

AN INVESTIGATION ON THE PERFORMANCE OF MODIFIED COIR SPINNING MACHINE

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Abstract:

Coir fibre is a non-conventional fibre extracted from the husk of coconut fruit and is abundantly available in tropical countries. Coir yarn is produced in the decentralised cottage industry. Increase in the demand for the coir fibre yarns for value-added applications has forced the coir yarn manufacturers to improve the existing coir spinning machine in different ways. In this study, the working principle of the existing coir spinning machine has been studied from the perspective of further improvements in production rate, yarn quality and spinning performance. Modifications have been made in the existing coir spinning machine in fibre feeding, opening and cleaning. There is improvement in the production rate of up to 20% with significant improvements in the yarn quality and spinning performance.

Keywords:

Coir fibre, spinning machine, fibre feeding, opening, cleaning, yarn irregularity, breakage rate.

Introduction

Coconut (coir) fibre, a non-conventional fibre [1], is extracted from the outer shell of coconut fruit. It is abundantly available in tropical countries of Asia and East Africa [2]. Coir fibres are tough, resilient, moth-proof, resistant to fungi and rot and easy to clean. Coir fibre yarn is the raw material for the manufacturing of coir ropes [3]. Coir yarns are plied and twisted to form coir ropes. Coir yarn is used for the production of mats and matting. Geotextiles made from coir yarns are used to control soil erosion [4]. Spinning of the coir fibres into yarn is carried out in the southern states of India, including Tamil Nadu and Kerala, in a large unorganised cottage industry set-up. Both the traditional manual spinning process and the mechanised process are used for manufacturing coir yarns. More than 65% of the coir yarns are made in the mechanised spinning sector. There is an intense demand for better machine productivity and improved yarn quality in the mechanised sector.

In the present study, the limitations of the existing mechanised coir spinning system have been studied and modifications have been made in fibre feeding, opening and cleaning segments to achieve higher production rates and improved quality of the yarns.

Literature Review

Fibre characteristics

Fibre fineness is a fundamental property that has wide ranging effects on the processing methods, properties and performance of the products. Coir is a coarse fibre in comparison with commonly used commercial textile fibres such as cotton and wool. The mean diameter of coir is around 280–320 μm [5] as

against 10–15 μm for cotton fibre and 15–40 μm for wool fibre [6]. The coefficient of variation of coir fibre diameter is high at 50% [5].

Coir fibre exhibits high flexural rigidity [7]. The rigidity of the coir fibre is attributed to the combination of the coarseness of the fibre and to the high lignin content [8].

The coarseness of the fibre limits the linear density of yarns produced, as there is a requirement of the minimum number of fibres in the cross section [9].

In the case of short as well as long staple spinning systems, length of fibres significantly influence the processing methods and properties of the intermediate and end products. Coir fibre has a mean length of 183 mm with a minimum and maximum being 44 and 305 mm, respectively [5].

The combined effect of coarseness, long length with high variation and high rigidity of the fibres rules out the use of machines dedicated for short and long staple fibre spinning.

Tenacity is a strength metric that is defined as the mass specific stress at break. Coir has a breaking tenacity of 20–35 g tex^{-1} as against the breaking tenacity of 13–36 g tex^{-1} for jute. The moisture regain of coir fibre is 9.5% and that of jute is 12.5% [9].

Spinning system and yarn type

Regular spinning systems (e.g. ring spinning) used for the spinning of cotton and wool-like fibres with roller drafting are not suitable for coir fibres because of inadequate inter-fibre friction apart from difficult fibre properties such as high flexural and torsion rigidity.

Ratt spinning is the traditional manual spinning method used for the spinning of coir fibre ropes [10]. Opened coir fibres are fed manually to the hand-operated twisting wheel for twist insertion. As the technique involves an intermittent process, the production is low ($12\text{--}15\text{ kg day}^{-1}$) [11]. The yarns produced from this machine are coarse, weak and have high irregularity.

The next development in the coir machine was the motorising of the twisting element resulting in a semi-mechanised spinning machine [11].

A further improved mechanised spinning became highly popular with the introduction of continuous mechanised feeding and also eliminating the intermittent operation. This resulted in the improvement in the productivity and the quality of the product in comparison with the earlier semi-mechanised versions. This spinning machine works on open-end spinning principle. In open-end spinning process, the continuous fibre supply is broken by means of a suitable machine element (e.g. a toothed opening roller in rotor spinning machine) as individual fibres and then these fibres are collected and the continuity is restored by joining of the individual fibres to rotating yarn tail [12].

In the coir spinning machine, the fibre flow is also interrupted by the action of a beater and coir fibres are individualised. The opened fibres are collected in a trough kept at the bottom of the beater using the principle of gravity. The schematic diagram of the coir fibre spinning machine is shown in Figure 1.

The output of the mechanised coir spinning machine is, often, a two-ply twisted yarn [13]. The single yarn component of this two-ply yarn has a core–sheath structure. The core component is normally a polyester monofilament of around 15 tex and the coir fibres are wrapped over the core component. The single yarns from the two adjacent spinning heads are plied together to form the two-ply yarn.

The linear density of the resultant two-ply coir yarns made from mechanised coir spinning machine is generally in the range of 6.0–7.2 ktex.

In coir spinning industry, the linear of the coir yarn is referred as 'runnage'. The length of coir yarn in a standard mass of 1 k is called runnage. From the survey carried out in many mechanised coir fibre spinning units by a team that consist of the author of this article, it was observed that the runnage in the mechanised units lies between 140 and 160 (equivalent to about 6–7.2 ktex). It was also observed during the survey that runnage, yarn irregularity, the presence of impurities in yarn and machine running performance are given the highest importance.

Limitations of existing spinning systems

Literature review on the subject matter of coir machinery development and coir yarn quality has thrown up scant information; this could possibly due to the decentralised nature of the coir industry.

From the studies conducted in the industry, it was observed that the production speed is limited to 10 m min^{-1} for spinning 6.0-ktex yarn in the existing coir spinning machines. It has further been observed that any further increase in the delivery speeds leads to poor performance with frequent yarn breaks, higher waste generation and irregularity of the yarns. At higher delivery speeds with the existing machines, inconsistent fibre feed, poor opening and cleaning occur, resulting in poor spinning performance and deterioration in the yarn quality. Increase in demand for the coir fibre yarns with better quality has forced the technologists to modify the existing spinning machine to improve productivity, yarn quality and spinning performance.

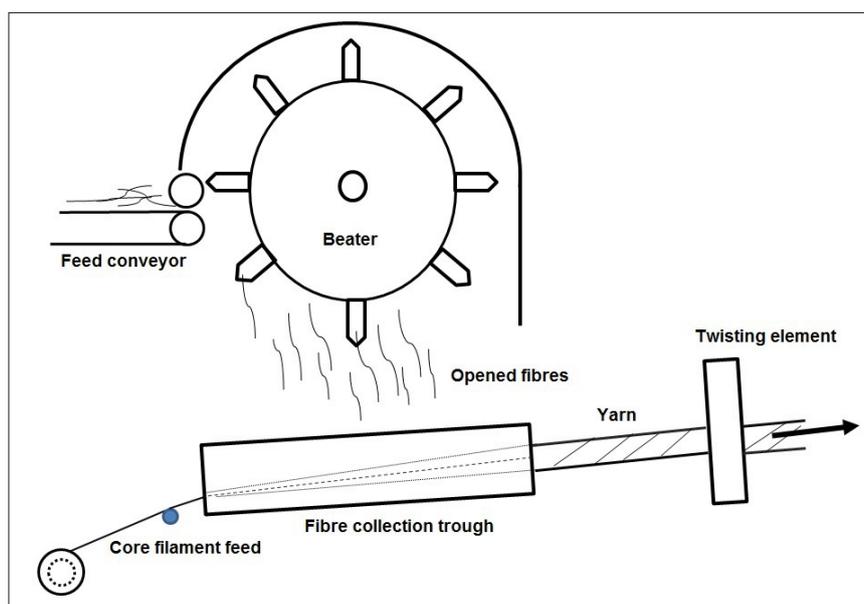


Figure 1. Coir fibre spinning machine

Modifications made in the spinning machine

Modifications have been made in the existing machine in fibre feeding, opening and cleaning as discussed below to address the limitations.

Modification in fibre feed

The existing coir spinning machine is equipped with one photo cell unit to control the fibre feed to the beater as shown in Figure 2.

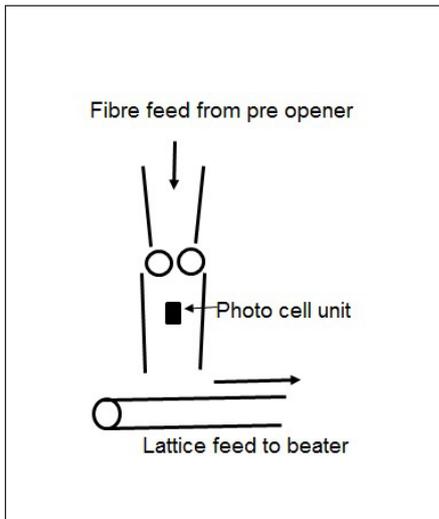


Figure 2. Fibre feeding arrangement in existing machine

In the modified set-up, a fibre reserve chute is introduced before the beater segment. The reserve chute consists of two photocell arrangements for controlling the fibre levels. One unit of photocell (consisting of an emitter and a receiver) is arranged at the top of the chute and the other set at the bottom of the chute, where the top photocell works as a stopper for the fibre feed and bottom photocell works as an initiator. The backside

wall of the reserve chute can be adjusted so that the volume of fibres in the reserve chute can be varied according to the linear density of yarn required. One of the feed rollers at the bottom of the fibre chute is provided with a pressure spring that assists in maintaining the pressure over the fibres for a controlled feed. The schematic diagram of the modified feeding arrangement is shown in Figure 3.

Modification in opening

The existing coir spinning machine has two separate beater segments for opening and cleaning of the coir fibre as shown in Figure 4.

In the existing machine, the fibres opened and cleaned by the first beater are collected in a conveyor and are taken to the second beater for further opening and cleaning. In the modified machine, the two beaters are kept one above the other as

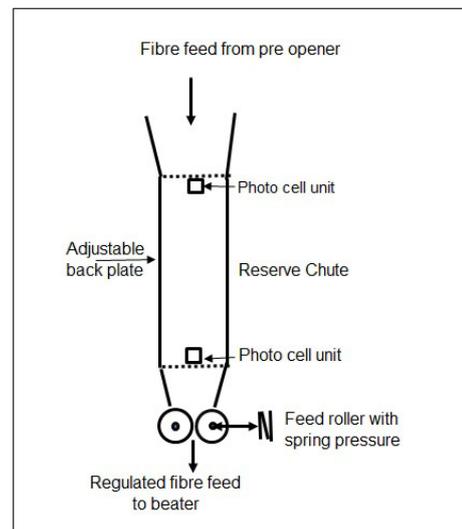


Figure 3. Modified fibre feeding arrangement.

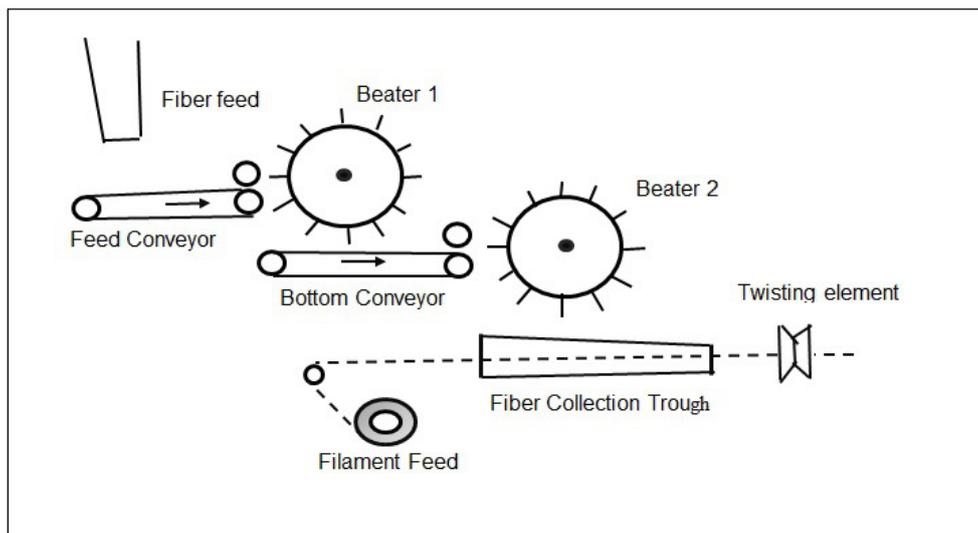


Figure 4. Beater arrangement in the existing coir spinning machine

shown in Figure 5. The coir fibres from the feed chute are taken by the top beater and the opened fibres are carried over to the bottom beater. The speed of the bottom beater is maintained at about 10–20% higher than that of the top beater. The backside cover of the top beater is adjustable so that the setting distance between the beater and the back plate can be varied. The pins of the both the beaters are arranged in intersecting manner for enhancing the opening process.

Results and Discussion

Improvement in fibre opening and cleaning

The intensity of fibre opening, in terms of openness value, was assessed by the method suggested by Szaloki [14]. The openness value as measured in this method is dependent on the specific volume of coir fibre. The openness values were assessed for both the existing and modified machines, and the results are given in Figure 6.

It is observed that the openness value of modified machine is better than that of the existing one by about 10% at the same speed and by about 60% at higher speed, namely, 12 min⁻¹. The uniform fibre feed from the reserve chute realised by the double-photocell arrangement results in a uniform treatment of fibre by the beaters. As the speed of the bottom beater is higher, there is a drafting action on the fibres when the fibres are transferred to the surface of the bottom beater. Straightening of the fibres is also highly likely. As the fibres are fed to the bottom beater in opened fibre tufts, the effectiveness of the bottom beater is expected to be better in terms of further opening and cleaning than in the case of existing beater where the fibre feed from the first to the second beater is in compressed form. Also because of the intersecting arrangement of beater pins, there is high likelihood of further improvement in fibre opening.

Yarn impurities

In the cotton spinning, yarn faults are measured by instruments working on capacitance/optical principle and the faults are expressed as number of incidents per 100 km of yarn.

Cleanness of the coir yarns is determined in terms of number of incidents of impurities present in the yarn. The impurities in the coir yarn usually consist of unopened fibre clusters and fibres embedded in the pith particles. Count of coir yarn impurities is the equivalent of yarn faults in cotton and wool spinning systems. The impurities affect the performance of the spinning machine and also detract from the appearance of the coir yarn.

Coir yarns are much coarser and, therefore, a short length of 100 m is taken as standard length for characterising the faults. The impurities in the coir yarn were studied by counting the incident of unopened fibre bundles and fibre entanglement with other vegetable matters per 100 m of yarn samples produced.

Trash content, the quantity of unopened cluster of fibres along with pith and other wastes, in the yarn was assessed using

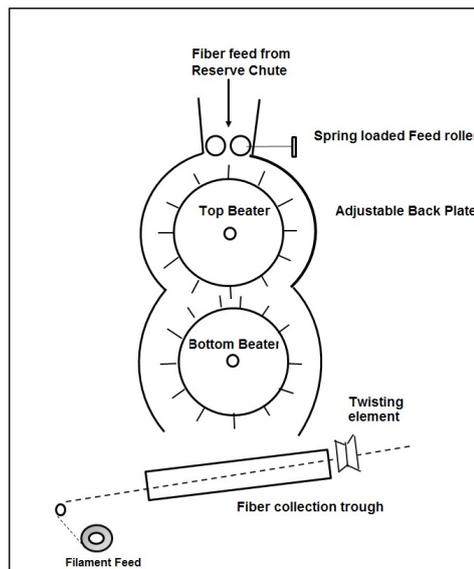


Figure 5. Modified beater arrangement

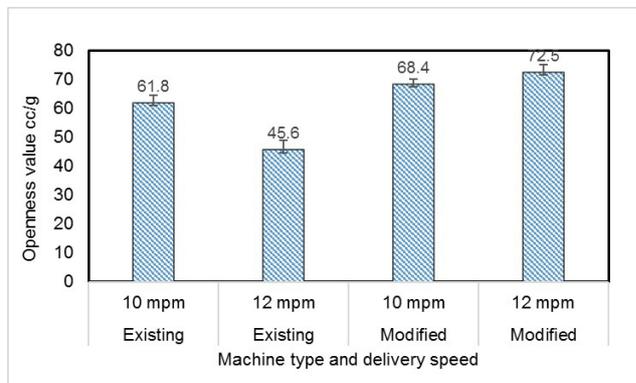


Figure 6. Openness value of existing and modified beaters

gravimetric method. A mass of 100 g of coir yarn was taken, and the impurities were manually separated and the impurities were weighed and expressed as a percentage as given below.

$$\text{Trash \%} = \frac{\text{Mass of trash}}{\text{Mass of yarn sample}} \times 100$$

The values of trash content for the yarn samples produced both in the existing and modified spinning machines are given in Table 1.

It can be observed that yarn made from the existing machine at 12 min⁻¹ is found to have more incidents of impurities and higher trash content. Modified beater arrangement improves cleanness, and there is about 70% reduction in the incidence of impurities and 5 percentage point reduction in trash level.

The reduction in the incidents of impurities in the yarn and the trash is attributed to the better opening and cleaning obtained because of the modifications in the machines.

Improved opening increases the surface area of the fibre tuft, thereby enabling easy and efficient removal of unopened clusters and embedded pith in the fibre clusters.

Yarn irregularity

Mass variation per unit length along the length of the yarn is a measure of yarn irregularity. The mass of 1-m cut lengths of coir yarn samples (sample size: 50) was measured, and the coefficient of variation (CV%) was calculated [15]. The results are given in Table 2.

It is observed from the table that there is a significant reduction in the CV% values of yarns made from the modified machine in comparison with the existing machine in all linear densities and in speeds in the current study. This is due to (1) the uniform fibre feed by the reserve chute installed in the feeding system and (2) the improved opening and cleaning by the modified beater arrangement.

A close scrutiny of the results obtained shows that in the existing machine, the increase in CV% is very steep as the machine speed is increased. However, in the case of modified machine, the CV% remains almost the same even at the increased speed. This is an indication that there is still much scope for the increase in the speed at least from the perspective of yarn variation.

Improvement in spinning performance

In the ring spinning process of cotton yarn manufacturing, the performance of spinning machine is assessed in terms

of breaks per 100 spindle hours [16]. Higher yarn breaks in the spinning result higher waste generation and deterioration in yarn quality. As the coir spinning machine consists of less number of delivery heads, breaks per delivery head hour was considered as the performance metric. The yarn breaks per delivery head hour for three linear densities of yarn at different delivery speeds were studied in the existing and the modified machines. The results are given in Table 3.

It was observed during the study that most of the yarn breaks occur because of the occurrence of weak spots and the presence of fibre lumps. It was further observed that weak spots were created by the thin places in yarn because of variation in the fibre feed. The poor opening of fibres leads to the presence of fibre bundles that block the nozzle of the spinning element creating a yarn break. With the modified machine, there is a substantial reduction in the occurrence of thin places and unopened fibre bundles.

In the modified machine, the reserve in the fibre feed chute maintains a uniform fibre feed to the beater. As the position of the back plate of the reserve chute can be altered, the volume of the fibre in the chute can be varied to maintain a uniform fibre feed irrespective of the linear density of the yarn produced and the machine speed. This reduces the yarn breaks rate at a higher delivery speed as shown in Figure 7.

Table 1. Incidents of yarn impurities and trash%

| Machine type | Delivery speed (m min ⁻¹) | Incidents of impurities per 100 m of yarn | Trash% |
|--------------|---------------------------------------|---|--------|
| Existing | 10 | 7 | 8 |
| Existing | 12 | 27 | 16 |
| Modified | 10 | 4 | 6 |
| Modified | 12 | 8 | 11 |

Table.2. Coefficient of variation (CV%) of 1-m cut lengths of coir yarn samples

| Machine type | Existing machine | | Modified machine | |
|--------------|------------------|------|------------------|------|
| | 10 | 12 | 10 | 12 |
| 7.2 ktex | 16.8 | 22.3 | 14.6 | 14.8 |
| 6.6 ktex | 18.7 | 24.7 | 16.6 | 17.0 |
| 6.0 ktex | 21.8 | 28.3 | 19.1 | 19.3 |

Table 3. Breaks per delivery head hour of spinning machine

| Yarn Linear density | Delivery speed | 8 m min ⁻¹ | | 10 m min ⁻¹ | | 12 m min ⁻¹ | |
|---------------------|----------------|-----------------------|----------|------------------------|----------|------------------------|----------|
| | | Existing | Modified | Existing | Modified | Existing | Modified |
| 6.0 ktex | | 0.4 | 0.1 | 0.5 | 0.2 | 7.2 | 0.7 |
| 6.6 ktex | | 0.2 | 0.1 | 1.2 | 0.4 | 6.3 | 0.5 |
| 7.2 ktex | | 0.3 | 0.1 | 1.4 | 0.2 | 10.2 | 0.5 |

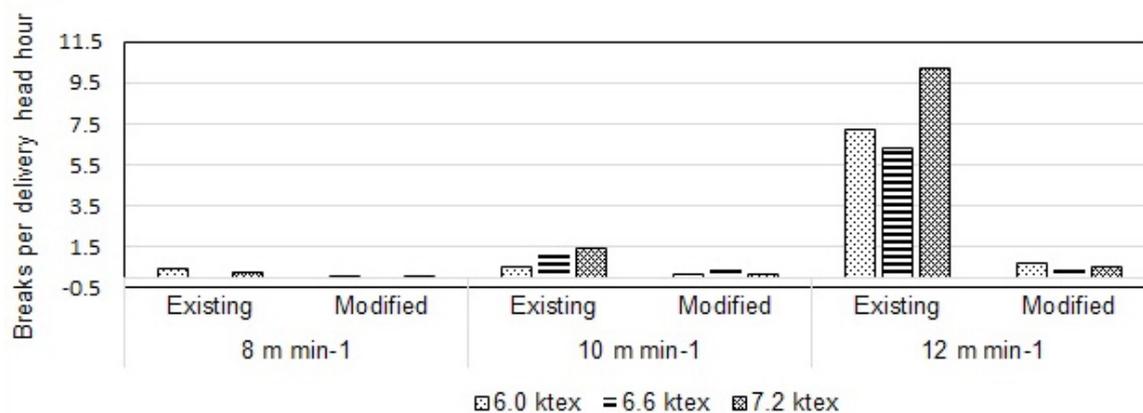


Figure 7. Breaks per delivery head hour

Conclusion

The modified machine produces yarn with improved cleanness, less irregularity and much reduced end breaks in comparison with existing machine. Fibre opening and cleaning is substantially improved by the modifications made in the fibre reserve chute and beater arrangements. In the modified machine, the yarn quality and performance has not deteriorated even at higher speeds. It indicates that there is much scope for further increase in the production rates.

Scope for further research

In the modified machine, the delivery speed could not be increased further because of the limitations imposed by capacity of the feeding and storage devices. With further design efforts in the feeding and storage areas/devices, the capacity of the machine to operate at still higher delivery speeds with improved yarn quality and running performance could be explored. The suitability of this spinning system for the spinning of other natural unconventional fibres such as banana and aqiva americana could be explored.

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