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Formulation of Experimental Data Based Model for Bamboo Sliver Cutting Using HPFM: A Literature Review

S. K. Undirwade[1], Dr. M.P. Singh[2], Dr. C.N. Sakhale[3]
[1]Research Scholar & Asstt. Professor, Mechanical Engg. Deptt.,Priyadarshini College of Engineering, Nagpur:440019, India
[2]Professor & Principal, Priyadarshini College of Engineering, Nagpur: 440019, India
[3]Associate Professor and Head PG, Mechanical Engg. Deptt.,Priyadarshini College of Engineering, Nagpur:440019, India

Abstract
The human power was neglected during the periods when there was the rapid use of fossil fuels. But due to very high prices of fossil fuels and hazardous environmental pollution from them, the human power again came in the light as renewable energy source.This paperreveals the detailed literature review for experimental work to be executed for establishing approximate generalized experimental data based models for slivercutting from bamboo using human powered flywheel motor (HPFM). This paper also includes the review regarding design and manufacture of human powered/manual bamboo sliver cutting machine.A detailed review taken comprises of vast literature survey on human powered machines and bamboo technology and different bamboo processing machines, more particularly the manual bamboo slicing machines.
Keywords: *Human powered machines, Bamboo Sliver, HPFM, Sliver cutting, Bamboo Technology, Bamboo Processing Machines.*

1. Introduction

To use the energy sources like solar energy, wind energy, geothermal energy, biomass energy, tidal energy etc., some limitations are noted down. It requires favourable local geographical and climatic conditions to use efficiently. Also these energy sources required costly equipment to transform the energy in usable form. The equipments like water turbines, windmills, solar energy collectors etc. and also storage media are out of the coverage of general people. The property of endless existence make the renewable energy sources important, but the high initial and maintenance cost of the equipments is the great obstacle to use these sources.
It is present need to find out an alternative to the renewable energy sources which will be suitable to use any time and at any place and which is reachable to general user. Human power is one such form of renewable energy that has been used historically to varying degrees.
It's so natural for mankind to search for alternative green energy resource for day to day energy needs and extensive research is going on in the area of unconventional green energy resources. Human power has also significant contribution in unconventional energy resources. Human power mostly used in form of pedalling by leg muscle is cited in history.
It is necessary to see the feasibility of energizing bamboo sliver cutting by human power for (i) On load human power feeding to a process unit and (ii) Intermittent power feeding to process unit. The literature review is carried out on following areas of this research:
(i) Human Powered Machines
(ii) Bamboo Processing Operations, Machines and Technology.

2. Operation of the Human powered Bamboo Sliver Cutting

The operator drives the bicycle by pedalling the mechanism while clutch is in disengage position. The human power operated flywheel motor is energy source. This energy source energizes the process unit i.e. bamboo sliver cutting unit through clutch and transmission. The flywheel is accelerated and energized which stores some energy inside it. When the pedalling is stopped, clutch is engaged and stored energy in the flywheel is transferred to the process unit input shaft by means of clutch.
The process unit is sliver cutting unit which comprises of feeder, two pairs of spring loaded

rollers, sliver cutter, adjusting knobs etc. When the energy from flywheel is transferred to the sliver cutting unit by engaging the clutch, the split bamboo is fed through feeder. It enters the first pair of push-in rollers, then comes out of push-out roller pair and strikes the sliver cutter which is kept fixed and the sliver is cut. The sliver cutting immediately commences upon the clutch engagement it continues for 5 to 20 seconds until the flywheel comes to rest.

There is a provision of operating the system at the speeds by properly choosing the gear ratio of a torque amplification provided on the sliver cutting unit shaft. The figure 1 shows the schematic diagram of bamboo sliver cutting unit driven by human powered flywheel motor (HPFM).

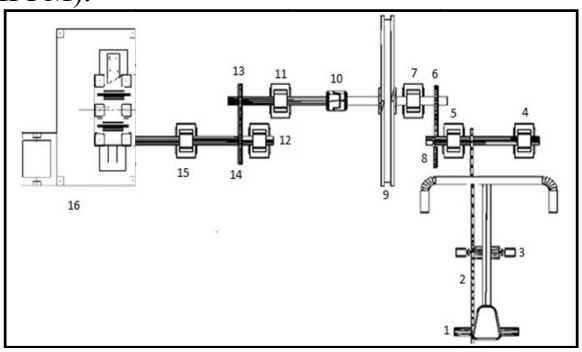


Fig. 1 Schematic arrangement of bamboo sliver cutting unit by HPFM

1 - Chain Sprocket, 2 - Chain, 3 - Pedal, 4 & 5 - Bearing for bicycle, 6 - Gear I, 7 - Bearing Flywheel Shaft, 8 - Gear – II, 9 – Flywheel, 10 – Clutch, 11 - Bearing for flywheel shaft, 12 - Bearing for Process Unit Shaft, 13 - Gear – III, 14 - Gear – IV, 15 - Bearing for Process Unit Shaft, 16 - Process Unit.

3. History of human powered machines

History records show that human power is used in different kind and forms over the past many centuries. Arm muscles, back muscles and leg muscles were used for powering human powered machines in the history. Leg muscles are strongest amongst all the muscles and those are found mostly used to power machines.

Ever since the arrival of fossil fuels and electricity, human powered tools and machines have been viewed as an obsolete technology. This makes it easy to forget that there has been a great deal of progress in their design, largely improving their productivity.

The most efficient mechanism to harvest human energy appeared in the late 19th century: pedalling. Stationary pedal powered machines went through a boom at the turn of the 20th century, but the arrival of cheap electricity and fossil fuels abruptly stopped all further development. [1]

A. Hand cranks, capstans & tread wheels

Rotary motion has been the fundamental mechanism of most machines throughout human history. There have been several important innovations in applying human power to rotary motion, many of which already appeared the hand crank, the capstan and the tread wheel. Successively, each of these brought an improved mechanical advantage, being the factor by which the mechanism multiplied the human (or sometimes animal) input force into a higher output force. The tread wheel shown in figure 2 had another advantage over the hand crank: it replaced the use of the arm muscles by the use of the much stronger leg muscles, and it allowed the use of two limbs instead of one.

B. The treadle

Another novelty appeared in the middle ages: the treadle (shown in figure 3). From the 10th century onwards, the Chinese used wooden treadles to obtain continuous motion for water pumps, textile machinery and wood saws. In the western world, treadles were mainly applied to spinning wheels and lathes (machine tools used for working metal and wood).

Treadles were inefficient compared to capstans and tread wheels (feet and legs must be accelerated and subsequently decelerated by the muscles) but they were more compact and a viable alternative when power requirements were low. Their main advantage over the hand crank was that they left both hands free to control the machine.

C. Applying human power to rotary motion

The cleverest innovation in applying human power to rotary motion only appeared in the 1870s (shown in figure 4). Some of us still use it

as a means of transportation, but it is rarely applied to stationary machines anymore: pedal power. Initially, pedals and cranks were connected directly to the front (or sometimes rear) wheel. With the arrival of the 'safety bicycle' shortly afterwards, this direct power transmission was replaced by a chain drive and sprockets - still the basics of most present-day bicycles.

D. Applying human power to tools

From 1876 onwards, pedals and cranks were attached to tools like lathes, saws, grinders, shapers, tool sharpeners and to boring, drilling and cutting machines as shown in figure 5. These machines - which became very popular - were intended for small workshops and households without electricity or steam power.

E. Steel treadles

Steel treadles (figure 6) were applied to industrial machines like hat, broom, cigar and hook making machines, printing presses, punch machines and riveting machines. The farm saw the appearance of foot powered harvesters, threshers, milking machines and vegetable bundlers. The late 19th century dentist used a treadle powered drill.

F. Pedalled Powered Lathe

In 1880, lathe's use were powered by pedal power with the use of the flywheel as a step cone pulley, such a lathe machine is shown in the following figure 7. The lathe picture is from Eleutherian Mill's historical library [1].

G. Pedal Powered Winch: Substituting a Farm Horse or Tractor

Both the Dynapod and the Energy Cycle could also double up as a pedal powered winch, offering a whole new array of possibilities. A winch shown in figure 8 is useful for pulling, excavating, load lifting, or snow plowing. In agriculture, a winch can be utilized for cable-cultivation, a principle in which the motive power for plowing (or harrowing, cultivating, seeding and hay raking) is stationary and only the tool (attached to a multifunctional mobile tool carrier) moves across the field along a cable [2].

H. Pedal Powered Dynapod

A dynapod is a stationary pedal-powered device shown in figure 9. The word 'Dynapod' comes from the Greek words for power and foot. The dynapod can be attached to any kind of device or tool and used to generate power for a multitude of activities. The first design for this type of unit was introduced in 1968. Although it was not built, Alex Weir (Edinburgh University) built one and two person dynapods at Dar-es-Salaam in Tanzania. A cement-filled bicycle wheel was used as a flywheel. He developed and built many prototype units using square tubing for the framework. His prototype inventions were tested as corn grinders and a winnowing machine [1].

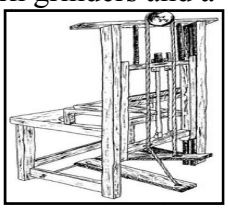


Fig 2: Tread wheel

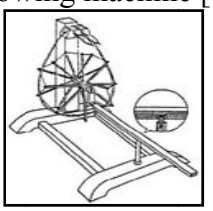


Fig 3: The treadle

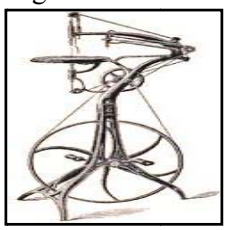


Fig5: Human power to tool

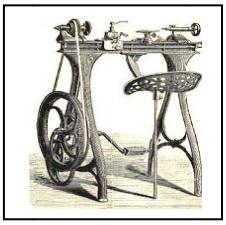


Fig6: Steel treadles

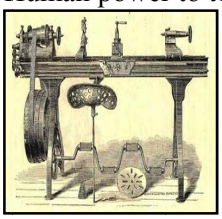


Fig.7 Pedal powered lathe

Fig.8 Pedal powered winch

Fig9 Pedal powered Dynapod

4. Need of human powered machines

From 1940 to 1980, exploration of petroleum products increased by many folds. At the same time use of the petroleum products also increased tremendously. Rapid increase in the use of petroleum products also increased environmental pollution. The exhaust gases produced after burning petroleum products pose a threat to the environment.

Growing demands for energy, coupled with expiable natural resources, has resulted in a demand for the development of renewable energysources. A renewable energy is the energyavailable in natural form can be replaced byanother form by the natural or artificial processes.In natural form it is not in usable form, so somedevices are required to transform the energy inusable form. There are so many sources which arequalified as renewable energy sources e.g. solar, water, tides, geothermal, biomass, and wind etc. andhaving endless existence. There are some limitations to usethese energy sources. Use of these energy sources requires favourablelocalgeographical and climatic conditions to useefficiently. Also the energy sources required costlyequipments to transform the energy in usable form.The equipments like water turbines, windmills, solar energy collectors etc. and also storage mediaare out of the coverage of general people. Theproperty of endless existence make the renewableenergy sources important, but the high initialandmaintenance cost of the equipments is the greatobstacle to use these sources.

It‘s a present need to find out analternative to these renewable energy sources which will be suitable to use any time and at anyplace and which is reachable to general user. Human power is one such form of renewable energy that has been used historically to varyingdegrees.

In view of increasing portion as discussed in the previous section is very much required to search for alternate energy resources and those should be renewable too. With this view in mind, Modak J.P. started working on human powered flywheel motor and its application to harvest green energy to run various process machines since 1977 [11].

5. Recent developments in human powered/pedal powered/ machines and cycling phenomenon

Andrzerj A. Stepniewski and Jerzy Grudzinski [3] have presented influence of mass parameters and gear ratio on the speed and energy expenditure of cyclist wherein he discusses about the wavelength of moment of active forces (driving forces) for a full cycle while pedalling with platform pedals. He discusses that with most commonly used gear ratios (above 1.5); the effect of increasing mass of the bicycle is negligible.

JamesC. Martin, Christopher J. Davidson,and Eric R. Pardyjak [4] presented in paper that Maximal cycling power is influenced by pedalling rate, muscle size and fibrecomposition, and fatigue. Cycling speed is resisted by aerodynamic and rolling friction and any imbalance in applied versus required power results in changesin system energy.

E.A. Hansen et al.[5] tested bicyclist at power 150 W and 250 W and freely chosen pedalling rate under inertial crank load conditions concluded that freely chosen pedalling rate would increase with the increase in inertial crank load

Hui Huang et.al.in research paper [6] discusses about inertia energy harvesting technology from various motions of the human body and the produced energy is in electrical energy form. And also write about how the orientation of the energy harvester affects the power produced during human body motion, how the energy differs from upper and lower body parts.

Haichang Liu, Jihai Jiang [7] lays significance of the flywheel as an energy storage device, they also spoke about flywheel design and geometry. As per their investigation, thin rim flywheel is best to store energy and second position is taken by the flywheel rim with the web. As per the investigation disc type flywheel is worst to store

energy and its energy stored to flywheel-weight ratio is very low.

Aleksandar Tomas, Emma Z. Ross, and James C. Martin [8]reported in their work that the Maximal cycling power has been reported to decrease morerapidly when performed with increased pedalling rates and increasing pedalling rate imposes two constraints on the neuromuscular system: (a) decreased time for muscle excitation and relaxation and (b) increased muscle shortening velocity. Using two crank lengths allows theeffects of time and shortening velocity to be evaluated separately. They also concluded and confirm that pedalling rate, rather thanpedal speed, was the main factor influencing fatigue and power decreased by a similar increment with each crank revolution for the two conditions, indicating that each maximal muscular contraction induced a similar amount of fatigue.

Paul R. Barratt et al[9] explain that the effect of crank length on relative joint-specific power production was dependent on the control of pedalling rate and crank length did not affect relative joint-specific powers when pedalling rate was set to optimize maximum power (matched for cyclic velocity). They also revealed that crank length had no significant effect on relative joint-specific powers at the hip, knee, or ankle joints when pedalling rate was optimized and When pedalling rate was constant, crank length had a small but significant effect on hip and knee joint power.

Eugene A. Avalloneet. al. [10] states that a trained cyclist can produce about 400 watts of mechanical power for an hour or more, but adults of good average fitness produces power between 50 and 150 watts for an hour of vigorous exercise. A healthy well fed labour over the course of an 8 hour day sustains an average output of 75 W.

The concept of human powered flywheel motor (HPFM) is put forth by J. P. Modak[11].J. P. Modak and his associates [11 to 21] developed a human powered flywheel motor (HPFM). A human being can pedal a bicycle at 75 W [1] power input rate conveniently. A bicycle mechanism is pedalled to store kinetic energy in a flywheel. And then spinning flywheel is clutched to process unit to transfer the motion to the process unit. He tried various applications like brick making of extrusion, water lifting, winnowing, wood cutting and turning, a smiths hammer, potter's wheel, Chaff cutting, electricity generation, fertilizer mixing etc. on HPFM and established functional and the economic viability of HPFM for rural based applications.

6. Overview of literature regarding bamboo processing machines and bamboo technology

In this research work, since the process unit is bamboo sliver cutting unit which is energized by human powered flywheel motor (HPFM) i. e. energy unit, it becomes necessity to make the overview of the literature regarding bamboo processing machines and the bamboo technology.

Bamboo splits and slivers are longitudinal sections of a bamboo pole (culm). Splits are the full thickness of the culm wall and have the green outer layer still attached. Slivers are thin, narrow sections of bamboo wood. They are the primary materials used for weaving a wide range of products. On a small scale they may be used for handicraft items and objects of daily use. On a large scale, one of the most useful products they can be woven into are the mats that are used toproduce bamboo mat board.Bamboo slivers are the primary raw material for mat making and the demand for mats is closely related to the demand for mat board. Mat board is a versatile type of plywood and its markets are increasing rapidly.

6.1 History of the development of bamboo sliver making technology:

Mechanical sliver making has been developed over the past few decades in a number of countries, but most particularly in China where it is very widely practiced, and from

where a wide range of relevant machines and equipment are available. The technology has mostly been developed by private companies and research institutes. In India a unit for the primary processing of bamboo was established at Indian Plywood Industries Research Institute (IPIRTI), Bangalore under a project sponsored by the International Development Research Centre (IDRC), Canada in 1997 using machinery imported from Taiwan.

Although these processes have been done by hand for many generations as shown in figure 10, the mechanical unit described in this work permits the efficient production of numbers of slivers for large-scale supply, generally to industrial processing plants.

Fig. 10 Traditional/old Methods of making splits and Slivers from bamboo by hands

6. 2 Scenario of Bamboo as a Material:

In India, although several products have been developed, bamboo mat board (BMB), Bamboo Mat Veneer Composites (BMVC) and Bamboo Mat Corrugated Sheets (BMCS) developed at IPIRTI have already attracted entrepreneurs and gained user acceptance as alternate to wood, plywood and corrugated ACC and GI Sheets.

Roofing and walling are two crucial elements of a house and several R&D institutions have been engaged in developing innovative, alternative roofing and walling materials and construction systems. Considering the need for developing alternate environment-friendly and cost-effective roofing materials for North-Eastern and other earthquake prone and hilly regions the Building Materials and Technology Promotion Council (BMTPC) under the Ministry of Urban Development & Poverty Alleviation and the Indian Plywood Industries Research and Training Institute (IPIRTI) functioning under the Ministry of Environment and Forests, have jointly developed a technology for manufacturing of Bamboo Mat Corrugated Sheets (BMCS) as shown in figure 11.

Several manufacturing units are already engaged in production and marketing of bamboo based building materials (boards, panels, composites, laminates, roofing sheets). Variety of industrially produced products and elements are being used in building construction besides hundreds of traditional systems and types where bamboo is predominantly used for house/building construction [12]. The example of “bamboo-as a house/building construction” is shown in figure 12.The excellent and sustainable use of bamboo is going on in a furniture industry as shown in figure 13.

The bamboo slivers are being continuously used for weaving the bamboo mats which is having different wide applications like furniture, handicrafts, wall panelling, wall papers etc. as shown in figure 14. This shows the extensive use of bamboo slivers in manufacturing industry [13].

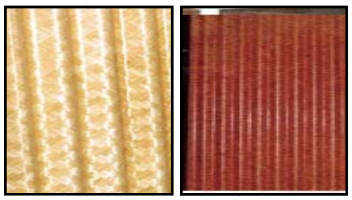


Fig. 11Bamboo slivers as roofing material

Fig. 12Bamboo for house/building construction

Fig. 13 Usage of Bamboo in furniture industry

(a)Furniture (b) Handicrafts (c)Wall panelling (d)Wall papers

Fig. 14 Applications of Bamboo Mat Weaving

6.3 Research Review in Bamboo Processing Machines and Bamboo Technology:

Janssen, J. J. A. [14] presents the various mechanical properties of bamboo with some empirical data which are very important to use a bamboo as material for different applications. He also reveals the relationship between the mechanical properties and the biological and chemical composition of bamboo.

Liese W. [15], discusses the various opportunities for bamboo processing and operations. He further lays more emphasis on the constraints and scope of processing and utilization of bamboo and rattan in north east India.

Vermah, J.C. and Bahadur, K.N. [16]explores their study on the conditions and scope of research on bamboo in Asian countries. They elaborate the idea on availability of different bamboo species depending on environmental conditions and gives the information about the scenario of bamboo research overall.

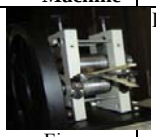
C. N. Sakhle et al [17], presented his research work, "the design and development of Comprehensive Bamboo Processing Machine". In his work, he has designed and developed single bamboo processing machine comprising of four bamboo processing operations which are (i) cross cutting of bamboo, (ii) splitting of bamboo, (iii) internal knot removal and sliver cutting operation and (iv) stick making operation. The machine developed by him is operated by electric motor. Thus the four bamboo processing operations can be done simultaneously by means of electric motor. He established approximate generalized empirical model forBamboo(machining properties) processing operationssuch as cross cutting, external knot removal(two side planning),splitting, internal knot removal, sliver(slats) and stick making, using methodology of engineering experimentation. It includes design and development of a machine with specialty of multiple operations of bamboo processing in a single unit.

In the present research work, the aim is to formulate experimental data base models for sliver cutting operation from bamboo in which electricity is not required i.e. the sliver cutting machine/unit is operated by human powered flywheel motor (HPFM) so that the rural area based people can also have the use of such a human operated machine.

6.4 Review of Available Bamboo Sliver Cutting Machines:

Some available machines are reviewed given in table 1.

Table 1: Some Available Sliver Making Machines

Machine	Source	Description
 Fine Slivering Machine	India mart	Manually/electrically Driven. Wheel is rotated by hand or power. Strips ranging from 0.5mm to 2mm thickness can be slivered.
 Motorized Fine Slivering Machine	India mart	Electrically Driven. 1 hp motor is used
 Motorized Bamboo Slicing	Cera-Therm International Bengaluru, Karnataka-560073, India	Electrically Driven
 Bamboo Sliver Making Machine	Anil Enterprises, Dewas Madhya Pradesh, India-455001	Electrically Driven. Round Plate Slicer Features(left): 3 H.P/960 rpm. Heavy Duty Sliver(Right): 3 H.P, 60 R.P.M

 Manual Sliver Making	bamboocomposites.com	The epidermal layer from the splints is removed using a sharp knife and can be set apart for making other products. Slivers ranging from 0.6 mm to 1.0 mm thickness are made from splints manually using a sharp knife
 Sliver Making from Machine	bamboocomposites.com	The processed splints are passed through slivering machine to produce sliver of about 0.6 mm to 1.0 mm thickness for each pass depending on machine settings.
 Slicing Machine	NMBA, India	Brand: Woodmaster. Sharp edge HcHc tool is used to make slice in the machine from bamboo with automatic feed

7. Summary of the LiteratureReview

Thus the whole literature review is carried out separately on following sections:
(i) Human Powered Machines
(ii) Bamboo Processing Operations, Machines and Technology and

Initially an introduction to worldwide scenario of existing energy sources is presented in which it is revealed the human power as one of the renewable source of energy and as a green energy alternative. Then it is focused on the history of human powered machines and need of human powered machines. Further the review is carried out in detail on need of human powered machines and human powered flywheel motor (HPFM). The detailed literature review on HPFM enlightens how the researchers have made the efforts since long back to use human power. Thereafter the review on the recent developments in human powered machines is carried out.

After doing the vast literature survey on human powered machines, the review on bamboo processing operations, machines and bamboo technology is done. It begins with history of development of bamboo sliver making technology. Then the scenario of bamboo as a material is put forth and the review regarding the importance of mechanical properties of bamboo is done by making comparison with some other materials like steel, wood and concrete. The detailed research review is made in the bamboo processing machines and bamboo technology carried out by many researchers and also the attention is made critically on the available bamboo sliver making machines.

8. Concluding Remarks of the Review

As per the literature survey cited in this work, it is found that the most of the researchers covered various operations through human powered flywheel motor but no research work or very less research work is carried out on bamboo cutting operation by using human power. So far all the researchers who have worked in the field of human powered flywheel motor for any operation have not considered the total resistive torque of the operation. They have worked for only average resistive torque of the operation. Hence it is needed to study the effect of total resistive torque on the operation by formulating the models for this factor.

Keeping view towards the available machines in the market, the manufacturers are not utilizing the standard design data related to the process, and they are not emphasizing over the various independent factors affecting the response variables of the operation due to unavailability of this data. Due to this they are unable to explore the factors like minimizing the processing time of the operation, requirement of minimum human energy for maximum output etc. As per discussions in the literature review, the available manual bamboo slivering machines are hand operated, due to which there are restriction on power requirement and energy utilization for these machines and therefore there are the limitations on length of slivers to be produced. Most of these machines are able to produce the slivers of length 1.0 to 1.5 feet. Thus

this work aims at overcoming these deficiencies discussed above.

According to the review on the mechanical properties of bamboo, the bamboo is better in the strength and safe for various applications like building constructions, roofing, wall panelling, ornaments, furniture, household materials etc. hence there is a scope for producing bamboo slivers to achieve these applications. Also bamboo as a material is found to be better as compared to others like Concrete, Steel, and Wood. Hence it is in demand for utmost all the applications cited in this paper. It is also revealed from the survey that the bamboo is better in machining operations due to its marginal characteristics in energy needed for production, safety of the material, the strain energy: deviation in the strength, strength and the stiffness per unit of material and simplicity of production.

Acknowledgments

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Prof. Siddharth K. Undirwade is Research Scholar and Assistant Professor at Mech. Engg. Deptt at Priyadarshini College of Engg., Nagpur. His specialization is in Mechanical Design. His has published 21 papers in National and International Journals and conferences.The current research work received the RPS grant from AICTE.

Dr. M. P. Singh is working as Principal at Priyadarshini College of Engg., Nagpur. His is having 25 years of experience in teaching and research. His specialization is in Industrial Engg. He received 02 RPS grants from AICTE. He has published 60 papers in International Journals and Conferences.

Dr. C. N. Sakhale is working as Associate Professor in Mechanical Engineering at Priyadarshini College of Engg., Nagpur. He is having 15 years of experience in teaching, Industry and research. His specialization is in Mech. Design. He received 03 RPS grants from AICTE. He has published 65 papers in International Journals and Conferences. He is recipient of ISTE's U.P. Government Award-2014, Maharashtra states Utkrushta Kalavant Award-2013 and Young scientist award-2011 in IFToMM, Gunanjuato, Mexico. He is member of ISTE, AMM, ISHRAE, ISB. He has also written two books. Presently he is member of Board of Studies, Aeronautical Engg, R.T. M. Nagpur University.