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M. Salama
*Textile Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.*

S. Ibrahim
*Textile Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.*

R. Farag
*Textile Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.*



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# A STUDY OF DYNAMIC YARN TENSION ON TWO-FOR-ONE TWISTER

## دراسة الشد الديناميكي للخيط على ماكينة الزوى اثنين لواحد

by

M.SALAMA, S.IBRAHIM AND R.FARAG *

خلاصة – الشد في الخيوط أثناء عملية التصنيع له أهمية كبيرة وذلك لانه يؤثر على كفاءة التشغيل وكذلك على خواص الخيوط وبالتالي على خواص الاقمشة المنتجة. وفي هذا البحث تمت دراسة الشد الديناميكي للخيط على ماكينة الزوى اثنين لواحد وتأثير العوامل المختلفة على هذا الشد. وقد تم بناء جهاز يحاكي ماكينة الزوى اثنين لواحد ليسهل دراسة تأثير سرعة المردن، سرعة التدوير وأبعاد بكرة التغذية على الشد الديناميكي للخيط. وقد وجد من النتائج المعملية أن شد الخيط عند الدليل بعد عملية الزوى يتغير تغيرا طفيفا عندما تزداد سرعة المردن حتى ٥٥٠٠ لفة / دقيقة ولكنه يبدأ في التزايد بصورة كبيرة عندما تزداد سرعة المردن فوق ٥٥٠٠ لفة / دقيقة. وقد وجد أن زاوية التفاف الخيط حول قرص التخزين تتغير عندما تتغير ظروف تغذية الخيط وذلك بدلالة شد المردن وأبعاد بكرة التغذية للحصول على شد ثابت في الخيط وقد وجد أن زيادة انتاجية ماكينة الزوى اثنين لواحد تؤدي الى زيادة الشد في الخيط. وقد أجري تحليل احصائي لايجاد تأثير العوامل المختلفة على شد الخيط دعمت نتائجه النتائج المعملية.

ABSTRACT:

Yarn tension during manufacturing has a large influence on the processing efficiency, yarn properties, and hence on fabric characteristics. In this work the dynamic yarn tension on Two-for-one twister was investigated and the effect of various parameters on the dynamic yarn tension were studied.
A test set-up unit was built to simulate the Two-for-one twister, so the effect of spindle speed , winding velocity and feed package dimensions on dynamic yarn tension was investigated.
It was found that the yarn tension at the eye slightly changed when the spindle speed increased up to 5500 r.p.m.. The yarn tension was higly affected by the increase in spindle speed above 5500 r.p.m.. It was also found that the wrap angle changed when the feed conditions in terms of feed package dimensions, spindle tension and winding velocity were changed to mentain a constant yarn tension at the eye. The increase of productivity of the Two-for-one twister causes an increase in the yarn tension at the eye. Statistical analysis was carried out to find the effect of the various parameters on yarn tension and to verify the experimental results.

## 1. INTRODUCTION

The main feature of the Two-for-one twisting machine is the insertion of two turns of twist in the yarn or each revolution of the spindle. Figure (1) shows the principle of yarn twisting on the Two-

* Dept. of Textile Engineering, Mansoura University.

for-one twister. The yarn from the stationary feed package (1) passes through the eye of the flyer arm (2) to the top of the hollow spindle (3). Then, it passes through the hollow spindle under tension which is supplied by the tension device (4), inside the hollow spindle. The amount of tension depends on the running conditions. At the bottom of the spindle, the yarn is turned 90° and then passes through a hole in the storage disc (5). A certain length of yarn is wrapped on the storage disc. The yarn forms a balloon (6) between the hole (5) and the guide (7). When the storage disc rotate, the yarn inside the hollow spindle rotates around its own axis to insert the first turn of twist. The second turn of twist is inserted in the yarn as it leavs the storage disc before forming the balloon. The twisted yarn passes over the over-feed roller (8) to the winding head (9).

The mechanics of the Two-for-one twister was studied by many researchers /1,2,3,7 and 8/ who found that, the unwinding yarn tension and tension variation are affected by:

1- The dimensions of the feed package ,
2- The unwinding speed, and
3- The spindle tension.

The unwinding yarn tension was found to be increased as the feed package diameter decreased. The rotational speed of the flyer affected this tension. Also, the position of yarn onto the feed package determined the friction force which resisted the yarn movement. The unwinding speed and spindle tension had a large influence on yarn friction and consequently yarn tension .

Kothari and Leaf /7/ derived the equation of motion of the yarn as it moves on storage disc of a Two-for-one twister. These equations were combined with the theory of balloon to determine tension variations in the yarn as it leavs the twister. These equations showed that the variables affecting the Two-for-one twisting conditions are the rotaional speed of the twister, the rate of unwinding of the yarn, the vertical height of the eye, the air drag parameter, the tension in the yarn as it emerges from the hole in the storage disc, the coefficient of friction between the yarn and the disc, and the yarn torsional rigidity.

It was found experimentally by Kothari and Leaf /8/ that the tension at the eye is proportional to the square of the rotational speed. Also, the amount of wrap on the disc decreased with the reduction in tension at the eye. When the tension at the hole increased, the amount of wrap on the disc decreased, but the tension at the eye remained nearly constant. They suggested that more experimental investigation of the mechanics of Two-for-one twisting would lead to more understanding of the way in which the system works.

The objective of this work is to investigate experimentaly the effect of feed package dimensions, spindle speed and winding speed on the dynamic yarn tension at the eye to get more information about the Two-for-one twisting system.

## 2. EXPERIMENTAL WORK

### 2.1. Test Set-up

Figure (2) shows a drawing for the test set-up unit , which was built up , consists of a steel frame (1) carring the spindle (2) and the winding unit (3). The spindle and the balloon limiter (4) were taken from "SAVIO" Two-for-one twisting machine model "TDS 212". The spindle was driven by tape (6) from motor (5). The motor speed was changed by a "variac" which varies the supplied voltage to the motor from 0 to 220 V , so the spindle speed from 0 to 11000 r.p.m can be obtained . The winding unit consists of a grooved drum (8) and presser arm (9). The drum was driven by pulleys and V-belt (10) from a motor (11). A set of pulleyes of different diameters were used to change the winding speed from 10 to 61 m/min. The twisted yarn was wound onto the package (12).

### 2.2. Method of measurements

The tension of the twisted yarn was measured just above the eye (13) as shown in figure (2). The electronic ROTHSCHILD tension meter was used to measure the yarn tension. The signal from the measuring head (14) was recorded on a chart recorder for one complete cycle of yarn movement on the surface of the feed package (yarn moves from top to bottom of the package and back again to the top). The length of yarn wrap on the storage disc was measured by the help of a Stroposcope. The tension of the twisted yarn was measured at different spindle and winding speeds. The wrap angle was recorded for each case.

## 3. EXPERIMENTAL RESULTS AND DISCUSSIONS:

Tables (1 and 2) show the results of the dynamic yarn tension measured at different running conditions.

### 3.1. Effect of spindle speed on the value of yarn tension:

At a certain winding velocity, the increase in the spindle speed resulted in change in the amount of yarn tension at the eye. There is no doubt about the fact that the balloon tension increases rapidly as the spindle speed is increased , this was found also by many other authers. In case of the Two-for-one twisting, the mean yarn tension which was measured at the eye resulted not only from the balloon tension, but also from the balance of yarn tension at the hole in the storage disc. The yarn tension which was measured at zero spindle speed was the tension required to unwind the yarn from the feed package. This is known as the unwinding yarn tension and it was fully investigated in previous work /2 and 3/. When the spindle rotated (up to 5500 r.p.m.) , the mean yarn tension at the eye was decreased and return to increased below that measured at zero spindle speed . This may be explained as follows; as the spindle rotates , a balloon is created and the balloon tension helps in unwinding the yarn from the feed package, the resultant yarn tension at the eye decreased . The increase in spindle speed resulted in an increase in the yarn balloon tension. The matter which increased the amount of unwinded yarn from the feed package more than it needed for the winding of the twisted yarn. Thus, the excess of the unwinded yarn was wound onto the reserve disck. This developed friction between the yarn and the disc to balance the excess in yarn tension due to balloon. As shown in table (1), the wrap angle increased and the change in the yarn tension at the eye was small. At higher spindle speeds, more than 5500 r.p.m., the balloon tension increased rapaidly, this required a large wrap angle, the matter which was practically difficult for yarn running. Thus, the unwinding conditions in terms of spindle tension had to be raised to increase the unwinding yarn tension and thus, the wrap angle was reduced to a value suitable for yarn running.

The results in table (1) show that the variation in yarn tension at the eye (range of yarn tension) decreased as the spindle speed was increased. This can be explained by observing the results of wrap angles at different speeds. Baisically, the variation in yarn tension resulted from the variation in unwinding yarn tension which was investigated in the privious work /2/. The length of the yarn which was wrapped on the disc developed a friction force. This friction force balanced the balloon tension and at the same time, acted as a damper to reduce the variation in the yarn tension due to unwinding the yarn from the feed package. As the wrapped yarn length on the storage disc increased, the yarn tension was more damped and thus, the variation in yarn tension at the eye was reduced. Figures (3,4 and 5) show a sample of the recorded yarn tension at the eye during one complete cycle on the chart at different running conditions.

## 3.2. Effect of feed package dimensions on yarn tension

Table (2) shows the measured yarn tension at the eye at differnt running conditions and at different feed package diameters. Generally, the feed package diameter affected the unwinding yarn tension, as it was found by /2,3 and 8/.

At a certain spindle speed and winding velocity, as the feed package diameter decreased, the unwinding yarn tension increased and thus the wrap angle was reduced. This was to balance the yarn tension at the hole in the storage disc. The result was nearly unchanged yarn tension at the eye during the twisting , from full to empty feed package.

## 3.3. Effect of productivity on yarn tension

Figure (6) shows the relationship between the mean yarn tension at the eye and the winding velocity for different materials .In this case, the ratio between the spindle speed and winding velocity was kept constant to produce the same twist level in the yarn. This was done to study the effect of increasing the productivity of the Two-for-one twister on yarn tension at the eye. In previous work /2/, the winding velocity was found to have a large infeleuence on the unwinding yarn tension. The stick-slip phenomenen, between the yarn and feed package surface, which was observed during unwinding together with the inertia of the flyer arm were highly affected by the winding velocity . Thus, a combined effect occured at the hole of the storage disc from the change in the unwinding yarn tension due to the increase in winding velocity and the increase in the balloon tension due to the increase in the spindle speed. The result was a change in the wrap angle to balance the yarn tension at the hole and an increase in yarn tension at the eye.

## 4. STATISTICAL ANALYSIS

A statistical analysis was made to find the correlation between the various factors and the influence of these factors on the dynamic yarn tension. This was important to verify the discussions of th results. The multiple regression and correlation technique was used to find the influence of these factors separatly and together on the yarn tension. This is due to the mutual effect of these factors. The statistical analysis was carried out for the results obtained at spindle speed above 5500 r.p.m. , which falls in the practical runining limits.

Table (3-a) shows the results obtained from the statistical analysis of mean yarn tension as a function of spindle speed and winding velocity . The multiple correlation coefficient ( 0.991 ) is highly significant at 0.01 level . The partial correlation coefficient between mean yarn tension and spindle speed at constant winding velocity is 0.99 , and the simple correlation coefficient (r= 0.97). Both coefficients are highly significant at 0.01 level. The partial correlation coefficient between mean yarn tension and winding velocity at constant spidle speed is 0.432 , which is significant at .05 level. This means that the spindle speed and winding velocity affects the mean yarn tension .

Table (3-b) shows the statistical analysis of the range of yarn tension as a function of spindle speed, winding velocity and mean yarn tension.The multiple correlation coefficient ( 0.888 ) is significant at 0.01 level. The partial correlation coefficient between the range of yarn tension and spindle speed at constant winding velocity and mean yarn tension is 0.1374 . This means that the spindle speed is slightly affected the range of yarn tension. The partial correlation coefficient between the range of yarn tension and winding velocity at constant spindle speed and mean yarn tension is - 0.685 . This shows that the variation in yarn tension is highly affected by the winding velocity. The negative sign means that the range of yarn tension decreases as the winding velocity increases. This is also clear in fig.(4). The partial correlation coefficient between the range and mean yarn tension at constant spindle speed and winding velocity is 0.101 . This means that, there is no correlation between the range and the mean of yarn tension.

Table (3-c) shows the statistical analysis of wrap angle as a function of spindle speed. winding velocity and spindle tension. The multiple correlation coefficient ( 0.935 ) is highly significant at 0.01 level. The partial correlation coefficients between the wrap angle and spindle speed , winding velocity and spindle tension are 0.8955 , -0.7896 and -0.8159 respectevely. This shows that the wrap angle is affected by these parameters. The change in any of these parameters causes the wrap angle to be changed to keep the mean yarn tension nearly constant.

## 5. CONCLUSIONS

The previous expermental results and discussions show that, the dynamic yarn tension at the eye of the Two-for-one twister slightly changed when the spindle speed was increased up to 5500 r.p.m.. This was observed, as long as, the feed conditions remained unchanged. The length of the yarn wrapped on the storage disc played an important role in keeping a constant yarn tension at the eye .At higher spindle speed the yarn tension increased rapaidly and it was necessary to increase the spindle tension to maintain a reasonable wrap angle which was suitable for running. It was foud that the feed package diameter doesn't affect the yarn tension at the eye. It was found that the yarn tension at the eye increased as the productivity increased.

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Table (1) : Yarn tension and wrap angle at different spindle speeds and winding velocities.

| | Vw = 10 m/min | | | | Vw = 15.75 m/min | | | | Vw = 22 m/min | | | | V = 33.25 m/min | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ns | Ts | Tav | Tra | θ | Ts | Tav | Tra | θ | Ts | Tav | Tra | θ | Ts | Tav | Tra | θ |
| 0 | 1 | 41 | 65 | 0 | 1 | 50 | 90 | 0 | 1 | - | - | 0 | 1 | - | - | 0 |
| 2750 | 1 | 36 | 47 | 45 | 1 | 45 | 59 | 45 | 1 | 52 | 76 | 45 | 1 | 59 | 86 | 45 |
| 4125 | 1 | 39 | 30 | 90 | 1 | 47 | 42 | 90 | 1 | 34 | 17 | 225 | 1 | 39 | 20 | 90 |
| 5500 | 1 | 50 | 24 | 270 | 1 | 56 | 32 | 270 | 1 | 50 | - | 270 | 1 | 50 | 13 | 225 |
| 6875 | 5 | 67 | 26 | 360 | 1 | 85 | 18 | 435 | 5 | 72 | 21 | 315 | 4 | 75 | 19 | 360 |
| 8250 | 8 | 99 | 38 | 405 | 8 | 94 | 38 | 405 | 6 | 95 | - | 405 | 6 | 103 | 26 | 405 |
| 9625 | - | - | - | - | 8 | 120 | 40 | 595 | 12 | 118 | - | 315 | 12 | 131 | 30 | 315 |
| 11000 | - | - | - | - | 12 | 146 | 44 | 475 | 12 | 148 | - | 595 | 12 | 154 | 36 | 595 |

Table (1): Continued.

| | Vw = 43 m/min | | | | Vw = 53.25 m/min | | | | Vw = 61 m/min | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ns | Ts | Tav | Tra | θ | Ts | Tav | Tra | θ | Ts | Tav | Tra | θ |
| 0 | 1 | 55 | 90 | 0 | 1 | 50 | 72 | 0 | 1 | 53 | 81 | 0 |
| 2750 | 1 | 58 | 76 | 45 | 1 | 52 | 35 | 67 | 1 | 45 | 40 | 22 |
| 4125 | 1 | 36 | 16 | 67 | 1 | 42 | 24 | 45 | 1 | 41 | 22 | 99 |
| 5500 | 1 | 46 | 9 | 90 | 1 | 52 | 11 | 70 | 1 | 50 | 12 | 90 |
| 6875 | 1 | 67 | 14 | 405 | 1 | 74 | 16 | 405 | 4 | 74 | 16 | 270 |
| 8250 | 6 | 100 | 32 | 315 | 6 | 109 | 28 | 360 | 4 | 106 | 28 | 405 |
| 9625 | 12 | 131 | 26 | 360 | 12 | 133 | 26 | 270 | 12 | 132 | 24 | 270 |
| 11000 | 12 | 162 | 36 | 450 | 12 | 165 | 34 | 450 | 12 | 167 | 38 | 450 |

Table (2): Yarn tension at different feed package diameters.

| | | | Db = 75 mm | | | Db = 105 mm | | | Db = 140 mm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ns | Vw | Ts | Tav | Tra | θ | Tav | Tra | θ | Tav | Tra | θ |
| 3000 | 10 | 1 | 60 | 80 | 22 | 44 | 52 | 22 | 37 | 42 | 45 |
| 4725 | 15.75 | 1 | 75 | 59 | 22 | 45 | 25 | 135 | 45 | 26 | 225 |
| 5775 | 19.25 | 1 | 57 | 22 | 45 | 61 | 30 | 190 | 57 | 26 | 315 |
| 6600 | 22 | 4 | 70 | 20 | 135 | 64 | 15 | 225 | 72 | 37 | 360 |
| 8025 | 26.75 | 7 | 89 | 18 | 225 | 95 | 30 | 270 | 100 | 40 | 315 |
| 8925 | 29.75 | 9 | 111 | 22 | 270 | 116 | 32 | 315 | 122 | 44 | 315 |
| 9975 | 33.25 | 9 | 132 | 24 | 360 | 138 | 24 | 495 | 144 | 36 | 495 |

Ns : Spindle speed r.p.m., Vw: winding velocity m/min., Ts: spindle tension (from 1 to 12 )
Tav: mean yarn tension g., Tra: range of yarn tension g., θ : wrap angle degrees, Db: bobbin diameter mm.

Table (3) : Statistical analysis

--) PROG:MLINREG FILE:B:MSRHH

Table (3-a)

| TERM | COEFFICIENT | STD. ERROR | T-STATISTIC | PART. CORR | CONTR. R-SQ |
|---|---|---|---|---|---|
| B 0 | -64.2944 | 4.56741 | -14.0768 | --- | --- |
| B 1 | .0196131 | 5.24909E-04 | 37.3647 | 0.9908 | 0.9431 |
| B 2 | .137538 | .0562872 | 2.4435 | 0.4322 | 0.0040 |

Y Mean yarn tension
B1 Spindle speed
B2 Winding velocity

| | SUM SQ | DEG FR | MEAN SQ |
|---|---|---|---|
| DUE TO REGRESSION | 41221 | 2 | 20610.5 |
| ABOUT REGRESSION | 736.894 | 26 | 28.3421 |
| TOTAL | 41957.9 | 28 | 1498.5 |

R-SQUARED: .982437 CORRECTED R-SQUARED: .981086
F-TEST: 727.204 STD ERROR OF REG: 5.32373

--) PROG:MLINREG FILE:B:MSRHH

Table (3-b)

| TERM | COEFFICIENT | STD. ERROR | T-STATISTIC | PART. CORR | CONTR. R-SQ |
|---|---|---|---|---|---|
| B 0 | 7.77972 | 11.9549 | .650757 | --- | --- |
| B 1 | 2.40104E-03 | 3.46061E-03 | .693821 | 0.1374 | 0.0041 |
| B 2 | -.261876 | .0556398 | -4.70662 | -.6851 | 0.1876 |
| B 3 | .088819 | .174824 | .508049 | 0.1011 | 0.0022 |

Y Range of yarn tension
B1 Spindle speed
B2 Winding velocity
B3 Mean yarn tension

| | SUM SQ | DEG FR | MEAN SQ |
|---|---|---|---|
| DUE TO REGRESSION | 2096.4 | 3 | 698.8 |
| ABOUT REGRESSION | 563.048 | 25 | 22.5219 |
| TOTAL | 2659.45 | 28 | 94.9803 |

R-SQUARED: .788284 CORRECTED R-SQUARED: .762878
F-TEST: 31.0275 STD ERROR OF REG: 4.74573

--) PROG:MLINREG FILE:B:MSRHH

Table (3-c)

| TERM | COEFFICIENT | STD. ERROR | T-STATISTIC | PART. CORR | CONTR. R-SQ |
|---|---|---|---|---|---|
| B 0 | -410.144 | 79.7087 | -5.14554 | --- | --- |
| B 1 | .142701 | .0141876 | 10.0582 | 0.8955 | 0.5119 |
| B 2 | -3.29815 | .512651 | -6.43351 | -.7896 | 0.2094 |
| B 3 | -42.5939 | 6.03718 | -7.05528 | -.8159 | 0.2518 |

Y wrap angle
B1 Spindle speed
B2 Winding velocit
B3 Spindle tension

| | SUM SQ | DEG FR | MEAN SQ |
|---|---|---|---|
| DUE TO REGRESSION | 401744 | 3 | 133915 |
| ABOUT REGRESSION | 58174.5 | 25 | 2326.98 |
| TOTAL | 459919 | 28 | 16425.7 |

R-SQUARED: .873511 CORRECTED R-SQUARED: .858333
F-TEST: 57.5487 STD ERROR OF REG: 48.2388

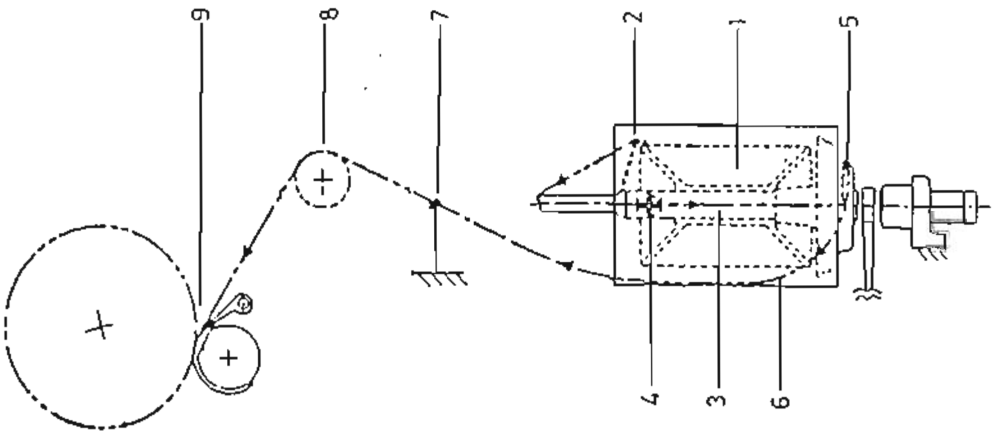


FIG. (1): SPINDLE OF TWO-FOR-ONE TWISTER

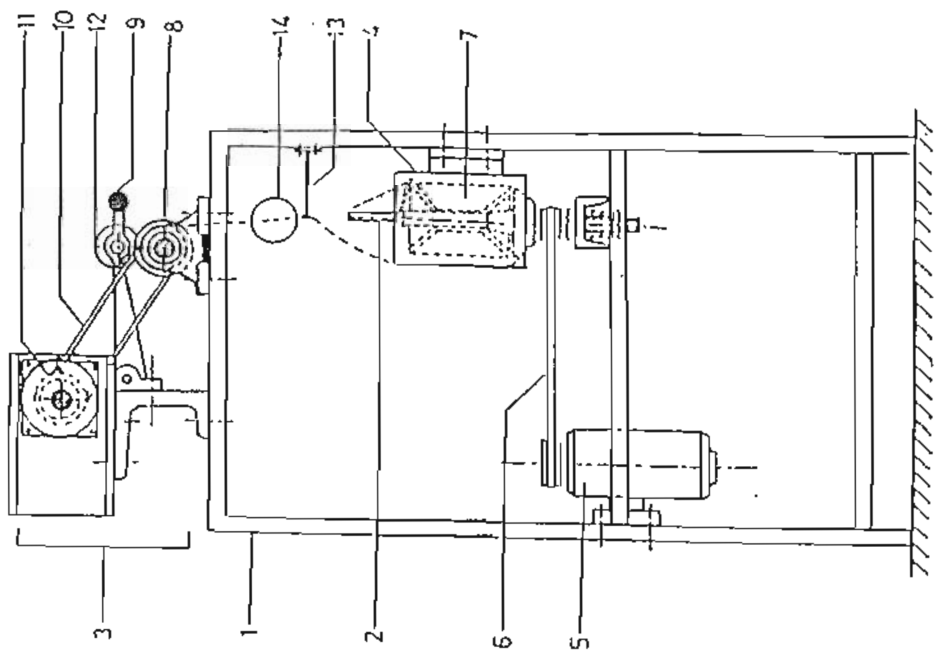


FIG. (2): TEST SET-UP UNIT.

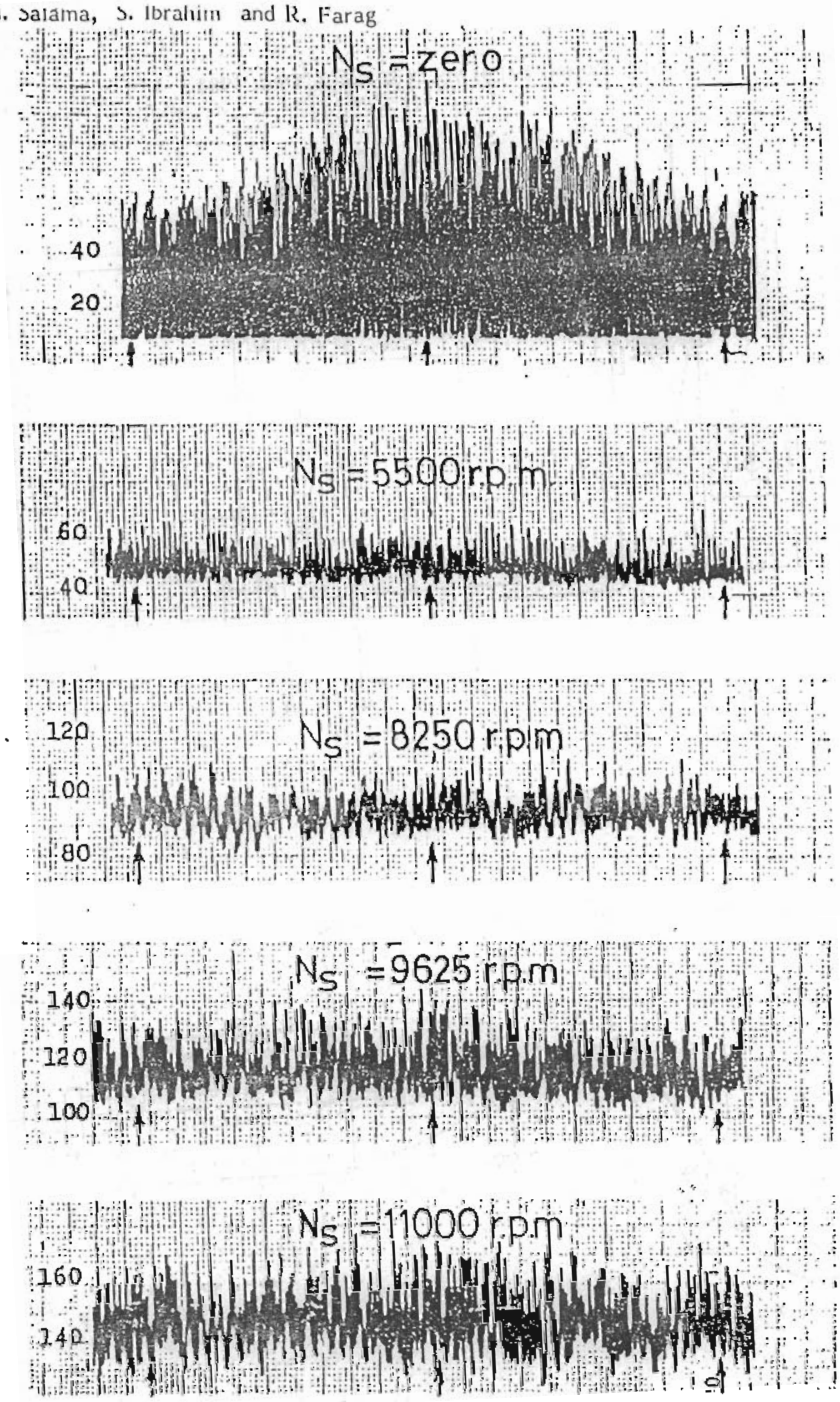


FIG. (3): EFFECT OF SPINDLE SPEED ON YARN TENSION

V= 33.25 M/MIN. D= 110 MM

2* 20 TEX COTTON YARN

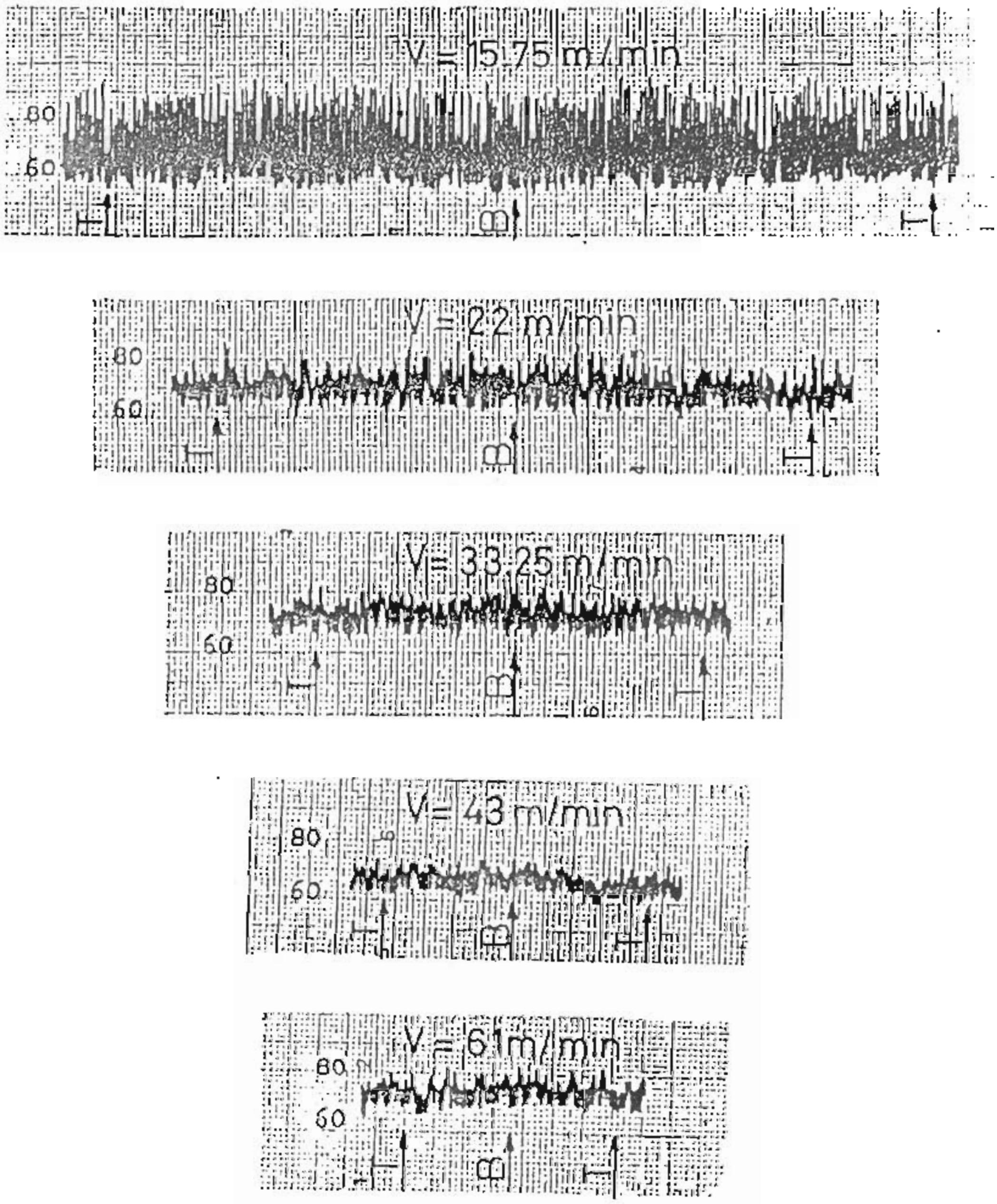


FIG. (4): EFFECT OF WINDING VELOCITY ON YARN TENSION

$N_s$ = 6875 R.P.M. , D= 110 MM

2*20 TEX COTTON YARN

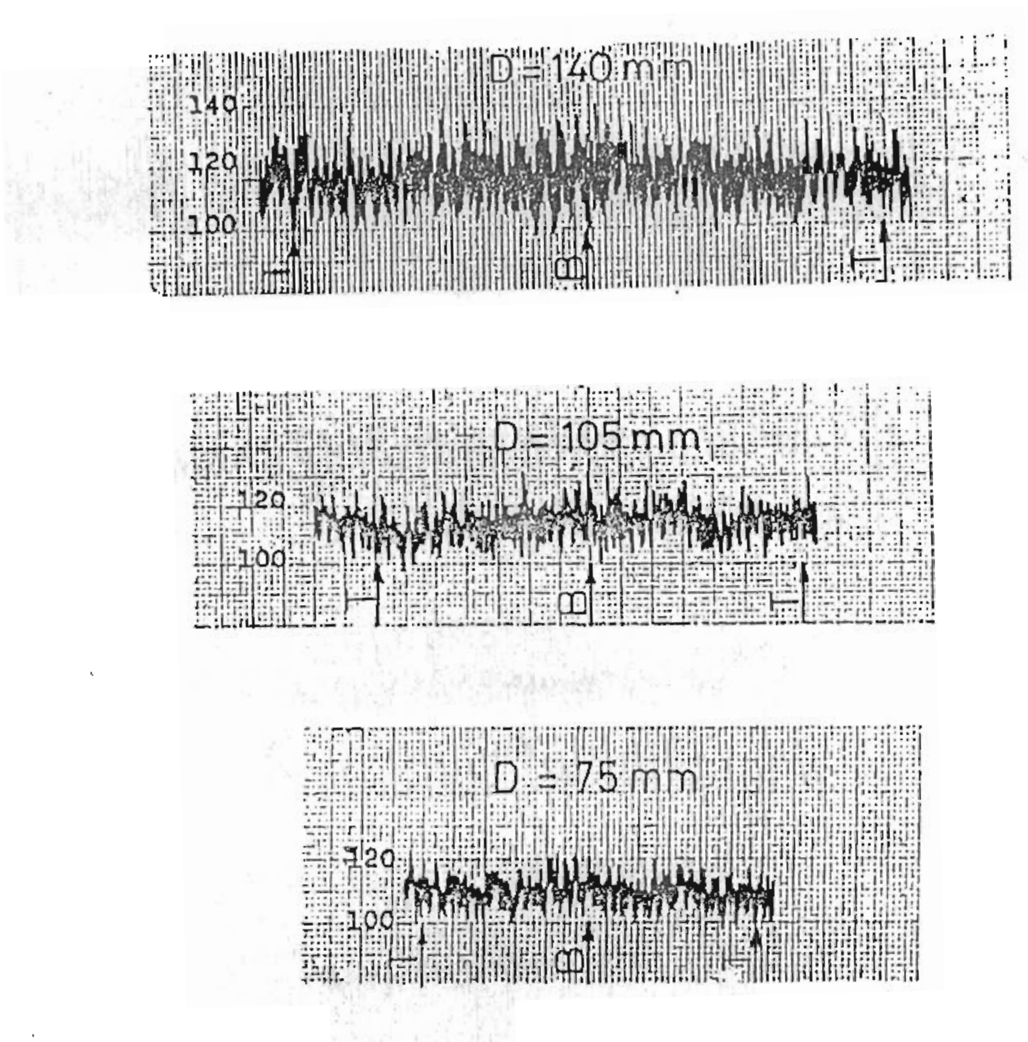


FIG. (5) EFFECT OF FEED PACKAGE DIAMETER ON YARN TENSION

$N_s$ = 8925 R.P.M V= 29.75 M/MIN.

2*20 TEX COTTON YARN

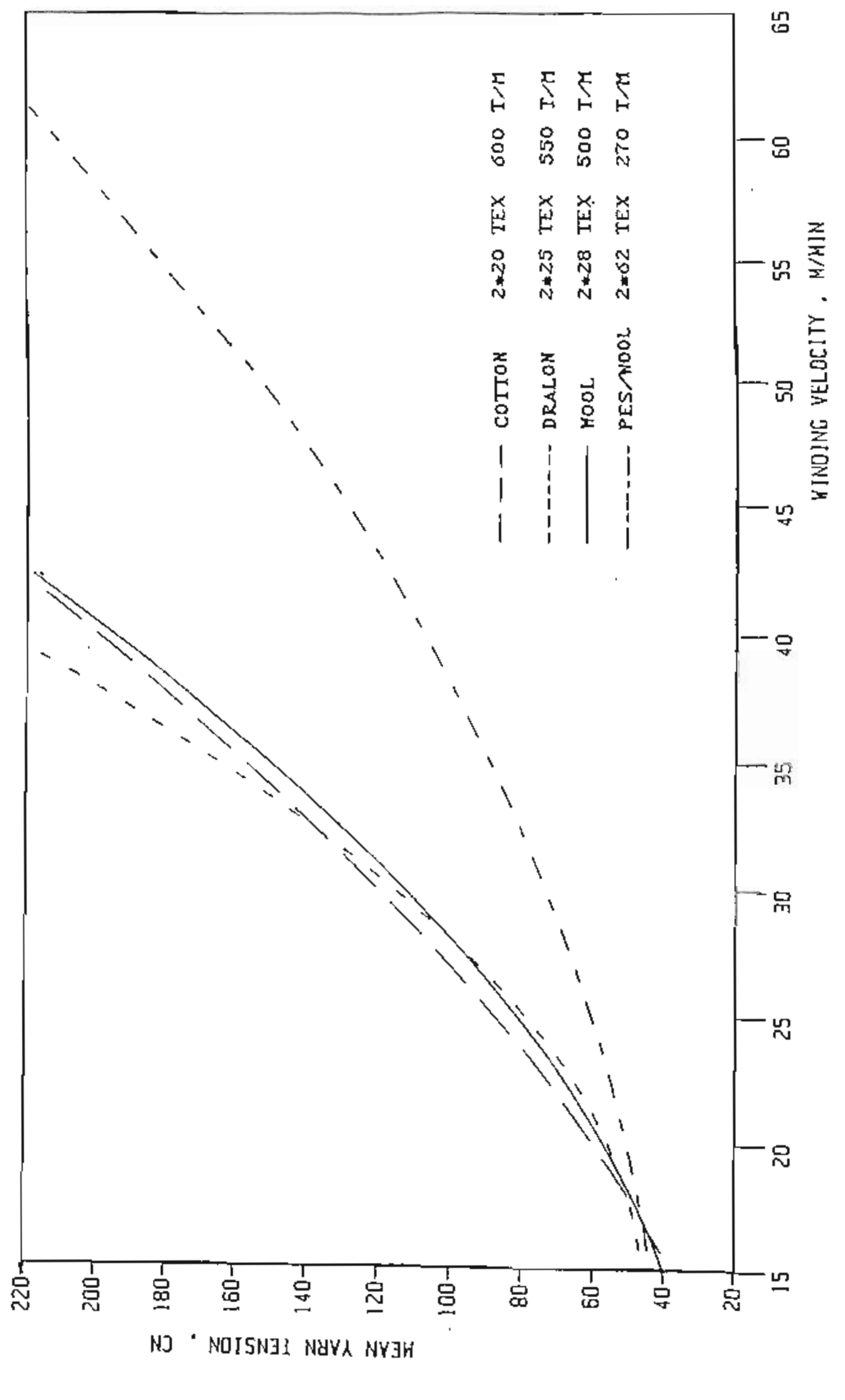


FIG. (6): RELATIONSHIP BETWEEN YARN TENSION AND WINDING VELOCITY AT CONSTANT TWIST LEVELS.