JARQ 30, 245–248 (1996)

Impact Counter for Fruits during Transportation

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Abstract

Fruits and vegetables sustain mechanical damage from impacts and vibrations during transportation. To measure the degree of impacts and vibrations, an impact counting device was developed, which can be packed with fruits in a corrugated cardboard box and transported. Between the transportation, the apparatus counts the number of impacts above the threshold acceleration in each of triaxial directions. The impact counter consists of a sphere for detecting the acceleration and a box with an electronic circuit. The sphere is made of acrylic resin and contains a triaxial piezoelectric accelerometer.

Discipline: Agricultural machinery
Additional key words: vibration, acceleration, accelerometer

Introduction

Fruits and vegetables sustain mechanical damage from impacts and vibrations during transportation. Many kinds of packaging materials are used to absorb the shocks and to protect the products. However, some of the packages used at present lack the capability to prevent damage, or in contrast, some of them are overdesigned. Recently, overdesigned packaging in particular has become a serious problem in saving energy and resources. For selecting a suitable packaging system, impacts and vibrations must be measured in many cases, and a large amount of data must be collected.

A number of studies have been carried out to measure the impacts and vibrations during transportation and handling of fruits. These previous studies are divided into 2 groups. One of them consists of an analogue data collection system for long term transportation. In the system, one or several accelerometers are attached to a fruit to measure the acceleration. Generally the acceleration is recorded continuously by using a data recorder, and analyzed with a computer after transportation. Although precise acceleration data were obtained by this method, long term measurements were laborious, because the tested package should be monitored by someone during the transportation to operate the data recorder and the other devices. Another method consists of a pseudo-fruit data collection system. Some devices for the pseudo-fruit method have been developed to measure the acceleration[4–6]. However, most of the devices could not be used for long term measurement. These devices were designed for short term data collection during harvest or handling.

The purpose of the studies described here was to develop an automatic impact detection device for fruit during long term transportation. In such a system, the acceleration can not be recorded continuously in analog or in digital form due to the limitation of the size of data storage. It was preferable to process the required information for the acceleration signal and record only for estimating the influence of the impacts and vibrations on fruits. In previous studies, it was observed that the mechanical damage occurring during transportation could be estimated from the peak acceleration, the number of impacts and the frequency of vibration[1–3]. It was also found that serious damage occurred under an acceleration above 9.8 m/s^2 (1 G)[3]. The objective of this study was to develop an ideal device that would enable to measure the acceleration and obtain data on peak, number and frequency of impacts or vibrations by using a microprocessor.

The device reported here is the first generation

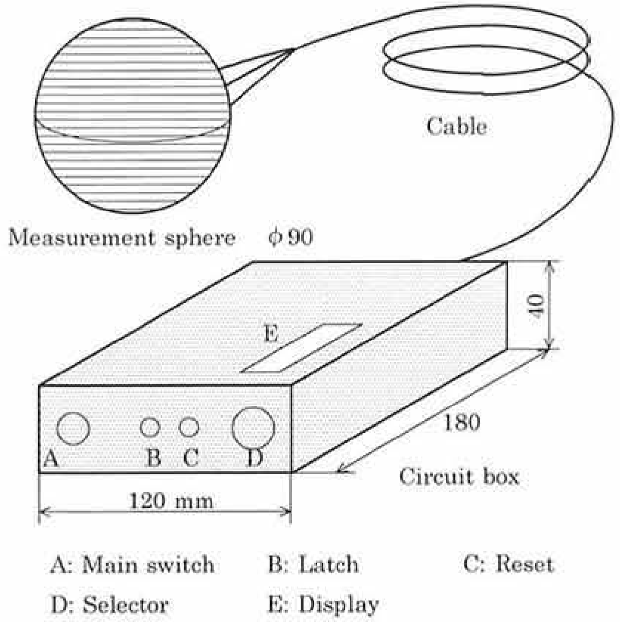

Fig. 1. Schematic diagram of the impact counter

prototype which enables to detect the acceleration and count the number of impacts above the threshold acceleration in each of triaxial directions. The device is referred to as the impact counter.

Development of the impact counter

1) Design characteristics

A schematic diagram of the impact counter is shown in Fig. 1. The measurement sphere and the circuit box are packed with fruits and transported. The measurement sphere is a pseudo-fruit, on which the number of impacts is counted in each of triaxial directions. In comparison with previous data recording methods, the system exhibits the following characteristics: (1) easy operation that does not require particular expertise, (2) long term measurement without an operator, and (3) the counts can be used as an index of the degree of impacts and vibrations without analysis.

Therefore, a large number of tests can be easily carried out at a low cost. In the tests, practical data can be obtained because the measurements are carried out without being noticed by truck drivers or workers. On the other hand, since the device can not record the raw data of acceleration, the shortcomings are as follows: (1) the acceleration or the frequency can not be analyzed in detail and (2) the cause of the impacts or vibrations can not be determined.

For these reasons, the impact counter is not suitable for detailed studies on impacts and vibrations but it is useful for wide-ranging studies on transportation or packaging.

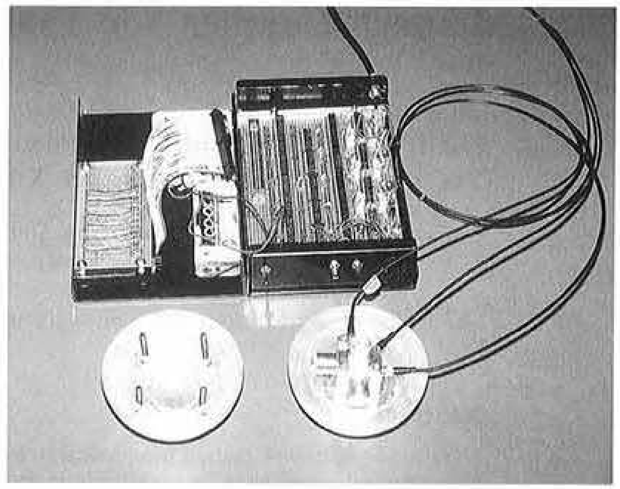

Plate 1. Internal view of the impact counter

Table 1. Specification of the impact counter

Type	3-Axis accelerometer (NP-550)
Sensitivity	10 mV/G
Natural frequency	20 kHz min
Shock	150 G
Temperature	− 20° ~ 110°C
Noise	20 μV max
Weight	50 g
Dimensions	31(H) × 41(W) × 41(D)

2) Construction of the impact counter

The impact counter consists of a measurement sphere for detecting the acceleration and a box for the electronic circuit as shown in Fig. 1. The sphere shell is made of acrylic resin with a diameter of 90 mm and it contains a triaxial piezoelectric accelerometer as shown in Plate 1. The accelerometer was manufactured by Ono Sokki Co. in Japan (Model NP-550), the specifications of which are shown in Table 1. The mass of the sphere was adjusted to about 380 g by cutting the inside part of the acrylic shell. Therefore, the specific gravity of the sphere was about 1, and the center of gravity was located at the center of the sphere.

In this case, the measurement sphere was constructed with such a specification because the study was carried out on apples. For various kinds of

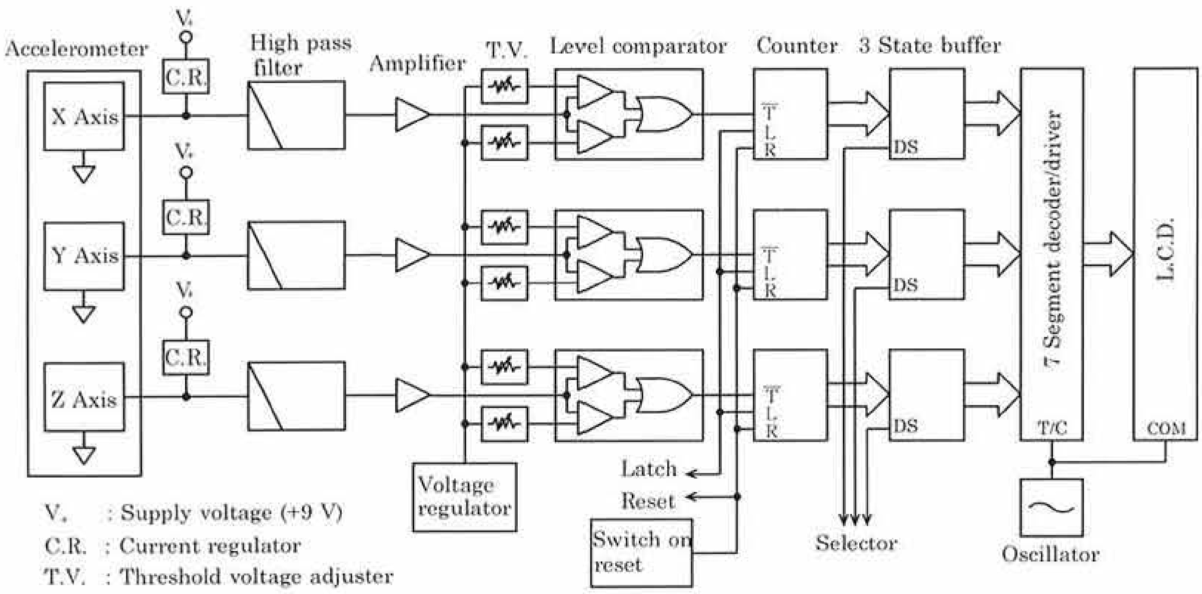

Fig. 2. Block diagram of the impact counter

fruits and vegetables, instruments with different shapes and sizes are available. A triaxial accelerometer with a smaller size was manufactured by Ono Sokki Co. It is designated as Model NP-505 with a mass of only 10 g. A smaller measurement sphere can be made by using the accelerometer for studies on smaller fruits.

The electronic circuit is placed in an aluminum box (180 × 120 × 40 mm). Fig. 2 shows a block diagram of the circuit. Each current regulator supplies a constant current of 0.5 mA to the accelerometer. The accelerometer contains 3 acceleration detectors and 3 pre-amplifiers, 1 for each axis. The output voltage of each pre-amplifier varies in proportion to the acceleration in the direction of the axis. The signal is filtered with a high pass filter and amplified. The cut off frequency of the filter is about 0.3 Hz. The signal of the lower frequency such as the gravity acceleration is cut off there. An OP Amp. TLC 271 is used as the amplifier. It can be operated with a single power source at a very low current.

The amplified signal is fed into a level comparator. The signal is compared with the threshold voltage. Fig. 3 shows an example of the relationship between the detected acceleration and the comparator output. The acceleration plot was obtained from the output of the amplifier. "H" and "L" indicate, respectively, high (9 V) and low (0 V) voltage of the comparator output. In the example, the threshold accelerations were set at ± 9.8 m/s^2(± 1 G). When the acceleration is higher than the threshold level,

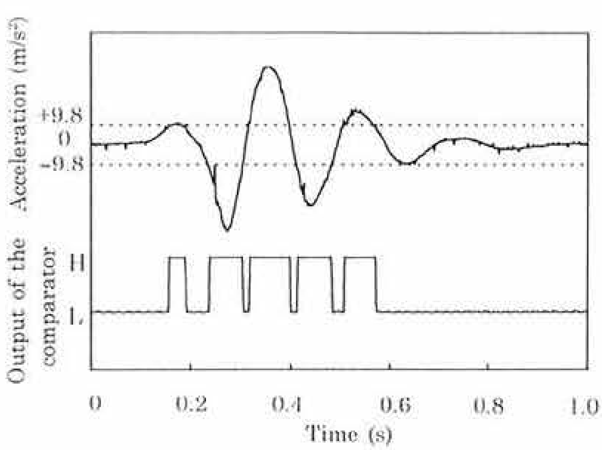

Fig. 3. Measurement of the number of impacts

the output of the comparator corresponds to high voltage as shown in the figure. An OP Amp. TLC 27L2 is used as the comparator. The slew rate of it is as slow as about 0.6 V/μs so that the comparator acts as a low pass filter simultaneously. High frequency noises were eliminated.

The number of impacts larger than the threshold in the direction of each axis is counted by using a counter (CMOS 4553) in the range of 999,999, and displayed on an LCD (liquid crystal display). As the accelerometer requires a relatively high voltage, the power is provided by 6 AA batteries in series. Because most of the components of the electronic circuit are low power CMOS ICs, the impact counter can operate continuously for more than 1 week.

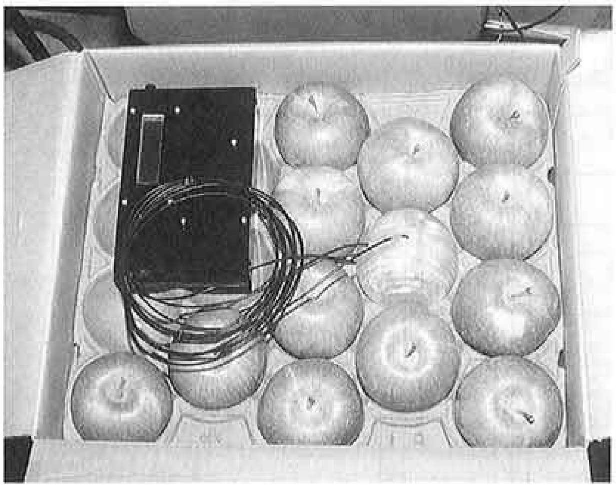

Plate 2. Impact counter packed with apples in a corrugated cardboard box

Example of measurement

A measurement test using the impact counter was made with a package delivery service. The workers of the delivery company were not informed of the experiment. The impact counter was packed with apples (Fuji) in a corrugated cardboard box as shown in Plate 2. The capacity of the box was 36 apples, the total weight of which was 10 kg. In this case, 6 apples in the upper layer were removed and replaced by the impact counter. A thin plastic cushion was put on top of the apples in the experiment as in the case of normal packaging. An example of the measurements was as follows: The package was transported by a truck from the University of Tokyo to Utsunomiya University (distance of about 100 km). The number of measured impacts above $\pm 9.8\ m/s^2$ (± 1 G) was 583 in a vertical direction, while 240 and 414 in horizontal 2 directions.

Conclusion

The impact counter was developed to measure the degree of impacts and vibrations on fruits during transportation. It enables to count the number of impacts above a threshold acceleration in each of triaxial directions. It can run continuously for more than 1 week without an operator. A measurement test of the impact counter was made with a package delivery service. The device was packed with apples (Fuji) in a corrugated cardboard box and transported from the University of Tokyo to Utsunomiya University by a truck (distance of about 100 km). In the experiment, the number of impacts above $\pm 9.8\ m/s^2$ (± 1 G) was 583 in a vertical direction, while 240 and 414 in horizontal 2 directions.

References

1) Iwamoto, M., Kawano, S. & Hayakawa, A. (1978): Engineering approach to simulated transportation test for fruits and vegetables (Part 2). *J. Jpn. Soc. Agric. Mach.*, **40**(1), 61-67 [In Japanese with English summary].
2) Iwamoto, M., Kawano, S. & Hayakawa, A. (1980): Engineering approach to simulated transportation test for fruits and vegetables (Part 3). *J. Jpn. Soc. Agric. Mach.*, **42**(3), 369-374 [In Japanese with English summary].
3) Kawano, S., Iwamoto, M. & Hayakawa, A. (1984): Evaluation of in-transit mechanical injury of fruits and vegetables for simulation of transport test. *Rep. Natl. Food Res. Inst.*, **45**, 92-96.
4) Klug, B. A., Tennes, B. R. & Zapp, H. R. (1989): Analysis of impacts recorded with an instrumented sphere. *Trans. ASAE*, **32**(3), 1105-1110.
5) O'Brien, M. et al. (1973): Telemetry for investigating forces on fruits during handling. *Trans. ASAE*, **16**(2), 245-247.
6) Tennes, B. R. et al. (1988): Self-contained impact detection device. *Trans. ASAE*, **31**(6), 1869-1874.

(Received for publication, January 8, 1996)