Measurement of energy required to detach cotton fibres from seed—Some practical considerations

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While using the Shirley attachment strength tester, a commercially available instrument that measures the energy required to separate cotton fibres from the seed, it has been found that the process of fibre separation does not simulate the roller ginning process and that considerable fibre breakage occurs during the test, leading to high energy values. A partial modification of the experimental setup is suggested such that the process of fibre separation more closely resembles roller ginning. Also suggested is a testing procedure in which all the fibres on a seed, divided into five tufts, are tested one after another so that besides the average energy per fibre, the average energy per unit weight of fibres can be calculated without assuming arbitrary weightages for the micropylar, side and chalazal regions.

Keywords: Chalazal region, Cotton fibre, Cotton seed, Detachment energy, Micropylar region, Roller ginning

1 Introduction

It is well recognised that the strength of attachment between cotton fibre and seed influences the extent of fibre breakage during ginning and that the energy required to separate fibres from the seed influences the energy requirement in commercial ginning. Studies on attachment strength were initiated by Smith and Pearson, Iyengar and Chapman. In these early studies, existing tensile testing instruments were used which worked at slow rates of loading.

Recognizing that the slow rates of loading fail to simulate the actual ginning process, Prakash and Iyengar designed an apparatus that measured the ballistic energy required to separate a tuft of fibres from the cotton seed.

For over two decades, since the pioneering work referred to above was carried out, no further studies on strength of attachment were reported till 1984 when Fransen et al. developed a refined model of what was originally described by Prakash and Iyengar. Using this instrument, which has since been manufactured and marketed by Shirley Developments Ltd (U.K.), Fransen et al. as well as Verschraege and Kiekens, carried out tests on some varieties of cotton. Attachment energy was determined separately for the micropylar, chalazal and side regions and it was observed that energy required to pull out a fibre tuft of unit weight is only weakly related to fibre strength.

The studies did not generate experimental data that could be used for prediction of energy requirements in commercial ginning. Prakash and Iyengar’s work included fibres only from chalazal (C) and side (S) regions, but not from the micropylar (M) end. Moreover, the method chosen by them for calculating the energy for ginning a given quantity of lint was based on arbitrary weightages for the chalazal and side regions. In the work of Fransen et al., the micropylar fibres were also included but the data were still not amenable to estimation of energy demands in ginning. This has been so because the intention of these researchers was to relate attachment energy with fibre strength. For this, attachment energy in different regions was determined on different seeds.

Ever since the pioneering work carried out at CIRCOT, several new varieties, including hybrids, have been evolved for the various cotton tracts in India. No data are available on these varieties in respect of attachment energy. Information on energy required to obtain unit weight of lint in various genotypes will be useful to cotton breeders while making selections for easy ginnability besides other desirable characteristics.

This work was undertaken with a view to evolve a test procedure, while using the Shirley
instrument, that may render possible the evaluation of the energy to extract a certain weight of lint from a variety, irrespective of the location on the seed. The suggested procedure involves testing of all the fibres on a given seed so as to avoid the need to employ arbitrary weightages for different regions suggested by earlier workers. Some changes in the experimental set-up, have also been attempted such that the new test condition will simulate roller ginning more closely than the set-up originally present in the Shirley instrument. The energy data thus obtained will be more appropriate for consideration while studying demands in commercial ginning of cotton. This paper outlines the new test procedure and discusses the preliminary results on 18 varieties of cotton.

2 Materials and Methods

2.1 Shirley Cotton Seed Attachment Tester

It is a ballistic instrument\textsuperscript{5,6} that permits determination of the energy required to separate a tuft of fibres from the cotton seed. The main part of the instrument is a suitably weighted pendulum (25 cm length) which, when released from the horizontal position, swings over a semi-circle. When the pendulum is at the lowest point, a metal strip attached to the tip of it knocks off the seed, some of the fibres of which are held in a Pressley clamp. The rise of the pendulum after the seed is dislodged will depend on the energy required to separate fibres from the seed. A pointer moving over a scale will permit a direct reading of the energy used up in what resembles the roller ginning operation.

2.1.1 Modified Procedure

The procedure for tests adopted while using the Shirley instrument in the present work was slightly different from the one suggested by the instrument designers. In the procedure recommended by them, the seed (C) is made to remain entrapped in a slot (S) in a metal plate (P) as shown in Fig. 1a. Between the Pressley jaws (J) in which the fibres (F) are held and the slot (S), there is a gap (B) of about 3 mm. The pendulum strikes the fibre tuft in this gap, causing a sudden pull on the fibres which get detached from the seed.

In the above arrangement, the seed is restrained during the impact of the pendulum. The pull on the fibre is directed almost normal to the seed surface and there are chances of fibre breakage. The action does not fully simulate roller ginning in which fibres are pulled by forces almost tangential to the seed surface.

In the present work, the slot was dispensed with and the seed was allowed to remain free as shown in Fig. 1b. The pendulum rod (not shown) was brought closer to the Pressley jaw housing, such that only a minimal gap (B') existed between them. Fibres were mounted on Pressley jaws at a distance of less than 3 mm from the seed by using a Pressley vice with marginal alterations made on it. As the pendulum swings, the blade hits the seed which is now allowed to take any orientation with respect to the fibre tuft anchored in the jaws. The manner in which the seed moves with respect to the fibres during the impact resembles its behaviour during roller ginning.

2.2 Test Procedure

Fibres on a given seed were gently combed into a halo formation and the seed was then conditioned for 2 h at 65 ± 3% RH and 27 ± 2°C. Tufts from three distinct locations on the seed surface, namely micropylar (M), side (S) and chalazal (C) regions, were isolated as shown in Fig. 2 and test-
ed one by one on the Shirley instrument, and the work of attachment was calculated separately for the three regions. After each test, the fibres clamped in the Pressley jaws were trimmed at both the ends and the weight of fibre segments in the jaws was found out so as to calculate the number of fibres that have participated in the test.

Using the values of mean fibre length and linear density (mtex), determined by separate experiments, the following quantities were calculated.

2.2.1 Determination of Mean \( E/n \)

The energy required to detach a single fibre from the seed (\( E/n, \text{erg} \)) was calculated from the energy (erg) used in detaching the tuft and the number of fibres in the tuft (\( n \)) obtained from the following relationship:

\[
E/n = w \times 10^5 \times \frac{x}{1.18 \times \rho}
\]

where \( w \) is the weight of tuft in mg; \( \rho \), the linear density of the cotton fibres in millitex; and 1.18 represents the length (cm) of the fibres in the Pressley jaws.

It may be noted that \( E/n \) was calculated for the three regions (micropylar, side and chalazal regions) separately as well as for the entire seed. For the latter, the energy values for all the five tufts were added up and this total energy was divided by the total number of fibres in all the five tufts.

2.2.2 Determination of Energy per Unit Lint Weight \((E/W)\)

The energy (joules) required to separate 1 kg of lint was calculated from the total energy to remove all the fibres on a given seed and the total weight of fibres on the seed was calculated using the following relationship:

\[
E = \frac{W \times I}{1.18}
\]

where \( W \) is the total weight (mg) of fibres on the seed; \( W' \), the weight (mg) of all the five fibre tufts in the Pressley jaws (1.18 cm cut lengths); and \( I \), the mean fibre length (cm).

3 Results and Discussion

3.1 Evaluation of the New Set-up

Table 1 gives detachment energy data for four cottons obtained by using the modified set-up as well as the original one. The data relate to side region tufts tested from twelve seeds belonging to each variety. It is observed that the energy per fibre \((E/n)\) is much lower when the new set-up is used. The CV\% values are also generally lower. Examination of the seed after the test indicated the possibility of fibre breakage. The absence of fibre breakage in the new procedure, attributable to the unrestrained condition of the seed, must be primarily responsible for the lower \( E/n \) values.

There is also likelihood of considerable energy being wasted in stretching the portion of fibre tuft between the jaws and the seed. Since this portion is much shorter (< 3 mm) in the modified set-up, the energy wastage in this case would also be less. The lower values of \( E/n \) in the modified set-up would thus be due to both these reasons. Since the state of the seed during the test and the manner in which it is knocked off by the pendulum are identical with the conditions obtaining in the roller gin, the energy values obtained by the new set-up will be more appropriate for prediction of energy requirements in commercial ginning of cotton.

3.1.1 Detachment Energy in Different Locations

Table 2 shows the energy required to extract fibres from seeds of 18 cotton varieties. From each variety, 12 seeds were selected and, as discussed earlier, the fibres on each seed were segregated into five tufts and all the five tufts were tested on the Shirley instrument. The averages for 12 seeds are given in the table. The coefficients of variation (CV\%) among the tufts from 12 seeds are given in parentheses.

From the \( E/n \) values for different regions (Table 2), it is clear that the micropylar fibres are more tenaciously held than the fibres in the side and chalazal regions in all the 18 varieties. Between side and chalazal regions, the ranking in respect of attachment energy differs with the cotton. In some varieties, the chalazal fibres demand more energy for detachment than the side region fibres, while in others the reverse is true.
The variability among the seeds in respect of $E/n$ values is very large, most of them showing a CV% of 20–40. The high variability results from the fact that the identity of fibres in different locations is not certain. While grouping the fibres representing a particular location for test, it is likely that some fibres belonging to the neighbouring location(s) are also collected. The values of energy per fibre for different locations can not, therefore, be determined with high accuracy.

### 3.1.2 Mean Detachment Energy

The mean detachment energy per fibre (mean $E/n$) shown in Table 2 was obtained by dividing the total energy required for removing all the fibres (in 5 bunches) on a given seed by the total number of fibres on it. The mean $E/n$ shows a low order of variation among the 12 seeds tested from each cotton variety. The CV% generally remains in the range of 15–25, showing the advantage of using all the fibres on a given seed in the test for attachment energy.

It may be noted that Prakash and Iyengar\(^4\) had calculated the average energy per fibre using the energy values obtained for the side and chalazal regions, assigning arbitrary weightages for the two regions. The micropylar fibres were not considered at all on the assumption that their number is small. The present procedure based on all the fibres on a seed would give a more representative value of the average attachment energy for each cotton variety.

The mean detachment energy per fibre ranges between 34 ergs for Suvin and 106 ergs for G.12. While barbadense and herbaceum cottons seem to demand relatively low amounts of energy for detachment, the cottons belonging to arboreum and hirsutum species require considerably larger energy for fibre separation. Of course, there is considerable overlap of energy values among the four species categories. It is well known that in barbadense varieties, fibres are held weakly to the seed coat and that ginning removes all the fibres, leaving only a naked seed. In the earlier work by Prakash and Iyengar\(^4\), the values reported for different varieties ranged from 50 ergs to 105 ergs for attachment energy per fibre. This was arrived at on the assumption of arbitrary weightages as explained earlier. The average energy values thus calculated were of the same range as in the present work albeit for another set of cottons.

### 3.1.3 Energy Required to Extract 1 kg of Lint

The energy required to extract 1 kg of lint $[E/$
Data on energy per unit weight of lint required for fibre extraction in different varieties are not available in literature. With the arbitrary weightages for side and chalazal region fibres, Prakash and Iyengar had arrived at the energy required for ginning 80 lb of kapas (seed cotton). Using these values and assuming a ginning percentage of 35, we calculated the energy required for ginning 1 kg of lint from cottons used by these workers. The values were found to range between 800 J/kg for SI Andrews and 2800 J/kg for the Kalyan variety. Broadly, the energy per kg of lint obtained in the present work lies in a comparable range. Since the cottons are different in the two cases there is no scope for detailed comparison of the data.

The energy to extract 1 kg of lint calculated by the modified procedure in the present work could be expected to reflect the energy needs in commercial ginning of different varieties of cotton. Data derived from earlier work have shown that energy for fibre detachment is related to the electrical energy used in ginning, though the latter is many times higher. This is so because the energy required for running the parts of the roller gin is much higher than the energy needed in actual ginning. Even after considering the energy wasted in running the machine parts, the energy consumed is still far more than what is expected to be used for fibre extraction alone. More experiments are required for explaining this discrepancy and work on these lines is in progress at CIRCOT.

It would also seem appropriate to enquire if the strength of attachment is related to the incidence of seed coat fragments (SCF) in cotton lint. A logical surmise would be that high attachment energy will promote fragmentation of the seed coat. Although data are not being presented here, visual examination of ginned lint from most of the varieties tested for attachment energy has shown that energy and SCF are not quite related. It has been observed that the fragment generally drops out from a tiny area at the chalazal tip and its liberation must be attributed to the features of the epidermal cells at this location. Another factor for consideration is the size and shape of the fibre base which can influence the attachment strength. These aspects are also under study at CIRCOT.

4 Conclusions

4.1 While using the Shirley cotton seed attachment tester, it is possible to bring about better simulation of the roller ginning process by modifying the manner in which the seed cotton specimen is held.

4.2 The testing of all the fibres on a given seed yields attachment energy values with low CV% between seeds, leading to reliable values of energy needed to separate unit weight of lint in a variety. This procedure also obviates the need to employ arbitrary weightages for the fibres in different regions as suggested by earlier workers.

4.3 Attachment energy varies widely among varieties. G. barbadense and G. herbaceum varieties have relatively low values of attachment energy, while G. hirsutum and G. arboreum varieties have considerably higher values of attachment energy.

References

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