Indian Journal of Fibre & Textile Research
Vol. 39, December 2014, pp. 358-363

Drafting force measurement and its relation with break draft and short term sliver irregularity

Qasim Siddiqui[1, 2] & Chongwen Yu[1, a]
[1]College of Textiles, Donghua University, 2999 North Renmin Road, Shanghai 201620, China
[2] Department of Textile Engineering, BUITEMS Quetta 87100, Pakistan

Received 24 September 2013; revised received and accepted 15 January 2014

The interaction between dynamic drafting force and its variability with break draft and short term irregularity of carded cotton sliver has been discussed. Drafting force data have been collected from online draftometer, installed on break draft zone of cotton drawing frame. The results indicate that the dynamic drafting force initially increases with the increase in break draft up to a certain point, followed by attaining peak region with some fluctuation in drafting force. After reaching the maximum point, drafting force gradually decreases with any further increase in break draft. The CV% of drafting force and short term sliver irregularity show the same trend with each other and oppositely to drafting force. Study on drafting force is not only applicable in optimization of break draft, but also the variability of drafting force provides better understanding of the dynamic behavior of the flowing fibre bundles and its impact on short term sliver irregularity.

Keywords: Break draft, Cotton, Carded sliver, Drafting force, Short term sliver irregularity

1 Introduction

Drafting is one of the mechanical processes used to attenuate and equalize the fibre bundles to get the required linear density. Lack of complete control on the motion of each fibre results in more or less irregular fibre assembly. Drafting force is the spontaneous factor resulting from the inter fibre friction and cohesive forces generated during attenuation of fibre strands. The dynamic behavior of the flowing fibres depends upon the surface frictional forces and, in particular, on the variation of frictional forces among adjacent fibres. Drafting forces not only influence the linear density regularity of silver, but also affect the quality of resultant products and process efficiency. It is an important parameter to understand the ingrained mechanisms for the configuration of drafting waves.

Martindale characterized drafting force as an essential force for pulling out the high speed fibres from the low speed fibres. Plonsker and Backer[1] described it as a force required to cause the fibres to slide past one another during the drafting process Further research has focused on determining the drafting force and its relation with drafting parameters experimentally[2-5].

[a] Corresponding author.
E-mail: yucw@dhu.edu.cn

Drafting force of sliver is dependent on fibre properties such as fibre fineness, length, surface lubricant, crimp, fibre hooks, tenacity, fibre compactness[6-11] and on drafting parameters such as break draft, ratch, input weight, top roller pressure, front roller covering, roller speed and spinning efficiency[12-15]. Most of the studies of drafting force on roving do not represent free fibre bundle movements because of the presence of twist.

Recently, Lin *et al.*[16] discussed the concept of 'characteristic point'[17] on drafting force-draft ratio curve which gives new dimensions to optimize the break draft. Using ITT draftometer, installed on a pilot scale drafting system limits to characterize the industrial drawing scenario. Zhang and Yu[18] established an online drafting force measuring device, which simulate commonly used drafting conditions, such as doubling, speed, draft ratio and ratch, installed on the front drafting zone of industrial scale drawing frame.

The result reported[18] demonstrates that front draft settings have a considerable effect on the drafting force, and the draft ratio has a distinct relation with sliver irregularity but it did not discuss the effect of ratch at back zone. Furthermore, it lacks to separate the effects of break draft from main draft because the drafting force was measured only in the front drafting zone.

All the efforts are not yet adequate to describe the dynamic states of the fibre bundles in back draft zone, because several factors are affecting the drafting force. Fortunately, with the advancement of technology, there may exist a potential way to quantify the drafting force with more precision.

To cast more light on the above mentioned aspect, this study elucidates the explicit effect of drafting force on break draft and sliver irregularity, on industrially used draw frame, while measuring it at back zone. Furthermore, the effects of coefficient of variation (CV) of drafting force on break draft and the irregularity index (or unevenness) of output slivers are also discussed and analyzed. This study is therefore a continuance of research on the relation of online dynamic drafting force and its variability with the short term unevenness of cotton silver at the break draft zone.

In order to evaluate the drafting force experimentally, a number of devices have been employed and reported in the literature. There are two basic designs for the measuring of drafting force. The first type is based on the design with one set of rollers made as the deflecting element of the force transducer, and tension in the strand is measured by the amount of deflection[1,3,19,20]. The aforesaid equipments are based on single drafting zone and mounted on a special pilot (laboratory scale) drafting system. While the second one, recently introduced[18] is based on a pressure bar placed between the drafting rollers (Fig.1) and can be installed on industrially used draw frames.

In this study, online drafting force values are measured at break draft zone on DHU drawing frame mounted with the drafting force measuring device developed by Zhang and Yu[18]. The measuring system comprises two weighting sensors (one on each side of the device), a digital measurement controller, pressure bar, and a processor (Fig.1).

2 Materials and Methods

Carded sliver (linear density 3700 tex, 0.16 Ne) was prepared from 100% cotton. Fibre properties

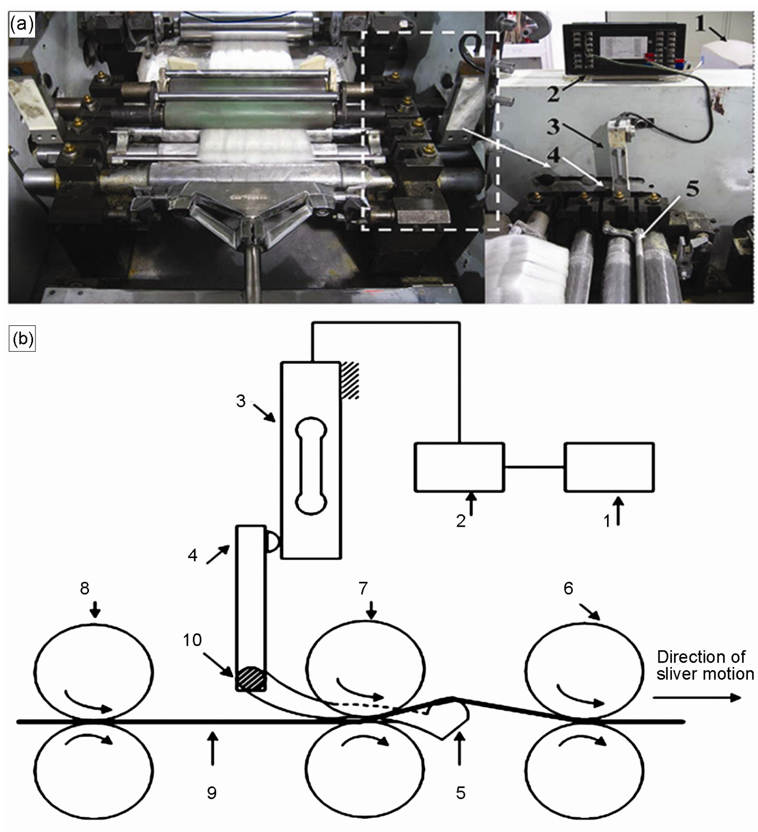

Fig. 1—(a) Photograph of drafting zone of the DHU drawing frame[18] and (b) Schematic diagram of drafting zone [1- computer system, 2- digital measurement controller, 3- weighting sensors, 4- arm, 5- pressure bar, 6- front rollers, 7- middle rollers, 8- back rollers, 9- sliver, and 10- shaft]

were tested on Uster HVI 1000 and AFIS Pro-2 and were kept as follows: fibre mean length (by wt) 24.8mm, SFC (< 12.7mm span length) 8.8 %, UQL (by wt) 30.22mm and fineness 155 mtex. Fibre nep and maturity ratio were kept 274Cnt/g and 0.89 respectively. The carded slivers were drafted on DHU drawing frame under different ratch and break draft ratios. Values of break draft, sliver doubling, and ratch were all kept close to the actual production settings. The drafting system comprises 3 over 3 drafting rollers with pressure bar. Drafting force values has been collected by online drafting force measurement device, installed at the back drafting zone of the DHU drawing frame. Mean drafting force value and its variability (coefficient of variation CV %) was calculated from 300 measured values using online draftometer for each break draft. Five sliver samples were tested for irregularity on the unevenness tester (Changling YG135) for each break draft. Experimental work involved break drafts ratios, namely 1.12, 1.2, 1.26, 1.36, 1.45, 1.52, 1.7 and 1.9. Throughout all experiments, top roller pressures were kept constant to eliminate its effect on drafting force and sliver irregularity. To elucidate the effect of back zone ratch, four gauges were selected at 43, 46, 48 and 51 mm between back and middle rollers. Furthermore, the speed of back roller was fixed at 44 rpm. In order to explicit the effect of break draft from front draft, the front draft ratio and ratch were also kept constant at 4 mm and 40 mm respectively. To ensure the accuracy of observations, drafting force device has been calibrated between each ratch change. Both back and middle bottom rollers diameters were 30 mm and the front rollers diameter was 45 mm, all with spiral flutes. Back and front rollers were positively driven by servo motors. Spring weighing system was applied on top rollers with 30 kg both on back and middle rollers, while 25kg on front roller, all of 37mm diameter. The output sliver hank for each break draft was same for all gauges (Table 1).

Before sliver testing, all samples were conditioned for 24 h at $20^{o} \pm 2\,^{o}C$ and 65 ± 5 % relative humidity. Sliver samples were tested for irregularity on the unevenness tester (Changling YG135) at the speeds of 25 m/min, for 5 min according to ASTM 1425.

3 Results and Discussion

3.1 Effect of Break Draft on Dynamic Drafting Force and its Variability

The carded cotton sliver (linear density 3700 tex, 0.16 Ne) was drafted on DHU 301 drawing frame. The drafting force has been measured at back zone through online drafting force measuring device at 51 mm ratch and the results are shown in Fig.2 (a) & (b). The drafting force-break draft curve [Fig.2 (a)] is in general agreement with previous studies[1-4]. To further elaborate, the curve can be categorized into three phases. At first phase (break draft 1.1) the drafting force is found to be the lowest, because the speed difference between the middle roller and the back roller is relatively small with corresponding high variability (CV of drafting force), along with fibre slippage between middle rollers. A further little increase in break draft results in rapid increase of drafting force. That may be categorized by narrowing

Table 1—Output sliver weight and their corresponding sliver CV and irregularity index

Break draft	Output weight g/m	Sliver CV	Irregularity index
1.12	2.38	7.18	9.17
1.2	2.19	6.85	8.28
1.26	2.05	6.60	7.69
1.36	1.90	6.39	7.10
1.45	1.72	7.00	7.40
1.52	1.64	7.18	7.54
1.7	1.56	7.98	8.04

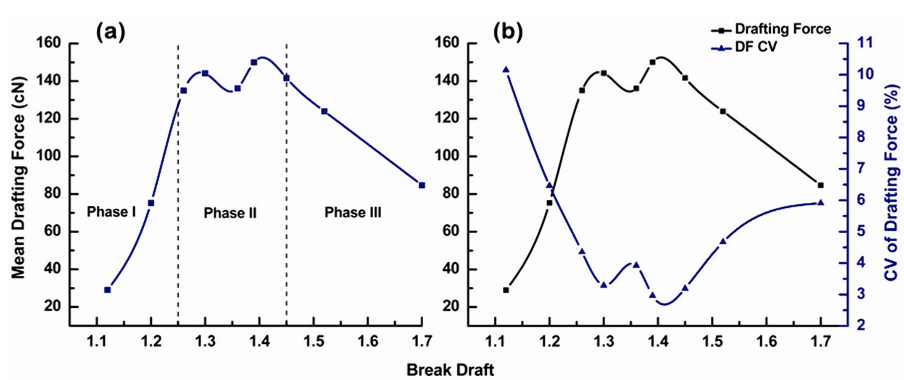

Fig. 2—Effect of break draft on (a) mean drafting force, and (b) CV % of drafting force (DF CV)

of the sliver cross section due to the alignment of fibre, removal of fibre crimps and hooks (straightness is usually about 70 -80%), all of which contribute to increased fibre-to-fibre friction. This initial increase in drafting force with draft is found at variance with the results of some others researche due to the difference in draft range.

Phase II can be attributed as peak region, ranges (break draft 1.25 - 1.45). This trend is obvious in all ratch shown in Fig. 3(a). In this experiment, drafting force reaches its highest point, when the draft ratio is set close to 1.45. At this region, the dynamic friction among fibres is predominant, and the shearing force more readily overcomes the inter-fibre friction. The high fluctuation of dynamic drafting force may be attributed to the area, where the fibres are trying to overcome the binding stage.

During third phase, after reaching its maximum at around 1.45 break draft, drafting force decreases gradually with the further increase in draft ratio. Due to the increased difference in the relative speed of middle and back roller (higher break draft) or high average fibre speed, fibres trigger out to move relative to each other. This results in decrease of the number of contact points amongst surrounding fibres and hence fibres begin to slip more easily, thus causing reduction in drafting force.

These phases were not present in some other researchers because of the differences in draft range.

Figure 2 (b) shows the relationship between drafting force and its variation (CV) corresponding to the break draft ratios. The CV of drafting force shows opposite trend to the drafting force. On moving from lower break draft to higher break draft, first the CV % of drafting force decreases and then increases after touching its lowest point around 1.4 break draft. The maximum drafting force near break draft 1.4 is corresponding to the lowest CV of drafting force. With further increase in break drafts, the CV of drafting force began to get worse, caused by the sudden increase in relative movement of drafting rollers, and hence results in uncontrolled stretching of fibre strands.

3.2 Effect of Back Ratch on Dynamic Drafting Force

In order to study the impact of back ratch on drafting force and its variability, carded sliver (linear density 3700 tex, 0.16 Ne) was drafted on DHU 301 drawing frame. Drafting force was measured at back zone through online drafting force measuring device, under different ratch and draft ratios. Usually the ratch settings are adjusted according to the length of fibres. The variation in length distribution of different cotton is an important factor to predict and control the fibre motion. The trends in Fig. 3 (a) & (b) shows that as ratch increases, the magnitude of the drafting force significantly reduce. It can be said that there is a

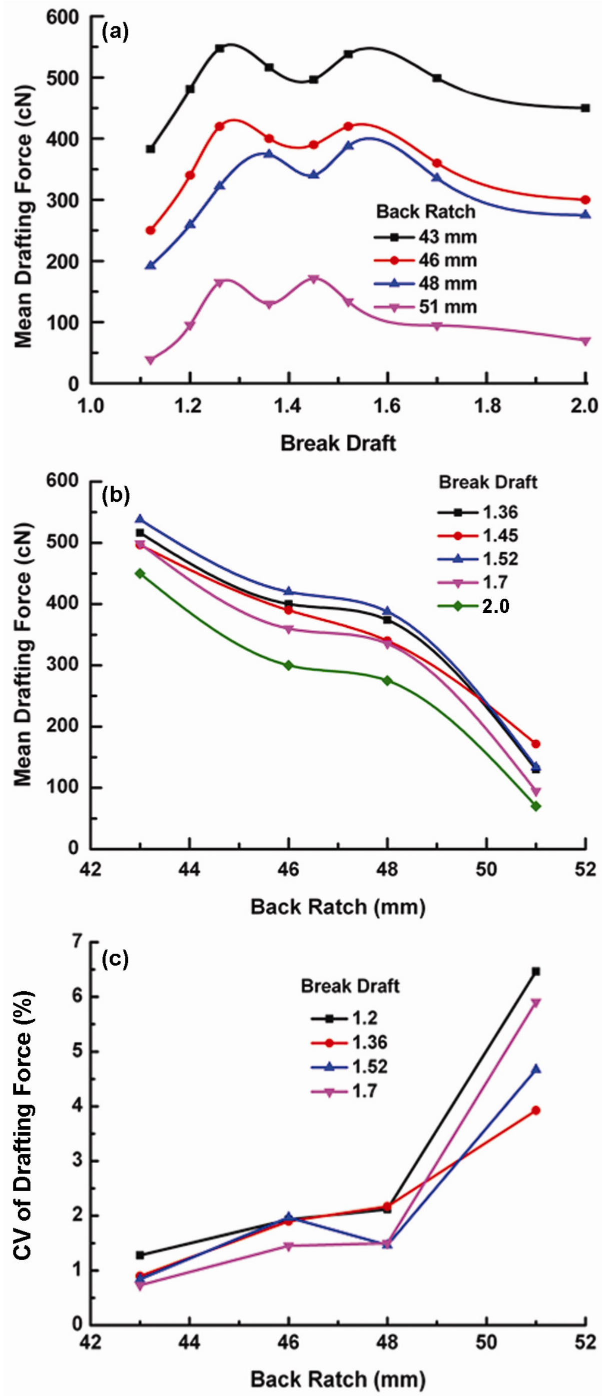

Fig. 3—Effect of back ratch on (a) mean drafting force at back zone; (b) drafting force with different break drafts; and (c) CV of drafting force at different break drafts

linear relationship between drafting force and reciprocal of ratch. Furthermore, it is obvious that within the same ratch, maximum drafting force is dependent on break draft. Figure 3 (b) illustrates interdependence of the drafting force on ratch and break draft, which is in agreement with previous studies of Plonsker and Backer[1], and Lin *et al* [16]. This decline in drafting force (Fig. 2) can be interpreted in terms of more progressive reduction in sliver count as ratch is increased; this is because the fibres being attenuated by the middle roller are subjected to the friction of fewer fibres with less contact points. A slight variation in the peak region of drafting force can be seen as the ratch is changed from 43 mm to 51 mm. It is because of the dependence of speed change points on the distance between two rollers (ratch).

As depicted in Fig. 3 (c), variability (CV %) of drafting force increases with the increase in roller setting. At start, variability shows a steady rising trend, with an increase of ratch but after a certain point (48mm) it increases sharply. This is due to the fact that at lower roller setting, there is more friction field (more cohesion) and hence fibre movement occurs in a more controlled manner, but wider ratch results in more uncontrolled fibres (floating) movement due to less contact points. At a higher draft ratio, lesser fibres are drawn out of the sliver and thus contribute to deteriorating the stability of the drafting force.

Break drafts 1.2 and 1.7 show high variability (CV) of drafting force as compared to other break drafts (1.36). It is also associated with the lower values of drafting force at these break drafts.

3.3 Effect of Drafting Force in Break Draft Zone on Sliver Irregularity

It is acclaimed that the dynamic friction coefficient of fibres is usually lower than the static friction coefficient, and the difference contributes to the irregular motion of fibres which causes the drafting waves in roller drafting[21]. Drafting force and sliver irregularity has been measured at back ratch 46 mm with different back draft ratios. The curve in Fig 4 (a) helps to understand the relation between dynamic drafting force and short term sliver irregularity. To eliminate the effect of output sliver weight on sliver irregularity, the irregularity index is employed, which is the ratio of tested irregularity to the theoretical irregularity. Figure 4 (a) shows that the minimum sliver irregularity is achieved at around 1.45 break draft. As the break draft further increases the sliver regularity decreases at 46 mm back gauge. The best sliver regularity values are corresponding to the high drafting force region. At lower break drafts, the sliver irregularity is higher, which indicates sliver slippage through middle roller nip.

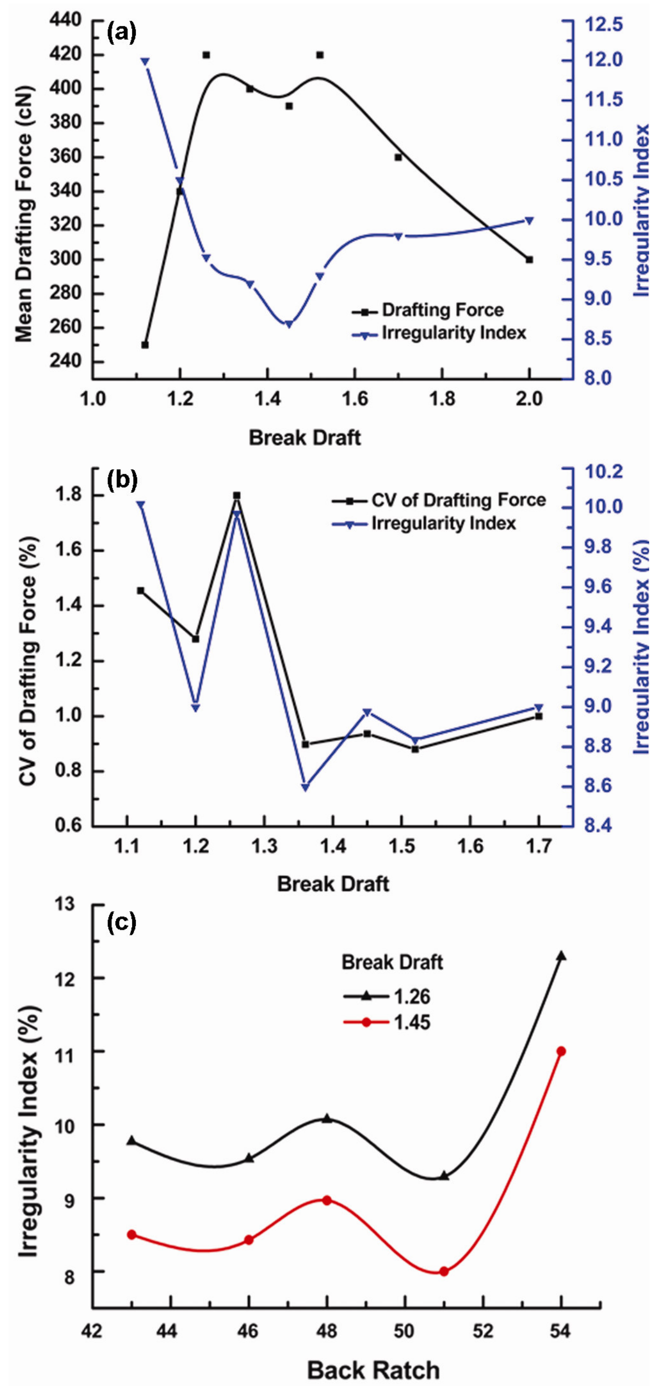

Fig. 4—(a) Effect of break draft on drafting force and sliver irregularity at 46mm back ratch, (b) the CV of break draft on the CV of drafting force and sliver irregularity and (c) Effect of ratch on sliver irregularity

CV of drafting force and sliver irregularity shows somehow same trend [Fig. 4(b)] at 48mm gauge. This means that the higher drafting force variability (CV %) corresponds to higher sliver irregularity. This is because high drafting force values and low variability of drafting force provide better opening and equalizing of fibres.

Minimum sliver irregularity can be achieved when the CV of the drafting force reaches its minimum. The uniformity of opening of fibre bundles in drafting zone may be recognized by the variability of drafting force. To elucidate the effect of ratch, two break drafts 1.26 and 1.45 (both in the high drafting force region) [Fig. 4(a)] have been selected and are shown in Fig. 4(c).

It is obvious that the sliver irregularity is minimized near 50mm ratch. Furthermore, the sliver irregularity is less affected at around 44-50 mm ratch, but with a further widening of ratch the irregularity increases rapidly. The break draft 1.45 gives a slightly better evenness than break draft 1.26, which correlates to higher drafting force at the break draft of 1.45 as compared to break draft of 1.26 [Fig. 4(a)]. The same experiment was performed on 48 mm back gauge and individual values of CV of sliver (breaker drawing) for each break draft is shown at Table 1, which indicates the same trends but with different magnitude and different minimum sliver evenness with corresponding break draft. It may be concluded that the break draft and ratch settings have a combined effect on silver irregularity[21]. In this study, break draft 1.36 and 48mm back ratch provide minimum values of sliver irregularity (Table 1). It is therefore deduced that the high drafting force (lower variability) contributes to more stable attenuation of fibre bundles, and hence produce more regular fibre assemblies.

4 Conclusion

The study on dynamic drafting force and its variability provides better understanding of fibre behavior during the drafting process. The results obtained show that it is possible to optimize break draft settings with the help of drafting force and its variability; therefore, better linear density of cotton sliver may be achieved. It is inferred that the drafting force is dependent on break draft, and there exists a peak region where drafting force reaches its maximum point. The draft ratio at which CV % of drafting force begins to decrease and stabilize, associates with high drafting force, and can be chosen as an optimum break draft in roller drafting process. In short, higher values of drafting force correspond to low values of drafting force variability (CV %) and this provides better sliver short term regularity. Further study is underway to establish the relation between the variability (CV %) of drafting force and the flowing fibre bundle behavior with different top roller pressure.

References

1 Ploansker H R & Backer S, *Text Res J*, 37 (1967) 673.
2 Audivert R, Villaronga M & Coscollá R, *Text Res J,* 37 (1967) 1.
3 Olsen J S, *Text Res J*, 44 (1974) 852.
4 Dogu I, *Text Res J*, 41 (1971) 534.
5 Siddiqui Q & Yu C, *Proceedings*, *4th ITMC International Conference* (ENSAIT Roubaix, France), 2013, 95.
6 Korkmaz Y & Behery H M, *Text Res J*, 74 (2004) 405.
7 Su C, Lo K J & Lee J Y, *Text Res J*, 68 (1998) 559.
8 Röder H L, *Text Res J*, 28 (1958) 819.
9 Mcalister I D, Bargeron J D & Godbey L C, *Appl Eng Agricult*, 19 (2003) 637.
10 Graham J S, Taylor R A, *Text Res J*, 50 (1980) 271.
11 Lawson R, Worley S & Ramey H H, *Text Res J*, 47 (1977) 755.
12 Louis G L & Fiori L A, *Text Res J*, 46 (1976) 322.
13 Su C I & Fang J X, *Text Res J*, 76 (2006) 441.
14 Das A & Ishtiaque S M, *Indian J Fibre Text Res* , 29 (2004) 173.
15 Das A & Ishtiaque S M, *Indian J Fibre Text Res* , 29 (2004) 179.
16 Lin Q, Oxenham W & Yu C, *J Text Inst,* 102 (2011) 994.
17 *Automatically reaching the optimum, Draw Frame TD-03 Manual* (Truetzschler Spinning), 2013, 12.
18 Zhang Z & Yu C, *J Text Inst*, 103 (2011) 341.
19 Bartlett G W, Smith T M & Thompson H A, *Text Res J*, 23 (1953) 647.
20 DeLuca L B, Hebert J J, Simpson J, *Text Res J*, 35 (1965) 476.
21 Siddiqui Q & Yu C, *Text Res J*, (in press) 2014.