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IMPACT OF STRIKING FORCE OF CARDING TAKER-IN CLOTHING ON FIBRE BREAKAGE IN SPINNING TECHNOLOGY

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ABSTRACT

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One of the ways to increase production rate and cleaning efficiency of the card in the manufacturing of cotton yarn is to increase rotational speed of different rollers of the machine. However, higher rotational speed of rollers with saw toothed metallic clothing is often considered to be a cause of fibre damage that ultimately lowers strength of yarn. Review of research works on cards shows that fibre damage or deterioration in the zone of the feed roller and the taker-in is influenced by various factors other than higher speed of the taker-in. But influence of the taker-in rpm alone and the nature of damage or deterioration of fibres in this zone are not enough clear. This paper has examined one of the very important aspects of fibre damage – breakage of fibre due to high rpm of the taker-in of the card - from a novel view point. According to this view fibre breakage may take place due to the cross-sectional deformation of the fibre caused by the striking force of clothing teeth. Here the dynamic impact of the striking force of metallic clothing of taker-in on cotton fibre was determined proceeding from the consideration that the revolving metallic tooth strikes on a fibre and creates cross-sectional displacement (deformation) of it at the point of striking that spreads along the length of the fibre like the propagation of longitudinal waves along a slender rod. The maximum and minimum striking force of taker-in tooth on fibre were calculated and found to be 0.834 cN and 0.124 cN respectively which are 5-34 times less than breaking strength of single cotton fibre (say 4.2 cN). Therefore it may be concluded that the fibres are not broken immediately on account of its deformation caused by higher rotational speed of taker-in teeth.

Key words: *card mat, fibre fringe, fibre deterioration, wave motion of displacement, tenacity of fibre*

INTRODUCTION

With the advancement of technology last few decades have witnessed remarkable increase in the production rate of some spinning machinery. For example, since 1965 production rate of short staple card has been increased from 5 kg/h to about 80-100 kg/h (Borzunov 1982). In many cases higher production rate is achieved by increasing the rotational rate of different machine organs. The requirement of high cleaning efficiency in cotton yarn manufacturing is also generally met by resorting to higher rpm of opening and cleaning rollers.

But higher rotational rate is often believed to cause fibre damage that ultimately lowers yarn strength. Especially rollers, covered with saw toothed clothing and acting on clamped fibre mass of lower orientation, pose high risk to fibre. In this regard the zone of the feed plate and the taker-in of the card involving high rotational speed of the taker-in is regarded as a major point of fibre deterioration.

Fibre deterioration or damage may be in the forms of cuts, bruises and deformation on surface of fibres, elongation and breakages of fibres. In the zone of feed plate and taker-in fibre damage is largely determined by the intensity of action of taker-in which is represented by the number of points per fibre (N_p). This number is obtained averaging of total fed fibres per unit time over the number of points available in the same time as follows (Klein 1995):

$$N_p = \frac{\pi D H}{h t} \times \frac{n T_f l_f}{T_{fm} V_{fr}} \times 10^{-3} \qquad (1)$$

Where- D, H, n and h are diameter(mm), width(mm), rpm, and groove pitch of the taker-in respectively; T_f - linear density of fibre(tex), $T_{f.m}$-linear density of fibre material ie card mat(tex), l_f -average fibre length(mm), t - tooth pitch(mm) and $v_{f.r}$-linear velocity of feed roller(mm/min). It follows from eqn. (1) that intensity decreases with the increase in linear density of feed material, and increases with increase in taker-in rpm. Equation (1) also shows how Np depends on other factors.

In the relevant literature, besides above mentioned factors, fibre damage in this zone is also attributed to factors like, orientation of fibres in the card mat, profile of feed plate and parameters of taker-in clothing. Obviously the phenomenon of fibre damage is multifaceted. Here only the dynamical aspect of taker-in rpm on fibre in the zone of the taker-in and the feed plate has been considered in order to investigate the possibility of breakage of fibre.

MATERIALS AND METHODS

Review of relevant works on the effect of taker-in rpm and various related parameters on fibre damage

The main task of the card is individualization of fibre mass or flocks and the taker-in covered with saw-toothed clothing is the first organ of the machine to treat the mass to that end. Lawrence CA describes that taker-in opens the fibre tufts effectively when one end of a tuft is momentarily held while the teeth of the taker-in pull individual fibres and groups of fibre from the other end. The front of the feed plate facing the taker-in has a narrow plateau (*ED* in the fig. 1) and it then bevels steeply toward the taker-in, making a wedge space in which the fibre fringe comes into contact with the taker-in teeth. This wedge space enables the taker-in teeth to progressively penetrate the fibre mass of the fringe.

The opening of fibre between feed roller and taker-in is the most serious problem zone of the card because the taker-in must tear individual flocks out of the fairly thick feed sheet (400-800 g/m) with enormous force. Fibre damage is scarcely to be avoided here (Lawrence 2003).

According to reference, the taker-in performs the greatest part of opening and cleaning of the carding machine. It combs through a fairly thick fibre fringe at a rotational rate of 1000 rpm (giving approximately 600,000 points per second), a circumferential speed of around 13 m/s and a draft of more than 1000. In high performance cards rotational speed of taker-in lies in the range of 800-1500 min^{-1}. Treatment imparted by the taker-in is therefore very intensive, but not very gentle. So fibre deterioration at this opening point is very likely to occur. Reference also refers to the results of research work undertaken by G Abt and Dr. W Top f to show the influence of the rotational rate of taker-in on the degree of openness and quality parameters of yarn including strength. According to the results of with the increase in sliver weight (thickness) from 4.35 Ktex to 5 Ktex (i.e with the change of degree of openness) the strength of yarn decreased with simultaneous worsening of other yarn quality parameters like evenness and imperfections. An increase in taker-in rpm from 740 to 1040 led to decrease in yarn strength with simultenuous worsening of yarn quality. However in case of an increase in taker-in rpm from 400 to 470 min^{-1} with simultaneous increase in cylinder rpm from 770 to 920 min^{-1}, the yarn strength was found to be increased but with worsening of yarn quality. Reference also refers to the results of research work of P. Artzt and O. Schreiber to show change in staple depending on taker-in rpm (up to 1600 /min) and sliver thickness. Results of the works show that, among other factors, rotational speed of taker-in causes shortening of fibres. However, experiments with slivers of higher thickness (6.7Ktex) showed mixed results were in the range of taker-in rpm around 700-1600 min^{-1} no shortening of fibre length was observed.

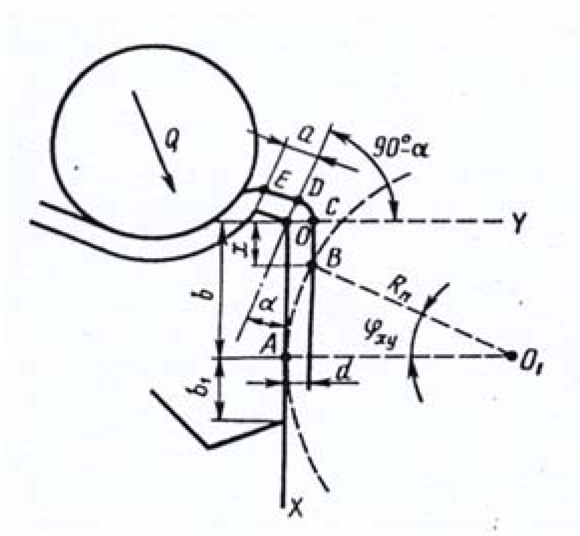

Fig -1

Accordingly to reference, increase in rpm of taker-in from 450 to 900 min^{-1} leads to improvement of sliver evenness which also facilities better waste removal without causing reduction in fibre length due to breakages. In practice the taker-in with a diameter of around 250 mm and rpm of 1600 or more with possibility of setting around 2200 rpm) is applicable (Venkatasubramani 1996).

Fibre damage may be caused in various ways. The work explains how the geometry of the feed plate may cause damage to fibre. Figure (1) represents the disposition of the feed roller, the feed plate and the taker-in of a card; where O_1 is the centre of the taker-in and B is the entrance point of teeth on the fibre fringe. The length *BCDE* on the fringe remains beyond the action of taker-in teeth. For better combing action this length should be as less as possible. Breakage of a fibre by a tooth will not take place if the fibre folded in two with its two ends remaining between the clamp of feed plate and feed roller forms a loop and if the loop hanging along *BCDE* does not come under the action of the tooth. It has been shown in that minimum distance *BCDE* at which the fibre will not be broken by the teeth depends on the width of the plateau of the feed plate (*ED*), thickness of fibre fringe and the angle of inclination of feed plate(Fig. 1). It has also been shown that the width *DE* and the length of the front edge of the feed plate (*OA*) should correspond with the staple length of the fibre and, with a view to preventing breakage of fibre in the processing fibre of longer staple, the feed plate is required to be lifted to certain extent in respect of the taker-in.

Depending upon the type of cotton to be processed the taker-in speed ranges from 350 to 800 rpm. For longer staple it is run at lower speed because of the fact that longer fibres are held for longer duration by the bite of feed roller after the taker-in starts working on the fringe. As a result, more teeth act on the fringe of fibres and there is every chance of the fibres getting damaged.

From all above discussion it is evident that fibre deterioration in the zone of feed plate and taker-in is influenced by various factors such as thickness of feed material (card mat), geometrical profile of feed plate, fibre type, parameters of clothing and parameters involved in eqn.(1) etc. As regards the taker-in rpm it ranges in practice from 350 to 1600 or more. But a generalization about any trend of worsening or improvement of yarn quality can hardly be made. In some cases the results are rather conflicting. For example, with the increase in taker-in rpm from 780 to 1040, as referred to in, yarn strength is reduced with worsening of overall yarn quality. On the contrary, according to the results of, with the increase in taker-in rpm from 450 to 900 the sliver evenness improves without any reduction in fibre length due to breakages. In practice, higher taker-in rpm of 1600 or more is also applied. Thus, though fibre damage or deterioration is associated with various factors, the aspect of immediate fibre breakage by the influence of higher taker-in rpm was not revealed. The latter is studied here from the view point of impact of fast revolving metallic part of machine on fibre.

RESULTS AND DISCUSSION

Determination of effect of striking force of taker-in on fibre proceeding from longitudinal wave motion of displacement

The interaction between entangled fibres and metallic teeth may be considered to be a combination of the impact or striking forces of taker-in teeth on the fibres and combing action of the teeth on the fibres. And the former i.e. the impact of a metallic tooth on the fibre may be considered to create cross-sectional displacement/deformation of the fibre which spreads along the fibre like the propagation of longitudinal waves along a slender rod.

The longitudinal wave motion of the displacement of fibre cross-section due to impact of taker-in may be expressed by the following equation:

$$\frac{\partial^2 u}{dt} = a^2 \frac{\partial^2 u}{ds^2} \qquad (2)$$

Where, u= displacement of the cross-section of fibre at a point on it.

s- the coordinate of the point on fibre which undergoes displacement at the moment time, t.

a- velocity of propagation of wave along the fibre which is given by follwing equation:

$$a = \sqrt{\frac{E_f}{\rho_f}} \qquad (3)$$

Where ρ_f -linear density of the fibre and E_f-Young's modulus of elasticity of fibre.

The relative deformation of the fibre may be expressed through a and v by the formula:

$$\varepsilon_{dyn} = \frac{v}{a} \qquad (4)$$

Here, v= velocity of striking force or impact and is equal to velocity of taker-in clothing.
Relation between relative deformation, force and young's modulus is given by the equation

$$\varepsilon_{dyn} = \frac{Fs_{\cdot f}}{E_f} \qquad (5)$$

From equation (2), we have $E_f = \rho_f a^2$

The value of a for cotton is between 1000-1500 m/sec
In case of a=1500m/sec and liner density of fibre equal to 186 mtex (i.e $0.186\text{x}10^{-6}$kg/m)

$$E_f = P_f a^2 = 0.186\text{x}10^{-6} \text{ x } (1500)^2 = 0.4185 \qquad (6)$$

In case of a=1000 m/sec and the same linear density of fibre

$$E_f = P_f a^2 = 0.186 \text{ x } 10^{-6} \text{ x } (1000)^2 = 0.186 \qquad (7)$$

Let us now take minimum and maximum practical values of taker-in to be v_{min} = 10m/sec and v_{max}= 20m/sec
Putting v=10m/sec and a=1500m/sec in the equation (4)
We get,

$$\varepsilon_{dyn} = \frac{10}{1500} = 0.00667 \qquad (8)$$

Similarly putting v = 20 m/sec and a = 1000 m/sec in the equation (4), we get

$$\varepsilon_{dyn} = \frac{20}{1000} = 0.02 \qquad (9)$$

Now from (4) we have the following relation:

$$Fs_{\cdot f} = \varepsilon_{dyn} . E_f \qquad (10)$$

Using formula (6), (7), (8) and (9) we can find the striking force by formula (10) as follows:

$$\left.\begin{aligned} F_{sf}^1 &= 0.00667 \text{ x } 0.186 = 0.00124 \text{ N} \\ F_{sf}^2 &= 0.02 \text{ x } 0.4185 = 0.00834 \text{ N} \\ F_{sf}^3 &= 0.00667 \text{ x } 0.4185 = 0.00279 \text{ N} \\ F_{sf}^4 &= 0.02 \text{ x } 0.186 = 0.00372 \text{ N} \end{aligned}\right\} \qquad (11)$$

From (11) it is evident that maximum and minimum values of striking force on the fibre are

$$F_{sf}^{max} = 0.00834 \text{ x } 10 = 0.834 \text{ cN}$$

and $$F_{sf}^{min} = 0.00124 \text{ x } 10^2 = 0.124 \text{ cN}$$

CONCLUSION

From above results it is evident that the maximum and minimum striking forces developed on a cotton fibre as a result of impact of taker-in are 0.834 cN and 0.124 cN respectively which are 5 to 34 times less that the tenacity, or breaking strength of single cotton fibre (say,4.2cN). Therefore it may be concluded that the cotton fibres are not broken immediately due to their deformation caused by the striking force of teeth of the taker-in.

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