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MECHANISM TO REDUCE THE BASECUTTER'S IMPACT IN SUGARCANE HARVEST

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Abstract. *Based on information from quality of sugarcane harvesting works, evaluating the damage caused to stalks due to the inertial cut, this work presents a proposal for improvement the active tools of the basecutter mechanism for sugarcane harvesters. The soil-machine interaction during mechanical harvesting of sugarcane promotes the wear of blades and reduces the stalks cutting performance. The damages to the stems cause losses due to multiple cuts and cracks, reducing the quality of the harvested material. At the ratoon stalks the damages can reduce the next crop production by damaging the plant gem which is responsible for regrowth and increase the exposure of the ratoons to pest and diseases attacks. Considering this, the objective of this work was to design a device for coupling the blades to discs that helps in cutting of sugarcane stalks to reduce the inertial impact caused by the rotary motion of the blades from basecutter system of sugarcane harvesters. The proposed model provides the cutting of the sugarcane stalks by sliding, can be used in any sugarcane harvester and with different types of blades for basecutter systems. The developed device can be considered a simple mechanism, because it has only mechanical drives and low-complexity parts.*

Keywords: *agricultural mechanization, sugarcane harvester, operational quality, basecutter's blades, sugarcane damages.*

1. INTRODUCTION

The first sugarcane harvester developed in 1890 has used a large pendulum mechanism for cutting the stalks near the base with removal of leaves and pointers. However, it was not successful. Since then, Kroes (1997) reports that several attempts to design and develop cutting systems, citing examples like giant scissors, rotary saws, chain saws, blades, water jets, and even laser beams, and concludes by saying that the goal to develop the ideal cutting system still continue.

With the shortage of labor in the 1940s and 1950s in Australia, the industry realized the need to focus on the mechanization of the harvesting operation. There, in the 1950s, the most part of the load operation in sugarcane harvest after the manual cut was made by mechanical loaders (semi-mechanized harvest) being approximately 100% in the mid-1960s. Initially, the whole sugarcane harvesters showed satisfactory results, however, the development of the chopped sugarcane harvesters was more promising for Australian conditions, making it commercially viable and attractive to producers. Consequently, in the late 1960s, mechanized harvesting was already prevalent, with use of chopped sugarcane harvesters. The author also reports that in 1978 the last stems manually harvested were processed (Kroes, 1997).

In Brazil, the history of mechanized operations for sugarcane production is newer and less accelerated. In the 2008/2009 harvest in Brazil, only 37.1% of the areas of sugarcane were harvested mechanically. In the Center-South region this proportion rises to 42.8% of the areas, the equivalent of 2.5 million hectares (CONAB, 2011).

With regard to research projects for sugarcane harvest, Gupta *et al*. (1996) developed a sugarcane whole harvester, self-propelled using a handlebar tractor, for small-scale producers in developing countries. According to the equipment tests, they achieved an average field capacity of 0.13 ha h^{-1} with 71% efficiency.

Oliveira *et al*. (2005) designed a segmented basecutter mechanism, in order to verify the stem reach efficiency during cutting, and pointed out that the cutting height was the most influential variable in the proposed system. The analysis has shown promising results in terms of reaching and feeding of stems that are bedridden on the surface.

Another proposal of basecutter mechanism for sugarcane harvesters was presented by VOLPATO *et al*. (2005a; 2005b), a four-bar system to follow the soil microrelief, which achieve good performance for less demanding conditions, such as speeds less than 1.8 m sec^{-1} and soil microrelief amplitude of 0.025 m.

Gray *et al*. (2009) showed a pantographic suspension for the basecutter to apply in semi-mechanized harvest systems. In tests on soil boxes with sinusoidal profiles between 25 and 50 mm, they could say that the designed mechanism performed satisfactorily the tracking of the soil microrelief with an average error of 8 to 9 mm s^{-1} for the harvest speeds of 0.14 m s^{-1} and 0.42 m s^{-1}.

A major problem of mechanical harvesting is the damage caused to the sugarcane stalks by the basecutter mechanism. During the cutting there is no support, being only the plant inertia that provides resistance to the blades impact. It is assumed that happen a pre-compression in the sugarcane outside which results in breaking or splitting of the stem, causing the damage (KROES, 1997).

Probably this pre-compression is related to the thickness of the blades cutting edge, depending on the blade-stem contact area. So, with the blades wear and thickness increase, this pre-compression will increase, and consequently the damage to stalk ratoons and stems of sugarcane (Kroes, 1997).

Studies performed by Chang *et al*. (1982), Sverzut (1982), Ferraz (1987), Maciel (1989), Kroes (1997) and Filippini Filho *et al* (2004) also demonstrate a concern to measure the cut resistance offered by the cross section of the stalks of cane sugar.

The interaction with the soil promotes the wear of cutting blades and undermines the performance. Kroes (1997) shows and classifies the types of damage caused by the basecutter system. This system causes losses by multiple cuts and cracks in the stalk ratoon. Worn blades spread damage to stubble and can reduce the production of the next crop, to increase their exposure to attack by pests and diseases or by destroying or removing the gems responsible for the sprouting of the stumps (Gray, 2008).

Gupta and Oduori (1992 *apud* Gray, 2008) studied the rotational speeds and the blades sharpening angles and concluded that the best match in terms of cutting quality occurs at an angular speed of 800 rpm, oblique angle of 35 degrees and inclination angle of 27 degrees. The authors also reported that speed below 600 rpm tend to break the stalk at its base and higher than 800 rpm facilitate the completion of the cut.

The basal cutting of sugarcane stalks is a major cause of damage and losses in mechanical harvesting. Stalks are cut by the impact of cutting blades, but this impact usually causes damage to them. This impact is also a source of disturbance for the ratoons and may damage the root system (Toledo *et al*., 2013).

It is expected that the device that reduce substantially this impact, reduce also the percentage of damage to stems, increasing the level of quality of sugarcane mechanized harvest operation.

Considering the literature information and based on works carried out on damage to stalk ratoons, the aim of this study was to propose a device model to assist in the cutting of sugarcane stalks, held by sliding, to reduce the impact caused by the inertial rotary motion of the basecutter system.

2. METODOLOGY

2.1 Preliminary considerations

Based on the findings related in works that evaluated the cutting quality and considering that the basecutter system providing tilting for the cutting face of the blades in relation to the disk radial line, results in superior cut quality, assessed by the damage index (Toledo *et al.*, 2013), it was proposed a device to reduce the impact of cutting the sugarcane stalks carry out by sliding.

Those following principles were considered in the development of the device:

1. Minimize the damage to stems and stalk ratoons due to the excessive impact during cutting;
2. Avoid breaking the blades for impact in obstacles which offer greater resistance than the sugarcane stalks;
3. Reduce the demand for power and energy required to cut the stems;
4. Avoid contamination of the material collected by mineral impurities;
5. Perform cutting the stalks of sugarcane by sliding the blades in relation to the stem, and not by impact, reducing the possibility of damage stems and stalk ratoons;
6. Being adaptable to the existing basecutter mechanisms without complex modifications;
7. Design a simple device and easy construction to meet the principles considered.

The design of the device was performed using the computer aided drawing software (CAD) for mechanical design Autodesk® Inventor®.

2.2 Prototype description

The proposed device was designed to provide to the blades of cutting mechanism a degree of freedom in the direction of its action plan, in order to perform the reduction of the impact generated at the cutting of sugarcane stalks during mechanical harvesting.

The general view of the device mounted on the basal cutting disks is shown in Fig. 1. The Fig. 2 depicts the side and the top views of the device, which is designed to be installed on the basecutter's discs for simple adaptation and attachment passage the drive shaft. The device was designed to be installed in each blade of basecutter fixed by two screws on the rear of the shaft, as can be seen in Fig. 3.

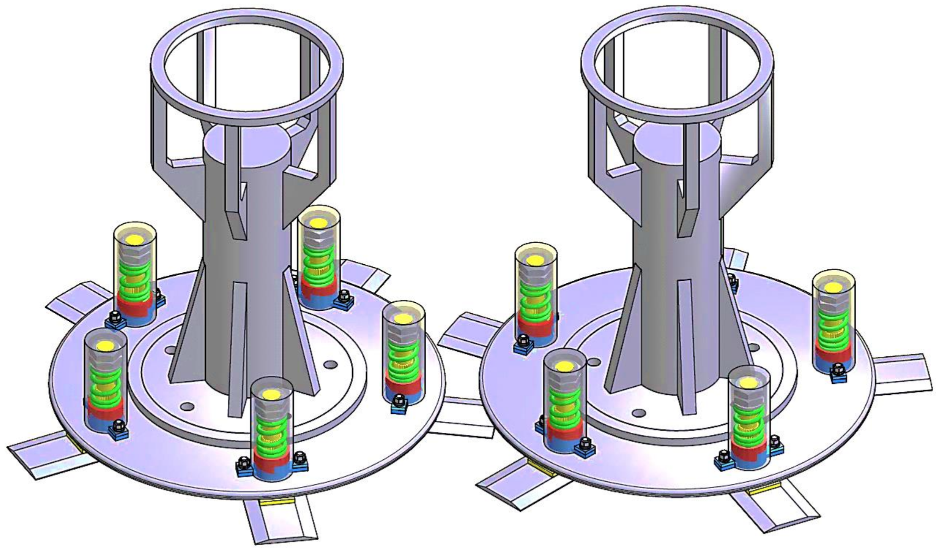

Figure 1. General view of the basecutter system with the developed mechanism

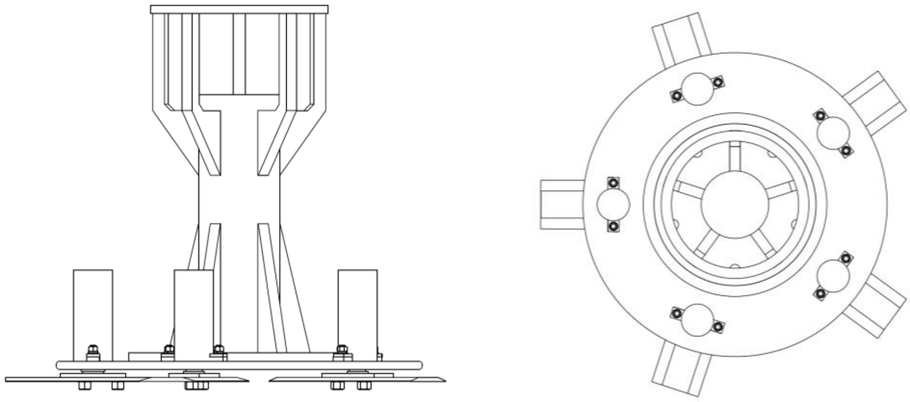

Figure 2. Side and top views of the basecutter system with the developed mechanism

The device actuation principle is the transmission of the stem of the reaction force sugarcane the compression spring, with the displacement orthogonal plan of action of the blades while providing cushioning the impact generated at the time of cutting but providing sufficient strength to hold the cut by sliding with blades acquiring angle relative to the disk radial.

The constituent parts of the model, numbered in Figs. 3 and 4 and cited in brackets in the text below are presented with brief description of the functions in Tab. 1.

The model viewed in section in Fig. 3 and the exploded view in Fig. 4, to be adapted to the disc (1) consists of a hole corresponding to each blade (2), for the installation of a wear sleeve (4) and the shaft drive (3) of the device. And, the upper drive two screws for fixing the cover (6) of the device which protects the drive system.

The attachment of the blades is held on screen attached to the end of the shaft (3) having two threaded rods to secure the blades, instead of the screws used on conventional discs, as can be seen in Fig. 3.

Device triggers are two cylindrical bodies with central hole for the shaft passage, with one surface ramp and the other flat, both made of material with high abrasion resistance and low coefficient of friction. The first, fixed actuator (5) is stuck to the disc along with the cover (6), as previously described. The movable actuator (9) is integral to the shaft (3) by means of grooves in its inner bore and the shaft.

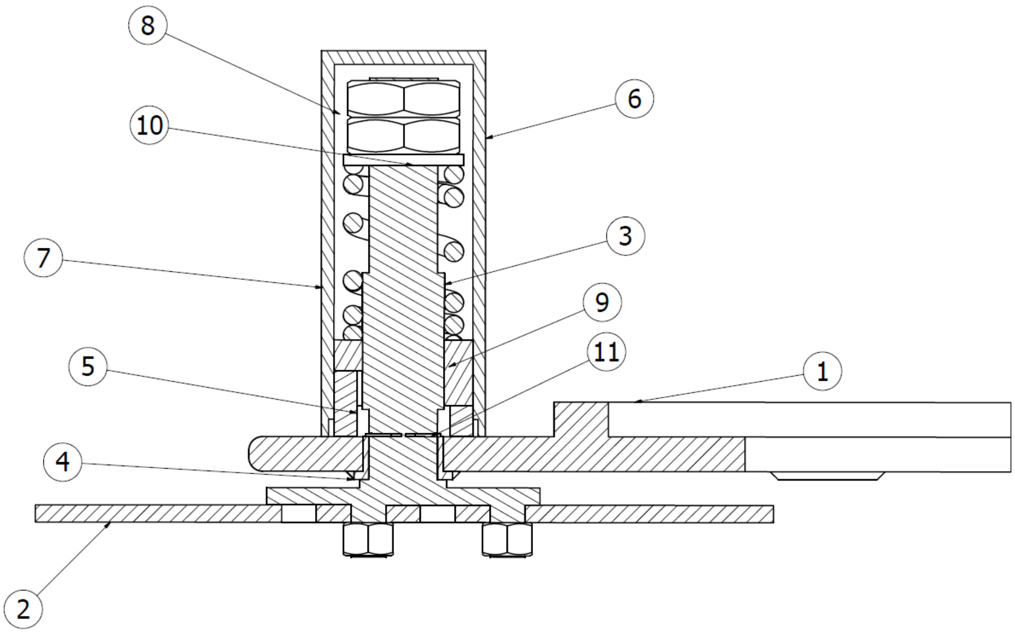

Figure 3. Section view of the designed device. (The description of each part numbered is presented at Tab. 1).

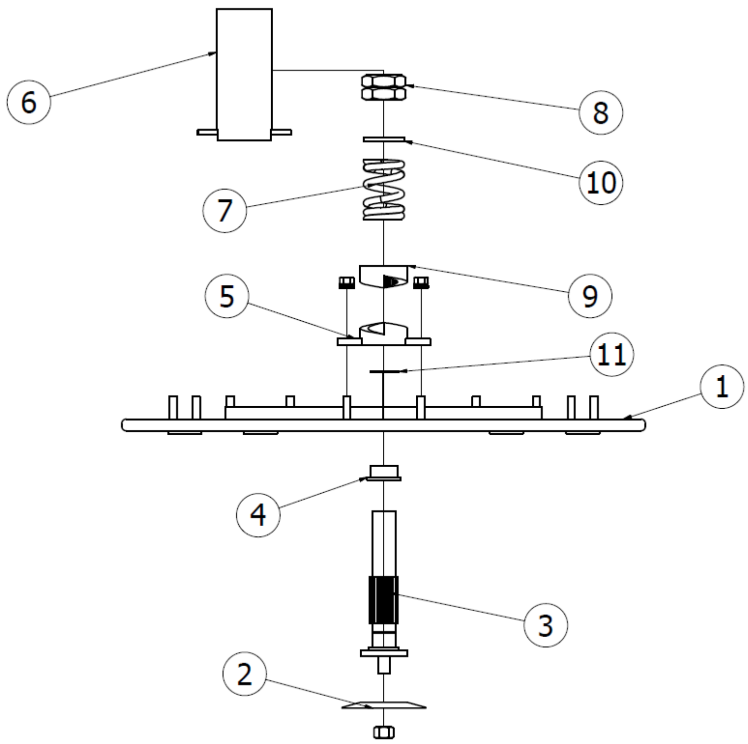

Figure 4. Exploded view of the designed device. (The description of each part numbered is presented at Tab. 1).

The compression spring (7) is disposed on the movable actuator (9) with pre-load adjustment performed by nut and counter-nut (8) and washer (10) positioned at the other end of the shaft (3).

The device also has the pressure ring (11) fitted onto the shaft (3) to prevent vertical displacement of the internal system and also an outer sleeve (6) to protect the device drive system.

Table 1. Description of device parts and their functions as showed in Figs. 3 and 4

Notation (Figs. 3 and 4)	Piece	Function
1	Disc	Support the device designed for impact reduction in sugarcane base cutting.
2	Blade	Cutting of the sugarcane stems.
3	Shaft	Perform circular motion for cushioning the impact of the blades (2) in sugarcane stem; Support of the blades (2) of designed device.
4	Wear sleeve	Avoid shaft wear (3) by direct contact with the disc (1).
5	Fixed actuator	Assist in vertical displacement of the mobile actuator (9) that compresses the spring (7) providing circular motion to the blade (2) in its action plan.
6	Cover	Protect the internal system of the device
7	Compression spring	Allow the circular motion of the blades (2); Provide sufficient strength to perform the cutting of the sugarcane stalks.
8	Nuts	Allow the adjustment pressure in the spring (7); Lock the system.
9	Movable actuator	Transmit the circular movement of the blade (2) for the spring (7) in longitudinal motion in the action supported by the fixed shaft drive (5).
10	Washer	Support for the compression spring (7).
11	Pressure ring	Avoiding the vertical displacement of the whole system

2.3 Action of the device

The reaction force of sugarcane thatch applied to blades (2) at impact for cutting inertial is transmitted to the shaft (3), sympathetic to the mobile trigger (9) through slots. The torque generated on the shaft is transmitted to the movable actuator (9) which is in contact with the fixed starter (5), whose drawing into overlapping ramps transmits the twisting motion to linear displacement movement, pressing the compression spring (7).

Initially, the resistance offered by the spring reaction force provide lower the force needed to make the stem cutting, based on the presented by Kroes (1997) in Figure 5 approximately 430 N, corresponding to F 'of the Figure 5 graph.

At the start of cutting, when the impact occurs and the force applied is next to F ', the spring will be compressed to x', providing tilting the blades and therefore cutting takes place by sliding. At the moment when the applied force becomes smaller than F ', the spring reaction force causes the blades to return to their initial positions.

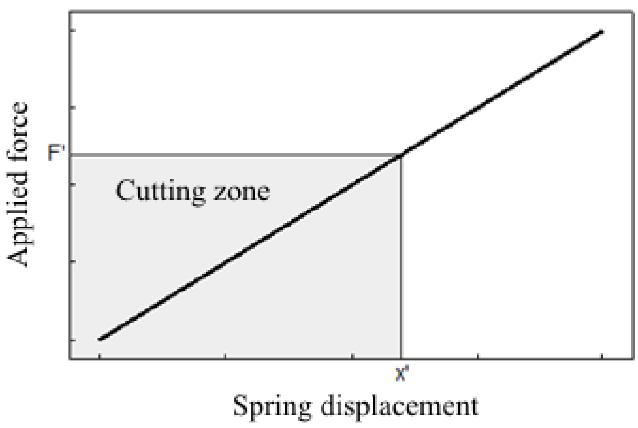

Figure 5. Compression spring displacement by applied force (Kroes, 1997)

The cutting zone of Fig. 5 corresponds to the spring movement range and stalk reaction forces during cutting. Even if the applied force is greater than F ', the device will continue to operate. If this force is excessively higher, the blade will shift approximately 90° while the force is being applied in the event of reaching a stone, for example, and this force has ceased, return to its original position without the occurrence of breakage or undesired wear of blades.

The device also has pressure pre-load regulation over the spring, which will determine the initial force required to be vertical spring compression, and consequently, the angle of the blades. In Figure 7 the device can be displayed in the tripped position, representing a force applied to the blade.

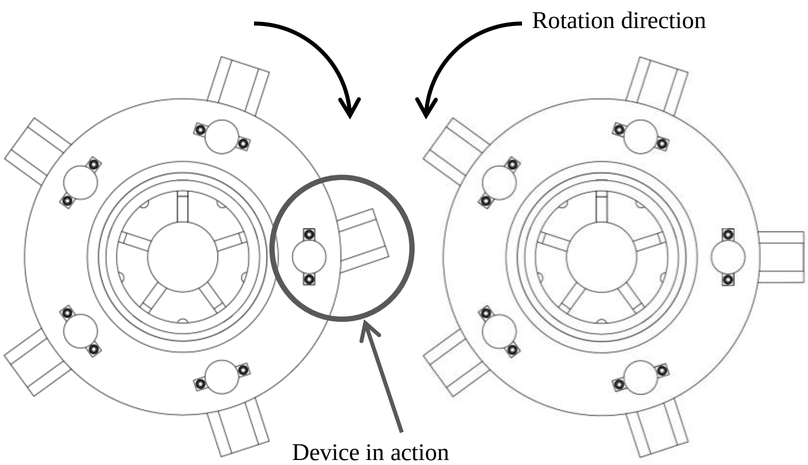

Figure 6. Illustration of the device in action

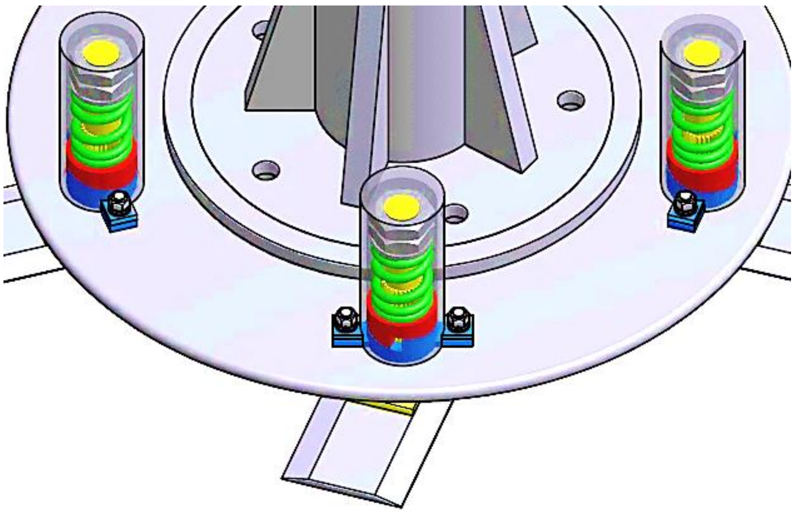

Figure 7. Detail of the simulation of the device in action

3. CONCLUSIONS

The presented designed device provides the sliding cut of the stems, in order to reduce the damage caused by the impact by the traditional basecutter system in sugarcane mechanical harvest.

The designed device can be coupled to any commercial basecutter mechanism with rotating discs from the current harvesters and use any kind of blades.

The designed device can be considered simple to construct, because it has only mechanical drives and low-complexity parts.

4. FINAL CONSIDERATIONS

The application of this device is focused on reducing the damage caused to the sugarcane stem and stalks ratoons, and with other techniques, has among other objectives, to increase the longevity of sugarcane.

It is necessary continue the development of this device, working on the simulation and construction of the prototype to check while cutting energy demand with the device application.

It is suggested for further works, perform a comparative evaluation of the quality of the cutting device with the current mechanisms, with other models as well as with manual cutting system.

5. ACKNOWLEDGEMENTS

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