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# THE RELATION OF HVI AND AFIS FIBER MEASUREMENTS TO YARN STRENGTH IN EGYPTIAN COTTON

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**ABSTRACT**

Seven Egyptian cotton varieties widely different in fiber attributes were used to explore the relationship between fiber properties and yarn strength. The instruments (methods) used for the determination of fiber properties include the High Volume Instrument (HVI) in the two modes; USDA and ICC, and the Advanced Fiber Information System (AFIS).

The simple correlation coefficient estimates between fiber properties and yarn strength were significant. Correlation values of fiber properties with yarn strength were the same from count to count in the three methods, to a large extent. Regression analysis showed that fiber characteristics of each of HVI–USDA mode, HVI–ICC mode and AFIS can predict yarn strength through highly significant contributions. Although the mean length and 50 % span length (SL) were related strongly with yarn strength, these variables did not exhibit any contributions to variation in yarn strength. The carded count of yarn contributed significantly to variation in yarn strength since it was the second contributor to yarn strength in the three methods.

***Key words**: AFIS, cotton, fiber properties, HVI, yarn strength*

## 1. INTRODUCTION

The majority of crop management practices, which increase yield, will also increase fiber quality. One exception may be instances of high yielding crop with undesirable high micronaire cotton. Fiber length and micronaire value are significantly affected by agronomic and climatic conditions, though fiber strength is more influenced by cotton variety.

As cotton is grown to be spun, it is a primary concern of the cotton breeder to know the relative importance of the different fiber characteristics contributing to yarn properties so that he can select for such properties to achieve yarn strength and quality. HVI was designed to evaluate multiple fiber characteristics in a high volume of samples at a relatively high speed. HVI system remains popular today for both marketing and breeding objectives because it is efficient in terms of time and cost (Kelly *et al.*, 2012).

HVI uses a fibrosampler to grab a portion of cotton from the whole sample. This subsample is used to create a beard of approximately parallel fibers that is optically scanned for relevant measurements such as fiber length and length uniformity. AFIS uses an aeromechanical separator to separate micro dust, trash and fibers within a sample. One of the primary objectives in the early design of AFIS was the ability to measure trash and neps. This was followed by efforts to measure fiber dimension, number of short fibers and eventually a complete fiber length distribution (Bragg and Shofner, 1993 and Shofner *et al*., 1988 & 1990).

Yarn strength, which is the most important property of spun yarns, is largely influenced by the tenacity, fiber length, length uniformity, short fiber content and fiber fineness of the constituent cotton fibers (Hussein, *et al* , 2010, Hussein and Ebaido, 2011 and Kotb, 2012).

Egyptian cotton (*Gossypium barbadense* L.) is the world's finest and longest cotton, and also has some noble characteristics apart from other natural fibers. The length and fineness of the fiber make it possible to make the finest yarns without sacrificing yarn strength. Fiber strength make yarn and fabric more solid and more resistant to stress (Mahmood *et al*., 2010).

Hussein, and Ebaido (2011) and Majumdar *et al*. (2005) suggested that the method of MCDM (multiplicative AHP) could enhance the correlation between the technological value of cotton and yarn strength. Hussein *et al*. (2013) revealed that the two main criteria determining technological value are fiber length and fiber strength that had the highest weights in $MI_{AHP}$. These workers also managed to verify the accuracy of weights of variables by comparing partial correlations with spearman correlations of fiber properties with yarn strength.

Improving fiber quality has long been a primary objective of cotton breeders. One major obstacle facing early breeders was the lack of reliable methods to measure fiber characteristics (Kelly *et al*., 2012). However, reliable methods have become available with the advent of HVI in the late 1960`s and AFIS in the 1980`s (Murthy and Samanta, 2000).

Several mathematical models have been used to understand and predict the complex relationships between fiber properties and yarn characteristics, and substantial research has been done to determine methods of predicting yarn properties (Baykal and Erol, 2006 and Nurwaha and Wang, 2012).

El-Hariry *et al.*(1990) found that the contribution of fiber strength, fiber length, fiber elongation and micronaire value to yarn strength, were responsible for 82.1 % and 79.4 % of the total variation in yarn strength at the phenotypic and genotypic levels, respectively.

Fiber length at 2.5 % SL was the most contributor to yarn strength, whereas micronaire value was of little magnitude (Abdel Fattah, 1988). El-Sourady *et al.*(1974) found that the relative contributions of fiber properties to predicting yarn strength were fiber length and fiber fineness. Sawires *et al.* (1990) pointed out that fiber length parameters were the best variables contributing to variation in yarn strength of the Egyptian cotton variety Giza 77.

The present study was carried out to investigate the relative importance of fiber properties of Egyptian cotton to carded yarn strength at different levels of yarn counts.

## 2. MATERIAL AND METHODS

Seven Egyptian commercial cotton varieties having a wide range of fiber properties were used for this study. Four of these varieties, *i.e.* Giza 70, Giza 87, Giza 88 and Giza 92 belong to the extra-long staple category; while the other three varieties, *viz.*, Giza 86, Giza 80, and Giza 90 belong to the long staple class. Fiber characteristics were measured using instruments located at:

### 2.1.South India Textile Association (SITRA), Coimbatore, India

After sampling , the hand made slivers were prepared , loose cotton lint was used for HVI testing (ASTM, D: 4603-86), according to International Calibration Cotton (ICC) mode which provides measurements of 50 % span length (SL), 2.5 % SL, uniformity ratio (UR) and short fiber index (SFI), fiber strength (FS) and micronaire value (MIC).

Hand-made slivers prepared formerly,were used for Advanced Fiber Information System (AFIS) testing according to ASTM, D: 5866-95. This instrument was used to measure the mean length (ML), upper quartile length (UQL), length uniformity (CV), short fiber content (SFC), fiber fineness (FF), maturity ratio (MR) and nep count (neps).

All tests were carried out under standard atmospheric conditions of 65 ± 2 % RH and 27 ± 2 $^{o}$C.

### 2.2.Cotton Research Institute (CRI) in Giza, Egypt

The High Volume Instrument (HVI) testing (ASTM, D: 1776-98 was used according to USDA (HVI) calibration mode which provides measurements of mean length (ML), upper half mean (UHM), uniformity index (UI), short fiber index (SFI), fiber strength (FS) and micronaire value (MIC). Cotton samples were conditioned prior to testing for at least 48 hours at 65 ± 2 % RH and 21$^{o}$ C ± 2$^{o}$ C temperatures.

Fibers of the seven Egyptian cotton varieties were spun to produce carded ring yarns (YS) at twist multiplier 3.6 for four counts (Ne), *i.e.*, 30s, 40s, 50s, and 60s. Yarn strength (YS) in terms of lea count strength was measured by the Good-brand lea tester according to ASTM, D: 1878- 67.

Using the SAS computer statistical software package, the collected data were subjected to the proper analysis of simple correlation coefficient and stepwise regression analysis to construct the best models for predicting yarn strength according to Little and Hills (1978).

## 3. RESULTS AND DISCUSSION

The present investigation was undertaken to evaluate the role of each of HVI and AFIS measurements as determinants of yarn strength. The Multiple regression analysis was used to estimate the relative importance and contributions of the predictors to yarn strength.

### 3.1. The relationship between HVI-USDA mode measurements and yarn strength

Simple correlation coefficients of yarn strength at different counts with HVI-USDA mode measurements are shown in Table (5). The correlation values indicate that the correlation coefficients of yarn strength at the four counts with mean length (ML), upper half mean (UHM),

**Table (1): Descriptive statistics of HVI fiber properties in ICC calibration mode.**

| Variable | Mean | SE. Mean | St. Dev. | Coef. Var. | Min. | Max. |
|---|---|---|---|---|---|---|
| 50% span length | 15.35 | 0.222 | 1.173 | 7.64 | 13.07 | 16.65 |
| 2.5% span length | 32.51 | 0.511 | 2.706 | 8.32 | 27.43 | 35.99 |
| Uniformity ratio | 47.24 | 0.136 | 0.719 | 1.52 | 46.00 | 48.70 |
| Short fiber index | 5.39 | 0.075 | 0.399 | 7.40 | 4.50 | 6.10 |
| Fiber strength | 32.91 | 0.673 | 3.559 | 10.81 | 25.11 | 36.76 |
| Micronaire value | 3.95 | 0.098 | 0.519 | 13.12 | 3.10 | 4.50 |

**Table (2):Descriptive statistics of AFIS fiber properties by weight.**

| Variable | Mean | SE. Mean | St. Dev. | Coef.Var. | Min. | Max. |
|---|---|---|---|---|---|---|
| Mean length | 29.23 | 0.547 | 2.896 | 9.91 | 24.30 | 32.10 |
| Upper quartile length | 34.46 | 0.626 | 3.313 | 9.61 | 28.80 | 38.70 |
| Length uniformity | 31.86 | 0.278 | 1.469 | 4.61 | 29.10 | 34.40 |
| Short fiber content | 4.93 | 0.237 | 1.253 | 25.38 | 3.00 | 8.40 |
| Fineness | 153.21 | 2.25 | 11.92 | 7.78 | 131.00 | 167.00 |
| Maturity ratio | 0.94 | 0.005 | 0.02 | 2.92 | 0.90 | 0.99 |
| Nep count | 70.75 | 5.37 | 28.39 | 40.13 | 35.00 | 122.00 |

**Table (3):Descriptive statistics of HVI fiber properties in HVI calibration mode.**

| Variable | Mean | SE. Mean | St.Dev. | Coef.Var. | Min. | Max. |
|---|---|---|---|---|---|---|
| Mean length | 28.94 | 0.431 | 2.281 | 7.88 | 25.12 | 32.16 |
| Upper half mean length | 33.54 | 0.433 | 2.292 | 6.83 | 29.40 | 36.50 |
| Uniformity index | 86.25 | 0.326 | 1.725 | 2.00 | 83.00 | 89.20 |
| Short fiber index | 6.40 | 0.080 | 0.426 | 6.65 | 5.70 | 7.40 |
| Fiber strength | 43.81 | 0.990 | 5.240 | 11.96 | 34.62 | 51.00 |
| Micronaire value | 4.02 | 0.063 | 0.333 | 8.27 | 3.40 | 4.60 |

**Table (4): Descriptive statistics of carded yarn strength at different counts.**

| Carded yarn strength at | Mean | SE.Mean | St.Dev. | Coef.Var. | Min. | Max. |
|---|---|---|---|---|---|---|
| count30 | 3142 | 96.8 | 512.2 | 16.30 | 2285 | 3750 |
| count40 | 2939 | 91.8 | 486.0 | 16.53 | 2185 | 3525 |
| count50 | 2741 | 95.7 | 477.8 | 17.43 | 2000 | 3585 |
| count60 | 2873 | 90.3 | 506.4 | 17.62 | 2005 | 3325 |

**Table (5): Simple correlation coefficients of carded yarn strength with HVI fiber properties in HVI calibration mode.**

| Variable | Carded yarn strength at | | | |
|---|---|---|---|---|
| | count 30 | count 40 | count 50 | count 60 |
| ML | 0.94<br><0.0001 | 0.92<br><0.0001 | 0.91<br><0.0001 | 0.91<br><0.0001 |
| UHML | 0.96<br><0.0001 | 0.94<br><0.0001 | 0.92<br><0.0001 | 0.94<br><0.0001 |
| UI% | 0.44<br>0.0180 | 0.44<br>0.0191 | 0.44<br>0.0163 | 0.38<br>0.0423 |
| SFI | -0.55<br>0.0021 | -0.52<br>0.0039 | -0.49<br>0.0075 | -0.52<br>0.0039 |
| FS | 0.98<br><0.0001 | 0.97<br><0.0001 | 0.90<br><0.0001 | 0.97<br><0.0001 |
| MIC | -0.59<br>0.0008 | -0.59<br>0.0008 | -0.53<br>0.0032 | -0.62<br>0.0004 |

short fiber index (SFI), fiber strength (FS) and micronaire value (MIC) were highly significant, whereas the correlation coefficients between uniformity index (UI) and yarn strength at all counts were significant.

Fiber strength (FS) exhibited the highest correlation with yarn strength (r = 0.98) at 30,s and the lowest correlation was of uniformity index with YS at 60s (r = 0.38).

All variables showed positive association with yarn strength except for short fiber index and micronaire value which showed negative correlations with YS.

The relative contribution of each of fiber strength (FS), yarn count (Ne), upper half mean (UHM), micronaire value (MIC) and uniformity index (UI) to yarn strength are shown in Table (6). The highest contribution to variation in yarn strength (YS) apparently resulted from fiber

**Table (6): Stepwise regression variation for carded yarn strength from HVI fiber properties in HVI calibration mode.**

| Variable | Sort contributors | Parameter estimate (slope) | $R^2$ Partial | $R^2$ Model | F Value | Prob. > F |
|---|---|---|---|---|---|---|
| Intercept | - | -673.44300 | - | - | 0.71 | 0.4022 |
| FS | 1 | 58.22050 | 0.844 | 0.844 | 603.06 | <0.0001 |
| Ne | 2 | -12.68036 | 0.077 | 0.921 | 111.21 | <0.0001 |
| UHML | 3 | 74.92659 | 0.008 | 0.929 | 13.84 | 0.0003 |
| Mic | 4 | -65.72495 | 0.0012 | 0.930 | 1.94 | 0.1669 |
| UI | 5 | -7.31504 | 0.0004 | 0.931 | 0.68 | 0.4131 |

**Table (7): Simple correlation coefficients between carded yarn strength with HVI fiber properties in ICC calibration mode.**

| Variable | Carded yarn strength at | | | |
|---|---|---|---|---|
| | count 30 | count 40 | count 50 | count 60 |
| 50% SL | 0.93<br>< 0.0001 | 0.92<br>< 0.0001 | 0.86<br>< 0.0001 | 0.93<br>< 0.0001 |
| 2.5% SL | 0.93<br>< 0.0001 | 0.92<br>< 0.0001 | 0.86<br>< 0.0001 | 0.93<br>< 0.0001 |
| UR | -0.42<br>0.0226 | -0.40<br>0.0342 | -0.38<br>0.0449 | -0.041<br>0.0282 |
| SFI | -0.38<br>0.0420 | -0.37<br>0.0496 | -0.35<br>0.0668 | -0.35<br>0.0659 |
| FS | 0.96<br>< 0.0001 | 0.94<br>< 0.0001 | 0.91<br>< 0.0001 | 0.93<br>< 0.0001 |
| Mic | -0.67<br>< 0.0001 | -0.65<br>< 0.0001 | -0.60<br>< 0.0001 | -0.66<br>< 0.0001 |

**Table (8): Stepwise regression variation for carded yarn strength from HVI fiber properties in ICC calibration mode.**

| Variable | Sort contributors | Parameter estimate (slope) | $R^2$ Partial | $R^2$ Model | F Value | Prob. > F |
|---|---|---|---|---|---|---|
| Intercept | - | -1369.50544 | - | - | 40.30 | <0.0001 |
| FS | 1 | 87.61977 | 0.804 | 0.804 | 456.80 | <0.0001 |
| Ne | 2 | -12.68036 | 0.077 | 0.881 | 73.10 | <0.0001 |
| 2.5% SL | 3 | 60.91852 | 0.014 | 0.895 | 15.58 | 0.0001 |

**Table (9): Simple correlation coefficients of carded yarn strength with AFIS fiber properties.**

| Variable | Carded yarn strength at | | | |
|---|---|---|---|---|
| | count 30 | count 40 | count 50 | count 60 |
| ML | 0.92<br><0.0001 | 0.92<br><0.0001 | 0.89<br><0.0001 | 0.90<br><0.0001 |
| UQL | 0.93<br><0.0001 | 0.93<br><0.0001 | 0.90<br><0.0001 | 0.90<br><0.0001 |
| CV | -0.73<br><0.0001 | -0.75<br><0.0001 | -0.65<br><0.0001 | -0.75<br><0.0001 |
| SFC | -0.75<br><0.0001 | -0.75<br><0.0001 | -0.69<br><0.0001 | -0.74<br><0.0001 |
| FF | -0.55<br>0.0022 | -0.53<br>0.0035 | -0.51<br>0.0054 | -0.55<br>0.0023 |
| MR | 0.44<br>0.0173 | 0.45<br>0.0158 | 0.44<br>0.0179 | 0.43<br>0.0202 |
| neps | 0.29<br>0.1217 | 0.28<br>0.1371 | 0.27<br>0.1507 | 0.29<br>0.1251 |

**Table (10): Stepwise regression variation for carded yarn strength from AFIS fiber properties by weight**

| Variable | Sort contributors | Parameter estimate (slope) | $R^2$ Partial | $R^2$ Model | F Value | Prob. > F |
|---|---|---|---|---|---|---|
| Intercept | - | 2463.93094 | - | - | 3.52 | 0.0634 |
| UQL | 1 | 128.26175 | 0.774 | 0.774 | 383.71 | <0.0001 |
| Ne | 2 | -12.68036 | 0.077 | 0.851 | 58.61 | <0.0001 |
| FF | 3 | -8.02530 | 0.0617 | 0.913 | 80.10 | <0.0001 |
| MR | 4 | -1195.02772 | 0.0012 | 0.914 | 1.61 | 0.2070 |
| CV | 5 | -38.55713 | 0.0010 | 0.915 | 1.28 | 0.2612 |
| neps | 6 | 1.09003 | 0.0007 | 0.915 | 0.90 | 0.3442 |
| SFC | 7 | 24.90630 | 0.0006 | 0.916 | 0.77 | 0.3837 |

strength (FS). Thus, about 84 % of the variation in YS were attributable to FS, which is in conformity with simple correlation coefficients between fiber strength and yarn strength as shown in Table (5).

Yarn count (Ne) came second in the contribution to YS by about 7.7 % of variation, followed by the upper half mean length by a low significant value (about 0.8 %) of variation in yarn strength. Non significant contributions came from micronaire value and uniformity index. A good model for yarn strength included five predictors, *viz.*, FS, Ne, UHM, MIC and UI.

Thus, the final regression equation with $R^2$ = 93 % is:

YS = – 673.44 + (58.22* FS) – (12.68* Ne) + (74.92* UHM) – (65.72* MIC) – (7.31* UI)

Although the mean length and short fiber index were significantly correlated with YS (Table 5), these variables did not appear in the best model of stepwise regression analysis. This may be due to the interrelationships of ML and SFI with the other fiber properties and yarn count.

### 3.2. The relationship between HVI - ICC mode measurements and yarn strength

Average simple correlation coefficients between each of 50 % SL, 2.5 % SL, uniformity ratio (UR), short fiber index (SFI), fiber strength (FS) and micronaire value (MIC) with yarn strength at 30s, 40s, 50s and 60s are shown in Table (7). It is evident from Table (7) that the simple correlation coefficients between 50 % SL, 2.5 % SL, FS and MIC and carded yarn strength at the four counts were highly significant.

Uniformity ratio and SFI showed low values and significant correlations with yarn strength. The highest correlation coefficient with yarn strength was of fiber strength (r = 0.96), at 30s. The 50 % span length, 2.5 % SL and FS showed positive relation with carded yarn strength, whereas, UR, SFI and MIC showed negative relation.

The relative contribution of each of fiber strength (FS), yarn count (Ne) and 2.5 % span length (SL) to carded yarn strength (YS) are shown in Table (8). The highest contribution to variation in carded yarn strength (YS) exhibited from fiber strength, which contributed by 80.4 % of the variation in carded yarn strength, followed by yarn count with about 7.7 % and 2.5 % SL with about 1.4 % of the variation in carded yarn strength. The best model for yarn strength is one with only the three variables, *viz*., fiber strength, yarn count and 2.5 % SL.

The final regression equation with $R^2$ = 89.5 % is:

YS = – 1369.5 + (87.6 * FS) – (12.68* Ne) + (60.9 * 2.5 % SL)

As a result of the interrelationships of 50% SL and micronaire value with other fiber properties and yarn count, these variables were not included in the best model of the regression analysis although the 50 % SL and MIC were highly correlated with carded yarn strength (Table 7).

### 3.3.The relationship between AFIS measurements and yarn strength

The correlation coefficients of yarn strength at 30s, 40s, 50s and 60s counts with the AFIS fiber measurement are shown in Table (9). Simple correlation coefficients of each of mean length (ML), upper quartile length (UQL), length uniformity (CV), short fiber content (SFC) and fiber fineness (FF) with yarn strength at all yarn counts were highly significant. Maturity ratio (MR) showed significant correlation with yarn strength, whereas Nep count exhibited no significant influence on YS. The mean length and UQL exhibited the strongest correlations with yarn strength ($0.93 \geq r \geq 0.89$).

All variables showed positive relations with yarn strength, except for CV, SFC and FF which negatively influenced carded yarn strength. The best model for the stepwise forward regression of yarn strength with AFIS candidate predictors, *i.e.*, UQL, Ne, FF, MR, CV, neps and SFC are shown in Table (10). The highest contribution to variation in carded yarn strength (YS) was for upper quartile length (UQL), indicating that about 77.4 % of the variation in yarn strength is attributable to UQL. This result is in agreement with the highest correlation value between upper quartile length and YS (Table 7).

The second contributor to variation in YS was yarn count by about 7.7 % Partial $R^2$, and the third variable was fiber fineness (FF) which contributed about 6.17 % to variation in YS. Maturity ratio, length uniformity, neps count and short fiber content showed non significant contributions to variation in YS. Therefore, the best model for yarn strength included all of these variables, except for mean length, although it was strongly correlated with YS. This due to the interrelationships among ML and the other fiber length measurements and yarn count.

The final regression equation with $R^2$ = 91.6 % is:

YS = 2463.9 + (128.3 * UQL) – (12.68 * Ne) – (8.02 * FF) – (1195 * MR) – (38.5 * CV) + (1.1 * neps) + (24.9 * SFC)

It is worth mentioning that although the AFIS measurements did not include fiber strength, these measurements can predict yarn strength with highly significant contribution.

**Conclusion**

Most HVI-USDA & HVI-ICC modes and AFIS cotton fiber measurements exhibited strong relations with yarn strength at different counts. The simple correlation coefficient values between fiber properties and yarn strength were largely not different from yarn count to yarn count in the three methods.

Although mean length and 50 % span length were strongly correlated with carded yarn strength, their contributions to variation in yarn strength were not detectable due to the interrelationship of these variables with the other fiber properties and yarn count.

The AFIS measurements which did not contain fiber strength predicted yarn strength with high contribution ($R^2$ = 91.6 %). Yarn count exhibited high contribution to variation in yarn strength as it was the second contributor to this trait in the three methods.

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## علاقة قياسات HVI & AFIS بمتانة الخيط فى القطن المصرى

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**ملخص**

تم إستخدام سبعة أصناف من القطن المصرى تمثل مدى واسع من الإختلافات فى صفات أليافها المقدرة بواسطة جهاز HVI بطريقتى المعايرة USDA & ICC ، و بواسطة جهاز AFIS ، وذلك لغرض دراسة العلاقة بين صفات ألياف أصناف القطن محل الدراسة وجودة المنتج النهائى منها ممثلا فى متانة الغزل عند نمرخيط (عدود) مختلفة.

وأستخدم لهذا الغرض تحليل الإرتباط البسيط الذى أظهر وجود علاقة معنوية بين صفات ألياف أصناف القطن ومتانة الغزل ، بينما كانت الفروق محدودة بين قيم الإرتباط البسيط بين صفات تيلة القطن المقدرة بواسطة الأجهزة المختلفة ومتانة الغزل عند نمرالخيط المختلفة.

أظهر تحليل الإنحدار أن متانة الخصلة المقدرة بجهاز HVI بطريقتى المعايرة USDA & ICC وطول أطول الشعيرات المقدر بجهاز HVI بطريقتى المعايرة USDA & ICC وجهاز AFIS هى أعلى الصفات مساهمة فى توقع متانة الغزل. كانت نمرة الخيط المساهم الثانى بعد متانة الخصلة و طول أطول الشعيرات فى التغير فى متانة الغزل فى الثلاث طرق. على الرغم من أن متوسط الطول المقاس بكلا الجهازين HVI & AFIS قد ارتبط بقيم معنوية عالية مع متانة الغزل عند نمر الخيط المختلفة ، لم يبين متوسط الطول أى مساهمات فى معادلات الإنحدار لتوقع متانة الغزل.

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