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# OPTIMUM CONSTRUCTIONAL FACTORS OF DUST KNITTED FILTER FABRICS

## العوامل الانشائية المثالية لأقمشة مرشحات الأتربه المصنوعه من التريكو

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**خلاصة** – فى هذا البحث اجريت محاولة للتعديل فى التركيب الانشائى لأربعة أنواع من تصميمات أقمشة تريكو اللحمه المنتجة على الماكينات الدائرية وهى الجرسيه الساده والانترلوك والأقمشة الوبريه وأقمشة البيكه المفرده. هذا التعديل أمكن تحقيقه عن طريق معرفة العوامل الانشائية المثالية لكل تصميم وهى نوع الشعيرات ومعامل الاحكام وأس برم الخيط. هذا البحث اهتم بتقييم تصميمات التريكو المختارة من حيث الخواص الميكانيكية وخواص الترشيح وهى الشغل المبذول لقطع القماش أثناء الشد ومقاومة الأنفجار ومعدل التآكل والإنبعاج العرضى (القطرى) وكفاءة الترشيح وفرق الضغط ومقاومة مرور الهواء وقطر مسام القماش . الموديلات الرياضية التى تصف هذه الخواص أمكن الحصول عليها باستخدام طريقة تصميم التجارب للتنبؤ بأداء مرشح التريكو .وباستخدام طريقة حل المعا.لات الرياضية وجد أن التركيب الانشائى الأمثل يوصى بأن يكون التصميم المناسب هو انترلوك بحيث يحتوى على خيوط مصنوعة من شعيرات البولى استر المتجعدة بنسبة ١٠٠٪ وبأس برم انجليزى مقداره ٣,٢٥ وبمعامل احكام للقماش يساوى ١٦,٩٨ (اى ان نمرة خيط التريكو ٢٠ انجليزى ، وطول الغرزه ٠,٣١ سم وعدد الصفوف في البوصة ٤٣,٥) .

**Abstract** - In this research an attempt has been made to modify the construction of a number of circular knitted structures i.e. single jersey, interlock, pile fabrics and single pique - This modification could be achieved by means of knowing the optimum constructional factors of each knitted structure such as type of fibres, tightness factor and yarn twist multiplier. This research is concerned with the evaluation of the selected knitted structures for mechanical and dust filtration applications with regard to specific work of rupure, bursting pressure, rate of abrasion, lateral expansion, filtration efficiency, pressure drop, air resistance and eqivalent pore diameter. Mathematical models describing these properties could be obtained, by using factorial design method, for predicting the knitted filter performance. By using the mathematical methods, it was found that the optimum fabric construction is recommended to be interlock contained 100% crimped polyester fibres yarn, 16.98 tightness factor (i.e. yarn count 20 Ne, loop length 0.31 cm, courses per inch 43.5 and 3.25 $\alpha e$ twist multiplier).

## 1- INTRODUCTION

The processing of fibrous materials in the opening lines gives a gradual decrease in the size of the tufts. This takes place due to the action of the different major and minor opening points in the blowing room. The opened fibrous materials transmit between different machines either mechanically or pneumatically through pipe lines. The dust suck to filters is within pipe lines. Air currents generated by the machines cause the fine dust to enter the environmental air in the spinning mill, especially in the blowing room. When the cotton dust enters the mill air, worker health may be adversely affected. The essential principle of fabric filtration is to cause dusty gas to flow through elements of a permeable textile fabric by either pressure or suction and to retain the dust on the fabric. These dusts and impurities are filtered in a room at the end of opening and cleaning line

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containing bag filters through where the air which carries fine fibres and suspended impurities passes, then the fabric retains dust and impurities and the air comes out clean.

The environmental pollution problem has become one of the most important problems which faces our society nowadays. So, all the efforts are directed to control this danger, specially it has a bad effect on man's health which is considered a national wealth for any country. The sources of this pollution are dust emission from cement and porcelain factories and dusts and fine fibres emitted from spinning mills. This research is concerned with the pollution from the conventional opening and cleaning lines where it has a direct effect first, on worker's health, then on material quality, also on pollution of the outer air out of the mill. Consequently the control on this pollution is healthy and economical necessity. Then it is clear that filtration process and filters are very important in this field also they have an economical importance if it is known that the fabrics which are used in spinning mill now are imported or local but the local have not the required specifications as the imported fabrics in conventional opening and cleaning lines.

From the review of the literature, very little work was reported upon the effect of knitted structures and comprehensive studies of the effect of vavious parameters on the mechanical and filtration properties of the filter fabrics[1-3].So, the aim of this work is to find the optimum constructional factors of weft knitted filter fabrics.

## 2.EXPERIMENTAL WORK

### 2.1-Test Samples:

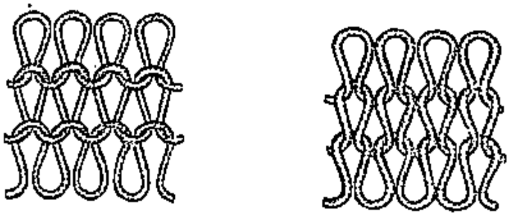
A range of 32 single and double-jersey fabrics was produced on circular knitting machines to change values of courses/inch i.e. loop length and tightness factor for four different structures, single-jersey, interlock, pile fabrics and single piqué.

Fabrics were produced on a Mair/C(German machine) 36 feeds, 20 gauge (20 needles/inch) double-jersey machine. The knitted fabrics were produced in Cairo Garments and Knitting company (Tricona). These fabrics were made of crimped polyester and cotton fibres in which two levels each of type of fibres, yarn count, courses/inch,tightness factor and yarn twist multiplier were represented. The Knitting yarns were produced in Cairo Industrial Shops for Cotton and Viscose Rayon (ESCO). Specifications of the knitting yarns produced are detailed in Table(1).

**Table(1): Yarn Specifications.**

| Yarn specifications | min. value (-1) | max. value (+1) |
|---|---|---|
| 1- Type of fibres | 100% Cotton | 100% Polyester |
| 2- Yarn count: (Ne) | 20 | 30 |
| : (Tex) | (29.53) | (19.68) |
| 3- Twist multiplier ($\alpha e$) | 3.0 | 3.5 |

From these yarns, knitted fabric structures were produced using four different knitting machines i.e. single-jersey, interlock, loop-pile and single piqué circular knitting machines. All these machines are Mair and C type with gauge 20 which means 20 needles/inch. The surface appearance and graphical representation of the different structures produced are given in Figures (1-4).



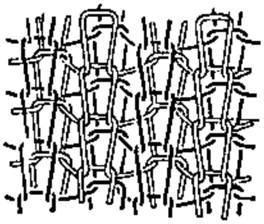
Back of Jersey Face of Jersey

a- Surface appearance

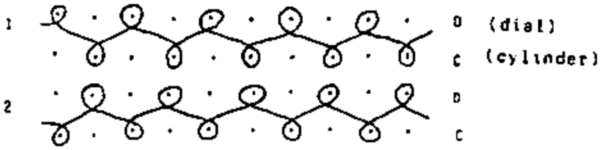
Back of Jersey Face of Jersey

b- Graphical representation

Fig. ( 1 ): Single-jersey Structure

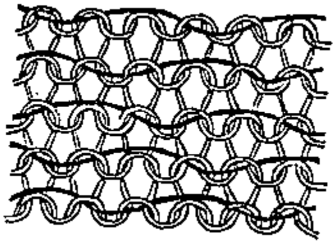


a- Surface appearance

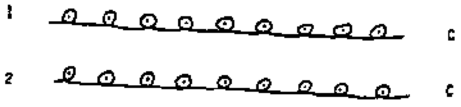


b- Graphical representation

Fig. ( 2 ): Interlock Structure

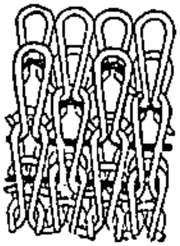


a- Surface appearance

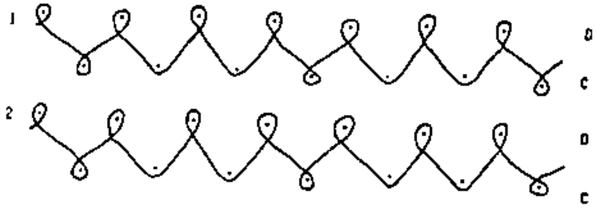


b- Graphical representation

Fig. ( 3 ): Loop-pile Structure



a- Surface appearance



b- Graphical representation

Fig. ( 4 ): Single-piqué Structure

On each machine, it was produced two types of fabrics, one of them is light weight i.e.low courses/inch long loop length, and the other is heavy weight i.e. high courses/inch short loop length. The construction of knitted fabrics could be analyzed in Tricona Company after steam-relaxed condition and heat-setting process for crimped polyester fibric at 170 °C and after steaming cotton knitted fabric at 90°C. All Knitted fabrics were heat-set without any tension on the fabric either length or width direction.

### 2.2-Exerimental Design:

The experiments for each structure were planned according to the factorial design ($2^3$) [4,5] for the three variables i.e., type of fibres (XI), tightness factor (X2) and twist multiplier (X3). Tightness factor is defined as T.F. = $\sqrt{T}$/L, where T is the yarn linear density in tex and L is the average loop length in cm [6]. By using small changes in yarn count and loop length, fabric tightness can be varied between approximately 9 and 19 ($g^{1/2}$ / $m^{3/2}$ ). The range of variation of these factors is given in Table (2) and the experimental plan is given in Table (3).

**Table (2): Range of Variation for Studied Fabrics.**

| Level / Factor | min. value (-1) | max. value (+1) |
|---|---|---|
| X1 - type of fibres | 100% cotton | 100% polyester |
| X2-tightness factor (($g^{1/2}$ / $m^{3/2}$ ) | | |
| : for single- jersey | 13.86 | 18.74 |
| : for interlock | 10.08 | 16.98 |
| : for pile fabrics | 10.56 | 14.30 |
| : for single piqué | 9.44 | 19.41 |
| X3 - twist multiplier (αe) | 3 | 3.5 |

**Table (3): Experimental Plan of Studied Factors for Each Structure.**

| Exp. No. | Sample Code | Coded Levels of Factors | | |
|---|---|---|---|---|
| | | X1 | X2 | X3 |
| 1 | 102 | 1 | -1 | -1 |
| 2 | 401 | -1 | 1 | -1 |
| 3 | 502 | -1 | -1 | 1 |
| 4 | 801 | -1 | 1 | 1 |
| 5 | 202 | 1 | -1 | 1 |
| 6 | 701 | 1 | 1 | -1 |
| 7 | 302 | -1 | -1 | -1 |
| 8 | 601 | 1 | 1 | 1 |

Specifications of the knitted fabrics produced for each structure are detailed in Tables (4-7).

### 2.3- Test Methods:

#### 2.3.1- Relaxation and Conditioning:

The Knitted fabrics produced in Cairo Gaments and Knitting Company (Tricona) were tested in the laboratories of Textile Engineering Department, Mansoura University,

** Table (4) : *Measurements of Mechanical and Filtration Properties of Single-jersey Structure*

| Sample Code | Mechanical Properties | | | | Filtration Properties | | | |
|---|---|---|---|---|---|---|---|---|
| | Sp.w.r., (g/tex) $\sqrt{W.C^*}$ | Bursting pressure, (Kg/cm$^2$) | Rate of abrasion, (%) | Lateral expansion (perimeter), (cm) | $\eta$, (%) | $\Delta P$, mm of water | R, (N.sec)/m$^3$ | de, micron |
| | y1 | y2 | y3 | y4 | y5 | y6 | y7 | y8 |
| 102 | 7.0 | 8.80 | 3.1 | 18.2 | 53.9 | 2.0 | 30.30 | 408.8 |
| 401 | 4.9 | 13.40 | 7.2 | 16.2 | 68.3 | 6.0 | 211.25 | 258.4 |
| 502 | 5.8 | 7.04 | 5.4 | 20.3 | 61.3 | 3.4 | 56.70 | 307.1 |
| 801 | 4.9 | 13.05 | 4.8 | 15.2 | 66.5 | 5.0 | 197.50 | 216.1 |
| 202 | 7.6 | 8.60 | 3.1 | 18.5 | 56.5 | 2.0 | 31.10 | 352.4 |
| 701 | 7.5 | 14.90 | 2.8 | 14.4 | 62.3 | 5.0 | 85.30 | 279.4 |
| 302 | 6.1 | 8.10 | 6.5 | 20.0 | 61.8 | 3.0 | 59.50 | 286.9 |
| 601 | 6.8 | 13.90 | 3.8 | 14.3 | 93.4 | 5.0 | 78.00 | 281.9 |

** Table ( 5 ) : *Measurements of Mechanical and Filtration Properties of Interlock Structure*

| Sample Code | Mechanical Properties | | | | Filtration Properties | | | |
|---|---|---|---|---|---|---|---|---|
| | Sp.w.r., (g/tex) $\sqrt{W.C}$ | Bursting pressure, (Kg/cm$^2$) | Rate of abrasion, (%) | Lateral expansion (perimeter), (cm) | $\eta$, (%) | $\Delta P$, mm of water | R, (N.sec)/m$^3$ | de, micron |
| | y1 | y2 | y3 | y4 | y5 | y6 | y7 | y8 |
| 102 | 8.84 | 9.60 | 4.7 | 24.5 | 86.84 | 2.0 | 26.8 | 307.08 |
| 401 | 7.74 | 21.40 | 8.0 | 15.2 | 96.18 | 38.8 | 1123.1 | 88.04 |
| 502 | 6.26 | 9.15 | 11.3 | 21.9 | 84.3 | 6.0 | 90.8 | 240.79 |
| 801 | 7.84 | 21.00 | 5.2 | 15.2 | 92.85 | 30.0 | 1035.13 | 101.88 |
| 202 | 10.65 | 10.73 | 4.4 | 22.1 | 85.38 | 3.0 | 34.2 | 286.94 |
| 701 | 11.45 | 22.64 | 4.0 | 15.1 | 97.56 | 9.8 | 354.5 | 129.03 |
| 302 | 6.82 | 9.32 | 8.2 | 22.1 | 88.18 | 3.4 | 96.29 | 252.54 |
| 601 | 10.9 | 23.46 | 2.8 | 14.5 | 91.7 | 10.2 | 332.13 | 135.92 |

$C^*$ means Sp. w. r. in course direction.

$W^*$ means Sp. w. r. in wale direction.

** Table ( 6 ) : *Measurements of Mechanical and Filtration Properties of Pile Fabric Structure*

| Sample Code | Mechanical Properties | | | | Filtration Properties | | | |
|---|---|---|---|---|---|---|---|---|
| | Sp.w.r., (g/tex) $\sqrt{W.C}$ | Bursting pressure, ($Kg/cm^2$) | Rate of abrasion, (%) | Lateral expansion (perimeter), (cm) | η, (%) | ΔP, mm of water | R, ($N.sec)/m^3$ | de, micron |
| | y1 | y2 | y3 | y4 | y5 | y6 | y7 | y8 |
| 102 | 2.9 | 7.3 | 5.5 | 17.2 | 90.6 | 4.6 | 150.3 | 240.8 |
| 401 | 2.4 | 9.8 | 8.7 | 15.8 | 96.6 | 23.6 | 869.9 | 126.1 |
| 502 | 2.3 | 6.3 | 8.3 | 17.7 | 90.8 | 6.6 | 302.7 | 273.5 |
| 801 | 2.4 | 10.3 | 9.4 | 15.7 | 90.8 | 21.8 | 803.5 | 124.5 |
| 202 | 2.6 | 7.3 | 7.7 | 16.5 | 86.2 | 4.6 | 85.1 | 266.0 |
| 701 | 3.0 | 11.3 | 5.1 | 15.2 | 96.5 | 11.8 | 431.3 | 169.1 |
| 302 | 2.2 | 6.2 | 8.8 | 18.1 | 85.0 | 6.0 | 162.6 | 220.8 |
| 601 | 2.6 | 10.4 | 4.5 | 16.0 | 92.0 | 11.2 | 421.4 | 163.0 |

** Table ( 7 ) : *Measurements of Mechanical and Filtration Properties of Single-Piqué Structure*

| Sample Code | Mechanical Properties | | | | Filtration Properties | | | |
|---|---|---|---|---|---|---|---|---|
| | Sp.w.r., (g/tex) $\sqrt{W.C}$ | Bursting pressure, ($Kg/cm^2$) | Rate of abrasion, (%) | Lateral expansion (perimeter), (cm) | η, (%) | ΔP, mm of water | R, ($N.sec)/m^3$ | de, micron |
| | y1 | y2 | y3 | y4 | y5 | y6 | y7 | y8 |
| 102 | 5.46 | 13.0 | 7.30 | 21.6 | 79.2 | 3.0 | 33.04 | 405.7 |
| 401 | 5.13 | 16.2 | 10.40 | 16.7 | 98.6 | 8.6 | 293.2 | 179.4 |
| 502 | 4.62 | 10.0 | 9.90 | 19.4 | 84.3 | 4.4 | 83.9 | 234.9 |
| 801 | 5.18 | 16.1 | 7.20 | 16.1 | 91.5 | 7.2 | 280.0 | 164.3 |
| 202 | 7.01 | 13.3 | 4.30 | 18.6 | 85.2 | 3.0 | 34.7 | 384.6 |
| 701 | 5.98 | 19.9 | 4.96 | 15.3 | 97.4 | 5.0 | 115.7 | 217.0 |
| 302 | 4.84 | 9.7 | 9.50 | 20.3 | 96.2 | 3.8 | 77.8 | 213.1 |
| 601 | 5.54 | 19.7 | 4.40 | 15.7 | 95.3 | 5.0 | 101.8 | 252.5 |

Faculty of Engineering and Textile Department of National Research Centre. In order to determine the most important properties such as specific work of rupure, bursting resistance, rate of abrasion, lateral expansion of tubular filter, filtration efficiency, pressure drop, air resistance, equivalent pore diameter. These properties could be measured after dry- relaxed condition for 24 hours and heat-setting process for crimped polyester fibres fabric at 170 °C and after steaming cotton knitted fabric at 90°C.

### 2.3.2- Mechanical Properties:

#### (i) Specific Work of Rupture (g/tex):

Here each fabric was tested on Lloyd Universal Tester. Ten fabric specimens, with 140 mm × 50 mm, were cut with the long side parallel to the wales or the courses. The gauge length between the jaws was set at 100 mm and the cross-head speed was set at 50 mm/min during extension and at 100 mm/min during recovery.

The average specific work of rupture of knitted fabrics could be represented by the geometric mean of both wale and course results which can show the significance of the individual readings and magnify the higher value and minimize the lower value to a wide range to be suitable for comparing the different samples.

#### *(ii) Specific Bursting Pressure (kg/cm$_2$).*

The bursting tests of knitted fabrics were carried out on the Hydraulic Bursting Strength Tester using diaphragm test according to (British Standard. No. 11, 1949).

#### *(iii) Rate of Abrasion (%).*

The fabrics were tested by means of Turbo Wear Tester using Impeller Tumble Method. For testing the rate of abrasion (percentage loss of weight due to abrasion), the following conditions were used. Tested specimen 5x5 cm, abrasion time, 5 min, and number of specimens from each sample, 10.

#### *(iv) Lateral Expansion (E):*

An apparatus was designed for measuring the lateral expansion or the perimeter of the tubular knitted filter fabrics.

Fig. (5) shows a schematic diagram of the apparatus. Air is passed from the compressor (10) to the hollow shaft. The compressed air goes out from the hollow shaft through many radial holes in the middle of the shaft to the perforated cylinder (4). The internal compressed air compresses on the cylindrical membrane (5) and consequently, cylindrical filter specimen (6) expands according to membrane expansion. When the lamp into the photo box (I) is lit in the dark, then it is possible to measure the maximum shadow diameter (D) of the cylindrical specimen (6) on a quadratic millimetres paper fixed on the barrier (7). From the ratio between real scale and shadow scale, the real diameter of the tubular specimen after expansion can be determined at a constant air pressure p=4 bar = 60 psi (lb/in$^2$). And consequently, the perimeter of the tubular specimen in cm after expansion can be calculated and equal $\Pi D$. Ten readings were taken for each fabric.

1- Photo box.
2- Manometer.
3- Hollow shaft.
4- Perforated cylinder.
5- Cylindrical membrane.
6- Cylindrical specimen of fabric.
7- Barrier and quadratic millimetres paper
8- Pressure gauge.
9- Valve.
10- Compressor.
11- Base

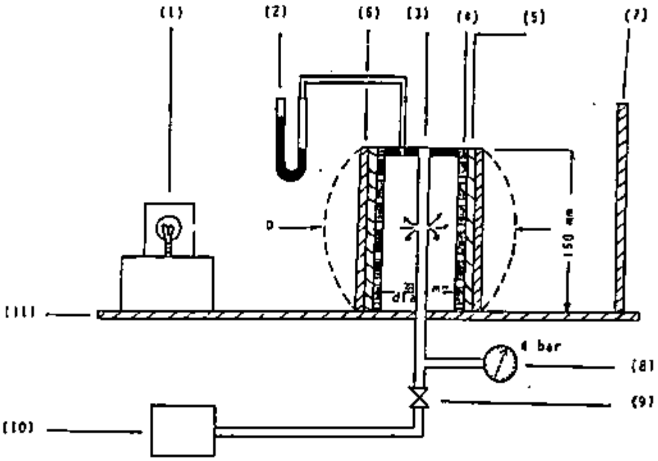


*Fig. ( 5 ): A Schematic diagram of the lateral expansion apparatus*

1- Pipe
2- Regulator
3- Flowmeter
4- Pressure gauge
5- Fabric specimen
6- Valve
7- Manometer
8- Vacuum pump
9- Filtration paper
10- Dust feeding device

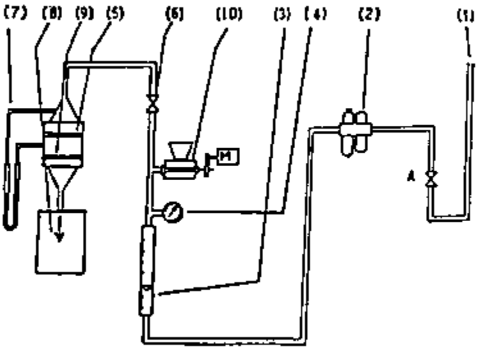


*Fig. ( 6 ): A Schematic diagram of gas filtration apparatus*

### 2.3.3- Filtration Properties:

The selection of fabric filter media depends to a great extent on many primary properties such as: filtration efficiency (η), pressure drop (Δp), air resistance (R), and equivalent pore diameter (de).

***(i) Filtration Efficiency (η).***

The measurement of filtration efficiency of fabrics is the main object of this work. It is tested on the apparatus shown in Figure (6) and references [7.10]. Air is drawn from the atmosphere through the pipe (1) by the action of vacuum pump (8). When valve (A) is open, the air flows through the apparatus. A filter and regulator (2) is used to get dry air in the system. A flowmeter (3) is used to measure the rate of air flow. The pressure gauge (4) measures the air pressure in the line. A dust feeding device (10), feeds the system with a constant amount of the dust. This dust is mixed with the air flow. The fabric specimen (5) prevents the coarse particles of dust and permits the fine ones to pass through it. The fine particles are accumulated on the upper surface of the filtration paper (9). The pressure drop across the fabric specimen is measured by the manometer (7).

The following operating conditions were kept constant.

1- Area of test filter : 15 $cm^2$.

2- Rate of air flow : 183.3 cm3/sec(11 litre/min).

3- Air velocity : 12.2 cm/sec.

4- Time of experiment : 3 minutes.

**Test Method :** Both the fabric specimen and filtration paper are weighed before experiment $W_1$, $W_2$ and after experiment $W_3$, $W_4$ respectively. Then filtration efficiency η can be calculated as follows :

$$\eta=\frac{W_3-W_1}{(W_3+W_4)-(W_1+W_2)}X100,(\%) \qquad .....(1)$$

**(ii) Pressure Drop (ΔP)**

Pressure drop is an important parameter in the design of tubular filters and for practical reasons must fall within prescribed limits . These limits control , to a large degree , the filltration that are obtainable. Raising the pressure drop improves the filtration efficiency (η) and thus reduces the number of dust particles that penetrate the filter. This implies that any increase in the value of filtration efficiency would require a somewhat larger increase in the pressure drop and filter mass. In filtration experiments the pressure drop was registrated for three minutes. Pressure drops were determined in mm of water using filtration apparatus, in which water manometer and air-flow rate of 183.3 $cm^3$/sec was used. (1 mm of water = 9.8 $N/m^2$).

**(iii) Air flow Resistance ®**

Air flow resistance was measured using Shirley Air Permeability Tester. From the measured pressure difference ($\Delta p$ = 5 mm of water = 49 $N/m^2$) between the two sides of the fabric, the air permeability (B) can be calculated using the following equation:

$$B=\frac{V}{A.\Delta p},m^3/(N.sec) \qquad ...(2)$$

Where,

V-air volume in cubic metres per second flowing through the speciment.

A- actual area of the test specimen in square metres and,

Δp- pressure head in $N/m^2$.

Conseqently, air flow resistance ( R ) can be determined as follows:

$R=1/B$ ,$(N.sec)/m^3$ ...(3)

**(iv) Equivalent Pore Diameter (de)**

Fabric pore diameter could be measured by the following apparatus.

**Apparatus:** A photograph of the apparatus used is shown in Fig. (7) and the main features of the apparatus are shown in Fig.(8). and reference [8]. The specimen holder consists essentially of a brass cylindrical vessel (1) over which the specimen (2) is clamped by a clamping ring (3) and screw (4). It is fitted with a rubber gasket (5) of 50 mm internal diameter to make a seal against the specimen. Circular specimens are clamped between rubber gaskets over the orifice. Compressed air enters the vessel through a tube (B), thereby forcing air up against the specimen. Tube (B) is also connected to U-tube manometer (D) by means of a valve (C) and the pressure of air against the fabric is the pressure shown on the adjustable scale mounted on one arm of the manomenter tube. The air supply for the test is drawn from a reservoir which is itself fed through a flow control device from a source (Hydrostatic Head Tester) which may vary between 4 and 20 lb/sq.in. The flow control device is designed to give the required rate of increase of pressure at 10 cm of water per minute, the rate of loading will be within the limits of 10+ 0.5 cm/min up to the limit of the apparatus. The maximum head attainable is 150 cm of water.

**Test Procedure :** A circular specimen 6 cm in diameter, is conditioned at 65±2 percent R.H. and 20 °C ± 2 and then completely immersed and soaked for three minutes in white alcohol. After soaking, it is mounted on the testing head of the apparatus and the upper surface is covered with white alcohol. The air pressure is raised on the lower surface, at rate of pressure of 10 cm head of water per minut, until streams of bubbles appear at three places in the specimen , this pressure , Δp , in cm of water is then noted. Ten specimens are tested and the equivalent diameter of the third largest pore in the specimen, de, is calculated for each specimen from the formula [9].

$$d_e = \frac{4s}{\Delta p.g} \times 10^{-4} \quad ,\text{microns} \qquad ...(4)$$

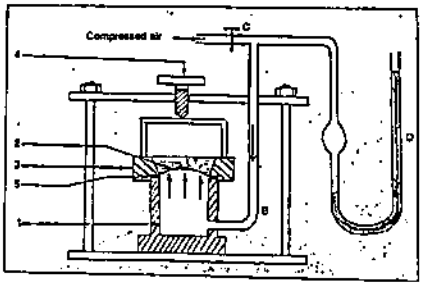
Where,

$d_e$ - equivalent pore diameter , microns

S - the surface tension of the white alcohol in dynes per cm at the temperature at which the test is carried out (S = 25.9 dyne/cm at 23°C).

Δp- the acceleration of gravity, is taken as 981 $cm/sec^2$.The mean equivalent pore diameter of ten specimens is then calculated for the fabric.

*Fig. ( 7 ): A Photograph of the equivalent pore diameter apparatus*



1 - Brass cylindrical vessel
2 - Specimen
3 - Clamping ring
4 - Screw
5 - Rubber gasket
B - Tube
D -U- tube manometer
C - Valve

*Fig. ( 8 ): A Schematic diagram of the equivalent pore diameter apparatus*

## 3. RESULTS AND DISCUSSION

### 3.1- Experimental Analysis:

The results obtained for mechaical Properties: specific work of rupture, bursting strength, rate of abrasion, lateral expansion of tubular knitted filter fabrics and filtration properties: filtretion efficiency (η), pressure drop (Δp), air flow resistance ( R ) and equivalent pore diameter (de) for each knitted structure are listed in Tables (4-7).

### 3.2-Design of Experiment :

A complete factorial designs [4,5] of three variables at two levels, namely, -1 and +1 were chosen to investigate all the four knitted structuress.

The response Y is given by second - order polynomial, i.e.:

$$Y = bo + \sum_{i=1}^{n} b_i x_i + \sum_{ij=1}^{n} b_{ij} x_i x_j, \qquad ...(5)$$

Where,

$X_i$ - I th variable

n - number of variables, and

bo,$b_i$ and $b_{ij}$ - regression coefficients associated with the variable.

The results obtained were fed to IPM Comuter, and regression coefficients were determined. The coefficients were tested for significance at the 95% significance level. The response-surface equations for the various fabric properties for each knitted structure are given in Tables (8-11).

Given in Tables (12-19) comparison between measured and calculated values obtained from the response - surface equation for each structure with the correlation coefficients between them. The response surface agrees fairly with the experimental data as can be seen from the high correlation coefficients.

**Table (8) : Response-Surface Equations For Single-jersey Structure.**

| Response - Surface Equations |
|---|
| **Y1** $= 6.325 + 0.9 X_1 - 0.3 X_2 - 0.005 X^*_3 + 0.225 X_1 X_2 + 0.025 X_1 X^*_3 - 0.125 X_2 X_3$. |
| **Y2** $= 11.03 + 0.52 X_1 + 2.895 X_2 - 0.27 X_3 - 0.045 X1 X^*_2 - 0.003 X_1 X^*_3 + 0.045 X_2 X^*_3$. |
| **Y3** $= 4.59 - 1.39 X_1 + 0.06 X_2 - 0.31 X_3 + 0.0375 X_1 X^*_2 + 0.56 X_1 X_3 - 0.0375 X_2 X^*_3$. |
| **Y4** $= 17.14 - 0.79 X_1 - 2.1 X_2 - 0.006 X_3 + 0.11 X_1 X_2 + 0.11 X_1 X_3 - 0.21 X_2 X_3$. |
| **Y5** $= 65.5 + 1.025 X_1 + 7.13 X_2 + 3.93 X_3 + 4.2 X_1 X_2 + 4.5 X_1 X_3 + 3.4 X_2 X_3$. |
| **Y6** $= 3.925 - 0.425 X_1 + 1.325 X_2 - 0.075 X^*_3 + 0.175 X_1 X^*_2 + 0.075 X_1 X^*_3 - 0.175 X_2 X^*_3$. |
| **Y7** $= 93.71 - 37.53 X_1 + 49.31 X_2 - 2.88 X^*_3 - 23.83 X_1 X_2 + 1.26 X_1 X^*_3 - 2.38 X_2 X^*_3$. |
| **Y8** $= 298.88 + 31.75 X_1 - 39.93 X_2 - 9.5 X_3 - 10.05 X_1 X_2 - 3.98 X_1 X^*_3 - 0.45 X_2 X^*_3$. |

* Means unsignificant factor or interaction

**Table (9) : Response - Surface Equations For Interlock Structure.**

| Response - Surface Equations |
|---|
| **Y1** $= 8.81 + 1.65 X_1 + 0.67 X_2 + 0.1 X_3 + 0.045 X_1 X^*_2 + 0.215 X_1 X_3 - 0.212 X_2 X_3$. |
| **Y2** $= 15.91 + 0.695 X^*_1 + 6.21 X_2 + 0.172 X^*_3 + 0.23 X_1 X^*_2 + 0.315 X1 X^*_3 - 0.068 X_2 X^*_3$. |
| **Y3** $= 6.08 - 2.1 X_1 - 1.1 X_2 - 0.15 X_3 + 0.5 X_1 X_2 - 0.23 X_1 X_3 - 0.85 X_2 X_3$. |
| **Y4** $= 18.8 + 0.21 X_1 - 3.84 X_2 - 0.39 X_3 - 0.44 X_1 X_3 + 0.26 X_2 X_3$. |
| **Y5** $= 90.37 - 0.038 X^*_1 + 4.2 X_2 - 1.82 X^*_3 + 0.06 X_1 X^*_2 - 0.014 X_1 X^*_3 - 0.48 X_2 X^*_3$. |
| **Y6** $= 12.9 - 6.65 X_1 + 9.3 X_2 - 0.6 X^*_3 - 5.55 X_1 X_2 + 0.95 X_1 X_3 - 1.5 X_2 X_3$. |
| **Y7** $= 386.62 - 199.71 X_1 + 324.6 X_2 - 13.55 X^*_3 - 168.19 X_1 X_2 + 9.81 X_1 X^*_3 - 14.03 X_2 X^*_3$. |
| **Y8** $= 192.8 + 22.0 X_1 - 79.0 X_2 - 1.39 X^*_3 - 3.21 X_1 X_2 - 1.92 X_1 X_3 + 6.58 X_2 X_3$. |

**Table (10) : Response - Surface Equation For Pile Fabric Structure.**

| Response - Surface Equations |
|---|
| **Y1** $= 2.55 + 0.225 X_1 + 0.05 X_2 - 0.075 X_3 - 0.025 X_1 X^*_2 - 0.1 X_1 X_3 - 0.025 X_2 X^*_3$. |
| **Y2** $= 8.625 + 0.47 X_1 + 1.85 X_2 - 0.05 X^*_3 - 0.05 X_1 X^*_2 - 0.2 X_1 X^*_3 - 0.08 X_2 X^*_3$. |
| **Y3** $= 7.25 - 1.55 X_1 - 0.33 X^*_2 - 0.23 X^*_3 - 0.57 X_1 X^*_2 + 0.18 X_1 X^*_3 - 0.2 X_2 X^*_3$. |
| **Y4** $= 16.53 - 0.3 X_1 - 0.85 X_2 - 0.05 X_3 + 0.225 X_1 X_2 + 0.075 X_1 X_3 + 0.225 X_2 X_3$. |
| **Y5** $= 91.1 + 0.26 X^*_1 + 2.91 X_2 - 1.11 X_3 + 0.01 X_1 X^*_2 - 1.11 X_1 X_3 - 1.46 X_2 X_3$. |
| **Y6** $= 11.28 - 3.23 X_1 + 5.83 X_2 - 0.23 X^*_3 - 2.38 X_1 X_2 + 0.08 X_1 X^*_3 - 0.38 X_2 X^*_3$. |
| **Y7** $= 403.35 - 131.3 X_1 + 228.18 X_2 - 0.18 X^*_3 - 73.9 X_1 X_2 - 18.6 X_1 X_3 - 18.9 X_2 X_3$. |
| **Y8** $= 197.98 + 11.75 X_1 - 52.3 X_2 + 8.77 X_3 + 8.63 X_1 X_2 - 4 X_1 X_3 - 10.7 X_2 X_3$. |

**Table (11) : Response - Surface Equations For Single - Piqué Structure**

| Response - Surface Equations |
|---|
| **Y1** $= 5.47 + 0.52\ X_1 - 0.02\ X^{*}_{2} + 0.11\ X^{*}_{3} - 0.22\ X_1\ X^{*}_{2} + 0.16\ X_1\ X^{*}_{3} - 0.21\ X_2\ X^{*}_{3}.$ |
| **Y2** $= 14.7 + 1.7\ X_1 + 3.2\ X_2 - 0.002\ X^{*}_{3} + 0.05\ X_1\ X^{*}_{2} - 0.05\ X_1\ X^{*}_{3} - 0.15\ X_2\ X^{*}_{3}.$ |
| **Y3** $= 7.25 - 2.0\ X_1 - 0.51\ X_2 - 0.8\ X_3 - 0.06\ X_1 X^{*}_{2} - 0.1\ X_1\ X^{*}_{3}\ 0.15\ X_2\ X^{*}_{3}.$ |
| **Y4** $= 18 - 0.16\ X_1 - 2.0\ X_2 - 0.51\ X_3 - 0.29\ X_1\ X_2 - 0.14\ X_1\ X_3 + 0.46\ X_2\ X_3.$ |
| **Y5** $= 90.96 - 1.69\ X_1 + 4.74\ X_2 - 1.89\ X_3 + 2.34\ X_1\ X_2 + 2.86\ X_1\ X_3 - 0.41\ X_2\ X_3.$ |
| **Y6** $= 5.0 - X_1 + 1.45\ X_2 - 0.1\ X^{*}_{3} - 0.45\ X_1\ X_2 + 0.1\ X_1\ X^{*}_{3} - 0.25\ X_2\ X^{*}_{3}.$ |
| **Y7** $= 127.5 - 56.2\ X_1 + 70.2\ X_2 - 2.42\ X^{*}_{3} - 32.7\ X_1\ X_2 - 0.64\ X_1\ X^{*3} - 4.36\ X_2\ X_3.$ |
| **Y8** $= 256.4 + 58.5\ X_1 - 53.1\ X_2 + 2.46\ X^{*}_{3} - 27.1\ X_1\ X_2 + 0.96\ X_1\ X^{*}_{3} + 2.46\ X_2\ X^{*}_{3}.$ |

### 3.3- Mathematical Solution:

By using the computer all eight nonlinear equations for each structure are solved and one result could be printed as one optimum solution for the eight equations. Table (20) shows the typical computer solution for the eight equations.

Thus, these computed optimum factors can be used to design a new tubular filter for protecting the workers in spinning mills from the air pollution.

**Table( 12 ): *Comparison Between Measured and Calculated Values of Mechanical Properties of Single-jersey Structure***

| Sample Code | Sp. w. r. (g/tex) | | Bursting Pressure, (kg/cm$^2$) | | Rate of abrasion (%) | | Lateral expansion (perimeter) (cm) | |
|---|---|---|---|---|---|---|---|---|
| | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. |
| 102 | 7.0 | 7.2 | 8.8 | 9.038 | 3.1 | 2.896 | 18.2 | 18.1 |
| 401 | 4.9 | 5.1 | 13.4 | 13.638 | 7.2 | 6.996 | 16.2 | 16.1 |
| 502 | 5.8 | 6.0 | 7.04 | 7.358 | 5.4 | 5.128 | 20.3 | 20.2 |
| 801 | 4.9 | 4.7 | 13.5 | 13.262 | 4.8 | 5.000 | 15.2 | 15.3 |
| 202 | 7.6 | 7.4 | 8.6 | 8.362 | 3.1 | 3.304 | 18.5 | 18.6 |
| 701 | 7.5 | 7.3 | 14.9 | 14.582 | 2.8 | 3.072 | 14.4 | 14.5 |
| 302 | 6.1 | 5.9 | 8.1 | 7.782 | 6.5 | 6.772 | 20.0 | 20.1 |
| 601 | 6.8 | 7.0 | 13.9 | 14.218 | 3.8 | 3.528 | 14.3 | 14.2 |
| (r) | 0.980 | | 0.996 | | 0.983 | | 0.999 | |

**Table( 13 ): *Comparison Between Measured and Calculated Values of Filtration Properties of Single-jersey Structure***

| Sample Code | $\eta$, (%) | | ΔP, mm of water | | R, (N.sec)/m$^3$ | | de, micron | |
|---|---|---|---|---|---|---|---|---|
| | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. |
| 102 | 53.9 | 50.3 | 2.0 | 1.862 | 30.30 | 30.346 | 408.8 | 397.193 |
| 401 | 68.3 | 64.7 | 6.0 | 5.862 | 211.25 | 211.297 | 258.4 | 246.79 |
| 502 | 61.3 | 56.5 | 3.4 | 3.216 | 56.70 | 56.762 | 307.1 | 291.62 |
| 801 | 66.5 | 70.1 | 5.0 | 5.138 | 197.50 | 197.453 | 216.1 | 227.71 |
| 202 | 56.5 | 60.1 | 2.0 | 2.138 | 31.10 | 31.053 | 352.4 | 364.01 |
| 701 | 62.3 | 67.1 | 5.0 | 5.184 | 85.30 | 85.238 | 279.4 | 294.88 |
| 302 | 61.8 | 66.6 | 3.0 | 3.184 | 59.50 | 59.438 | 286.9 | 302.38 |
| 601 | 93.4 | 88.6 | 5.0 | 4.816 | 78.00 | 78.062 | 281.9 | 266.42 |
| (r) | 0.945 | | 0.992 | | 0.999 | | 0.961 | |

**Table( 14 ): *Comparison Between Measured and Calculated Values of Mechanical Properties of Interlock Structure***

| Sample Code | Sp. w. r., (g/tex) | | Bursting Pressure, (kg/cm$^2$) | | Rate of abrasion (%) | | Lateral expansion (perimeter) (cm) | |
|---|---|---|---|---|---|---|---|---|
| | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. |
| 102 | 8.84 | 9.22 | 9.60 | 9.61 | 4.7 | 4.08 | 24.5 | 24.3 |
| 401 | 7.74 | 8.12 | 21.40 | 21.41 | 8.0 | 7.38 | 15.2 | 15.0 |
| 502 | 6.26 | 6.64 | 9.15 | 9.16 | 11.3 | 10.68 | 21.9 | 21.7 |
| 801 | 7.84 | 7.46 | 21.00 | 20.99 | 5.2 | 5.83 | 15.2 | 15.4 |
| 202 | 10.65 | 10.27 | 10.73 | 10.72 | 4.4 | 5.03 | 22.1 | 22.3 |
| 701 | 11.45 | 11.07 | 22.64 | 22.63 | 4.0 | 4.63 | 15.0 | 15.2 |
| 302 | 6.82 | 6.44 | 9.32 | 9.31 | 8.2 | 8.82 | 22.1 | 22.3 |
| 601 | 10.90 | 11.28 | 23.46 | 23.47 | 2.8 | 2.18 | 14.5 | 14.3 |
| (r) | 0.979 | | 0.999 | | 0.972 | | 0.981 | |

**Table( 15 ): *Comparison Between Measured and Calculated Values of Filtration Properties of Interlock Structure*

| Sample Code | η, (%) | | ΔP, mm of water | | R, (N.sec)/m² | | de, micron | |
|---|---|---|---|---|---|---|---|---|
| | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. |
| 102 | 86.84 | 87.46 | 2.0 | 0.65 | 26.80 | 20.21 | 307.08 | 306.90 |
| 401 | 96.18 | 96.80 | 38.8 | 37.45 | 1123.1 | 1116.51 | 88.04 | 87.86 |
| 502 | 84.30 | 84.92 | 6.0 | 4.65 | 90.80 | 84.21 | 240.79 | 240.61 |
| 801 | 92.85 | 92.23 | 30.0 | 31.35 | 1035.13 | 1041.72 | 101.88 | 102.06 |
| 202 | 85.38 | 84.76 | 3.0 | 4.35 | 34.20 | 40.79 | 286.94 | 287.12 |
| 701 | 97.56 | 96.94 | 9.8 | 11.15 | 354.50 | 361.09 | 129.03 | 129.21 |
| 302 | 88.18 | 87.56 | 3.4 | 4.75 | 96.29 | 102.88 | 252.54 | 252.72 |
| 601 | 91.70 | 92.32 | 10.2 | 8.85 | 332.13 | 325.54 | 135.92 | 135.74 |
| (r) | 0.991 | | 0.994 | | 0.999 | | 0.999 | |

**Table( 16 ): *Comparison Between Measured and Calculated Values of Mechanical Properties of Pile Fabric Structure*

| Sample Code | Sp, w. r., (g/tex) | | Bursting Pressure, (kg/cm²) | | Rate of abrasion (%) | | Lateral expansion (perimeter) (cm) | |
|---|---|---|---|---|---|---|---|---|
| | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. |
| 102 | 2.9 | 2.89 | 7.3 | 7.48 | 5.5 | 6.0 | 17.2 | 17.05 |
| 401 | 2.4 | 2.40 | 9.8 | 9.98 | 8.7 | 9.2 | 15.8 | 15.65 |
| 502 | 2.3 | 2.33 | 6.3 | 6.48 | 8.3 | 8.8 | 17.7 | 17.55 |
| 801 | 2.4 | 2.40 | 10.3 | 10.13 | 9.4 | 8.9 | 15.7 | 15.85 |
| 202 | 2.6 | 2.60 | 7.3 | 7.13 | 7.7 | 7.2 | 16.5 | 16.65 |
| 701 | 3.0 | 3.10 | 11.4 | 11.23 | 5.1 | 4.6 | 15.2 | 15.35 |
| 302 | 2.2 | 2.17 | 6.2 | 6.03 | 8.8 | 8.3 | 18.1 | 18.25 |
| 601 | 2.6 | 2.63 | 10.4 | 10.58 | 4.5 | 5.0 | 16.0 | 15.85 |
| (r) | 0.998 | | 0.996 | | 0.960 | | 0.972 | |

**Table( 17 ): *Comparison Between Measured and Calculated Values of Filtration Properties of Pile Fabric Structure***

| Sample | $\eta$, (%) | | $\Delta P$, mm of water | | R, (N.sec)/m$^2$ | | de, micron | |
|---|---|---|---|---|---|---|---|---|
| Code | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. |
| 102 | 90.6 | 89.16 | 4.6 | 4.38 | 150.3 | 117.58 | 240.8 | 237.93 |
| 401 | 96.6 | 95.16 | 23.6 | 23.38 | 869.9 | 837.18 | 126.1 | 123.23 |
| 502 | 90.8 | 89.36 | 6.6 | 6.38 | 302.7 | 269.98 | 273.5 | 270.63 |
| 801 | 90.8 | 92.24 | 21.8 | 22.03 | 803.5 | 836.23 | 124.5 | 127.38 |
| 202 | 86.2 | 87.64 | 4.6 | 4.83 | 85.1 | 117.83 | 266.0 | 268.88 |
| 701 | 96.5 | 97.94 | 11.8 | 12.03 | 431.3 | 464.03 | 169.1 | 171.98 |
| 302 | 85.0 | 86.44 | 6.0 | 6.23 | 162.6 | 195.33 | 220.8 | 223.68 |
| 601 | 92.0 | 90.56 | 11.2 | 10.98 | 421.4 | 388.67 | 163.0 | 160.13 |
| (r) | 0.930 | | 0.999 | | 0.993 | | 0.999 | |

**Table( 18 ): *Comparison Between Measured and Calculated Values of Mechanical Properties of Single-Piqué Structure***

| Sample | Sp. w. r., (g/tex) | | Bursting Pressure, (kg/cm$^2$) | | Rate of abrasion (%) | | Lateral expansion (perimeter) (cm) | |
|---|---|---|---|---|---|---|---|---|
| Code | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. |
| 102 | 5.46 | 5.75 | 13.0 | 13.05 | 7.30 | 6.55 | 21.6 | 21.2 |
| 401 | 5.13 | 5.42 | 16.2 | 16.25 | 10.40 | 9.64 | 16.7 | 16.3 |
| 502 | 4.62 | 4.91 | 10.0 | 10.05 | 9.90 | 9.14 | 19.4 | 19.0 |
| 801 | 5.18 | 4.89 | 16.1 | 16.05 | 7.20 | 7.96 | 16.1 | 16.5 |
| 202 | 7.01 | 6.72 | 13.3 | 13.25 | 4.30 | 5.06 | 18.6 | 19.0 |
| 701 | 5.98 | 5.69 | 19.9 | 19.85 | 4.96 | 5.72 | 15.3 | 15.7 |
| 302 | 4.87 | 4.58 | 9.7 | 9.65 | 9.50 | 10.26 | 20.3 | 20.7 |
| 601 | 5.54 | 5.83 | 19.4 | 19.45 | 4.40 | 3.65 | 15.7 | 15.3 |
| (r) | 0.913 | | 0.999 | | 0.993 | | 0.990 | |

**Table( 19 ): *Comparison Between Measured and Calculated Values of Filtration Properties of Single-Piqué Structure*

| Sample Code | $\eta$, (%) |  | $\Delta P$, mm of water |  | R, (N.sec)/m$^2$ |  | de, micron |  |
|---|---|---|---|---|---|---|---|---|
|  | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. | Meas. | Cal. |
| 102 | 79.2 | 80.81 | 3.0 | 2.75 | 33.04 | 32.57 | 405.7 | 394.01 |
| 401 | 98.6 | 100.21 | 8.6 | 8.35 | 293.2 | 292.73 | 179.4 | 167.71 |
| 502 | 84.3 | 85.91 | 4.4 | 4.15 | 83.9 | 83.43 | 234.9 | 223.21 |
| 801 | 91.5 | 89.89 | 7.2 | 7.45 | 280.0 | 280.47 | 164.3 | 175.99 |
| 202 | 85.2 | 83.59 | 3.0 | 3.25 | 34.7 | 35.17 | 384.6 | 396.29 |
| 701 | 97.4 | 95.79 | 5.0 | 5.25 | 115.7 | 116.17 | 217.0 | 228.69 |
| 302 | 96.2 | 94.59 | 3.8 | 4.05 | 77.8 | 78.27 | 213.1 | 224.79 |
| 601 | 95.3 | 96.91 | 5.0 | 4.75 | 101.8 | 101.33 | 252.5 | 240.81 |
| (r) | 0.971 |  | 0.991 |  | 0.999 |  | 0.990 |  |

**Table( 20 ): *Solution of Equations For Each Structure.*

| Structure |  | Single-jesey |  | Interlock |  | Pile Fabric |  | Single-pique |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Level | Value | Level | Value | Level | Value | Level | Value |
| Optimum Factors | $X_1$ | +1.0 | 100%P | +1.0 | 100%P | +1.0 | 100%P | +1.0 | 100%P |
|  | $X_2$ | +1.0 | 18.74 | +1.0 | 16.98 | +1.0 | 14.30 | +1.0 | 19.41 |
|  | $X_3$ | +0.5 | 3.37 | 0.0 | 3.25 | -0.5 | 3.13 | +0.5 | 3.37 |
| Corresponded Parameters | $Y_1$ | 7.088 |  | 11.13 |  | 2.9 |  | 5.78 |  |
|  | $Y_2$ | 14.31 |  | 23.045 |  | 11.06 |  | 19.55 |  |
|  | $Y_3$ | 3.404 |  | 3.38 |  | 4.925 |  | 4.155 |  |
|  | $Y_4$ | 14.307 |  | 14.73 |  | 15.48 |  | 15.455 |  |
|  | $Y_5$ | 83.77 |  | 94.592 |  | 96.12 |  | 96.63 |  |
|  | $Y_6$ | 4.913 |  | 10.0 |  | 11.765 |  | 4.875 |  |
|  | $Y_7$ | 79.66 |  | 343.32 |  | 445.17 |  | 107.51 |  |
|  | $Y_8$ | 273.685 |  | 132.59 |  | 169.025 |  | 237.64 |  |

## 4. CONCLUSION

From the results obtained in the present work, the following conclusions can be drawn out:

1- Knitted fabrics made of 100% polyester fibres offer properties different from those of all cotton fabrics, to an extent depending on the type of structure.

2- The use of 100% polyester knitted fabrics is a remarkable improvement in both the mechanical and filteration properties compared to 100% cotton fabrics.

3- Both tightness factor and twist multiplier affect to a great extent on the mechanical and filtration properties.

4- For all polyester structures, specific work of rupture, bursting strength,.filtration efficiency, and pressure drop increase but pore diameter and lateral expansion decrease as tightness factor increases. Conversely, rate of abrasion decreases as tightness factor increases especially for both pile fabric and single piqué structures.

5- The most suitable structure is interlock which has a maximum filtration efficiency at a relatively low pressure drop and is not costly but the other structures are less efficient dust extractors and have a larger pressure drop on the fabric which makes them less suitable for extracting dust from the air and have higher power for the pressure drop.

6- An interlook knitted fabric composed of 100% polyester, 16.98 tightness factor (20 Ne yarn count, 0.31 cm loop length and 43.5 courses per inch) and 3.25 &e twist multiplier is well suited for manufacturing cylindrical filters.

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