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Title:

Characterization of a 90° Transfer Point in a Fruit Packing Line

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Summary:

Characteristics of the impacts suffered by the fruit on a transfer point of an experimental fruit packing line were analysed. The transfer is made up by two transporting belts at different heights forming an angle of 90°. These transfer points are very common in fruit packing lines, in which fruits receive two impacts: the first onto the belt base and the second into the lateral plate.

Different tests were carried out to study the effect of transfer height, velocity, belt structure and padding on the acceleration values recorded by an instrumental sphere (IS 100). Results showed that transfer height and belt structure affect mainly impact values on the belt base, and padding affects mainly impact values registered in lateral impact. The effect of belt velocity in both impacts is less important when compared to the rest of the variables.

Additionally, two powered transfer decelerators were tested at the same point with the aim of decreasing impacts suffered by the fruit. Comparing impacts registered using these decelerators to those analysed in the first part of the study without decelerators, a high reduction of the impact values was observed.

Characterization of a 90° transfer point in a fruit packing line

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1. Introduction

Quality of fruits is one major factor of consumer acceptance. Fruits are exposed to several handling procedures (harvesting, transport, packing) where they may become damaged. This causes an effective reduction of the product quality, and, subsequently, of its commercial value.
Damages on packing lines are usually produced in transfer points where fruit is conducted from one to the next element. Impact characteristics depend on different parameters: velocity, transfer height, padding materials and transfer point design.
A typical transfer point which appears in most packing lines is the transfer between two transporting belts. This is a really dangerous point when belts are disposed forming an angle of 90°. In this case, fruit receives at least two impacts: the first onto the transporting belt base and the second into the lateral plate of the belt where fruit is transferred. Apart from that, the number of impacts fruit-fruit increases in this kind of transfer points at 90° (product impacts against lateral plate and, due to bouncing, fruit-fruit impacts are produced).
The structure under the transporting belt can be made up by different elements: metallic or plastic rollers, metallic plates or metallic beams. In many cases this structure is just placed (under the belt) at the point where fruit is dropped. This problem was asserted by Guyer et al., 1991, although impact data were not obtained.
Instrumented spheres (Zapp et al., 1989) are used to study fruit packing lines (Brown et al., 1987; Miller and Wagner, 1991; García et al., 1996), by identifying where each impact is produced and its characteristics (intensity, velocity change and materials implied). Impact data must be related to bruise susceptibility of each fruit by establishing impact damage thresholds of the products (Schulte et al., 1990).
The objective of this work has been to study the characteristics of the impacts produced in a "transporting belt-transporting belt at 90°" transfer point using instrumented spheres, with the aim of obtaining impact information in function of belt velocity, transfer height and materials implied. The goal was to obtain limiting values for the height, belt velocity and padding material in transfer points of packing lines, and to test two powered transfer decelerators designed to reduce the impact level and to improve fruit flow on the packing line.

2. Materials and methods

An instrumented sphere IS 100 (161 g mass and 7 cm diameter) was used to evaluate characteristics of the impacts produced in a "transporting belt-transporting belt at 90°" transfer on an experimental packing line (Ortiz-Cañavate et al., 1999). Each impact data is reported in acceleration of gravity units (*G*), where $1G = 9.8\ m/s^2$.
Tests were carried out on an experimental packing line located in the Rural Engineering Department at the Polytechnic University of Madrid. In the transfer point (*Figure 1*), each belt has a width of 30 cm, the height of transfer can be easily modified and belts' velocities are variable and electronically controlled.

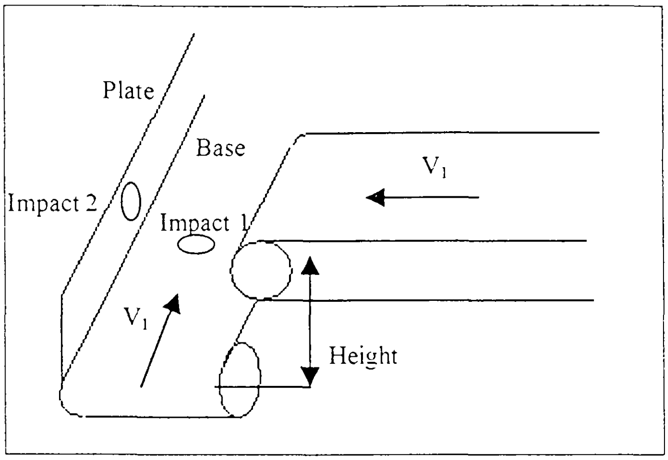

Figure 1. Transfer point between two transporting belts at 90°.

In a second step, two powered transfer decelerators (brushes) were tested at the same transfer point (*Figure 2*). The first element consists of a rotating cilindrical brush with-horse hair bristles on a horizontal shaft propelled by an electric motor. The second one was a mobile belt brush with polythene bristles and two vertical shafts (one of them driven by an electric motor). The position of these mobile brushes can be easily adjusted.

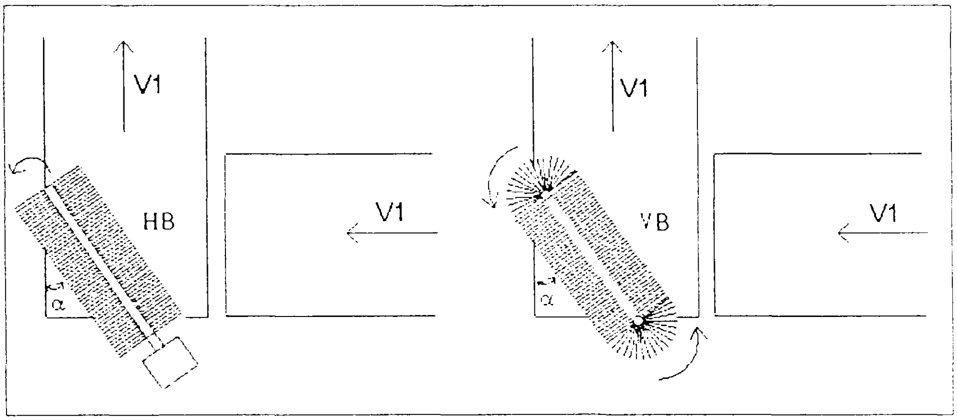

Figure 2. Powered transfer decelerators at 90° transfer point. HB: horizontal brush; VB: vertical brush.

2.1. *Belt base and lateral impact*

2.1.1 *Impact onto the transporting belt base*

When fruit is transferred from one belt to the other, the first impact is produced on the belt base. Impact characteristics vary according to the belt structure under the impact point. Tests were developed in different conditions: At first the electronic fruit IS 100 impacted against a belt area under which there was a metallic sheet. In the second trial the IS 100 impacted against an area under which there was no structural element and the belt was free to bounce.

Tests were carried out at different transfer heights and belt velocities. For each structural condition 40 measures were taken for each of the five heights at 8, 14, 20, 26 and 32 cm. Velocity (V_1) of both belts was the same in each test, and was fixed at 10, 20 and 30 m/min. A total number of 1200 impacts were recorded.

2.1.2. *Impact against the lateral plate of the transporting belt*

Several tests were carried out to know the characteristics of the impact produced when fruit strikes into the lateral plate. Trials were developed identically as in the former case at five transfer heights: 8, 14, 20, 26 and 32 cm. Velocity of both belts (V_1) was fixed successively at 10, 20 and 30 m/min. In fact both impacts were recorded at the same time. Furthermore, lateral plate of the transporting belt was studied in two conditions: with padding material over the metallic lateral (polyester with expanded polyethylene, 4 mm thickness) and without padding material (IS impacting directly on the steel plate).

Characteristics of the first impact (on belt base) were considered varying the structure beneath the transporting belt: metallic sheet under the belt and no structural element under the belt. For each test condition 20 measures with the IS 100 were taken.

2.2. *Powered transfer decelerators*

Powered transfer decelerators were tested for two transfer heights: 8 and 14 cm. For each height, velocity of both belts was fixed at 10, 20, and 30 m/min. Peripheral speed of brushes was the same than as the belts and 15% higher. Transfer decelerators were placed forming two different position angles, α, (*Figure 2)* with the flow direction of the receiving belt ($\alpha 1$ = 26° and $\alpha 2$ = 37°). 20 measures were taken with the IS 100 for each configuration of the trials. These tests were carried out without fruit. A total number of 960 measures were recorded (480 for each brush).

A further test was developed with fruit ("Golden" apples) on the experimental packing line. Heights were also 8 and 14 cm, belts velocity was 30 m/min and brushes peripheral velocity was 15% higher (34.5 m/min). Two angles were tested for the transfer devices ($\alpha 1$ = 26° and $\alpha 2$ = 37°). 20 measures were taken with the IS for both brushes. A total number of 160 measures were recorded (80 for each brush).

To compare the efficiency of the transfer decelerators, similar tests were carried out at the same transfer point without transfer decelerators and with a padding material in the lateral sheet (with and without fruit on the line). 20 measures were taken with the IS for each case. A total number of 80 measures were recorded.

3. Results and discussion

3.1. *Belt base and lateral impact*

3.1.1. *Impact onto the transporting belt base*

The data recorded by the instrumental sphere show the enormous difference in the impact acceleration due to the presence or absence of a structural element (in this case a metallic sheet) under the transporting belt: in most cases the value of impact acceleration was from 5 to 10 times larger in the hard impact compared to the soft one. The acceleration registered in each impact varies in function of velocity, transfer height and structure under the belt. *Figure 3* shows the acceleration values for both cases, soft or hard impact, and different heights and velocities (each mean value is calculated from 40 repetitions).

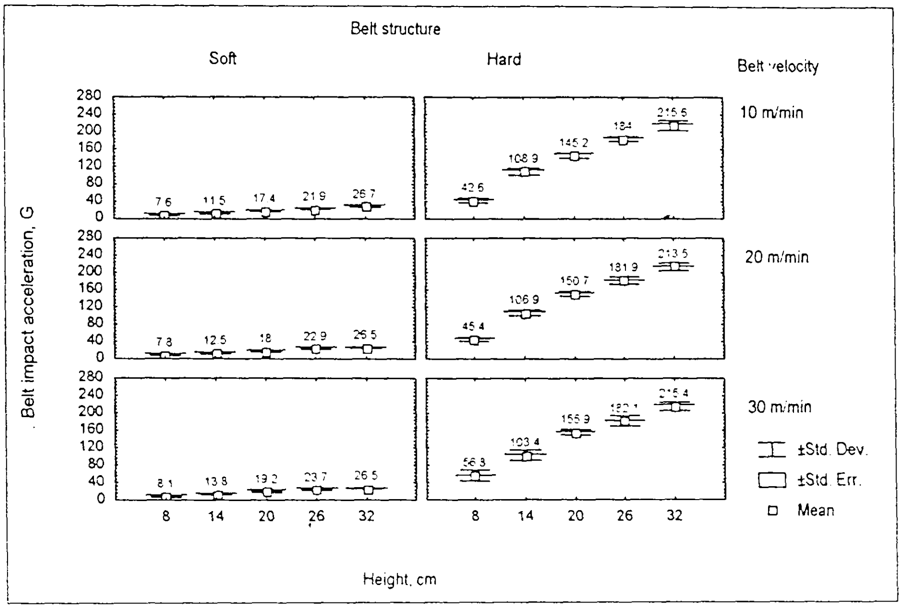

Figure 3. Effect of velocity, transfer height and belt structure on the impact acceleration against belt base

Data were analysed using a factorial analysis of variance. Belt structure ("soft" or "hard") and transfer height are the major causes affecting acceleration values. The effect of the velocity is not significant in comparison with the other factors.

Maximum acceleration values were modelled by a multiple regression analysis, obtaining iso-acceleration curves (*Figure 4*) for hard structure (metallic sheet) and soft structure (absence of structural elements) under the transporting belt. The adjusted R^2 values is 0.95 for both acceleration curves, hard and soft structure under the transporting belt. It is important to take in mind that impact values above 50 G on hard surfaces are usually cause of damage in most of the fruits (Barreiro, 1994). Knowing the damage threshold of the fruit to be handled, we can establish the conditions of the "belt-belt" transfer to minimize the fruit damage. In the case of absence of metallic structure under the transporting belt all the impacts are below 30 G, (with maximum heights of 32 cm).

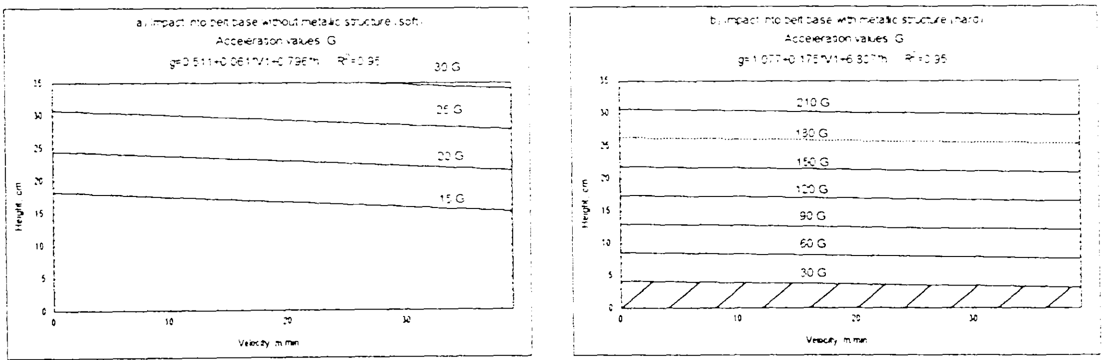

Figure 4. Iso-acceleration curves in the case of impact against belt base with metallic structure and against base without metallic structure

Taking into consideration *Figure 4*, it seems clear that metallic structures have to be avoided under the transporting belt. When there is such a metallic structure (roller or metallic plate) under the belt, the safety zone (values under 30 G) is very small, being the maximum transfer height allowed lower than 5 cm (*Figure 5b*). When there is a soft impact, that is when the plastic or rubber belt has not any metallic support under it and is free to bounce, the impact acceleration is always below 30 G (*Figure 3)* for any reasonable transfer height and belt velocity, that means that no damage to fruit is produced in this point.

3.1.2. . *Impact against the lateral plate of the transporting belt*

Impact data recorded when IS impacted into the lateral plate have a different evolution than impacts produced onto the belt base. The effect of the different variables on the acceleration values is shown in *Figure 5 and Figure 6.* The presence or absence of padding on the lateral plate produces differences around 100 G of the acceleration values, for any transfer height.

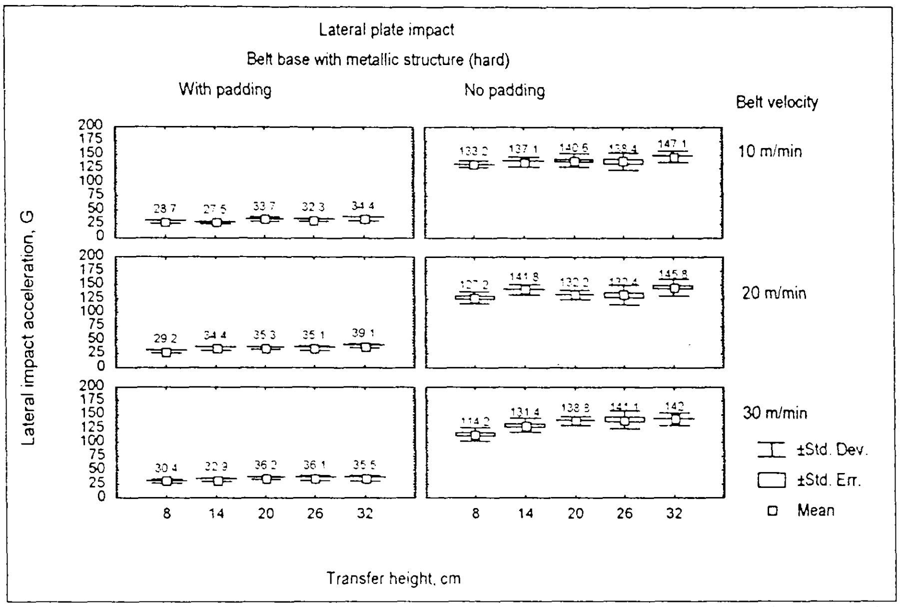

Figure 5. Effect of hard belt base, transfer height, lateral plate structure and velocity on the impact acceleration against the lateral plate

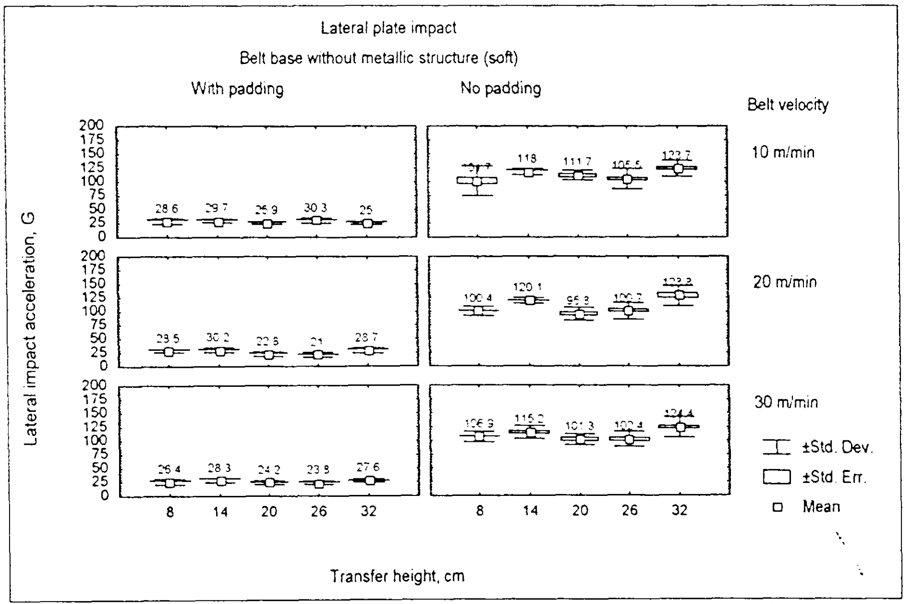

Figure 6. Effect of soft belt base, transfer height, lateral plate structure and velocity on the impact acceleration against the lateral plate

Data were analysed using a factorial analysis of variance. Presence of padding is the major cause affecting acceleration values. The effect of belt velocity and transfer height is significant but clearly inconsistent. The first impact (impact on belt base) affects significantly acceleration values in function of the belt structure. This effect is low but clearly consistent: Lateral impact acceleration values are slightly larger (around 20 G) when the first impact is produced on a "hard" belt compared to the impact on a "soft" belt (see *Figures 5* and *6*), showing that a faster bouncing is generated by this "hard" first impact.

3.2. *Powered transfer decelerators*

Impacts against both transfer decelerators (*Figure 2*) recorded with the IS, working without fruit, are always below 8 G. Comparing this value to those obtained against side wall with padding material, reduction of around 25 G are produced (Table 1).

Table 1. Impact acceleration, working without fruit at different cases (with transfer decelerators at whatever condition and without transfer devices but with padding material). WB: without brushes; HB: horizontal brush; VB: vertical brush; H: height, cm; BV: belt velocity, m/min.

		Average impact acceleration, G
Powered transfer decelerators	HB VB	< 8
Lateral plate without powered transfer decelerators	H=8, WB, BV=10	26.7
	H=8, WB, BV=20	29.2
	H=8, WB, BV=30	30.4
	H=14, WB, BV=10	27.5
	H=14, WB, BV=20	34.4
	H=14, WB, BV=30	32.9

Working with apples, the number of IS-apple impacts (considered as apple-apple impacts) varies according to the presence of powered transfer decelerators and its regulation. The vertical brush at both angles (26° and 37°) and the horizontal brush at 37° decrease the number of fruit-fruit impacts strongly (*Figure 7*). For the specific case of the vertical brush working at 26° ($\alpha 1$) the reduction in the number of fruit-fruit impacts varies between 60% and 43% (for 8 cm and 14 cm heights) as compared to the case of transference without transfer decelerators (WB). For this configuration of the transfer decelerator in 50% and 40% of the cases, apple-apple impacts are not registered (*Figure 8*). In the case of absence of powered transfer decelerators (WB), the number of cases with no apple-apple impacts is only 10% and 5%. The horizontal brush works correctly at 37° ($\alpha 2$), but in the case of 26° ($\alpha 1$) the effect is quite similar to the observed without powered decelerators. The vertical brush works correctly in both positions.

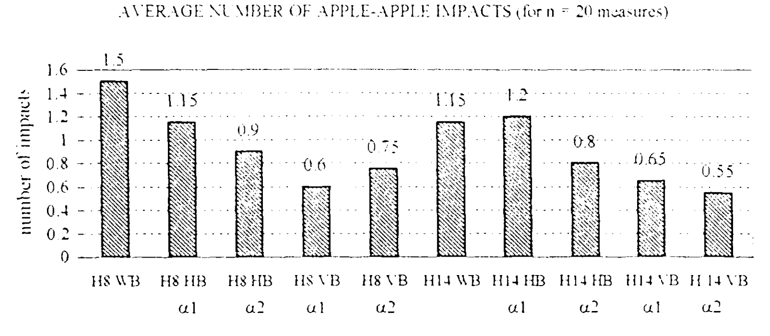

Figure 7. Number of apple-IS impacts at the 90° transfer point. Position angles; $\alpha 1$ = 26°; $\alpha 2$ = 37°.

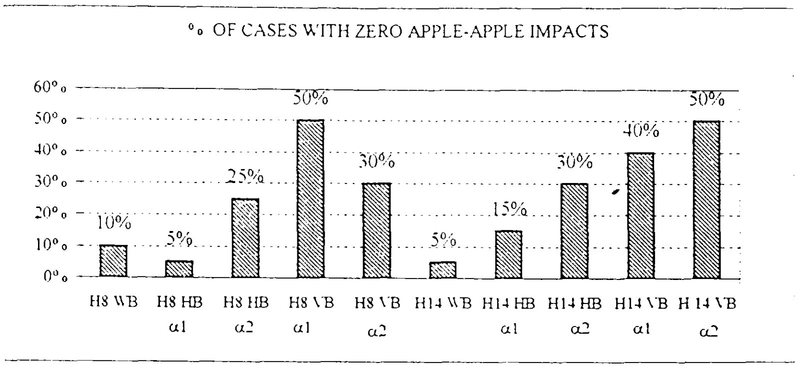

Figure 8. Percentage of cases with zero apple-apple impacts

Differences in the average intensity of the impacts (working with apples) for the different configurations of the tests (without brush, horizontal brush and vertical brush) are really low, with maximum differences of 8 G (Table 2).

Table 2. Apple-apple impact intensities at different cases

	Average impact acceleration, G
Transfer decelerators (HB, VB)	34
H=8 WB	31
H=8, HB, α1	39
H=8, HB, α2	36
H=8, VB, α1	35
H=8, VB, α2	32
H=14, HB, α1	30
H=14, HB, α2	39
H=14, VB, α1	36
H=14, VB, α2	32

4. Conclusions

4.1. *Belt base and lateral impacts*

4.1.1. *Impact onto the transporting belt base*

✓ Analysing the first impact (impact onto belt base), the acceleration values depend clearly on the transfer height and on the presence or absence of metallic structure under the transporting belt. Acceleration values increase with height transfer. Heights of 8 cm are able of producing damage to fruit when the belt structure is a metallic plate (values of impact acceleration around 50 G). When fruit is impacting on a transporting belt without any metallic structure below, transfer heights up to 30 cm (accelerations < 30 G) are admissible.

✓ The effect of "belt velocity" on the acceleration values is really low as compared to the rest of the variables (transfer height and belt structure).

4.1.2. *Impact against the lateral plate of the transporting belt*

✓ Acceleration values depend on the presence or absence of padding material on the lateral plate of the transporting belt. The presence of padding can reduce the acceleration values in more than 100 G. It is clear that padding is necessary on the lateral plate.

✓ The effect of "transfer height" and "velocity" does not affect appreciably the acceleration values. The "second impact" (impact against lateral plate) is not affected by the height of the transfer point.

- ✓ Lateral impact acceleration values are slightly larger (around 20 G) when the "first impact" is produced on a belt under which there is a metallic structure as compared to an impact against a belt without metallic structure.

4.2. *Powered transfer decelerators*

- ✓ The powered transfer decelerators tested perform successfully giving a value of impact acceleration below 8 G. The use of these decelerators is really important in elements of the packing lines where fruit travel individually, for instance from sizers to packing systems.
- ✓ Reduction in the number of fruit-fruit impacts can achieve the value of 60% in the case of the mobile vertical brush at 26° as compared to the case of absence of powered transfer decelerators. The vertical brush at both angles and the horizontal brush at 37° perform correctly in relation to the reduction of fruit-fruit impacts. The intensity of impacts is quite similar for all cases with maximum differences of 8 G.
- ✓ In the case of the horizontal brush the regulation of the angle is really important because of the movement of the element (with low angles the brush leads the fruit against the first belt increasing fruit-fruit impacts), whilst the vertical brush has shown more versatility.

5. Acknowledgements

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