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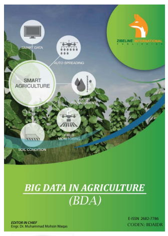

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RESEARCH ARTICLE

CLEANING MATERIAL ARRANGEMENT TESTING FOR SUGARCANE DETRASHER: A SIMULATION APPROACH

Kamran Ikram[1,3*], Yasir Niaz[1], Muhammad Zeeshan Mansha[2], Muhamad Usman Ghani[3], Faizan Shabir[1], Muhammad Mohsin Waqas[1], Muhammad Adnan Bodlah[1], Muhammad Nadeem[3], Arslan Afzal[4], Muhammad Mubashar Omer[3], Abdul Waheed[1]

[1]Department of Agricultural Engineering, Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan, Pakistan
[2]Department of Plant Pathology, College of Agriculture BZU, Bahadur Sub-campus Layyah, Pakistan
[3]Department of Agricultural Engineering, University of Agriculture Faisalabad, Pakistan
[4]Department of Agricultural Engineering, PMAS Arid Agriculture University, Rawalpindi Pakistan.
Corresponding Author Email: kamranikram@kfueit.edu.pk

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ABSTRACT

Sugarcane is cash crop in Pakistan. Its trash can be used as fertilizer and a source of energy. Sugarcane leaf stripping is time consuming and labour-intensive procedure. Shortage of modern machinery also highlights this problem. In this regard a sugarcane leaf stripper was designed. The heart of machine is its cleaning element in which cleaning material is mounted on shaft. Many researchers have paid their attention to find best suited arrangement of cleaning material. In this regard a simulation study was designed to find out best suited material arrangement. Three arrangements of cleaning material having *20^0 deflection angel*, *18.5^0 spiral angel* and straight arrangement were studied for induced stress, deformation, torque requirement and power consumption. The results revealed that *20^0 deflection angel* arrangement for cleaning material has minimum deflection, torque requirement, power consumption and induced stresses.

KEYWORDS

Sugarcane Cleaning Element, Spiral and Deflection, Trash, Leaf Removal.

1. INTRODUCTION

Sugarcane is a highly demanding cash crop throughout the world. During 2010, it was the largest crop grown in the world over 23.8 million hectares having a production of 1.69 billion Mg being Brazil and India as the largest sugarcane producing countries (Masute *et al.,* 2014). In Pakistan, sugarcane is mostly planted in Sindh, Punjab and NWFP provinces. The sugarcane production during 2018-19 was 62.7 million Mg over 1141 thousand hectares with an average yield of 54 Mg/ha. Due to shortage of water, less market price, labor shortage and non-availability of fertilizer and pesticides at peak time, production is decrease in current decade as compared to previous years (Anonymous, 2019).

Among all operations performed for sugarcane crop, harvesting is most time consuming, labour intensive and costly process which takes 45 to 48% of total cultivation cost (Bastin and Shridar, 2014). In developed countries, sugarcane harvesting is done by whole stalk harvester or by chopper harvester. Chopper harvester has facility to chop the whole stalk of sugarcane into the billets. But these billets are required to be transport to sugar mill within 3 days otherwise quality will be deteriorated (Ma *et al.,* 2014). According to Dawson and Boopathy (2007), the traditional method of sugarcane harvesting in developing countries is to burn the dry leaves in standing crop and then cut the stalk manually.

Sugarcane is mainly used for sugar production so it is necessary to remove the trash (leaves and tops) from sugarcane stalk. One major reason is that the leafy portion absorbs sugarcane juice during milling operation so nearly 10% deduction in selling price is made if trash is not properly removed (Ashfaq *et al.,* 2014). This trash may also have some soil, sand and mud which also affect the quality of sugar (Cansee, 2010). The leaf removal of sugarcane is mostly time-consuming process during harvesting process. If a farmer has 70 Mg/ha sugarcane yield, he needs 120 man-days for trash removal from all canes (Bastin and Shridar, 2014). Around 55-60% expenses of sugarcane harvesting is considered for manual de-trashing (Paulo et al. 2010). Leaf stripping is done not only at the time of harvesting but also during crop growth to enhance its production (Jain *et al.,* 2010).

Dry cleaning is the word commonly used to indicate the leaf and impurities removal process other than burning and washing. Removal of green leaves and tops manually can easily fatigue labour due to excessive stress on muscles and joints (Clemenson and Hansen, 2008). The skilled labour is mandatory for harvesting as improper harvesting may lead to poor crop quality (Masute *et al.* 2004). Mechanical means of dry cleaning includes use of compressed air and centrifugal cleaning action (Bastin and Shridar, 2014). It was found that 5-7% more sugar can be recovered when burning is avoided. The potential benefits of dry cleaning include cost saving, increase factory capacity, decrease energy utilization for production of same amount of sugar, improved sugar quality and supply of large quantity of biomass (Bernhardt, 1994).

Sugarcane trash is a huge source of biomass production. Trash amount varies with crop variety (Ashfaq et al., 2014) and *14%* is taken as an average (Woytiuk 2006). Sugarcane world production during 2017-18 is estimated about 179.64 million metric tons which will produce 25 million metric ton sugarcane trash (Anonymous 2018). Researches have revealed

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hidden benefits of sugarcane trash over conventional standing crop leaf burning practice. This trash may be utilized in cogeneration (Smithers, 2014), trash farming (Mendoza et al. 2001), ethanol production (Dawson and Bopathy 2007), pyrolysis (Treedet et al. 2011) and gasification (Jouce et al. 2006). Pakistan is among emerging countries and is facing energy shortage. Sugarcane trash may be helpful to mitigate energy problems. No proper mechanical system is introduced in the country yet to remove and use this trash. In this regard a small sugarcane leaf stripping machine was fabricated to facilitate farmers for trash removal. Being the key element of sugarcane leaf stripping machine, leaf cleaning element is of prime important. Its material and arrangement impart vital role in its working life and performance (Xiao et al. 2009) This paper presents a simulation study for better arrangement of cleaning element to improve its performance.

2. EXPERIMENTAL SETUP

Arrangement of cleaning material affects the leaf cleaning efficiency. Spiral angle provided to cleaning material enhance the beating force (Xiao et al. 2009). Three different scenarios for cleaning material arrangement were designed and checked for their properties. These scenarios included spiral angle, deflection angle and straight arrangement. Purpose of simulations was to find the best suited arrangement for cleaning material having less deformation and reaction force.

2.1 Model Development

Detrashing shaft provide space for cleaning material arrangement. A detrashing shaft with 1 inch diameter and 18 inch length was designed as shown in figure 1. Different materials can be used for cane cleaning among which metallic wire cause scratches to sugarcane stalk (Meng et al. 2009). Macromolecular materials were considered best suited for leaf cleaning because of low stalk scratches and material damage. High strength nylon was selected as cleaning material. Beside this, sugarcane stalk model with all its physical properties was developed. This sugarcane was passed through cleaning element.

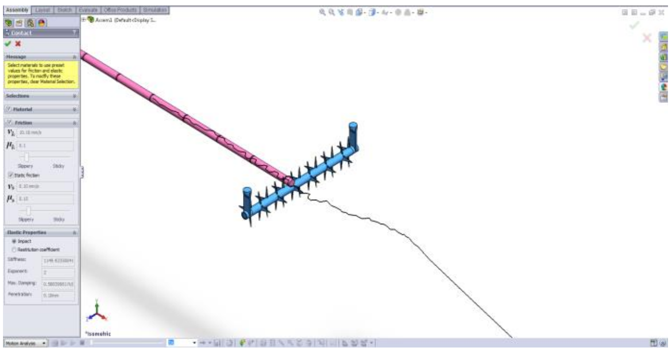

Figure 1: Sugarcane model passing through cleaning element

2.1.1 Scenario-1 for Detrashing Shaft

In this design 4 fingers were applied on detrashing shaft at 90^0 degrees to each other at a single plan and each finger had individual deflection angle of 20^0. Deflection angle means the angle which cleaning material made with shaft axis. To furnish the shaft with fingers linear pattern was applied. Detrashing shaft and spiral fingers are shown in figure 2. Height of each finger was 1 inch, pitch was 2 inch and diameter of detrashing shaft was 1 inch.

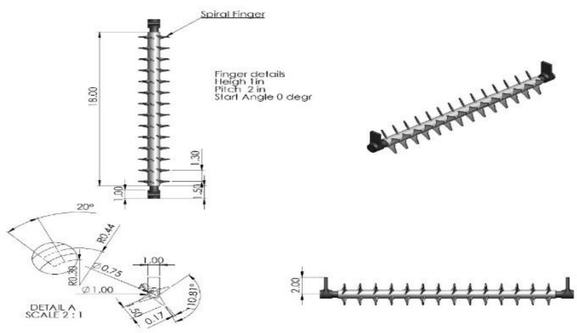

Figure 2: Detrashing material with deflection angle

2.1.2 Scenario-2 for Detrashing Shaft

In this design, each set of fingers had a spiral angle of 18.5^0 with 0^0 deflection angle. The arrangement of detrashing fingers on detrashing shaft is shown in figure 3. Specifications of shaft included height of detrashing fingers at 3 inch, pitch of 1.5 inch and detrashing shaft diameter of 1 inch. Height of fingers was 2.1 inch to increase the intersection depth between cleaning material and sugarcane stalk.

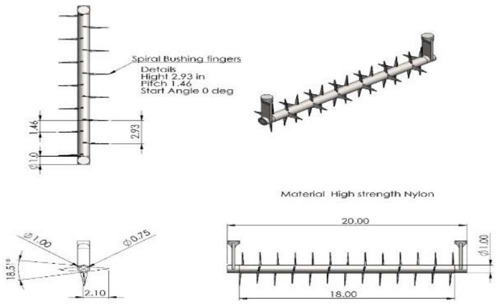

Figure 3: Detrashing Shaft with Spiral Angle

2.1.3 Scenario-3 for Detrashing Shaft

In this design, 30 straight fingers having angel of 90^0 with shaft axis, 0^0 deflection and 0^0 spiral angle were applied on detrashing shaft. These fingers had sharp edges on both ends to remove the dry leaves more effectively.

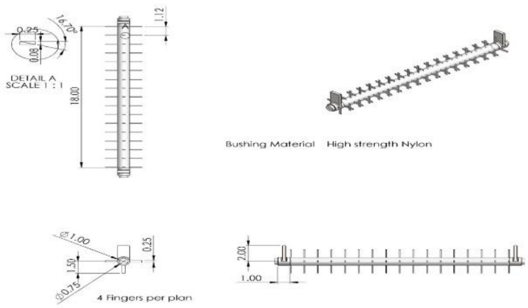

Figure 4: shows the arrangement of Detrashing material on Detrashing shaft.

The Figure 4 Detrashing Shaft with Straight Bars specifications of this scenario included height of detrashing finger at 1 inch, pitch at 1.5 inch, start angle at 0° and 1 inch of diameter for detrashing shaft and rotating speed of 1200 RPM.

2.2 Checking Parameters

Following parameters were selected for comparison to find out best cleaning material arrangement

i. Stresses induced on outer most fibre of de-trashing shaft
ii. Deformations produces in de-trashing shaft during operation
iii. Torque required to rotate the de-trashing shaft
iv. Power consumptions by de-trashing shaft

3. RESULTS AND DISCUSSIONS

3.1 Comparison of Stress

The results of three scenarios for induced stresses in detrashing bars were compared. It was observed that maximum stress was induced in concept 2 of detrashing material arrangement in which a spiral angle to detrashing material was given. These results were supported by (Xiao et al. 2009) who reported that with provision of spiral angle striking force increases. The minimum amount of induced stresses was observed for scenario 1 of detrashing material arrangement in which only deflection angle was provided. The maximum and minimum value for induced stress was 7.179 MPa and 0.073 MPa respectively. Figure 5 shows the scales of induced stresses in all three scenarios of detrashing material arrangement respectively.

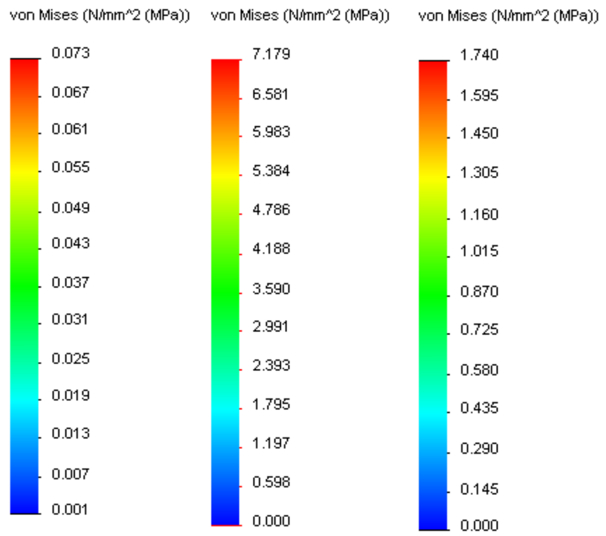

Figure 5: Stress Comparisons of concept 1, 2 and 3 respectively

3.2 Comparison of Deformations

Deformation in detrashing shaft was calculated during simulation study for each scenario of detrashing material arrangement. The deformation in detrashing material or finger bars was reaction of striking force being inserted on sugarcane stalk to remove the dry leaves. Increase in striking force tended to increase the deformation. Spiral arrangement increased the striking force so maximum deformation was observed in detrashing material arrangement scenario 2. Minimum deformation was observed in scenario 1 which was according to (Xiao et al. 2009) that deflection angle to detrashing material reduces the reaction force. Figure 6 is indicating deformations occurred in all three scenarios of detrashing material arrangement. The maximum deformation was 1.4 inch.

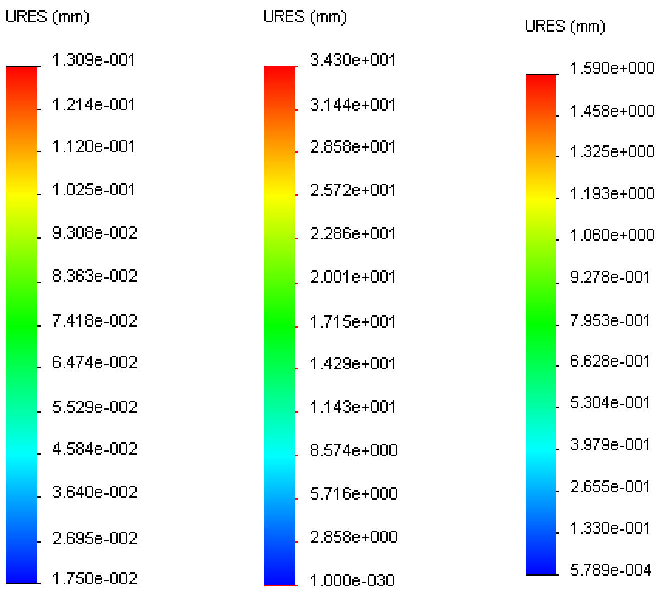

Figure 6: Comparisons of deformations in concept 1, 2, and 3 respectively

3.3 Comparisons of Torques

Torque requirement calculation was among most important parameters. To compare the torque in all three scenarios, the material of detrashing shaft, detrashing material and number of revolutions were kept constant. Figure 7 is indicating that the maximum and minimum torque mandatory for shaft operation was in detrashing material arrangement scenario 3 and scenario 1 having value of 10709.2 Ncm and 475.7 Ncm respectively. These results were supported by (Xiao et al. 2009) that with provision of deflection angle (scenario 1) the reaction force was reduced and detrashing shaft was operated easily. While in concept 3 no deflection or spiral angle was provides so reaction forces were maximum and more torque was required to operate the shaft.

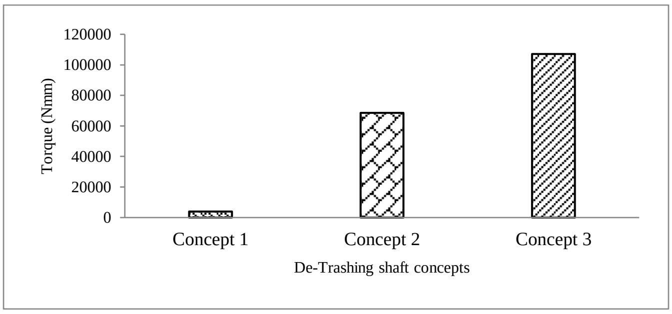

Figure 7: Comparison of torque values for concept 1, 2 and 3 respectively

3.3 Comparison of Power Consumptions

Power consumption increased with increase in torque applied. As shown in figure 4.26 that maximum torque was required in detrashing material arrangement scenario 3 so consequently more power consumption was observed for scenario 3 and smallest amount of power was required for scenario 1. It is shown in figure 8 that maximum and minimum power required was 13458 and 601 watts for scenario 3 and 1 respectively. The reason behind this scenario was the same as more torque was required in concept 3 so more power was consumed as compared to material arrangement concepts 1 and 2.

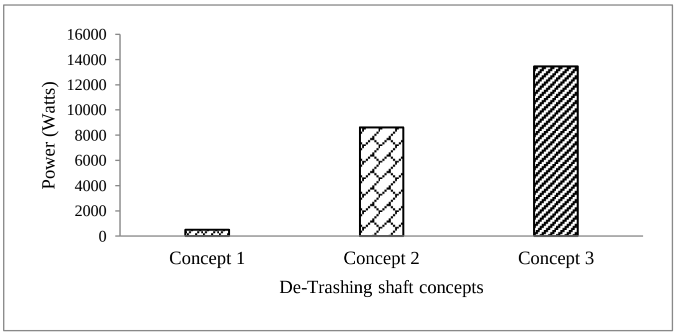

Figure 8: Comparison of power consumption for concept 1, 2 and 3 respectively

4. Conclusion

Simulations provide a mean to investigate the design before its practical application. In this study spiral angle, deflection angle and straight arrangements for cleaning material in sugarcane leaf stripper were taken under study. The results showed that provision of deflection angle not only reduced the reaction forces but also deformation and operating torque. Provision of 20^0 of deflection angle was suggested as best suited for sugarcane stripper cleaning material.

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