Devices for Carpet and Other Rural Sectors of India: An Opportunity for New Research

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Abstract

There are a lot of non-organized sectors in rural India whose needs are need to be studied and solved. In this paper, some attempts made by the author and his team in last ten years are reported. A few of them are in the carpet sectors. Others are in the areas of sheep shearing, developing an animal driven prime mover, etc. While working on the design and development of the devices for those sectors it has been realized that the modern knowledge like Finite Element Analysis, Multibody Dynamics, etc. can be easily applied for the design and performance improvements. As a result, an opportunity towards a new research is visualized which may change the attitude of the engineering students and professionals by focusing their research towards their own problems rather than concentrating on the research issues of the west, thereby, equipping the rural people of India and the World with more economic, energy efficient devices.

1. Introduction

In 2000, the author was approached by his colleague at IIT Delhi, Prof. Rajendra Prasad of the Centre for Rural Development and Technology (CRDT), to join hands with him to improve the tools and processes used in carpet sectors of India. Even though hesitated initially as the area appeared to be from Textile Engineering domain but later the work was found to be very much Mechanical Engineering. These experiences are shared in Section 2. While working on the projects several devices were developed and tested successfully in the field, but no research materials for publications was easily identifiable which is must for a successfully career of an academician like the author, particularly, in an organization like IIT Delhi. Hence, the author was in search for research contents in those developments. Soon he could find something that was obtained through engineering analysis and synthesis. For example, the design of the beams of a carpet loom and synthesis of the 8-bar carpet scrapping mechanism. Hence, the first pair of publications appeared in the proceedings of the 11th National Conference on Machines and Mechanisms (NaCoMM) held in 2003 [1,2]. Later, a Ph. D research problem was identified in the area of Multibody Dynamics, i.e., dynamics complex mechanical systems like the carpet scrapping machine, that resulted in not only several publications in the internally reputed journals and conferences but also in book published by Springer, Germany in 2009 [3]. This proved that a new research was possible with the devices of rural non-organized sectors by utilizing the advanced knowledge otherwise applied to the design of equipments in the well-organized sectors like automobiles, robotics, spacecraft industries, etc. The author has emphasized this point in his book published by Springer, Germany [3]. A portion from the preface of the book is quoted here as follows:

> "This book has evolved from the passionate desire of the authors in using the modern concepts of multibody dynamics for the design improvement of the machineries used in the rural sectors of India and The World. In this connection, the first author took up his doctoral research in 2003 whose findings have resulted in this book. It is expected that such developments will lead to a new research direction MuDRA, an acronym given by the authors to "Multibody Dynamics for Rural Applications." The way MuDRA is pronounced it means 'money' in many Indian languages. It is hoped that practicing MuDRA will save or generate money for the rural people either by saving energy consumption of their machines or making their products cheaper to manufacture, hence, generating more money for their livelihood."

It is worth mentioning here that the author has also worked with the National Innovation Foundation (NIF) in Ahmedabad during 2000-2003 where he used the scientific knowledge to improve the designs of the grass-root innovators.

This paper is organized is as follows: Section 2 provides the list of devices developed for carpet sectors, followed by the devices for other sectors in Section 3. Section 4 illustrates how the advanced knowledge was blended to improve some of the designs, thereby, bringing the new opportunity in research. Finally, conclusions are given in Section 5.

2. Devices of Carpet Sectors

A typical hand-knotted carpet requires the weaving in looms (typically made of woods), washing it manually using wooden planks, sun-drying it in an open area, and post-processing the same using some tools like scissors, etc. In order to enhance the efficiency, productivity and quality of the hand-knotted carpets, the following tools and processes were chosen for improvements under the financial support of Development Commissioner (Handicrafts) during 2000-2003 [4]:

- Loom for weaving hand-knotted carpets
- Carpet washing
- Drying
- Moisture measuring device
- Trimming device
- Four hand-tools: Beater (Panja), Knife (Chhura); Scrapper (Phawra); Metal Comb

Here first three items with two hand-tools of the last item will be explained.

2.1 Carpet Loom

Present looms that are used for weaving hand-knotted carpets in India are made of wood, which are susceptible to termite attacks and have low service life. Besides, the high tension in the warps is generated manually by pulling a rope with the help of 4-5 persons. This type of tensioning using rope takes about 30 minutes. In order to improve the tensioning and other features of the loom, a metallic loom with a gear-box was developed by IIT Delhi in 2001, which has made tensioning easy and weaving more convenient. The improved loom takes about 10 minutes by only one person. The traditional loom used to make the carpets shown in Fig. 1, whereas the

improved on is shown in Fig. 2. A quick comparison of carpet weaving in traditional wooden and improved metallic loom is given in Table 1.

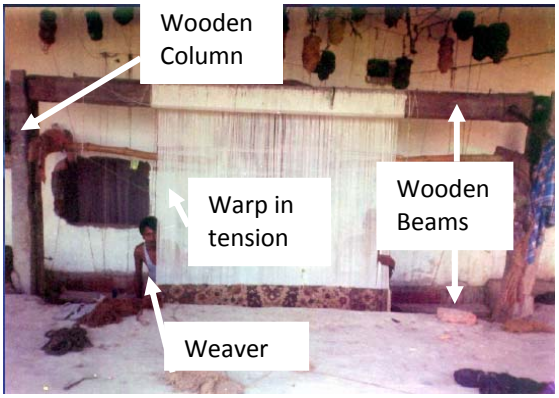


Fig. 1 Traditional wooden loom

Fig. 2 Improved metallic loom

Table 1 Comparison of carpet weaving in wooden and metallic looms

Parameters	Wooden Loom	Metallic Loom
Quality	• Termite • Bending • Weaving quality decreases with time • Non uniform tension	• No bending termite problem • No bending • Quality of weaving is high • Uniform tension
Productivity	• Number of person required is more • Tensioning time is more and difficult • Frequent tensioning is required	• Single person can operate • Tensioning time is less and easy • Single time tensioning is sufficient
Human Effort	• More effort is required for tensioning • Accident prone • Cumbersome shading	• Effort is less for tensioning • Safe • Easy shading arrangement

2.2 Carpet Washing

In traditional carpet washing, a long scrapper made of wood, as shown in Fig. 3, is used to spread the detergent liquid over the carpet, followed by the scraping actions to remove the dirt inside the carpet piles. The associated feedback with this method of washing was as follows:

1. Short life and less inertia forces for effective scraping pressure on the carpet.
2. More power was spent as the scrapper is light-weight.
3. Less area could be scraped in a specified time as the speed depends on the health and power of the human being.
4. Each carpet requires about an hour.
5. Non-uniform washing.

In order to overcome the above-mentioned difficulties, two separate machines were developed, as shown in Figs. 4 (a) and (b). Figure 4(a) takes care of the spreading of the detergent liquid over the carpet and its mixing. This is called mixing machine. The other one takes care of the scraping called the scraping machine. Features of the mixing machine are listed below:

1. Soft brushes mounted on two rollers that rotate in opposite directions to provide proper detergent mixing.
2. The brushes thoroughly remove all dirts from the carpet.
3. The piles are opened in both the directions in single movement of the machine.
4. Due to the constant speed of mixing brushes, mixing is uniform.
5. Quality of mixing is much better.

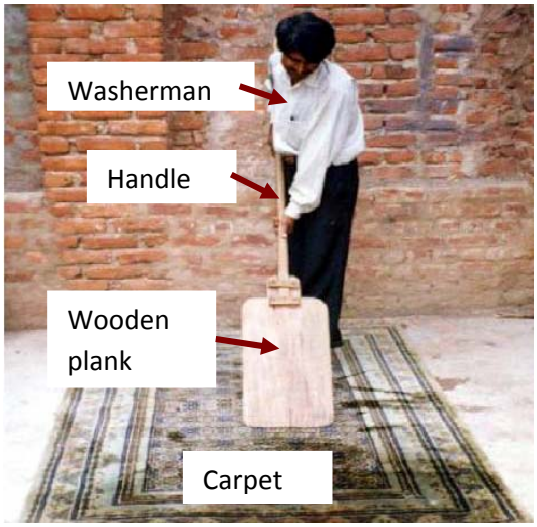
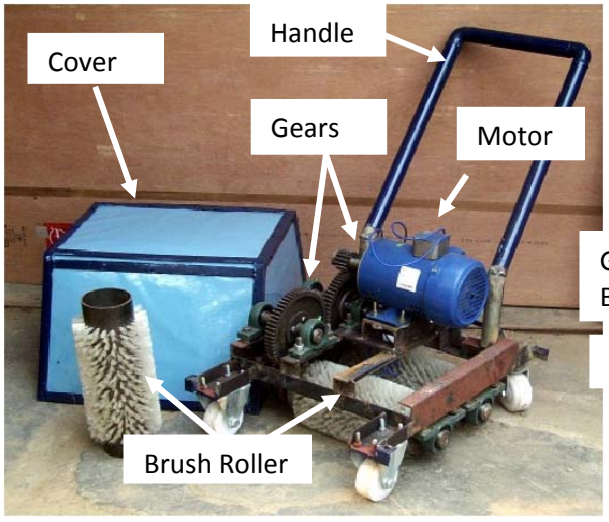


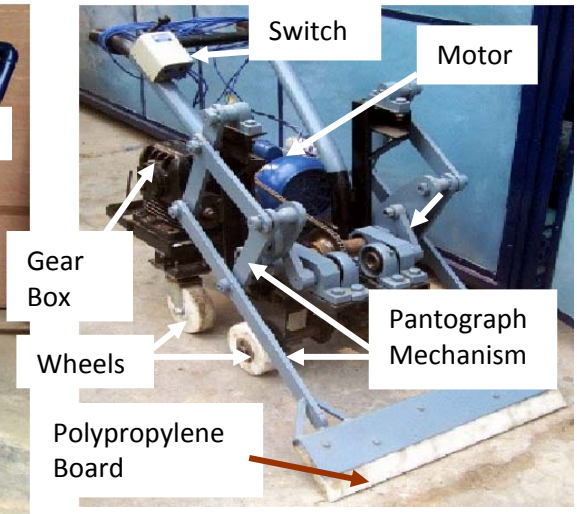
Fig. 3 Traditional carpet washing

Figure 4(b) showing the scrapping machine has the following features:

1. Scrapper machine is based on Hoeken's Straight-line mechanism. Pantograph mechanism is used to magnify the stroke of scrapping pads. The scrapping operation is covered in a short time with less power consumption. The lead screw provided with the scrapping machine helps in transversal motion across the carpet platform.
2. Two out of the five wheels are powered.
3. A lifelong reduction gearbox is provided.
4. Speed of scrapper is same as that of manual speed of scrapping.
5. A single person can handle the machine.



(a) Mixing machine



(b) Scraping machine

Fig. 4 Carpet washing machines

2.3 Semi-automatic Carpet Washing Machine

This concept was based on the three washing-related machines, namely, mixing, scraping, and squeezing, combined into a single machine. It is shown in Fig. 5. The operations are as follows:

1. Chemical mixing by powered brushes.
2. Automated scrapping pad for removal of water from the carpet.
3. Squeezing of the carpet.

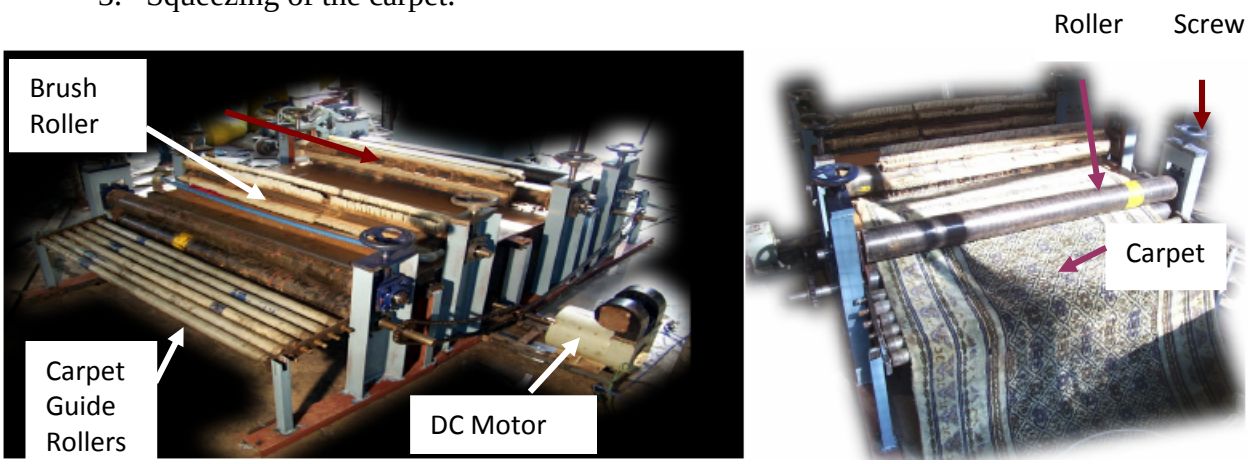


Fig. 5 Semi-automatic squeezing plant

The salient features of the above machine are as follows:

1. Three different operations are incorporated in one machine.
2. Slider-crank mechanism is used for chemical mixing. This mechanism ensures straight line mechanism which is very effective in opening the piles uniformly. This whole operation is done within a short period of time and is also helpful in retaining gloss shining of carpet.
3. Squeezers are provided for draining water using powered rollers. The carpet is squeezed in two or more passes.
4. Provision is made for easy exit of the carpet from the machine.
5. All mechanisms are powered by motors.

2.4 Carpet Drying

Traditional carpet drying involves two steps. In the first step, a carpet is rolled after it is washed for about 12 hours, as depicted in Fig. 6(a), which drains about 50% water. Next, it is put for sun drying as shown in Fig. 6(b) in on open area for few days. Typically, the above processing varies from 2-3 days depending on the carpet size and climatic condition. For example, during rainy seasons and winters, they may take very long time, may be a week. As a result, the deadline for the supply mainly for the export orders cannot be met. To overcome the above mentioned difficulties a carpet squeezing machine and drying chamber were developed as shown in Figs. 7(a) and (b), respectively.

The salient features of the carpet squeezing machine shown in Fig. 7(a) are as follows:

1. The machine is both motor as well as manually operated.

2. The height of the rollers from the ground is according to the desired level for facilitating easy feeding of the carpets to the rollers.
3. Amount of water squeezed out is approximately 30 – 50% depending upon the quality of carpet being squeezed.

(a) Rolled wet carpet

(b) Unrolled carpet in an open area

Fig. 6 Carpet drying

Table 2 Comparison of traditional and proposed drying

(a) Draining of water

Parameter	Traditional	Proposed
Quality	• Direction of pile is not maintained.	• Direction of pile is maintained.
Productivity	• 12 hours is needed to squeeze out the water.	• ½ hour is needed to squeeze 33 to 50% water.
Human Effort	• More to carry the carpets	• Less

(b) Drying

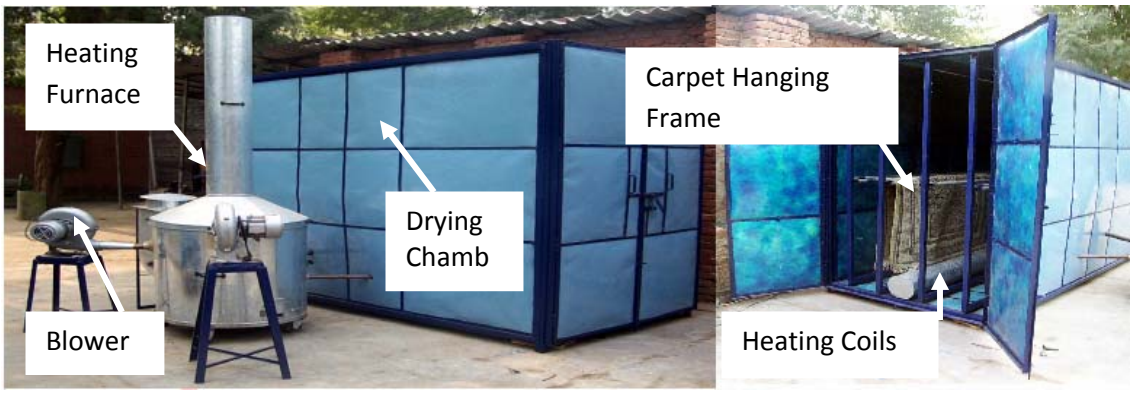
Parameter	Traditional	Improved
Quality	• Same	• Same
Productivity	• Time required for drying is more. • Drying depends upon weather conditions. • Floor space required for drying depends upon number of carpets to be dried.	• Time required for drying is less. • Drying is independent of weather conditions. • Floor space required for drying is fixed. • Operates on fossil fuel such as cow dung and electricity.
Human Effort	• Less	• Less

The salient features of the drying chamber shown in Fig. 7(b) are as follows:

1. The model combines option of operating the drying process on electricity or agro-based fuel.
2. Improved system for easy loading and unloading of carpets.
3. Room for four carpets is available for drying at one time.
4. Drying capacity increased using re-circulation of flue gases. A separate arrangement to accomplish the same is incorporated.
5. Two blowers are used for the circulation of hot air inside the chamber.

Table 2 shows the comparison between both kinds of drying techniques.

(a) Squeezing machine



(b) Drying chamber (left) and loading of a carpet (right)

Figure 7 Carpet drying devices

2.5 Hand tools

There are several hand tools used during the weaving of a carpet on the loom. Four of them, namely, beater, knife, comb, and scrapper, were improved mainly from the ergonomics point of view for the comfort and effectiveness of their usage. Two of them are explained here. If these improved tools are widely adopted significant reduction in the time for carpet weaving is expected, resulting in more productivity. Besides, hand injuries will be avoided improving the health conditions of the artisans.

2.5.1 Beater

Figure 4(a) shows an existing beater used by the artisans. Its purpose is to bring the knots together. From its look it appears that it has not changed over ages. Moreover, it has the following drawbacks:

1. The tool is heavy with no positive comfortable gripping.
2. The blades have non-uniform gaps.
3. The whole tool has to be discarded if one blade gets damaged.

(a) Traditional (b) Improved

Fig. 8 Beaters for carpet weaving

Hence, a new beater design was done, as shown in Fig. 4(b), which has the following features:

1. The tool has positive gripping with cushioning.
2. Adjustable gap between the blades.
3. Adjustable shape of blades.

A comparative study of the traditional and improved beaters is given in Table 3.

Table 3 Comparison of beaters

Parameter	Traditional	Improved
Quality	• Uniformity is not maintained.	• Aesthetically and ergonomically designed. • Standardized parts have been used.
Productivity	• Life cycle is less.	• Life cycle is more.
Human Effort	• Cumbersome to use.	• Easy and comfortable to use.

2.5.2 Knife

The traditional knife in shown in Fig. 9, which has the following drawbacks:

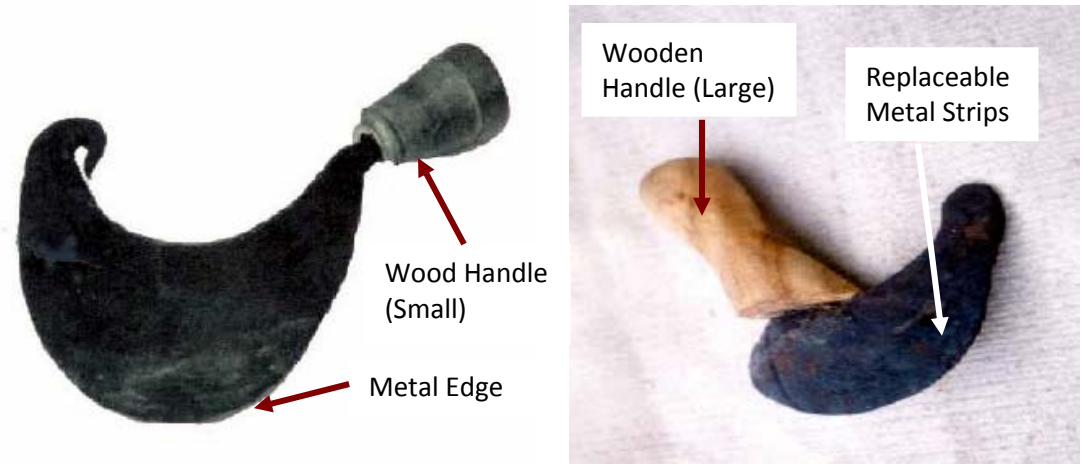
1. The handle was not comfortable which caused fatigue for the worker.
2. The knife edge required frequent sharpening.
3. Disproportionate weight of the knife made the knife ergonomically poor in design.
4. The cutter profile was uncomfortable.

The improved knife offers the following advantages:

1. Self-sharpening property due to the use of spring steel for cutting edge.

2. Weight of the knife was reduced to avoid fatigue.
3. The contact area of the handle was increased to reduce the possibility of any harm to the fingers.

Table 4 shows the comparison between the two knives.



(a) Traditional (b) Improved

Fig. 9 Knife for carpet weaving

Table 4 Comparative study of the knives.

Parameter	Traditional	Improved
Quality	• Uniformity is not maintained.	• Aesthetically and ergonomically designed. • Standardized parts have been used.
Productivity	• Life cycle is less.	• Life cycle is more.
Human Effort	• Cumbersome to use.	• Easy and comfortable to use.

3. Other Rural Sectors

In this section, the experiences of the author in developing technology for some other rural sectors are briefed. One of them in the area of sheep shearing, and the other one is in driving a machine using animal power.

3.1 Sheep Shearing

With the involvement of the carpet projects, the author was approached by the Central Wool Development Board (CWDB) under the Ministry of Textiles to develop an indigenous powered hand-held device to shear the hairs of a sheep. Figure 10 shows the action of such shearing in the

field. One such device which was developed after carefully studying the existing devices available in the World market is shown in Fig. 11. The new device has following features:

1. It was possible to develop comb and cutter materials which are comparable to the imported components.
2. The device was able to work with acceptable vibration range but with little more noise than the imported devices.
3. The manufacturing cost after several trials came out to be around Rs. 25,000 per device compared to about Rs. 60,000 for the imported one.

Fig. 10A shearer cutting sheep's body-hairs

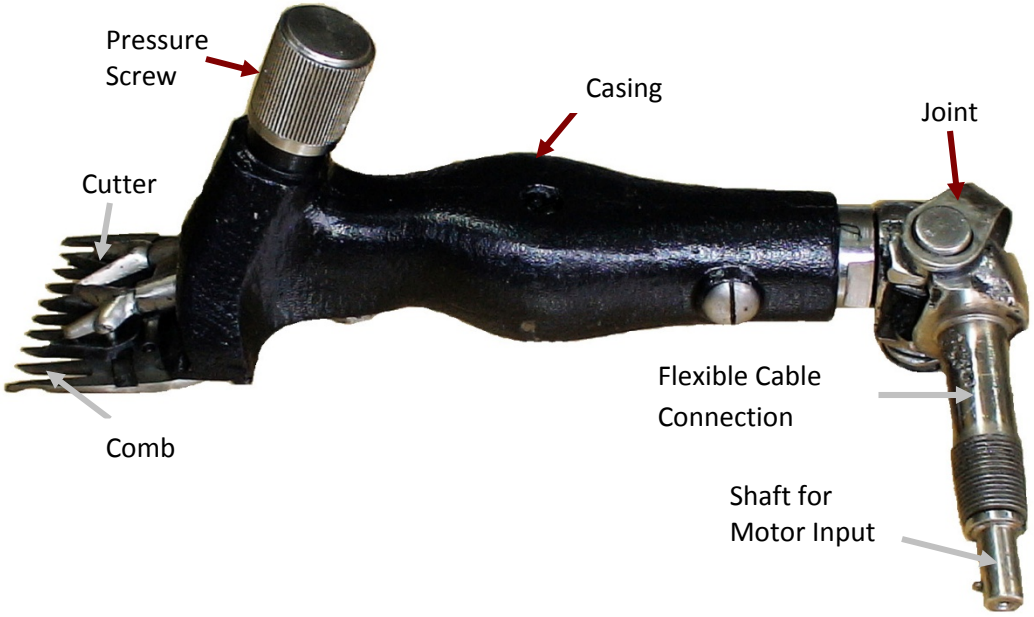


Fig. 11 Indigenously developed shearing device

3.2 Animal Driven Prime Mover (ADPM)

There are several places in India, e.g., Kanpur, Bhopal, where bullocks are used to run a machine in the villages, e.g., chaff cutting, water pumping, oil expelling, etc. These machines run at speeds ranging between 200 rpm to even 1400 rpm. Figure 12 shows the arrangement where two bullocks pulling a wooden rod of about 10 meter length. This walking typically generates about 2-3 rpm at the center of rod. This speed is then enhanced using a gear-box. The gear-box consists of several pairs of spur or helical gears giving speed-up ratios of 1:100 to 1:400. In 2003-2004, the author along with his co-workers took up a study on such gear-boxes for its optimum size and ratio. Additionally, a device to evaluate the performances of such device was also developed, which is shown in Fig. 13 [5]. This testing device is capable of comparing several such gear-boxes by evaluating its efficiency. At present a project is also undertaken under the Rural Technology Action Group (RuTAG) to use it for the evaluation of such gear-boxes developed by several individuals and NGOs.

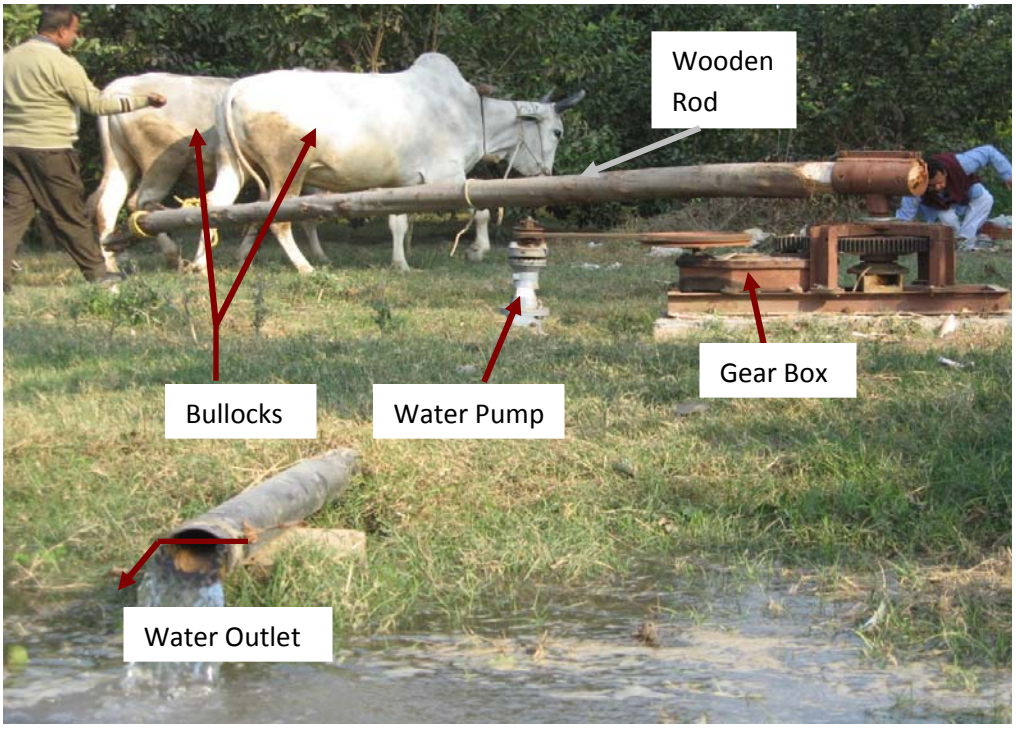


Fig. 12 Animal driven water-pump

4. A New Research Opportunity

While over the years several technologies for carpet and other sectors were attempted with the help of temporary project assistants/associates and rarely few students of IIT Delhi were involved. A general apathy or lack of enthusiasm was observed by the students. When these topics were floated as B. Tech or M. Tech projects, there was no taker. When enquired with the students, they replied “it is very interesting but I want to do in the area of Finite Element Analysis, Robotics, …” The author then realized that the above projects are not fashionable and

the students may feel that with the exposures to those topics they may not get a good job in the multinational companies or they may not be able to go abroad for higher studies. When these matters were discussed with his colleagues, their attitudes were not much different as those of the students. Barring few faculty colleagues others were keeping themselves away from such projects. These have led the author to think seriously for ways to attract the students, faculty colleagues, and other engineering professionals. It was realized that if Indian researchers do not take up research of their own needs then the problems will remain unsolved for ever. One such evidence is with respect to the hand-tools shown in Figs. 8(a) and 9(a). They appear to have not changed over last 40-50 years. As a result, the following actions were taken by the author:

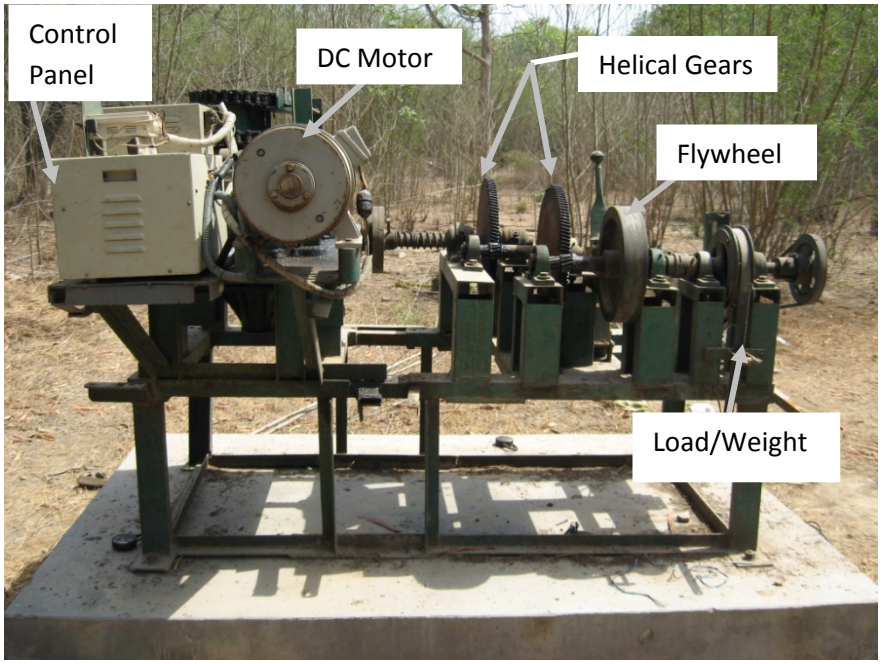


Fig. 13 Performance measuring test set-up for ADPM

1. Starting a campaign in the form of lecture series called “Multibody Dynamics for Rural Application (MuDRA)---Connecting Engineering Minds with Society.” This lecture was delivered already 20 different institutions across India and once in Poland to make students and faculty aware of the issues and how the modern knowledge can be blended with the rural problems.
2. Engaging M. Tech 1st and 2nd year students to analyze the rural systems, e.g., the metallic looms for carpet weaving, against some extra payment that is allowed by IIT Delhi. These results were then communicated to several conferences in India, mainly, to encourage them to participate in those conferences, thereby, enhancing their experiences. Such participations helped in exposing research contents in those rural problems to the audiences of the conferences.
3. The attempt of making students aware of the research contents in rural problems attracted one Ph. D student to take up the problem of “Dynamics analysis and optimization of complex mechanical systems like carpet scrapping machine.” This Ph. D research work resulted in not only several publications in reputed international journals and conferences but also a book published by the internationally reputed publisher Springer, Germany [3].

Through the publications it was proven to the academic community that even a rural problem has sufficient research content.

In the following, some of the above attempts are explained to give the reader a flavour of how the advanced knowledge can be blended with the rural problems.

4.1 Optimization of Carpet Looms

The metallic loom developed for weaving carpets was not readily acceptable to the users mainly due to the high price (about Rs. 13,000 in 2003 for weaving a 4 feet × 6 feet carpet compared to then price of Rs. 10,000 for the traditional wooden loom). Hence, an attempt was made by the Ph. D student to investigate the loom scientifically. First, the loading pattern was obtained based on the tensions provided to the warps (vertical threads), as shown in Fig. 14.

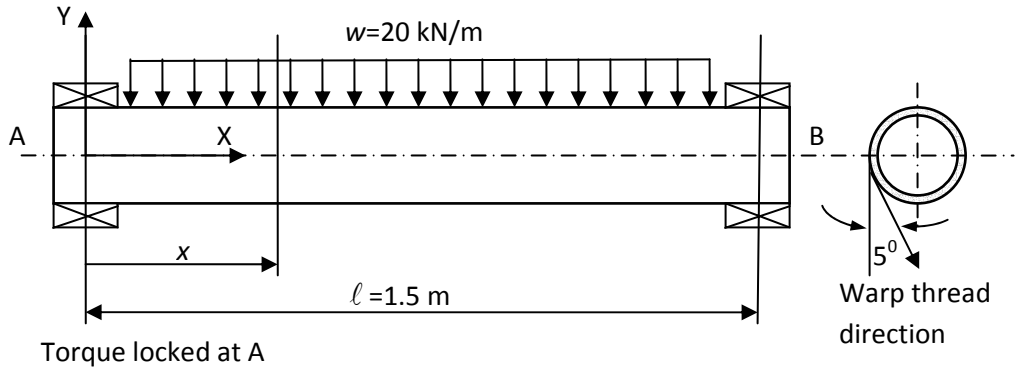


Fig. 14 Load model for the upper beam of the loom

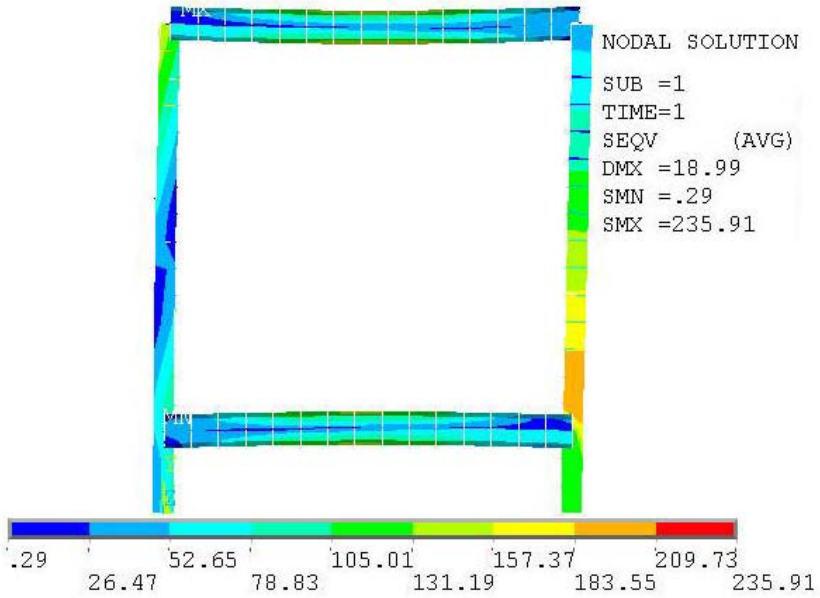


Fig. 15 The von-Mises effective stress contours in the beams and columns

Based on the above loading, complete static analysis and optimization of the loom was carried out to arrive at a design which has about 25% lighter, and accordingly the cost was less by same percentage. Further, to verify if the loom will sustain the tension or not Finite Element Analysis (FEA), a popular tool for the static analysis, using the commercial software called ANSYS was carried out. The results are shown in Fig. 15, which confirmed that the stress generated is within the strength of the loom materials. Hence, the optimized loom was satisfactory.

Through the above exercise, the candidate was exposed to a rural problem using the advanced knowledge of "constrained optimization" and modern computing tools like "MATLAB" and "ANSYS". Hence, publications were possible, e.g., [6,7].

4.2 Dynamic Analysis of Carpet Scraping Mechanism

The carpet scraping machine developed by IIT Delhi is shown in Fig. 4(b). Its kinematic diagram is given in Fig. 16, whose dynamics was analyzed by the Ph. D student using the knowledge of Multibody Dynamics, the core research area of the author. A general methodology was proposed by the Ph. D student for the closed-loop system using a methodology called "Decoupled Natural Orthogonal Complement (DeNOC)" user earlier for the robot analysis [8,9]. In order to reduce its vibration the machine was optimized for its reduced weight. To verify the results obtained using the proposed dynamic methodology [9], the mechanism was modeled using the commercial software ADAMS, a software used by a large number of automobile manufacturers for the analysis of the vehicle systems. The ADAMS' model and the verification are shown in Figs. 17(a) and (b), respectively.

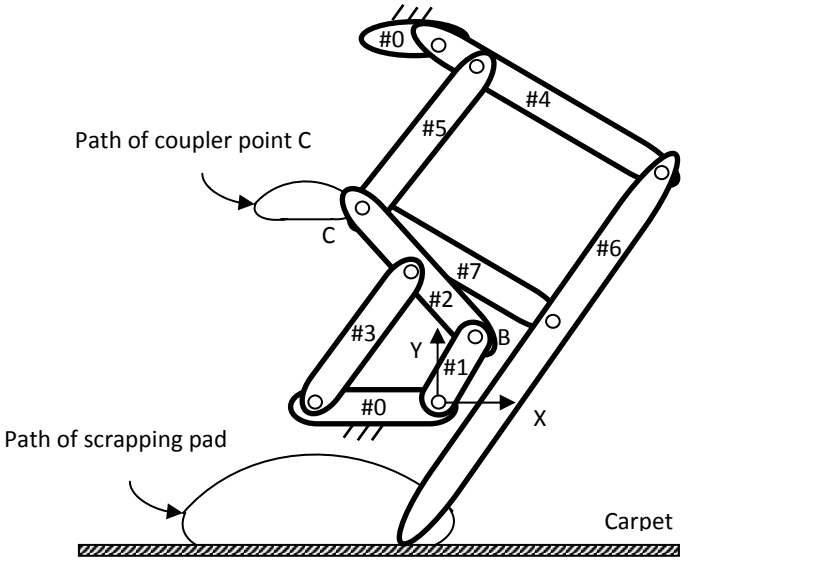
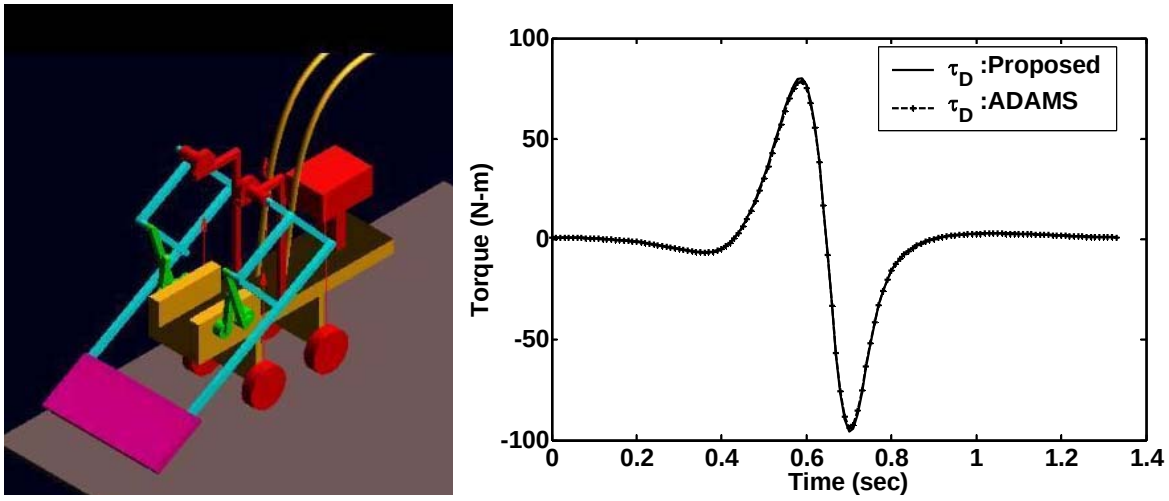
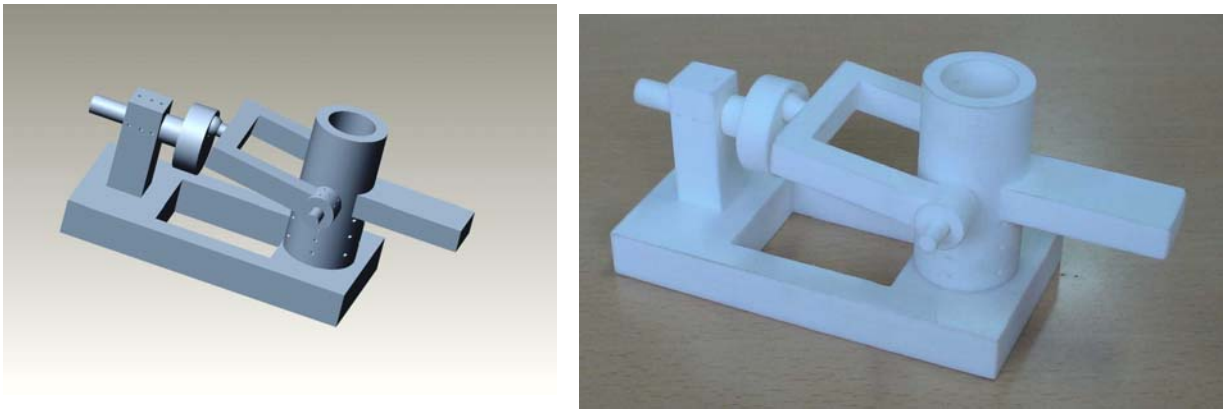


Fig. 16 Kinematic diagram of the carpet scraping machine



(a) ADAMS model (b) Comparison of the driving torques

Fig. 17 Verification of analysis results



(a) CAD model (b) Rapid prototype model

Fig. 18 A new synthesized 4-bar spatial mechanism

4.3 Analysis of Sheep Shearing Device

Inside the device shown in Fig. 11 lies a spatial 4-bar linkage that provides the reciprocating motion of the cutter in the front for the input motion of the shaft at the rear. Four M. Tech students were engaged on part-time basis to analyze the mechanism and synthesize a new mechanism for the same input-output motion characteristic. While the analysis results were published in a conference in Surat [10] the synthesized mechanism was reported in the 15th NaCoMM [11] held in IISC, Bangalore. The students were not only paid honoraria for their analysis/synthesis work as per IIT Delhi's norm but also paid for their travel and other expenses to attend the conferences. The students enjoyed the new places. In addition, they felt proud to be able to present their research output amidst many important dignitaries. Attending conferences was additional reward for the students besides getting exposed to real-life problems. Figure

18(a) shows the CAD model of the synthesized 4-bar spatial mechanism to obtain the same rocking motion of the cutter as available in the existing device. Its rapid prototype is shown in Fig. 18(b) to demonstrate the movements of the new mechanism.

5. Conclusions

In this paper, a set of devices developed for the rural sectors of India are presented. Whereas these developments have seen some degree of success they were not immediately accepted by our students and research community. Hence, an attempt was made to popularize them through the use of modern knowledge.

In fact, in many instances the problems associated with rural sectors were found to be quite difficult as no literature or document is easily available on their development. For example, what would be the end conditions for the columns of the metallic loom shown in Fig. 2. It took sometime by the author and the Ph. D student before satisfactory end conditions were found for which the analytical results and those by the ANSYS software are same. The non-availability of the well-documented literature may be one of the reasons that the students and researchers are reluctant to take up rural projects. This, however, can be considered as an opportunity for new research---the theme of this paper. The point was in the author's book on "Dynamics and Balancing of Multibody Systems" [3]. It is hoped that success stories of being able to publish books and journal papers would attract more and more students and researchers who are evaluated on the basis of such academic parameters towards such socially relevant rural projects.

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