Determination of Cotton Fineness
By an Air Flow Method

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ABSTRACT

Of all the physical properties of cotton, the fineness constitutes a property which arouses particular concern to spinners. Unlike, for example, fibre length, which is subject to a little effect of environmental conditions, the fineness of cotton is susceptible to many influences of environmental circumstances, e.g. temperature, relative humidity, maturity and particularly the amount of cotton irrigation water.

Cotton, grown as a rain crop, can be more prone to immaturity than the cotton grown by artificial irrigation. Such immature cotton is weak and must be spun at a higher twist. This lowers the spinning production, since the production of this machine is inversely proportional to the amount of twist. This is a negative factor for production economy. This paper repre-sents a research work on fineness measurements of many cotton samples from a variety of countries, using the Micronaire as a testing appliance for fineness measurements. Factors affecting fineness are discussed and mathematical relationships of some important parameters are highlighted.

INTRODUCTION

This paper presents cotton fineness measurements by use of the Sheffield Micronaire fineness tester. Cotton samples from different countries were tested. Cotton, as a natural product, is subject to quality fluctuations which exist from cotton bale to another, even from a layer of the bale to another.

It has been, for a long time, the tradition in the local ginning factories to sort the cotton into lots of 300 bales. This is no more convincing to international cotton markets and spinners. The modern trend is to treat each bale as a separate entity. This has constituted a heavy burden on cotton testing laboratories, but the continuous innovations of the cotton testing appliances have tremendously facilitated the cotton testing procedures. The High Volume Instrument (HVI), for example, is today a powerful testing instrument, in which a variety of cotton tests can be made, which were earlier made on a number of different separate appliances.

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الخلاصة

من كل الخواص الفيزيائية للقطن فإن النعومة هي الخاصية التي تثير اهتمام الغزال. فخلافاً لخاصية طول التيلة مثلاً التي لا تتأثر كثيراً بالعوامل البيئية فإن النعومة عرضة لمثل هذه التأثيرات فيتأثر نضج الشعيرات بكمية مياه الري . فالقطن الذي يزرع مطرياً عرضة لعدم النضج أكثر من القطن المروى صناعياً

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مثل هذا القطن قليل المتانة ويجب أن يغزل بمستوى عالٍ من البرم مما يحد من إنتاج ماكينة الغزل لأن إنتاجها يتناسب عكسياً مع مقدار البرم وبالتالي فإن هذا يضر بإقتصاديات الإنتاج.

هذه الورقة تمثل بحثاً في قياسات النعومة للأقطان من أقطار عديدة باستخدام جهاز الميكرونير لقياس النعومة. ولقد نوقشت العوامل التي تؤثر على نعومة القطن كما سلط الضوء على علاقات رياضية لبعض المَعْلَمات الهامة.

, as it defines the fineness of cotton. However this property, as stated above, is affected by different factors, some of which are briefly discussed prior to the analysis of the test results.

Some local authorities estimate a national loss of twenty five million dollars per year in cotton sales as a result of bad cotton preparation and discounted cotton quality as defined by its physical properties, most important of which is the property of fineness. It is only possible by exerting great national efforts to reinstate the Sudanese cotton to its previous glory.

MATERIALS AND METHODS

In this research work fineness measurements of 35 cotton samples from different countries were conducted by the author using the Sheffield Micro-naire fineness tester which is sketched in Fig.1. Following this instrument other instruments were produced later, e.g. the Shirley Fineness Maturity Tester (FMT), developed in Britain, which has the advantage of measuring both cotton fineness and maturity. The HV1, the latest develop-ment, has superseded both the FMT and the Micronaire tester.

1.1. Mode of Operation of the Micronaire

The measuring principle of the Micronaire is by an air flow method. A cotton fibre sample weighing 3.24 ± 0.006 g is put in the fibre compression chamber 5 (Fig-1). Air flows through the instrument via a reduction valve 1 with a pressure of 25 pounds per square inch (psi, equiv. to 1.75 kg /cm2) read on the pressure gauge 2, being from a pressure supply with 8kg/cm2

The base of chamber 5 and the fibre compression piston 12 are perforated in such a way that these perforations offer no resistance to the air flow, only the fibre sample offers such a resistance.

3 and 4 are calibration elements used for cotton testing. Elements 3' and 4' are used for wool. By placing 3 and 4 in chamber 5 and actuating a foot pedal the swimmer 7 should assume the positions 2.8 and 6.2 respectively in the Micronaire scale. The screw 6 is used for the fine adjustment of these calibration points.

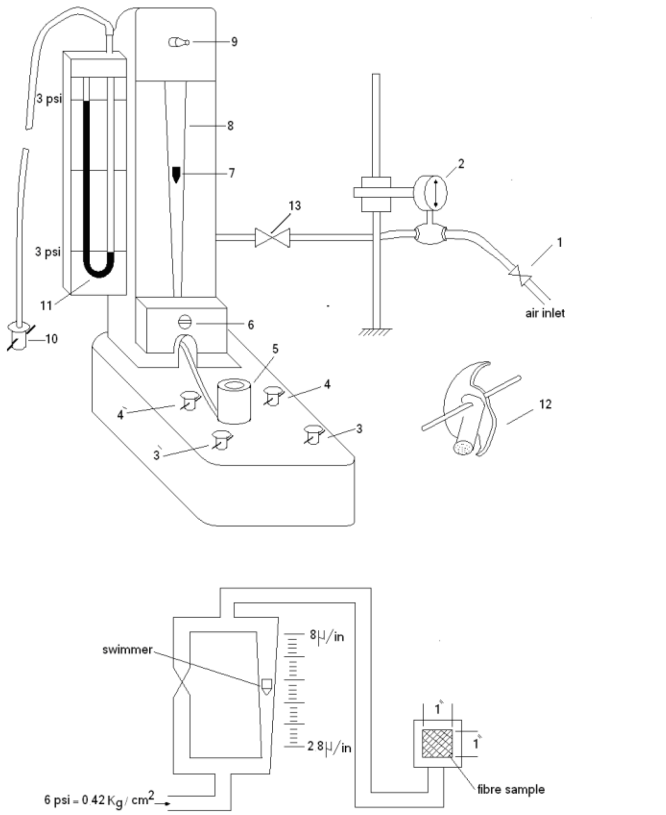

Fig.1: Micronaire Fineness Tester

Knob 9 serves to control the swimmer motion such that it performs a rotational movement and a linear motion inside the conical glass tube 8 without touching the glass wall.

A pressure differential in the fibre chamber 5 is adjusted exactly at 6 psi by the pressure regulator 13 by pressing the foot pedal several times until the pressure of 6 psi is maintained. After maintaining the calibration points 2.8 and 6.2 the pressure differential of 6.psi shall be checked again by placing the plunger 10 in the compression chamber 5.

All these steps being satisfied the cotton sample can be placed in chamber 5, the fiber compression piston is pressed in the chamber, the foot pedal is actuated and the swimmer position represents the Micronaire Value read on the scale of the conical glass tube.

1.2 Empirical rating of cotton fineness

Generally the cotton fineness, as measured by the Micronaire Value, is rated as follows:

Micronaire Value µg/in	Rating of Cotton
3 – 3.9	fine
4 - 4.9	medium fine

5- 8	coarse and very coarse cotton

Micronaire values have been determined (Abdelmageed, 2005) by use of a FMT for a cotton fibre weight of 4 g applying low and high pressure for different readings . He rated the fineness and the micronaire values as well as the cotton maturity as follows:

Degree of fineness	**Micronaire Value µg/in**
Fine fibres	≤ 3.5
Medium fine fibres	4 - 5
Coarse fibres	≥ 5.0

Furthermore he rated the cotton maturity, as given by the maturity ratio MR, as follows:

Maturity ratio MR	**Maturity rating**
≥ 0.95	Excellent
0.85	Very good maturity
0.75	Average maturity
0.65	Poor maturity

The Micronaire Value MV, an American system, ranges between 2.8- 8 µg/in. It simply means the weight in µg (10^{-6} g) of a fiber one inch long and it represents in actual fact the linear density of the fibre. Linear density of fibres or yarns is given by weight per unit length. In the English system the fibre linear density is given by fibre weight 10^{-8} g per cm and is denoted by H.

Normally fine fibres have lower Micronaire values than coarser fibres, the fibre mass being constant for both and for all tested cotton samples weighing 3.24 ± 0.006 g. This is because fine fibres, for a given mass, have a larger specific surface area SSA, which offers a greater resistance to the air flow through the fibres and hence the swimmer is lifted a lower position in the conical glass tube.

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1.3 Maturity Test

The cotton maturity test is made by the Causticaire method. A cotton sample is impregnated in a solution of caustic soda with a concentration of 18%. The histology of the fibres is determined by use of a microscope.

The maturity ratio MR is calculated from the following relationship (Lord, E., 1956):

MR = [(N – D) / 200] + O.7

Where N denotes normal mature fibres which appear round in the microscopic test, while D represents dead fibres whose wall thickening is less than 2O % of the fibre diameter. The standard values for a mature cotton fibre are 67 % and 7 % for N and D respectively, giving a maturity ratio of unity. However it is not a general practice to run a causticaire test in a spinning factory.

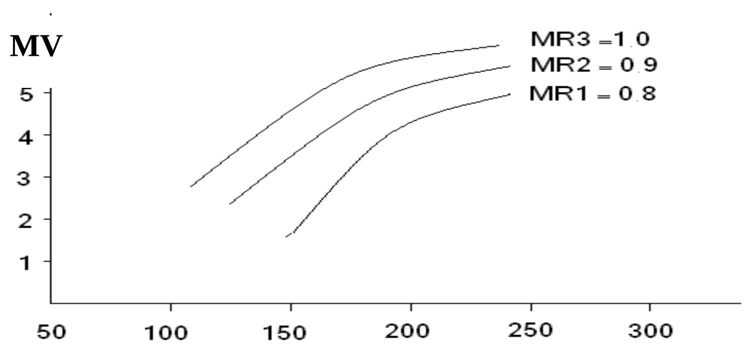
It is therefore advised that spinners may resort to another alternative, since the causticaire test is admittedly difficult to be made in the testing laboratories of spinning mills with all the testing equipment being based on mechanical principles. This alternative maybe by the use of the Pressley tester or the Stelometer for measuring the fibre strength , since the fibre strength is also a parameter which has a strong say in cotton maturity, since immature cottons are notoriously famous for low strength. This is, in a sense, a great help to spinners, but it is not claimed that a maturity ratio can be computed from such a mechanical test.

2. Factors Affecting Fibre Fineness

2.1 Effect of fibre maturity on the Micronaire Value

Mature cotton fibres, for a given fibre weight per unit length, have generally a higher MV than immature fibres. Fig.2 shows different maturity ratios MR3 > MR2 > MR1 for three cotton samples all with an equal fibre weight per unit length, say 200 x 10^{-8} g/cm. The corresponding MVs are MV3 > MV2 > MV1.

If, for example, MR3 = 1, this cotton represents the most suitable cotton with the desired fineness based on a maturity ratio of unity.



$^{-8}$ glcm H Fibre weight 10

Fig.2: Relationship between Micronaire Value MV and fibre weight for different levels of maturity**.**

Analysis of Fig.2

The following can be inferred from the analysis of Fig.2. The object is to come to specific conclusions and suggestions for the benefit of the cotton spinners

1. In spite of the equality of the linear density, for example H = 200 x 10^{-8} g/cm for the three cotton samples, yet each sample has a Different MV, which itself, like H, represents a linear density, as Explained earlier. This means that a given fibre fineness, as given by H, Cannot be expressed by a single MV.
2. The relation between MV and H can be determined mathematically From their units 10^{-8}g/cm and 10^{-6}g/in for H and MV respectively as Follows:
    a. Multiply H by 2.54 to get the weight per inch.
    b. Multiply the weight 10^{-8} g by 10^{6} to get the weight in µg.
    c. Thus for H =200x 10^{-8}g/cm, it follows:

MV = 2.54 x 200 x 10^{-8} x 10^{6} = 5.08 µg/in.

Thus the general relationship, to convert H to MV, shall be:

MV = 2.54 x H x 10^{-2}µg/in

3. It therefore looks odd, from Fig.4, that for a single value H = 200 x 10^{-8} g/cm three MVs – MV3, MV2, MV1, are obtained, which Stands in contradiction with 2. c. above. The reason resides in the Effect of maturity.
4. It can therefore be deduced that a given H and consequently a MV Are both values which include a latent property, namely the fibre? Maturity.
5. It is therefore logical to say that a MV, as a measure of fineness, Should be considered with reservations, as it may include a Concealed immaturity of the fibres, a matter which can be Detrimental to the spinning performance.
6. However the British system, defining the fibre linear density in Terms of H, categorically differentiates between H =f (MR) and Hs, the standard linear density of fibres of a maturity ratio of unity, By the following relationship:

H = MR x Hs

7. The mathematical relationship in 2.c above, giving the MV in terms of H, can therefore be misleading, if a MV, free of immaturity, is desired.
8. It can be concluded that fineness determination by the MV should be considered with caution. The normal practice in the industry of taking the MV on its own as indicative of cotton fineness, is however, acceptable provided the measured MVs follow the empirically established rating stated in 3 earlier. However if MVs, say, 2.9 and 3.6 µg/in are measured for Barakat and Acala cottons, respectively, then a strong belief exists that both cottons are immature, since the measurements are not in the empirically accepted ranges. A maturity test can, therefore, be made in case level of maturity is to be determined.

2.2 Concept of Specific Surface Area SSA

Fig.3 (Abu Salma, 2001) shows an example of a cylinder A with a diameter d of 5 cm and a length L of 10 cm and a SSA (π dl) of 157 cm^2 and a volume ($\pi r^2 L$) of 196 cm^3. Two cylinders B are made from the entire mass of cylinder A, each with a volume of 98 cm^3, a diameter of 3.5 cm and both have a SSA of 220cm^2. If three and ten cylinders are made from cylinder A their SSAs shall be 272 and 496 cm^2 respectively.

Likewise if two cotton samples A and B have the same weight, and if A is coarser than B, it shall have a fewer number of fibres with a smaller SSA while the finer cotton B shall have a greater number of fibres with a larger SSA.

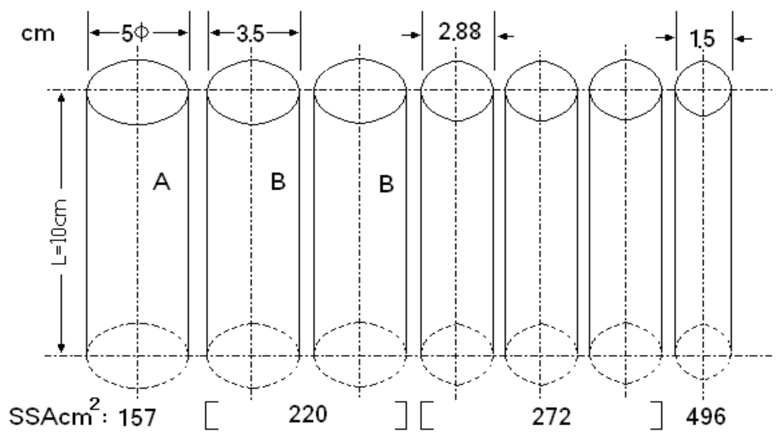
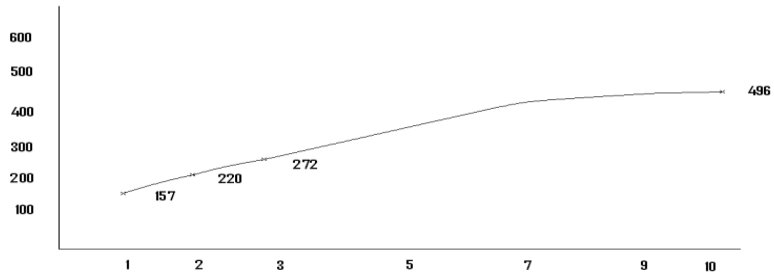


Fig3: Specific surface areas of cylinders made from a given Cylinder

This may be visualized in Fig 4 below:



Number of cylinders

Fig.4: Graphical representation of specific surface areas (cm^2) of cylinders made from a given cylinder

2.3 Effect of rainfall on the Micronaire Value

This relationship has been investigated for eleven cotton growing loca-tions, harvest 1955/56, Fig.5, (Wilhelm & Fleishle, 1957.) The loca-tions Texas, California and Arizona are exceptional cases because of intensive artificial irrigation applied in these areas. It can easily be observed that the decreasing amount of rainfall causes a declining trend of the Micronaire Values, due to reasons of insufficient maturity.

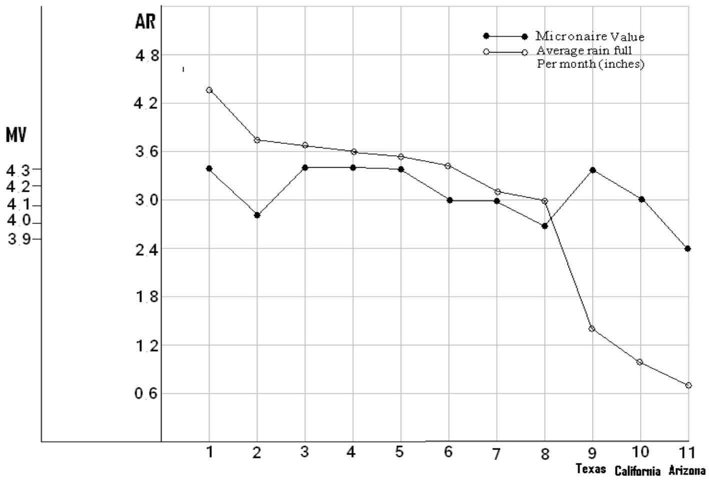


Fig.5: Relationship between the Micronaire Value MV (µg/in) and the Amount of Rainfall AR (inch)

3. RESULTS AND DISCUSSION

3.1 Experimental Results

From experimental measurements of 35 cotton samples only 22 measure Ments are quoted in Table 1. The samples were subjected to the correct atmospheric conditions prior to being tested. The Micronaire was calibrated thoroughly, by the steps indicated in 1.1 to guarantee the accuracy of the recorded Micronaire Values.

Two laboratory samples I and II were tested and two measurements were made for each test sample.

Table 1: Test Results of Cotton Fineness

Ser. No.	Measurement µg/in	MV_1	MV_2	MV_3	MV_4	Average MV µg/in
	Test Sample / Laboratory sample	I		II		
1	USACalifornia gm.st.c 1 1/16 in	5.20	5.30	5.30	5.20	5.25
2	Mexico Metamoros strm. st.c. 1 1/32 in	4.65	4.65	4.65	4.72	4.67
3	North Brasil st.II strm.teils v.1.sp 11/32 in	3.70	3.70	3.80	3.82	3.76
4	Guatemala strm. 1 1/16 in	4.15	4.10	4.20	4.10	4.14
5	Turkey , Izmir st. 111 1 1/16 in	3.85	3.90	3.85	3.80	3.85

6	Peru , Pima 1 9/16 in	3.30	3.30	3.30	3.28	3.30
7	India, Bengal	8.00	8.00	8.00	8.00	8.00
8	Syira 1 3/32 in	4.85	4.90	4.90	4.80	4.86
9	Iran Coukers 1 3/32 in	4.78	4.80	4.70	4.70	4.75
10	USSR , Pervys 3 2 /32 in	5.20	5.20	5.20	5.18	5.20
11	Nicaragua 1 1/16 in	4.65	4.55	4.66	4.68	4.64
12	Columbia bystrm 1 1/32 in	4.40	4.25	3.30	4.35	4.33
13	Greece 1 5/32 in	4.30	4.30	4.25	4.30	4.29
14	Spain, bystrm. 1 1/16 in	4.50	4.60	4.70	4.60	4.60
15	Pakistan	5.16	5.00	5.10	4.95	5.05
16	Argentin ca. bystrm. 1 1/32 in	3.15	3.15	3.10	3.20	3.15
17	Tanganika strm.v.1.sp. 1 1/16 in	4.20	4.10	4.10	4.15	4.14
18	Sudan ca.strm. 35- 36 mm	4.10	4.10	4.05	4.05	4.08
19	Karnak Fully good 1 1/2 in	3.65	3.60	3.60	3.65	3.63
20	Giza 45 1 3/8 in	3.40	3.40	3.40	3.40	3.40
21	Giza 47 1 1/4 in	4.60	4.58	4.58	4.60	4.59
22	Arizona bylm 1 1/16 in	3.96	4.10	3.96	3.98	4.00

3.2 Analysis of Results and Discussion

3.2.1 General Assessment

It can be observed that the great majority of the test results represent cottons of the American type, similar to the Sudanese Acala cotton, which has a MV of 4-5 µg/in.

″However some exceptional cases may be cited which are rather different from the majority of the samples:

a. Sample 3, North Brasil SII with a MV of 3.75 µg/in, arouses a strong belief of lack of maturity, since the MV is short of the range of 4-5 µg/in which is determined empirically for this type of cotton of medium staple length of 1 1/32″.
b. Likewise cotton sample 5, also an American cotton type, Turkey, Izmir with a MV of 3.85 µg/in, is on the low side of maturity.
c. Sample 16, Argentin, 1 1/32″ with a MV 3.150 µg/in is also clearly lacking maturity.
d. Sample7, India-Bengal, has a strikingly high MV indicating exceptionally very coarse cotton.
e. The two samples of the long staple type, namely Peru-Pima (sample 6) and the cotton Giza 45 (sample 20), with MVs of 3.30 and 3.40 µg/in respectively, are both within the empirically defined range of 3 - 3.9 µg/in and have a similar staple length as the Sudan cotton sample (18), yet the latter has a MV of 4.08 µg/in which slightly exceeds the normal range.

3.2.2 Interpretation of the MV into fibre metric number

The fineness of fibres and yarns is normally given in terms of number. It is either given by a direct numbering system – tex, denier and linear density or by an indirect system- the English or the metric number. The MV is a direct measurement system. Direct systems give fineness in terms of weight per unit length, while indirect systems do that in terms of length per unit weight.

A high MV means a larger fibre diameter by virtue of higher weight, whereas a high metric number indicates a smaller fibre diameter by virtue of greater length for the same weight.

A mathematical relationship between the Micronaire Value MV and the fibre metric number Nmf can be determined as follows:

In Fig.6, the fibre axis is parallel to the x-axis: dx = infinitesimal fibre length, **dW =10^{-6} g** , weight of element.

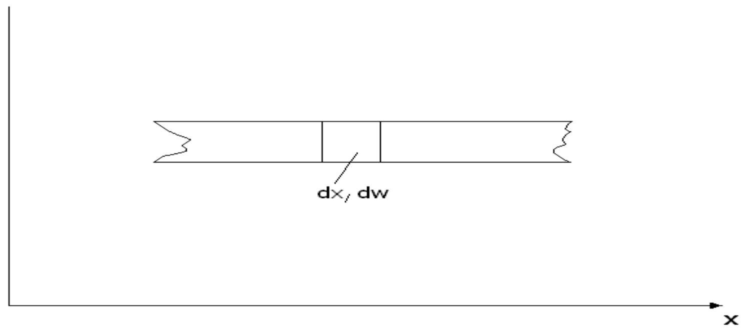


Fig.6: Single fibre

The general equation for fineness, as expressed in terms of fibre or yarn number, for both the English and the metric systems is as follows:

Number = Length /Weight

The following is therefore valid:

Nmf = dx/dW

$$\int_0^L dx = Nmf \int_0^W dW$$

The integration limits L and W are in the Micronaire Value, namely 2.54 cm or 0.0254 m and 10^{-6} g respectively. Assuming a MV of, say, 4 µg/in, the weight is $4x10^{-6}$ g, thus

$$\int_0^{0.0254\,m} dx = Nmf \int_0^{4 \times 10^{-6}\,g} dW$$

L = Nmf x W +c

For L = 0, also W = 0, and the integration constant c = 0.

It follows:

0.0254 = Nmf x 4 x 10^{-6} g,

i.e. Nmf = 0.0254 ÷ 4 x10^{-6} g = 25400 ÷ 4 = 6350 m/g,

the general relationship is, however, given as follows :

Nmf = 25400 ÷ MV, i.e. it follows generally:

The fibre metric number = 25400 ÷ Micronaire Value.

The Micronaire Value is therefore a direct measure of the fibre fineness as expressed by the fibre number Nmf. This constitutes the very base for the production of a desired yarn. It is however needless to mention that a reliable computation of fibre metric number by the above equation should always be in terms of a micronaire value free of any immaturity doubt.

CONCLUSION

This research work has been dedicated to the measurements of the fineness of cotton samples from different countries, by use of the Sheffield Micronaire tester, in terms of Micronaire Values MV (µg/in), being a linear density as per the American system.

The relationship between the Micronaire Value MV in (µg/in) and the fibre weight H in g/cm, denoting also a fibre linear density in the English system, has been given mathematically and the effect of fibre maturity highlighted.

Furthermore a mathematical relationship between the fibre metric number Nmf and the Micronaire Value MV has been established. The fibre metric number is the very base for the production of any desired yarn.

However it has been stipulated that, though the Nmf can be computed By a simple relationship from the Micronaire Value MV, yet this has to be based on MV free from any doubts as to the fibre maturity. Such doubts can be stirred if the measured MV is not in conformity with the stipulated empirically defined rating, i.e. when it is lower than the bottom level of the range.

Since it is admittedly seldom to make a maturity test in spinning mills, where the testing procedures are based mainly on mechanical principles, spinners are advised to resort to mechanical testing of fibre strength by use of the Telemeter or the Prestley testers. The fibre strength is an indication of fibre maturity.

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هذه الورقة تمثل بحثاً في قياسات النعومة للأقطان من أقطار عديدة باستخدام جهاز الميكرونير لقياس النعومة. ولقد نوقشت العوامل التي تؤثر على نعومة القطن كما سلط الضوء على علاقات رياضية لبعض المَعْلَمات الهامة.