ISSN 0511-5728
The West Indian Journal of Engineering
Vol.37, No.2, January 2015, pp.54-62

A Mechanism for Cutting Coconut Husks

Kishan Ramesar[a], Chris Maharaj[b,Ψ], and Umesh Persad[c]

[a,b] Department of Mechanical and Manufacturing Engineering, The University of the West Indies, St. Augustine Campus, St. Augustine, Trinidad and Tobago, West Indies. E-mails: kishanramesar@gmail.com; chris.maharaj@sta.uwi.edu

[c] Centre for Production Systems, The University of Trinidad and Tobago, O'Meara Campus 78-94 O'Meara Industrial Park, Arima, Trinidad and Tobago, West Indies; E-mail: umesh.persad@utt.edu.tt

[Ψ] - Corresponding Author

(Received 29 August 2014; Revised 19 November 2014; Accepted 30 January 2015)

Abstract: *This paper details the conceptual design of a machine for cutting coconut husk halves into pieces for activated carbon production. Alternative interlocking and welded blade arrangements are presented with the potential for scaling up the processing of coconut husks into smaller pieces. Virtual simulations and the experimental testing of a functional prototype are used to validate the conceptual design. The design is shown to be functionally acceptable, and directions for further improvements and development are outlined.*

Keywords: *Machine design, conceptual design, coconut shell processing*

1. Introduction

Activated carbon has the strongest physical adsorption forces of any material known to mankind and it is applied in numerous industries including the Semi-Conductor, Petrochemical and Gold Recovery Industries (Cheremisinoff, 2002a). It is the most commonly used product for the adsorption of volatile organic compounds from vapour and gas phases (Cheremisinoff, 2002b; Wypych, 2001) and is typically applied in water treatments ranging from municipal water treatments to even treatment of landfill leachate water (Grand View Research, 2014). This USD$2 billion product industry is traditionally made from bamboo, coconut shells, wood, ignite and coke (Grand View Research, 2014; Rodriguez-Reinoso, 2001). Currently, there is a need for finding inexpensive and effective alternatives to the existing commercially available activated carbon because the environmental sustainability and benefits for future commercial applications could be improved (AlOthman et al., 2013).

Recent studies have shown that activated carbon made from coconut husks can adsorb impurities ranging from dyes (Purkait et al., 2005) to heavy metals such as arsenic (Manju et al., 1998). In addition to this, it has been suggested that activated carbon made from coconut husks can be used as a replacement for the existing commercially available activated carbon (Gupta et al., 2010). However, in utilising coconut husks for activated carbon production, there is a need to resize the coconut husk pieces to improve the efficiency of the conversion process. In anticipation of industrial scale devices that are capable of cutting the coconut husks into required sizes, this paper presents a conceptual design for a cutting mechanism that addresses this problem.

2. Background to the Study

There are two main methods of manufacturing activated carbon: physical activation and chemical activation. However, many variations of these processes have been employed and in some instances both of these processes have even been combined (Gupta et al., 2010; Low & Lee 1990; Manju et al. 1998; Vargas et al. 2011). Figure 1 highlights the main steps in activated carbon manufacturing.

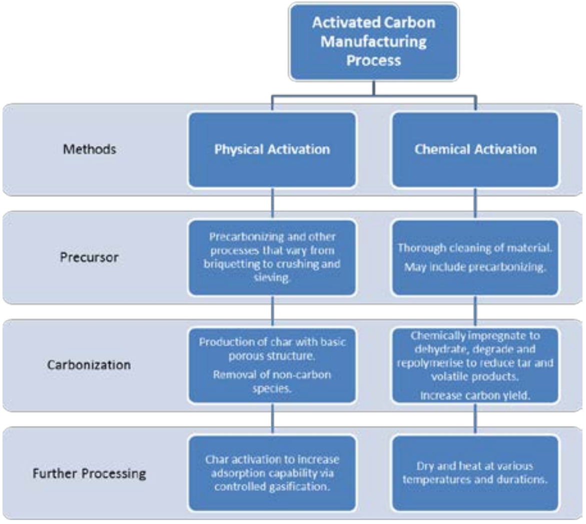

Figure 1. The activated carbon manufacturing process

In using coconut husks for producing activated carbon, the coconut husks are initially cut into smaller pieces as the first preparatory step. This is done to increase the efficiency of the carbonisation process where a size of approximately 50 mm cubed was recommended (Dyall, 2012).

The production of activated carbon from coconut husks has not been attempted on an industrial scale. Therefore, in anticipation of this requirement to effectively and efficiently size coconut husk pieces for activated carbon production, cutting mechanisms embedded in devices such as wood chippers, guillotines, paper/plastic shredders and fruit/vegetable processing equipment are potentially applicable. Three of these prototypical mechanisms are shown in Figure 2.

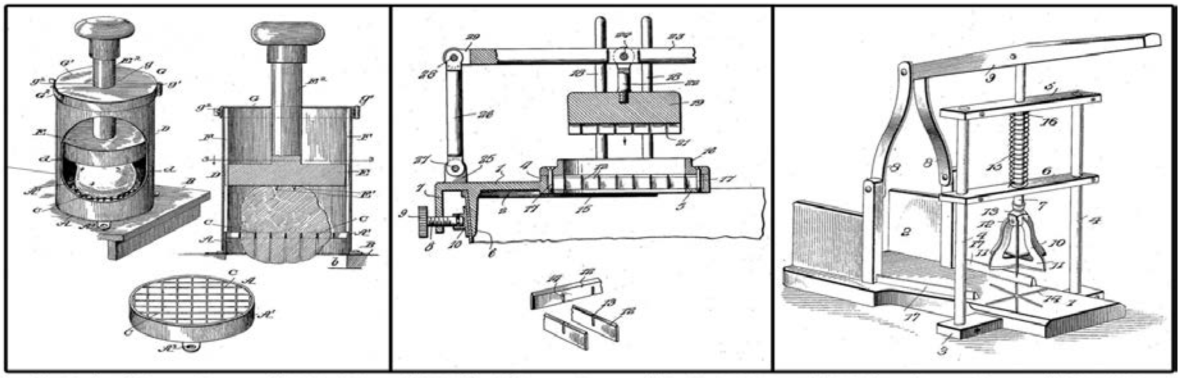
(a) United States Patent # 563,652 (b) United States Patent # 2,004,585 (c) Unites States Patent # 880,057

Figure 2. Cutting mechanism configurations from filed patents

The majority of cutting mechanisms could be regarded as multi-blade linear food cutters due to the plurality of blades used and relative motion between the food item and the device's cutting blades. In some devices, as shown by Wheeler (1908) in Fig 2(c), the food item is stationary and the cutting blades descend with force through the food item thereby cutting it. The opposite is observed in some devices (Bulette, 1896; Farabough, 1935) as shown in Fig 2(a) and 2(b), where the food item is forced through stationary blades.

Further to this, the latter mentioned devices use plungers to force the food item through the device. In one configuration, the plunger is designed to accommodate movement beyond the surface of the blades to ensure the entire food item is cut (Farabough, 1935). In another configuration, the plunger uses small spikes to penetrate the top of the food item in order to restrict undesirable rotation and translation of the food item before or while it is being forced through the blades (Bulette, 1896).

Although all cutting mechanisms use a plurality of blades, there are differences in their orientations and connections. On one hand, in the design presented by Wheeler (1908), the blades are angled at 60˚ to each other and bolted together. In other designs, the blades are positioned perpendicular to each other, with either a welded configuration or an interlocking configuration (Farabough, 1935).

The means of actuation of the cutting process is also diverse as some designs utilise mechanical advantage via a lever system to amplify the cutting force applied (Farabough, 1935; Wheeler, 1908) while others are actuated by the linear translation of a plunger (Bulette, 1896). In addition to this, the device designed by Gangi (1993) incorporates a hydraulic motor in conjunction with a pulley configuration to actuate the system.

The cutting devices are capable of cutting various food items into specific pieces, yet they are insufficiently equipped to cut coconut husks due to the size of the husk and the magnitude of the cutting force required. Other devices such as shredders were not considered as possible solutions because they are unable to cut the coconut husk into specific sizes. Therefore, there remains a need for an effective method of cutting coconut husks into pieces that could be scaled up for the future industrial production of activated carbon.

3. Methodology

In order to address the need for an effective coconut husk cutting method, a survey of patents and existing cutting machines (wood chippers, guillotines, paper and plastic shredders and fruit and vegetable processing equipment) was undertaken to gain insight into current solutions. Additionally, in order to identify the main design requirement, an experiment was conducted to determine the magnitude of the force required to cut half the coconut husk at various orientations and ages. 10 machinists were also interviewed to determine their requirements for operating a machine to cut coconut husk halves into pieces, and their views were taken into consideration at the early conceptual design stages.

Varying alternative conceptual designs were generated to fulfil the main function of cutting the coconut husks halves into pieces. These were iteratively developed and evaluated against each other according to their ability to fulfil functional requirements. A final conceptual design was selected and refined to better satisfy ergonomic and safety requirements of the device to produce a final working concept (Ullman, 2009).

To validate the new design concept for cutting the coconut husk, a simulation study and an experimental study were performed. The Finite Element Analysis (FEA) simulation study was executed on CAD models using SolidWorks 2013. A physical prototype was constructed and an experimental study was also performed to gain insight into the performance of the cutting mechanism. The new design concept and the design validation studies would be detailed in the following sections.

3.1 Cutting Force Requirements

A Tinius Olsen Benchtop Tester was fashioned with a specially fabricated blade and used to cut the coconut husk half sections at different orientations. This was done to investigate the force required to cut the coconut husk when the blade was angled to approximately 45˚ to the grains of the husk, parallel to the grains of the husk, and perpendicular to the grains of the husk. This was repeated for the same species of coconut husks that were less than 3 days old after being cut by the coconut vendor. A summary of the results is presented in Table 1.

Table 1. Results from Cutting Force Experiment

Test	Orientation		
	Force Parallel to grain (N)	Force Perpendicular to grain (N)	Force Angled at 45 degrees (N)
Test 1	819	2329	2264
Test 2	1163	1881	2138
Test 3	1222	2700	2107
Average	1068	2304	2169

The recorded maximum force required to cut the husk perpendicular to the grains (2700N) was more than double that which was required when the blade was oriented parallel to the grains (1222 N). This highlighted that there was a significant relationship between the cutting force required and the orientation of the coconut husk, given the fibrous nature of the coconut husk. It was observed that if the cutting force was applied parallel to the grains, the husk split along the grains, but if the cutting force was applied at an angle to the grains, the husk deformed before the grains were cut.

For the purposes of this study, the maximum force of 2700N was used as the maximum cutting force required by the cutting mechanism. A more extensive study to determine the statistical distribution of cutting force by type and orientation of coconut husk is required to fully characterise the design requirements. However, for the purposes of developing the conceptual design presented in this paper, the maximum cutting force found experimentally coupled with an appropriate safety factor was deemed sufficient to serve as the maximum cutting force requirement. Pending such a study, the conceptual design presented could be easily scaled to accommodate a change in the maximum required cutting force.

3.2 Machine Conceptual Design

A conceptual design for a coconut husk cutting machine was developed and this is shown in Fig. 3. The sequence of operation is as follows. The operator will place the coconut husk on the 'Loading Area (4)', and then the 'Pusher (5)' will be used to slide the coconut on top of the 'Cutting Blades (10)' in the 'Cutting Chamber (3)' of the device. As the 'Pusher (5)' advances towards the 'Cutting Chamber (3)', a pulley system, which connects the 'Pusher (5)' to the 'Sliding Shield (2)', raises the 'Sliding Shield (2)' to allow the coconut husk to enter the 'Cutting Chamber (3)'. Further to this, when the 'Pusher (5)' is retracted to its initial position, so too does the 'Sliding Shield (2)'.

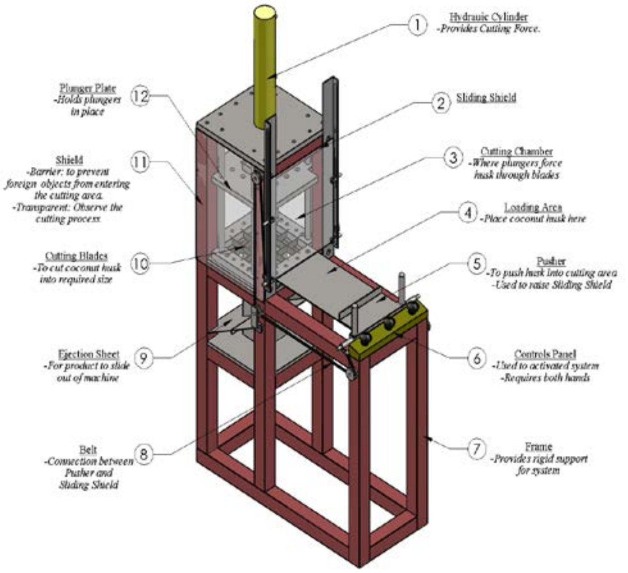

Figure 3. Isometric view of the cutting machine conceptual design

At this juncture, the 'Controls Panel (6)' will be used to activate the system. The 'Controls Panel (6)' contains a Programmable Logic Computer (PLC) to control the hydraulic cylinder extension and retraction. The PLC is coded so that the two buttons, on either side of the 'Controls Panel (6)', must be activated for the cutting process to begin. This was done to ensure that both of the operator's hands were away from the 'Cutting Chamber (3)' when the cutting process starts. Further to this, a limit switch is placed inside of the cutting chamber, so that after the plunger descends and cuts the coconut husk, a signal is sent to the PLC to retract the cylinder. This automatic step reduces the amount of human input required by the machine and also decreases operational time. In addition to this, the button at the centre of the 'Controls Panel' is the emergency stop button which will stop the process at any point once activated.

After the hydraulic system is actuated, the 'Hydraulic Cylinder (1)', at the top of the machine, will force the 'Plunger Plate (12)' to descend towards the 'Cutting Blades (10)'. The plungers, which are attached to the bottom of the 'Plunger Plate (12)', will force the coconut husk through the arrangement of the 'Cutting Blades (10)', thereby, cutting them. The cut coconut husks will then fall onto the 'Ejection Sheet (9)' and slide out of the device. All of these components can be seen in Figure 3.

The proposed design solves the dilemma of the current state of the art, i.e. the insufficient cutting force, by utilising a hydraulic actuator to apply the cutting force to the system. The use of hydraulic equipment (specifically hydraulic presses) in the extraction of oils and fruit juices is fairly common (Fellows, 2009). However, this technology has not been applied in the fruit cutting industry as it has been in the current design.

As a consequence of the magnitude of the applied force and the toughness of the coconut husk, significant stresses will develop in the cutting blades. To counteract this, supports for the cutting blades in the central portion of the cutting area were incorporated into the design of the system. This feature was also absent in the devices reviewed. In addition to this, the cutting blades used in the proposed device are basically an evenly spaced grid of three rows of blades in one direction connected to three perpendicular rows of blades. However, the device is capable of using blades with different connections between them. On one hand, the blades can be welded together, as seen in Figure 4, akin to that highlighted by Bulette (1896).

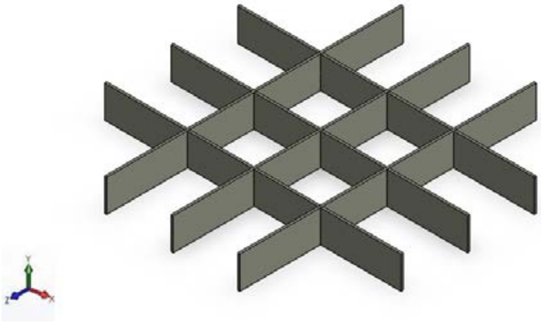

Figure 4. Isometric view of the welded blade configuration

Alternatively, the blades can be a series of specially machined interlocking blades, as shown in Figure 5, similar to that presented by Farabough (1935).

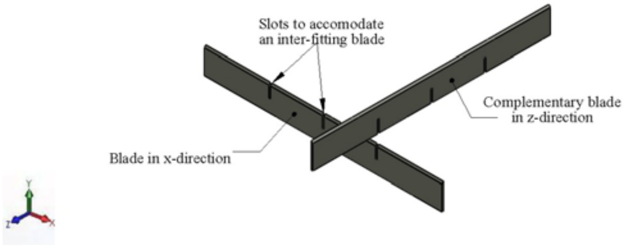

Figure 5. Isometric view of the interlocking blade configuration

Figure 6 shows the cutting mechanism assembly. The ends of the 'Cutting Blades (10)' are wedged into groves cut into the 'Blade Holder Strips (14)'. This provides a tight fit for the blades. In turn, the 'Blade Holder Strips (14)' are bolted onto the 'Locator Plate' and the combination of the two restricts motion of the blades. Furthermore, 'Guide Pins (16)' are bolted onto the 'Locator Plate' through the 'Blade Holder Strips (14)' on one end, and bolted onto the top of the machine at the other end. These 'Guide Pins (16)' are used to align the 'Plunger Plate (12)' over the arrangement of blades.

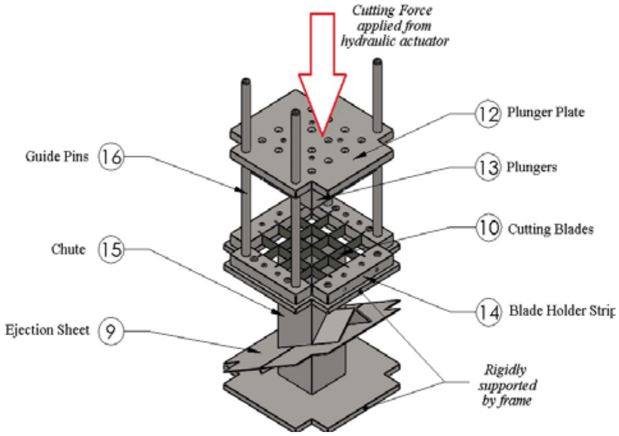

Figure 6. Isometric view of cutting mechanism assembly

The cutting process begins when the hydraulic piston is actuated. This causes the 'Plunger Plate (12)' to descend towards the coconut husk placed on the blades. Attached beneath the 'Plunger Plate (12)' are individual 'Plungers (13)', as shown in Figure 6, which are specifically sized to fit between the blades and are carefully positioned to ensure that no collision takes place during the cutting operation. These 'Plungers (13)' apply the cutting force to the coconut husk.

When the 'Plungers (13)' make contact with the coconut husk, the initial force is transferred through the coconut husk onto its support, the blades, and its reaction is what starts cutting the husk. As the 'Plunger Plate (12)' descends further, the 'Plungers (13)' force the coconut husk between the blades. This continues until the ‘Plungers (13)’ advance beyond the surface of the blades thus cutting the coconut husk. The pieces of the husk then fall through the blades and the ‘Plunger Plate (12)’ is retracted to end the cutting process.

4. Manufacturing and Assembly Process of Cutting Mechanism

4.1 Cutting Blades

Two lengths of 800 mm x 1.5 mm x 25.4 mm of Steel Rule were used in the manufacturing of the cutting blades (10) (see Figure 6). They were cut into lengths of 230.2 mm via a Wire Electrical Discharge Machine (EDM). Subsequent to being cut to length, the Wire-EDM was again used to cut three 12.7 mm slots (one at the blade mid-point and two others spaced 50.8 mm from the mid-point). The slots were cut on the top of the blades that pointed in the x-direction (x-blades) and on the bottom of the blades that pointed in the z-direction (z-blades) when assembled, as seen in Figure 5.

4.2 Blade Holder Strips

An 850 mm x 50.8 mm x 30 mm mild steel block was used to manufacture the 204.8 mm x 50.8 mm x 25.4 mm blade holder strips (14) as shown in Figure 6. The block was first milled to the required dimensions. Afterwards, three 25.4 mm tall by 12.7 mm deep grooves were cut into the 25.4 mm face of the strips via Wire-EDM. The slots were cut so that the cutting blades would be wedged into them as to restrict motion in all directions.

Following this, a pair of counter bore holes, to accommodate M8 Socket Head Cap Screws, was drilled on the 50.8 mm face of each of the strips. These holes were used to attach the strips onto a Locator Plate. Two additional 8 mm diameter through holes were drilled, reamed and counter bore with a 19.1 mm diameter to a depth of 3mm in one pair of strips, which were placed on either side of the cutting chamber. This was done to allow the Guide Pins (16), as shown in Figure 6, to be attached to the Locator Plate beneath the Blade Holder Strips. Finally, one pair of threaded 6.4mm holes was drilled on the strip with which the Loading Area (4), as shown in Figure 3, was bolted onto.

4.3 Plunger Plate

A 350 mm x 350 mm x 20 mm mild steel plate was used to manufacture the Plunger Plate (12) in Figure 6. Firstly, the plate was machined via milling to a flat 306 mm x 306 mm plate, and then four 50.8 mm x 50.8 mm squares were cut out from the corners of the plate. Proceeding from there, four rows of four evenly spaced 38.1mm x 38.1mm x 6.35 mm slots were milled in the central portion of the plate and 8mm diameter through holes were drilled through their centres. This was done so the plungers (13) could be fitted into and bolted onto the Plunger Plate.

5. Design Simulation Study

The most critical components in the cutting process are the cutting blades. A CAD model of the blade arrangement and geometry was used to investigate the responses of the cutting blades to various loading scenarios. The worst case scenario was modelled as a statically applied load acting on the central portion of one blade as shown in Figure 7. Von Mises Stress, resulting displacement and factor of safety studies were executed for both the interlocking and welded blade configurations. The cutting force modelled included a 2.4 factor of safety of the maximum recorded force (2700N) required to cut the coconut husk. This was due to the assumptions that the machine will be operated at room temperature and that the model accurately represented the system.

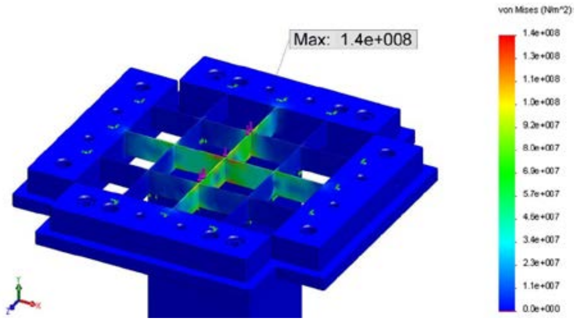

Figure 7. Interlocking blade configuration Von Mises stress analysis results

In the case of the interlocking blades configuration, the Von Mises Stress Analysis illustrated that the most stressed portions of the blades were localised at the areas where the perpendicular blades connected with each other. This was expected because the area surrounding geometric discontinuities would have a stress concentration. In addition to this, it is expected that the majority of the deformation will be in the y-direction. The maximum stress was calculated to be 140 MPa which is less than the rated 210 MPa Yield Strength of the low-carbon steel material.

The resulting displacement study showed that the central portion of the blade deflected the most. This also was anticipated because that segment of the blade was only supported at its ends. More so, the defection is expected mainly in the y-direction. The displacement of 0.054mm as seen in Figure 8 is acceptable. The factor of safety study revealed that the weakest point in the blades was at the junction of the intersecting blades. The minimum factor of safety registered at 1.3 as shown in Figure 9.

In the case of the welded blades configuration, the Von Mises Stress analysis indicated that the most stressed area was the central portion of the interlocking blade assembly (see Figure 10). This was reckoned to be because the ends of the blades are supported and the blade has a constant cross-section. The maximum stress was calculated to be 42 MPa which is much less than the rated 210 MPa yield strength of the material.

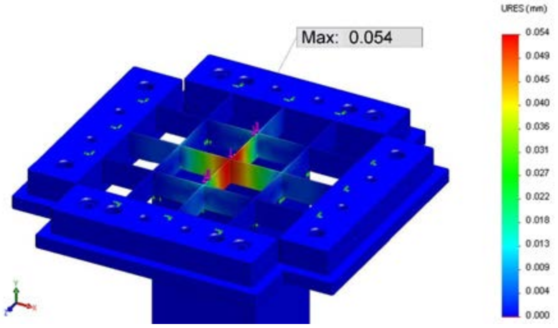

Figure 8. Interlocking blade configuration displacement study results

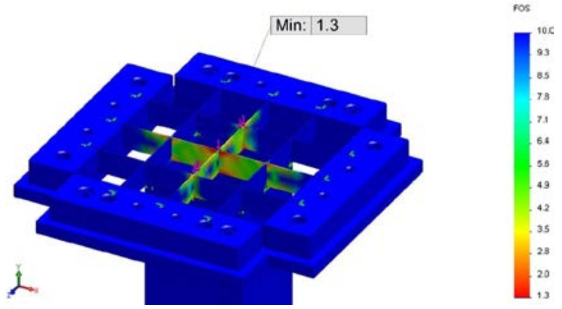

Figure 9. Interlocking blade configuration factor of safety study results

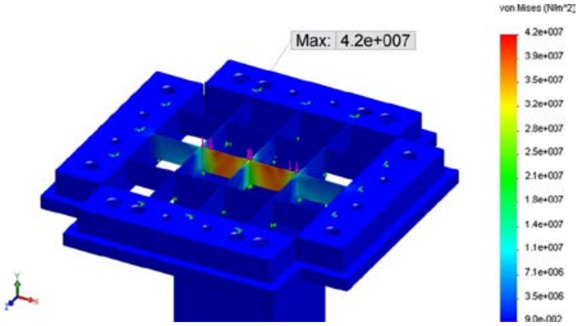

Figure 10. Welded blade configuration Von Mises stress analysis results

The resulting displacement study showed that the upper portion of the majority of the blade deflected the most. This result was attributed to the constant cross-section of the blade. More so, the deflection is expected mainly in the z-direction. The displacement of 0.005mm as seen in Figure 11 is acceptable.

The factor of safety study resulted in a minimum factor of safety of 4.9 at the upper portion of the blade (see Figure 12). However, the majority of the blade appears to have a similar value. The constant cross-section of the blade was again credited for this.

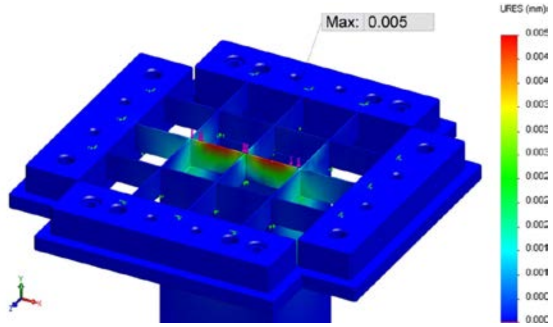

Figure 11. Welded blade configuration displacement study results

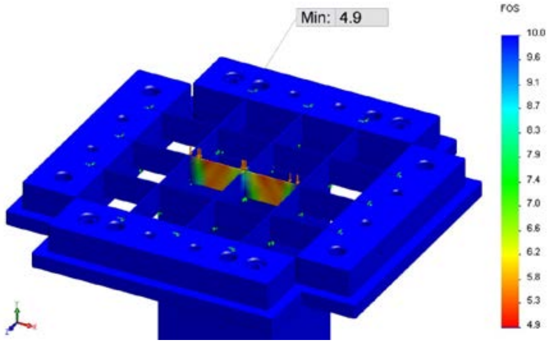

Figure 12. Welded blade configuration factor of safety study results

Though these values can be deemed safe, it is in excess of what is required which implies that the blade is over designed. A review of the summary of results from the simulation tests (shown in Table 2) shows that both types of blade configurations are capable of cutting the coconut husk with the welded blade design appearing superior.

Table 2. Summary of results from the Simulation Study

Study Type	**Interlocking Blade Design**	**Welded Blade Design**
Maximum Von Mises Stress	140 MPa	42MPa
Resulting Displacement	0.054 mm	0.005 mm
Factor of Safety	1.3	4.9

However, the ease of manufacture and availability of the particular blade designs need to be considered. The blades used in the interlocking configuration are readily available and only require the cutting of grooves on individual blades to complete its manufacture. This can be easily done via electrical discharge machining. Alternatively, the welded blade configuration must be fabricated in its entirety.

The general maintenance or repair of the blades is also affected by the design. The blades in the interlocking configuration are capable of being separated from each other easily whereas the welded blade configuration is not capable of being disassembled. In the event that a particular blade is chipped or even broken, the said blade can be simply replaced in the interlocking configuration but the entire blade unit in the welded blade configuration will have to be replaced. Given these considerations, the interlocking blade configuration was selected as being better suited to the overall design requirements and it was used to fabricate a working prototype for further testing.

6. Experimental Testing of Prototype

Four main experiments were performed with the prototype to investigate the functional acceptability of the design and whether variations in the position and orientation of the coconut husk, with respect to the blades, had any effect on the final product.

In the first two experiments, the coconut husk was positioned with the flat side faced downwards on the blades, and in the other test, the coconut husks were placed with the flat side faced upwards. Further to this, the coconut husks were oriented, in such a manner, so that the grains of the husk were parallel to a blade. These experiments were repeated, but instead of the grains of the husk being oriented parallel to the blade, they were oriented at an angle to a blade. More so, all of the main experiments were repeated for coconuts that were aged up to three days after being cut by the coconut vendor.

The prototype successfully cut the coconut husks into the required size, regardless of the position and orientation of the husks. However, more useable pieces were obtained from the 'parallel to grain' experiments. Figure 13 shows a '0 days old' coconut that was cut by the machine which was positioned with its flat face on top of the blades and oriented with its grain parallel to a blade. Figure 14 shows a '3 days old' coconut that was cut by the machine which was positioned with its flat face on top of the blades and oriented with its grain angled at 45˚ to a blade.

Figure 13. Final product from cutting machine (0 days old, faced downward, cut parallel to blade)

Figure 14. Final product from cutting machine (3 days old, faced downward, cut angled to blade)

Further to this, it was observed that the coconut husks exhibited behaviour of compression, deflection and fracturing under the applied load before they were fully cut which is an acceptable and typical behaviour for this type of solid food (Fellows, 2009). Also the lack of support to the cavity in the concaved coconut husk has been observed as the key reason for this behaviour.

In the experiment with the flat side of coconut facing upwards towards the plungers, when the plunger descended upon the husk, the portion of the husk that was in contact with the blades was briefly indented. At that point, the area of contact between the flat side of the husk and the plungers was larger than the area of contact between the coconut husk and the blades. Therefore, the force received by flat face of the husk was large enough for the reaction of the blades to indent the skin of the coconut.

As a result of the indenting/cutting, a larger area of the coconut was in contact with the cutting blades which also exposed grains that were perpendicular to the blades. As a consequence to that, the energy used to produce the cutting force was absorbed by the coconut and it compressed slightly. Then, as the plungers descended further because of the increasing cutting force, the deflection phase began.

In this phase, the flat face of the husk began to spread across the face of the plungers. This showed that the coconut husk had a strong ability to deform without sustaining permanent damage i.e. a relatively small modulus of elasticity. This, in conjunction with the cavity of the coconut husk, was attributed as an explanation for the behaviour of the coconut husk in this phase. The deformation continued until the coconut husk was almost flattened and then it fractured along its centre-most portions. At this juncture, the husk was unable to be compressed further and the plungers forced the husk through the blades thereby cutting it.

In the experiment with the flat side of coconut faced downwards, the results of this series of experiments were similar to when the husks were faced flat side up, in that the coconut husk exhibited similar behaviours of compressing, deforming and fracturing before being cut. This can be seen in Fig 15. However, in this experiment, the deflection phase came to a premature end when the coconut husk fractured before any significant deflection occurred. Afterwards, the plungers then proceeded to compress the husk until it was almost flat before finally being forced through the blades and ending the cutting process.

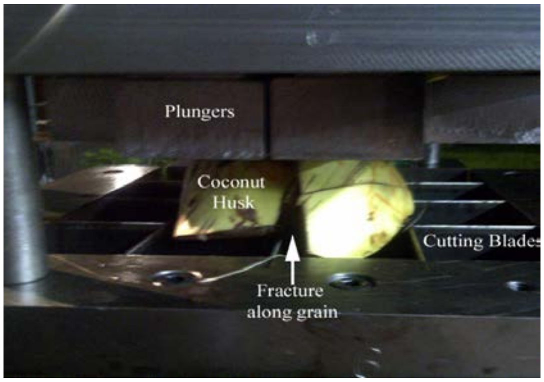

Figure 15. Fracture of coconut husk in cutting machine

7. Discussion

A design process was executed to develop a mechanism to cut half of a coconut husk into smaller pieces ideal for conversion into activated carbon. After validating the overall conceptual design via virtual simulation, a prototype of the design was fabricated and it successfully passed performance testing by safely and effectively cutting the coconut husk into specific sizes regardless of the husk's age, position and orientation.

Activated carbon produced from coconut husks has not been attempted on an industrial scale. As a result of this, customers (from whom the customer needs were to be derived) and existing equipment (from which system requirements were to be obtained) were not present. To overcome these issues, machinists were interviewed (due to their familiarity with operating equipment) and similar equipment was investigated. However, some parameters in the equipment examined were unavailable so their values were assumed during conceptual design. The conceptual design must now be subjected to more rigorous user and functional testing so that usability and acceptability requirements could be met.

Limitations in the research also included the number and type of coconuts used to investigate the cutting force required. Small samples of coconuts were used to investigate the force required to cut the coconut husk at the specified positions and orientations and, in addition to this, most were of the same species and collected from the same tree. Further to this, the cutting speed when investigating the cutting force required was not varied to determine whether there was a significant relationship between the cutting speed and the cutting force. Future work can address these issues in addition to improving the overall operation of the cutting mechanism.

One such improvement can be for the machine to better accommodate the coconut husk. During the cutting operation, it was observed that the lack of support, for the concaved shaped coconut husk, caused it to be compressed until it was flat before it was cut. Although the effect of this is negligible, it is still undesirable. Assuming that the half coconut husks were positioned with their flat sides facing upwards, if the plungers that were in-line with the cavity of the husk were longer, they would make contact with the centre of the cavity first and support it. This will eliminate the compression of the husk before it was cut and would improve the quality of the cut pieces. However, the husk would have to be precisely placed on the cutting area with its cavity directly beneath the plungers.

Also, further research would have to be executed to determine the extension of the centre plungers required, in relation to the others, and the width of the plungers so that they fit inside of the husk. Another potential solution to the identified problem would be to curve the blades to accommodate the curved face of the husk assuming the same positioning. Also, the blades could be made to accommodate the cavity of the husk assuming positioning with the flat side facing downwards. Furthermore, both the plungers and blades can be fabricated to accommodate a particular positioning. Research into the curvature of the coconut husk and its cavity will have to be extensively performed to facilitate coconut husks of various ages and sizes.

Another proposal for future work is to automate the entire system. The reduction of human input can increase the efficiency of the system and reduce the time required to load, actuate and cut the coconuts. A constant supply of half-sectioned coconut husks can be provided to a cam actuated cutting mechanism via a conveyor. The only human input required would be to start the system and place the husks on the conveyor. However, this will need financial justification.

A final recommendation for future work is to surpass the limitation of cutting half coconut husks and to design a machine to process a whole coconut husk. The device can be made so that the husk is strategically cut in halves which then fall into a loading mechanism that delivers them to a pair of machines similar to the one designed in this project. This will expand the availability of raw material for this machine. More so, the device can also be designed to cut a whole coconut (one that still contains water) into the required pieces and also harvest the water inside which can be used for commercial benefit.

8. Conclusion

A conceptual design for a mechanism to cut coconut halves has been presented. The results from a virtual simulation study and the functional testing of a fabricated prototype demonstrate that the proposed design is capable of cutting coconut husk halves regardless of position and orientation. Further work involves detailed performance testing, design optimisation and user acceptability testing in order to produce a working product for use in industry. It is hoped that the solution offered in this paper would contribute to the ease of production of activated carbon from coconut husks.

References:

AlOthman, Z.A., Habila, M.A., Ali, R., Ghafar, A.A., El-din Hassouna, M.S. (2013), "Valorization of two waste streams into activated carbon and studying its adsorption kinetics equilibrium isotherms andthermodynamics for methylene blue removal", *Arabian Journal of Chemistry*, available at http://ac.els-cdn.com/S1878535213001275/1-s2.0-S1878535213001275-main.pdf?_tid=b7599dec-2fae-11e4-b0f9-00000aab0f6c&acdnat=1409338997_a2c24dee08b0a23f07a0a68781f4703e (Dated: 18th February 2014)

Bulette, O.A. (1896). *Potato Cutter*, US Patent 563652

Cheremisinoff, N.P. (2002a), "Ion Exchange and Carbon Adsorption", *Handbook of Water and Wastewater Treatment Technologies*, Elsevier, USA, pp. 404-440

Cheremisinoff, N.P. (2002b), "Prevention and Control Hardware", *Handbook of Air Pollution and Control*, Elsevier, USA, pp. 446-448; 467

Dyall, K. (2012), "An investigation into the creation of charcoal and activated carbon from coconut by-products for use in metallurgy and filtration applications", MSc Thesis in Industrial Innovation, Entrepreneurship and Management, The University of Trinidad and Tobago.

Farabough, G.M. (1935), *Potato Cutter*, US Patent 2004858.

Fellows, P.J. (2009), *Food Processing Technology - Principles and Practice,* Woodhead Publishing, England

Gangi, J.C. (1993), *Machine for Cutting Fruit into Sections*, US Patent 5241902

Grand View Research (2014), *Activated Carbon Market Analysis And Segment Forecasts To 2020*, Grand View Research, California, USA

Gupta, V.K., Jain, R. and Shrivastava, M. (2010), "Adsorptive removal of Cyanosine from wastewater using coconut husks", *Journal of Colloid and Interface Science*, Vol. 347, No.2, pp. 309-314

Low, K.S. and Lee, C.K. (1990), "The Removal of Cationic Dyes Using Coconut Husk as an Adsorbent", *Pertanika*, Vol.13, No.2, pp. 221-228

Manju G. N., Raji C. and Anirudhan T. S. (1998), "Evaluation of Coconut Husk Carbon for the removal of arsenic from water", *Pergamonl*, Vol. 32, No. 10, pp. 3062-3070.

Purkait, M. K., Das Gupta, S., and De, S. (2005), "Adsorption of eosin dye on activated carbon and its surfactant based desorption", *Journal of Environmental Management*, Vol.76, No.2, pp. 135-142**.**

Rodriguez-Reinoso, F. (2001), "Activated Carbon and Adsorption", Buschow, J.K.H., Cahn, R.W., Flemings, M.C., Ilschner, B., Kramer, E.J., Mahajan, S. (eds), *Encyclopedia of Materials - Science and Technology, Volumes 1-11*, Elsevier, USA, pp. 22-35

Ullman, D.G. (2009), *The Mechanical Design Process*, McGraw-Hill, New York, USA.

Vargas, A.M.M., Cazetta, A.L., Garcia, C.A., Moraes, J.C.G., Nogami, E.M., Lenzi, E., Costa, W.F. and Almeida, V.C. (2011), "Preparation and characterization of activated carbon from a new raw lignocellulosic material: Flamboyant (Delonixregia) pods", *Journal of Environmental Management*, Vol. 92, No.1, pp. 178-184.

Wheeler, M.M. (1908), *Potato Cutter*, US Patent 880057.

Wypych, G. (2001), "Solvent Recycling, Removal, and Degradation", *Handbook of Solvents*, ChemTec Publishing, Canada, pp.1513-1514

Authors' Biographical Notes

Kishan Ramesar *graduated from the Faculty of Engineering at The University of the West Indies in 2013 majoring in Engineering Design. He is currently working as a Teacher's Assistant in the Faculty of Engineering in addition to pursuing a Master's of Science Degree in Petroleum Engineering at The University of the West Indies.*

Chris Maharaj *is a Lecturer in the Mechanical and Manufacturing Engineering Department of The University of the West Indies (UWI). He holds BSc and MSc qualifications in Mechanical Engineering and Engineering Management respectively from UWI. He started his career as a Mechanical Engineer in Condition Monitoring and Inspection and worked in the industry for five years. He later went on to pursue his PhD at Imperial College London in Mechanical Engineering. His present teaching and research interests are in alternative use of waste materials, mechanical design optimisation, failure analysis, component life assessment, asset management, and innovation management.*

Umesh Persad *is an Assistant Professor in Design and Manufacturing at The University of Trinidad and Tobago. He obtained his BSc. in Mechanical Engineering (First Class) from The University of the West Indies, and his Ph.D. from The University of Cambridge in the area of Engineering Design, with a special focus on Inclusive Design and Healthcare Design. He is a member of ASME, ACM, and The Design Society. His research interests include the computational design of medical products and general product design.*

■