Performance Analysis of Coconut De-Shelling Machine

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***Abstract*—the traditional method used in India, for the separation of copra and shell from partially-dried split coconuts, is labour intensive. To overcome this problem, a power operated coconut de-shelling machine was designed and developed. A coconut de-shelling machine comprising of cutter with belt drive. Performances test analysis conducted show that the machine de-shelled the fruits without nut breakage and also that its average de-shelling efficiency and capacity are 90% and 195 coconut per hour. The result of the performances test carried out showed that the machine shelling efficiency increased with the increased the speed All materials used in the fabrication of this machine are of standard specification and locally sourced. The estimated cost of producing one unit of the machine is twenty four thousand nine hundred (Rs.24, 900). The machine also eliminated dependency on the epileptic public electric power supply in our rural areas which constitutes the major obstacle in the use of other mechanized coconut de-shelling equipment in the rural area**

***Index Terms*— Coconut De-shelling machine, de-shelling efficiency, capacity, small scale farmers**

I. INTRODUCTION

Agriculture is the potential area that has to be automated which can be applied for activities like irrigation, harvesting, ploughing, weeding etc. This project aims at automating the process of removing the outer shell of coconut by some pure mechanical oriented thoughts. This machine is designed to remove the outer shell from the coconut fruit using cross cutter operated by a motor power producing unit which engages with the shell and opens in such a manner to get the shell removed from the coconut fruit. The process remains safe and only one operator is required to operate this machine with a process of no breakage of coconut. This serves added advantage to this machine. The fiber production (both white and brown) in the country at 3.75 tonne.
Lack of an effective husk collection mechanism and consequent inadequate raw material availability is the main bane of the industry affecting its development. Meanwhile, the shell available with the small holdings, are now wasted in the absence of an organized system for collection of shell and its mobilization for being to the industry. There is a shortage of fiber as the industry is the industry is able to use only 35 percent of the 13,000 million coconut shell produced in a year. The coir board has urged the center to allow duty free imports of 20,000 tonne of coir fiber from Sri Lanka in a bid over its shortage. According to senior coir board official, the country produced around 13,000 million coconut husks a year .Yet, there is a shortage of fiber as the industry is able to use 35 percent of these shell.

Rey (1955) reported a knife-shaped shallow spoon, which moved back and forth upon the rotation of a cam, and in the process, the coconut meat was scooped in fragments. Mix (1957) designed a shelling machine for removing the shell from the fresh coconut meat, while Blandis and Glaser (1973) used water under pressure to separate the coconut meat from the shell. Even in large processing units, about 15-20 labours are used for de-shelling 20,000 to 30,000 nuts (Singh,2004). This is a labour-intensive operation and takes several hours to separate shell and copra. However, no attempt has been made so far to develop a mechanical de-shelling machine, With this objective, an attempt has been made in the present study to develop a de-shelling machine.

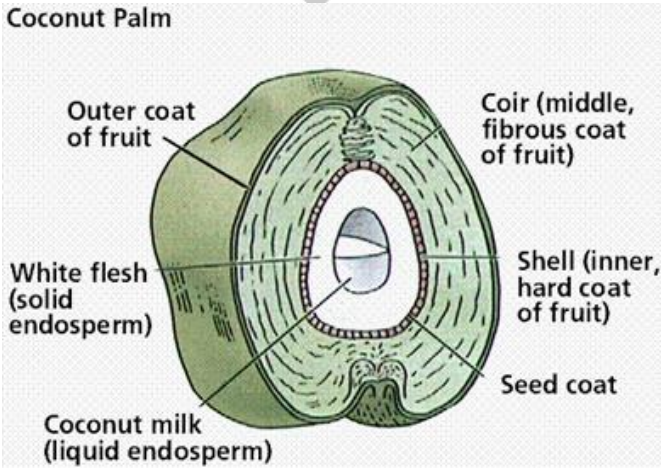


Fig 1:- Structure of Coconut Fruit

II. MATERIAL AND METHOD

The major components of the developed coconut de-shelling machine shown in Figure 6.1 are frame, Cross cutter, conveying unit, driven and driver pulleys, rubber belt and motor and bearing housing. The frame is the main supporting structure upon which other components of this machine were mounted. The frame is a welded structure construction from 50x50x5 mm angle iron with dimensions of 650 mm length, 740 mm width and 1000 mm height. The de-shelling unit comprises of three shaft one is intermediate shaft 3or shaft 2 and other is cutter shaft 1. Intermediate shaft is a mild steel rod of 25mm diameter and 610 mm long and also mounted cutter shaft 25 mm diameter and 250 mm long supported at both ends by ball bearing. A 1 H.P (0.745 KW) induction motor, which is attached to the base of stand transmits power from motor shaft to intermediate shaft No. 3 through single groove pulley P1 (4.5") and pulley P2 (10") which are attached to motor shaft, intermediate shaft respectively and is connected by V-belt drive 680 mm. Motor shaft is rotated at 1440 RPM and intermediate shaft is rotated at 643 RPM. In intermediate shaft located the pulley P3 (2.5") which transmitted the power to shaft 2 at which rotate speed 388 RPM, Since coconut shell contain low strength, hence it requires low speed for cutting, The de-shelling rod attached to frame structure which is near to disc cutter. The coconut eye of the coconut fruit and locate it to the de-shelling rod, without touching the disc cutter and rotate smoothly to de-shelled the coconut.

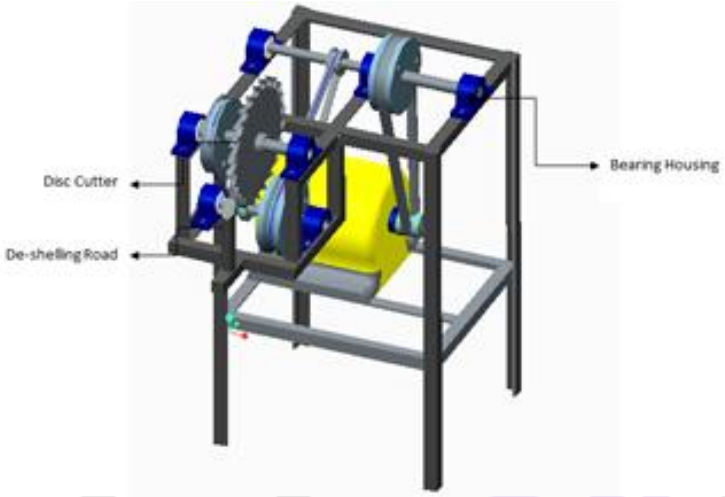


Fig. 2 Cad Modal of the developed coconut de-shelling machine

III. DESIGN ANALYSIS OF MACHINE

A. *Design consideration:*

The coconut de-shelling machine was developed based on the following consideration:

1. The availability of materials locally to reduce cost of production and maintenance of the machine.
2. The de-shelling rod was introduced in between and near to disc cutter without touching the disc cutter and smoothly conducts the operation.
3. It is desired that the coconut fruits should be well de-shelled without nut breakage and also that cobra extracted should not be distorted, thus pulleys were carefully designed/selected to meet the required synchronized speeds of the de-shelling units.

B. *Determination shaft diameter:*

The diameter, *d* for each of the two shaft of this machine was determine using maximum stress relation given by [11] as;

$$\tau_{max} = \frac{16 \times 10^3}{\pi D^3}\sqrt{(Kt \times T)^2 + (Kb + M)^2} \quad \ldots(1)$$

Where :

τ= Allowable shear stress for steel shaft with provision for key ways = 88.8 N/mm^2

T = Torque transmitted by the shaft , N-mm

M = Maximum bending moment on the shaft, N-mm

K_t = Combined shock and fatigue factor for twisting.

K_b = Combined shock and fatigue for bending.

Shaft material consider as SAE 1030 steel Sut = Ultimate tensile strength=527 MPa and Syt = Yield strength in compression =296 Mpa Therefore , design shear stress (τ_{max}) should be τ_{max}< 0.30 Syt or τ_{max}< 0.18 Sut. τ_{max} < 0.30 x 296 = 88.8 Mpa or τ_{max}<0.18 x 527 =94.86 Mpa. Selecting minimum value i.e. τ_{max} = 88.8 Mpa.

Now, because there is a keyway at critical section τ_{max} should be reduced by 25 precent. Therefore τ_{max}=0.75 x 88.8 = 66.6 Mpa.

C. *Electric motor Specifications:*

A three phase 1hp electric motor with a rated speed of 1440 rpm was chosen for the de-shelling machine. It is because it is the range of electric motor available in the market with a specification close to the estimated minimum power requirement of 0.745 kW and by virtue of the coconut mass and density the high shelling speed like 190 rpm is needed to give the coconut adequate momentum to let the coconut be shelled by impaction.

D. *Determination of shaft Load and Reactions:*

- Figure 3 and 4 shows a schematic representation of the cutter shaft in the vertical and horizontal planes respectively.

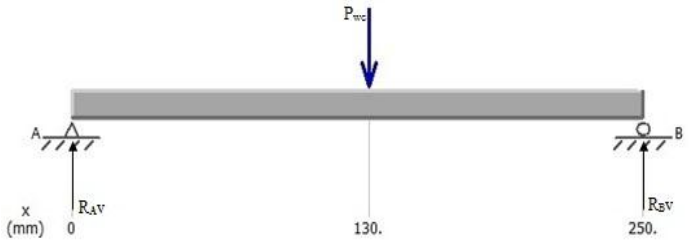


Fig. 3. Cutter shaft loading in the vertical plane

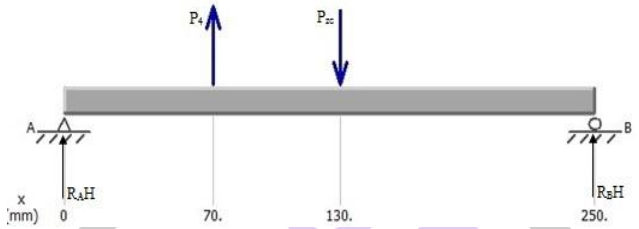


Fig. 4. Cutter shaft loading in the horizontal plane

With reference to figure 3, the summation of forces in the vertical direction is given as

$$\sum Fr \uparrow = R_A V + R_B V - P_{wc} = 0 \quad \ldots(2)$$

With reference to figure 4, the summation of forces on the horizontal direction is given as

$$\sum Fr \uparrow = R_A H + R_B H + P_4 H - P_{ZC} = 0 \quad \ldots(3)$$

Using the Shelled strength of coconut to be 230N/m,the valves obtained using equations are $R_A V$ = 22.32 N, $R_B V$ = 24.19 N, $R_B H$ = 142.5 N and $R_A H$ = -104.5 N.

Therefore, the maximum bending moment on this shaft is 101668 N-mm. The de-shelling of the coconut fruit by the driven shaft is partially sudden with minor shock at the start of each operation and gradual as the process progresses, hence, *Kb* =1.5 and *Kt* =1.5 . Hence, the minimum diameter of this shaft was determined as 22.14 mm using Equation (1). Thus, a standard solid mild steel shaft of 25mm in diameter was selected for this machine's driven cutter shaft.

- Figure 7 and 8 shows a schematic representation of the intermediate shaft in the vertical and horizontal planes respectively.

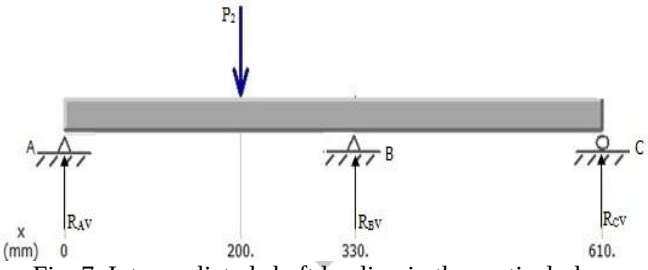


Fig. 7. Intermediated shaft loading in the vertical plane

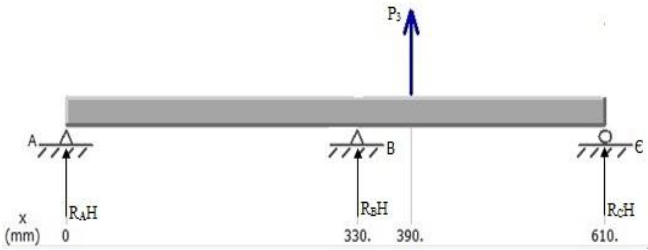


Fig. 8. Intermediated shaft loading in the horizontal plane

With reference to figure 7,the summation of forces in the vertical direction is given as

$$\sum Fr \uparrow = R_A V + R_B V + R_c V - P_2 V = 0 \quad \ldots(4)$$

With reference to figure 8, the summation of forces on the horizontal direction is given as

$$\sum Fr \uparrow = R_A H + R_B H + R_c H + P_3 H = 0 \quad \ldots(5)$$

Using the Shelled strength of coconut to be 230N/m,the valves obtained using equations are R_AV = 360.41 N, R_BV = -224 N and R_cV=232 N , R_BH = 1256 N and R_AH = --1066 N and R_cH= 1012N.

Thus, the maximum bending moment on the conveyor shaft is 251877.89Nmm. The twisting and conveying of coconut fruit by the auger during as the fruit is been de-shelled is sudden with minor shocks, hence, *Kb* = 2 and *Kt* =1.5 [11]. The minimum diameter of this intermediated shaft was determined from Equation (8) as 23.13mm. Therefore, a standard 25mm diameter solid mild steel shaft was selected for the intermediated shaft.

IV. EXPLICIT DYNAMICS ANALYSIS BETWEEN CUTTER AND COCONUT SHELL

In Cross cutter, each tooth on a tool removes part of the stock in the form of a chip. The basic interface between tool and work part is shown in fig.1. This shows only a few teeth of a peripheral cross cutter:

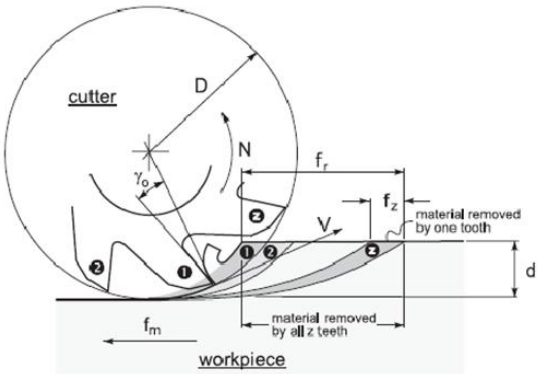


Figure 3. Cutting Operation

Cutting velocity V is the peripheral speed of the cutter is defined by V = πDN, where D is the cutter outer diameter and N is the rotational speed of the cutter. As in the case of turning, cutting speed V is first calculated or selected from appropriate reference sources and then the rotational speed of the cutter N, which is used to adjust machine controls, is calculated. Cutting speeds are usually in the range of 0.1~4 m/s, lower for difficult-to-cut materials and for rough cuts.

- Feed per tooth, fz: the basic parameter in cutter equivalent to the feed in turning. Feed per tooth is selected with regard to the surface finish and dimensional accuracy required. Feeds per tooth are in the range of 0.05~0.5 mm/tooth, lower feeds are for finishing cuts.
- Feed per revolution, fr: it determines the amount of material cut per one full revolution of the cross cutter. Feed per revolution is calculated as
- f r = fzz z=being the number of the cutter's teeth;
- Feed per minute, fm: Feed per minute is calculated taking into account the rotational speed N and number of the cutter's teeth z,
- f m = fzzN = frN Feed per minute is used to adjust the feed change pulley.

V. FINITE ELEMENT ANALYSIS OF FACE TCT SAW BLADE CROSS CUTTER

In order to perform a finite element analysis, it is necessary to determine the forces acting on the cutter. From the given conditions the load (Wt) acting on a single tooth may be represented as:

$$W_1 = \frac{60000H}{\pi D_n} \quad \ldots(6)$$

where H is the power, in kW, n is the speed, in rpm, and D is the diameter of the cutter. The stress calculation at the tip of the tooth of the cutter is estimated based on the concept of gear tooth stresses. The stress at each speed is determined by

$$\sigma = \frac{6W_1 l}{Ft^2} \quad \ldots(7)$$

The maximum allowable stress at the tip of the cutter is determined as:

$$\sigma_{allowable} = \frac{S_1 K_L}{K_T K_R} \quad \ldots(8)$$

VI. ANSYS 14 & ANSYS14-WORKBENCH SOFTWARE APPROACH & RESULT

A. Material properties

High Speed steel is the material chosen for the Cross cutter and the properties are tabulated in

Tensile strength (Mpa)	900/1000
Young Modulus E (Mpa)	200000/210000
Compressive Strength(Mpa)	3000/3200
Ductility(compression) %	8/10
Thermal Expansion /0C	11.5/11.8
Thermal Conductivity(W/m k)	17/18
Specific Heat (J/Kg K)	500

Table 1 Material Properties

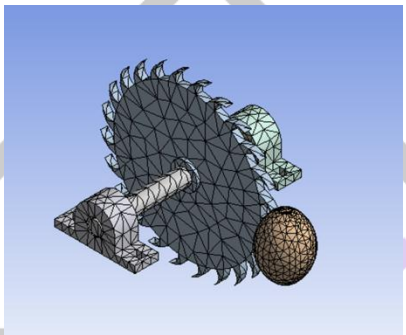
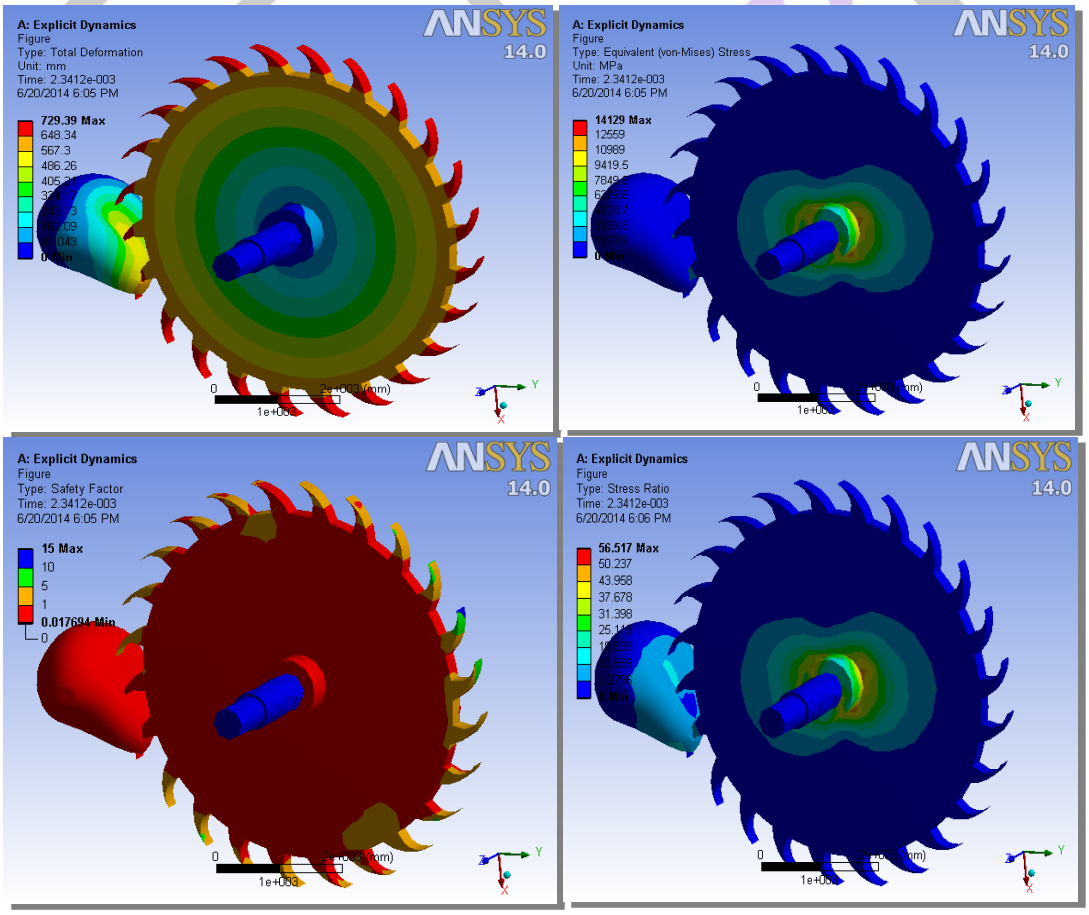


Figure 4 Meshing of triangular element



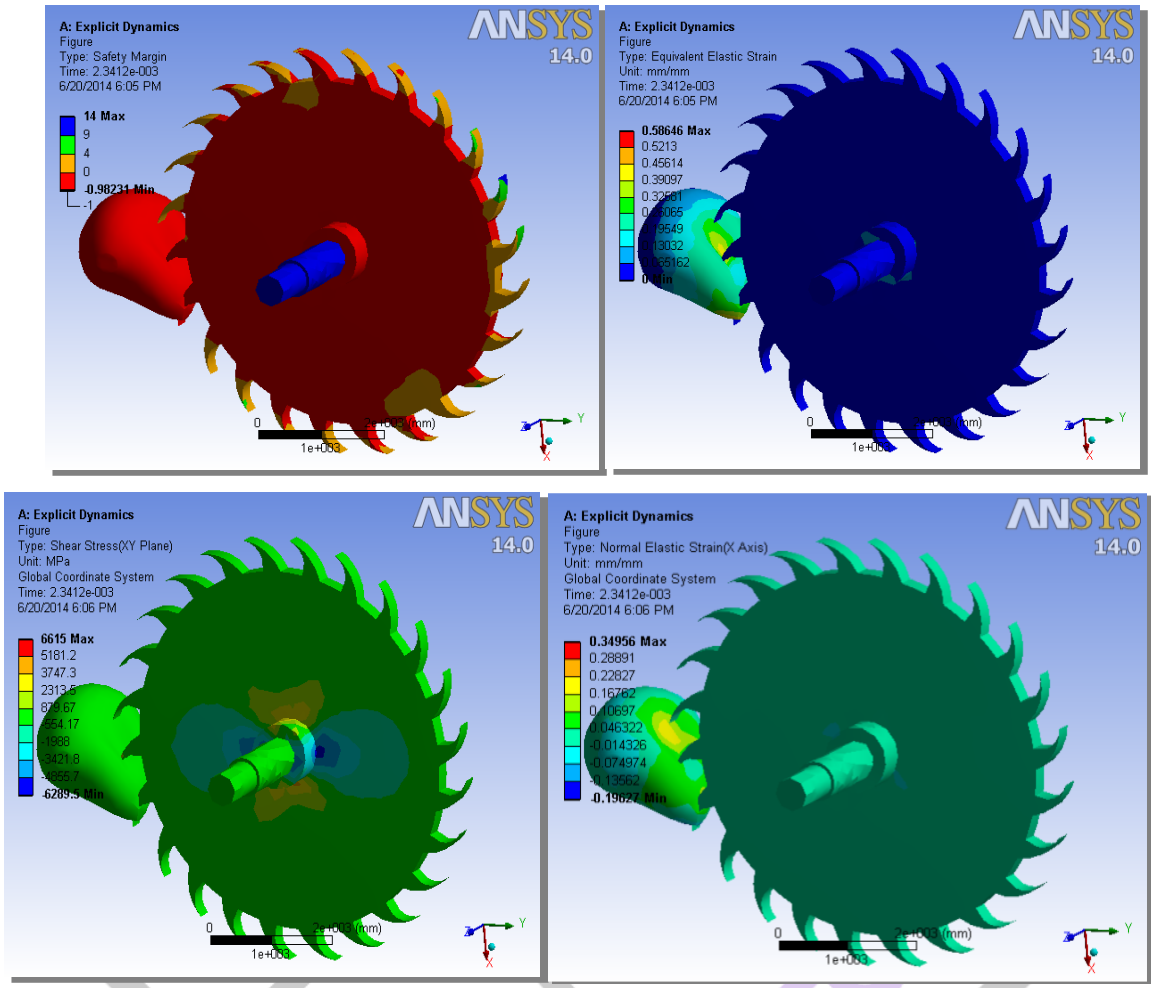


Figure 5 Software FEM Simulation Result of Ansys 14 Cutter and coconut Shell

VII. WORKING PRINCIPLE OF THE DESELLING MACHINE

When the motor is given A.C power supply, then the output from motor is the mechanical power in the form of rotation of shaft. The de-shelling unit comprises of three shaft one is intermediate shaft(3) and shaft(2) and other is cutter shaft. . This motion is transferred to intermediated shaft which is attached the pulley and transmitted the power to shaft 2 for the speed reduction power is transmitted to the cutter shaft. Cutter is rotated at the clockwise direction which is near to knife rod. Then hold the coconut in hand and find the coconut eye of the coconut fruit and locate it to the de-shelling rod, without touching the disc cutter. Hold firmly the coconut fruit and slowly tilt it to the disc cutter until the de-shelling process started. Gently rotate the coconut fruit so the de-shelling process continues, until all the shell are cleared, and leave alone the de-shelled coconut fruit.

VIII. TEST AND EVALUATION PROCEDURE:

In order to actualize the aims of this project, the deshelling capacity and efficiency of the coconut deshelling machine were evaluated using ten experimental runs after its fabrication. Each test involved operating the machine by a different operator at three different speed and recording of the total number of fruits, N_T each of the twenty operators deshelled in a given time. The deshelling process as per each operator was timed with a stop-watch. Also determined in each test are number of well deshelled nuts without distortion on the length of the Shell extract, N_{df} and number of well deshelled nuts with distorted husk extract, Ndw. Thereafter, the efficiency, η and capacity, C of the machine were computed in each case using the following relations:

$$\eta(\%) = \frac{N_{df}}{N_T} \times 100 \qquad \ldots(9)$$

$$C(Coconut/h) = \frac{N_T}{t} \qquad \ldots(10)$$

Machine Speed												
24 rpm					32 rpm				45 rpm			
Sr.No.	Total No. of fruits	No. of fruits shelled	No. of fruits damage	Time (Second)	Total No. of fruits	No. of fruits shelled	No. of fruits damage	Time (Second)	Total No. of fruits	No. of fruits shelled	No. of fruits damage	Time (Second)
1	17	12	5	423.45	15	12	3	352.34	16	14	2	292.58
2	16	11	5	456.56	17	13	4	372.45	15	13	2	282.68
3	15	9	6	478.54	16	13	3	382.56	17	16	1	308.78
4	17	10	7	437.87	15	14	1	325.67	16	15	1	297.56
5	16	11	5	467.98	16	12	4	345.56	15	13	2	272.78
6	15	11	4	432.92	17	14	3	392.66	17	15	2	321.89

Table 2 Result of the performance tests at various speed

Machine Speed						
24 rpm			32 rpm		45 rpm	
Sr. No.	Deshelling Efficiency (%)	Capacity (Coconut/h)	Deshelling Efficiency (%)	Capacity (Coconut/h)	Deshelling Efficiency (%)	Capacity (Coconut/h)
1	70.58	144	80.00	153	87.50	196
2	68.75	126	76.00	164	86.66	191
3	58.82	112	81.25	150	94.11	198
4	60.00	139	93.33	165	93.75	193
5	68.75	124	75.00	166	86.66	197
6	73.33	123	82.35	155	88.23	190
Average	**66.70**	**128**	**81.32**	**158**	**90.01**	**195**

Table 3 Result of the performance test

IX. Result and Discussion

Table shows mean values of machine performaces at various speed.the shelling efficiency of the machine increased with the increase the speed .The results of the performance test (Table 3) show that the machine performed above 86% efficiency the highest shelling percentage of 90 % was obtained at the 45 rpm shelling speed. At level of percentage fruits damage decreases, when the speed was increased from 32 to 45 rpm. Lowest percentage fruit damage of 10 % was obtained at thhe speed of 45 rpm shelling speed. It is also obvious from this table that the capacity of the developed machine ranges between 191 and 197 nuts per hour depending on the operator, however, on average an operator deshelled 195 nuts per hour with this machine. This machine was fabricated with standard and locally sourced materials and its estimated cost Twenty five thousand six hundred (Rs.2,4900.00) thus, the machine is affordable to small scale farmers and maintainable.

X. Conclusion

A power operated coconut deshelling machine was designed and constructed and tested . Coconut deshelling machine which deshelled coconuts without nut breakage and machine is easy to operate and perform .shelling efficiency of te machine increase with the increase speed under consideration and percentage damage decreased with the increase the speed.With an average deshelling efficiency and capacity of 90% and 195 nuts per hour. Introduction of this machine eliminates the problem of extracted shell length distortion associated with the use of some risks involved in the use of cut and hold the coconut de-shelling

References

[1] Foale, M.A. The Coconut Palm. In: Chopra, V.L. and Peter K.V. edited Handbook of Industrial Crops. Haworth Press, New York, 2005.

[2] APCC. Coconut Food Process – Coconut Processing Technology. Information Document. Arancon, Jr, R.N., ed. Asian and Pacific Coconut Community. Jakarta, Indonesia,1996.

[3] Brandis, C. and Glaser, F. (1973). Specification for separations of kernels from coconuts. Philippine patent No: 9865.

[4] Madhavan, K. (1985). Design and development of copra moisture meter. J. Planta. Crops. 16: 113-116.

[5] Tilledaratne, H.A. Processing of Coconut Products inSri Lanka. Asian and Pacific Coconut Informantion Document. Arancon, Jr., R.N., ed. Asian and Pacific Coconut Community. Jakarta, Indonesia.

[6] Thampan, P.K. Handbook on Coconut Palm. Oxford & IBH Publishing Co., New Delhi. 1996.

[7] Ohler, J.G.. Coconut, Tree of Life. FAO Plant Production and Protection Paper 57. FAO, Rome, Italy, 1984.

[8] Rethinam, P. (2003). Prospects for the coconut industry. J. Planta. Crops. 31(1): 1-7.

[9] Rey, H.O. (1955). Device for removing meat from coconut. Philippine Patent No. 793.

[10] Thampan, P.K. (1981). Hand Book of Coconut Palm, Oxford and IBH Co. Pvt. Ltd., New Delhi. Pp. 311.

[11] Shiwalkar B.D., Design Data for Machine Elements, Dattatraya Publications, Nagpur (India).

[12] Sharma, P.C. and Aggarwal, D.K. Machine Design. S.K. Kataria and Sons, Nai Sarak Dechi. Katra 2006.