Critical Parameters for Mimicking Manual Decortications of Pongamia Oil Seed

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Abstract— Renewable energy source is one of the potential energy sources to cater to the energy demand in future. The use of this source ensures the energy sustainability and environmental protection. Many non-edible oil seeds offer the opportunity to forestation, rural employment and energy security. However there is a technology barrier to harness it efficiently in the large scale. The existing drawbacks in harnessing bio-fuel from non-edible oil seeds are its collection, decortications and efficient technology to get higher yield of fuel at lesser cost and time. In this context, the present research work proposes an efficient method of decortications in which tedious manual approach is replaced with a mechanical system which utilizes a decision making module to decorticate the oil seed pod mechanically. The work entails the study of manual decortications process with judgment on force to be applied in order to extract an intact seed from the pod. This has been achieved with the use of a programmable electronic circuit to control the mechanical linkages such that the appropriate force is applied as done in the manual method but at higher speed and eliminating human fatigue. An intelligent decorticator is fabricated and tested for its performance. The results are promising that the similar approach may be used to decorticate any type of oil-seed to harness bio-fuel at faster rate in lesser time economically.

Index Terms—De-Corticator, De-huller, Intelligent De-corticator, Microcontrolled Impact, Pongamia Seeds, Pneumatic Hammer, Seed Impact.

1 INTRODUCTION

The population growth and corresponding economic and social development results in rise in the energy utilization globally. It is expected that the world‟s population would exceed 10 billion by the year 2050 and in the next 50 years it may grow up to 11.5 billion [27] resulting in further rise of energy demand. To cater to this energy need, energy harnessing plans will have to rely upon other sources in addition to fossil fuels. This deviation makes the society to look towards renewable forms of energy resources

The need of the present time is to have the energy which is clean from the source, not to be causing ill effects on the environment during its utilization and be cost effective. So these challenges call for a paradigm shift, for which the whole world is now looking towards such sustainable sources of energy. The renewable energy source is potential enough to meet the future demand for energy in the global level. But in spite of having potential, the way it is to be harnessed in an economical and socially acceptable way without affecting the environment is the question. The difficulties associated in harnessing will differ from one source of energy to another.

Among many renewable energy sources, biomass energy is a promising source. There are various ways by which biomass energy can be harnessed. They are thermal conversion, biochemical conversion and chemical conversion methods. In the context of declining fossil fuel reserves, bio-fuels contribute significantly to the future energy demands. As the use of bio-fuels poses a green house gas (GHG) neutrality and its cultivation can be done in any waste land, it offers very good opportunity to produce sustainable fuels. There are various oil seeds out of which bio-diesel is produced. Some of them are; Simaruba, Jatropha, Pongamia Pinnata etc. Out of these Pongamia is abundantly available in India.

Pongamia is a commonly grown medium size tree in Indian sub continent. Presently the pongamia is a reliable source of oil in demand from bio-fuel industry. The extraction of bio-fuel from pongamia is done through a well established technology and it is well recognized as a potential source of bio-fuel. To extract bio-fuel from Pongamia oil seeds are not directly available from the trees. It has to be processed and obtained from the pongamia pods. Pongamia pods are collected, and brought to a place where the pods are broken to get the pongamia seeds which is crushed and squeezed to expel the oil out of it. In this whole process, collection of pongamia pods and break opening of the pods to get the seeds are not standardized yet.

In this context this research work proposes development of an automatic machine to decorticate the pongamia pods similar to manual decortications method to ensure the undamaged pongamia seeds with considerable speed and economy. To achieve this, the manual process of decorticating is studied and attempted to incorporate it in the decorticator which is capable of taking decisions on the decorticating parameters analogous to a human.

2 Literature Riview

In extraction of bio-fuels, the de-cortication of pods is a primary activity for which manual or mechanized approaches are adopted. Several types of de-coordinators are designed and evaluated to enhance the production of bio-fuels. The following issues with the successful decortication is brought out with the literature review.

Firstly, the decortication of oil-seeds depends on its characteristics like shape, size, moisture content. Kabir A A et al., [1] reviewed many machines like, shelling machines for pods, threshing machines for seeds, de-hulling and decorticating machines for nuts, and brought out that, decorticating of nuts depends mainly on the properties of pods, seeds and nuts. R.C. Pradhan et al., [2] have designed, developed, and tested hand operated de-corticator for Jatropha seeds. Evaluation of the de-corticator in terms of the performance parameters like, percentage of whole seeds, broken seeds and percentage of partial de-corticated pods was carried out and brought out optimum moisture content is crucial for better decortications.

Secondly, the decortication effeiciency depended on decorticator parameters like speed of the drum and force applied on the seeds. R.K. Gupta et al., [3] evaluated performance of centrifugal de-hulling of sun flower seeds. The result showed that the non-recoverable kernel fraction increased with increased impeller speed, reduced feed rate and reduced moisture content of the seed. A. O. D. Adejumo et al., [4] have studied performance characteristics of jatropha seed de- corticator. Finally it was found that the speed of the decorticator was the sole parameter of the efficiency of the decorticator. A. E. Kate et al., [5] have conducted many experiments to optimize the machine parameters of apricot decorticator. The machine parameters like, crank shaft speed, moisture content of the seed, feed in a stroke and clearances during impact were considered to carry out the experiments.

Majority of the decorticators developed adopted the application of force on the seeds by impacting and threshing. J.R. Ashes et al., [6] have devised a simple de-hulling machine for seeds and grains. The de-huller works on the principle of bouncing the seeds in between a ripple plate and a squirrel cage kind of rotor to impact out the hull from the kernel. B. A. Adewumi et al., [7] have fabricated an impact type hand operated cocoa pod breaker. A simple hammering method was adopted for breaking many pods at a time. They found the impact energy for breaking one pod and several pods at a time. With this, breaking of the pods right from one at a time to four or five at a time was achieved. David Wylie Hall et al., [8] have invented and patented the de-corticating apparatus in which there were two plates moving relatively to each other which create rolling and crushing forces. This combined rolling and crushing forces were responsible for de-corticating the nuts. Norman J. Peck et al., [9] have got the patent in United States of America for designing an impact de-corticator. The design has a squirrel cage rotating in a horizontal axis concentric to another cylinder which acts as a case. P. P. Said et al., [10] developed a mechanical de-corticator to de-shell nutmeg pods. The nutmeg de-corticator developed had a cylindrical frame made of steel angles and covered by rubber sheet to create an impact on nutmeg shells. The impact was between rubber sheet and a concave made of mild steel rods. R. V. Sanglikar et al., [11] have developed a pedal operated castor de-corticator. The study claims that the developed de-corticator bears facilities better than manual and power operated de- corticator. The deshelling happened between two concentric drums where the inner drum accommodated pieces of rubber on it. The rotation of the drum was achieved by a chain pedal arrangement and de-shelling was done by rubbing action.

When compared with the manual decortication the mechanical decorticators available decorticate the seeds at faster rate but with unshelled pods and damaged seeds. This imposes the need for manual sorting of the good seeds. Presence of damaged seeds makes the quality of the seed inferior and also have shorter shelf life. This necessitates requirement of a decorticator which yields higher undamaged seeds. Hence it is thought of developing a decorticator that mimics the manual operation with less cycle time with improved yield.

3 METHODOLOGY

The critical parameters of the oil seed are size of its cover and size of the seed and its shape. These parameters have direct relationship in the force required to break open them. This needs a study on identifying the size of the pod and estimating the force required to open different sizes of pods. Hence in the de-corticators, there has to be an arrangement to adjust the gap between the hammer and stationary base so that the required force can be applied on the pod. In such an arrangement the chances of opening the pods without damaging the seed is more. This is exactly what is happening in the manual method of de-cortication. If the manual method of de- cortication is revisited and analyzed, we understand that when a person holds the pod in hand, he estimates the size of it in his mind and hammers appropriately to break open the pod.

Pongamia oil seeds are widely available in India which can contribute considerably to reduce carbon emissions from diesel automobiles if diesel produced out of pongamia seeds is used. As the break opening of pongamia pods to get seeds is difficult due to the reason that they are in varied shapes and sizes. Usually in rural area the pongamia pods are processed manually to get seeds. This process is slower but yields a very good quality of undamaged seeds. The damaged seeds have very less shelf life, as they absorb moisture very fast and attract fungus infection. This leads to lesser yielding of oil from the seeds. So break opening of the pongamia pods to get seeds undamaged is the challenge. The manual method of opening the pods is justifiable in this regard despite the process being very slow.

There are some machines available in the market which de-corticates the pongamia pods in bulk. These de-corticators are heavy in construction and accommodates a rotor which holds the hullers which hammers the pods. Because the sizes of the pods are varying in nature, a bulk group of pods will have varied sizes and makes de-cortication ineffective. This is the reason, the commercially designed de-corticators though having larger capacity of de-coritcating ends up producing damaged seeds. The objective of the proposed project is to establish the relationships among the critical parameters of pongamia pod to mechanize the manual process of decortication.

In the manual de-cortication the worker takes a decision based on his senses. To have the mechanical solution to the above process, a mechanism to move the hammer at high velocities and reverse the movement once the hammer hits the pod is required in addition to take decision about positively hitting the Pod with right force and when to retract the hammer. To achieve the hammering process, pneumatic approach to move hammer at high velocities may be used and to take decisions the machine may be trained by discrete learning process which is a part of Artificial Intelligence (AI) with the help of Micro Controller Unit (MCU).

To achieve this, large quantities of measurements of the dimensions like lengths, widths and thicknesses of the pongamia pods and seeds and thereby the difference between width of the pod and seed have been found to be the de-corticating parameter. It is established that parameters vital for de-cortication is the dimension of the Pod measured in the direction where it is hit to break open it. It is recognized that the direction of hit to be in the direction where width of the Pod is measured and the hitting point should be the joint in the larger radius of curvature section. The direction of hit so identified is a key aspect in designing of the de-corticator. It is found by measurements that on an average the difference between the pod and seed width is ranging between 5 mm to 8 mm and to open the pod successfully, the travel of the hammer should be between this ranges. This gives rise to the distinct design variable of the de-cortication process. To realize this, the pneumatic hammer should be intelligent.

A series of de-cortication experiments with different sized pods were conducted to establish the time required to open the pod successfully and without damaging the seed. Depending on the shape and size of the pod, the successful de-cortication is achieved over a range of time period which is overlapping across the width range. Hence, the average time of successful de- cortication for each width range is considered as the representative time value for de- cortication. The following table 1 is showing the width of the pods and the corresponding time range in milli seconds.

Table 1 Width of the Pods & Corresponding De-corticating Time in Milli Second

	Width of the POD **(mm)**	Time Range to De-corticate **(ms)**
1	18	75
2	18	90
3	19	71
4	19	86
5	20	72
6	20	85
7	21	70
8	21	81
9	22	70
10	22	78
11	23	60
12	23	70
13	24	58
14	24	68
15	25	55
16	25	63
17	26	50
18	26	60
19	27	49
20	27	58
21	28	48
22	28	57
23	29	46
24	29	56

It is evident from the figure 1 that, pods can be segregated based on widths of the pods as three different zones with respect to the time of pneumatic hammer travel to successfully de- orticate the pod.

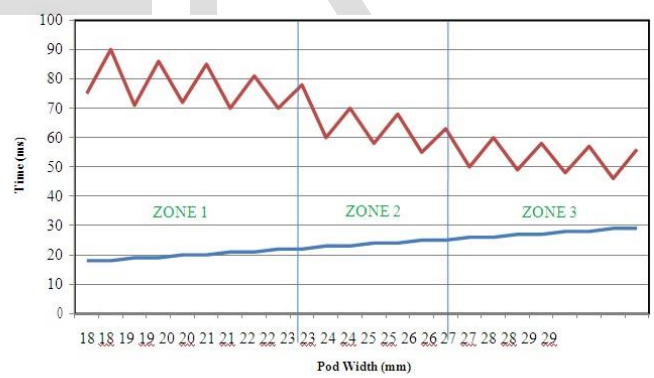

Figure 1 Graph of Pod Width in mm vs De-cortication time in milli second

With the experimentation, it has been brought out that for decorticating the pongamia pod without damage; the hammer movement is based on the size range of the pod. This is achieved by estimating the pneumatic hammer travel time which is analogous to hammer movement. The size ranges of pod width and its corresponding time for hammer movement for successful decortication is as shown in the table 2.

Table 2 Segregated Size Ranges in terms of Widths with Corresponding Average De-cortication time

Sl. No.	Width Range in **mm**	Average Time for De-cortication in **ms**
1	Low - 18 - 22	78
2	Medium - 23-25	63
3	High - 26-29	53

Based on the study of nature of pods, a flow chart of the de-corticator in the present work using pneumatic system and electronic controls is as shown in figure 2.

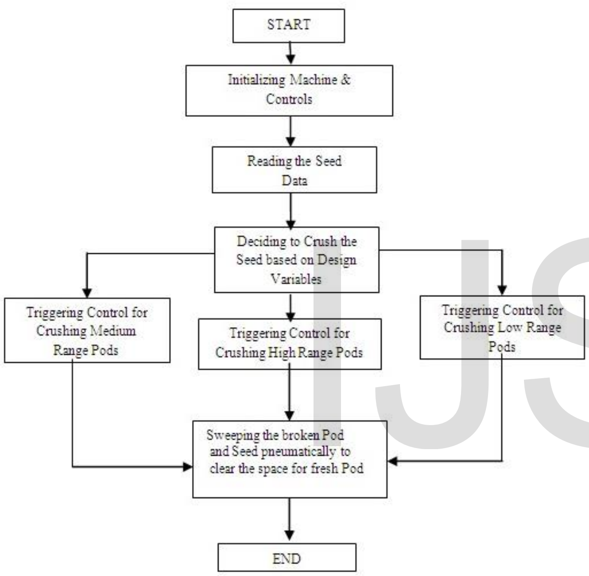

Figure 2 Task Flow of the De-corticator

4 Design and Fabrication

Development of Pneumatic System: The pneumatic system is designed for 6 kg/cm² of pressure as an usual practice in its field. While mimicking the manual hitting of pongamia pod, 1.2 cm diameter of the pneumatic linear actuator is selected to produce 11 kg of force in 0.5 seconds. The air supplied at 6 kg/cm² will flow at a rate of 0.0002 m³/s in the selected pneumatic actuator to obtain the extension speed of 2m/s and takes 50 milli-second to extend the actuator by 10 cm. If this velocity of actuator is used to crush the pongamia pod, it produces 1 Nm of energy which is double the value for crushing pongamia pod manually. So the system pressure is set to 3 kg/cm² for appropriately mimicking the manual de-cortications process. In support of this, the pneumatic system has a FRL Unit to supply clean air, a 5 x 2 solenoid operated Direction

Control Valve to control the extension of the actuator. This pneumatic system is very fast acting and pongamia pods are available in various sizes. So a fast decision making is necessary to estimate the size of the pod and corresponding time analogous to this size should be calculated. And for this calculated time the actuator is to be kept extended for decorticating the pod. So this requirement of the decorticator mechanism is fulfilled by an electronic circuit which estimates the size of pods with the help of IR Sensor and time equivalent to this size is calculated by the Arduino MCU. The same Arduino also sends the signal to solenoid operated Direction Control Valve for the stipulated amount of time calculated so that the pneumatic actuator keeps extending until this time to break open the pod similar to the manual decortications process. So the pneumatic mechanism in association with the decision making electronic circuitry successfully mimics the manual decortications of pongamia pods.

5 Results and Conclusions

The test results of the developed decorticator are done by segregation of seeds into three size ranges as they are the representative sizes available. The Pods of each range are collected and de-corticated to examine the effectiveness of the de-cortication process. Three observations were made viz., „Proper", „Just Broken" and „Seed Fly Up". Proper means the shell is broken correctly and seed is separated from the shell of the Pod, Just Opened condition is the shell is broken but the seed is still stuck with the one of the halves of the Pod. And Seed Fly Up is the seed is totally separated from the shell and fly up in the air.

In all the above observations, the de-cortication is 100% and the seed is undamaged. When the de-cortication process is keenly analyzed, the following advantageous factors are found to be achieved.

- The de-cortication process in its real sense is achieved hundred percent and analogy of hitting the Pods in a particular direction is proved to be correct.
- There was about 15-20% just broken cases which increase the labor of post processing. This can be overcome by incorporating continuous size estimation and corresponding actuator extension.

Analyzing the developed de-corticator from the economic perspective reveals that it lags production capacity as compared to conventional decorticators. The production capacity estimated is based on 6 seconds for the complete decortications cycle of a single pod. In all other parameters compared with mechanical decorticators it either leads or remains same in performance. In addition if the energy consumption is compared with production capacity, both the decorticators consumes same energy and newly developed decorticator is superior to the commercial one as all Pods decorticated are intact and undamaged. If means of improving the production capacity is investigated, the decorticator with decision making capability is better than commercially available de-corticator.

To get the same kind of de-cortication, estimation of size of each pod in de-corticator has to be done instead of estimating the range to which seed belongs to. In spite of the discrete size ranges, the results of the de-corticator are satisfactory compared to manual de-cortication in many perspectives.

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