PHYSICAL PARAMETERS TO DESCRIBE THE TIGHTNESS OF TEXTILE STRUCTURES

Part I. Knitted Structures

By

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ABSTRACT

The tightness of 1x1 rib, half cardigan and full cardigan structures could be expressed in terms of the physical parameters packing density coefficient Ø, hardness (H) and compression energy coefficient (b). These parameters are well related to structure tightness factor (TF), while Ø and H tend to increase with the increase of tightness factor, b tends to decrease. The packing density coefficient Ø is well related to tightness factor by a relationship in the form of; $Ø = K' (TF)^2$, where K' is a constant for each structure. The product of hardness and compression energy coefficient for all structures is constant, i.e. Hb = 435, and the relative tightness represented by Ø for 1x1 rib, half cardigan and full cardigan structures is 1:0.685:0.612 respectively.

1. INTRODUCTION

The purpose of the present work is to find physical parameters that could be used in describing the degree of tightness /or compactness of weft knitted structures. Also to find common parameters that could be used for comparing the tightness of various textile structures relative to knitted structures.

For weft knitted fabrics, the terms cover factor, or tightness are alternatively used to specify the degree of tightness or openness of the structure. Earlier and for practical purposes the tightness has been expressed as $1/l \sqrt{N}$ (where l is the loop length and N the indirect yarn count). In fact this expression and because of the number of assumptions and omissions, cannot be regarded as representing "the fractional area occupied by the knitted loop". But from the practical point of view the formula $1/l \sqrt{N}$ is easily calculated and has considerable potential on the factory floor, and generally it should not be described as a measure of cover[1].

Postle[2] proposed the use of the term "tightness factor" to describe such a formula, and this recommendation will be considered here, although we prefer to use the term Structural tightness factor (STF) proposed by Knapton[2], especially when dealing with complex weft knitted structures such as half cardigan and full cardigan.

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An alternative formula in the form of; $\sqrt{Tex}/l$ was also introduced[1], where tex is the linear density of the yarn and l is the loop lenth in metric units. However these methods for expressing tightness produce scales of measurment which overlap and this could cause confusion. For example Knapton[2] defined the structural tightness factor (STF) as:

$$STF = \frac{K_s \sqrt{N}}{SCSL} \qquad \ldots\ldots(1)$$

Where SCSL is the structural-cell stitch length, K_s is the structural-cell stitch density and N is the yarn linear density in tex.

However these different definitions for tightness do not a lter the ranking of fabrics when the stitch density constant (K_s) is compared for different fabrics. In the absence of a single definition for tightness(since the above definitions have been used for either a "practical" or an "academic reasons), we have used the simple formula for calculating the tightness factor (TF) for all structures; i.e..

$$TF = \sqrt{Tex}\ /l \qquad \ldots\ldots(2)$$

Where l is the average loop length in the repeat unit in Cms.

In addition to the above, other parameters have been mentioned in the literature of textiles and used to express the degree of compactness of the textile structure, such as packing density coefficient (Ø), and hardness (H). These physical parameters have not been examined in details especially for knitted fabrics. In the present work these parameters have been adopted for knitted structures and examined for 1x1 rib, half cardigan and full cardigan structures.

2. Specifications of Fabrics

The fabrics used in the present work are namely 1x1 rib, half cardigan and full cardigan, all knitted from acrylic yarn (Various number of ends were used to alter the count), and left to relax in air for 72 hours, before being measured for loop length, stitch density, mass/unit area and thickness.

3. Thickness-Pressure Relationship

Since the calculation of packing density coefficient, and fabric hardness necessitates the determination of fabric thickness, hence it was necessary to determine first the pressure at which thickness should be measured. To find this for the 22 fabric of the present work, thickness was measured at pressure ranges between 0.20 and 104.2 g/cm^2. A relationship in the form of;

$$t = a + b/p+c \qquad .....(3)$$

was found suitable[3] to relate the thickness (t) to the pressure "p" where a is the thickness measured at $104.2 g/cm^2$, "c" is a correction for the pressure, and "b" is a constant. Over the range of pressure used b was approximately constant at pressures ranging between 0.20 and $1.2 g/cm^2$ for majority of fabrics. Also over this range the difference (%) between thickness at any pressure and that measured at $0.2 g/cm^2$ was not more than 5%, (i.e. within the permissible experimental error). Hence b could be obtained directly at $P = 0.6 g/cm^2$, since the average b-value obtained is very close to that calculated at this pressure. The value of b at $0.6 g/cm^2$ ($t_{0.6}$) was used for calculating packing density coefficient (Ø) and hardness (H). This is more logic since the thickness used in the packing density coefficient equation should be measured actually at Zero pressure, but because of the practical difficulty of this, the choice of the pressure at which thickness is measured, was arbitrary, but as low as possible and within the lowest pressure provided by the thickness meter used.

4. Relationship between Tightness Factor, Packing Density Coefficient and Fabric Hardness

The packing density coefficient (Ø) is calculated from the equation:

$$\emptyset = M/\rho t \times 10^{-3} \qquad .....(4)$$

Where M is the mass/unit area (g/m^2), ρ is fibre density(g/cm^3) and t is fabric thickness (mm). The thickness used in this equation is measured at pressure = $0.60 g/cm^2$.

Fabric hardness (H) is calculated from the equation:

$$H = P_2 - P_1/t_1 - t_2 \; g/cm^2/mm \qquad .....(5)$$

Where $P_1 = 0.6 g/cm^2$, and $P_2 = 104.2 g/cm^2$ (the maximum pressure available in the thickness-tester using a foot of $50 cm^2$), and t_1 and t_2 are the thickness measured at these pressures respectively. The definition of hardness and the above hardness equation has been originally proposed by Pierce[4] for woven fabrics.

Plotted in Figs. 1 and 2 the values of packing density coefficient (Ø) and hardness (H) versus tightness factor (TF) respectively for 1x1 rib, half cardigan and full cardigan. It is evident from the plots that both Ø and H tend to increase with tightness factor, and that 1x1 rib shows the highest packing density coefficient and hardness compared with that of half and full cardigan structures. These results show that the introduction of tuck loops in the knit-cell reduces the packing of stitches within the knit-cell, and hence leads to a reduction in hardness. One has to remember that both half and full cardigan structures are originally based on 1x1 rib structure.

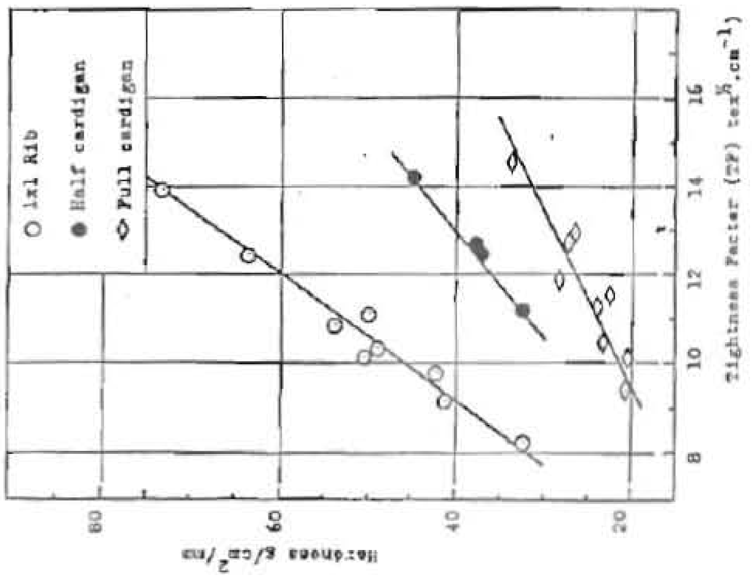

Fig.2 Hardness Versus Tightness Factor

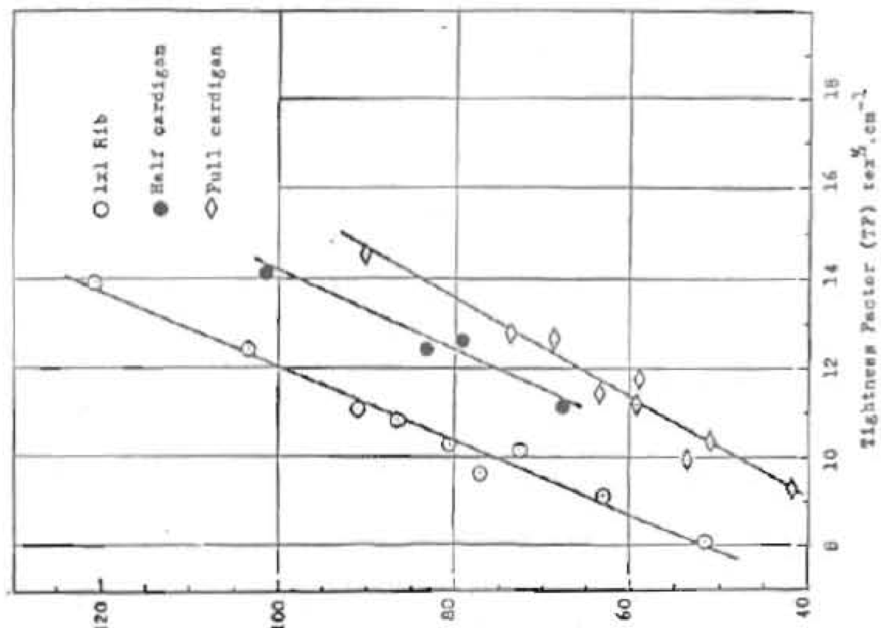

Fig.1 Packing Density Coefficient Versus Tightness Factor (TF)

Given in Table 1 the range of tightness factor (TF), packing density coefficient (Ø) and hardness (H) for various structures.

Table 1: Range of TF, Ø and H Values for 1x1 Rib, Half Cardigan and Full Cardigan.

Structure	Range of TF ($tex^{\frac{1}{2}}. cm^{-1}$)	Range of $Ø \times 10^3$ (dimensionless)	Range of H ($g/cm^2/mm$)
1x1 Rib	8.11-13.91	52.4-121.2	32.5-72.9
Half Cardigan	11.80-14.14	68.3-101.7	32.4-45.0
Full Cardigan	9.23-14.50	42.5- 90.9	20.9-33.9

5. Theoritical Relationship between Packing Density Coefficient (Ø) and Tightness Factor (TF)

The equation of packing density coefficient; i.e.

$$Ø = M/\rho t \times 10^{-3} \qquad .....(6)$$

Could be rearranged and re-written in terms of knitted fabric geometry. It was possible to prove[5] that for any weft knitted structure the mass/unit area (M) could be written as:

$$M = \frac{K_s . Tex}{10\ l} \ g/m^2 \qquad .....(7)$$

Where l is the loop length, tex is the linear density of the yarn, and K_s is the stitch density constant. In the present work the value of K_s was obtained from finding the relationship between the stitch density (S) and loop length (l), i.e. ($K_s = S.l^2$).

Hence equ. 6 becomes;

$$Ø = \frac{K_s . Tex}{10 \rho\ l\ t} \times 10^{-3} \qquad .....(8)$$

but since $TF = \sqrt{Tex}\ /l$

then equ. 8 becomes;

$$Ø = \frac{K_s .(TF). \sqrt{Tex}}{10\ \rho\ t} \times 10^{-3} \qquad .....(9)$$

This equation shows that $\emptyset$ will be a function of the tightness factor (TF), if the parameter $\sqrt{Tex}/t$ is constant for any particular weft knitted structure, since K_s and ρ are also constants for any structure knitted from a particular type of yarn. To prove this point the values of $\sqrt{T}/t$ were plotted versus tightness factor (Fig. 3), and was interesting to find that the relationship is linear and passing through the origin, hence we can write equ. 9 as:-

$$\emptyset' = \frac{K_s . K' \ (TF)^2}{10\ \rho} \times 10^{-3} \qquad .....(10)$$

Where K'is the slope of the line for each structure. Then from the knowledge of K_s, K'and ρ , the equation of packing density coefficient and tightness factor for acrylic knitted strutures in the dry state could be written as:-

For 1x1 Rib; $\emptyset = 0.759\ (TF)^2$ .....(11)

For Half Cardigan; $\emptyset = 0.520\ (TF)^2$ .....(12)

For Full Cardigan; $\emptyset = 0.465\ (TF)^2$ .....(13)

From these equations it is evident that the relative packing density coefficient (or tightness) at equal tightness factor, will be 1:0.685:0.612 for 1x1 rib, half cardigan and full cardigan structures respectively.

Plotted in Fig. 4 the values of $\emptyset$ as obtained from equs. 6 and 10 respectively. The correlation coefficient r = 0.988 and highly significant at the 5% level.

6. Relationship between the Compression Parameter "b", Tightness Factor (TF) and Hardness (H)

Plotted in Fig. 5 the values of b versus tightness factor for 1x1 rib, half cardigan and full cardigan. It is evident from the plot that b tends to decrease with the increase of tightness factor. This relationship is the reverse of that found between hardness and tightness factor for the same structures. According to the definition of b, it represents the energy absorbed in compression, hence one would expect this value to be low for hard to press structures and vice-versa. This is more clear from Fig. 6 in which the values of b are plotted versus hardness for all structures. Also it is interesting to find that the product of hardness (H) and compression energy parameter b is always constant irrespective of the structure, i.e. Hb ≃ 435. This result could be proved from the original definitions of H and b as follows:

Since $$H = \frac{P_{104.2} - P_{0.6}}{t_{0.6} - t_{104.2}}\ g/cm^2/mm \qquad .....(14)$$

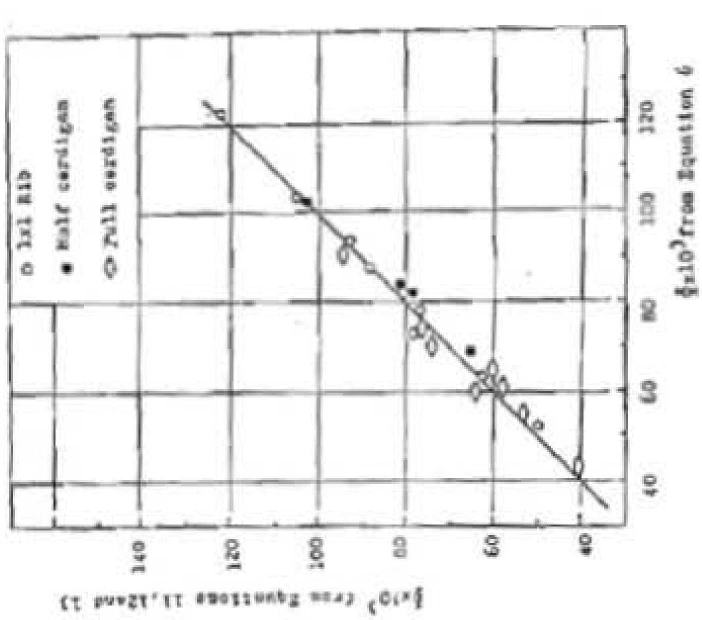

Fig.4 Values of ξ obtained from Equation 6 Versus Values obtained from Equations 11,12 and 13

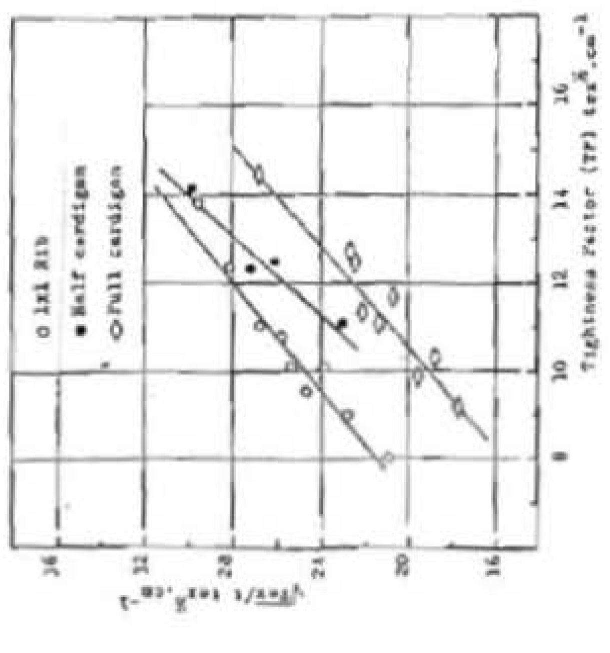

Fig.3 Values of the Parameter √Tex/t Versus Tightness Factor

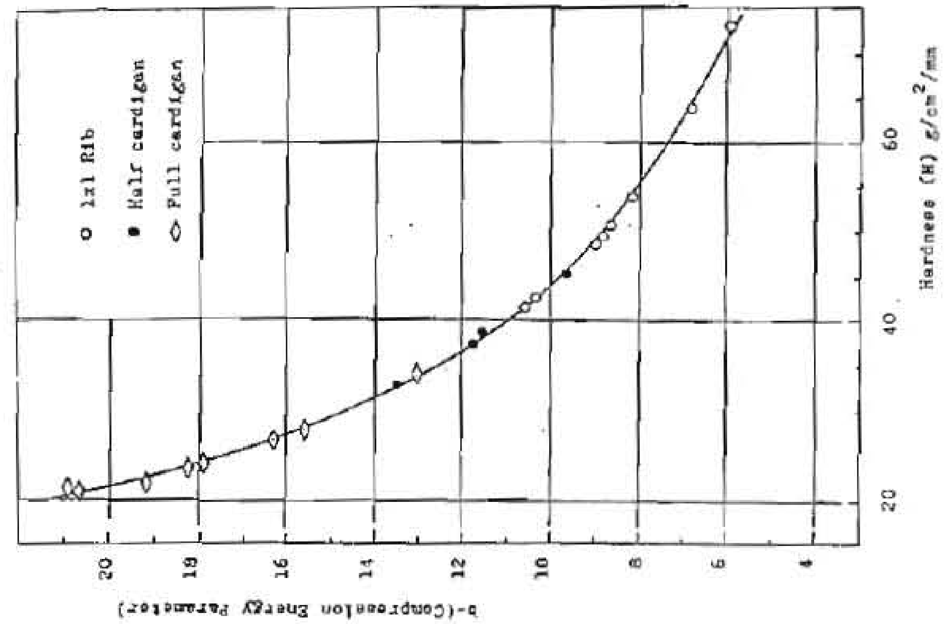

Fig.6 Compression Energy Parameter Versus Hardness

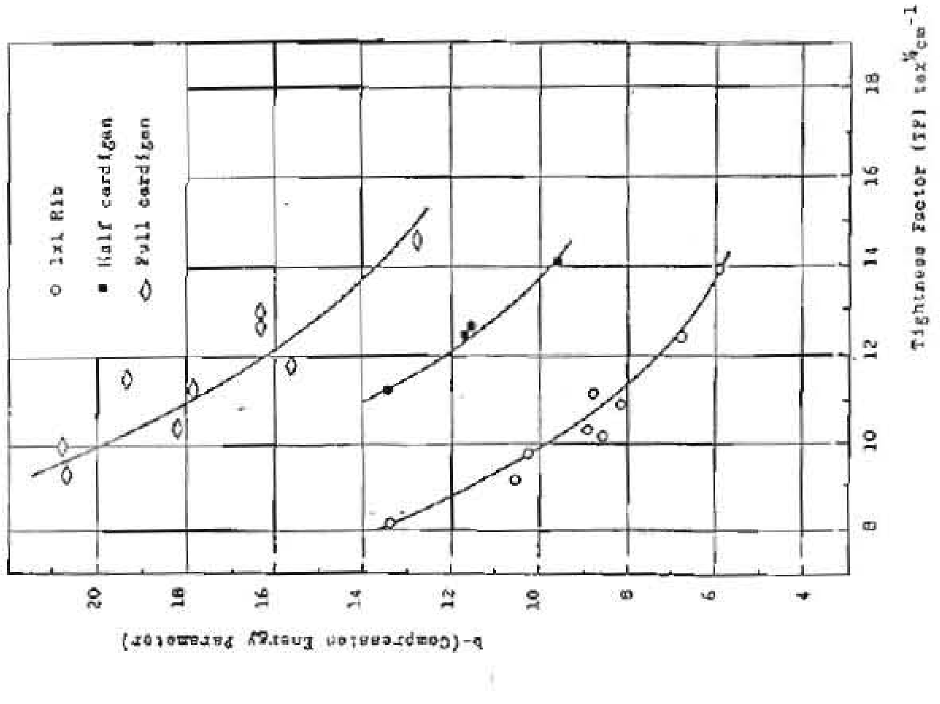

Fig.5 Compression Energy Parameter (b) Versus Tightness Factor (TF)

and $b = (t_{0.6} - t_{104.2})(P + C)$ .....(15)

(the thickness "t" is measured at pressures P = 0.60, and 104.2 g/cm^2)

then equ. 14 could be written as;

$$H = \frac{104.2 - 0.6}{b/(P + C)} \quad .....(16)$$

The value of (P + C) as determined from the thickness-pressure relationship is equal to 4.2 g/cm^2, then equ. 16 becomes: $Hb \approx 435$ .....(17)

For the range of the extreme pressure values used in the experiment.

7. General Discussion and Conclusions

It is evident from the results obtained that the tightness of 1x1 rib, half cardigan and full cardigan structures could be expressed in terms of the physical parameters, packing density coefficient (Ø), hardness (H) and compression energy coefficient (b) instead of the classical tightness factor, since these parameters are well correlated to tightness factor. These parameters could now remove the confusion arising from the lack of a real definition of tightness of knitted structure, since in all the attempts made for this purpose, investigators[2] were looking for any arbitrary number indicating a point on an arbitrary scale of values that allow judgement to be made about the relative compactness or openness of a structure when knitted. It is known that to produce an expression for true loop cover, it is necessary to consider; a) the projected length of yarn per stitch rather than the actual length; b) the effect of yarn overlap in the structure, and c) the true yarn diameter in the fabric at the various parts of the loop[2].

For 1x1 rib, half cardigan and full cardigan structures the following conclusions are found:-

1) Packing density coefficient and hardness tend to increase with the increase of tightness factor.

2) The compression energy coefficient "b" tends to decrease with the increase of hardness, and the product of hardness and compression energy coefficient is constant irrespective of the structure, i.e. Hb = 435.

3) The packing density coefficient (Ø) is well related to tightness factor (TF), by a relationship in the form of;

$$Ø = K' (TF)^2$$

Where K' is a constant that depends on the structure.

4) The parameters Ø, H and b could be used equally to describe the tightness of the knitted structure.

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