Chapter 12
Redesigning the Humble NMC (New Model Charkha)

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1 Introduction

The word “Khadi” is synonymous to natural, freedom, and self-reliance in India. A large population in India is engaged in khadi activity, i.e., producing yarn and fabric manually using cotton, silk, and wool fibers. Over 12 lakh people are involved in the Khadi sector and a vast majority of them are women. It gives employment opportunities to large number of people in rural India. Khadi production has increased from Rs. 811 crore (Rs. 8,110 million) in 2103–14 to Rs. 1066 crore (10,660 million) in the year 2015–16 [1]. Out of this cotton, khadi production has increased from Rs. 672.74 crore in 2013–14 to Rs. 936.20 crore in 2015–16. Government of India is trying to popularize Khadi especially amongst the youth. Kahdi sector faces many challenges, which are given as follows:

- availability of spurious mill made look alike khadi products
- development of fashionable products suitable for young aspiring new generation Indians
- opening up sales and distribution network to ensure steady sale at remunerative prices
- increase in wages to stop migration of artisans to other economic activities and
- development of efficient, affordable equipment used in khadi sector.

NMC (New model charkha) is a small manually driven spinning machine equipped with 4–8 spindles. These are running across the country to produce cotton and poly-vastra (polyester-cotton blended) khadi yarns. A large number of ladies from lower

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strata of society in the villages are engaged in spinning yarn. It is the only means of livelihood for these people during the months when farm activities are minimal. It also supplements their family income by keeping them occupied whenever they are free from household chores. There is an urgent need to improve the existing N M charkha for enhancing productivity and reducing the effort required to run it for reducing drudgery. A design analysis of NMC from technological consideration was reported [2]. In the present study, an attempt has been made to redesign the NMC with a view to eradicate drudgery and improve productivity.

2 Working Mechanism of NMC Charkha

NMC charkha is a miniaturized version of commercially available ring spinning machine. The machine essentially consists of four sections as shown in Fig. 1. Roving feed unit keeps the roving bobbins hanging in a creel. The bobbin holders are almost frictionless. The roving ends are passed through roving guides and fed to the nip of back drafting rollers. The drafting unit consists of three pairs of rollers pressed against each other by spring. The bottom drafting rollers are made of steel with grooved surface. The top rollers (back and front) are made of steel with synthetic rubber sleeve fixed on it. An apron passes over the middle pair of rollers and extends forward close to the nip of front rollers to guide the fibers in the front drafting zone where the draft is quite high. This guidance is required to avoid uncontrolled movement of short fibers which causes irregularity in the yarn otherwise. The three pairs of rollers move at progressively higher speed in order to stretch the roving (known as drafting). As a result, the roving becomes finer as it emerges from the front roller nip of the drafting unit.

Each twisting unit consists of a spindle, ring, and a traveler. The circular rings are mounted on a platform called "ring rail" that moves up and down along the length of the bobbin fixed on the spindle. The ring acts as a track for the tiny C-shape traveler. The movement of ring rail helps in laying the yarn over the entire length of bobbin. Initially, a small segment of yarn is wound on the bobbin. The end is pulled out and is threaded through the traveler, lappet guide up to the nip of front rollers. As the handle is turned, both the drafting rollers and the spindles start rotating. The

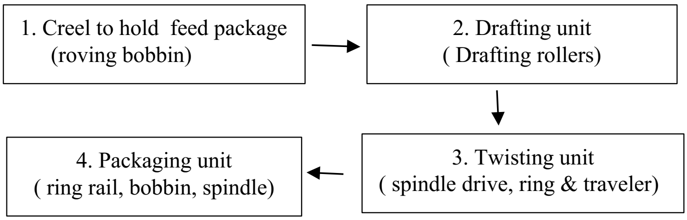


Fig. 1 Schematic of different sections of NMC Charkha

drafted roving along with the yarn end already attached to the nip of front rollers are delivered together. The yarn rotates around the spindle axis forming an envelop called balloon. Each revolution of the balloon inserts one twist into the yarn. As the yarn end receives twist it transmits twist into the delivered fleece of fibers emerging from the front roller nip. The twisted yarn is simultaneously wound on the bobbin. The rotation of the spindle, therefore, serves two purposes: twisting and winding of the yarn.

Kinematic Relationship

At steady-state operation, whatever length of yarn is delivered, the same is wound on the bobbin and hence

$$yarn\,delivery\,rate = winding\,rate$$

Let,

d_B = bobbin diameter, d_{FR} = Front drafting roller diameter, n_{FR} = Front drafting roller speed, n_B = bobbin speed, n_S = spindle speed, and n_T = Traveler speed and v = front roller delivery.

$$yarn\,delivery\,rate : v = \pi \times d_{FR} \times n_{FR} \tag{1}$$

$$yarn\,winding\,rate = \pi \times d_B \times (n_B - n_T) = \pi d_B(n_S - n_T), [n_B = n_S] \tag{2}$$

Mathematically, $v = \pi \times d_B(n_S - n_T)$

Rearranging the above equation, it can be stated that

$$Traveller\,speed : n_T = n_S - \frac{v}{\pi d_B} \tag{3}$$

Yarn twist is the number of turns inserted by the traveler per unit length of delivered yarn.

$$Yarn\,twist = \frac{Traveller\,speed}{front\,roller\,delivery} = \frac{n_T}{v} \approx \frac{n_S}{v} \tag{4}$$

As the ratio $1/\pi d_B$ is too small in comparison to spindle speed. For all practical purposes, traveler speed is almost equal to spindle speed.

Draft

Mechanical draft is based on linear speeds of drafting rollers. It reflects stretch the roving experiences during drafting.

$$Mechanical\,draft = \frac{surface\,speed\,of\,front\,drafting\,roller}{surface\,speed\,of\,back\,drafting\,roller} = \frac{\pi \times d_{FR} \times n_{FR}}{\pi \times d_{BR} \times n_{BR}} \tag{5}$$

$$Or = \frac{linear\,movement\,of\,front\,roller\,per\,revolution\,of\,backroller}{linear\,movement\,of\,back\,roller\,per\,revolution}$$

Actual draft is based on weight per unit length of input and output material. Accordingly

$$Actual\ draft = \frac{Roving\ count(tex)}{Yarn\ count(tex)} = \frac{yarn\ count(Ne)}{Roving\ count(Ne)} \quad (6)$$

where tex and Ne are units of count of roving/yarn in direct and indirect systems.

3 Broad Design Objective

The broad design objective was to modify the existing design of NM charkha with a view to improve productivity and reduce drudgery.

4 Methodology

The methodology followed is depicted in the form of a flowchart (Fig. 2). To fulfill the broad design objective, it was felt necessary to thoroughly study the existing charkha first. The focus areas were:

- User friendliness of the charkha from operator's point of view and
- Analysis of existing design (motion transmission from handle to different parts of the equipment).

The study was conducted in actual user environment.

After through interaction with the operators, the following observations were made:

- In the hand-driven NMC (New model Charkha), the operator sits on the floor in a squatting posture and turns the handle by right or left hand. The posture leads to stress generation in trunk muscles and spine. Fatigue sets in and the efficiency of worker gets reduced.

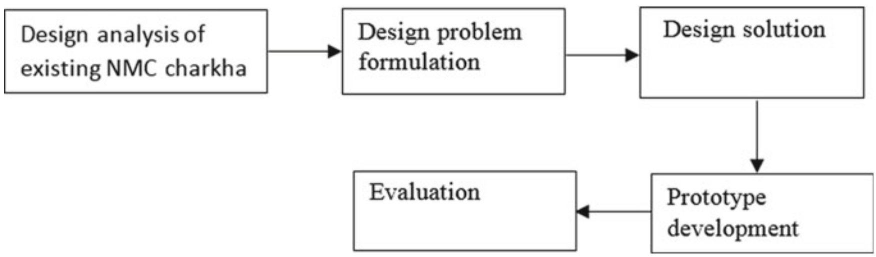


Fig. 2 Block diagram of design activities

Table 1 Specific design objectives

S. no.	Objectives	Reason	Means
1	Reduction in power required for transmission of motion	Reduction in drudgery	Redesigning the motion transmission
			Replacement of gears by chains and sprockets wherever possible
			Reduction in weight of shafts
			Employing bearing on shaft and gears wherever possible
			Reduction in number of pulleys driving the spindles by half, i.e., development of twin spindle drive
2	Use of leg power	Reduction in drudgery, increase in productivity and making hands free	Conversion from hand driven to pedal driven
3	Provision to run by hand	Options in case operator does not like sitting on a stool to turn the handle of the machine	Providing detachable handle to turn by hand keeping pedal in inoperative mode
4	Smoothening ring rail movement	Reduction in end break and better bobbin formation	Redesigning of mechanism of ring rail movement
5	Minimum change	Fabrication easy	Using existing frame

- The operator suffers from many health-related problems such as back stress, muscle pain, body ache, etc.
- In case, one thread breaks during spinning, the operator has to stop rotation of the handle, i.e., stop the equipment and use both hands to mend the thread. Production of rest of the spindles suffers due to stoppages.
- For mending thread break, she has to bend repeatedly causing bending stresses and strains on her trunk.
- The operator sits not at the center of the charkha but nearer to the handle. Hence, she has to stretch her body whenever end breaks to reach the spindle.
- Ring rail was found to move in jerky manner while changing direction of traverse at both the upward and downward strokes while laying the yarn on the bobbin.

Based on the problems cited above, the specific design objectives were formulated as stated in Table 1.

5 Design Solution

5.1 Gear Reduction by Incorporating Chain and Sprocket

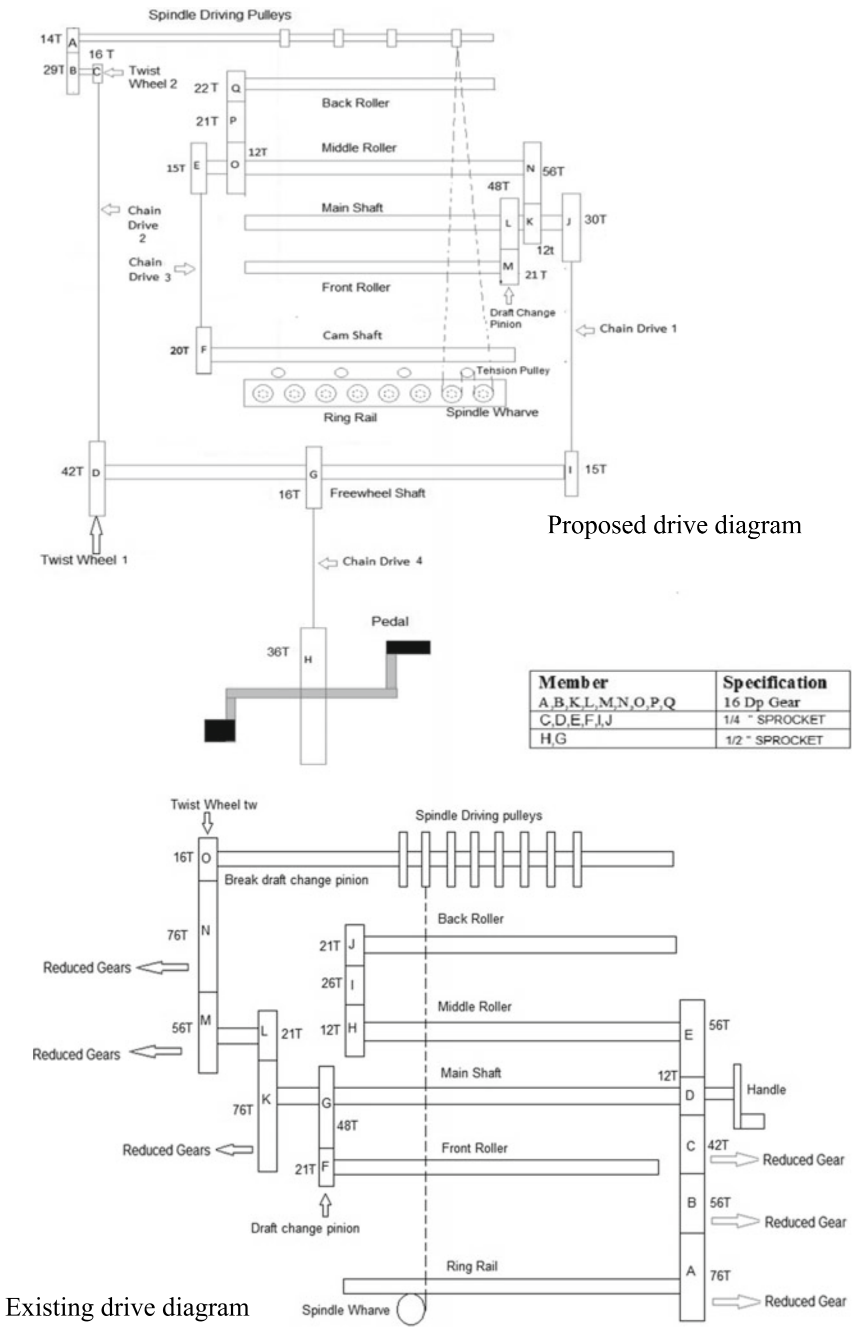
The gearing drive of old and new designs are shown in Fig. 3. There are 15 spur gears in the present model of Charkha to transmit drive to all rotating members from a single source, i.e., turning handle, mounted on main shaft. Gears on left-hand side are used to provide motion to spindle-driving pulley shaft and front drafting roller. In the existing design, motion is transferred from main shaft to spindle-driving pulley shaft maintaining a speed ratio of 12.66:1. The train of gears in the LHS of the machine was replaced by chain and sprocket gear.

A pedal was introduced to run the machine by feet. A new shaft (Freewheel) was fixed on the machine frame on which a free sprocket wheel was mounted. A speed ratio of 2.25:1 was used between the pedal and freewheel shaft. From the freewheel shaft, motion is transmitted by chain and sprocket to the spindle-driving pulley shaft. Chain drive between D (42T) and C (16T) is used to transmit motion to the carrier gear. Speed ratio of 2.625:1 is maintained in the first step. The remaining ratio of 1.81:1 is achieved using a group of spur gears B (29T) and C (16T). As a result, the initial four-step drive mechanism is reduced to two-step mechanism. The schematic side view of the charkha is shown in Fig. 4.

5.2 Ring Rail Drive Design

The ring rail is a platform to hold the rings on which the traveler runs. It rests on the end of a lever which is pivoted at the other end on the machine frame. The lever is moved up and down along an arc by a rotating cam—follower arrangement (Fig. 5). In the existing design, the lever is bolted on the side frame. With continuous movement, the hole on the machine frame to which the lever end is fixed becomes eccentric resulting vibration and occasional jerks in its movement. The tip of the lever makes point contact with ring rail. The point contact shifts along the width of the ring rail and moves away from the center of gravity which produces a tilt in the ring rail. With minor disturbance in alignment, the motion of rail momentarily stops as it gets jammed in vertical guiding slots.

The first limitation was solved by inserting a bush with bearing on the side frame. A small shaft was passed through the bearing and the long lever was fixed to it. The second issue was tackled by converting point contact between lever tip points with ring rail by a line contact by attaching a small bearing at the tip of the lever.



Member	Specification
A,B,K,L,M,N,O,P,Q	16 Dp Gear
C,D,E,F,I,J	1/4 " SPROCKET
H,G	1/2 " SPROCKET

Fig. 3 Gearing diagram of existing and proposed NMC Charkha

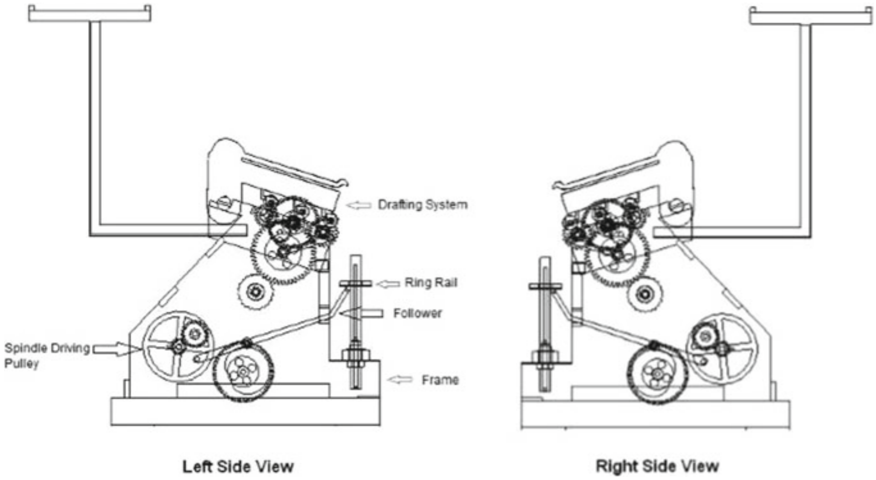


Fig. 4 Schematic side view of NMC

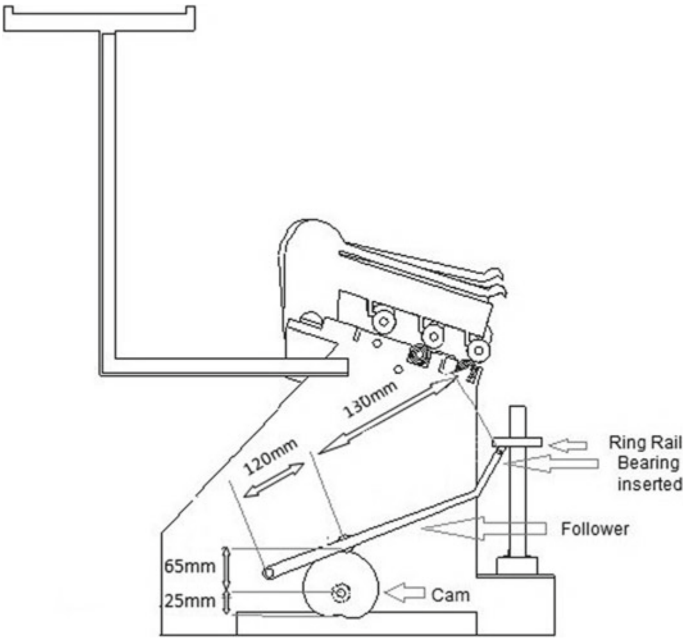


Fig. 5 Schematic view of drive to ring rail (lower)

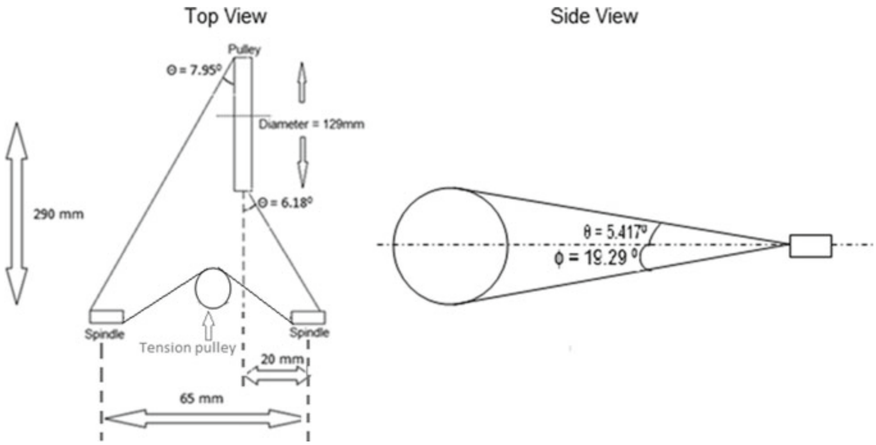


Fig. 6 Twin spindle drive from single pulley

5.3 Spindle Drive

At a normal speed of 60–80 revolution of the handle, the spindle rotates at about 6000–8000 rpm. Cords are used to transmit motion from driving pulleys to the spindles. Eight equidistant pulleys are mounted on spindle-driving shaft to drive eight spindles.

For twin spindle drive, eight pulleys were replaced by four pulleys only. The driving pulley was placed at a distance of about 12.5 mm offset from the center of two consecutive spindles (Fig. 6). A tension pulley in spindle drive was introduced to avoid slippage of the belt driving a pair of spindles.

For every rotation of the paddle, the spindle rotates by 148 turns and delivers 7.83 in. (19.8 cm) of yarn per spindle position.

5.4 Weight Reduction

The existing ring rail is made of cast iron and therefore is quite heavy. Its weight was reduced by choosing aluminum which resulted in weight reduction from 1.02 to 0.46 kg. Due to the replacement of many gears and pulleys of the existing model by chains and sprockets, there was a further reduction in weight of rotating/moving parts as shown in Table 2.

Therefore, 2.52 kg of dynamic weight was reduced in the proposed model which will reduce the effort required to spin the yarn and make its motion smoother.

Table 2 Weight comparison

Model	Weight (kg)	Components
Present model	5.58	Gears (8) + pulleys (8) + ring rail (1)
Proposed model	3.06	Gears (2) + chain (2) + sprocket (6) + pulleys (4)

5.5 Operation

A seat was provided at the center of the machine at an appropriate distance and height for the operator so that she can pedal easily. For support, a hand bar was provided for gripping.

Provision was kept to disengage the chain and sprocket and run the machine by turning the handle as some women operator was found to prefer running the machine in sitting posture on the floor.

6 Productivity Calculation

In the present model, the handle is the primary source of power, whereas in modified design, pedal is the primary source of power. Front roller delivery was estimated for the existing model and modified models by considering one revolution of the handle and the paddle, respectively.

For existing model:
Revolution of front roller per revolution of handle, $\mathrm{N} = 1 \times \frac{48}{21} = 2.2857$ turn
Therefore, front roller delivery $= \pi$ D N $= 3.14 \times 1 \times 2.2857 = 7.18$ inch $=$ 18.24 cm.
For Modified model:
Revolution of front roller for one revolution of handle, $\mathrm{N} = 1 \times \frac{36}{16} \times \frac{15}{30} \times \frac{48}{21} = 2.57$
Front roller delivery $= \pi$ D N $= 3.14 \times 1 \times 2.57 = 8.07$ inch $= 20.5$ cm.

Therefore, in modified model, productivity is increased by nearly 12%.

Apart from direct increase in front roller delivery to increase productivity, the other measure chosen was:

- Addition of two more spindles, i.e., instead of eight-spindle charkha it is ten-spindle charkha. Which increases productivity by another 25%.

7 Energy Consumption

One of the objectives of the project was to decrease drudgery. With a view to asses this, the energy consumptions before and after design modification were assessed.

Table 3 Power consumption

Model	Spindle Speed (rpm)	Average main shaft speed (rpm)	Power consumption (W)
Existing	6800	63	125
Modified design	6800	61.5	96

Table 4 Comparison of Yarn properties

Yarn	Khadi institutions			
	Jhargram Khadi and Village industries association	Swarajya Ashram, Kanpur	Udyog Bharti, Gondal, Rajkot	Coimbatore North Sarvodaya Sangh
Nominal count (Nm)	55 Nm (33 Ne)	38 Nm (23 Ne)	45 Nm (26.4 Ne)	55 Nm (33 Ne)
Actual count (Ne)	33	22.2	26	19
Twist multiplier (TM)	4.5	3.62	4.36	4.4
Twist (tpi)	26	19.7	22.2	19.2
Tenacity (g/tex)	9.4	14.0	12.2	9.6
Count strength product (CSP)	1898	2070	1660	1614

The energy consumption in different zones (viz. spindle drive zone, drafting zone, and gearing zone) were measured with a view to identify major energy consuming zone/zones.

It can be observed (Table 3) that steady-state power consumption in modified design is 96 W in comparison to existing model which is 125 W. This means there is a saving of 23% power in running the new charkha.

8 Yarn Quality

Four prototype charkhas of modified design were made and sent for field trial to four Khadi institutions at different parts of the country. They were asked to spin whatever they were spinning with their existing raw material. Yarn samples were collected from them and quality testing was carried out at IIT Delhi. The results are stated in Table 4. The count spun being different strict comparison between the yarns is not justifiable.

The general observations are given as follows:

- On the charkha 38–55 Nm yarn can be spun successfully.

Table 5 Features of newly developed charkha

1	Mode of drive: Pedal or by hand (Hence, it gives flexibility to run either by feet or hand)
2	Free rotation of chain in case of accidental reverse turning of pedal (avoids reverse rotation of rollers and thereby end breakage)
3	Number of spindles increased from 8 to 10
4	Reduction in number of gears and spindle-driving pulleys to make it lighter
5	Less soiling of operator's clothing (being above the floor)
6	Ring rail movement smoothened
7	Hands-free operation: support handle for balancing
8	Twin spindle drive (single pulley drives two spindles)
9	Adjustable location of seat (height and distance from machine)
10	Central seating arrangement of operator (ergonomically suitable)

- The tenacity of the yarns varies between 9.4 and 14.0 g/tex. It appears that the fiber mixing quality for the yarns spun were not same.
- The twist values are within limits.
- It appears that the yarn produced is suitable to be used in Khadi sector.

9 Features of the Modified Charkha

The features of the modified design are summarized in Table 5.

10 Conclusion

After carefully analyzing the existing design, pedal operated hands-free charkhas were designed. Twin spindle drive, addition of bearings and replacement of gears by chain and sprocket made the charkha lighter in terms operation easiness and effort required to run it. Number of spindles increased from 8 to 10. Flexibility to run the equipment either by hand or feet was also provided. Central seating arrangement made operation of the equipment easy and ergonomically better suited for the operator.

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