Published in the Proc. of the 14th ISME Int. Conf. on Mech. Eng. in Knowledge Age, DCE, New Delhi, Dec. 12-14, Elite Publishing House Pvt. Ltd., New Delhi, pp. 66--72

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DEVICES AND MACHINES IN HANDMADE CARPET MANUFACTURING

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Abstract

A systematic approach to improve the existing tools and processes used by the artisans engaged in carpet sectors to enhance the productivity and the quality of the finished products in a cost effective manner have been initiated in 2000 by IIT Delhi [1]. Several machines like Carpet Loom, Scrapping Machine, Drying Machine, and Tools used in carpet manufacturing have been developed and tested in many carpet manufacturing belts, namely, Bhadohi, Mirzapur, Jaipur, Srinagar and other places of India. Among those two machines, namely, a carpet loom and a scrapping machine are taken up in this paper for further improvement to reduce their cost. The loom is a static structure and the scrapping machine is a dynamic system. This paper presents the overview of these newly developed machines and the associated features. In order to get wider acceptance to the users, the machines should be available at affordable prices. Hence, as a part of further improvement, modelling and optimization of the loom [4] and scrapping machines are undertaken.

Key word- Carpet Loom, Scrapping Machine, Handmade Carpet

1 Introduction

In recent time, if the highly labour intensive handmade carpet industry has to compete with the machine made carpets, it has to use innovative products by improving the associated devices which will improve the quality and rate of production. It should also provide a safe working environment. Handicraft sector is one of the largest export earners of India and it provides employment to a large number of craft-persons across the country. It is facing a tough competition from other handicraft exporting countries of Asia-Pacific region due to market liberalization [1]. Also, this labour intensive carpet industry has to compete with the machine made carpets. Thus, it has to improve mechanical devices which will improve the quality and rate of production. At the same time the safe working environment of the craft-persons should be improved using ergonomic principles wherever it is possible to do without significant increase in the cost.

Manufacturing of carpet involves several processes, as illustrated Fig. 1. A project [1] with the aims to improve processes, tools and machines involved in manufacturing of carpet was initiated in IIT Delhi in 2000. In the project a range of machines, processes, and tools designed and developed. They were Carpet Looms of different sizes, Scrapping machines for carpet washing, Drying machines, Moisture measuring device, Semi-automating washing machine, Embossing trimming device, and hand tools. These tools and machines have been tested in many carpet manufacturing belts, namely, Bhadohi, Mirzapur, Jaipur, Srinagar, Bhalsar and other places of India. Among those two machines, namely, a carpet loom and a scrapping machine are taken up in this paper for further improvement to improve their performance and reduce their cost.

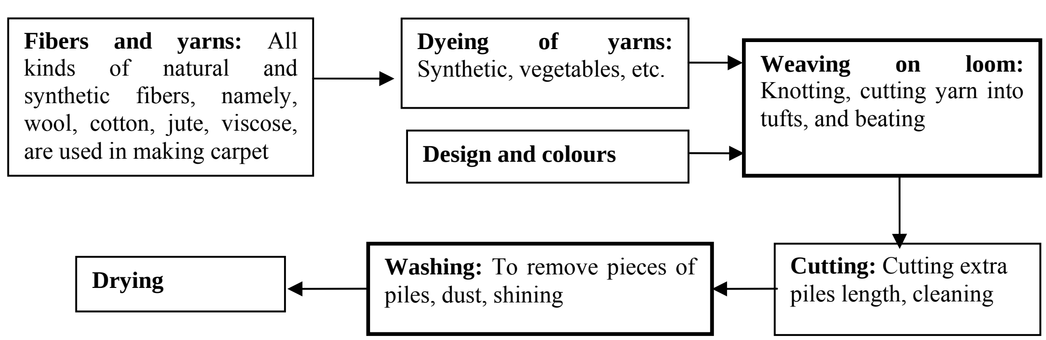


Fig. 1 Flow chart of carpet manufacturing process

The paper is organized as follows: Section 2 introduces carpet handloom, difficulties with traditional loom, and salient features of the new metallic loom. Besides, the outline of its optimization [2] is provided with its dimensions of the main components. Also, dimensions of the components of the optimized loom are given. In Section 3, the carpet scrapping machine and its working is introduced. Attempts to reduce forces transmitted to the ground that cause vibration in the machine [3] are also highlighted in the section. Conclusions and scope for further study are given in Section 4.

2 Carpet loom

Carpets woven by hand on a structure called loom. Weaving of carpets is different in many aspects from the weaving of a fabric [4]. There is no better kind of the carpet than carpet made by hand; though this is far from implying that all hand-tufted carpets are superior to all machine-made ones [5]. The carpet is generally woven in a warp, i.e., a chain of vertical threads, fixed almost vertically in front of the weaver. Required length of warp threads wrapped over upper beam is called warp-beam. The warp-beam is supported by a pair of columns, which is about 1.8 m high, as shown in Fig. 2. Tuft of wool or silk is inserted between two warp threads and knots it. The knotting continues along the whole row. Then, the row is pressed using a tool called beater. Carpet's knotting proceeds according to the carpet design. Traditionally, carpets are woven on wooden looms, as in Fig. 2. They are becoming economically, environmentally, and functionally non-viable due to the following reasons [6]:

- Life is limited (5-8 years) due to susceptibility to termites and frequent investments are required;
- Deforestation;
- Laborious tensioning, as rope arrangement is used to generate high tension in the warps (take 30-40 minutes for 3-4 persons required to do this job);
- Rope is flexible. Hence it is loosed over the time and frequently tightening is required; and
- Non-uniform tension in the warps over the time because the wooden beams gradually bends. The non-uniformity affects quality of the carpet.

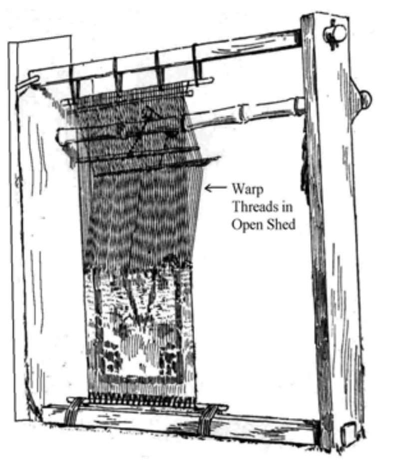
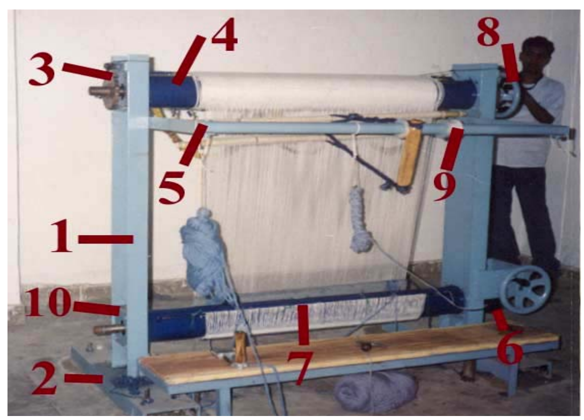


Fig. 2 A wooden loom



(1. Support Channel; 2. Base Channel; 3. Ratchet and pawl; 4. Upper (Warp) Beam; 5. Shedding Pipe; 6. Tensioning Device; 7. Lower (Cloth) Beam; 8. Handle; 9. Shedding Roller; 10. Bush Bearing)

Fig. 3 Metallic improved loom [6]

To get over these difficulties, a metallic loom was developed, considering all the aspect of carpet [6], as shown in Fig. 3. It has the following silent features:

- Metallic structure and long life (about 20 years);
- Geared tensioning device that make easy to generate tension in the warps by one person only. It is a self-locking device that locks lower beam rotation;
- Upper beam locking is provided by ratchet and pawl mechanism;
- Beams are hollow pipes to carry more load with low weight;
- Shedding arrangement with polypropylene rollers on shedding beam which help in easy movement of shedding shaft;
- Seating arrangement for weaver.

The side columns that support the beams are made of rolled channel sections. The upper and lower beams, and two side supports contribute almost 90% of the loom weight and proportionately its cost. In order to reduce the cost of the loom (presently it is about Rs.15000 for 1.5m×1.8m loom size) and make it affordable to the poor-weavers, weight optimization has been carried out in the Ph.D. research work of the first author [2].The optimization problem is formulated as to find the optimum weight of hollow circular beam and hollow square columns. The problem is mathematically posed as

For beams:

$$\text{Minimize,} \quad W \equiv \rho \pi \ell \alpha t^2 \tag{1}$$

$$\text{Subject to,} \quad \sigma_{max} \le S_y ; \tag{2}$$

$$\delta_{max} \le \delta_{all} ; \text{ and} \tag{3}$$

$$t \ge t_{min} \tag{4}$$

For columns:

$$\text{Minimize,} \quad W \equiv 4 \rho L \beta t^2 \tag{5}$$

$$\text{Subject to,} \quad \sigma_{max} \le S_y ; \tag{6}$$

$$\sigma_{Buk} \le S_y ; \text{ and} \tag{7}$$

$$t \ge t_{min} \tag{8}$$

where ρ is the density of the material, σ_{max} is the maximum Von Mises stress, δ_{max} is the maximum deflection, and t is the thickness of the beam. Moreover, S_y, δ_{all} and t_{min} are the yield strength of the material of the beam, the allowable beam deflection so that the carpet quality is not suffered, and the minimum available beam thickness, respectively. α is mean-diameter-to-thickness ratio of the beam. For the column, $\beta = b/t$—b being the mean width and σ_{Buk} is the stress due to local buckling. ℓ and L are the length and height of the beam and column, respectively. The optimization problems posed in eqs. (1)-(4), for the beam and in eqs. (4)-(8), for the columns, are nonlinear two-dimensional constrained minimization problem as there are two variables, namely, d and t, for the beams, and b and t for the columns. Hence, the graphical method [10] can be easily adopted. The optimized dimensions of the cross-sections of beams and columns are given in Table 1. The results are also verified by the standard finite element analysis (FEA) tool ANSYS 7 [6] under more realistic boundary conditions. The comparison of results with those reported in [4] is shown in Table 1. The optimized weight per unit length, W, for beams and columns is found for allowable deflection of beam denoted by δ_{all}. It shows substantial weight saving, almost by 34.5% for beams and 83.8% for columns.

Table 1 Comparison of optimized components with that those reported in [6]

Components		Saha et al. [6]	Optimized
Beam	Section	Hollow Circular	Hollow Circular
	Sy, MPa	360	150
	δ_{all}, mm	5	3
	d, mm	135	114
	t, mm	5	3.8
	W, Kg/m	16.2	10.6
Column	Section	Channel 200×75	Hollow Square
	S_y , MPa	240	240
	b, mm	-	76.9
	t, mm	-	1.4
	W, Kg/m	20.6	3.33

3 Carpet scrapping machine

Carpet processing involves several steps, e.g., weaving (hand knotting), washing, drying, trimming, etc. In this section, focus is given on the carpet washing. The carpet woven on handloom is to be washed and trimmed an extra tuft length. This is traditionally done manually using wooden plank, as depicted in Fig. 4. The manual work causes a lot of fatigue and the workers cannot the clean carpets evenly. The following is the feedback from the washers about the manual scrapper based washing [7]:

- Scrapper with long wooden handle has short life, low weight and breaks easily;

- Because of the low weight, a washer needs to apply more pressure to wash, and the cleaning requires several scrapping repetitions;
- It is time consuming process and not safe due to chemicals used with the water to clean the carpet.

To overcome the problems, a carpet scrapping machine, as shown in Fig. 5, has been conceived, designed and fabricated at IIT Delhi [7]. The machine generates a path like a washer man. Hoeken's four-bar linkage, O_1-A-B-O_2 of Fig. 6, is suitable for this application [8]. The mechanism is a crank-rocker which is driven using an electric motor. The straight line stroke generated by the Hoken's mechanism is less. Hence, to magnify the stroke length, a pantograph mechanism, O_3-D-F-C-E, Fig. 6, is used. Schematic diagram of the combination of the Hoeken's and the Pantograph mechanisms of the carpet washing machine is shown in Fig. 6. The scrapper pad is attached at the point, T, of link #5. To generate a straight line of about 450 mm, the followings links lengths are required [9]:

Fig. 4 Traditional method for washing carpets

O_2A=38.1; AB=115.2; O_2B=115.2; O_1O_2=89.5; AC=2AB;
O_3E=95.6; O_3D=334.6; CE=ED=DF=FC=239; DT=836.5

The system has 8 links, #0, …, #7, and three independent closed loops namely, 0-1-2-3-0; 0-1-2-7-0; and 0-1-2-6-5-4-0. All the joints in the machine are revolute. The salient features of the machine are as follows:

- Speed of scrapper attached to the machine is same as that of manual speed of scrapping;
- The machine is supported on 4 wheels; Two front wheels are powered;
- Reduction gearbox is provided;
- The machine can be handled by one person;
- Scrapper pad covers 600×800 mm^2 area in a single stroke, which is approximately, two-times than that of manual scrapping;
- Even washing and the scrapping pad opens piles more than a manual operation.

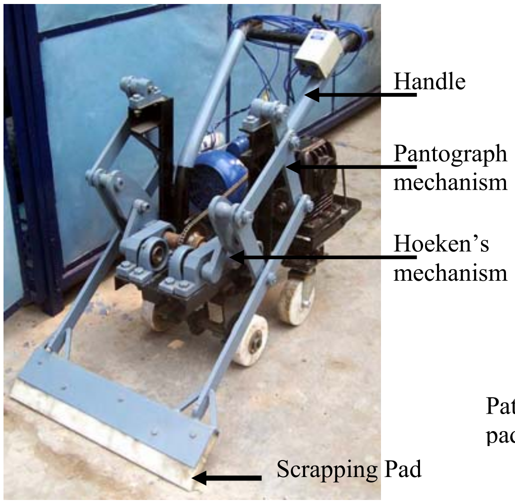
The mechanical device serves the purpose fairly well but it is heavy to manoeuvre and again not affordable to the poor carpet washers. To reduce its weight and smooth running, a systematic approach based on the multibody dynamics concepts has been undertaken in the Ph.D. research of the first author. The system being dynamic, it is necessary that its dynamics is understood well before taking up the optimization activities. The following aspects are important for the study:

- Understanding the closed-loop dynamics to find the constraint forces and moments;
- The dynamic equations of motion to compute the constraint reaction forces;
- Optimize the shaking forces/moments transmitted to the frame;
- Reduce the weight and price by changing shape, size, and material of the components.

Table 2 Link parameters

Link	Length (mm)	Mass (Kg)	Moment of inertia@ C.G. of link ($Kg\text{-}mm^2$)
O_1A	38.1	0.35	42.34
AC	230.4	2.45	10838.02
O_2B	115.2	0.55	608.26
O_3D	334.6	1.70	15860.60
DT	836.5	3.50	204088.86
FC	239.0	1.27	6045.30
CE	239.0	1.27	6045.30

Kinematic and dynamic analyses of the machine were also done using ADAMS (Automated Dynamic Analysis of Mechanical System) software available in IIT Delhi. The ADAMS model is shown in Fig. 7. The input motion provided to link # 2 is a constant speed of 45 rpm (4.7124 rad/sec). Link lengths and inertia properties are given in Table 2. Driving torque needed to run the machine at constant speed (45 rpm) along with the bearing forces at O_1, O_2, and O_3, are shown in Fig. 8. Figure 6 shows that the torque changes sharply during 0.4 to 0.8 sec. Because of this sudden change, the machine is not working smoothly. In the next phase, we are trying to optimize the machine for minimum weight, smooth the driving torque, and minimize the vibrations by reducing the bearing forces.



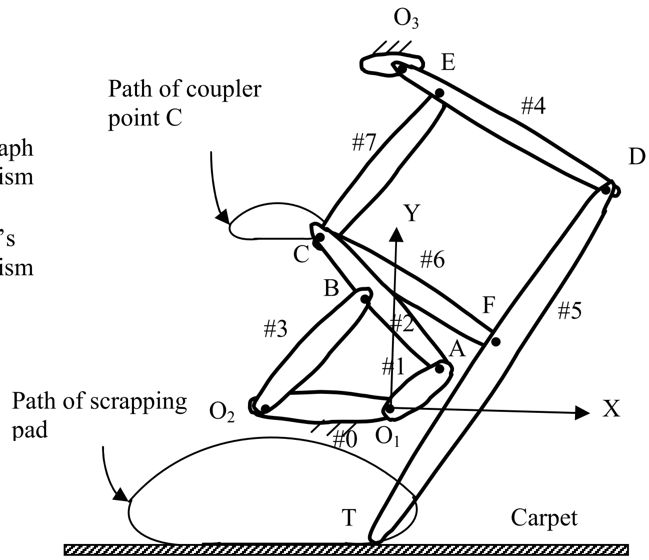


Fig. 5 Photograph of scrapping machine

Fig. 6 Schematic diagram of mechanism

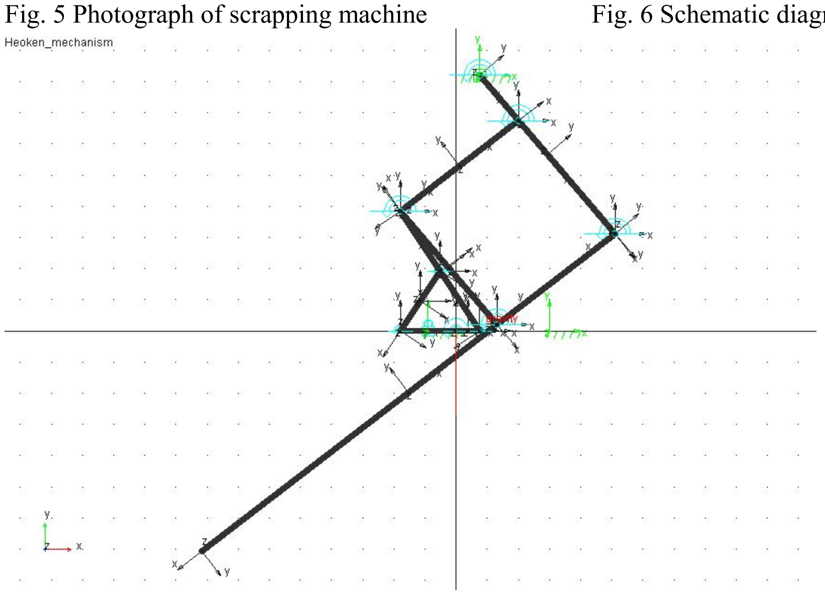
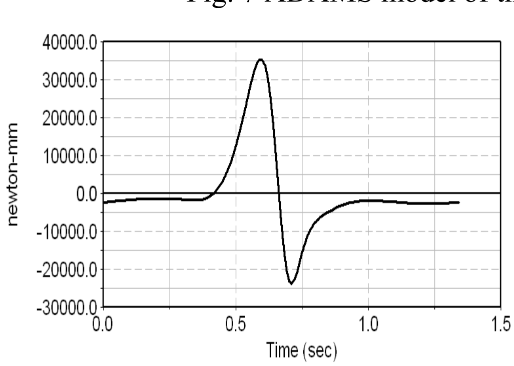
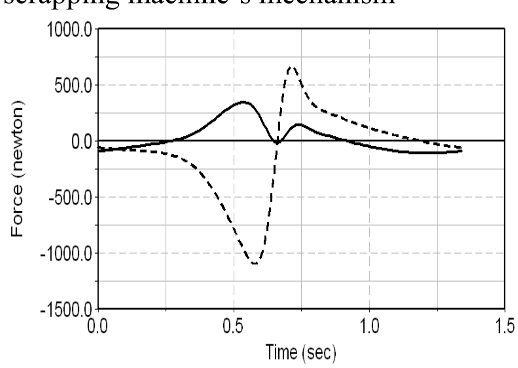


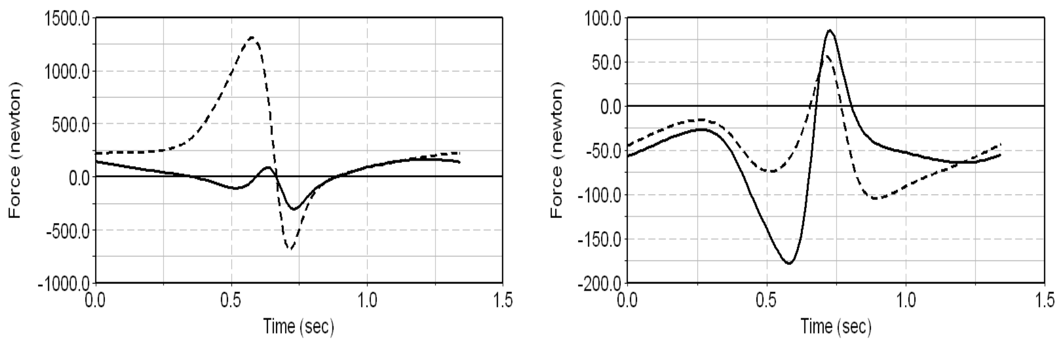
Fig. 7 ADAMS model of the scrapping machine's mechanism



(a) Driving Torque



(b) Reaction at O_1



(b) Reaction at O_2 (b) Reaction at O_3

Fig.8 Driving torque and bearing forces

4 Discussion and conclusions

Overview of the development of two machines used in handloom carpet industries is presented in this paper, including their improvement and scientific analyses. Modern tools like ANSYS and ADAMS were used to analyses the static structure of the loom and dynamic behavior of the scrapping machine, respectively. Though this work a new research dimension which is expected to improve and help the carpet and rural industries is exposed.

Acknowledgements

The research work reported here was possible due to the financial support provided by the Government of India under Quality Improvement Program, and the study leave granted by M.L.V. Textile Institute, Bhilwara (Raj.), India to the first author.

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