NMC Charkha: A Design Analysis from Technological Considerations

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Introduction

Khadi is hand-spun and hand-woven fabric made largely out of natural fibres like wool, cotton and silk. The charkha is designed to produce yarn by the process known as spinning. The charkha performs three basic operations

- Drafting of the feed material (i.e. roving or sliver) until the required fineness is achieved;
- Twisting of the drafted fibre strand to impart strength; and
- Winding the resulting yarn in a form of suitable package.

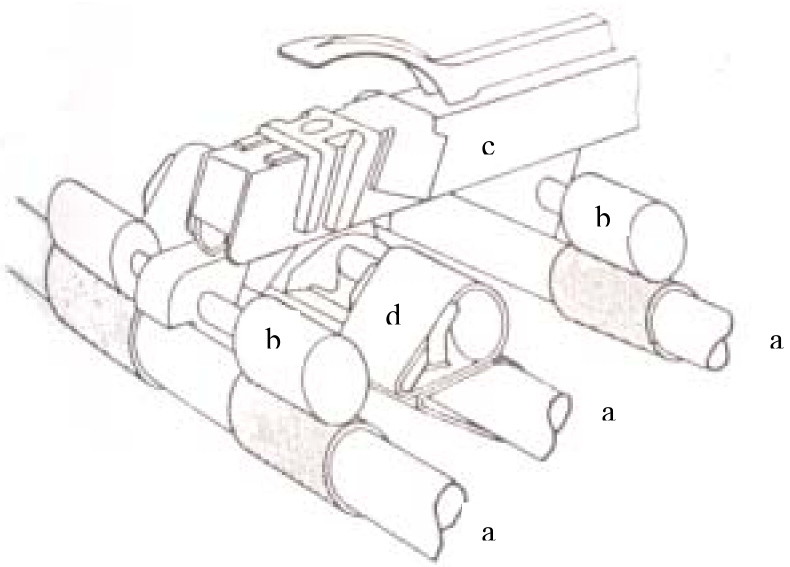
Working Principle

The input material to the charkha is roving/sliver which contains large number of fibres in its cross section. The numbers must be reduced to about 100 in the yarn cross section. The reduction of fibres in the cross section is effected through drafting. In charkha 3-line single-apron drafting system is used (Fig. 1). During drafting the fibres are firmly nipped between the bottom steel fluted roller and the weighted top pressure roller. The pressure is applied by spring weighting system. The roller pairs rotate at an incremental speed resulting stretch (i.e. draft) in the material nipped between the rollers. The controlled two stage stretching operations (i.e. drafting) elongate the feed roving and bring it to the required yarn dimension from the point of view of mass per unit length.

Once the drafted product emerges from the nip of the front pair of roller, it is to be twisted to impart strength to the fibre matrix. Twist is imparted by the combination of ring and traveller. The traveller is a small loop of wire loosely mounted on the ring and hence free to move on the circular ring. The spindle which holds the package (bobbin) causes the traveller to rotate on a ring. The yarn loop between the front roller to the bobbin via the traveller, causes required force to be imparted on the traveller by the spindle. Every revolution of traveller causes the yarn to be twisted around its own axis. The twisted yarn is simultaneously wound on the package. The ring rests on a platform which is made to oscillate from bottom to top of the package at a certain frequency. As the ring moves up and down, the traveller also follows the same and hence the yarn is guided from bottom to top of the bobbin for laying.

Drafting

The bottom drafting rollers made of steel are mounted on an inclined roller stand having fixed brackets. The top rubber covered rollers are mounted in a pendulum lever arm which is pivoted in the machine frame. The lever can be swung to lift all the rollers together. The top rollers are pressed against the bottom steel rollers by spring pressure. The bottom rollers are positively driven and top rollers are surface driven.



a: Bottom fluted roller, b: Top roller, c: Pendulum lever arm, d: Apron

Fig. 1 Drafting arrangement of charkha

Certain flexibility in fixing the values of draft is required to be able to spin yarns of different fineness from the same feed material and hence while designing drive to the rollers change gears needs to be incorporated.

Twisting

Twist is imparted to the yarn by the rotating traveller (Fig. 2). Each revolution of the traveller imparts one turn of twist to the strand. The traveller rotates on the surface of the ring. The traveller does not have its own drive. It is dragged by the yarn that passes through it on to the bobbin surface which is mounted on the spindle. The yarn is pulled by the rotating spindle.

Mathematically the yarn twist is the ratio of traveller speed to delivery rate. The traveller speed practically being very close to spindle speed the twist is

$$\text{Yarn twist} = \frac{\text{Traveller speed (rpm)}}{} = \frac{\text{Spindle speed}}{\text{Front roller delivery}}$$

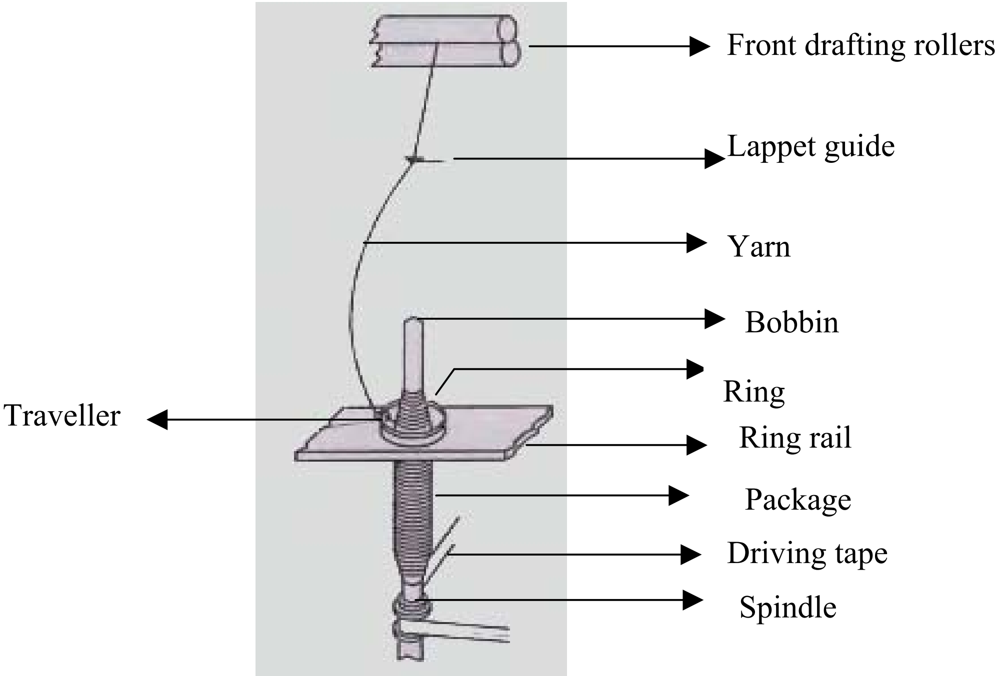


Fig. 2 The passage of yarn in the charkha.

The strength of yarn is manipulated by varying twist. Strength generally increases with twist. However too high twist make the yarn hard and also reduces productivity as twist is usually increased by reducing delivery. In order to change twist the delivery by front drafting rollers is changed.

Package Formation

For package formation the yarn needs to be wound around the package and laid uniformly across the entire length of it. As the traveller and spindle rotate in the same direction, the difference in the peripheral speeds of the traveller and the spindle causes the yarn to be wound on to the package. The speed difference is due to the lagging of the traveller relative to the spindle due to continuous delivery of yarn from front roller and traveller ring frictional drag. Since the traveller also acts as a guide for the yarn it is oscillated back and forth across the entire length of the package for laying the yarn uniformly. This oscillating movement is imparted to the ring rail which holds the ring on which the traveller runs.

Technological Requirements.

Charkha has some technical shortcomings. It is not flexible in terms of adjustment of draft, twist, roller settings and the top roller pressure. This is required for producing different yarn counts in the same charkha. Finer yarn requires higher draft and twist as compared to coarse yarn.

There should be provision on the charkha for varying this. Finer yarn is produced from finer fibre of longer length. So the distance between the rollers should be adjustable according to the fibre length. Also there should be provision for changing the top roller pressure.

The charkha is designed to be operated by sitting in the floor. This leads to physical strain after a few hours of operation. Also there are some technical shortcomings which lead to drudgery after running for the charkha for hours.

Kinematical Analysis of Drive

The charkha is operated by turning a handle usually. Pedal operated charkhas are also available. The prime mover is the main shaft which is turned by hand or pedal. As this shaft turns, the motion gets transmitted through a series of gears and pulleys to different rotating parts of the machine. A plan view of the drive is shown in Fig. 3.

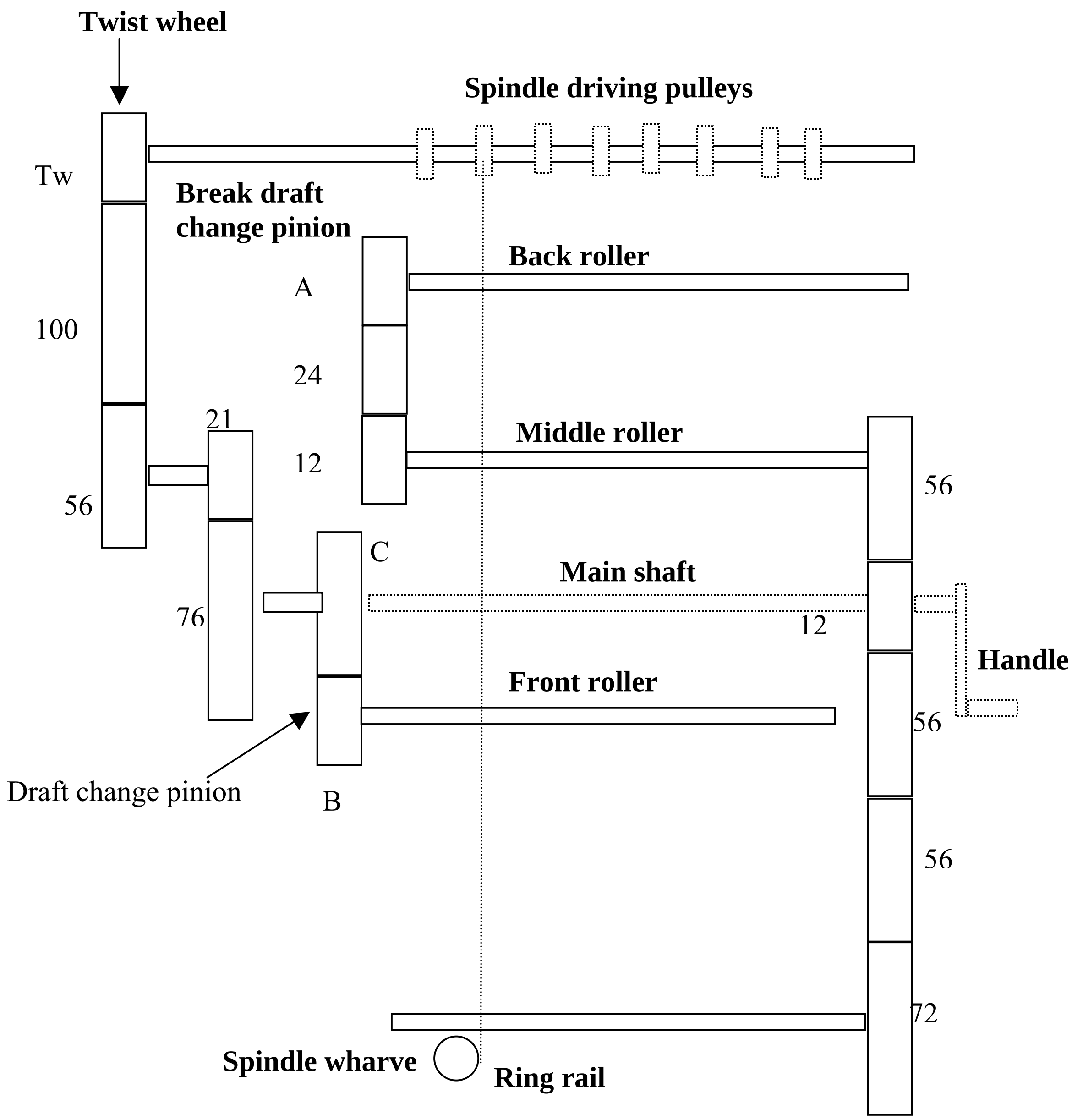


Fig. 3 Gearing diagram of NMC charkha

Drafting Operations

Draft is the result of differential velocity imparted to the three sets of rollers viz. back middle and front. The respective draft can be worked out from the drive. Since the source of drive to all the rollers is same and all being of same diameter, the draft would be the ratio of number of revolution of the concerned rollers in a drafting zone assuming one of them turned by one revolution. Accordingly break draft and total draft would be

Break draft (i.e. draft between back and middle roller)

= 1 / (12 /A) = A / 12 = 24/12 = 2

Total draft (i.e. draft between front and back roller)

= 1/ (B / C) x (12 / 56) x (12 / A)

= (C/B) x (56/12) x (A/12)

= (46 / 22) x (56 / 12) x (24 / 12) =19.51

A change in break draft and total draft is a technological necessity in order to produce a yarn of different fineness from same feed material i.e. sliver or roving. However in the existing design it is fixed and cannot be changed. However this flexibility can be brought about by making the gears A and either C or B changeable gears.

If gear B is made changeable for altering the total draft, then

$$\text{Total draft} = \frac{1}{B} \times \frac{46 \times 56 \times 24}{12 \times 12} \quad \ldots. (1)$$

Where B is number of teeth in gear B. Since B becomes only variable in the equation of draft calculation while others are constant, the total draft becomes

$$\text{Total draft} = \frac{\text{Draft constant}}{B} \quad \ldots.. (2)$$

$$\text{Where} \quad \frac{46 \times 56 \times 24}{12 \times 12} = 429.3 = \text{draft constant}$$

So total draft becomes inversely proportional to number of teeth in draft change pinion. The change in draft with change in number of teeth of draft change gear is shown in Fig. 4. It can be seen that the change in draft with change in teeth of draft change pinion is not constant and progressively reduces with increase in number of tooth. A finer adjustment of draft is possible when the teeth number is on the higher side.

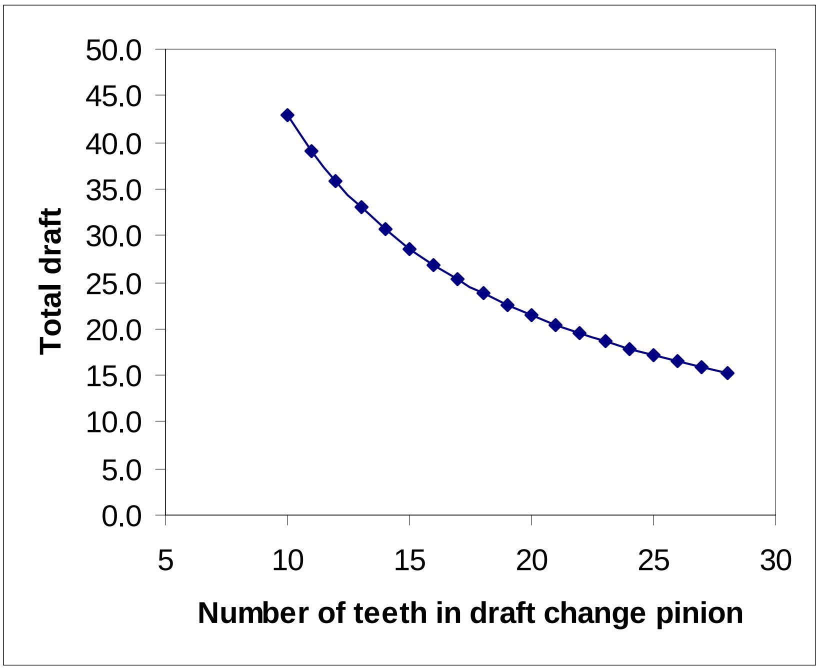


Fig. 4 Draft Vs number of teeth in DCP

Roller Setting

An adjustment in the distances between the drafting rollers is essential to suit the fibre length being processed. There is every likelihood that the fibre length may change from season to season or region to region even for the same variety. For spinning yarns of different fineness different fibre length are used. Hence a provision to adjust the length is necessary. However this flexibility does not exist in the design. Limited flexibility can be attained by mounting the base of bottom rollers on a slot in which it can move. The top roller positions in a given pendulum lever top arm can be moved little bit to accommodate small changes in fibre length. However for bringing a larger change, apron length, nose bar and cradle length all need to be changed. This normally practiced in industry. The charkha manufacturers has designed charkhas that suit a given count range i.e. a given length of fibres with appropriate twist imparting capability. Designing a universal drafting system that suit all length of fibres need to be looked into.

Twisting

The twist is the ratio of spindle speed to delivery rate. In the given diagram the twist can be worked out by finding out the ratio of number of revolution the spindle makes per unit length of yarn delivered.

Hence twist (T) is

$$T = \frac{(B/46) \times (76/21) \times (56 / Tw) \times (Dp / Ds)}{\pi \times Dr} \quad \ldots\ldots (3)$$

Where Dr, Dp and Ds are diameters of front roller, spindle driving pulleys and spindle wharve respectively and Tw is the number of teeth in the gear. TW is known as twist change pinion (TCP). Twist therefore can be changed by changing variable gears B & Tw and pulley Dp. A change in B would also cause a change in draft. As an example a higher value of B would reduce total draft but increase twist. Where as if Tw is only changed then draft remain unaffected. A change in Dp will also keep the draft unaffected. A provision to change the teeth of gear Tw can be made to alter twist. If Tw is made the only variable in equation (3) then

$$T = \frac{\text{Twist constant}}{Tw} \quad \ldots.(4)$$

$$\text{Where} = \frac{(B/46) \times (76/21) \times 56 \times (Dp / Ds)}{\pi \times Dr}$$

$$= \frac{(22/46) \times (76/21) \times 56 \times (13.1/1.15)}{3.142 \times 2.61} = 134.6 = \text{twist constant}$$

The change in twist value with change in twist in twist wheel is shown in Fig. 5. The requirement of twist varies from 15 to 50 twist per inch. For the given twist constant this would need twist wheel having 7 to 22 teeth. A gear having too less teeth is not suitable from engineering consideration. Hence on the same machine if we want to spin entire count range, the twist constant has to be changed so that appropriate twist can be obtained by employing gears having reasonable number of teeth.

The motion transmission from the main shaft to the spindle is through a set of gears and pulleys. Since the pulley shaft is located a bit away from the main shaft, four gears had to be used to transmit motion. This increase load on the operator since more power will be required to turn all of them. A driving belt arrangement between main shaft and pulley shaft can reduce the load on the operator. Some of the gears can also be made from ebonite instead of mild steel to reduce their weights.

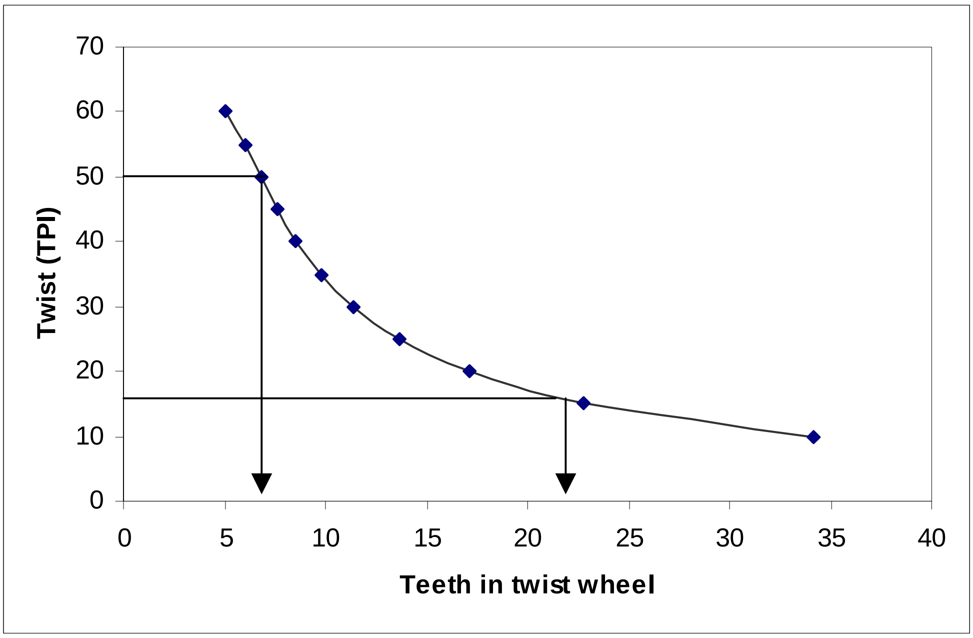


Fig. 5 Twist Vs number of teeth in twist wheel

The motion from spindle driving pulley shaft to the spindles is transmitted by a connecting thread. The thread joint causes the spindle to vibrate and also there is lot of slippage. Uncontrolled slippage leads to twist variation from spindle to spindle. A rubber cord could be a better alternative.

Ergonomic Considerations

The charkhas are generally floor mounted. As a result the operator has to sit on the ground with folded legs to run it by hand. A table mounted charkha where the operator can sit on a chair of appropriate height can reduce his/her drudgery. Pedal operated charkha can serve the same purpose. In fact the hands can be made free since the feet will be engaged to run the machine. Improved bearings in the driving rollers can cause them to roll easily necessitating less power.

A pedal operated charkha with a provision to run it by hand can be better alternative as it will offer flexibility to the operator to use either hand or feet . Since through feet more power can be applied, bigger package with same number of spindle can be made by employing bigger diameter ring with appropriate spindle and bobbin. This will reduce the frequency of package doffing and may improve productivity.