

NOVEL APPROACH FOR DETERMINING DIAMETER OF A YARN WITH UNKNOWN COUNT

تحديد قطر الخيط مجهول النمرة

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خلاصة:

يقدم هذا البحث طريقة لتحديد قطر الخيط بناءً على الفهم العلمي لطبيعة الألياف مع تجنب العراقيل المرتبطة بالطرق التقليدية المستخدمة في قياس قطر الخيط سواء عن طريق التكبير أو الحساب بالتعويض في صيغ فرضية. وتعتمد الطريقة الجديدة المقدمة في هذا البحث على وضع الخيط في شكل محدد هندسياً ثم الاستفادة من العلاقة بين طول الخيط وطره ووزنه من خلال هذا الشكل الهندسي. ولما كان طول الخيط هو العامل المشترك بين الشكل الهندسي المختار وبين وزن الخيط، ولما كانت العلاقة بين طول الخيط ووزنه يمكن إيجادها من خلال نمرة الخيط، ولما كانت نمرة الخيط مجهولة أو يفرض عدم معرفتها يتم إعادة تشكيل الخيط بحيث يتغير طول الجزء المستخدم في التشكيل. وبذلك نحصل على توليفتين من المعلومات يمكن حذف نمرة الخيط بينهما رياضياً. وبذلك يمكن تطوير صيغة بسيطة لتحديد قطر الخيط لأقرب أو ميكرون أو أدق من ذلك. ويقدم البحث أيضاً تفاصيل الجهاز المستخدم في التشكيل وتوضيحاً لطريقة الاختيار المستخدمة في تحديد قطر الخيط.

1-ABSTRACT:

This research work presents a perfect method to determine yarn diameter based on scientific understanding of things nature and avoiding the obstacles of classical methods of yarn diameter measuring by magnification or calculating it from empirical formulae. The suggested method presented here depends on putting yarn in a geometrically well defined form and getting use of the relation between yarn length, yarn diameter, and yarn weight through this selected form. Yarn length, in this state, is a common factor between the selected geometrical form and the weight of the formed yarn. The relation between yarn weight and yarn length is well known through the count. As count is unknown, yarn is formed with changing length of its pattern. By this arrangement, two sets of informations are obtained. Yarn count, being a common factor between the two sets, can be cancelled. This results in a simple relation from which yarn diameter can be determined to the nearest 0.1 micron or more accurate. Details of forming device called *EYDM* (Estimated Yarn Diameter Meter) and testing procedure are indicated.

2- INTRODUCTION:

Yarn diameter must be accurately measured to suit *Remote Monitoring* of warp threads in weaving. This is a new trend in weaving which aims at feeling warp end without touching it. Single-end and entire warp sheet monitoring devices were designed solely for warp threads of a diameter greater than several hundred micrometers. The scope of monitoring system could be extended to finer thread diameters of the order of some ten micrometers. Individual threads can be detected even if their diameter is finer than 30 μm [1]. Yarn diameter was used for determining its weavability limit [2 and 3] and expressing woven fabric cover factor [4]. The ratio between warp and weft diameter was used to formulate maximum weavability of plain woven fabrics [5]. Yarn diameter affects its properties. Effect of yarn count on its tenacity was studied [6]. A family of five ring spun yarn sizes, each with five twist factors was tested by different tensile strength testers. Results were different from tester to tester and with the change in the time-to-break.

Measuring dimensions of a solid body could be achieved by using a ruler, a gauge, a planimeter, or by getting use of its physical and chemical properties. The problem in textiles is that boundaries of a textile structure are difficult to, or can not, be located. So devices based on compression are of doubtful use in measuring thickness of a yarn because of the interaction of count and twist in determining yarn compressibility [7]. Yarn thickness at any point on the yarn length is defined as a local diameter of its core. Edge of yarn core should be determined first. Standard procedures of yarn edge determination are insufficient. A method to determine core edge was recently developed [8]. But this method is costly and sophisticated.

Yarn diameter may change after finishing processes. One of such processes is air-jet texturing. Texturing improves bulk on the account of strength, modulus, and flexural rigidity. Air-jet texturing of certain structures such as carded ring spun yarns and Siro yarns gives a high level of bulk compared to other structures. Rotor-spun yarns get lower bulk after air-jet texturing because of their tripartite structure, twist angle variation, and alternating Z and S helices in their fibre belts [9]. Yarn density and, consequently, fibre packing affect yarn preparatory processes. Bulking potential of spun yarn structure with air-jet texturing was recently studied with respect to fibre packing density, fibre fineness and length distribution, mean fibre extent, and migration parameters. Yarns with higher packing and migration produced yarns with reduced bulk [10].

The idealized model of a yarn assumes a yarn of circular cross section in the undeformed state, with each fibre in the yarn following a helical path. Deformed polyester twisted filament yarn under tension, compression and bending was investigated during its passage over three steel rods of 1.76 mm diameter with centres forming corners of a 30° isosceles triangle. Tension was applied by an Instron tensile tester which applied tension at both ends of the yarn sample. The changes in both the major and minor diameters of the yarn bent over the three-rod unit and subjected to extension increments of 1%, 5%, 10%, 15%, etc. were observed by means of a travelling microscope. Major yarn diameter was 220 μm -310 μm . Minor yarn diameter was 155 μm -195 μm . Yarn count was 64 tex. It consisted of 320 filaments. Twist was from 393-709 turns / meter. It was found that the degree of deformation in the cross section depends on the levels of the bending moment, the compression or extension load applied, the helix angle, and the ratio of flexural rigidity to torsional rigidity of helix material. Deformation is less as the helix angle increases [11].

Kienbaum [3] calculated yarn diameter assuming yarn density. The shadow of magnified yarn was measured using Shirley Yarn Diameter Projector [7]. Yarn thickness was measured photoelectrically by Chamberlain Apparatus [13]. Ashenhurst [12] determined empirically a constant for every kind of yarn to use it with linear density to estimate yarn diameter. Peirce [5] calculated yarn diameter from its count assuming its specific volume as 1.1 cm^3/g but this value was for only highly twisted yarn [7]. Oxley [7] measured yarn diameter under a compressive load. He found that softness and hardness of yarn portions affect the measured value. Computer aided geometric design techniques were used to present yarn shape and simulate its appearance [13].

3- THEORY:

When yarn form is changed to a new geometrically determined form, it can be geometrically and analytically dealt with. The new yarn form is obtained by lapping it around cylinders of a certain diameter in an alternating order as in plain weave such

that lap angle on each cylinder is 180° . This is achieved when cylinders reach jamming condition. This procedure is not carried out on one yarn end but on a sheet of parallel equi-spaced ends from the same yarn which diameter is required to be measured. If

D : cylinder diameter (mm)

d : yarn diameter (mm)

N_1 : number of yarn ends in yarn sheet

N_2 : number of cylinders used

N_m : yarn metric count (mm / mg)

then,

Length (mm) of yarn sheet lapping around cylinders

$$L_s = \frac{\pi}{2} N_2 (d + D) \quad (1)$$

and

Length (mm) of yarn lapping around cylinders

$$L_y = \frac{\pi}{2} N_1 N_2 (d + D) \quad (2)$$

Weight (mg) of yarn lapping around cylinders

$$W = \frac{\pi N_1 N_2}{2 N_m} (d + D) \quad (3)$$

If the last procedure is repeated with cylinders of another diameter D' (mm), then a new weight of yarn lapping around cylinders will be obtained. Let the new weight be W' (mg).

$$\therefore W' = \frac{\pi N_1 N_2}{2 N_m} (d + D') \quad (4)$$

Yarn count N_m can be cancelled between equations (3) and (4). From equations (3) and (4)

$$\therefore d = \frac{W' D - W D'}{W - W'} \quad (5)$$

4- TESTING PROCEDURE:

The following procedure is followed:

4-1- PREPARING YARN SHEET:

Yarn is withdrawn from its package and wound onto a reel. Yarn is distributed across the reel using a screw of a suitable pitch. Yarn sheet on the reel is then clamped in two positions separated by a distance equal to the length of yarn sheet required on the forming frame. Fig. (1) shows a sketch of the forming device. Number of ends in yarn sheet (N_1) is counted and registered. Fig. (2) shows a sketch of one pair of clamps.

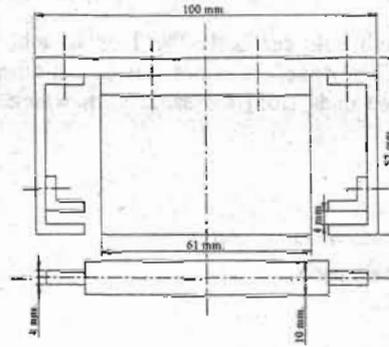


Fig. (1): A Sketch of The Device (a plan view) indicating the two vertical 4-mm slots, the 61-mm wide base plate, and one 10-mm diameter cylinder drawn separately

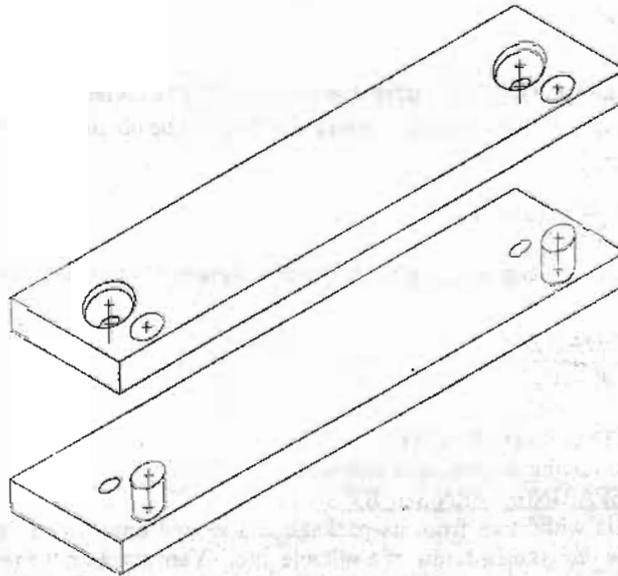
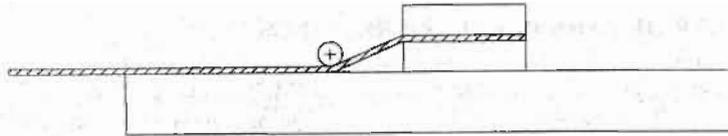


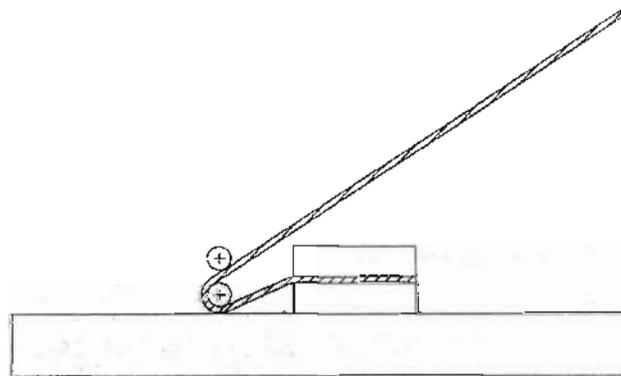
Fig. (2): A Sketch of One Pair of Clamps

4-2- FORMING YARN SHEET:

Yarn sheet is lapped manually and gently around cylinders of a diameter D (mm) as shown in Fig. (3) in an alternative manner such that lapping angle around each cylinder is 180° (this occurs at cylinder jamming state in one plane). Number of cylinders (N_2) is registered.



3-a: Inserting First Cylinder on Yarn Sheet



3-b: Inserting Second Cylinder on Yarn Sheet

Fig. (3): Lapping Process

4-3- SEPARATING FORMED YARN SHEET:

Yarn sheet is cut using a sharp cutter in two locations: just before the first cylinder and just after the last one such that complete lapping arcs are contained. Formed yarn sheet is then removed from the frame.

4-4- WEIGHING:

Removed yarn sheet is weighed to the nearest 0.1 mg to obtain the value W (mg). Atmospheric conditions with respect to temperature and relative humidity are also registered.

4-5- REPEATING PREVIOUS STEPS:

Another sheet of the same yarn and with the same number of ends is lapped around the same previous number of cylinders but of a new diameter D' (mm). Formed sheet is separated and weighed to obtain the value W' (mg).

4-6- TABULATING DATA:

Data obtained from repeated lapping and weighing are put in a table to be used in calculations. In the title of the table, atmospheric conditions with respect to temperature and relative humidity are mentioned.

4-7- CALCULATING:

Yarn diameter is determined by substituting for the test data in equation (5). With every pair of measurements, a value of yarn diameter is calculated.

5- NUMBER OF YARN DIAMETER READINGS:

If test procedure is carried out m times with m different cylinder diameters, then m different weight values of yarn are obtained. Making computations of 2 between these m results a number of yarn diameter readings n is obtained. The relation between number of yarn diameter readings and number of samples is as follows:

$$n = {}^m C_2 = \frac{m(m-1)}{2} \quad (6)$$

m : number of yarn sheets lapped or number of cylinder sets used.

n : number of yarn diameter readings.

It is clear from equation (6) that beginning from 4 cylinder sets, number of diameter readings will be more than number of test specimens. This is indicated in Table (1). Standard methods of sampling can be used to obtain a small sample size. Sample size will be equal to the number of tests or cylinder sets. The test method explained previously is followed to obtain m values of weights whereas n values of yarn diameter are estimated by both computations and substituting in equation (5).

Table (1): Number of Yarn Diameter Readings n Obtained from m Lapping and Weighing Procedures:

m	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n	0	1	3	6	10	15	21	28	36	45	55	66	78	91	105
m	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
n	120	136	153	171	190	210	231	253	276	300	325	351	378	406	435

6- STATISTICAL DATA OF YARN DIAMETER:

Yarn diameter readings are statistically analysed to get means such as arithmetic mean and measures of dispersion such as coefficient of variation.

7- PHILOSOPHY BEHIND TEST METHOD:

The philosophy behind this test method is that as yarn sheet is wrapped or lapped around cylinders one by one, and as yarn is laid without applying any extension to it, there will be no chance for yarn migration from one cylinder to the next. Moreover, if yarn is flattened at nipping points between cylinders, yarn migration will be local i.e. on the cylinder on which it wraps. This is due to yarn flexibility. Therefore, length of yarn interlacing with cylinders will not be affected by yarn flattening if it occurred.

8- VERIFICATION:

To verify the applicability of this test method, a ring-spun cotton yarn of unknown count was tested. Table (2) shows some values of yarn diameter estimated by substituting in equation (5).

Table (2): Some Values of Yarn Diameter Readings
Obtained by Substituting in Equation (5):

First Cylinder Diameter (mm)	First Yarn Weight (mg)	Second Cylinder Diameter (mm)	Second Yarn Weight (mg)	Estimated Yarn Diameter (mm)
10	134.8	4	55.1	0.1481
10	133.8	4	54.8	0.1620
10	135.2	4	55.0	0.1147
10	134.8	4	55.4	0.1864
10	133.8	4	55.0	0.1878
10	133.8	8	107.5	0.1749
10	138.0	12	165.2	0.1470
4	56.3	10	137.5	0.1601
4	55.9	12	164.9	0.1027
10	138.0	12	165.2	0.1470
4	55.9	12	164.4	0.1216
8	110.4	4	56.3	0.1627
12	164.6	4	55.9	0.1141
12	165.4	8	110.9	0.1394
12	164.4	8	110.4	0.1777
8	108.5	4	55.4	0.1732

9- CONCLUSION:

By using *EYDM* (Estimated Yarn Diameter Meter), yarn diameter can be determined without measuring yarn count. The presented method generates a great number of diameter readings from a small number of tests. This method avoids compressing the yarn, measuring yarn length, and subjective judgment with respect to determining yarn boundaries. The accuracy is relatively high. Yarn can, by this method, be dealt with as any engineering material. Determining yarn diameter in such an accurate manner helps avoid mistakes in machine adjustments and consequently improve production quality.

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