ASSESSING THE POTATO IMPACT RESPONSE USING A PENDULUM CONTROLLED AND DESIGNED BY COMPUTER

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Abstract: *This study is focused on using a computer designed and controlled pendulum to asses the potato impact response in harvesting and handling operations. The computer controlled pendulum method is adequate in studying the impact between potatoes and hard surfaces. A Labview application was realized for fast visualization and analysis of the impact parameters. A CAD application was used in order to design the pendulum.*

Key words: *potato, impact, pendulum, energy, force, time.*

1. Introduction

The Potato is one of the most important crops in the world. Some reports state that "Potato is the world's fourth important crop after wheat, rice and maize because of its great yield potential and high nutritive value [2].

It constitutes almost half of the world's annual output of all root and tuber crops. With an annual global production of about 300 million tones, potato is an economically important staple crop in major countries". Potatoes are subject to different stress levels both during harvest and during subsequent post-harvest processing. This stress causes damage to the produce, compromising its preservability; lowering the consumption quality and bringing considerable economic loss. Mechanical forces are among the most important causes of fruits and vegetables bruising in the world [2].

The effects of bruising are felt by every handler and consumer of potatoes are a major economic drain on the industry. The preponderance of tuber bruising typically results from impacts sustained by the tubers during harvesting and handling. The impacts occur primarily when the tubers strike hard surfaces or each other while being conveyed, or in dropping from one conveyor to another.

According to R. Peters, 42% of potatoes are damaged on harvesting, and 54% after grading [5]. The potato transport raises the incidence of bruised potatoes with 10%. As a consequence almost two thirds of the potatoes purchased by the consumer have internal or external damage [5]. The losses caused by potato damage are estimated at £200 per hectare by the British Potato Marketing Board [5]. If one should consider other fruits and vegetables with low texture resistance the quality losses problems are much bigger. It therefore becomes

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important, above all, to measure the intensity of the impacts to the produce during harvest and post-harvest and subsequently to correlate this with the probability of damage to the produce itself.

2. Material and method

Current technique allows the utilization of some methods that will reduce mechanical impacts by reproducing in the laboratory the process which harm the tubers under mechanical loadings produced by external forces.

The computer controlled pendulum is a very useful tool to impact tubers to short time loadings. The schematic representation of the computer controlled pendulum for testing the potato tubers to short mechanical impacts is shown in figure 1 [1].

The pendulum presented was designed using an application named CATIA which stands for Computer Aided Three-dimensional Interactive Application and is the most powerful and widely used CAD (computer aided design) software of its kind in the world .

CATIA is the only solution capable of addressing the complete product development process, from product concept specification through product-in-service, in a fully integrated and associative manner. Based on an open, scalable architecture, it facilitates true collaborative engineering across the multidisciplinary extended enterprise, including style and form design, mechanical design and equipment and systems engineering, managing digital mock-ups, machining, analysis, and simulation.
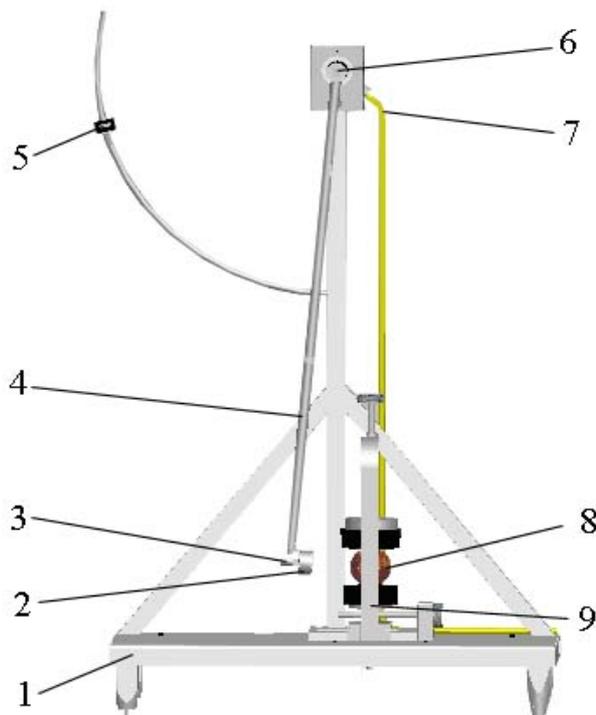

Fig. 1. *The schematic representation on pendulum*
1- mainframe; 2 - impact body; 3-accelerometer; 4 – pendulum arm; 5- electromagnetic device;6 – rotary encoder ; 7- electrical connector; 8 – potato; 9 - sample holding system.

The pendulum arm 4, is a cylindrical metal tube with a length of 600 mm fixed on the top at the mainframe 1, directly on a rotary encoder axe 6 which registers the rotation angle of the pendulum arm. The acceleration after impact and deceleration during the impact is measured by an accelerometer 3 [3, 4].

The accelerometer is fixed on the arm of the pendulum at the backside of the impact body as in the figure 2 [1].

The quartz shear ICP® accelerometer used for tests is model 353B03, designed special for general purpose has 0 - 500 g measuring range and a sensitivity of 10 mV/g.
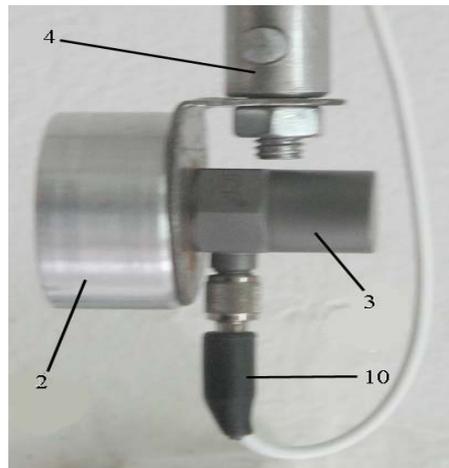

Fig. 2. *The accelerometer fixed on the impact body*
2 – impact body, 3 – accelerometer, 4 – the pendulum arm; 10 – signal cable

In figure 3 is presented a detailed view for accelerometer. The quartz shear-mode reduces sensitivity to adverse environmental inputs, such as thermal transients, base strain, and transverse motion. . Its frequency range of 1 to 7 000 Hz (±5 %) makes this sensor very useful for vibration measurements [3, 4].

An electromagnetic system 5 fixes the pendulum arm in a position necessary to administer the desired potential impact energy. At the other end of the pendulum arm is fixed a non spherical impact body 2. The electrical signals produced by the accelerometer and encoder when the pendulum arm is released by the electromagnetic system, are isolated and amplified by a data acquisition system.

Another element of the pendulum is the sample holding system 9, designed to fix the potato 8 and to avoid supplementary loadings.

3. Testing method

The potatoes from three varieties *Roclas*, *Nicoleta* and *Dacia* were harvested in October and stored individually on soft ventilation pads to minimize mechanical

Fig.3. *The accelerometer 353B03*

damage [3, 4] .The first experiments were done in January, three months after harvesting. For experiments 30 potatoes from each variety were used. Every potato sample was separated, marked, fixed in the pendulum holding system.

Next the potato sample was impacted with by pendulum arm in four different positions (a, b, c, d) situated on the potato length and wide extremity as shown in figure 4.
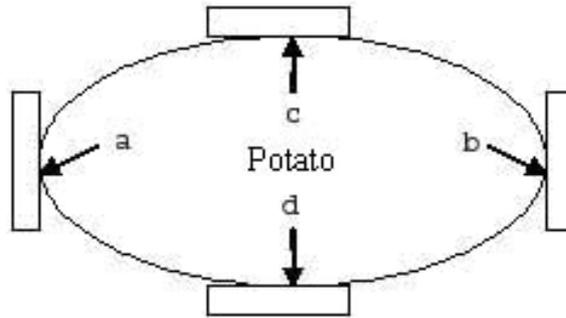

Fig.4. *The impact positions*

In order to analyze the signal generated by the accelerometer and transform it in an impact force, a Labview application was used.

The Labview programs are virtual instruments composed of a frontal panel and a block diagram.

The frontal panel specifies the entrances and the exits and creates the part of interactive operations.

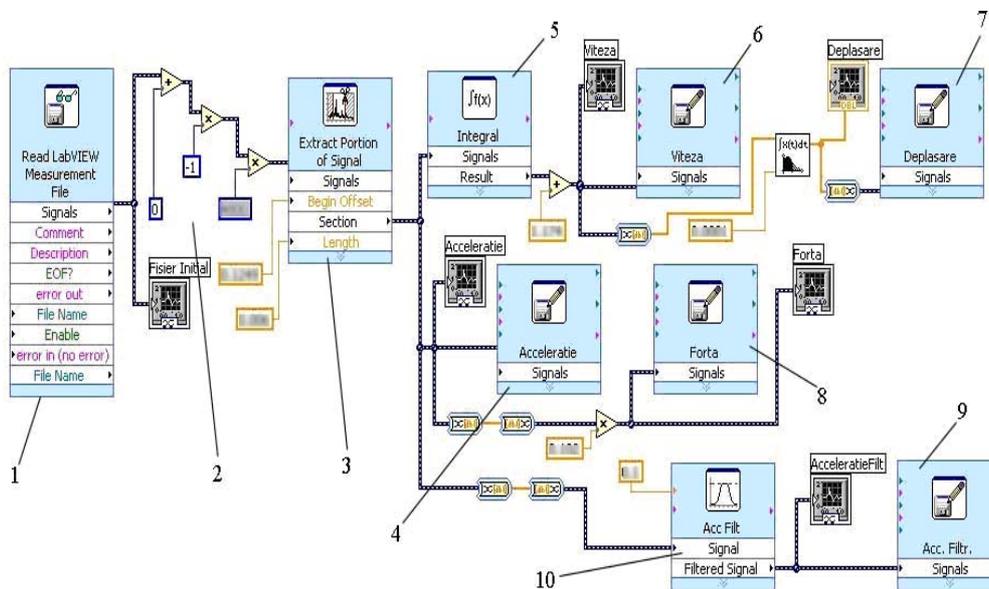The figure 5 shows the way of transforming the acceleration signal in force using Labview.

Fig. 5. *Sequence from the Labview block*
1-impact folder; 2 – recording block ; 3- block for signal extract; 4 – block for acceleration signals; 5- block for integration ; 6- block for velocity signals; 7 – block for deformations signal; 8 – block for force display; 9,10 – blocks for signal filtrate.

The impact accelerations for every position are transmitted from accelerometer to computer where are viewed and analyzed with a Labview application.

The real time visioning of the impact acceleration with this application is presented in the figure 6. A number of three impacts appear in the image.
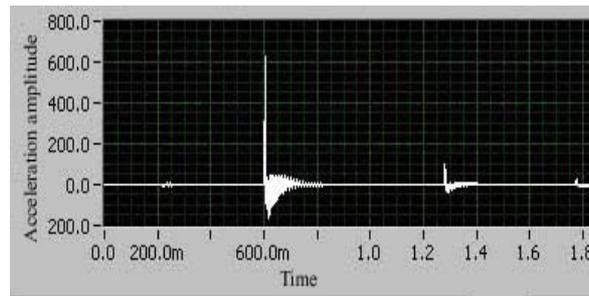

Fig. 6. *Accelerations viewed by Labview*

4. Results and discussions

The impact acceleration determination is very important because on its basis the impact force, and the absorbed energy can be determined. When the impact body hits the potato an Ascii file (impact folder) is generated containing the impact parameters. This file is analyzed by the Labview processed by the block presented in figure 5 and transformed in impact forces presented in figure 7.

A Mathlab application is used also to transform the Ascii file in force - time curves. In figure 6 are presented the impact force curves versus time for three different initial impact energies: $E_1 = 0,072$ J, $E_2 = 0,325$ J, $E_3 = 516$ J obtained with the Mathlab application.

When the potato sample is exposed to impact from the specified energies, tubers suffers a compression followed by a rebound phenomenon that occurs over a period of time called impact duration
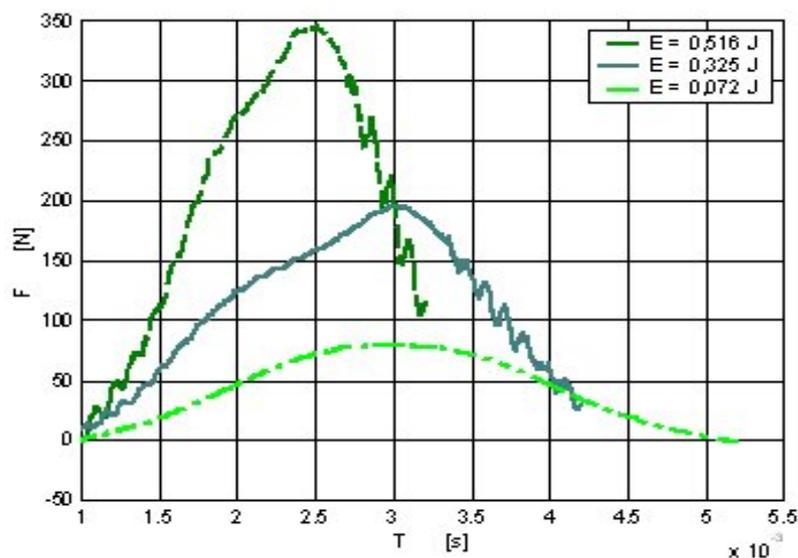

Fig.7. *The force versus time curves*

This duration represents the time of the contact between the sample and the hard impact body during collision. Further several trends of the impact collision can be observed. In the chart from figure 7 can be observed the duration and impact force according to the initial impact energies.

When the initial energy of impact increases (from 0.072 to 0.325 J) the impact duration decreases with 0.93 ms (from 5.25 ms to 4.35 ms) and the impact force increases with 140 N (from 55 N to 195 N).

Further, increasing the initial energy of the impact to a value of 0.516 M, the impact time value reaches the value of 3.25 m/s and the impact force reaches the value of 348 N.

4. Conclusions

The computer controlled pendulum proved to be a very useful tool to impact tubers to short time mechanical loadings to provide the impact velocity and duration precisely and reproducibly. As the device is adjustable to a wide range of impact situations, it can be acquired in order to asses the impact parameters. The Labview and Catia applications were very useful tools in impact studying.

From the analysis of the variation curves of the impact parameters experimentally obtained can be established that for all varieties tested, the mean values of impact forces increase with increasing initial energy impact.

Also, the results shows that increasing the initial energy of impact, causes a decrease in contact time between sample and pendulum

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