Comparative study of different test methods used for the measurement of physical properties of cotton

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Ten cotton varieties/hybrids with varying properties, such as 2.5% span length measured by HVI, AFIS & Baer Sorter; bundle strength at 3.2mm measured by HVI and Stello meter; and linear density measured by AFIS, HVI and Gravimetric method, have been studied. Maturities are also compared between AFIS and caustic soda methods. In addition, short fibre content measured by HVI, Baer Sorter and AFIS are also compared. Results show that AFIS values may be considered more realistic for length parameters, viz. 2.5% span length and short fibre content, as compared to HVI values. However, the linear density as measured by AFIS is not correct. Micronaire value (micrograms/inch) from HVI agrees quite well with the gravimetric linear density. Maturity value as measured by AFIS does not agree with the percentage maturity determined using caustic soda method.

Keywords: AFIS Method, Baer Sorter method, Cotton, HVI method, Linear density, Maturity, Strength

1 Introduction
Cotton is a seed hair that grows from the epidermal cells on the surface of the seeds. The cotton plant (Gossypium species) is a shrub, native to tropical and subtropical regions around the world. Seed hair, also called as cotton fibres or lint, are usually off-white in colour although some varieties exist having naturally coloured fibres.

Chemically, cotton consists of 88-96% pure cellulose along with protein, pectic substances (congealed gum-like carbohydrates), ash and wax. After scouring and bleaching, cotton contains about 99% cellulose. The fibre length varies with the type and quality within the range 10-45 mm and the fibre diameter ranges from 11 µ to 22 µ. Cotton is a relatively strong fibre with a strength of 25-35 cN/tex and a breaking elongation of 7-9%.

The mechanical behaviour of native cotton fibres depends on their molecular structure. The properties of cotton, viz. length, fineness, strength and maturity, play an important role in determining its behaviour. There are many methods and instruments used to measure the physical properties of cotton. There are large variations in these characteristics not only between fibres of different samples but also between the fibres constituting the same sample. Studies have shown that the variations in fibre length in a bulk sample are of the same order as those observed between fibres on a single seed of that variety. The characteristics of any random sample picked out from a bulk may not be representative of the bulk in view of this large variation. Hence, before carrying out any tests for fibre characteristics, it is preferable to prepare a test sample, which is as far as possible true representative of the constituents of the bulk.

The conventional methods used for measuring fibre properties tend to be tedious and time consuming. Moreover, a certain amount of expertise is required for the results to be reproducible and accurate. The two commonly used instruments, namely high volume instrument (HVI) and advanced fibre information system (AFIS), are fully automatic machines which test a number of fibre parameters at the same time, which, in turn, intend to save a lot of time and effort spent in testing through the conventional methods. Moreover, these instruments are also meant to be useful since operational errors are minimized due to
their automation. It may be noted here that the United States Department of Agriculture (USDA) has made it mandatory to test quality of each bale of cotton using the HVI system. Trading of cotton lint in bale form is therefore based on HVI test results. In India, trading is based on testing of a lot consisting of 55 bales. Fibre samples are drawn from 3-5 bales at random and tested using HVI. AFIS on the other hand is mainly used by modern textile mills for evaluating the individual fibre properties in order to optimize their downstream processing.

Proper knowledge of these parameters and their values help the spinner to get the best quality yarn spun from the sample. Different methods are used for the determination of the same parameters. It is expected that the results for a particular parameter expressed by different methods agree numerically within a narrow tolerance zone. If not, at least they should follow the same trend.

The present investigation intends to correlate the same physical property of cotton obtained from both the conventional as well as the hi-tech instruments, with each other to give an idea of the similarity or variations in the results obtained from various instruments.

2 Materials and Methods

Ten cotton varieties, based on a wide range of micronaire (fineness) values, were used for the study. The varieties/hybrids include DCH 32 (Dharwad, Halyal and Kiruvatti), Bunny (Bailhongal), F-1378 (Dabwali), F-846 (Elanabad), F-1861 (Faridkot), G.Cot 19 (Amreli), G.Cot Dhy 7 (Surat) and MCU-5-B (Guntur). After sampling, the hand-made slivers were prepared. Loose cotton lint was used for HVI testing while hand-made slivers were used for testing fibre length (Baer Sorter), linear density (gravimetric method), maturity percentage (caustic soda method), and fibre bundle tenacity (Stellometer and AFIS).

All the tests were carried out under standard atmospheric conditions of 65% ±2% RH and 27°C ± 2°C temperature.

2.1 Determination of Length and Length Variation

Comb Sorter or Baer Sorter instrument consists of a bed of upright and parallel combs which control the fibres and enable the sample to be fractionated into length groups. A sample of fibres is arranged in the form of an array of uniform density in the descending order of length. Some of the fibre length and fibre length distribution parameters like average or mean length, effective length, short fibre percentage and dispersion percentage, are calculated by tracing of this array. Two patterns were prepared for each sample to arrive at the results.

2.2 Gravimetric Linear Density

In the gravimetric or cut and weigh method (a direct method), a bunch of combed parallel fibres is cut to a length of 1.5cm. The fibres are then placed between two slides sealed at one edge and spread evenly so as to parallelize the fibres with each other. The fibres are viewed under a projection microscope and the number of fibres present in the slide is counted. These fibres are then weighed on a sensitive balance and the linear density (millitex) is determined. Around 800 – 1000 fibres are used to calculate the linear density of each sample.

2.3 Fibre Maturity

The direct method of determining the fibre maturity (Pm%) is used and the percentage of mature fibres is determined by the caustic soda swelling method. A homogenous sliver is prepared from the sample. About 100-200 fibres are drawn from the sliver, mounted on a glass slide and a cover slip is placed over the fibres. The fibres are then irrigated with 18% caustic soda. By viewing the fibres under the microscope, they are classified into two groups, namely mature and immature fibres. Mature fibres are those which have a greater wall thickness than the width of their lumen. Moreover, when irrigated with caustic soda and viewed under the microscope, they appear to be cylindrical with little or no convolutions. Immature fibres follow opposite trend than that observed in mature fibres. From the total number of fibres and the number of mature fibres, the percentage of mature fibres (Pm%) is calculated. Two slides containing about 100-200 fibres each were tested for each sample.

2.4 Bundle Strength

Stellometer is a precision fibre testing instrument for measuring bundle strength and elongation simultaneously. It is a pendulum type of instrument working on the constant rate of loading principle. Normally, the rate of loading used is 1kg/s. A pointer freely mounted on the axis and driven by a sensing pin mounted on the pendulum moves over a scale, indicating the breaking load. In addition, a small pointer indicates the percentage elongation on
an auxiliary scale. Six tufts were broken for each sample and an average of these is reported here.

2.5 High Volume Instrument
The testing is carried out in the following two stages in the stand-alone mode:

- Fibre fineness/micronaire measurement
- Length and strength measurement

High volume instrument (HVI) system provides measurement of length, uniformity, strength, elongation, micronaire, colour and short fibre content. For each sample, micronaire was determined by testing four properly opened masses of cotton weighing between 8.5 g and 11 g and by testing four combs for length and strength. Average of these results is reported.

2.6 Advanced Fibre Information System
This instrument measures length, fineness, maturity, circularity, etc. of each fibre fed, and from the data so obtained provides average length of individual fibres in a sliver fed to the system, as also the length distribution both by number and weight after measuring the individual fibre length for a selected number of fibres. This number can be varied between 1000 and 10000. Other parameters the instrument can measure are short fibre content, immature fibre content, neps/g and percentage of dust and trash. In the present case, 3000 fibres were used for measurements per sample.

3 Results and Discussion
As explained, several parameters are determined by the HVI and AFIS instruments but only the main fibre properties, viz. 2.5% span length, linear density, maturity, strength and short fibre content (SFC), have been dealt with in the paper. The above-mentioned properties obtained from these instruments have been correlated with the values of the same parameters tested via conventional methods. The idea of carrying out tests for measurement of some physical or mechanical parameters is to get the most accurate and reproducible results. Reproducibility of results generally depends on proper sampling and the inherent variability in the material. But the accuracy of measurement of a parameter depends on the physical principals used in the test method. The following discussion shows limitations in determination of some physical parameters using HVI and AFIS. These limitations are mainly due to the limitation of physical test methods used for these determinations.

3.1 2.5% Span Length Parameters
Fibre length in a cotton sample has length distribution corresponding to variation in fibre length of individual fibres. If one can measure separately all the individual fibres present in a sample, he would be able to get the true distribution of the fibre length. But this is almost impossible. However, a true representative tuft constituting thousands of fibres taken from the sample can also give a distribution almost similar to the true distribution. Moreover, the measurements of lengths of individual fibres for a few thousand fibres are also difficult and time consuming, though not impossible. Length can be determined from this distribution, where 2.5% of the fibres in the specimen have length greater than this particular length. This length is called as 2.5% span length. The data of the length parameters and their correlation matrix are given in Table 1. From the correlation matrix, it is evident that the 2.5% span length parameters obtained from HVI, AFIS and Baer Sorter are positively correlated at 0.01 level of significance.

Table 1 shows that though all the values are of the same parameter, there is a variation in the values observed by HVI, AFIS and Baer Sorter. It is observed that 2.5% span length by Baer Sorter always gives the highest values. On the other hand, 2.5% span length by HVI is lowest for any sample with a minimum difference of 6 mm with respect to Baer Sorter values. Comparatively, AFIS and Baer Sorter values are matching more with each other, particularly in the shorter fibre segment. But for fibre length ≥ 30 mm HVI value, the difference between AFIS values and HVI values as well as between Baer Sorter and HVI values is considerably high. Also, the difference between Baer Sorter and AFIS values is of the order of 3-4 mm for these samples.

In HVI, fibres are caught in the comb at one end while the other end is straightened and takes part in the length determination. For each fibre to get entangled in the comb wire, some length is used. Therefore, 2.5% span length by HVI is bound to give lesser values than those obtained by AFIS or Baer Sorter. The portion of the fibre caught in the comb appears to be at least 6 mm. For samples containing longer fibres, it appears that this entangled length for the fibre also becomes more and can be as high as...
12.7 mm when compared with Baer Sorter values. In fact, Baer Sorter values for 2.5% span length can be considered as the basis for the actual fibre length since this is physically observed. It appears that AFIS is able to measure fibre length to a good extent comparable to Baer Sorter fibre length. But in AFIS also the fibres might be getting broken due to the opening and individualization process in the instrument. This may be more so for longer fibres which have lesser linear density. If one has to get the actual fibre length distribution Baer Sorter is the best, though it is clumsy and time consuming. AFIS values may be considered more realistic as compared to HVI values.

### 3.2 Linear Density

For the determination of fibre strength, the cross-sectional area cannot be used as it varies along the length of the fibre and is therefore difficult to measure. Instead, for the material strength determination in textile fibres, linear density (weight per unit length) of the fibres is used. Most accurate method would be to measure total length of fibres in a given sample corresponding to a given mass. An easier way is to cut all the fibres to a specific length say 1 cm and count the number of fibres using a microscope along with their mass determination. Here, it is assumed that the mass distribution along the length of the fibres is uniform. This is more or less true for cotton fibres. Table 2 presents the values of linear density and its correlation matrix. From the correlation matrix, it is evident that the fineness values obtained from different methods are positively correlated at 0.01 level of significance.

One micronaire means 1 µg/inch which is equal to 39.37 m/tex. Hence, in Table 2 the micronaire values obtained from HVI have been multiplied by 39.37 to obtain the millitex values. Table 2 clearly indicates that the linear density as obtained by converting micronaire into millitex and actually gravimetrically measured agrees very well with each other. The maximum difference in linear density observed by these two methods is 5 m/tex for Bunny. In all other cases, the difference is either not there or 1 or 2 points only. However, linear density as indicated by AFIS shows some difference with respect to gravimetric value. AFIS and gravimetric values match around 150-160 m/tex but for finer cottons, AFIS shows higher linear density as compared to gravimetric method and for coarser samples, it shows lower linear density as compared to the gravimetric method. Since gravimetric measurement is based on the actual physical measurement, gravimetric linear density should be considered as more realistic. From the results, it can be inferred that the micronaire from HVI is more indicative of correct linear density than that obtained from AFIS.

### 3.3 Maturity

Maturity of cotton fibres is associated with the deposition of cellulose in the secondary wall. The higher the cellulose deposition the more mature is the fibre. Quantification of maturity is done by different methods such as NaOH method, circularity method, degree of thickening, modulus of rigidity, etc. The generally accepted method of maturity is the NaOH method. The maturity values and their correlation matrix are given in Table 3. It can be seen that the maturity values as observed by NaOH method and as given by AFIS do not show any correlation. The maturity as given by AFIS is based on some internal
3.4 Strength

Fibre strength is determined by breaking a tuft of fibres held in two jaws separated by 3.2mm. Breakage is obtained by pulling the jaws apart using constant rate of loading or constant rate of elongation device. The load developed is measured using a strain gauge. Linear density of the tuft so tested is used for the determination of tenacity. The values of strength and its correlation matrix are presented in Table 4. From the correlation matrix, it is evident that the strength parameters obtained from HVI and Stellometer show a positive correlation, significant at 0.01 level.

It can be seen from Table 4 that the values of strength obtained from HVI and Stellometer do not exactly match but show a small difference. The difference observed does not exceed 2 g/tex. On the whole, the strength values obtained from stellometer are found to be higher than that obtained from HVI. The short staple fibres show a higher variation in the Stellometer and HVI strength values. Stellometer uses the constant rate of loading principal while HVI uses constant rate of elongation principal. Also, the linear density in the case of stellometer is obtained by measuring the mass of the tuft while in the case of HVI it is determined by using optical density of the tuft used in the strength determination. In spite of these differences, HVI tenacity as measured in ICC mode agrees quite well with the Stellometer tenacity.

3.5 Short Fibre Content (SFC)

It is observed that the short fibres in a sample give rise to thick and thin places in the yarn. The more the
short fibres, the more is the non-uniformity in the yarn. Generally, there are two methods for the determination of short fibres. In one method, per cent number of fibres (less than half an inch i.e. 12.7 mm length) in a given sample is considered as short fibre content. In the other method, short fibres lesser than half of the upper half mean length are considered as short fibre content. Short fibre content based on this method appears to be more relevant since the machine settings during yarn production are done based on upper half mean length or 2.5% span length which are almost equal to each other. The values of SFC and their correlation matrix are presented in Table 5.

Looking at the correlation matrix it is found that SFC (w) obtained from AFIS has a positive correlation with SFC (n) but a negative correlation with SFC% is obtained from Baer Sorter, both significant at 0.05 levels. Moreover, SFC (n) also bears a negative correlation (significant at 0.05 level) with SFC % of Baer Sorter. There is no significant correlation observed between the other parameters.

In Baer Sorter, the SFC is determined by taking percentage number of fibres having length less than half of the upper half mean length, while in AFIS the SFC is determined by per cent of fibres having length less than 12.7 mm. This difference in method of determination of SFC may be the reason for getting a negative correlation between the same parameters measured by two different methods. As explained earlier, in HVI a part of the fibre length is entangled within the comb. Therefore, the short fibres as determined by HVI using its internal algorithm are very less and do not show any correlation with that determined by either AFIS or Baer Sorter. The SFC determined by HVI therefore seems to be not reliable.

4 Conclusions

4.1 The best method to obtain the actual fibre length distribution is the Baer Sorter method though it is time consuming and requires good expertise.

4.2 AFIS values for length may be considered more realistic as compared to HVI values.

4.3 Since gravimetric measurement is based on the actual physical measurement, gravimetric linear density should be considered as more realistic.

4.4 Micronaire from HVI is more indicative of correct linear density than that obtained from AFIS.

4.5 Since the physical significance of the algorithm used to determine the maturity value in AFIS is not known, value of maturity obtained from AFIS needs to be carefully considered.

4.6 The SFC determined by HVI seems to be not reliable since its algorithm is very low and does not show any correlation with the SFC determined by either AFIS or Baer Sorter.

Industrial Importance: Precise knowledge of correct values of the fibre parameters would ensure proper/optimum machine settings for better quality yarns, which, in turn, would help in the production of better end-products.

References


