Penerbit Akademia Baru

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 4, No.1. Pages 9-19, 2015

Design and Development of a Coconut De-Husking Machine (Machine Component Design)

H. Azmi [*,a], *A. B. Sanuddin*[b], *M. Z. Zakimi*[c], *M. S. Jamali*[d], *H. Radhwan*[e], *A. N. M. Khalil*[f], *A. N. A. Akmal*[g] *and A. F. Annuar*[h]

School of Manufacturing Engineering, Universiti Malaysia Perlis, Kampus Tetap Ulu Pauh, Jalan Arau-Changlun, 02600 Arau, Perlis, Malaysia

[a,*]*azmiharun@unimap.edu.my*, [b]*asmawi@unimap.edu.my*, [c]*zakimizakaria@unimap.edu.my*, [d]*jamali@unimap.edu.my*, [e]*radhwan@unimap.edu.my*, [f]*nabilkhalil@unimap.edu.my*, [g]*aiman_akmal1988@yahoo.com*, [h]*faizalannuar@unimap.edu.my*

Abstract – *A coconut de-husking machine comprising of two rollers with spikes, chain drives, presser, clearers, shafts and belting system was developed for small-scale production in rural areas. Performance test analysis showed that the machine de-husks coconut fruits without any nut breakage or distortion of the extracted fibre length. The objective of this project is to improve the efficiency and productivity in producing coconut fruits without husks by using the best selection of mechanical mechanisms with minimum costs. One electric motor (2hp, 1500rpm) is used to drive two shafts using a combination of pulley and belt. In between the motor and the shafts, one box of worm gears is used to reduce the rotation speed from 1500rpm to 21rpm (ratio 70:1). Two metal cylinders with a series of spikes are used to remove the husks from the coconut fruit and are attached to the rotary shaft. The machine's average de-husking efficiency and capacity are 90.42% and 222 coconuts per hour, respectively. In addition, the development of the machine is also a solution to the constraint of space, whereby a compact-size machine is more suitable for small and medium enterprises (SME's). Plus, it operates with lesser noise, which also contributes to a more viable operating condition for the environment.* ***Copyright © 2015 Penerbit Akademia Baru - All rights reserved.***

Keywords: Mechanical mechanism, machine efficiency, machine capacities

1.0 INTRODUCTION

The price hike of coconuts in the market has made it beneficial for cultivators to have a reliable yet cost efficient equipment to process coconuts either for personal use or even retailing in small and medium enterprises (SME's). In the past, machining of coconuts was done manually or semi-automated using separate machines that individually accommodate the process of de-husking, grating and extracting. Nowadays, with the development of modern technology, which had been absorbed into the manufacturing sector to improve capabilities and production capacity, it is possible to engineer a machine with mechanisms that can serve multiple tasks. This will provide something new in the manufacturing sector such that the production of goods can be accomplished swiftly and with quality. Current practices in the market today have shown that in order to produce coconut milk, several

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 4, No.1. Pages 9-19, 2015

individual machines are being used. Coconuts have to undergo a husking process to remove the husk from the coconut; the husk is the outermost covering of the coconut fruit that provides protection for the endocarp (coconut shell) surrounding the seed. The next process is the shell removing process that uses a coconut grater machine to acquire the kernel by separating it from the shell and finally, a coconut extracting machine is used to obtain the coconut milk. However, in this project, the machine designs are only focused on improving the efficiency of the de-husking process i.e., producing clean coconut fruits without husk.

2.0 MACHINE DESCRIPTION

The major components of the proposed coconut de-husking machine are shown in Figure 1 – Figure 6 and consist of a machine frame, drive mechanism, holding mechanism and roller type blade mechanism.

The frame is the main supporting structure upon which the other components of this machine are mounted on. The frame is a welded structure, constructed from 50x50x5mm angle iron with dimensions of 933mm in length, 515mm width and 845.1mm height. The drive mechanism comprises of a motor, worm reduction gears with a belt drive system and a rotating shaft with chain drive system. A single phase 2hp induction motor with speed of 1500rpm is used to drive the components. The machine also uses a gearbox with a 70:1 ratio and connected to a shaft, which is a long rotating cylinder that transmits power from one place to another. For the holding mechanism, bearing blocks function by reducing vibrations or wobbling caused during shaft rotation at longer lengths due to heavy loads. Therefore, to reduce machine vibration, two bearing blocks were used between the reduction gear box and the roller blades while another two is placed at the right end of the roller shaft. The roller type mechanism can be explained as two rollers, each having an elongated configuration, are disposed by spacing the pieces apart, substantially parallel to one another with respect to the base and in a readily accessible configuration. Each roller is formed by welding thirty-two metal spikes (2 x 20 x 5mm) on a 115mm diameter mild steel pipe, mounted on a roller shaft. Each roller shaft is made from a mild steel rod of 40mm diameter, with 890mm length for the main shaft and 644.87mm length for the parallel one, supported at both ends by ball bearings with a sprocket mounted at the left end. The clearer is constructed by cutting u-notches on one edge of a mild steel plate of 2mm thickness. The clearers were fastened onto the frame above the rollers. The developed coconut de-husking machine is very easy to operate and requires only one operator. When the switch is turned on, the rollers with spikes rotate in opposite directions towards the centre, causing both gripping and tearing of the husk of the coconut fruit placed in between the rollers. The system was designed for an efficient de-husking process where the nuts will be de-husked without any break off and thus, ensures a proper discharging of the de-husked nuts.

2.1 Machine Frame

The frame is the main supporting structure upon which other components of this machine are mounted on. The frame is a welded structure constructed from 50x50x5mm mild steel angle iron with dimensions of 933mm in length, 515mm width and 845.1mm height. The steel are rigidly fixed onto the frame so that the vibration and weight are uniformly distributed to the support frame below. The geometric structure of the main frame is designed to give a good shape and also better stability to the entire structure.

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 4, No.1. Pages 9-19, 2015

Figure 1: Main frame

2.2 Drive Mechanism

The drive mechanism plays a vital role since the complete operation is mechanically oriented. The overall drive mechanism is shown in the figure below:

- Motor
- Worm reduction gears and belt drive system
- Rotating shaft and chain drive system

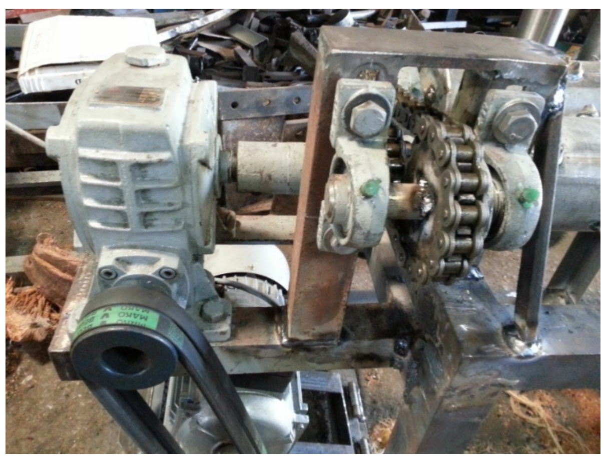

Figure 2: Main drive mechanism components

2.2.1 Motor

A single phase induction motor is used to drive the mechanism. This motor is generally used in various kinds of industrial drives. The motor acts as the driver wheel connected through a belting system directly to the gear box that acts as the driven wheel. The rotation speed of the output shaft of the motor is 1500rpm. The motor's output shaft is connected directly to the gear box through a belting system that will completely reduce the transmission losses. The motor bed is rigidly fixed onto the frame of the machine. Caution was taken such that the

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 4, No.1. Pages 9-19, 2015

motor shaft and the gear box input shaft were attached in a parallel line to minimize vibrations and completely utilize the power of the motor.

2.2.2 Reduction Gearbox

The worm gears are widely used for transmitting power of high velocity ratios. The gear box used in this machine has a speed ratio of 70:1. This reduces the speed from 1500rpm to 21 rpm. The mechanism used in the gear box is the worm gear mechanism. The gear box is coupled with the motor using a pulley connected to a v-belt. The output of the gear box is coupled to a long shaft that protrudes out from the centre of one of the rollers for the attachment to the holding mechanism. It consists of the worm and the worm wheel. The worm is, in essence, a cylinder having threads of the same shape as that of an involute rack. The worm is generally made of mild steel while the gear or wheel is made of bronze or cast iron for light service.

2.2.3 Rotating Shaft (Main Shaft)

A shaft is a long rotating cylinder that transmits power from one place to another. The power is delivered to the shaft by tangential forces and the resultant torque on one end of the shaft is connected to the output of the gear box, meanwhile, the other end is connected to the main roller and also acts as a support to the rolling system.

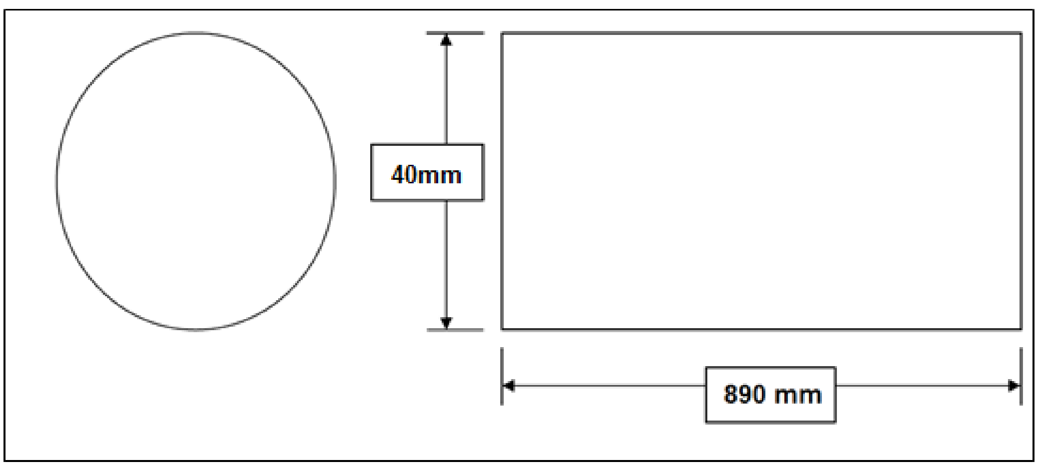

Figure 3: Main shaft specification

2.3 Holding mechanism

Bearing blocks are used to reduce vibrations or wobbling during the rotation of a long shaft with heavy loads. Therefore, to mitigate the vibrations of the machine, two bearing blocks are used between the reduction gear box and the roller blade while another two are placed at the right end of the roller shaft. Bearing blocks are also known as plummer blocks. Its construction is simple such that a bearing is concealed within a metal block and the metal block is rigidly fixed onto the frame of the machine. The bearing block is carefully centred so that the axis of the shaft and the bearing block are parallel to each other to reduce vibrations and wobbling during operation.

2.4 Roller type blade mechanism

The roller type mechanism is such that two rollers, each having an elongated configuration is disposed and spaced apart, substantially parallel to one another with respect to the base and in a readily accessible position. A drive means is also provided in support of the base and with direct driving engagement with the rollers. Interconnection of the rollers to the drive means is such that the rollers are forced to rotate in an opposite direction relative to the other and in a preferred embodiment to be described in greater detail hereinafter, at relatively different speeds. Collectively, the rollers define two outer exposed surfaces, which may be considered as the upper portions of the roller. In such orientation, the rollers rotate in a direction towards the centre such that a coconut, placed thereon, will be forced into the spacing between the rollers.

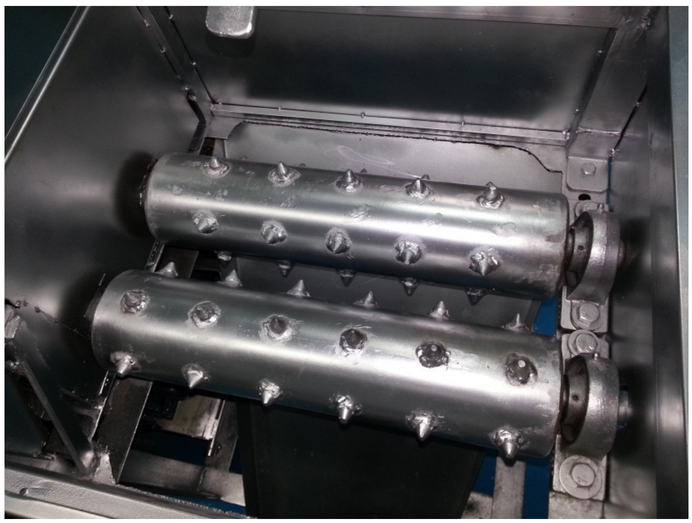

Figure 4: Roller type blade mechanism

2.4.1 Peeling Spikes

The spikes that are attached to the rotating shafts play a key role in peeling the coconut. It acts as the tool for the machine. The existence of penetrating means, formed on each roller blades in the form of multiple spikes, helps in delivering effective peeling of the husk from the coconut. The spikes are sharpened and spaced from one another at substantially an equal distance to each other, whereby the array of spikes are positioned to facilitate the penetration, gripping and tearing of the coconut husk. However, the sharpened spikes are interspersed with the blunt spikes. The sharp spikes grip the coconut husk by penetrating into it after the coconut is fed into the machine while the blunt spikes tear off the husks. In other words, if the coconut is exposed to a larger surface area consisting of sharpened spikes, it will increase the tendency for the nut to break-off because of larger penetrating forces. Thus, this design arrangement is suitable for the purpose of de-husking a coconut with optimum efficiency.

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 4, No.1. Pages 9-19, 2015

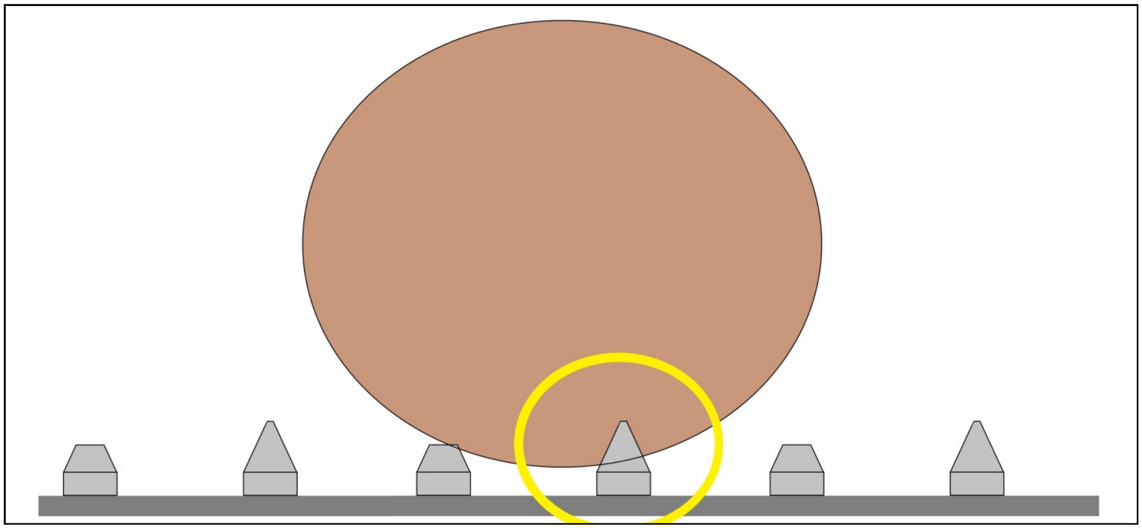

Figure 5: Action of the spike on a coconut

The slower rotations of the blades, once penetrated, provide a tearing action against the husk. It is apparent that the rollers should remain clear for efficient and effective engagement with the next coconut.

3.0 METHODOLOGY

3.1 Design Concept Generation

Design concept generation refers to the actual conceptual design where the design concept is an approximate description of the technology, working principles and form of the product. It has a detailed description on how the product will satisfy and meet customer requirements. Existing design constraints may even be solved by having a good development in the design concept.

For this project, many alternative concepts have been generated. The various generated concepts were then individually evaluated to find the most appropriate concept for the product. The concepts that gave the most advantages were considered as the best concept and awaits further evaluation. The product sketch for the chosen concept was further drafted.

Design concept generation is usually expressed in the form of sketches or rough 3-D models and often accompanied by a brief textual description for the overall design concepts. For this semi-automatic coconut machine, four concepts were proposed, which are concept A to concept D. As such, the concepts need to be evaluated (scoring and screening) in order to find the final concept design of the semi-auto coconut machine.

3.2 Design Calculation

A single phase motor with 2hp, speed of 1500rpm and 230v is used. Power will be transferred from the motor through several power transmission components designed to rotate the de-husking roller. Below is the calculation for the mechanisms showing all the calculation for the theoretical design.

$$\tau = \frac{9.55P}{n}$$

$$\tau = \frac{9.55\ (1500)}{1500}$$

$$\tau = \ 9.5\ Nm$$

where:

$\tau = \ torque\ (Nm), P = power\ (kW), n = speed\ (rpm)$

3.2.1 Selection of pulleys and determination of speed and belt tensions

The machine requires a belt drive that consists of two V-belts in parallel and on grooved pulleys of the same size for the drive is designed to maintain a constant speed. A standard pulley with angle of groove, $\beta = 30^{\circ}$ was selected due to simplicity in design, availability, economic in maintenance, absence of the end thrust on the bearings and suitability for heavy loads; which are some of the features for this type of pulley. Thus, the centre distance, C between the adjacent pulleys was computed as $114.3mm$ using Equation (2) [6]

$$C = \frac{1.5D}{(VR)^{\frac{1}{3}}} \tag{2}$$

where; VR is the speed ratio of this drive and D is the diameter of the driven pulley. As both pulleys have the same diameter, the velocity ratio, VR is equal to 1. Thus, the length of the belt, l was computed as $468mm$ from the expression given by [7] using Equation (3) as follows:

$$l = 2c + 1.57(D_2 + D_1) + \frac{(D_2 - D_1)}{4C} \tag{3}$$

The cross sectional area, a of the belt is shown in Figure 6.

Cross sectional area, a

$$a = (16 \times 9.37) - 2\left(\frac{1}{2} \times 3.5 \times 9.37\right) = 117.2 \times 10^{-6} m^2 \tag{4}$$

and mass of the belt per unit length, m

$$m = a \times l \times \rho = 0.07kg/m \tag{5}$$

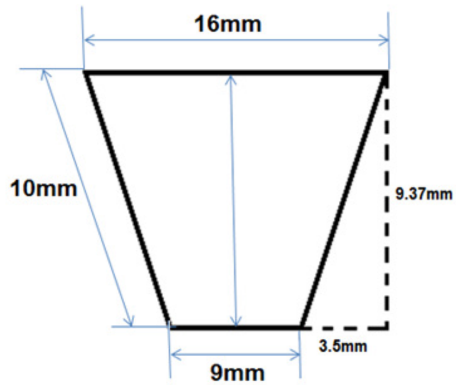

Figure 6: Dimension of cross sectional area, (a) of belt

Based on [13], a V-belt with density, mass per unit length, maximum safe stress and cross sectional area of 1200kg/m^3, 0.07kg/m, 7Mpa and 117.2 × 10^{-6}m^2, respectively, was selected for the drive. Consequently, the angle of lap, θ of the belt on the pulley and belt speed, v were used in the fabrication of the machine and determined as $180^{\circ}$and 5.98 m/s using Equations (6) and (7) respectively in accordance with [6].

Angle of lap of the drive, θ

$$\theta = 180^{\circ} - \left[\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right)\right] = 180^{\circ}$$

Velocity of the belt, v with motor speed N is $1500rpm$ can be calculated as

$$v = \frac{\pi DN}{60} = 5.98\text{m/s}$$

In addition, maximum, centrifugal, tight side and slack side tensions of the belt were sequentially computed as $820.4N$, $2.5N$, $817.9N$ and $190.21N$, respectively from the following relations using [6]:

Since the pulleys are of the same size, therefore, the angle of contact, $\theta = 180^{\circ}$and $\beta = 15^{\circ}$ and the coefficient of friction between the pulley and belt, $\mu = 0.12$. This gives the tension in the slack side of the belt, $T_2 = 190.21N$

4.0 RESULTS AND DISCUSSION

In this section, all the results of the calculations are shown.

4.1 Design Calculation

- Torque of motor =9.5 Nm

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 4, No.1. Pages 9-19, 2015

4.1.1 Selection of pulleys and determination of their speeds and belt tensions

- Maximum tension in the belt, T = $820.4N$
- Centrifugal tension, T_c = $2.5N$
- Tension in the tight side of the belt, T_1 = $817.9N$
- Tension in the slack side of the belt, T_2 = $190.21N$

4.1.2 Determination of shaft diameters

- Minimum diameter of the shaft, d = $40mm$

4.1.3 Power Requirement

- Speed of the driving roller, v_d = $0.11m/s$
- Power required to de-husk one coconut, P = $444.4W$

4.1.4 Performance Evaluation Procedure

a) De-husking process

- Efficiency, η = 90.42%
- Capacity of coconut fruits, C = 222nuts/hour

Table 1: Results of the Performance Evaluation of the Coconut De-husking Machine

No.	Number of fruit de-husk	Number of successful de-husking	Number of unsuccessful de-husking	Time, t (second)	Efficiency, η (%)	Capacity, C (Fruits/h)
1	10	10	-	161.3	100	223
2	9	8	1	144.2	88.89	225
3	10	8	2	160.7	80	224
4	8	7	1	129.5	87.5	222
5	9	8	1	145.0	88.89	223
6	9	9	-	144.8	100	223
7	10	8	2	162.2	80	222
8	8	8	-	131.1	100	219
9	10	9	1	163.4	90	220
10	9	8	1	146.6	88.89	221
				Average	90.42	222

The major components of the developed coconut de-husking machine are the frame and the de-husking unit, which consists of the drive mechanism, the holding mechanism and the roller type blade mechanism. The frame is the main supporting structure upon which the other components of this machine were mounted on. The frame is a welded structure constructed from 50mmx50mmx5mm angle iron with dimensions of 933mm length, 515mm width and 845.1mm height. The de-husking unit comprises of two rollers, two roller shafts

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 4, No.1. Pages 9-19, 2015

and two sprockets. Each roller was formed by welding thirty-two metal spikes (2mm x 20mm x 5mm) on a 115mm diameter carbon steel (galvanized) pipe mounted on a roller shaft. Each roller shaft is a mild steel rod of 40mm diameter, with length of 890mm long (main shaft) and 644.87mm supported at both ends by ball bearings and a sprocket mounted at left ends. Joining at the left end of the driving roller shaft is the worm reduction gear that is connected to a 3inch diameter v-belt pulley connected directly to a single phase induction motor through a belting system. The clearer was constructed by cutting u-notches on one edge of a mild steel plate of 2mm thickness. The clearers were fastened on the frame below the rollers. The coconut de-husking machine is easy to operate and requires only one operator. When the power is switched on, through the drive mechanism, the rollers with spikes rotate in opposite directions towards the centre causing both gripping and tearing of the husk of a coconut fruit placed in between the rollers.

Based on theoretical calculations, a 2hp of motor with a speed of 1500 rpm will produce torque with a value of 9.5 Nm. As for the selection of pulleys and determination of their speeds and belt tensions, the amount of the maximum, centrifugal, tight side and slack side tensions of the belt were sequentially computed as $820.4N$, $2.5N$, $817.9N$and $190.21N$, respectively. In determining the shaft diameters for this machine's driving roller shaft, the minimum diameter of a standard solid mild steel shaft of $40mm$ was selected. For the power requirement, with the ratio of 70:1, the gearbox reduces the speed by 70 times. Thus, the speed output of the gearbox to the driving roller shaft is computed as $21rpm$. Thus, the speed of the driving roller is determined as $0.11m/s$ and finally the power required for the de-husking of one coconut using this machine was calculated as $444.4W$. Finally, in Table 1, testing of the coconut de-husking process had shown that the machine has the efficiency of 90.42% and is capable of processing 222nuts/hour.

5.0 CONCLUSION

In the development of the coconut de-husking machine, a mechanism which de-husks coconuts by switching out nut breakage and distortion of the extracted husks has been developed for small scaled farm holders in rural areas. The machine is easy to operate and performs with an average de-husking efficiency and capacity of 90.42% and 222 nuts per hour. The introduction of this machine will not only eliminate the problem of limited manpower but also increases the productivity of de-husking coconuts.

REFERENCES

[1] Standard Handbook of Machine Design (2nd Edition) Edition by: Shigley, J.E.; Mischke, C.R. © 1996 McGraw-Hill

[2] Standard Handbook of Machine Design (3rd Edition) Edition by: Shigley, Joseph E.; Mischke, Charles R.; Brown, Thomas H. Jr. © 2004. McGraw-Hill

[3] Illustrated Sourcebook of Mechanical Components. Edition by: Parmley, R.O. © 2000 McGraw-Hill

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 4, No.1. Pages 9-19, 2015

[4] Machine Device and Components Illustrator Sourcebook. Edition by: Parmley, Robert O. © 2005 McGraw-Hill

[5] Material Selection in Mechanical Design (3rd Edition). By: Ashby, Michael F. © 2005 Elsevier

[6] Sharma, P.C. and Aggarwal, D.K. Machine Design. S.K. Kataria and Sons, NaiSarakDechi. Katra books @yahoo.com, 2006.

[7] Khurmi, R.S. and Gupta, J.K..A Textbook of Machine Design (S.I. Units), Eurasia publishing House (PVT) Ltd., Ram Nagar, New Delhi-11005s, 2005

[8] IS 2494-1974. Indian Standards. Indian Standards Institute, New Delhi, 1974.

[9] Rajput, R.K. Strength of Materials, S. Chand & Company Ltd, Ram Nagar, New Delhi, 2006.

[10] PCA-CETC. Coconut Processing Technology Manual of Procedures. Coconut Extension Training Centre, Davao City, Philippines, 1997.