated that the designed vibration absorber had a considerable effect in reducing the vibration of the equipment subjected to the oscillating excitation.

Zhao *et al.* (2012) presented a loss measuring device for separator unit of a rice combine using piezoelectric sensors (PVDF). In this research the frequency spectrum of vertical acceleration due to the combine body was approximately 3 kHz; also, in order to weaken the interaction effect of the combine vibration, a floating stabilizing arm including two separating layers has been designed.

Khalilvandi Behroozyar (2013) used a digital three-axis acceleration sensor to determine the vibration of the rear part of a combine harvester in different conditions of the farm. The sensor was installed in the rear part of John Deere 955 combine harvester and the acceleration values of this part were stored in the computer at three levels of forward speed and three levels of rotational speed as well. This process was replicated in two conditions; system without any crop yield and after inference of the crop inside. The obtained results from the statistical analysis of data declared that the effect of the ground roughness on the vertical acceleration is more significant than the effect of machine variables. The presence of the crop yield inside the combine harvester resulted due to the low moisture content of the harvested wheat.

The present research is mainly aimed to not only present a vibration absorption mechanism to minimize the interferential effect of vibrations generated within the back of combine harvester on the grain loss monitoring device performance, but also design and methods used to evaluate the performance of such mechanism.

MATERIALAND METHODS

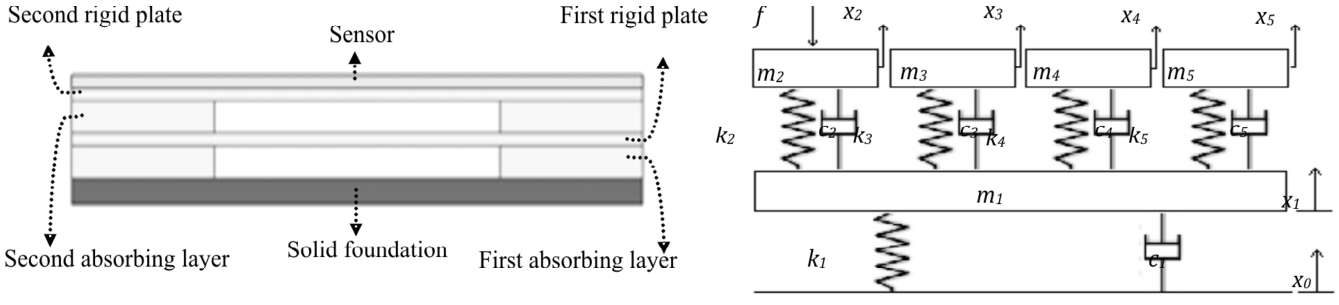
Explained in the following are the materials used along with manufacturing approach followed for the vibration absorption mechanism as well as its performance evaluation device:

Vibration Absorption Mechanism

The sensor used in grain loss monitoring device is typically a piezoelectric sensor to be installed on the back of combine harvester, with the vibration absorption mechanism placed in between the combine body and the sensor, so as to attenuate the body vibrations transmitted into the sensor. Trying to build up the vibration absorption mechanism, the damping vibration absorption structure demonstrated in Figure 1.a was designed. It was consisted of two layers of absorber, two rigid plates, and a rigid adapter through which the mechanism was attached to the combine harvester body.

Figure 1.b shows the analytical model of the vibration absorption mechanism. The first absorber layer was designed in one piece, while the second absorber layer was separately designed for each sensor. k_1 and c_1 refer to the first absorber, k and c represent the characteristics of the second absorber layer, m_1 is the mass of the first rigid plate, and m_2 denotes the mass of the second rigid plate. The grain impact force, f, was supposed to be exerted on the first sensor only; hence, $x_5 = x_4 = x_3$.

With the aim being to manufacture the vibration absorber from readily available materials, the rigid plates were made of steel, while the absorber layers were made of sponge.



(a) (b)

Figure 1 : (a) Vibration absorption mechanism (b) analytical model

A Performance Evaluation Device

In order to evaluate the performance of the designed vibration absorption mechanism, first of all, piezoelectric sensors incorporated into grain loss monitoring device should be set up. Once hit by the grain impact, piezoelectric sensors generate a proportional voltage to the impact intensity in their terminals. Based on the fact that the corresponding ranges of generated voltage amplitude to wheat and straw are well different, one can amplify the generated voltage before sending the signal to the processor. Accordingly, the processor will utilize its integrated pre-developed program to distinguish between wheat grains and straw.

Figure 2 is a simple block diagram of the data retrieval and processing system. Briefly speaking, proportional to the amount of material hitting the sensor, a series of electrical signals are generated. The signals are amplified by the first amplifier before being handed over the next level which is a comparator. Finally, the signal is read by AVR processor which then undertakes the required processes and sends the output data to the LCD screen on which it is displayed.

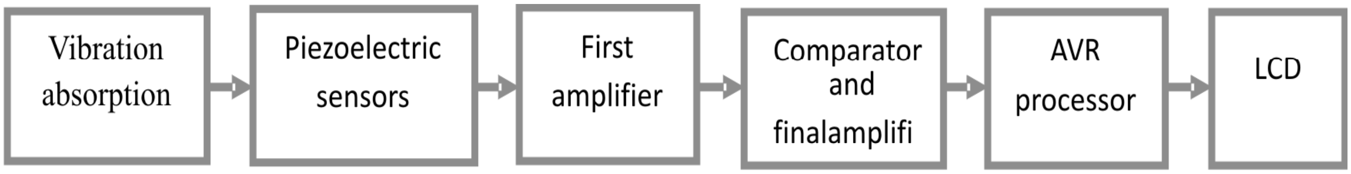


Figure 2 : Simple block diagram of the data retrieval and processing system

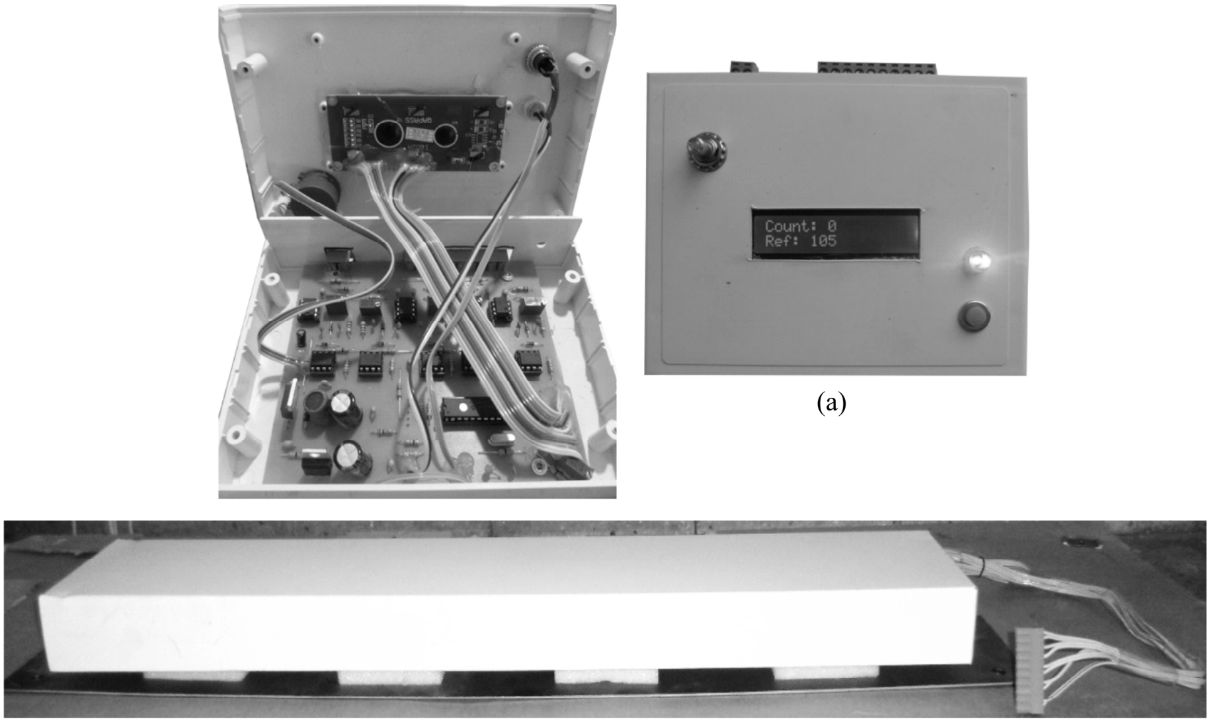
As the output signal from the piezoelectric sensors was way weak, a TL072 amplifier, as a non-inverting amplifier, was used to undertake initial amplification of the recorded signal. However, LM311N, as a comparator, was used for the sake of final amplification and detection of the desired impact signals.

Each of the sensors incorporated into the grain loss monitoring device was provided with a separate amplification circuit which was powered by a 12 V power source. MC7805 was used as the voltage regulator in the circuit. Further used along the circuit was an 8-bit ATmega16 microcontroller. Being an AVR controller, ATmega16 can be programmed in Basic Programming Language via BASCOM software. According to the program fed into the microcontroller, whenever the voltage amplitude received from the sensor exceeded the predefined threshold for the wheat grain, the microcontroller was to count once and add it to the previous value of count. The commands along each line of the program were executed using a 20MHz LDT4-028K crystal oscillator which produced the required pulses for the microcontroller.A 2 by 16 LCD screen was used as the output display (Figure 3.a).

Experimental Tests

Knowing that the cleaning unit within a combine harvester is approximately 1 m wide, the width of the vibration absorption mechanism was designed to be 70 cm. Five piezoelectric sensors were installed below the frame at 14 cm spacing. The frame was attached to the combine harvester body solely via the vibration absorption mechanism, so as to prevent vibrations from being transmitted into the frame. The frame was designed in such a way to encompass sensors as well as vibration absorption mechanism, so as to inhibit direct contact between straws or clashes and sensors or vibration absorption mechanism. Manufactured to be of 70 × 12 × 5 cm dimension, the frame was made of 0.5 mm thick steel (Figure 3.b). Output wires leaving the piezoelectric sensors' terminals were connected to the performance evaluation device.

Used for practical evaluation of the vibration absorption mechanism using the developed performance evaluation device was a Sahand s68 combine harvester of the following technical specifications:beater width: 1060 mm; beater diameter: 450 mm; beater speed range: 400 – 1550 rpm; and engine: a 6-valve Perkins of 125 hp. Beginning with the test, the vibration absorption



(a)

(b)

Figure 3: (a) Performance Evaluation Device, (b) Sensor and Vibration Absorption system

was mounted on the back of the cleaning unit of the combine harvester. The device was mounted about 10 cm below and 15 cm ahead of the end of the cleaning unit, at a 37° angle (Figure 4).

Once finished with mounting the device, the combine started to move under different scenarios: on paved road, on farm land, without running the beater, straw blowers and sieves, with the beater, straw blowers and sieves running on slope. In this phase, as the combine was moving without performing any actual harvesting operations, the grain loss monitoring device was supposed to return zero output, so as failure to return such an output might be interpreted as an indication of contributions from the combine body vibrations into the sensors' responses, i.e. the vibration absorber had failed to adequately perform its intended task. However, as shown in Figure 4, the device provided zero output under all five scenarios planned for the combine to move; i.e. sensors did not sense any impact, confirming the reliability of the vibration absorber. Meanwhile, manually releasing several wheat grains on the sensing plate (to ensure the functionality of the device), the generated impacts were well-counted. Therefore, one can conclude that, first, the proposed vibration absorption mechanism exhibits acceptable performance; and second, performance evaluation device is confirmed to perform properly.

CONCLUSIONS

Although the combine vibrations have an effective and useful role in the performance of the combine and grain separation process, transition of these vibrations from combine body to the device, is one of the factors causing malfunction in the performance of the sensitive sensors used in the grain loss monitoring device and detection of grain impact signal from vibration noise is difficult. So it's necessary to prevent the transfer of the vibration to the device. In the present research, presenting a vibration absorption mechanism for the sake of minimizing interfering effect of combine harvester vibrations on the performance of grain loss monitoring devices, a performance evaluation device was designed and manufactured to examine the performance of the proposed vibration absorption mechanism. In order to practically examine the vibration absorption mechanism using

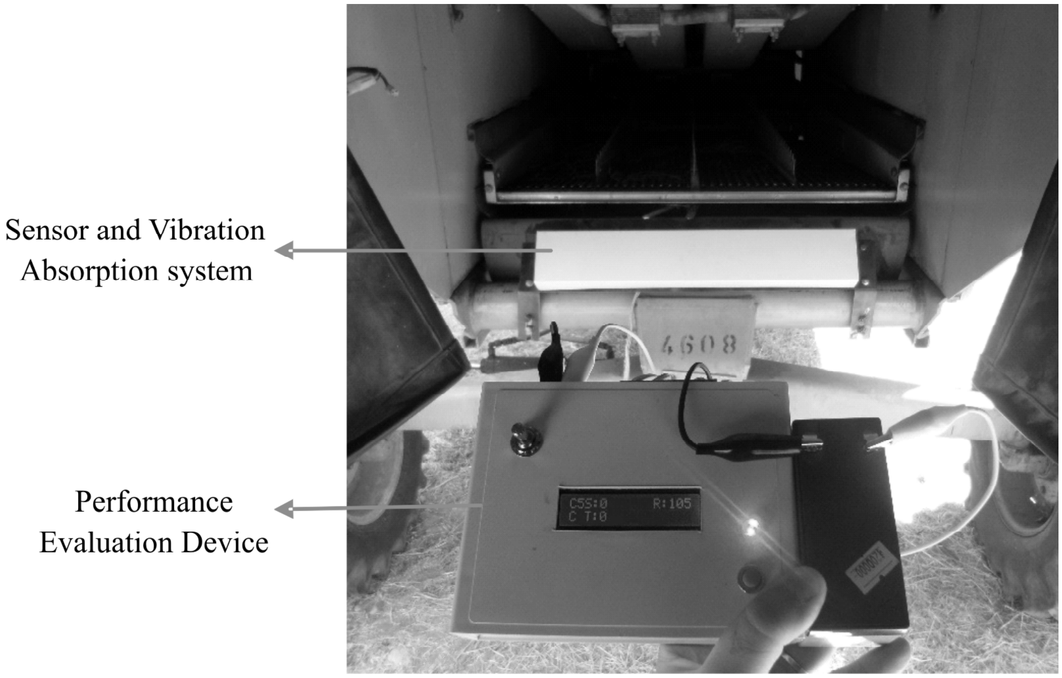


Figure 4: Practical evaluation of the vibration absorption mechanism

the developed performance evaluation device, the whole system was installed on a combine harvester and operated under various operating conditions. The results indicated that, not only the proposed vibration absorption mechanism exhibits acceptable performance in terms of preventing vibrations from being transmitted from combine harvester body to the sensors incorporated into the grain loss monitoring device, but also performance evaluation device is confirmed to perform properly.

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