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Fabrication of a Portable Groundnut Decorticating Machine for Domestic Purpose

S. Swetha Lilly Zerusha, B. Druga Prasad

Abstract: ***Groundnut is one of the important oil seed crops cultivated in India. India ranks first in groundnut area under cultivation and is the second largest producer in the world with 101 lakh tones with productivity of 1863 kg per hectare in 2021-22. Groundnut cultivation in India is done by small-scale farmers and is the predominant dryland crop. In the beginning, the peanuts were separated from their shells by the workers and the output from this method was much less and could not satisfy the market demand as it was a very time-consuming process. It is a time-consuming and tedious operation. Hence, a portable groundnut decorticating machine is designed and fabricated which is small in size, easy to carry anywhere, and very easy to operate (at any time). This is more useful for domestic purposes such as households, hotels, and restaurants. This paper describes about the design and fabrication of various components of a hand-operated groundnut decorticator. Small farmers or businessmen can start businesses by investing less capital. The output is about 40-42 kg/hour, shelling time taken 1.5 min/kg, and with a high cost-benefit ratio of 1:28.6. The machine is also lightweight and easy to operate and maintain, the spare parts are also available locally. Maintenance is very easy, purchase cost is low, and highly economical in use. No electric power or diesel or skill knowledge is required. The shelling operation can be done by women at any time by accommodating in the house itself. Small and marginal farmers can use regular shelling for the sowing of groundnut. This is a convenient equipment and can be used at any time (during day time or night time) based on their convenience. Not much labor is required and one person can manage the decortication process it is cost effective also.***

Keywords: ***G roundnut decorticator; Fabrication; Evaluation; Economics***

I. INTRODUCTION

Groundnut (*Arachis hypogaea L.*) is a leguminous crop widely cultivated in the tropics and subtropics between 40°N and 40°S latitudes. Groundnut is the fourth most important source of edible oil and the third most important source of vegetable protein globally. Globally, Groundnut covers 327 lakh hectares with a production of 539 lakh tons with a productivity of 1648 kg per hectare (FAOSTAT, 2021).

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India ranks first in groundnut area under cultivation and is the second largest producer in the world with 101 lakh tons with productivity of 1863 kg per hectare in 2021- 22 (agricoop.nic.in). Groundnut is cultivated in one or more (kharif, rabi, and summer) seasons, but nearly 90% of acreage and production comes from Kharif crops (June-October). India is an agricultural country with 70 - 72% of the population being farmers (Fig.-1).

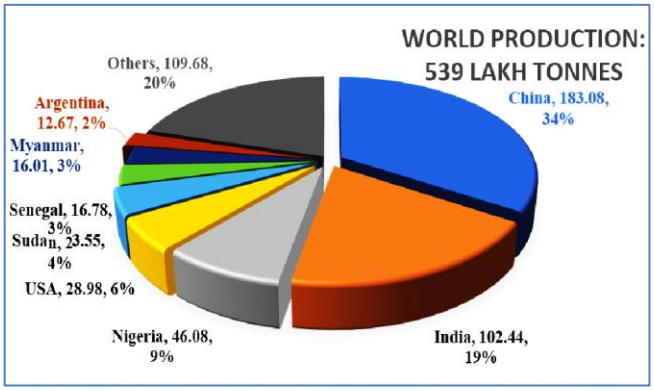

Fig.1: India's Position in Groundnut Production (with Shell) in the World During 2021-22 (Lakh Tons)

Shelling is a fundamental step in groundnut processing and is necessary as the activity allows the kernels and hull to be used as well as other post-harvesting technologies to take place such as oil extraction or hull briquetting [1]. Shelling can generally be done by hand or machines. Hand shelling is the process in which the pod is pressed between the thumb and first finger so that the kernel is released. It is the most predominantly used method in smallholder agriculture. While hand shelling keeps the rate of Kernel breakage low, it is labor-intensive and leads to "sore thumb syndrome" when large quantities are handled. So, optimizing and fabricating the performance of a hand-operated groundnut decorticator (HOD) is important so that the shelling efficiency is set at the maximum possible and kernel breakage set at the minimum possible. Manual shelling of groundnut is a time-consuming and tedious operation. The few existing power decorticators are imported and out of reach of the rural peasant farmers who are characterized by small holdings and low income.

II. LITERATURE REVIEW

A. Groundnut Decorticators

Manual groundnut decorticators are important equipment in the post-harvest processing of groundnut as the crop is a cash crop and income generator and also makes an important contribution to the human diet.

Most research in the area of groundnut production is concentrated only on the Agronomic aspects, while the processing ones have been neglected. This indicates that more research in groundnut should be directed toward post-harvest processing which includes stripping, decortications, storage of pods and kernels, and value addition. Decortication requires emphasis as it is the process in which a lot of time is lost and the production of kernels for seeds is compromised. A decorticator is a machine for stripping the husk off kernels in preparation for further processing, storage, or use as food [2]. The machine can dramatically reduce the labor costs associated with decortications, cleaning, and preparing groundnuts for further processing. Decorticators are classified as manual or motorized. Manual decorticators are powered by the human hand while motorized decorticators are powered by a motor or an engine. There are different types of decorticators used in the past which have more limitations. They are

i. Manually Operated Decorticators

Groundnut shelling has been done by hand (manually) and also simple machines have been devised for use in shelling for example in the North Eastern part of India, groundnut shelling was done using a bamboo crusher [3] studied groundnut decorticators and reported that using a bamboo crusher, 0.75Kg of groundnut pod can be shelled in one hour. While this Bamboo groundnut crusher ensures no “sore thumb syndrome", the efficiency is still low and cannot be used to make significant returns to farmers and also meet the timeliness requirements for the kernels. Using this kind of decorticator still makes groundnut production labor-intensive [4].

ii. Rubber Tire Decorticator

Rubber tire decorticator shells by rubbing action between a rubber tire and a wire mesh. The decorticator consists mainly of a mainframe, rubber tire, concave, and hopper. The rubber tire used is a worn-out rubber tire. Tire treads are cut to prevent excessive slip during operation. After shelling, the kernel and husk fall through the wire mesh into a collecting pan. Separation of the groundnuts from the kernel is done manually. [3] analyzed the factors that affect the shelling efficiency of a rubber tire decorticator.

iii. Revolving Stone Decorticator

This type of decorticator is mainly available in Thailand. It consists mainly of a revolving stone, wire mesh, hopper, and turn arm. In operation, groundnuts are loaded into the hopper [3]. The groundnuts flow into the clearance between the revolving stone and wire mesh, while the revolving stone is turning. The revolving stone then crushes the shells of the groundnuts against the wire mesh, releasing the kernels that fall through the wire mesh into a container. Separation of the shells from the kernels has to be done separately.

iv. CIAE Model Manual Groundnut Decorticator

The size of the decorticator is (250 mm X 500 mm X 630 mm) and weighs 5.7 Kg. [5] tested the performance of the CIAE model groundnut decorticator and found out that the capacity is about 35-40 Kg pods/hr with 1-2% broken. It was found that there is no adverse effect on germination of seeds by use of this equipment.

III. FABRICATION AND PERFORMANCE OF HAND-OPERATED GROUNDNUT DECORTICATOR (HOD)

A. Description of The Decorticators

i. Hand-Operated Groundnut Decorticator

The Manual-operated groundnut decorticator has the following parts

- Handle
- Hopper
- Foot Rest
- Sieve

All the required parts were collected to obtain good-quality equipment. All the parts were assembled in the workshop and the functional parts were tested whether they worked or not. Finally, the output of this process was the prototype of the manual hand-operated groundnut decorticator.

ii. Performance Test

To test the performance of the decorticators, seven demonstrations each replicated thrice in all four methods were given groundnut pods. Seven demonstration methods were provided with groundnut pods @ 5 kg/person to the manually operated method (MOM), @ 2 kg/person to hand-operated decorticator (HOD), @ 30 kg/person to diesel operated decorticator (DOD) and @ 30 kg/person to electric power operated decorticator (EPOD) in a randomized block design (RBD).

B. Important Formulae and Parametric Relations

i. Capacity of machine: C=W/t, kg/h where W= weight of groundnut pods fed in the machine, kg; and t= time taken for decortication

ii. Decorticating efficiency: percent = (1-Wu/w) x100 where Wu= weight of un-decorticated pods, kg; and w = total weight of pods fed in the machine, kg

iii. Breakage: percent = Wbx100 Wg+Wb where Wb= weight of broken kernels, kg; and Wg= weight of good kernels, kg.

C. Statistical Analysis

The data obtained in different methods was transformed using angular transformations wherever necessary and was statically analyzed using RBD (OPSTAT).

IV. RESULTS AND DISCSSION

A. Specifications of Hand Operated Decorticator (HOD)

By using this type of equipment i.e. HOD, we can extract the groundnut seeds from their shells. This is portable and can operate easily for domestic purposes. Domestic and small-scale farmers can gain lots of benefits from using this equipment. Adoption of this equipment showed an increase in productivity in terms of money by also selling deshelled kernels which helped in improving the benefit-cost ratio. Other benefits were drudgery reduction and time-saving, which may be better utilized in performing other household or farm activities.

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B. Working Principle

Manually hand-operated groundnut decorticator (HOD), can be used to shell groundnut pods and to separate kernels. It consists of a curved 'L' angle frame and four legs. A perforated sieve in a semi-circular shape is provided. Seven cast iron peg assemblies are fitted in an oscillating sector. It consists of an oscillating sector with a sieve bottom and a handle. Several hard cat iron-lined assemblies are fitted in the oscillating sector unit. The groundnut pods are shelled between the oscillating sector and the fixed perforated concave screen by rubbing action. The decorticated shells and kernels fall through the perforated concave sieve. The kernel and shells are collected at the bottom of the unit and separated manually. Clearance between the concave and oscillating sector is adjustable to suit the different varieties and concave sieves are also replaceable depending upon the pod size. Its overall dimensions are 500 X 500 X 250 mm. The capacity and efficiency of the unit are 40 kg/h and 74%, respectively.

C. Components and Specifications

Concave: A total of 37 rows of slots are provided. Two rows with 4 and 3 slots are provided in the concave sieve. This concave is mounted on a frame of iron angle with four legs as shown in Fig 2-10

Table- 1: Components of HOD

Name of Component	Length (mm)	Width (mm)	Thickness (mm)
Longitudinal angle iron	500	23	3
Legs of angle iron	500	23	3
Width-wise angle iron	250	23	3
Supporting sheets	240	500	2
T shape rod	650	40	5
Curved plate	240	210	5
Three equal m.s. Plates	210	50	3
Three iron rectangular plates with pegs	210	50	10
Handle unity	650	40	5
Shaft	240	-	50
Concave	780	240	2.5
Big slots	450	10	-
Small slots	450	10	-

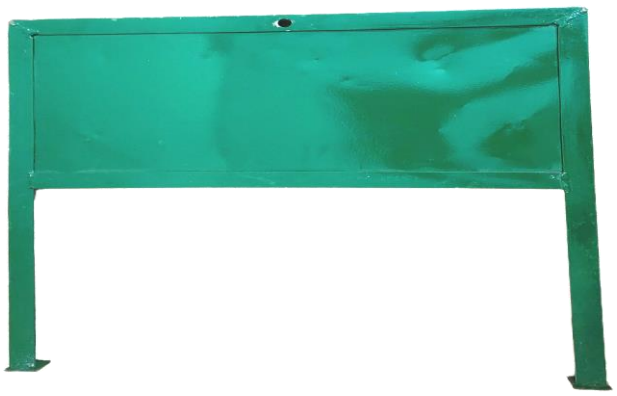

Fig- 2: Longitudinal Supporting Sheet

Fig- 3: Legs of Angle Iron with Connecting Rods

Fig- 4: Supporting Sheets with Angle Frame and Four Legs

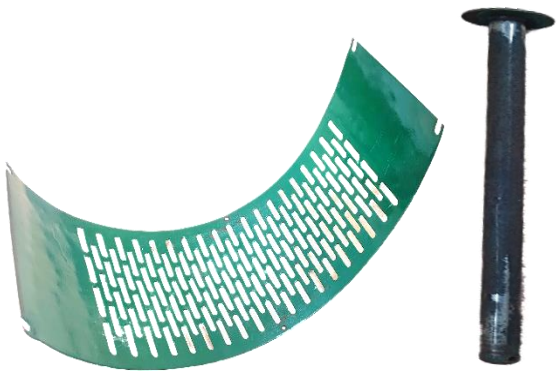

Fig- 5: Curved Plate and Shaft

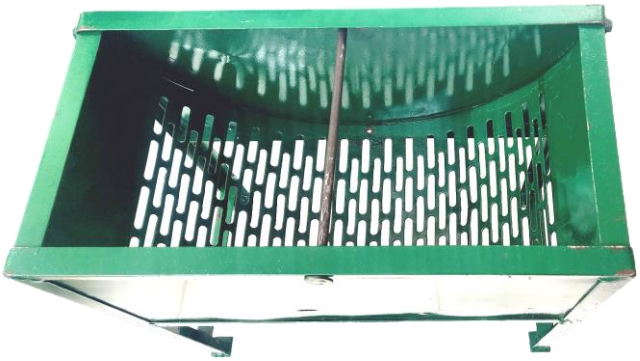

Fig- 6: Oscillating Sector with Curved Plate

Fig- 7: Three Iron Rectangular Parts with Figs (M.S. Plate)

Fig- 8: T Shape Handle Rod and 3 MS Plates

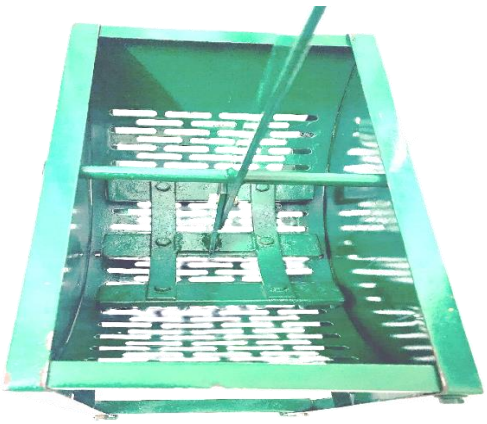

Fig- 9: Oscillating Sector with Sieve Bottom and A Handle

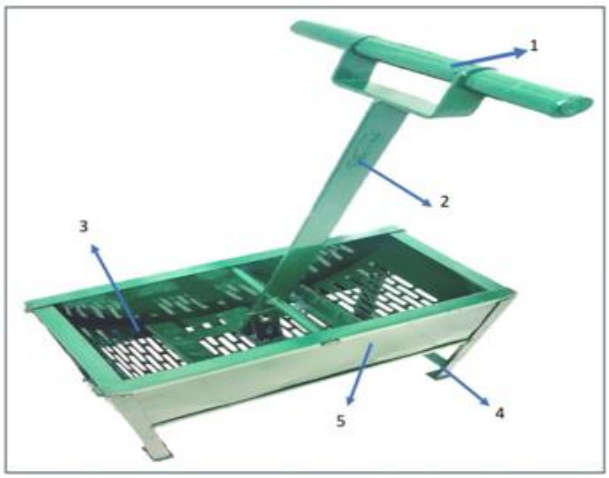

Fig- 10: Hand-Operated Groundnut Decorticating Machine

1. Handle 2. T Shape Rod 3. Concave Sieve 4. Legs 5. Supporting Sheets.

D. Performance of Different Decorticators with Performance Indicators

i. Shelling Time

The differences observed among demonstrations on time taken for shelling (min/kg) in the manual method were statistically non-significant. Among them, the mean shelling time varied from 31.5 to 32.4 (min/kg). The recorded data of the traditional method of shelling peanuts by hand showed an average mean of 32 minutes per kg of peanuts. But in an operated decorticator (HOD), the differences observed among women on time taken for shelling (min/kg) were statistically non-significant with an average mean of 1.5 min/kg [6] reported that one person can decorticate 2 to 4 kg of groundnut per hour but coincide that the average rate of production reduces with the number of increasing hours. The average percentage of peeled roasted groundnut seed during manual operation was 52.3%, as stated by [7]. The mean time was observed 51.65 minutes to de-shell for 2 kg of groundnuts. It was also observed that though groundnut shelling by hand results in a poor quantity of finished products it contributes to minimum breakage of kernels.

ii. Shelling Percentage (%)

The differences observed among four methods of decortications on shelling percentage (%) were statistically non-significant. The recorded data of shelling percentage of peanuts by MS, HOD, DOD, and EPOD showed an average mean of 72, 70, 77.7, and 75.3 percent respectively.

iii. Total Seed Output Weight (Normal +Broken Seed) (Kg)

The differences observed among four methods of decortications on total seed output weight (Normal +broken seed) (kg) were statistically non-significant. Among them, the mean total seed output varied from 1.45 to 1.52 (MS), 1.46 to 1.50 (HOD), 1.63 to 1.66 (DOD), and 1.60 to 1.64(EPOD) kg. The recorded data of total seed output weight (Normal +broken seed) (kg) of peanuts by MS, HOD, DOD, and EPOD showed an average mean of 1.48, 1.48, 1.65, and 1.61 kilograms respectively.

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iv. Production Capacity (Kg/Hr)

The differences observed among four methods of decorticators on production capacity weight (kg) were statistically non-significant. The recorded data on production capacity weight (kg) of peanuts by MS, HOD, DOD, and EPOD showed an average mean of 1.9, 41, 171, and 156 kilograms per hour respectively.

v. Broken Seed Weight (Kg)

The differences observed among four methods of decorticators on broken seed weight (kg) were statistically non-significant. Among them, the mean broken seed weight (kg) ranged from 0.042 to 0.048 kg in the MS method, 0.079 to 0.083 kg in the HOD method, 1.131 to 1.148 kg in DOD, and 1.630 to 1.680 in EPOD method. The average mean broken seed weights recorded were 0.044, 0.082, 1.390, and 1.640 by MS, HOD, DOD, and EPOD kilograms respectively. In the MS method more time will be taken for shelling that's why broken seeds are less compared to other methods.

vi. Unshelled Single-Celled Pods Weight (kg)

The data of the present study revealed that the unshelled single-celled pods (%) recorded were 0.0, 14.7, 17.4, and 37.0 percent in manual method, hand-operated, diesel, and electric power-operated decorticators respectively. In the MS method, more time will be taken for single-celled pod shelling that's why leftover single-celled pods are zero compared to other methods.

E. Correlation Studies Between Hand-Operated Decorticator and Other Performance Indicators

A correlation matrix was analyzed for ten performance indicators viz., shelling time, seed weight, seed weight percentage, production capacity, broken seed weight, broken seed percentage, unshelled single cell pods weight, unshelled single cell pods percentage, and total seed output weight and percentage. The correlation studies between total production output percentage and all other performance indicators viz., seed weight (0.976**), seed weight percentage (0.980**), production capacity (0.976**) parameters indicated highly significant positive (+) correlation and broken seed percentage (0.428NS) and total seed output weight (0.064NS) parameters indicated non-significant positive (+) correlations. While broken seed weight (-0.279NS), shelling time (-0.171NS), single-celled pods weight (-0.589NS), and single-celled percentage (-0.174NS) showed negative (-) correlations with hand-operated decorticator.

F. Economic Analysis

Evaluation of groundnut decorticator data reveals that the average production of shelled peanuts by hand-operated manual groundnut decorticator was 41 kg per hour with decorticator efficiency and mechanical (broken seeds) damage of 74 and 4.1 percent respectively. CIAE Bhopal, manufacturer of the same model suggested 30 kg/hr output. According to [8], a manually operated sheller has 5kg of groundnut sample and performed at 65% shelling efficiency with mechanical damage of 2.8%. [7] mentioned the manually operated sheller with roasted groundnut sample performed at 55% shelling efficiency. If we put input in large amounts then we get more output from the machine with a minimum wastage [9][11][12][12]. However, the total output of finished kernels was 22.5 times more than the traditional method per hour. The time taken to deshell groundnuts was only 2.46 minutes per 2.00 kg thus saving time, safety, and drudgery became major benefits [10]. Under the economic parameter of demonstration for MS, HOD, DOD, and EPOD methods demonstration data for gross cost (excluding pod cost) and gross return also has been calculated. MS method output recorded 1.9 kg /hour. The gross cost calculated for a day was Rs. 700/- including labor charges for winnowing, cleaning, and storage material whereas gross return was observed as Rs. 950/- for a total of 9.5 kg finished kernels @ Rs 100/kg. Thus, the Cost-benefit ratio was noted as 1:1.36 only. The hand-operated decorticator produced 40 kg/hr and the gross cost for labor, storage materials, and raw materials with the machine working for 5 hrs/day was Rs. 700/- per day.

The gross return calculated was Rs. 20,000/- for a total of 200 kg finished kernels (seeds) @ Rs.100/-. Hence Cost cost-benefit ratio calculated was 1:28.6. While in DOD and EPOD methods output recorded was 171 and 156 kg /hour. The gross returns calculated for a day were Rs. 1,02,600/- and 78,000/- for a total of 855 and 780 kgs finished kernel @ Rs.100/- per kg respectively. The gross cost for labor, diesel & electricity charges, storage materials, and raw materials with the machine working for 5 hrs/day was Rs. 3,400 and 2,900/- per day in DOD and EPOD methods with a cost-benefit ratio of 1:34.2 and 1:26.9 respectively.

V. SUMMARY AND CONCLUSIONS

This project is mainly about generating a new concept of groundnut decorticator that would make it easier to transport anywhere and suitable for crushing groundnut. The Output is about 40-42 kg/hour, Shelling time took 1.5 min/kg, and with a high cost-benefit ratio of 1:28.6. Further, the particular design of this prototype reduces all the causes and improves the efficiency. The machine is also lightweight and easy to operate and maintain, the spare parts are also available locally. Maintenance is very easy, purchase cost is low, and highly economical in use. No electric power or diesel is required. No skill knowledge is required. The shelling operation can be done by women at any time and it can be accommodated in the house itself. Small and marginal farmers can use regular shelling for the sowing of groundnut. This is a convenient equipment and can be used at any time (during day time or night time) based on their convenience. Not much labor is required and one person can manage the decortication process and it is cost effective also.

Table-2: Performance Comparison of Different Groundnut Decorticators

Make	Quantity of pods used for shelling (kg)	Shelling time Taken (kg/min)	Shelling percentage (%)	Total decorticated seeds (kg/2 kg pods)*	Decorticated seeds percentage (%)
Manual shelling (MS)	5	32	72.0	1.48	74.0
Hand-operated decorticator (HOD)	2	1.5	70.0	1.48	74.0
Diesel-operated decorticator (DOD)	30	0.35	77.7	1.65	82.4
Electric power operated decorticator (EPOD)	30	0.39	75.3	1.61	80.9

*Data calculated uniformly for 2 kgs.

Table-3: Performance Comparison of Different Groundnut Decorticators

Make	Broken seeds weight (kg)	Breakage percentage (%)	Single shelled pods weight (kg)*	Single shelled pods percentage (%)	Production Capacity (kg/hr)
Manual shelling (MS)	0.044	2.2	0.0	0	1.9
Hand-operated decorticator (HOD)	0.082	4.1	0.291	14.7	41
Diesel-operated decorticator (DOD)	0.090	4.6	0.350	17.4	171
Electric power operated decorticator (EPOD)	0.110	5.5	0.740	37.0	156

*Data calculated uniformly for 2 kgs.

Table-4: Performance Comparison of Different Groundnut Decorticators on The Cost-Benefit Ratio

Make	Investment (Labour, diesel, electricity, etc.,) requirements cost/ day (Rs.)*	Production Capacity (kg/hr)	Production Capacity (kg/day) (5 hr)	Gross returns (Rs.)	Cost Benefit Ratio
Manual shelling (MS)	700	1.9	9.5	950	1:1.36
Hand-operated decorticator (HOD)	700	41	200	20,000	1:28.6
Diesel-operated decorticator (DOD)	3400	171	855	1,02,600	1:34.2
Electric power operated decorticator (EPOD)	2900	156	780	78,000	1:26.9

*MS- 2 women labour cost @ Rs.350/day HOD-2 women labour cost @ Rs.350/day Finished seed cost @ Rs.100/kg DOD- 4 women labour cost @ Rs.350/- + diesel cost 10 liters @ Rs.100/- day EPOD- 4 women labour cost @ Rs.350/- + electricity power charges 10 liters @ Rs.100/- day

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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- **Authors Contributions:** The authorship of this article is attributed equally to all participating authors.

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Dr. B. Druga Prasad, Ph.D., MTech, BTech, Professor, Department of Mechanical Engineering, JNTUA College of Engineering, Anantapur A.P India. He continuously gives his services to the University. And also given His guidance throughout the completion of the project. His thoughts and ideas are very helpful to achieve more. Guided 150 MTech, dissertation works. Guided Ph.D. for 4 students registered with Sathyabama deemed University, Chennai. Guided Ph.D. for 25 students registered with JNTUA, Anantapur, and Guided 14 Ph.D. scholars registered with JNTUA, Anantapur. Acted as a doctoral committee member for 6 Research scholars registered with Anna University. Chennai.