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Deformation by one-dimensional loading of woven fabric

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ABSTRACT

The target of this current work was to examine of deformation behaviour of structures of woven fabrics after mechanical loading. The study concerns various fabric structures made from same yarns of polypropylene of weave structures of plain with different setts of weft and same setts of warp. In order to measure the mechanical properties of fabric objectively, testometric tensile tester is used to determine longitudinal and transversal deformation of fabric as the material under axial tension elongates in length which affects the geometrical properties and parameters of fabrics like crimp and diameter respectively. Strain increases in the loading direction and decreases in the transverse direction. Poisson's ratio is used for the analysis of the structure of fabrics subjected to deforming loads, and analysis of the property of fabrics with respect to the basic parameters of fibres and yarns. The statistical regression method was used for evaluation of the results. The relationship between Poisson‘s ratio and strain shows that Poisson's ratio decreases fast in the beginning and slowly towards the end. For all the fabrics elongated in warp and weft direction the results, show that for fabric with higher setts, higher contraction ratio is observed in the beginning and decreases at a higher speed and the fabric with lower sett has lower Poisson's ratio and decreases at a lower rate, reason being, for higher weft setts the yarns are more compressed than in small weft setts. After stretching, highest sett of warp or so called limit setts of warp occurred. In the case of limit setts of warp the bows of weft yarn are mutually connected (border), so that the length is close to zero. There is no model which describes decreasing tendency and the convex shape parameters of curves. They can be described according to the hypothetical structure of Pierce model, assuming that the yarn in the fabric are totally flexible but non deformable transversally. In reality the yarn in the fabric are flexible and extensible.

Key words: Mechanical properties, geometrical properties and parameters, yarn, Poisson's ratio, Pierce's model.

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Chapter 1

1.1 Introduction

The purpose of this study is to analyze deformation behaviour of structures of woven fabrics after mechanical loading and explain found relations by structural rules of Pierce's model. Plain weave fabric produced with 100% polypropylene of ring spun yarn from fibre fineness 17d/tex and Yarn count of 29.5Tex. Four different fabrics having the same setts of warp with different setts of weft was used. Method of specimen preparation of both warp and weft was prepared according to laboratory standard. Specimens were of different setts of warp and wefts loaded axially on a testometric tensile tester in a very controlled manner while the measuring load and elongation of specimen over distance. The measuring method was based on Poisson's ratio. The testometric tensile tester was connected to a camera for capturing of image from starting load until the maximum force at break. Fabric elongated in the direction of warp and weft, follows the geometry of Pierce's model. During elongation of fabric, yarn length elongates themselves at in warp yarns to their breaking elongation and weft yarns to less extend for all setts of fabrics then resultant effective yarn cross-sections have different (smaller) diameter then its initial value, as is known fact that the geometry of fabric changes when subjected to a strain.

Chapter 2

2.1 Literature review

2.1.1 Description of Poisson ratio‘s

Poisson's ratio (***ν***), named after Siméon Poisson, is the ratio, when a sample object is stretched, of the contraction or transverse strain (perpendicular to the applied load), to the extension or axial strain (in the direction of the applied load).When a sample cube of a material is stretched in one direction, it tends to contract (or occasionally, expand) in the other two directions perpendicular to the direction of stretch. Conversely, when a sample of material is compressed in one direction, it tends to expand (or rarely, contract) in the other two directions. This phenomenon is called the Poisson effect. Poisson's ratio ν (nu) is a measure of the Poisson effect. The Poisson's ratio of a stable, isotropic, linear elastic material cannot be less than −1.0 nor greater than 0.5 due to the requirement that the elastic modulus, the shear modulus and bulk modulus have positive values[1]. Most materials have Poisson's ratio values ranging between 0.0 and 0.5. A perfectly incompressible material deformed elastically at small strains would have a Poisson's ratio of exactly 0.5. Most steels and rigid polymers when used within their design limits (before yield) exhibit values of about 0.3, increasing to 0.5 for post-yield deformation (which occurs largely at constant volume.) Rubber has a Poisson' ratio of nearly 0.5. Cork's Poisson's ratio is close to 0: showing very little lateral expansion when compressed. Some materials, mostly polymer foams, have a negative Poisson's ratio; if these auxetic materials are stretched in one direction, they become thicker in perpendicular directions. Anisotropic materials can have Poisson ratios above 0.5 in some directions. [1]

Assuming that the material is compressed along the axial direction:

$$\nu = -\frac{\varepsilon_{\mathrm{trans}}}{\varepsilon_{\mathrm{axial}}} = -\frac{\varepsilon_{\mathrm{x}}}{\varepsilon_{\mathrm{y}}} \qquad (1)$$

Where:

ν is the resulting Poisson's ratio,

$\varepsilon_{\mathrm{trans}}$is transverse strain (negative for axial tension, positive for axial compression)

$\varepsilon_{\mathrm{axial}}$is axial strain (positive for axial tension, negative for axial compression).

The changing of width

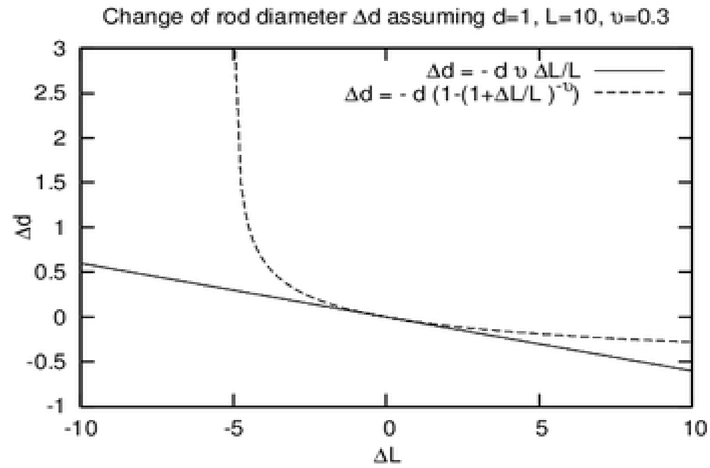

Figure 2-1: Comparison between the two formulas, one

for small deformations, and another for large deformations [1]

If a rod with diameter (or width, or thickness) *d* and length *L* is subject to tension so that its length will change by *ΔL* then its diameter *d* will change by:

$$\Delta d = -d \cdot \nu \frac{\Delta L}{L}$$

The above formula is true only in the case of small deformations; if deformations are large then the following (more precise) formula can be used:

$$\Delta d = -d \cdot \left(1 - \left(1 + \frac{\Delta L}{L}\right)^{-\nu}\right)$$

Where:

d is original diameter

Δ*d* is rod diameter change

ν is Poisson's ratio

L is original length, before stretch

Δ*L* is the change of length.

The value is negative because the diameter will decrease with increasing length.

2.2.2. Weave of a fabric

It is the textile art in which two distinct sets of yarns or threads, called the warp and the filling or weft (older woof), are interlaced with each other to form a fabric or cloth. The warp threads run lengthways of the piece of cloth, and the weft runs across from side to side manner in which the warp and filling threads interlace with each other is known as the weave. The three basic weaves are plain weave, satin weave, and twill [2]

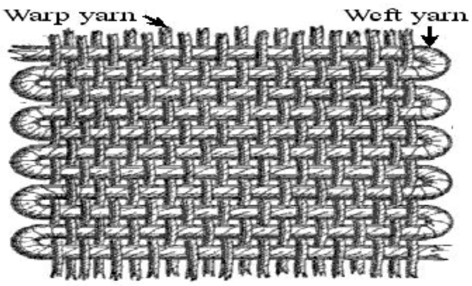

Figure 2-2: Warp and weft in plain weaving [2]

Plain weave is the most basic of three fundamental types of textile weaves It is strong and hard-wearing, used for fashion and furnishing fabrics.

In plain weave, the warp and weft are aligned so they form a simple criss-cross pattern. Each weft thread crosses the warp threads by going over one, then under the next, and so on. The next weft thread goes under the warp threads that its neighbour went over, and vice versa.[2]

- **Balanced plain weaves** are fabrics in which the warp and weft are made of threads of the same weight (size) and the same number of ends per inch as picks per inch

Figure 2.-3: The structure of woven fabric [2]

2.3 Fabric Parameters

It includes setts of threads, yarn diameter, binding of cell in woven fabrics, fabric width, and fabric length

2.3. 1 Yarn diameter

It is classified as basic construction parameter. Yarn diameter is influenced by many parameters .At the fabric geometry analysis as circular yarn diameter is presupposed [3]. The yarn diameter is given by this equation: $D = \sqrt{\frac{4T}{p * \rho}}$ (2)

Where D is the yarn diameter T is the yarn fineness, ρ is the fibre specific density and p is porosity factor

2.3 2 Setts of treads in woven fabrics

Setts of threads characterized for warp and for weft density:

Do [*treads/100mm*].

Du [*treads/100mm*].

The dimension of setts can be in $m^{-1}, cm^{-1}, inch^{-1}$

For evaluation of the fabric structure and weaving process, we use other kind of sett.This setts is expressed on the basic of briefly theory of fabric geometry. We can recognize two types of fabric sett;

a) 100% tight square setts, $D_{ct\max}$ of plain weave as well as the other weaves,

b) The real square sett, D_{ct} ‘for plain weave as well as the other weave,

Comments: For 100% tight square sett warp and weft in the fabric are identical wires with circle diameter form homogeneous material without air space. For description of 100_ tight square sett of plain weave fabric, we can use under mentioned equations:

1 the expression of 100% tight square sett on the basis of mean diameter of yarn in the fabric

$$[pn/100] = \frac{100}{\sqrt{4d_{str}^{2} - d_{str}^{2}}} \tag{3}$$

$D_{ct\max}$ The expression on the basis $D_{0\max} and D_{u\max}$

$$D_{ct\max}\left[pn/100mm\right] = D_{O\max}^{\frac{2}{5}} . D_{u\max}^{\frac{3}{5}} \tag{4}$$

Where:

$$D_{o\max}\left[{}^{pn}\!/_{100mm}\right] = \frac{100}{B_{\min}} = \frac{100}{\sqrt{3 * d_o}} \tag{5}$$

$$D_{u\max}\left[{}^{pn}\!/_{100mm}\right] = \frac{100}{A_{\min}} = \frac{100}{\sqrt{3d_u}} \tag{6}$$

Where D_{omax} is the maximal warp setts in the fabric(theoretical value), D_{umax} is the maximal weft setts in the fabric(theoretical value), A_{min} is the minimal weft distance of picks in the fabric, B_{min} is the minimal distance of ends in the fabric, d_{str} is the mean diameter if yarn fabric which is given by

$\frac{d_0 + d_u}{2}$, d_o is the diameter of warp threads, d_{os} is the substance diameter of warp threads, d_{oef} is the warp effective diameter, d_u is diameter of weft threads, d_{us} is the substance diameter of weft and $d_{ue}f$ ids the effective diameter if weft.

For real square setts of fabric is valid:

$$D_{ct\max}\left[{pn}/{100}\right] = D_{ct\ \max} \cdot \frac{H}{10^2} \tag{7}$$

Where H is the density of the fabric (real value of the fabric density is 55-99.5%)

2.3.3 Binding cell in woven fabrics

a) Distance of the threads in the weave

Binding point –the place crossing of warp and weft yarns

Weave in fabric, can be express on the basis of the pattern repeat. The numbers of interlacing of warp treads, n_o and n_u in weft tread in the pattern repeat gives the pattern repeat gives and number of repeat sections in the binding wave.

b) Distance of the threads in the weave

For warp distance, B and weft distance, A in woven fabrics are given by equations:

$$A[mm] = \frac{1}{D_u}.10^2 \tag{8}$$

$$B[mm] = \frac{1}{D_o}10^2 \tag{9}$$

There are number of warp and weft yarn in a pattern .The number of binding point in a pattern the product of number of warp and weft, according to equation: $v = n_o * n_u$ (9a)

Yarn segment is part of yarn that is connected to two neighbouring binding points. Therefore number of all segments in a pattern repeat is twice that of the binding points, according to equation: $2v = 2n_o * n_u$ (9b)

There are two types of segments that exists namely crossed and non crossed segments. Crossed segments connects warp and weft binding points together, non- crossed connects identical binding points (either warp-warp or weft-weft) together.

Note: Minimum of two cross segment must be on each yarn in the pattern repeated structural unit. Minimum of two yarns in each system (warp and weft) must repeat. Therefore minimum number of crossed segment per one system in repeat is that of crossed segment by two yarns in each system. The maximum number of crossed segment per one system (warp and weft) is represented by all segments in a pattern i.e. for each system by the number of ($v = n_o * n_u$).The number of the crossed segments of warp is z_o and weft z_u lies in the interval $z_o \varepsilon \langle 4, v \rangle$ and $z_u \varepsilon \langle 4, v \rangle$. The total no z of crossed segment in the pattern lies in the interval $z = (z_o + z_u) \varepsilon \langle 8, 2v \rangle$ .The Crossing factor are quotients of crossed segments in relation to number of all segments .Warp and weft crossing factor is given by equation: $\kappa_o = z_o / v \leq 1$ and $\kappa_u = z_u / v \leq 1$ respectively. The crossing factor of fabric is given by equation: κ =number cross segment/total no of all segments: $\kappa_o = z / 2v = (z_o / v + z_u / v) \therefore \kappa = \kappa_o + \kappa_u / 2$.

[Neckář]

2.3. 4 Thread‘s float in the fabric

Using Briefly theory we can express the influence of the on sett of warp and weft threads .Generally, for expression of the real as well as maximal square of fabric are given equations:

$$D_{ct\max}\left[{}^{pn}\!\!\diagup\!{}_{100mm}\right] = D_{ct\max} f^m \qquad (11)$$

$$D_{ct}\left[{}^{pn}\!\!\diagup\!{}_{100mm}\right] = D_{ct\max} f^m \qquad (11a)$$

Where *f* is the factor of threads ś interlacing in woven fabric, *m* is the interlacing exponents that describes the position of treads in the non interlacing parts. Float- non – interlacing part of the weave. On the basis of this float we can attain higher setts of treads in the fabric width non –plain weaves than in with plain weave.

The expression of factor of thread‘s interlacing for ground weaves. This coefficient is given by equation:

$$f = \frac{number of \quad \text{int} relacing \quad po\text{int} \quad in the \quad weave}{the \quad number \quad of \quad pick from \quad back \quad on the \quad face \quad of\, fabric \quad and reversly} \qquad (12)$$

The expression of threads interlacing for derived weaves, for weaves don't have identical pick transition from back on the face in each row (line) .Selected examples of thread's interlacing table 2.This coefficient is given by equation:

$$f = \frac{the\ \ number\ of\ \ \ rowwith\ \ different\ number\ of\ pick\ \ transiction\ \ inweave}{\dfrac{the\ \ number\ pick\ \ transiction\ in\ \ row}{the\ \ number\ of\ \ \ \mathrm{int}erlacing\ point\ \ in\ \ row}} \qquad (13)$$

Table 2-1: The selected examples of tread's interlacing coefficient

Weave	Factor of interlacing,,f	Interlacing exponent,,m	Interlacing coficcient,,f
Plain P 1/1	$f = \frac{2}{2} = 1$	0.45	1
Hopsack Pa 2/2(2+2)-expression see equation (9)	$f = \frac{4}{2} = 2$	0.45	1.37
Rep R 2/2(I0 – expression see equation (8)	$f = \frac{1}{\frac{2}{4}} = 2$	0.36	1.28
Rep R 2/2(-) – expression see equation (9)	$f = \frac{1}{\frac{2}{4}} = 2$	0.42	1.34
Twill(5)- expression see equation (8)	$f = \frac{5}{2} = 2.5$	0.39	1.43
Satin(5)- expression see equation (9)	$f = \frac{5}{2} = 2.5$	0.42	1.47

2.3.5 Fabric width

Fabric width expresses the dimension in weft direction .In the weaving process we can distinguish three kinds of fabrics width: reed width p, width grey fabric, $FW_g\,[cm]$width of finish fabric $FW[cm]$.[3]

The width of grey fabric can be express on the basis of following equation:

$$FW_g = \frac{RW}{\left(1+\frac{s_u}{10^2}\right)} \tag{14}$$

2.3.6 Fabric length

Fabric lengths express the dimension in warp direction

We can express the fabric length on the basis under mentioned equation:

$$FL\frac{L_0}{\left(1+\frac{s_0}{10^2}\right)} \tag{15}$$

Where *FL* is the fabric length, L_o is the warp length and s_o is the warp shortening.

2.4 Fabric properties

It includes Reeds number, Aerial cover factor, crimp, and aerial cover factor. [5]

2.4.1Crimp

Crimp is defined as the extent to which straightened length of yarn is higher than cloth length which contains the yarn. For determining crimp a length of fabric, is marked. Yarn is removed from marked length of fabric, straightened to remove the waves by application of tension and measuring its length. [5]

Fabric materials are constructed from yarns that are crossed over and under each other in a respective, undulating pattern. The undulations show in figure 2-6 is referred to as crimp, which is based on Pierce Geometric fabric model. Pierce's geometric model relates these parameters as they are couple among yarn families. The crimp length h is related to the crimp angle. [5]

The warp shortening and weft shortening can be express on the basis of under mentioned equations:

$$s_o = \frac{L_o - L_{vz\,tk}}{L_{vz\,tk}}.10^2 \qquad (16)$$

$$s_u = \frac{L_o - \check{s}_{vz\,tk}}{\check{S}_{vz\,tk}}.10^2, \qquad (17)$$

Where s_o is warp shortening, s_u is weft shortening, L_o is the length of warp threads that is unstitch from the fabric, L_u is the length of weft of the threads that is unstitch from the fabric, L_{vztk} is the length of fabric sample in the warp direction and S_{vztk} is the length of fabric sample in the weft direction.

$$c = \frac{L_{yarn} - L_{fabric}}{L_{fabric}} \qquad (18)$$

Where c is crimp, L_{yarn} is length of yarn and L_{fabric} is the length of fabric.

2.4.2 Reed number

The reed width is given by total length of reed with treads

The reed number is given by equation:

$$RN = \frac{D_o}{number \quad of \quad threads \quad in\,one \quad reed \quad dent.\left(1 + \frac{s_u}{10^2}\right)} \qquad (19)$$

Where D_o is the warp setts and s_u is weft shortening.

1.3.1 The reed width is given by total length of reed with treads. The width can be expressed on the basis of the following equation:

$$RW \frac{FW. \quad D_o}{number \quad of \quad threads \quad in\,one \quad reed\,dent \quad RN}, \qquad (20)$$

Where RW is the reed width, FW is the fabric weight, D_o is the warp setts and RN is the reed number.

2.4.3 Areal Cover of fabric

It is described in the basis of the projection of threads in the binding cell of the woven fabric .Binding cell of woven fabric is partly covered by warp threads and partly weft threads .The total areal cover of fabric can be expressed on the basis of partial warp and weft cover of fabric. [3]

NOTE:

a) A woven fabric has, therefore, two cover factors, i.e. the warp cover factor and the weft cover factor.

b) In the Tex system (q.v.) the cover factor is calculated by the expression: "number of threads per centimetre x 1 divided by the square root of the tex."

We can describe the areal cover of fabric in the basis of horizontal projection of treads and partly by weft threads. The total areal cover of fabric we can express on the basis of partial warp and weft of fabric.

$$Z = \frac{horizzontal \quad projection \quad of \quad threads}{area \quad of \quad binding\, cell} = \frac{d. + A + d_u.B - d_o.d_u,}{A.B} \qquad (21)$$

Where: $$Z_o = \frac{horizontal \quad projection \quad area \quad of\, warp \quad threads}{area \quad of \quad binding \quad cell} = \frac{d_o.A}{A.B} = \frac{d_o}{B} \qquad (22)$$

$$Z_u \frac{horizontal \quad projection \quad area \quad of\, weft \quad threads}{area \quad of \quad binding \quad cell} = \frac{du.A}{A.B} = \frac{du}{A} \qquad (23)$$

Where Z is the areal cover factor, Z_o is the partial warp areal cover ,Z_u is the weft areal cover, A is the distance of the weft treads in fabric, B is the distance of warp in the fabric, d_o is the distance of warp threads and d_u is the distance of weft threads.

2.4.4 Fabric density

Fabric density, $H[\%]$ expresses the relation between setts of fabric and its maximal setts [3]

2.4.5 Areal weight of fabric

Weight of fabric depends on the warp and weft sett and on the yarn count as well as yarn shortening. We distinguish two kinds of fabric weight: - the weight of linier meter of fabric and $M2\left[g.bm^{-2}\right]$ - the weight square meter of fabric [8]

$$M_1 = (M_o + M_u).FW.10^{-2} \tag{24}$$

$$M_1 = M_o + M_u, \tag{25}$$

Then:

$$M_1 = \left[D_o.T_o(1+\frac{s_o}{10^2}) + D_u.T_u(1+\frac{s_u}{10^2}\right].FW.10^{-2} \tag{26}$$

$$M_2 = \left[D_o.T_o(1+\frac{s_o}{10^2}) + D_u.T_u(1+\frac{s_u}{10^2}\right].10^{-2} \tag{27}$$

$T_o, _u$ $[tex]$-warp and weft thread count,

Weight of fabric depends on the warp and weft sett and on the yarn count as well as yarn shortening. We distinguish two kinds of fabric weight: - the weight of linier meter of fabric and $M2\left[g.bm^{-2}\right]$ - the weight square meter of fabric [8]

2.5 Model of woven fabrics

1) Mechanical models-respect that the yarn deformed by means of mechanical forces

2) Geometrical models- geometric assumption about yarn axes and results of mutual compressive forces and binding point,

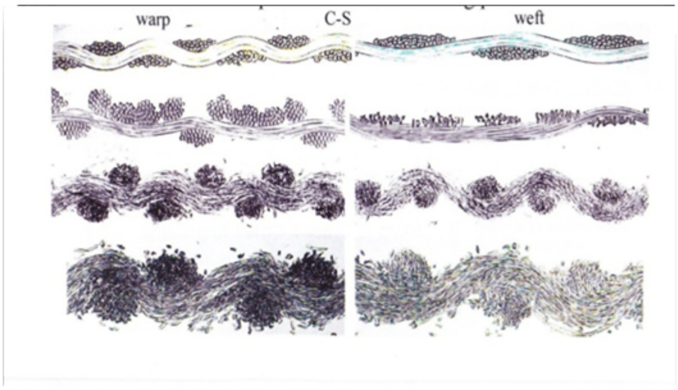

Figure 2-4: Cross section of a woven fabric by [Drasarova]

2.5.1 Geometrical models

1) Yarn axes are formed from abscissas, ring arches and abscissas, and from the curve

2) Yarn cross section are in binding points of fabric either circular or another

3) Crimping of warp and weft can either be balanced or non balanced fabric

2.5.2 Fabric geometry

2.5.2.1 The yarn cross section deformation in binding point

The yarn is not compact, solid or circular cross section, binding point, deformation of c-s and the compression of fibres.

2.5.2.2 Models of yarn cross sections

Initial yarn cross-section –circular, diameter *d*-becomes a flattened shape having **yarn width** a and d **yarn height** b . Usually. $a > d$, $b < d$.
(We suppose that yarn axis is in the middle of a and b)

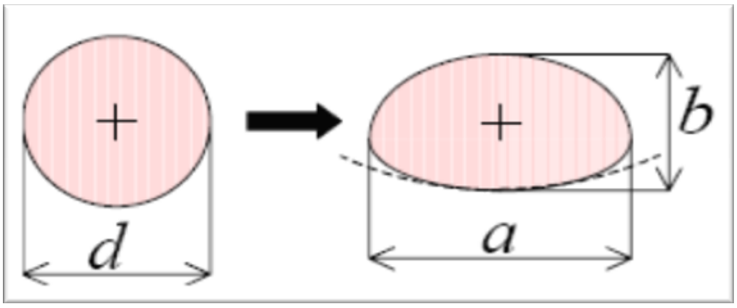

Figure 2-5 : Transversal deformation initial of yarns by [Neckář]

Yarn enlargement

$$\alpha = a/d \tag{28}$$

Yarn compression

$$\beta = b/d \tag{29}$$

2.5.3 Peirce's model of woven fabric

This model idea, where following assumptions are valid:

- Yarns have cylindrical shape.
- Axes of yarns are arches and abscissas
- Cross-sections of yarns are circular.
- Woven fabric is unbalanced

Figure 1: It shows cross-section of general unbalanced woven fabric according to Peirce’s model assumptions.

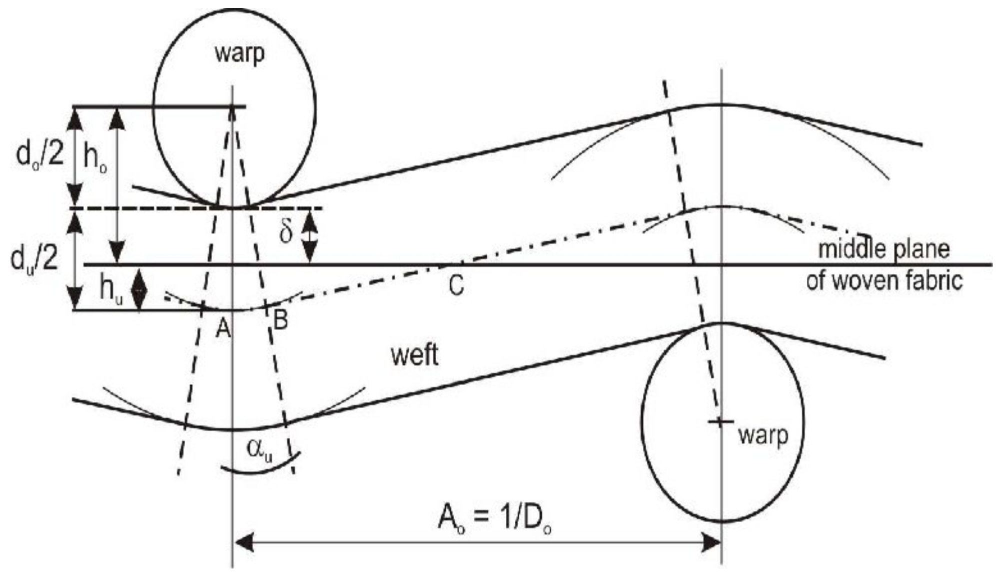

Figure 2-6: Geometrical relations in Pierce’s model of woven fabric by [Neckář]

2.5.4 Parameters needed to woven fabric binding point and binding weave drawing

- Pitch of warp yarns *Ao*
- Diameter of warp yarn *do*
- Diameter of weft yarn *du*
- High of weave *ho*
- High of weave *hu*
- Angle αu

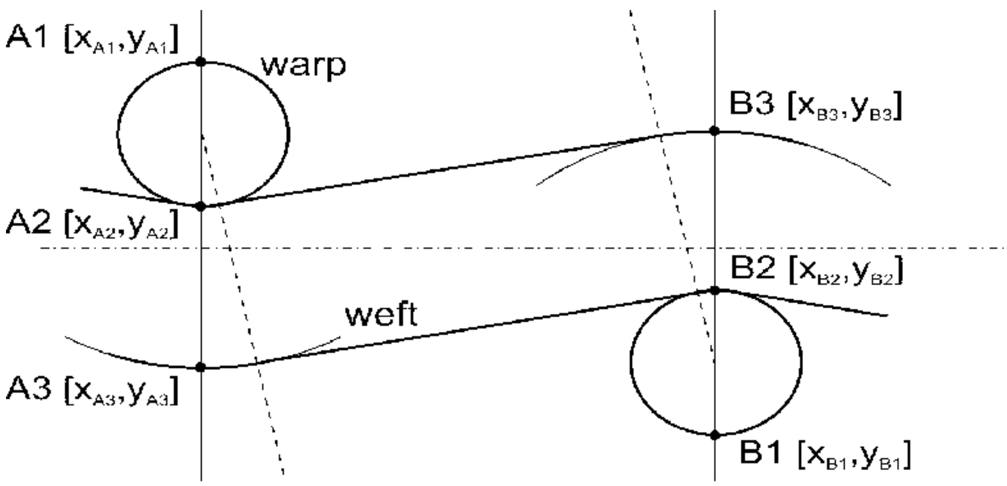

Figure 2-7: Description of binging points binding point and binding weaves by [Vysanska]

1) Pitch of warp yarns can be calculated using the equations below

$$A_o = \left[\left| \; x_{A3} - x_{B1} \; \right|\right] \tag{30}$$

$$A_o = \left[\left| \; \left| x_2 - x_{B2} \; \right|\right]\right. \tag{31}$$

$$A_o = \left[\left| \; x_{A1} - x_{B3} \; \right|\right] \tag{32}$$

2) Diameter of warp yarns can be calculated using the equations below:

$$d_o = \left| y_{A1} - y_{A2} \right| \tag{33}$$

$$d_o = \left| y_{B1} - y_{B2} \right| \tag{34}$$

3) Diameter of weft yarns can be calculated using the equations below:

$$d_u = \left| y_{A2} - y_{A3} \right| \tag{35}$$

$$d_u = \left| y_{B2} - y_{B3} \right| \tag{36}$$

4) High of binding wave h_o can be calculated using the equations below:

$$h_o = \frac{d_o}{2} + \delta \tag{37}$$

5) δ can be calculated using the equations below:

$$\delta = \frac{y_{B2} + y_{A2}}{2} \tag{38}$$

6) Highest value of wave h_u

$$h_u = \frac{d_u}{2} - \delta \tag{39}$$

7) The relationship between the diameter and wave height is given by equation below:

$$h_u + h_o = \frac{d_o}{2} = \frac{d_u}{2} \tag{40}$$

8) Angle α_u

$$a = \sqrt{\frac{1}{4} A_o^{\,2} + h_o^{\,2} - (h_o + h_u)^2} \tag{41}$$

$$\alpha_u = \frac{(h_o + h_u) - 2D_o h_o a}{a + 2D_o h_o (h_o + h_u)} \tag{42}$$

2.5.4.1This parameter ``height of binding waves can be determined on the basis of:

a) Experimental methods –from transverse and longitudinal method on the basis of: using image analysis,

b) Theoretical method – it is necessary to know diameter of treads $d_{mean}\left(\frac{d_o + d_u}{2}\right)$ (43)

c) and rate of warp and weft waviness e_o, e_u :

$$h_o = e_o . d_{mean} h_u = e_u d_{mean} \tag{44}$$

$$h = h_o + h_u \tag{45}$$

$$e_o + e_u = 1 \tag{46}$$

Knowing the rate of the threads waviness e_o, e_u, it is possible to estimate on the basis of individual phases of interlacing for Novikov work[8]see figure 6 .The theory has nine phases of interlacing see Fig .6:

1. Phase $e_o = 0...$ the warp threads is straight,

2. Phase $e_o = 0.125$

3. Phase $e_o = 0.25$,

4. Phase $e_o = 0.375$

5. Phase $e_o = 0.5$

6. Phase $e_o = 0.625$

7. Phase $e_o = 0.75$

8. Phase $e_o = 0.875$

9.Phase $e_o = 1$

- **Novikov Theory**

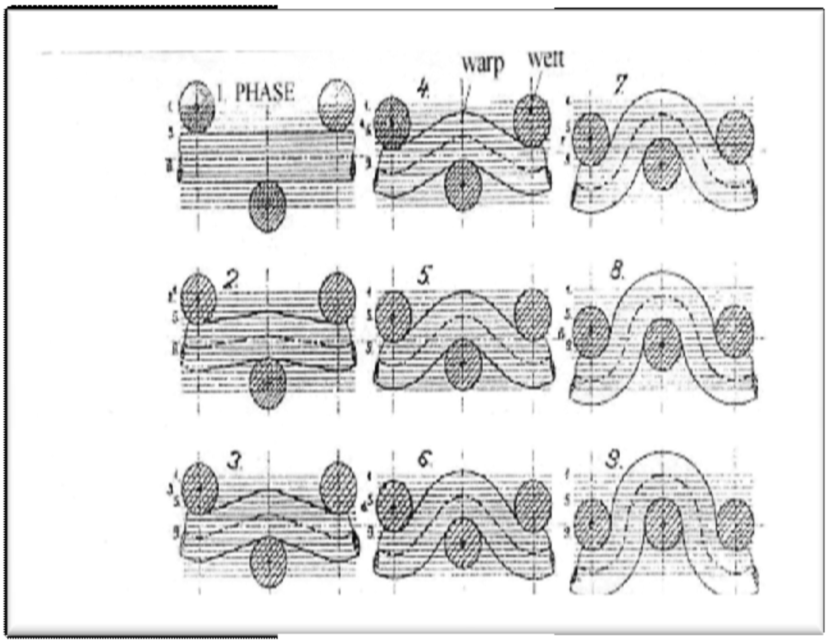

Figure 2-8: Phases of interlacing- Novikov theory[8]

2.5.5 Description of height of wave

Waviness height of warp and weft

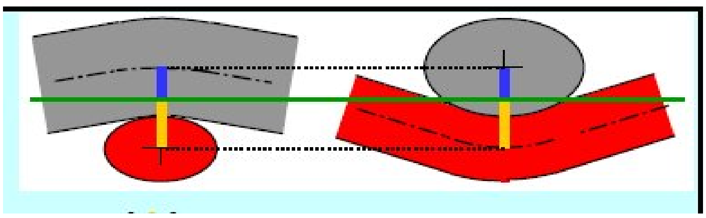

Figure 2-9 The measure of waviness is height of crimp

wave–hieghts distance of yarn axis from the central plane by [Neckář]

2.5.6 Crimping of a fabric

Shapes of warp and weft yarns and their mutual spatial form. Initial **geometry of** ("free") **yarn is changed** by its transformation to a fabric, and so:

Longitudinal shape-initially straight yarn crimps due to interlacing with other yarns []

Yarn waviness is limited by condition that the yarns must be mutually in contact in binding point.

Transversal shape-initially circular yarn cross-section becomes a flattened shape especially in binding point []. This transversal deformation of the yarn is a result of mutual compressive forces in binding point

2.5.7 Waviness

When the fabric is not balanced limited case:

There exists the relation between warp and weft waviness, resulting from the contact of both yarns. A) 1. Limit case–straight warp (stick) ⇒maximum waviness of weft.
C) 2. Limit case–straight weft (stick) ⇒maximum waviness of warp.
B) BALANCED FABRIC –warp and weft points are lying in the same height.
(Assumption of easier theoretical models.)
Note:—**central (middle) plane of fabric**

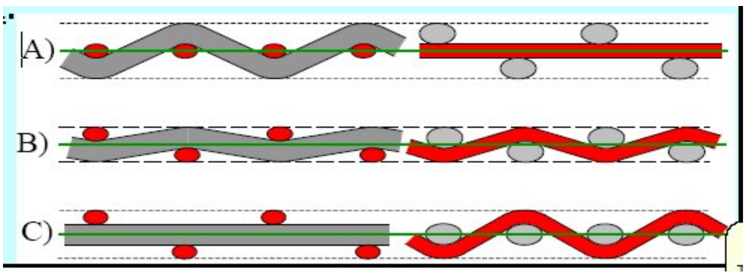

Figure 2-10: The relationship between warp and weft waviness by [Neckář]

2.5.7.1 For balanced fabric

For the structure of the fabric which is balanced we usually do not know the value of h_o and h_u or λ_o and λ_u.But empirically we know that warp and weft binding points often lies in the same length, model of balanced fabric, The warp and weft binding points lies in the same plain. It is valid that $h_o + \frac{d_u}{2} = ho + \frac{d_u}{2}$;

By using this expression $\lambda_o = \frac{2h_o}{d_u + d_u}$ (47)and $\lambda_u = \frac{2h_u}{d_u + d_u}$ (48)

It is valid that $\lambda_o = \lambda_u$ for a balance fabric

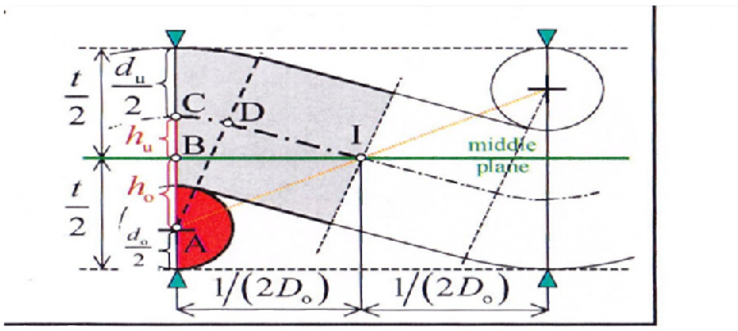

Figure 2-11: The structure for balanced fabric by [Neckář]

Pitch of warp yarns (distance $1/D_o$ Point I centre of punctual symmetry ("flex point"). It lies on the middle plane and on the join of warp yarn axes; $BI = (1/D_o)/2$ Circular bow CD centre A, radius $h_o + h_u$ is Thickness of fabric t (in non-balanced fabric) Note: Thenceforth, we shall use only the "half-wave "part.

2.5.8 Limit sets of warp

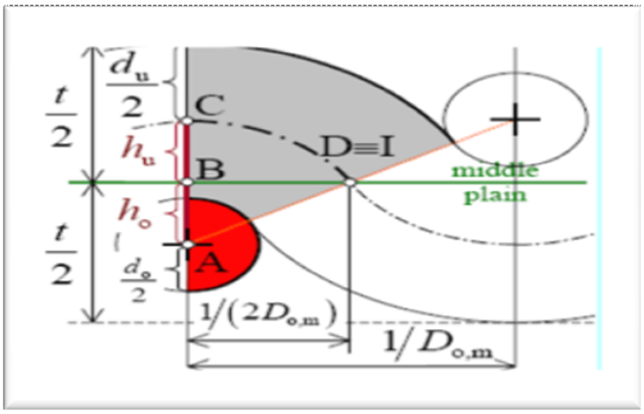

Figure 2-12: The structure showing the limit setts of warp [Neckář]

In the crossed segment, it is assumed that increase the warp setts D_O at still constant values of h_o , h_u , d_o ,and d_u We come upon some "barrier limit" in a moment. This highest warp sett is so called **limit setts of warp. I**n the case of limit setts the bows of weft yarn are mutually connected, so that the length DI is equal to 0.

2.5.9 Mechanical models

2.5.9.1 Deformable yarn

A generalised model by [Neckář]

Assymption1: Fabric –plain weave –elongated in the direction of warp and/or weft, follows the geometry of Peirce's model.

Assymption2: Yarn in fabric are-totally flexible, and-axially extensible(now); yarns extend to the level of their braking strain in the elongated direction; cross-yarns can also somehow elongate -transversally deformable(now); resultant effective yarn cross-sections have different (smaller) diameter then its initial value.

2.5.9.2 Elongated fabric

For extension in warp direction, fabric is elongated from hypothetical structure (imaginary) by conservation of yarn lengths and (effective, circular) yarn cross-sections, i.e. by conditions of earlier derived model. This is possible to consider but we must use the parameters of hypothetical structure in comparison of parameters of initial fabric parameters fabric .Note: However the setts of initial fabric must be used for fabric for calculation of breaking strain and contraction ratio calculation ratio, because we evaluate the changes of lengths in relation to the initial dimensions of fabric.

2.5.12 Strength of fabric

Strength of fabric (warp direction) Initial sample elongated in warp direction **fabric** (warp direction) Initial sample elongated in warp direction

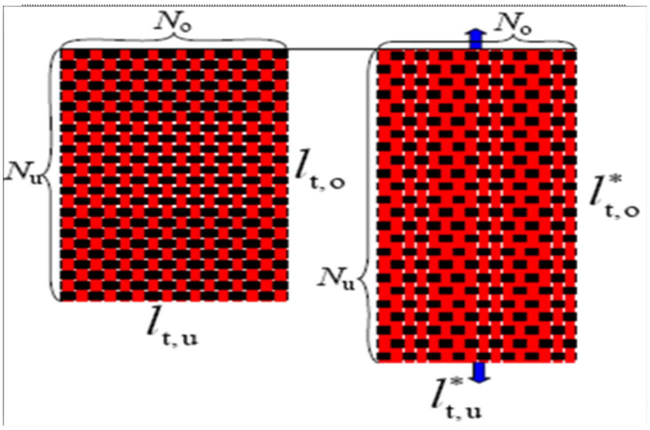

Figure 2-13 The determination of strength of a fabric [Neckář]

Strength of fabric (warp direction) Initial sample elongated in warp direction: Width of sample… $l_{t,u}$ (Usually 5 cm)

Setts of warp… D_o

Number of warp yarns in sample $N_o = D_o l_{t,u}$ (49)

Strength of sample (warp) … F_u

Strength per one warp yarn

$$F_{u,1} = F_u / N_u = F_u / D_u \, l_{t,o} \tag{50}$$

Strength of fabric (weft direction) Initial sample contract in weft direction
Width of sample… $l_{t,o}$

Setts of warp… D_u

Number of warp yarns in sample $N_u = D_u l_{t,o}$ (51)

Strength of sample (warp) … F_u

Strength per one warp yarn

$$F_{o,1} = F_o / N_o = F_o / D_o \, l_{t,u} \tag{52}$$

Chapter 3

3.1 Experimental Part

3.1.1 Material description

Material is composed of 100% of polypropylene fibre of fibre fineness 1.7dtex/40mm and yarn fineness of 29.5tex. It is produced from ring spun yarn. Fabric 01 is 8000 $\left[No.yarns/m\right]$ setts, Fabric 02 is 1300 $\left[No.yarns/m\right]$ setts, Fabric 03 is 1700 setts $\left[No.yarns/m\right]$ and Fabric 04 is 1930 $\left[No.yarns/m\right]$ setts respectively.

3.1.2 Methodology

Four types of fabric were used to perform the experiment. Ten specimens were made from each fabric in both warp and weft direction. The tests were performed at room temperature and humidity of 20ºC and 65% respectively. The specimens were cut in warp and weft direction according to this standard $\check{C}$SN EN ISO 13934-1-Tensile properties of fabric! Determination of maximum force and elongation at maximum force using the strip method. Parallel points of about 1mm from each on the creating squares, were marked on all specimens see figure 3.1: below.

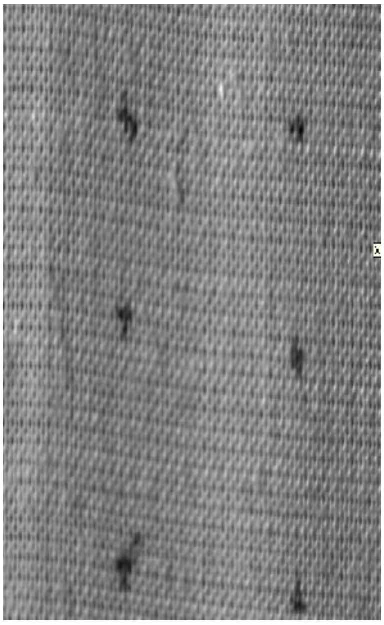

Figure 3-1 : Sample of a fabric

The specimens were taken for measurements of tensile strength end elongation using testometric tensile tester shown on figure 3.2. The tests was performed according to this standard, $\check{C}$ SN EN ISO 2062 80 0700, Textiles-yarn from packages-determination of single breaking force and elongation at break. Testometric tensile tester has gauge length and jaw speed of 200mm, 100mm/min respectively and strain rate is given by equation 53 below. The camera was also connected to the tensile tester for capturing of images.

$$S_r = \frac{jaw \quad speed}{gauge \quad length} \tag{53}$$

Force at break and elongation results for all specimens ware obtained at time of break. Matlab program was used to evaluate the force and elongation after every second. For cross(transverse) strain , the Nis elements image analysis program called macros for fabric deformation which determines the contraction between the two points, for the calculations of diameter before and after deformation. Gauge length and elongation results obtained from the tensile tester were used to determine vertical strain. For vertical and cross (transverse) strain see equations 53(a) and (b) below: of how they were evaluated and for further illustrations see figure 3.3:

$$\varepsilon_{horizontal} = \frac{d - d_o}{d_o} \quad (53a) \qquad \text{and } \varepsilon_{vertical} = \frac{l - l_o}{l_o} \quad (53b)$$

Where:

d_o is the diameter of specimen before deformation

d is the diameter of specimen after deformation

l_o is the length of specimen before deformation

l is the length of specimen after deformation

Vertical and cross strain were used to determine Poisson's ratio [Etha (η)] see equation 1 in Chapter 2 for elongation in warp and weft respectively. The results of Poisson's ratio were used to draw the graphs of Poisson's ratio versus force. transverse and vertical strain results were used to determine the relative strain at different loads see figure 4.1-0-1 and 4.1-0-1 in chapter 4, this was done for both elongation in warp and weft direction. Interpolation of force was made at interval of 25 from to obtain Poisson's ratio and Vertical strain until maximum force at break, because of different maximum forces at break of specimens, see table 4.12 in chapter 4 for illustrations. The overall curves of Poisson's ratio versus loads of all ten specimens together were drawn, but some of them were made out of on eight specimens, because all ten specimens did not break at the same maximum force, some were breaking earlier than other see table 4.2 in chapter 4 for illustrations .The problem might be production of the fabric or the testing but I do not know. The mean, maximum and minimum standard deviations were obtained using statically equation's to determine the variability between ten specimens. The strength of fabric for all fabrics was obtained using equation 41 and 43 in chapter 2, for elongation in both warp and weft. The relationship between Poisson's ratio and Vertical strain were determined see table 4.10 in chapter4. The overall curve of all four fabrics together is shown figure 4.1-0-20 and 4.1-0-21 in chapter 4. The regression curves of all four fabrics elongated in warp and weft direction were obtained using SSPS Software to determine the square of correlation coefficient see figure 4.1-011 in chapter 4 .Linearization of Poisson's ratio and strain were obtained using equation 54 below, and this was used for the determination of constants C and k values . The value of these constants is in table 4.4.1 in chapter 4. Strain, Etha, constant C and k with the use of equation 54 below. Then this was used for determination of all regressional curves see chapter 4 figure 4-15 for illustrations. The overall graph of all fabrics all together was plotted on one curve for both regressional and experimental results respectively.

Regressional equation

$$\eta = C \, . e^{k \, . \varepsilon_{vertical}} \tag{54}$$

$$\ln \eta = \ln C + k . \varepsilon_{vertical}$$

$$\eta = k . \varepsilon_{vertical} + q$$

$$C = e^{q}$$

$$\eta = e^{C} . e^{k . \varepsilon_{vertical}}$$

3.1.3 The instrument for the determination of strength and deformation of fabrics

Figure 3-2: Testometric tensile tester

3.1.3 The deformation of fabrics (method of data analysis)

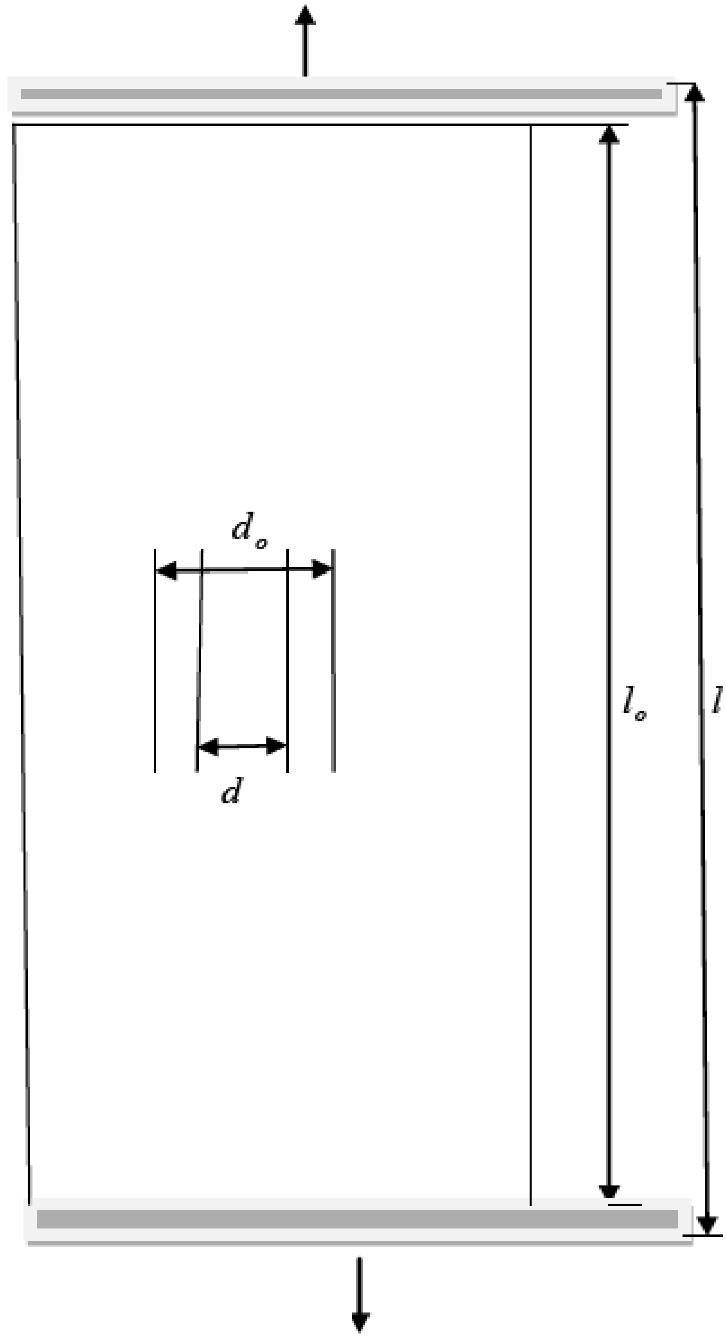

Figure 3-3: Deformation of specimen

Chapter 4

4. Results

Table 4-1: The specification of all setts of fabrics

Fabrics No.	Setts of warp (No. of Yarns/m)	Setts of weft (No. of Yarns/m)
Fabric 01	2180	8800
Fabric 02	2180	1300
Fabric 03	2180	1700
Fabric 04	2180	1930

Table 4-2: The results fabric 01; Elongated in the in WARP direction

Sample No.	Maximum (breaking) Force[N]	Breaking elongation [mm]	Breaking strain [-]	Transverse strain [-]	Poisson's ratio η[-]
1	726.7	60.288	0.30144	-0.14918	0.494878
2	754.1	61.287	0.306435	-0.14897	0.455403
3	429.95	36.306	0.18153	-0.16864	0.350165
4	429.95	36.306	0.18153	-0.16864	0.350165
5	705	61.627	0.308135	-0.14526	0.453395
6	702	61.295	0.306475	-0.14537	0.451846
7	725.6	61.952	0.30976	-0.14878	0.458545
8	602	48.959	0.244795	-0.16868	0.689056
9	512.5	40.298	0.20149	-0.15055	0.74716
10	401.98	33.639	0.168195	-0.1968	0.960624

Table 4-3: The results fabric 02; Elongated in the in WARP direction

Sample No.	Maximum (breaking) Force[N]	Breaking elongation [mm]	Breaking strain [-]	Transverse Strain [-]	Poisson's ratio η[-]
1	526.7	53.203	0.24111	-0.07596	0.315054
2	510.2	48.276	0.24138	-0.08068	0.334226
3	526.7	53.203	0.24111	-0.07596	0.315054
4	527.9	53.268	0.26634	-0.06988	0.262354
5	550.5	54.911	0.274555	-0.12184	0.443785
6	554.6	54.931	0.274655	-0.06251	0.227594
7	526.7	54.939	0.274695	-0.08108	0.295163
8	549.4	54.937	0.274685	-0.11503	0.418764
9	558.6	58.247	0.291235	-0.092	0.315901
10	555.2	54.955	0.274775	-0.16555	0.602475

Table 4-4 : The results fabric 03; Elongated in the in WARP direction

Sample No.	Maximum (breaking) Force[N]	Breaking elongation [mm]	Breaking strain [-]	Transverse Strain [-]	Poisson's ratio η[-]
1	732.7	58.917	0.299585	-0.12859	0.429223
2	776.4	58.207	0.291035	-0.19203	0.659819
3	930.2	91.562	0.45781	0.048034	0.104922
4	663.9	54.909	0.274545	-0.09814	0.357473
5	557.4	44.967	0.224835	-0.05297	0.235585
6	682.5	54.956	0.27478	-0.1266	0.460715
7	703.3	56.619	0.283095	-0.12837	0.453461
8	742.6	61.595	0.307975	-0.13039	0.423386
9	738.8	61.588	0.30794	-0.09852	0.319935
10	776.4	69.86	0.3493	-2.07438	5.938688

Table 4-5: The results fabric 04; Elongated in the in WARP direction

Sample No.	Maximum (breaking) Force[N]	Breaking elongation [mm]	Breaking strain [-]	Transverse Strain [-]	Poisson's ratio η[-]
1	905.3	81.563	0.407815	-0.18805	0.461109
2	1003.7	88.267	0.441335	-0.17079	0.386988
3	905.3	81.563	0.407815	-0.18805	0.461109
4	982	86.56	0.4328	0.068755	0.158861
5	831.3	68.235	0.341175	-0.15785	0.462655
6	269.41	29.938	0.14969	-0.05931	0.396251
7	810.1	63.244	0.31622	-0.15551	0.491788
8	879.4	73.247	0.366235	-0.14106	0.385157
9	827.8	64.91	0.32455	-0.09245	0.284856
10	502	41.614	0.20807	-0.0529	0.254264

Table 4-6: The results fabric 01; Elongated in the in WEFT direction

Sample No.	Maximum (breaking) Force[N]	Breaking elongation [mm]	Breaking strain [-]	Transverse Strain [-]	Poisson's ratio η[-]
1	301.35	56.957	0.284785	-0.14755	0.518098
2	300.43	56.629	0.283145	-0.14442	0.510047
3	933.8	76.589	0.382945	-0.17815	0.465198
4	964.8	83.267	0.416335	-0.19584	0.470397
5	882.8	74.914	0.37457	-0.18603	0.496647
6	901.2	69.931	0.349655	-0.19343	0.553204
7	911.8	76.613	0.383065	-0.21387	0.558303
8	929.6	73.259	0.366295	-0.214	0.58423
9	902.3	84.916	0.42458	-0.27882	0.656697
10	852.7	74.927	0.374635	-0.26042	0.695129

Table 4-7: The results fabric 02; Elongated in the in WEFT direction

Sample No.	Maximum (breaking) Force[N]	Breaking elongation [mm]	Breaking strain [-]	Transverse Strain [-]	Poisson's ratio η[-]
1	742.8	58.283	0.291415	-0.14469	0.49652
2	702.3	58.242	0.29121	-0.11045	0.379294
3	762	58.275	0.291375	-0.13328	0.457405
4	742.8	58.283	0.291415	-0.14469	0.49652
5	584.5	56.614	0.28307	-1.8799	0.641124
6	709.5	54.965	0.274825	-0.1551	0.564369
7	978.9	88.253	0.441265	-0.19808	0.448896
8	900.3	74.913	0.374565	-0.22927	0.612099
9	901.2	69.931	0.349655	0.238696	0.682661
10	689.9	58.278	0.29139	-0.217	0.744694

Table 4-8: The results of fabric 03; Elongated in the in WEFT direction

Sample No.	Maximum (breaking) Force[N]	Breaking elongation [mm]	Breaking strain [-]	Transverse Strain [-]	Poisson's ratio η[-]
1	753.5	68.274	0.34137	-0.18965	0.555547
2	868.7	73.243	0.366215	-0.19729	0.538729
3	825.4	68.246	0.34123	-0.19659	0.576108
4	880.5	73.279	0.366395	-0.20768	0.566831
5	801.8	71.589	0.357945	-0.15149	0.423209
6	878.6	69.923	0.349615	-0.19712	0.563807
7	838	73.142	0.36571	-0.23787	0.650446
8	725.4	73.248	0.36624	-0.19911	0.543652
9	782.9	73.235	0.366175	-0.22069	0.602684
10	800.4	73.253	0.366265	-0.18216	0.497337

Table 4-9: The results fabric 04; Elongated in the in WEFT direction

Sample No.	Maximum (breaking) Force[N]	Breaking elongation [mm]	Breaking strain [-]	Transverse Strain [-]	Poisson's ratio η[-]
1	600.3	51.621	0.258105	-0.15126	0.586028
2	518	48.268	0.24134	-0.09152	0.379208
3	603	56.63	0.28315	-0.12225	0.431759
4	603.6	54.941	0.274705	-0.16628	0.605291
5	590.9	56.604	0.28302	-0.1869	0.660389
6	605.7	56.587	0.282935	-0.13234	0.467751
7	799.6	71.613	0.358065	-0.15796	0.441157
8	657.8	73.278	0.36639	-0.16688	0.45546
9	609.2	68.283	0.341415	-0.21181	0.620399
10	603	56.63	0.28315	-0.15245	0.538405

4.1. Primary evaluation of results

4.1.1. The relationship between Etha (Poisson's ratio) and relative strain, for elongation in the warp direction

Fabric 01

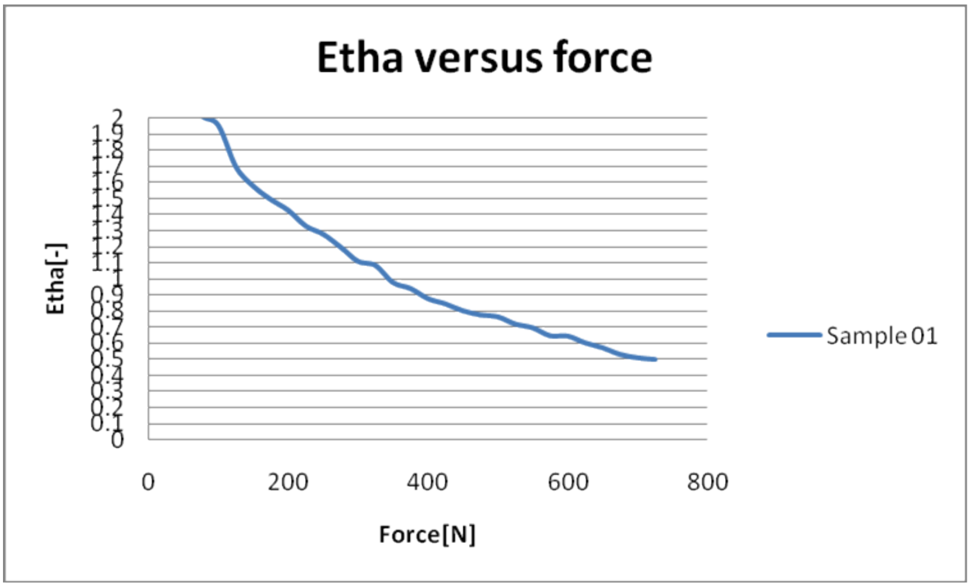

Figure 4.1-1: Relationship between Etha and Force

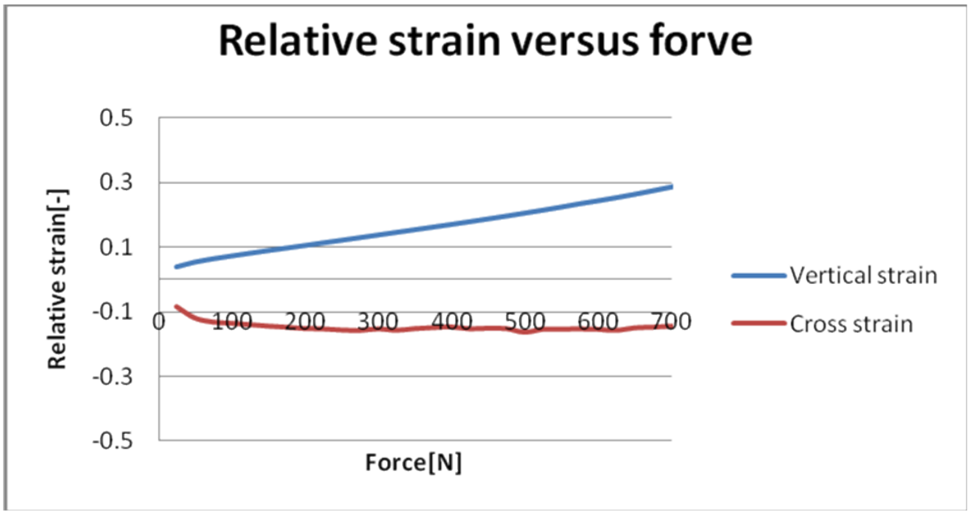

Figure 4.1-2: The relationship between relative strain and force

The curve of Poisson's ratio, vertical and cross (transverse) strain is shown on the figure: 4.1-1 and 4.1-2. respectively above .It relates relative strain and Poisson' s ratio at different loads , yarn length elongates themselves; warp yarns to their breaking elongation and weft yarns to lessen extend for all setts of fabrics .Etha(Poisson' s ratio) is decreasing with the as load increase. For cross (transverse) strain, it shows that at beginning decreases at fast rate and become stable toward the end, which shows the yarn length is near to zero, there is limit structure of yarn. The other graphs are in appendix 1 [4.1] and also check table 1.1 of how cross (transverse), vertical strain and as well as Poisson’s ratio.

4.1.2 Secondary evaluation of results

4.1.2.1 Relationship between strain and force for, elongation in the warp direction

Fabric 01

Interpolation of strain values at interval of 25 forces until the maximum force at break for all samples of fabrics was done due to the fact that the samples did not break at the same force

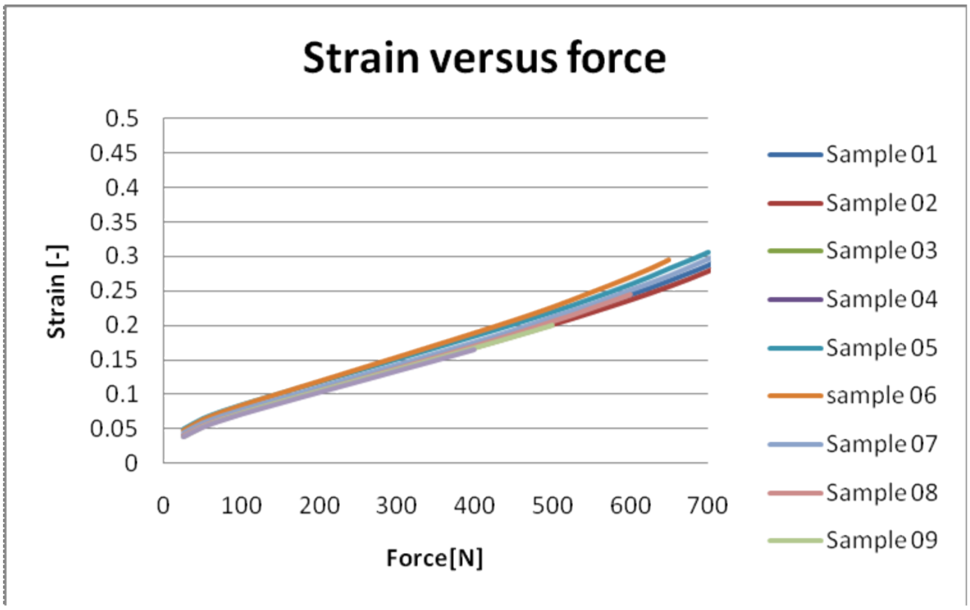

Figure 4.1-3: Overall curves for strain versus force of all samples together

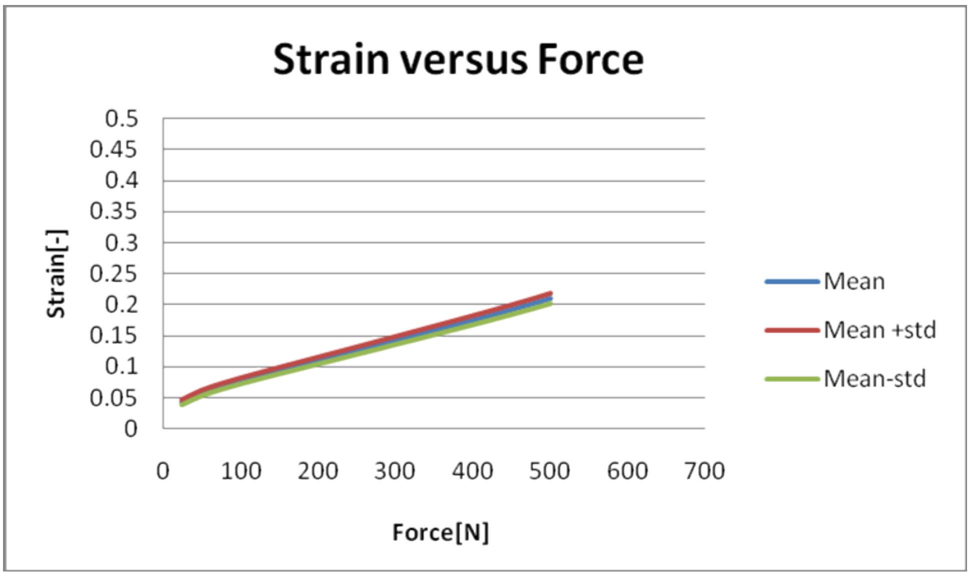

Figure 4.1-4: Mean curves for strain versus force of all samples together

For 01 fabric all sample maximum load at break more or less the same, it is show in figure 4.1-3 .The mean curve has the same characteristic trends as the overall curve of all samples. Figure 4.1-4 has low standard deviation which shows that the all samples were not away from the mean, variability is less. For some of the fabric the standard deviation was little bit higher which shows that they were much variability. For this fabric 02 all sample maximum load at break more or less the same it is shown in table 4.2. For fabric 03 all sample maximum load at break more or less the same it is show in 4.3. For fabric 04 the sample maximum load at break was not the same sample 10 was removed, as it has lower maximum force as compare to the other samples see table 4.4.The other graphs are in appendix 1[4.2] Table [1.7]and .1.8] of how mean and standard deviations were determined, for reference.

4.1.2.3 Relationship between Etha (Poisson's ratio) and Strain; elongation in the weft direction

Interpolation of Etha (Poisson's ratio) values at interval of 25 forces until the maximum force at break for all samples of fabrics was done due to the fact that the samples did not break at the same force.

4.1.2.3(b) Relationship between Etha and Strain; elongation in the weft direction
Fabric 01

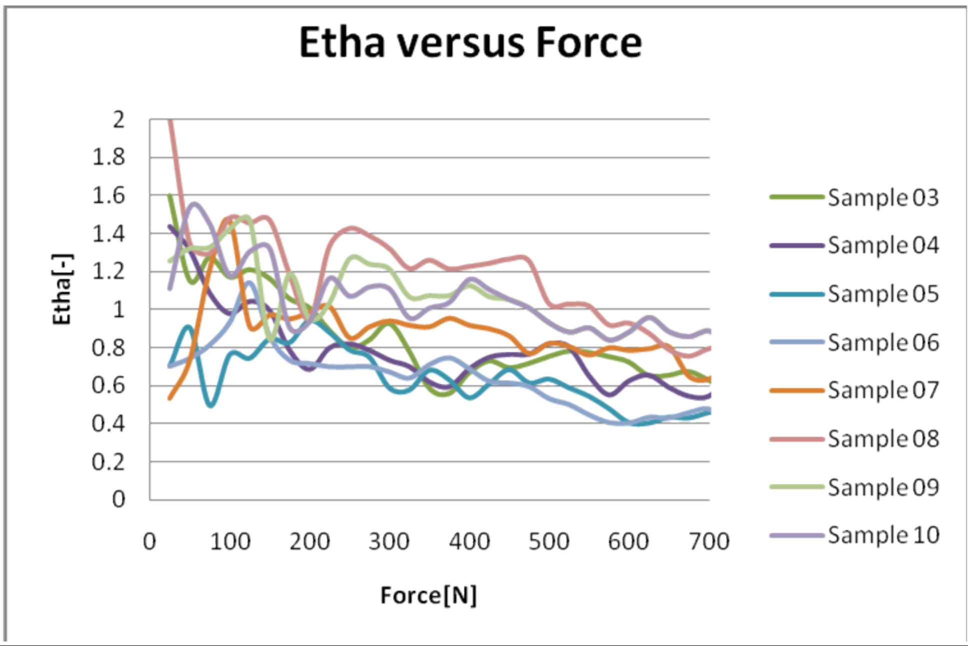

Figure 4.1-5 : Overall curves for Etha versus strain of all samples together

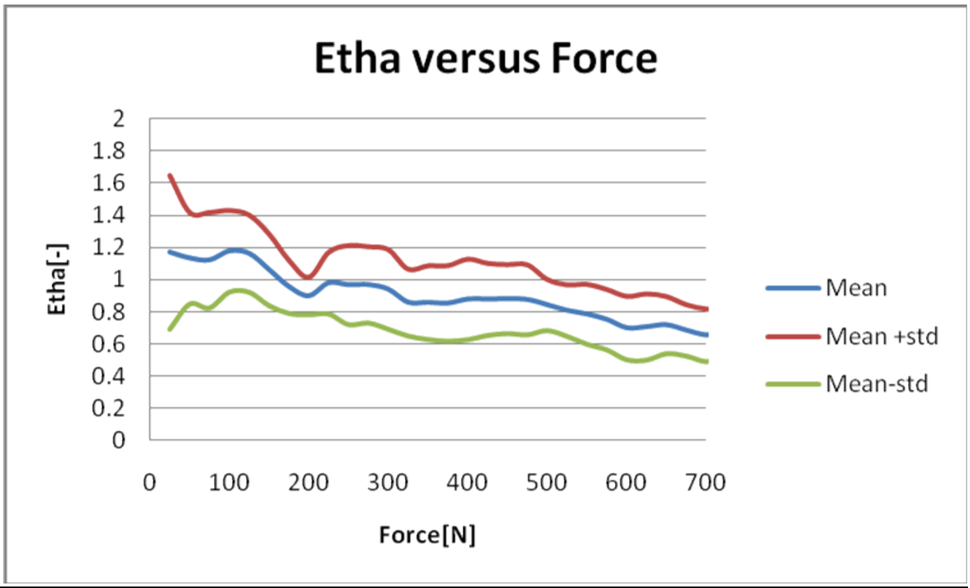

Figure 4.1-6 : Mean curves for Etha (Poisson's ratio) versus strain of all samples together

It is show in figure 4.1-5 that for this fabric a sample maximum load was at break not in the same time ,this is the reason why sample 01 and 02 was removed see table 4.6 for illustrations. The mean curve has the same characteristic trend as the overall curve of all samples. Figure 4.1-6 has higher standard deviation which shows that all samples were far away from the mean for some of the fabrics standard deviation was low which shows that all samples were not away from the mean, variability between samples was less. For fabric 02 a sample maximum load was at break not in the same time, this is the reason sample 01 and 02 was removed see table 4.6.For fabric 03 a sample maximum load was at break in the same time see table 4.7 for illustration. For fabric 04 all samples maximum load was at break in the same time see table 4.8.The other graphs are in appendix 1 [4.2] and Table [1.9] and [1.10], for reference of how mean and standard deviations were determined.

4.1.2.4 The relationship between mean of strain and load in the warp direction

4.2.4 (a) The relationship between mean of strain and load in the warp direction is shown on table 4-10 below:

Table 4-10 : The mean of strain of all fabrics elongated in the warp direction

Force[N]	Fabric 01	Fabric 02	Fabric 03	Fabric 04
25	0.042732	0.019553	0.031441	0.026383
50	0.057498	0.033966	0.04899	0.046285
75	0.067962	0.042231	0.059482	0.060976
100	0.076989	0.054243	0.071984	0.075223
125	0.085459	0.065565	0.082002	0.086726
150	0.093661	0.074681	0.090218	0.096076
175	0.101727	0.082178	0.100604	0.104347
200	0.109792	0.093283	0.10812	0.117294
225	0.117871	0.102615	0.116192	0.125583
250	0.125967	0.110725	0.123916	0.133976
275	0.134095	0.123427	0.135667	0.141159
300	0.142223	0.131338	0.143316	0.148436
325	0.150364	0.145171	0.151363	0.155678
350	0.158529	0.153699	0.159592	0.162994
375	0.166757	0.165473	0.166217	0.171271
400	0.175055	0.176633	0.1759	0.180767
425	0.183451	0.189565	0.185425	0.188032
450	0.192034	0.202252	0.193843	0.19634
475	0.200917	0.216528	0.204764	0.203485
500	0.210047	0.231388	0.209878	0.21076
525		0.247983	0.221403	0.218116
550		0.162636	0.231452	0.228693
575			0.239468	0.237056
600			0.249135	0.245324
625			0.258228	0.253768
650			0.268785	0.261223
675				0.270263
700				0.277338
725				0.291267

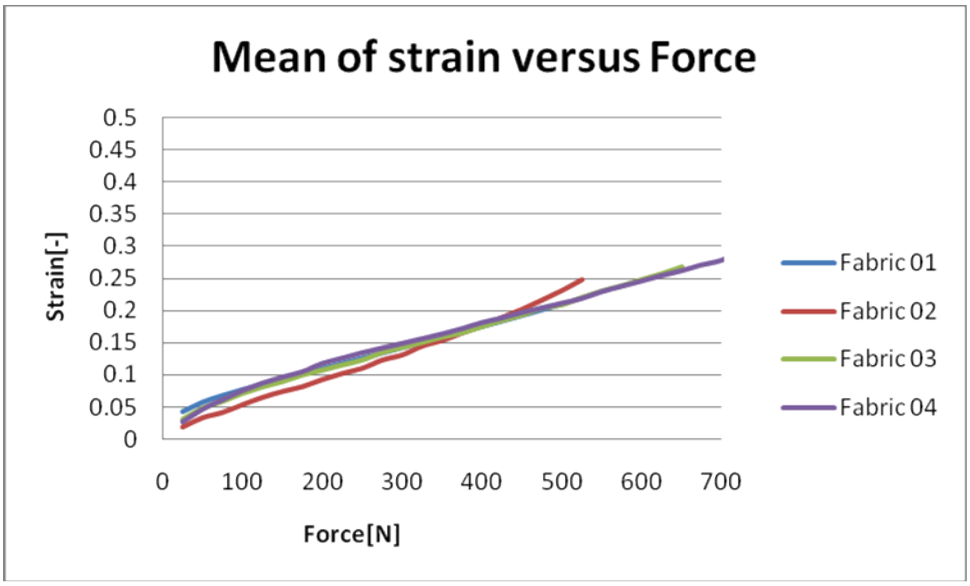

Figure 4.1-7: Mean of strain and Force, Elongated in the warp

For all setts of fabrics, it shows that strain increases as the load increases. All setts have the same increasing tendency. The curves of all setts are closer to each other because a sett of warp of fabrics is the same; this is shown on the graph 4.1-7 above:

4.1.2.4 (b) The relationship between mean strain and load in the weft direction is shown on table 4-11 below:

Table 4-11 : The mean of strain of all fabric elongated in the warp direction

Force[N]	Fabric 01	Fabric 02	Fabric 03	Fabric 04
25	0.04211	0.03907	0.036933	0.037821
50	0.052717	0.052533	0.067467	0.060544
75	0.065421	0.065852	0.083134	0.077253
100	0.07587	0.076902	0.096613	0.092469
125	0.091645	0.084984	0.10922	0.1041
150	0.10452	0.093611	0.120108	0.116846
175	0.112664	0.102812	0.129415	0.125836
200	0.121876	0.111115	0.138424	0.136845
225	0.123675	0.119599	0.146775	0.146037
250	0.129278	0.125272	0.155113	0.153943
275	0.136846	0.133558	0.163439	0.165988
300	0.147713	0.141962	0.171837	0.175982
325	0.158291	0.151133	0.180196	0.184133
350	0.165131	0.15863	0.189388	0.197893
375	0.170886	0.166158	0.196848	0.212979
400	0.177649	0.178137	0.205257	0.223
425	0.189039	0.185767	0.213663	0.236838
450	0.195237	0.18992	0.221143	0.254673
475	0.20177	0.199794	0.229507	0.26131
500	0.20708	0.208775	0.236043	0.270613
525	0.215996	0.21684	0.244518	0.281854
550	0.224756	0.225308	0.252781	0.298651
575	0.235225	0.236814	0.260286	0.320341
600	0.243569		0.268631	
625	0.25233		0.276904	
650	0.261143		0.284336	
675	0.269828		0.295333	
700	0.280207		0.304441	
725	0.29068		0.314439	
750	0.301367			
775	0.310267			
800	0.321638			
825	0.335704			
850	0.352428			

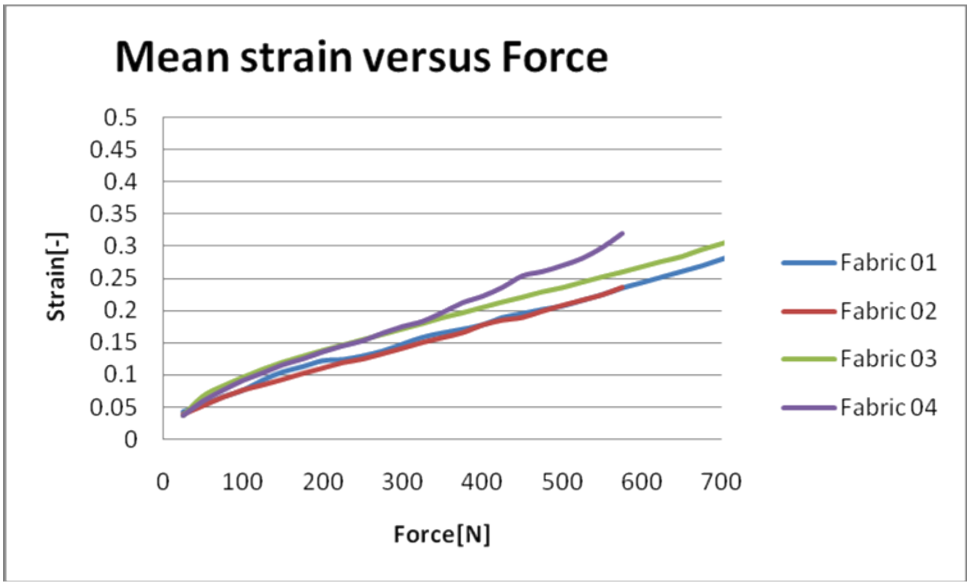

Figure 4.1-8: Mean of strain and force; Elongated in the weft direction

For all setts of fabric, it shows that strain increases as the load increases.

All setts have the same increasing tendency. The curves of all setts are not closer to each other because setts of weft are different; this is shown on the graph 4.1-8 above:

4.1.2.5(a) The relationship between mean of Etha (Poisson's ratio) and strength of all Fabrics

The mean of Etha (Poisson's ratio) and Strength for all of fabrics elongated in the warp direction is shown on the table 4-12 below:

Table 4-12 : The mean of Etha (Poisson's ratio) and Strength for all setts of fabric elongated in the warp direction

Force[N]	Force /1 yarn[N/1yarn]	Poisson' s ratio fabric 01	Poisson' s ratio fabric 02	Poisson' s ratio fabric 03	Poisson' s ratio fabric 04
25	0.229358	2.357129	1.202448	1.532254	1.457603
50	0.458716	2.260293	1.358927	1.40868	1.220267
75	0.688073	2.070658	1.239934	1.247752	1.139726
100	0.917431	1.941586	0.954768	1.191536	1.133747
125	1.146789	1.787316	0.854345	1.16171	1.091612
150	1.376147	1.656757	0.79859	1.085636	1.027108
175	1.605505	1.548724	0.736617	1.006276	1.004144
200	1.834862	1.432229	0.673548	1.068598	0.982059
225	2.06422	1.336482	0.565717	1.009895	0.92433
250	2.293578	1.283309	0.575737	1.02532	0.913843
275	2.522936	1.192665	0.531823	0.961394	0.860878
300	2.752294	1.14654	0.459035	0.897232	0.858371
325	2.981651	1.073637	0.382241	0.878269	0.837169
350	3.211009	1.026072	0.401002	0.917766	0.801524
375	3.440367	0.966378	0.378306	0.84968	0.778541
400	3.669725	0.890054	0.378131	0.817809	0.754092
425	3.899083	0.848113	0.345478	0.786465	0.722106
450	4.12844	0.813893	0.314975	0.792686	0.699047
475	4.357798	0.774263	0.350795	0.744771	0.68687
500	4.587156	0.748561	0.317947	0.708071	0.686181
525			0.321785	0.650104	0.660331
550				0.623061	0.636318
575				0.602349	0.603081
600				0.594784	0.569372
625				0.554425	0.554599
650				0.534595	0.544779
675					0.51744
700					0.541874
725					0.505512

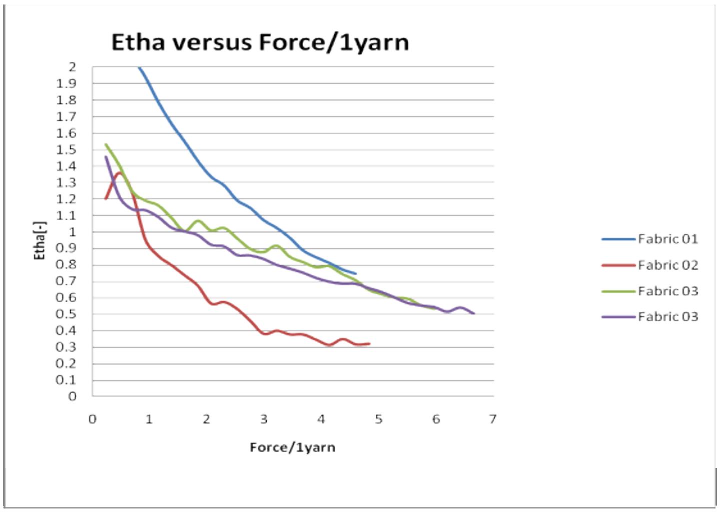

Figure 4.1-9: Mean of Poisson’s ratio (Etha) and force; Elongated in the warp direction

For all setts of fabric, it shows that Etha (Poisson's ratio) decreases as the strength increases. All setts of fabrics have same decreasing tendency. The curves of all setts closer to each other because sett of warp is the same for all fabrics; The fabric 01 break fast as compared to fabric 02, fabric 03 and fabric04 respectively because for higher setts the yarn are more compressed then it takes time to break. The variability of these four fabrics is shown on the graph 4.1-9. above:

4.1.2.5(b) The relationship between mean of Etha (Poisson's ratio) and Strength for all fabric elongated in the weft direction is shown on the table 4-13 below:

Table 4-13 : The mean of Etha (Poisson's ratio) and Strength for all fabric elongated in the weft direction

Poisson's ratio fabric 01	**Force /1 yarn[N/1yarn]**	**Poisson's ratio fabric 02**	**Force /1 yarn[N/1yarn]**	**Poisson's ratio fabric 03**	**Force /1 yarn[N/yarn]**	**Poisson's ratio fabric 04**	**Force/1 yarn [N/1yarn]**
1.169	0.568	1.357	0.385	0.925	0.294	0.859	0.259
1.133	1.136	1.296	0.769	0.927	0.588	0.792	0.518
1.121	1.705	1.212	1.154	0.852	0.882	0.887	0.777
1.176	2.273	1.210	1.538	0.895	1.176	0.863	1.036
1.161	2.841	1.036	1.923	0.882	1.471	0.897	1.295
1.061	3.409	1.042	2.308	0.918	1.765	0.806	1.554
0.955	3.977	0.949	2.692	0.921	2.059	0.801	1.813
0.898	4.545	0.955	3.077	0.866	2.353	0.761	2.073
0.979	5.114	0.927	3.462	0.819	2.647	0.816	2.332
0.966	5.682	0.894	3.846	0.859	2.941	0.733	2.591
0.968	6.250	0.871	4.231	0.831	3.235	0.731	2.850
0.939	6.818	0.849	4.615	0.816	3.529	0.706	3.109
0.858	7.386	0.823	5.000	0.809	3.824	0.673	3.368
0.858	7.955	0.822	5.385	0.819	4.118	0.666	3.627
0.853	8.523	0.720	5.769	0.806	4.412	0.642	3.886
0.878	9.091	0.739	6.154	0.778	4.706	0.612	4.145
0.878	9.659	0.718	6.538	0.735	5.000	0.576	4.404
0.879	10.227	0.686	6.923	0.746	5.294	0.616	4.663
0.875	10.795	0.620	7.308	0.718	5.588	0.599	4.922
0.843	11.364	0.642	7.692	0.722	5.882	0.552	5.181
0.808	11.932	0.660	8.077	0.707	6.176	0.555	5.440
0.785	12.500	0.623	8.462	0.718	6.471	0.549	5.699
0.752	13.068	0.616	8.846	0.699	6.765	0.563	5.959
0.700	13.636			0.680	7.059		
0.706	14.205			0.656	7.353		
0.718	14.773			0.655	7.647		
0.685	15.341			0.650	7.941		
0.655	15.909			0.614	8.235		
0.665	16.477			0.592	8.529		
0.654	17.045						
0.665	17.614						
0.644	18.182						
0.591	18.750						
0.579	19.318						

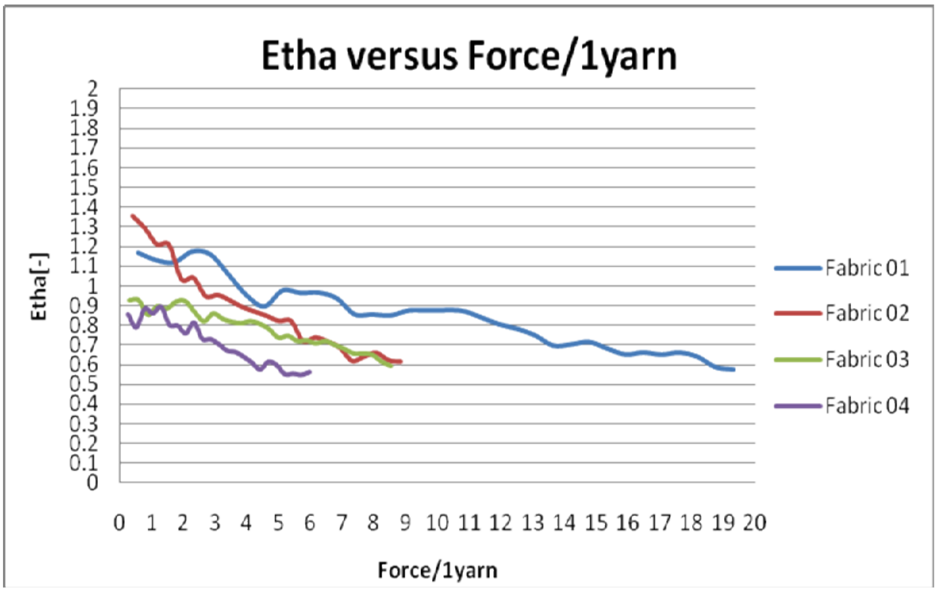

Figure 4.1-10 Mean of Poisson's ratio (Etha) and force; Elongated in the weft direction

For all setts of fabric, it shows that Etha (Poisson's ratio) decreases as the strength increases. All fabric have same decreasing tendency. Fabric 01 with small setts it break fast as compared to fabric 02, fabric 03 and fabric 04 respectively because ,strength of the setts increases with force and decreases as the number of setts increases; this is proven by the equation 50 and 53 in Chapter 2 and supported by the graph 4.1-10 above:

4.1.3 Tertiary statistical evaluation of results

4.1.3.1The linear regression curves for all four fabrics elongated in warp and weft direction

Fabric 01,Elongated in the warp direction

Table 4-14: The results from linearization of lnEtha and strain for fabric 01, elongated in the warp direction

R Square value	0.994
Constant	1.193
k	-7.34
$\ln Etha = 1.193 - 7.34(\varepsilon_{verticalstrain)})$	
$\eta = e^{1.193} * e^{-7.34.\varepsilon}$	

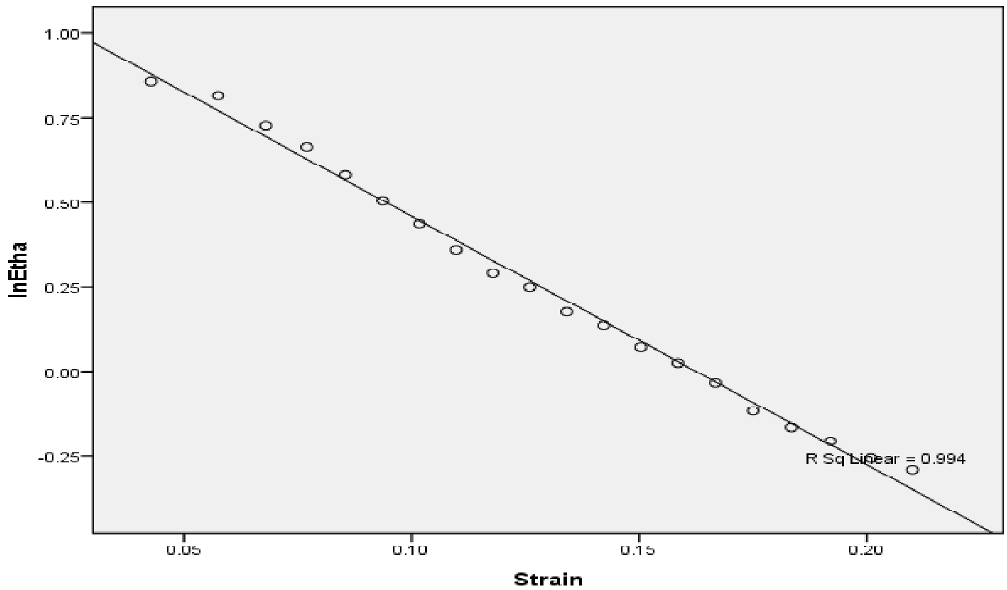

Figure 4.1-11: lnEtha versus strain for fabric 01 elongated in the warp direction

All curves for the elongation in the warp and weft direction shows that there is a negative regression (r=-1), according linearity. The square of correlation is high which shows that there is a degree of linear dependency or an agreement between the observed and the modelled values. Only fabric 02 was lower than fabric 01, 03 and 04 respectively but still good. The other graphs are in appendix 1 [4.3] for reference.

4.1.4 Results and Discussion

4.1.1.4. (a) The relationship between regressional and experimental curves, elongation in the warp direction. The regressional graphs were obtained from the linearization of Etha.

4.1.4.1. Elongation in the warp direction

Fabric 01

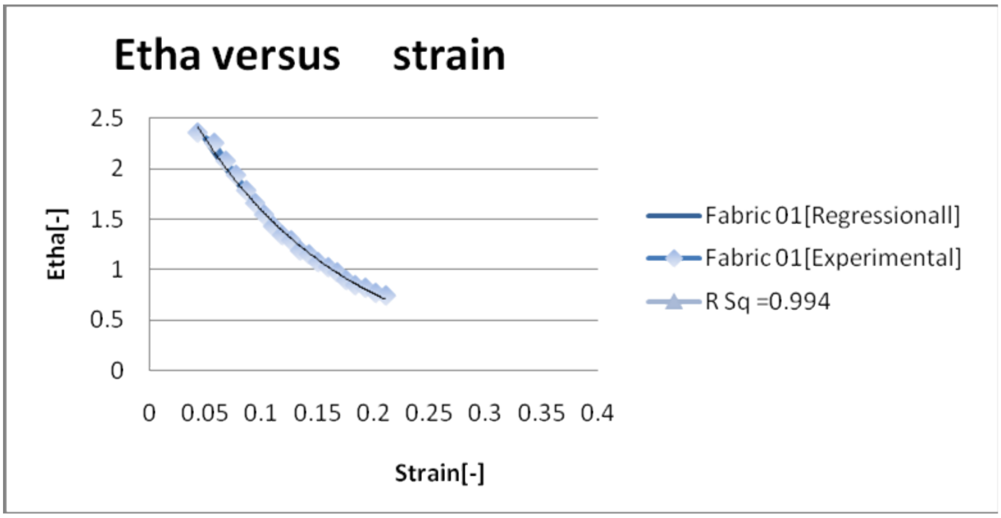

Figure 4.1-12: Etha versus force for both regressional and experimental results on the same curve

Fabric 02

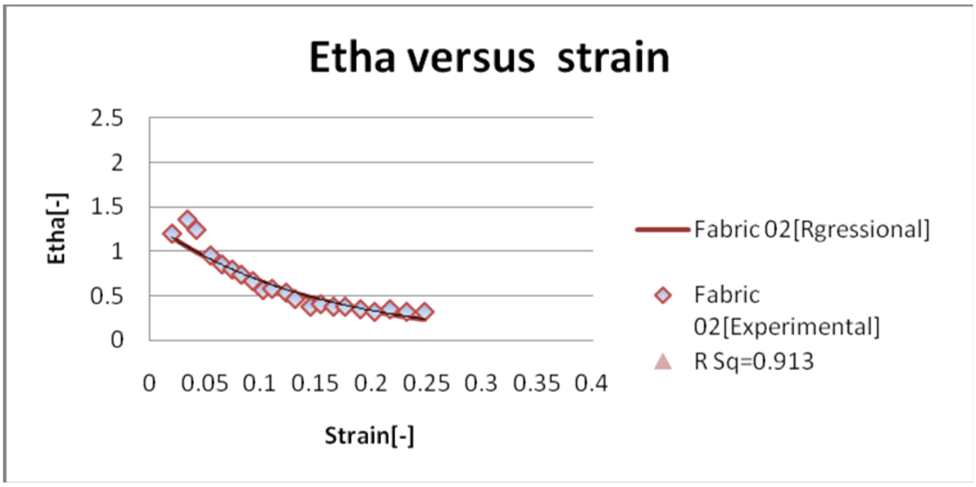

Figure 4.1-13: Etha versus force for both regressional and experimental results on the same curve

Fabric 03

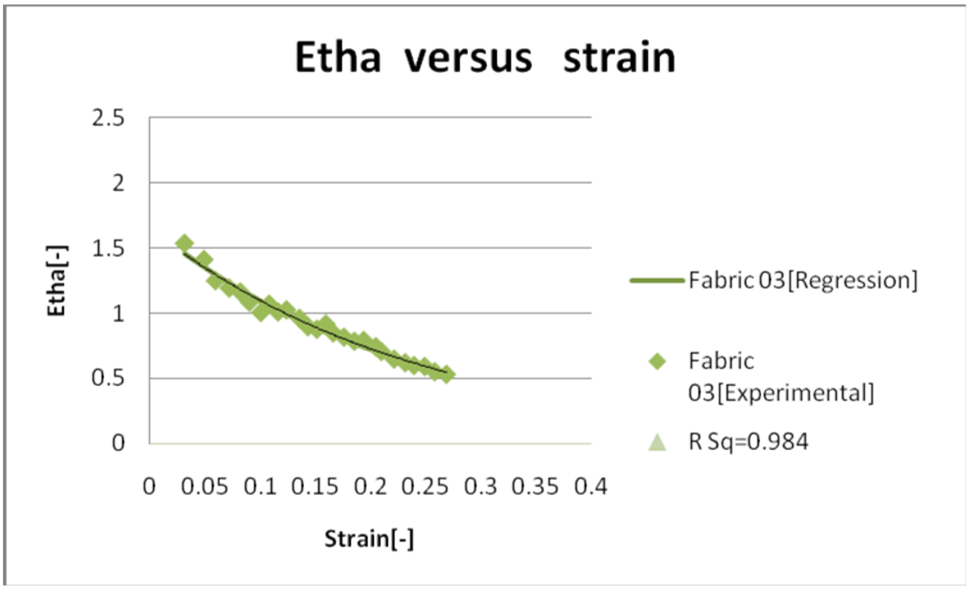

Figure 4.1-14: Etha versus force for both regressional and experimental results on the same curve

Fabric 04

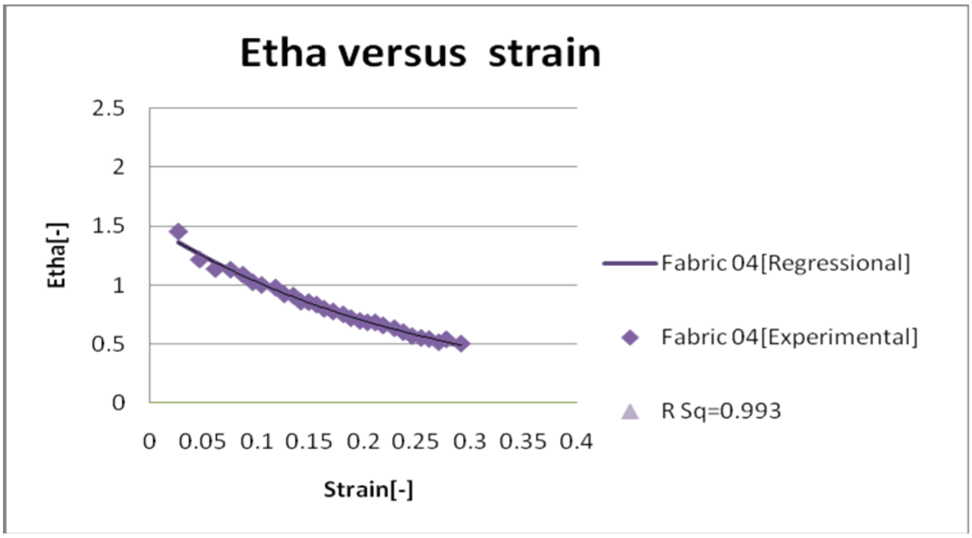

Figure 4.1-15: Etha versus force for both regressional and experimental

results on the same curve

This curve shows the, the theoretical curves can be used as the empirical curve for the substitution of the experimental curves as they have same trends.

4.1.4.2. Elongation in the weft direction

Fabric 01

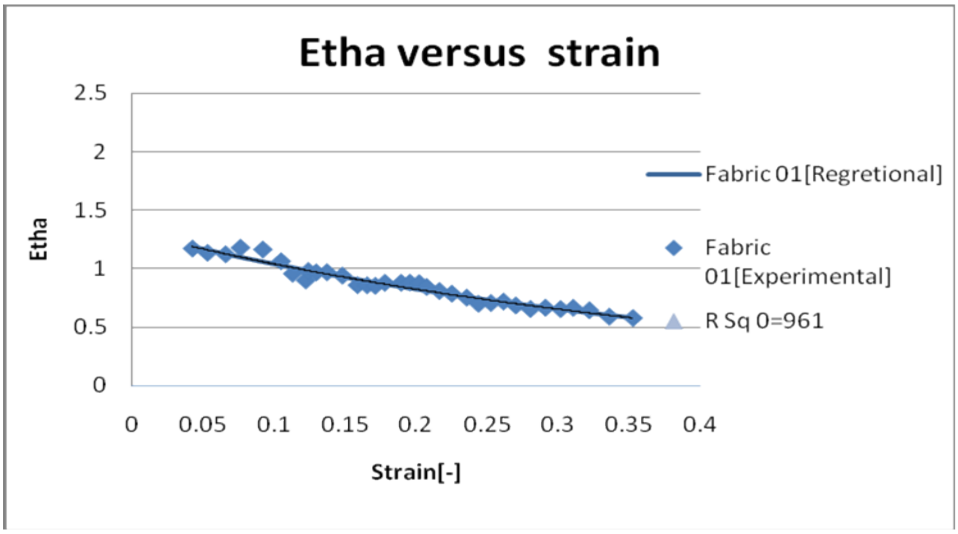

Figure 4.1-16: Etha versus force for both regressional and experimental

results on the same curve

Fabric 02

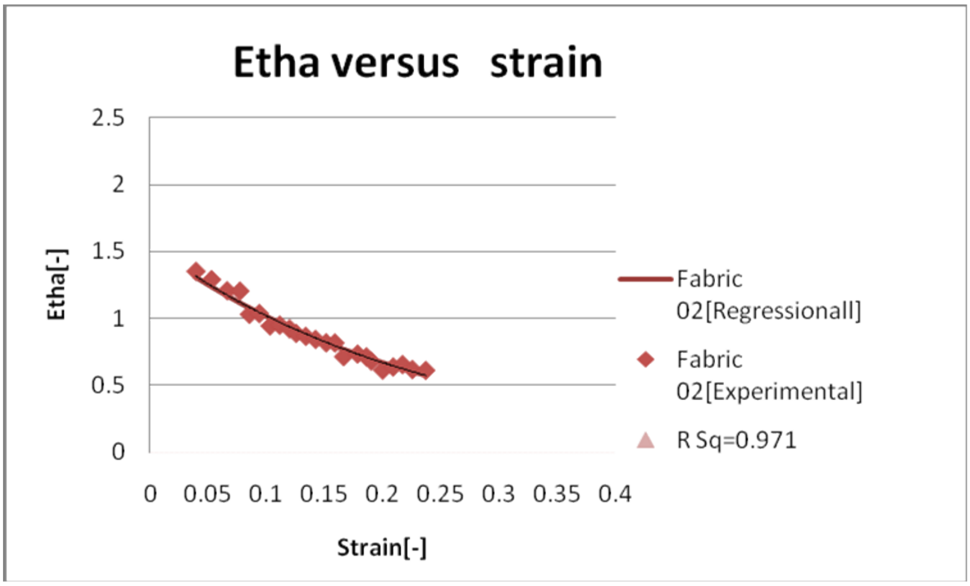

Figure 4.1-17: Etha versus force for both regressional and experimental results on the same curve

Fabric 03

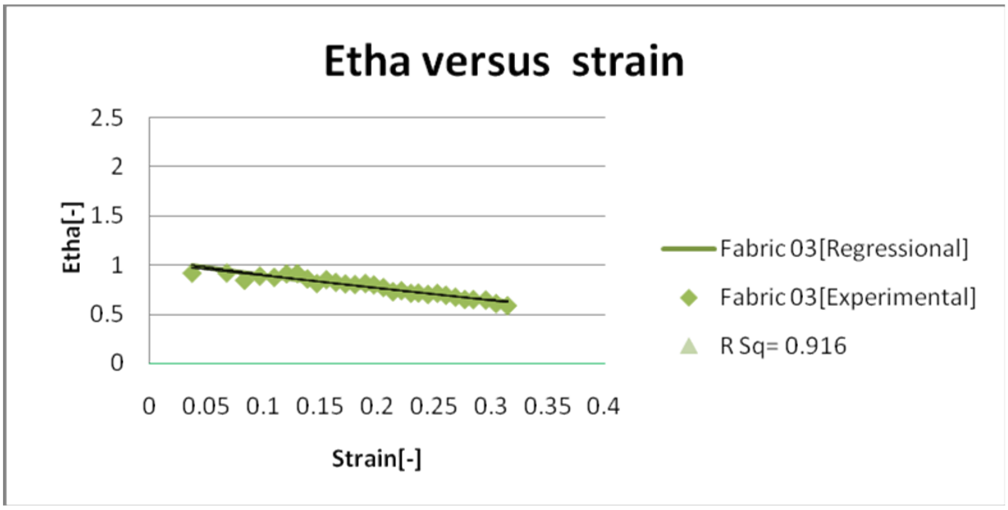

Figure 4.1-18:Etha versus force for both regressional and experimental results on the same curve

Fabric 04

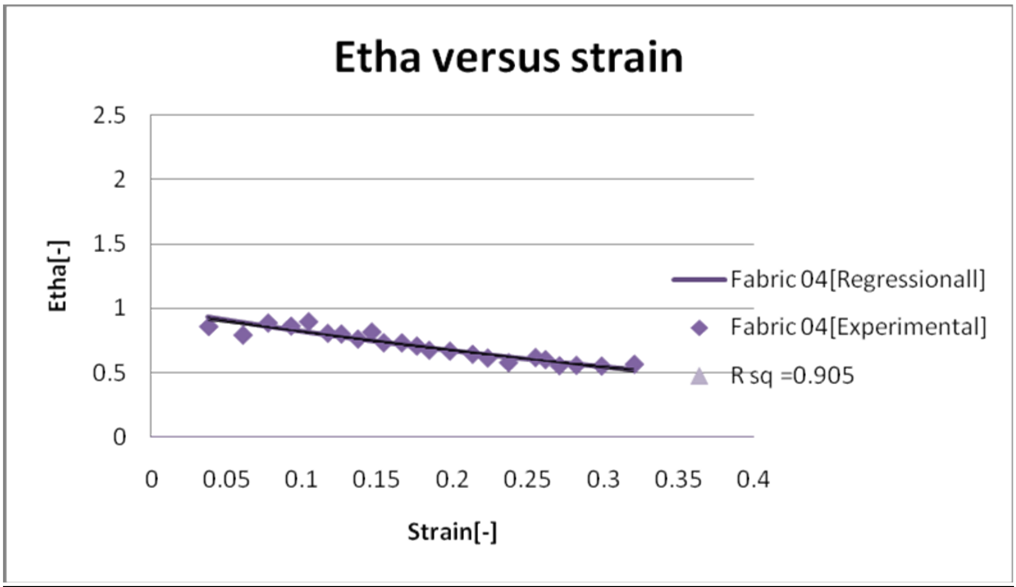

Figure 4.1-19: Etha versus force for both regressional and experimental results on the same curve

This curves shows that, the theoretical curves can be used as the empirical curve for the substitution of the experimental curves as they have same trends. Square of correlation coefficient is higher which is good, it shows that the there is a degree of linear dependency between Poisson's ratio and strain or an agreement between the observed and the modelled values

4.1.4.3(a) Experimental results

Elongation in the warp direction

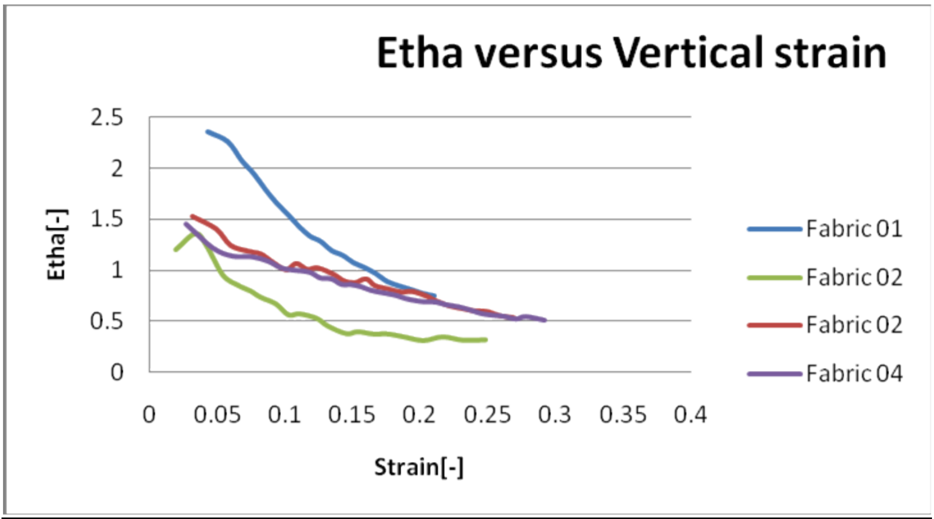

Figure 4.1-20: Overall for all fabrics all together on the same curve

Elongation in the weft direction

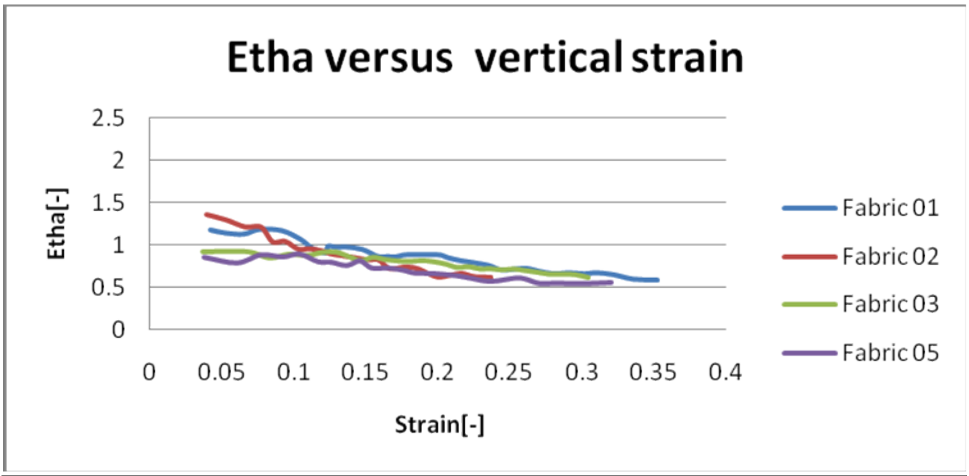

Figure 4.1-21 : Overall for all fabrics all together on the same curve

4.1.4.3(b) The regressional results

$$\eta = C.e^{k\varepsilon}$$

Table 4-15: Regressional Results for all fabrics elongated in warp and weft direction

Fabric No.	Setts (No. of yarns/m)		Warp elongation			Weft elongation		
	Warp	Weft	C	k	Square of correlation coefficient	C	k	Square of correlation coefficient
01	2180	8800	1.193	-7.34	0.994	0.272	-2.326	0.961
02	2180	1300	0.284	-6.866	0.913	0.439	-4.196	0.971
03	2180	1700	0.504	-4.12	0.984	0.063	-1.656	0.916
04	2180	1930	0.411	-3.850	0.993	0.002	-1.994	0.905

For the elongation in the warp direction

Square of correlation coefficient

For all fabrics a square of correlation coefficient is higher ,only fabric 02 a is less than others but it is still good. It shows that there is a degree of linear dependency between Poisson's ratio and strain.

Constant C

All fabrics have the same setts of warp, the setts of warp is high and for high setts constant values of C is decreasing, only fabric 02 is out as compared to the other fabrics ,I do not know the cause of this, see table 4.-15. For high setts for high setts the yarns are compressed where by existing the limit sett of warp whereby it is decreases at fast rate in the beginning and slowly towards the end, and the yarn are no longer extensible , this is according to hypothetical model of Pierce 's for the internal relation of fabric.

Constant k

All fabrics have the same setts of warp, the setts of warp is high and for high setts there is high value of k for all fabrics.

<u>**For the elongation in the weft direction**</u>

Square of correlation coefficient

For all fabrics a square of correlation coefficient is higher ,only fabric 03 and fabric 04 for elongation in the weft direction a is less than others but it is still good. It shows that there is a degree of linear dependency between Poisson's ratio and strain.

Constant C

For all fabrics ,C decreases when the setts increases because the smaller setts there is see table 4.15 for fabric 01 as compared to fabric 04 , for small setts the yarns are not compressed so the is no limit structure in this case . Poisson’s ratio is small at start and decreases at a lower rate. For constant value of C for fabric 02 is out as compared to the other fabrics. I do not know the cause of this as it again occurred in the setts of warp.

Constant k

For elongation in the weft direction, constant k increases as the setts increases. See table 4-15 for fabric 01 as compared to 04.The values of constant k for fabric 02 out as compared to the other fabrics and this had also happened in the setts of warp, but I do not know the reason.

<u>**Elongation in the warp direction**</u>

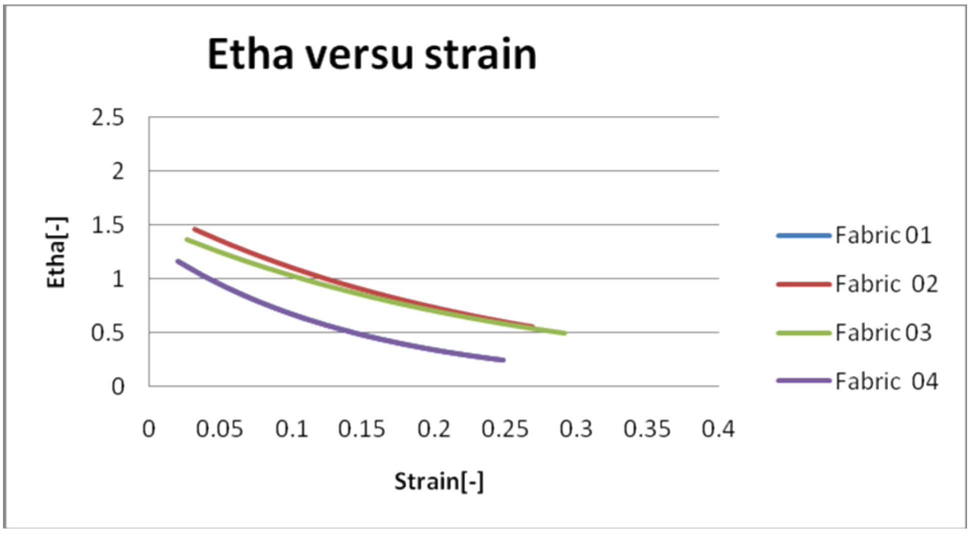

Figure 4.1-22: Overall for all fabrics all together on the same curve

<u>Overall graph for all fabrics</u>

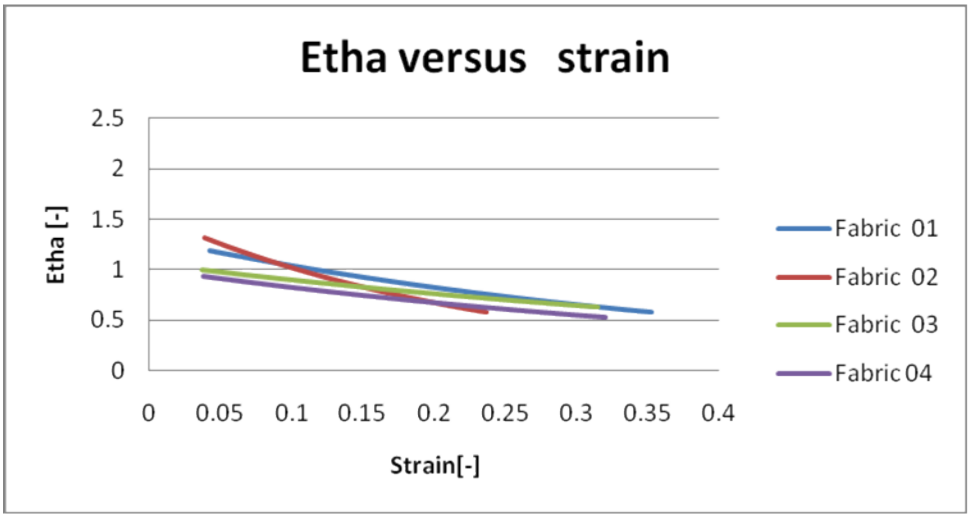

Figure 4.1-23: Overall for all fabrics all together on the same curve

For all graphs elongated in the warp and weft direction, they have the convex shape and the decreasing tentency. From figure 4.1-22 , it shows that Etha starts at the highest value as compared to the figure 4.1-23 , it is because of the the highest setts of warp than weft setts .For high setts of fabric there is high Poisson' s ratio.Figure 4.1-0-22 decreases at a fase rate and figure 4.1-23 has low decreasing rate, because for high setts the fabric is more compressed and have high constraction (Poisson ‘s ration), occurs the limit structure where lenght of yarn is close to zero.For small setts yarns are less compressed so there is less constraction(Poisson 's ratio).For fabric 02 in both elongation of warp and weft ,all have valuec of constant C which is out of range as compared to fabric 01 ,03 and 04 respectively.The problem might be the processing of this fabric, but i do not know.

Chapter 5

5.1 Conclusion

The graphs for all fabrics have a decreasing tendency and the rate is faster in the beginning, then slowly towards the end and the convex shape is observed. The regressional curves can be used as the emperical ones for the substitution of the experimental curves as it has the same trend. We do not have the model to describe this parameters yet. For all fabrics elongated in warp and weft direction the results, show that for fabrics with higher setts had higher contraction ratio in the beginning and decreases at a higher rate and the fabric with lower setts had lower ratio and decrease at a lower rated, reason being, for higher warp setts the yarns are more compressed than in small weft setts. For the highest setts of warp so called limit setts of warp occurred. In the case of limit setts of warp the bows of weft yarn are mutually connected (border), so that the length is closer to zero. This is according to the hypothetical structure of Pierce model, assuming that the yarn in the fabric are totally flexible but non deformable transversally. In reality the yarns in the fabric are flexible and extensible. For this research there is lot of unknowns for the internal structure of fabric. The calculations of the initial parameter of the fabric will take time to be determined. I did not manage to do this due to short period of time for my research work, so this parameter cannot be calculated numerically but they can be determined empirically. For extension in warp direction, fabric is elongated from hypothetical structure (imaginary) by conservation of yarn lengths and (effective, circular) yarn cross-sections, i.e. by conditions of earlier derived model. This is possible to be considered, but we must use the parameters of hypothetical structure in comparison of parameters of initial fabric parameters fabric. However the setts of initial fabric must be used for fabric for calculation of breaking strain and contraction ratio calculation ratio, because we evaluate the changes of lengths in relation to the initial dimensions of fabric.

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Appendices

Appendix 1: Referencing tables and figures

Table 1.1: The results of sample 01 for fabric 02 , elongated in the warp direction , before interpolation and the value gauge length ,width before and after for the determination of cross strain and strain

Force [N]	Elongation [-]	Gauge length [-]	Strain[-]	Width before[mm]	Width after[mm]	Cross (Transverse) strain[-]	Poisson's Etha[-]
-0.37	0	200	0	-2178	-2178	0	0
1.04	0.329	200	0.0016	-2178	-2178	-4.10E-05	0.025
1.6	0.659	200	0.0032	-2178	-2161	-0.00791	2.3995
2.16	0.994	200	0.0049	-2178	-2161	-0.00781	1.5705
2.67	1.321	200	0.0066	-2178	-2159	-0.00914	1.3835
3.23	1.659	200	0.0082	-2178	-2156	-0.0102	1.229
3.83	1.99	200	0.00995	-2178	-2157	-0.01006	1.0106
4.5	2.327	200	0.011635	-2178	-2139	-0.0182	1.5642
5.1	2.655	200	0.013275	-2178	-2128	-0.02308	1.7382
5.8	2.99	200	0.01495	-2178	-2124	-0.02521	1.6859
6.56	3.32	200	0.0166	-2178	-2148	-0.01378	0.83
7.37	3.66	200	0.0183	-2178	-2142	-0.01691	0.9238
8.22	3.988	200	0.01994	-2178	-2125	-0.02449	1.228346
9.15	4.318	200	0.0215	-2178	-2108	-0.03216	1.4895
10.14	4.661	200	0.0233	-2178	-2100	-0.03618	1.5523
11.18	4.989	200	0.0249	-2178	-2084	-0.04317	1.7306
12.36	5.323	200	0.0266	-2178	-2078	-0.04614	1.7335
13.55	5.659	200	0.028295	-2178	-2062	-0.05356	1.893
14.92	5.986	200	0.02993	-2178	-2065	-0.05201	1.7377
16.3	6.32	200	0.0316	-2178	-2037	-0.06493	2.0548
17.88	6.655	200	0.0332	-2178	-2039	-0.06382	1.917833
19.46	6.988	200	0.0349	-2178	-2010	-0.0772	2.2094
21.32	7.326	200	0.0366	-2178	-1999	-0.08249	2.252
23.24	7.661	200	0.0383	-2178	-1988	-0.08729	2.2788
25.29	7.986	200	0.0399	-2178	-1995	-0.08437	2.1128
27.48	8.316	200	0.0415	-2178	-1962	-0.09942	2.391038
29.86	8.655	200	0.0432	-2178	-1970	-0.09582	2.2141
32.28	8.98	200	0.0449	-2178	-1967	-0.09727	2.1662

35.15	9.322	200	0.0461	-2178	-1949	-0.10541	2.2615
38.03	9.654	200	0.0482	-2178	-1951	-0.1046	2.1669
41.04	9.985	200	0.04992	-2178	-1935	-0.1117	2.2374
44.33	10.318	200	0.0515	-2178	-1922	-0.11776	2.2825
47.75	10.659	200	0.0532	-2178	-1935	-0.11184	2.098
51.27	10.99	200	0.0549	-2178	-1910	-0.12313	2.24
54.95	11.315	200	0.0565	-2178	-1909	-0.12381	2.188
58.9	11.65	200	0.0582	-2178	-1915	-0.121	2.077
62.78	11.98	200	0.0599	-2178	-1877	-0.13849	2.311
67.07	12.322	200	0.0611	-2178	-1895	-0.13018	2.112
71.46	12.655	200	0.0632	-2178	-1907	-0.12473	1.971
75.72	12.985	200	0.0649	-2178	-1892	-0.13157	2.021
80.31	13.322	200	0.06661	-2178	-1891	-0.13217	1.984
84.84	13.649	200	0.0682	-2178	-1885	-0.1345	1.97
89.54	13.982	200	0.0699	-2178	-1878	-0.13797	1.973
94.42	14.32	200	0.0716	-2178	-1884	-0.13504	1.886
99.18	14.65	200	0.0735	-2178	-1862	-0.14522	1.982
104.08	14.986	200	0.0749	-2178	-1884	-0.135	1.801
109.04	15.319	200	0.076	-2178	-1876	-0.1388	1.812
114.11	15.653	200	0.0782	-2178	-1875	-0.1394	1.781
119.06	15.982	200	0.0799	-2178	-1879	-0.13745	1.72
124.16	16.317	200	0.0815	-2178	-1876	-0.1388	1.701
129.15	16.652	200	0.0836	-2178	-1875	-0.13928	1.672
134.17	16.984	200	0.08492	-2178	-1868	-0.14233	1.676025
139.29	17.312	200	0.08656	-2178	-1865	-0.14384	1.661739
144.62	17.653	200	0.088265	-2178	-1846	-0.15276	1.730737
149.63	17.976	200	0.08988	-2178	-1870	-0.14149	1.574234
154.99	18.314	200	0.09157	-2178	-1864	-0.14436	1.576492
160.22	18.654	200	0.09327	-2178	-1864	-0.1445	1.549254
165.35	18.98	200	0.0949	-2178	-1864	-0.14446	1.522223
170.68	19.312	200	0.09656	-2178	-1851	-0.15039	1.557485
175.99	19.651	200	0.098255	-2178	-1862	-0.14514	1.477146
181.01	19.976	200	0.09988	-2178	-1855	-0.14846	1.486397
186.42	20.313	200	0.101565	-2178	-1857	-0.1476	1.453299
191.61	20.645	200	0.103225	-2178	-1850	-0.15087	1.461577
196.7	20.976	200	0.10488	-2178	-1850	-0.15091	1.438864
202.14	21.313	200	0.106565	-2178	-1850	-0.15087	1.415738
207.35	21.648	200	0.10824	-2178	-1846	-0.15248	1.408732
212.5	21.982	200	0.10991	-2178	-1849	-0.15113	1.37502
217.69	22.312	200	0.11156	-2178	-1850	-0.15057	1.349704
222.81	22.642	200	0.11321	-2178	-1849	-0.15111	1.334776

228.14	22.981	200	0.114905	-2178	-1846	-0.15248	1.327036
233.27	23.309	200	0.116545	-2178	-1843	-0.15378	1.319481
238.65	23.648	200	0.11824	-2178	-1851	-0.15039	1.271942
243.66	23.978	200	0.11989	-2178	-1854	-0.14914	1.243961
248.96	24.31	200	0.12155	-2178	-1840	-0.15515	1.276457
254.09	24.643	200	0.123215	-2178	-1837	-0.15694	1.273738
259.2	24.977	200	0.124885	-2178	-1843	-0.15418	1.234544
264.5	25.31	200	0.12655	-2178	-1845	-0.15284	1.20776
269.63	25.641	200	0.128205	-2178	-1846	-0.1528	1.191857
274.64	25.973	200	0.129865	-2178	-1845	-0.15292	1.177531
279.97	26.312	200	0.13156	-2178	-1836	-0.15736	1.196122
284.93	26.639	200	0.133195	-2178	-1836	-0.15732	1.181139
290.03	26.974	200	0.13487	-2178	-1845	-0.1529	1.133683
295.24	27.31	200	0.13655	-2178	-1845	-0.15292	1.119893
300.31	27.638	200	0.13819	-2178	-1845	-0.15292	1.106589
305.43	27.974	200	0.13987	-2178	-1845	-0.1529	1.09318
310.64	28.314	200	0.14157	-2178	-1845	-0.1529	1.08004
315.74	28.64	200	0.1432	-2178	-1845	-0.1529	1.067736
320.81	28.976	200	0.14488	-2178	-1833	-0.15844	1.093573
326.03	29.305	200	0.146525	-2178	-1833	-0.15842	1.081161
331.24	29.648	200	0.14824	-2178	-1837	-0.15672	1.057236
336.22	29.975	200	0.149875	-2178	-1838	-0.15629	1.042783
341.5	30.31	200	0.15155	-2178	-1831	-0.15949	1.052403
346.51	30.641	200	0.153205	-2178	-1862	-0.14518	0.94759
351.64	30.978	200	0.15489	-2178	-1845	-0.15314	0.988686
356.68	31.305	200	0.156525	-2178	-1848	-0.15181	0.969857
361.97	31.646	200	0.15823	-2178	-1855	-0.14852	0.938623
366.85	31.973	200	0.15865	-2178	-1853	-0.1492	0.933276
371.89	32.308	200	0.16154	-2178	-1854	-0.14914	0.923229
377.05	32.639	200	0.163195	-2178	-1841	-0.15487	0.949005
382.06	32.972	200	0.16486	-2178	-1854	-0.14904	0.904033
387.21	33.307	200	0.166535	-2178	-1855	-0.14826	0.890279
392.2	33.643	200	0.168215	-2178	-1856	-0.14822	0.881134
397.18	33.975	200	0.169875	-2178	-1845	-0.15326	0.902194
402.14	34.304	200	0.17152	-2178	-1859	-0.14661	0.854764
407.15	34.643	200	0.173215	-2178	-1858	-0.14729	0.850309
412	34.971	200	0.174855	-2178	-1860	-0.14615	0.835852
416.93	35.303	200	0.176515	-2178	-1854	-0.14876	0.842755
421.94	35.636	200	0.17818	-2178	-1855	-0.14868	0.834434
426.82	35.975	200	0.179875	-2178	-1846	-0.15264	0.848589
431.83	36.31	200	0.18155	-2178	-1846	-0.15282	0.841749

436.56	36.635	200	0.183175	-2178	-1849	-0.15111	0.824942
441.35	36.971	200	0.184855	-2178	-1849	-0.15111	0.817444
446.34	37.303	200	0.186515	-2178	-1855	-0.14852	0.796288
451.32	37.644	200	0.18822	-2178	-1850	-0.15091	0.801764
456.03	37.974	200	0.18987	-2178	-1850	-0.15089	0.794693
460.92	38.31	200	0.19155	-2178	-1846	-0.1524	0.795622
465.57	38.638	200	0.19319	-2178	-1847	-0.15228	0.788259
470.22	38.966	200	0.19483	-2178	-1850	-0.15055	0.772739
475.04	39.301	200	0.196505	-2178	-1847	-0.15222	0.774648
479.94	39.643	200	0.198215	-2178	-1847	-0.15203	0.766977
484.26	39.963	200	0.199815	-2178	-1842	-0.15442	0.772798
489.1	40.308	200	0.20154	-2178		-0.15276	0.757983
493.78	40.64	200	0.22	-2178		-0.15206	0.748348
498.11	40.97	200	0.20485	-2178		-0.15252	0.744555
502.82	41.307	200	0.206535	-2178		-0.163	0.7892

Table 1.2: The values of cross (transverse) strain of fabric 02, after interpolation elongated in the in the warp direction

Force [N]	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain
25	-0.0183	-0.01755	-0.0183	-0.0236	-0.0039	-0.0075	-0.0113	-0.0242	-0.0409	-0.0631
50	-0.0488	-0.02413	-0.0488	-0.0404	-0.0559	-0.0231	-0.0099	-0.0516	-0.0274	-0.09877
75	-0.0518	-0.04745	-0.0518	-0.0337	-0.0485	-0.0373	-0.023	-0.0495	-0.0606	-0.0958
100	-0.0333	-0.06615	-0.0333	-0.0745	-0.0747	-0.0747	-0.0747	-0.0412	-0.0713	-0.11069
125	-0.0364	-0.04501	-0.0425	-0.0418	-0.093	-0.0358	-0.0348	-0.0354	-0.1015	-0.12953
150	-0.0434	-0.03422	-0.0434	-0.0504	-0.0725	-0.0503	-0.0722	-0.0818	-0.0881	-0.12303
175	-0.0563	-0.03359	-0.0564	-0.0742	-0.0925	-0.0325	-0.0428	-0.0428	-0.1152	-0.13364
200	-0.0474	-0.04045	-0.0474	-0.0378	-0.0771	-0.0345	-0.0677	-0.068	-0.0823	-0.1456
225	-0.0575	-0.03632	-0.0576	-0.0459	-0.1106	-0.0527	-0.0246	-0.0845	-0.0942	-0.03776
250	-0.0342	-0.05415	-0.0341	-0.025	-0.1167	-0.0221	-0.0264	-0.0778	-0.0907	-0.16569
275	-0.0514	-0.04557	-0.0514	-0.0728	-0.0998	-0.0649	-0.0862	-0.0859	-0.0891	-0.14927
300	-0.06	-0.05812	-0.06	-0.0502	-0.0939	-0.0669	-0.0669	-0.0527	-0.0763	-0.09822
325	-0.0304	-0.03227	-0.0304	-0.0347	-0.1006	-0.0307	-0.0377	-0.0915	-0.0808	-0.14494
350	-0.0383	-0.03333	-0.0383	-0.0518	-0.0799	-0.0337	-0.0845	-0.0834	-0.085	-0.0914
375	-0.0219	-0.05345	-0.0219	-0.0391	-0.0868	-0.0497	-0.0259	-0.0552	-0.098	-0.17087
400	-0.0356	-0.07569	-0.0356	-0.0485	-0.1374	-0.0682	-0.0258	-0.0662	-0.0891	-0.0749
425	-0.057	-0.06275	-0.057	-0.0378	-0.1022	-0.0655	-0.0304	-0.0831	-0.078	-0.1741
450	-0.0371	-0.04876	-0.0371	-0.0335	-0.1294	-0.0393	-0.054	-0.0597	-0.0912	-0.09916
475	-0.0592	-0.0722	-0.0592	-0.0335	-0.1365	-0.0839	-0.0324	-0.0749	-0.1118	-0.1824
500	-0.0439	-0.07042	-0.0439	-0.022	-0.1031	-0.0541	-0.0342	-0.1039	-0.088	-0.15683
525	-0.0395	-0.08239	-0.0395	-0.032	-0.0974	-0.0814	-0.067	-0.1191	-0.1024	-0.15722

Table 1.3: The values of cross (transverse) strain of fabric 02, after interpolation elongated in the weft direction

Force [N]	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain	Cross strain
25	-0.06	-0.07	-0.04	-0.06	-0.03	-0.05	-0.06	-0.07	-0.07	-0.09
50	-0.08	-0.07	-0.07	-0.08	-0.04	-0.10	-0.06	-0.09	-0.04	-0.09
75	-0.07	-0.05	-0.08	-0.07	-0.03	-0.08	-0.10	-0.11	-0.08	-0.14
100	-0.07	-0.09	-0.08	-0.07	-0.05	-0.09	-0.10	-0.11	-0.06	-0.13
125	-0.09	-0.10	-0.12	-0.09	-0.04	-0.10	-0.10	-0.14	-0.07	-0.15
150	-0.09	-0.09	-0.12	-0.09	-0.04	-0.08	-0.10	-0.10	-0.08	-0.17
175	-0.09	-0.06	-0.12	-0.10	-0.06	-0.12	-0.13	-0.14	-0.10	-0.17
200	-0.10	-0.07	-0.08	-0.10	-0.07	-0.08	-0.14	-0.16	-0.08	-0.16
225	-0.11	-0.08	-0.11	-0.11	-0.07	-0.11	-0.13	-0.14	-0.09	-0.19
250	-0.09	-0.06	-0.14	-0.09	-0.08	-0.11	-0.13	-0.17	-0.10	-0.19
275	-0.11	-0.04	-0.15	-0.11	-0.07	-0.13	-0.16	-0.16	-0.08	-0.17
300	-0.12	-0.05	-0.16	-0.12	-0.09	-0.13	-0.16	-0.16	-0.08	-0.18
325	-0.12	-0.07	-0.14	-0.12	-0.10	-0.12	-0.15	-0.16	-0.09	-0.19
350	-0.13	-0.05	-0.16	-0.13	-0.10	-0.14	-0.15	-0.18	-0.09	-0.20
375	-0.13	-0.07	0.16	-0.13	-0.11	-0.15	-0.15	-0.14	-0.12	-0.18
400	-0.13	-0.07	-0.12	-0.14	-0.11	-0.12	-0.13	-0.12	-0.10	-0.17
425	0.14	-0.06	-0.12	-0.14	-0.12	-0.13	-0.13	-0.14	-0.14	-0.23
450	-0.14	0.05	-0.14	-0.14	-0.10	-0.14	-0.12	-0.19	-0.11	-0.22
475	-0.14	-0.05	-0.13	-0.14	-0.12	-0.15	-0.13	-0.17	-0.10	-0.19
500	-0.12	-0.03	-0.13	-0.12	-0.14	-0.15	-0.13	-0.15	-0.10	-0.20
525	-0.15	-0.06	0.15	-0.15	-0.15	-0.15	-0.14	-0.20	-0.14	-0.20
550	-0.16	-0.06	-0.14	-0.15	-0.14	-0.17	-0.13	-0.17	-0.15	-0.22
575	-0.14	-0.07	-0.13	-0.14	-0.12	-0.16	-0.15	-0.17	-0.14	-0.22

Table 1.4: Strain o of fabric 02, after interpolation elongated in the weft direction

Force [N]	Strain 1	Strain 2	Strain 3	Strain 4	Strain 5	Strain 6	Strain 7	Strain 8	Strain 9	Strain 10
25	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.04
50	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.02	0.03	0.07
75	0.02	0.05	0.02	0.04	0.05	0.04	0.04	0.04	0.04	0.08
100	0.03	0.06	0.03	0.06	0.06	0.06	0.06	0.05	0.05	0.10
125	0.04	0.07	0.06	0.07	0.07	0.06	0.06	0.06	0.07	0.12
150	0.05	0.07	0.05	0.08	0.08	0.07	0.07	0.07	0.07	0.12
175	0.06	0.08	0.06	0.08	0.08	0.07	0.08	0.08	0.08	0.13
200	0.07	0.09	0.07	0.09	0.10	0.09	0.09	0.09	0.09	0.15
225	0.08	0.10	0.08	0.11	0.11	0.10	0.10	0.10	0.11	0.15
250	0.08	0.11	0.08	0.12	0.12	0.11	0.12	0.10	0.12	0.15
275	0.10	0.12	0.10	0.12	0.12	0.12	0.13	0.12	0.12	0.17
300	0.11	0.14	0.11	0.13	0.13	0.13	0.13	0.13	0.13	0.17
325	0.12	0.15	0.12	0.15	0.15	0.14	0.15	0.14	0.15	0.19
350	0.13	0.16	0.13	0.16	0.16	0.15	0.16	0.15	0.16	0.20
375	0.14	0.17	0.14	0.17	0.17	0.17	0.17	0.17	0.17	0.21
400	0.15	0.18	0.15	0.18	0.18	0.17	0.17	0.17	0.18	0.22
425	0.17	0.19	0.17	0.19	0.19	0.19	0.19	0.19	0.19	0.22
450	0.17	0.21	0.17	0.21	0.21	0.20	0.21	0.20	0.20	0.25
475	0.19	0.22	0.19	0.22	0.22	0.22	0.22	0.22	0.22	0.24
500	0.21	0.23	0.21	0.24	0.23	0.22	0.25	0.23	0.23	0.25
525	0.22	0.25	0.22	0.26	0.25	0.25	0.27	0.25	0.25	0.26

Table 1.5: The values of strain of fabric 02, after interpolation elongated in the warp direction

Force [N]	Strain 01 [-]	Strain 02 [-]	Strain 03 [-]	Strain 04 [-]	Strain 05 [-]	Strain 06 [-]	Strain 07 [-]	Strain 08 [-]	Strain 09 [-]	Strain 10 [-]
25	0.039	0.043	0.037	0.039	0.020	0.042	0.047	0.037	0.037	0.051
50	0.059	0.060	0.051	0.058	0.033	0.058	0.058	0.048	0.048	0.051
75	0.068	0.075	0.067	0.067	0.041	0.066	0.062	0.066	0.066	0.082
100	0.077	0.084	0.075	0.075	0.049	0.095	0.091	0.072	0.071	0.082
125	0.084	0.092	0.083	0.082	0.057	0.091	0.097	0.082	0.082	0.099
150	0.093	0.100	0.092	0.090	0.065	0.099	0.107	0.091	0.091	0.107
175	0.101	0.109	0.099	0.099	0.083	0.108	0.116	0.099	0.099	0.115
200	0.109	0.117	0.107	0.107	0.091	0.116	0.125	0.107	0.108	0.124
225	0.117	0.125	0.116	0.116	0.099	0.125	0.133	0.116	0.116	0.132
250	0.126	0.132	0.124	0.124	0.108	0.124	0.125	0.124	0.125	0.141
275	0.134	0.141	0.133	0.132	0.116	0.132	0.132	0.133	0.133	0.149
300	0.142	0.149	0.141	0.141	0.124	0.141	0.150	0.141	0.132	0.158
325	0.150	0.158	0.149	0.150	0.141	0.149	0.157	0.141	0.150	0.166
350	0.158	0.166	0.158	0.158	0.150	0.158	0.166	0.149	0.149	0.174
375	0.167	0.175	0.158	0.166	0.158	0.166	0.174	0.158	0.158	0.183
400	0.177	0.183	0.164	0.176	0.175	0.177	0.196	0.172	0.170	0.192
425	0.176	0.190	0.173	0.191	0.187	0.184	0.202	0.179	0.177	0.200
450	0.181	0.180	0.182	0.195	0.198	0.191	0.196	0.185	0.184	0.207
475	0.190	0.196	0.193	0.200	0.212	0.201	0.206	0.193	0.191	0.216
500	0.198	0.217	0.200	0.207	0.226	0.211	0.200	0.200	0.201	0.227
525	0.206	0.224	0.214	0.215	0.239	0.222	0.196	0.212	0.207	0.234
550	0.215	0.232	0.206	0.222	0.255	0.222	0.229	0.216	0.214	0.242
575	0.230	0.241	0.221	0.230	0.275	0.230	0.243	0.226	0.222	0.250

Table 1.6: The values of Etha of fabric 02, after interpolation elongated in the warp direction

Force [N]	Etha 01 [-]	Etha 02 [-]	Etha 03 [-]	Etha 04 [-]	Etha 05 [-]	Etha 06 [-]	Etha 07 [-]	Etha 08 [-]	Etha 09 [-]	Etha 10 [-]
25	1.99	0.58	1.16	1.31	1.21	0.84	0.70	1.13	1.98	1.13
50	1.27	0.80	2.28	1.01	1.32	1.04	0.60	1.64	2.28	1.33
75	1.27	0.76	2.29	0.73	1.13	0.76	0.76	1.01	2.29	1.41
100	1.22	0.65	1.22	0.62	1.34	0.61	0.62	0.71	1.22	1.35
125	0.80	0.79	0.97	0.75	1.18	0.56	0.45	0.85	0.97	1.24
150	0.93	0.66	0.93	0.65	1.04	0.48	0.37	0.80	0.93	1.22
175	0.84	0.40	0.84	0.53	1.31	0.40	0.40	0.63	0.84	1.16
200	0.75	0.46	0.75	0.53	0.90	0.46	0.31	0.80	0.75	1.05
225	0.59	0.36	0.59	0.40	1.01	0.36	0.24	0.68	0.59	0.84
250	0.46	0.39	0.57	0.48	0.90	0.39	0.30	0.78	0.57	0.92
275	0.54	0.46	0.54	0.30	0.75	0.46	0.30	0.54	0.54	0.90
300	0.40	0.36	0.40	0.28	0.70	0.36	0.30	0.52	0.40	0.85
325	0.28	0.22	0.28	0.28	0.59	0.22	0.24	0.60	0.28	0.82
350	0.34	0.22	0.34	0.40	0.51	0.22	0.19	0.55	0.34	0.90
375	0.26	0.35	0.20	0.40	0.61	0.35	0.27	0.36	0.20	0.80
400	0.24	0.42	0.24	0.28	0.64	0.42	0.20	0.39	0.24	0.73
425	0.28	0.27	0.28	0.25	0.54	0.27	0.17	0.36	0.28	0.77
450	0.16	0.23	0.16	0.20	0.63	0.23	0.24	0.33	0.16	0.82
475	0.26	0.31	0.27	0.11	0.63	0.31	0.21	0.36	0.27	0.76
500	0.19	0.29	0.19	0.13	0.45	0.29	0.22	0.46	0.29	0.66
525	0.24	0.33	0.24	0.12	0.46	0.33	0.27	0.45	0.24	0.66

Table1.7: The values of Etha (Poisson's ratio) of fabric 02, after interpolation elongated in the weft direction

Force [N]	Eth a 01 [-]	Etha 02 [-]	Etha 03 [-]	Etha 04 [-]	Etha 05 [-]	Etha 06 [-]	Etha 07 [-]	Etha 08 [-]	Etha 09 [-]	Etha 10 [-]
25	1.71	1.15	1.25	1.37	1.03	1.57	0.94	1.64	1.36	1.57
50	1.27	1.48	1.44	1.14	1.31	1.35	1.19	1.86	0.47	1.44
75	1.16	0.95	1.11	0.97	1.15	1.71	1.07	1.48	0.94	1.59
100	1.08	1.08	1.32	1.03	0.84	1.71	1.10	1.59	0.83	1.52
125	0.97	0.91	1.32	0.97	0.69	0.84	0.99	1.22	0.89	1.55
150	0.91	0.66	1.19	0.91	0.79	1.02	1.19	1.30	0.94	1.51
175	0.78	0.60	0.90	0.92	0.75	0.79	1.23	1.42	0.77	1.32
200	0.78	0.66	0.91	0.76	0.73	0.81	1.07	1.41	1.05	1.37
225	0.78	0.55	1.06	0.79	0.76	0.94	1.03	1.36	0.64	1.35
250	0.83	0.36	1.13	0.83	0.63	0.91	1.04	1.25	0.75	1.20
275	0.87	0.35	1.12	0.87	0.69	0.81	0.97	1.18	0.70	1.16
300	0.83	0.40	1.00	0.83	0.74	0.87	0.93	1.00	0.72	1.16
325	0.81	0.35	0.80	0.81	0.69	0.85	0.93	1.20	0.61	1.16
350	0.81	0.37	1.02	0.81	0.70	0.90	0.88	0.97	0.72	1.04
375	0.79	0.40	0.79	0.79	0.68	0.73	0.70	0.74	0.63	0.92
400	0.76	0.58	0.71	0.76	0.63	0.72	0.64	0.77	0.72	1.10
425	0.76	0.32	0.75	0.72	0.54	0.73	0.65	0.95	0.64	1.11
450	0.73	0.26	0.69	0.73	0.59	0.73	0.61	0.91	0.52	1.09
475	0.64	0.18	0.68	0.64	0.55	0.66	0.64	0.79	0.50	0.92
500	0.67	0.23	0.69	0.69	0.62	0.59	0.60	0.84	0.62	0.87
525	0.68	0.25	0.68	0.69	0.57	0.59	0.61	0.95	0.70	0.89
550	0.64	0.30	0.63	0.64	0.48	0.58	0.62	0.82	0.65	0.88
575	0.55	0.26	0.57	0.68	0.44	0.66	0.64	0.93	0.58	0.85

Table1.8: The Mean values of strain of fabric 02, after interpolation elongated in the warp direction

Force [N]	Sum	Mean	Std	Std+mean	Std-mean
25	0.195527	0.019553	0.000582	0.027181	0.011925
50	0.33966	0.033966	0.00132	0.045455	0.022477
75	0.422314	0.042231	0.00281	0.058995	0.025468
100	0.54243	0.054243	0.003679	0.073424	0.035062
125	0.655653	0.065565	0.003756	0.084945	0.046186
150	0.746807	0.074681	0.003725	0.093981	0.05538
175	0.821777	0.082178	0.003765	0.101582	0.062774
200	0.932829	0.093283	0.004654	0.114855	0.071711
225	1.026152	0.102615	0.003851	0.122239	0.082992
250	1.107253	0.110725	0.003092	0.12831	0.09314
275	1.234271	0.123427	0.003548	0.142263	0.104591
300	1.313382	0.131338	0.002276	0.146424	0.116253
325	1.451714	0.145171	0.003834	0.164752	0.125591
350	1.536986	0.153699	0.003811	0.173222	0.134176
375	1.654735	0.165473	0.002987	0.182756	0.148191
400	1.76633	0.176633	0.003206	0.194539	0.158727
425	1.895652	0.189565	0.002294	0.204712	0.174418
450	2.022521	0.202252	0.003673	0.221417	0.183087
475	2.165284	0.216528	0.002122	0.231096	0.201961
500	2.313882	0.231388	0.001969	0.245419	0.217358
525	2.479826	0.247983	0.001649	0.260823	0.235142

Table 1.9: The Mean values of strain of fabric 02, after interpolation elongated in the weft direction

Force[N]	Sum	Mean	Std	Std+mean	Std-mean
25	0.390702	0.03907	0.000618	0.046933	0.031207
50	0.52533	0.052533	0.000616	0.060382	0.044684
75	0.658523	0.065852	0.001013	0.075918	0.055787
100	0.76902	0.076902	0.001458	0.088977	0.064827
125	0.849845	0.084984	0.001217	0.096018	0.073951
150	0.936108	0.093611	0.00129	0.104967	0.082255
175	1.02812	0.102812	0.000836	0.111957	0.093667
200	1.11115	0.111115	0.000858	0.12038	0.10185
225	1.195986	0.119599	0.000871	0.128934	0.110264
250	1.252719	0.125272	0.000605	0.133053	0.117491
275	1.335582	0.133558	0.000618	0.141419	0.125698
300	1.41962	0.141962	0.00077	0.150736	0.133188
325	1.511329	0.151133	0.000527	0.158395	0.143871
350	1.586303	0.15863	0.000625	0.166534	0.150727
375	1.66158	0.166158	0.000698	0.174513	0.157803
400	1.781373	0.178137	0.00082	0.187191	0.169084
425	1.857671	0.185767	0.000918	0.195346	0.176188
450	1.899204	0.18992	0.000743	0.198542	0.181299
475	1.997938	0.199794	0.000735	0.208369	0.191219
500	2.087753	0.208775	0.001091	0.219222	0.198329
525	2.168396	0.21684	0.001511	0.229131	0.204548
550	2.253078	0.225308	0.001917	0.239154	0.211461
575	2.368137	0.236814	0.002428	0.252395	0.221232

Table 1.10: The Mean values of Etha (Poisson's ratio) of fabric 02, after interpolation elongated in the warp direction

Force[N]	Sum	Mean	Std	Std+mean	Std-mean
25	12.02448	1.202448	2.038661	1.653963	0.750932
50	13.58927	1.358927	2.899185	1.897368	0.820486
75	12.39934	1.239934	3.268707	1.81166	0.668208
100	9.547682	0.954768	1.0152	1.27339	0.636146
125	8.543454	0.854345	0.546919	1.088208	0.620482
150	7.9859	0.79859	0.617645	1.047115	0.550065
175	7.366171	0.736617	0.924468	1.040668	0.432566
200	6.735483	0.673548	0.471411	0.890668	0.456428
225	5.657167	0.565717	0.500636	0.789466	0.341968
250	5.757374	0.575737	0.431582	0.783483	0.367992
275	5.318231	0.531823	0.297987	0.704446	0.3592
300	4.590352	0.459035	0.305317	0.633768	0.284302
325	3.822408	0.382241	0.390083	0.579746	0.184735
350	4.010016	0.401002	0.399965	0.600993	0.20101
375	3.783057	0.378306	0.321016	0.557475	0.199136
400	3.781307	0.378131	0.294473	0.549733	0.206529
425	3.454778	0.345478	0.280128	0.512848	0.178108
450	3.149748	0.314975	0.460715	0.529618	0.100332
475	3.50795	0.350795	0.34974	0.537808	0.163782
500	3.17947	0.317947	0.23718	0.471954	0.16394
525	3.217853	0.321785	0.278228	0.488587	0.154984

Table 1.11: The Mean values of strain of fabric 02, after interpolation elongated in the weft direction

Force [N]	Sum	Mean	Std	Std+mean	Std-mean
25	13.56974	1.356974	0.627232	1.60742	1.106528
50	12.95812	1.295812	1.119348	1.630378	0.961245
75	12.12458	1.212458	0.690012	1.475139	0.949778
100	12.09975	1.209975	0.861954	1.503565	0.916384
125	10.35753	1.035753	0.582877	1.277181	0.794324
150	10.41789	1.041789	0.586209	1.283907	0.799672
175	9.488405	0.948841	0.692025	1.211904	0.685777
200	9.54893	0.954893	0.629824	1.205856	0.70393
225	9.267841	0.926784	0.686274	1.188752	0.664816
250	8.936514	0.893651	0.678346	1.154102	0.633201
275	8.708967	0.870897	0.581824	1.112107	0.629686
300	8.485722	0.848572	0.377792	1.042941	0.654204
325	8.226418	0.822642	0.5627	1.059855	0.585429
350	8.222216	0.822222	0.344612	1.007859	0.636584
375	7.195147	0.719515	0.168221	0.849215	0.589815
400	7.388535	0.738854	0.177928	0.872243	0.605464
425	7.176323	0.717632	0.411125	0.920395	0.51487
450	6.86491	0.686491	0.441874	0.896699	0.476283
475	6.197252	0.619725	0.341427	0.804503	0.434948
500	6.420426	0.642043	0.27198	0.806961	0.477124
525	6.601398	0.66014	0.323143	0.839902	0.480378
550	6.225431	0.622543	0.237061	0.776511	0.468575
575	6.160749	0.616075	0.320689	0.795153	0.436997

4.1.1. The relationship between Etha (Poisson's ratio) and relative strain, for elongation in the warp direction

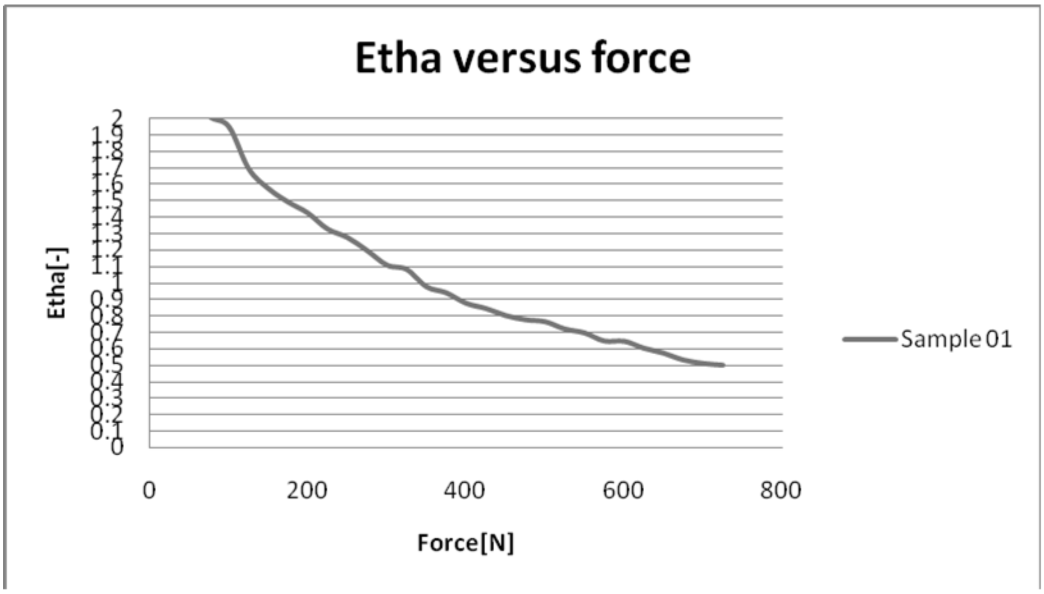

Figure: 4.1 .1(a) Relationship between Etha and Force, fabric 01

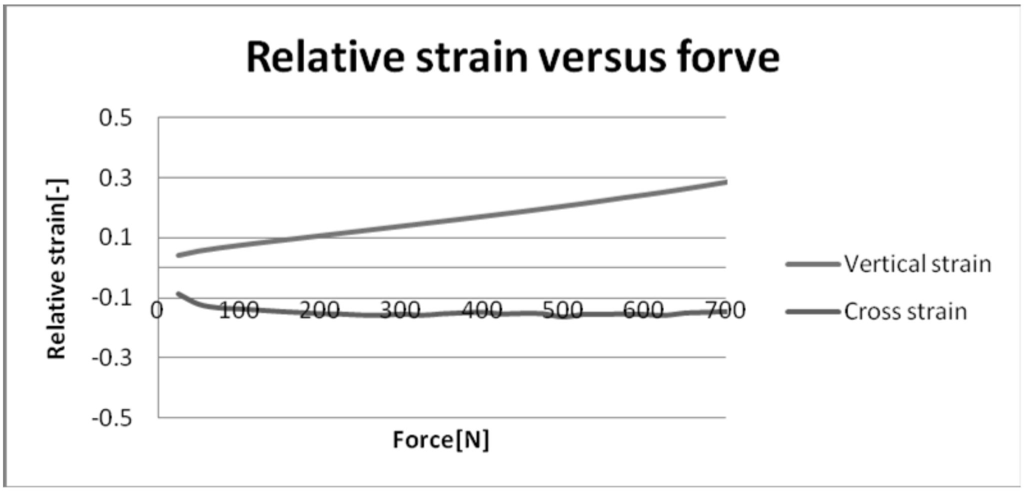

Figure: 4.1.1(b) The relationship between relative strain and force, fabric 01

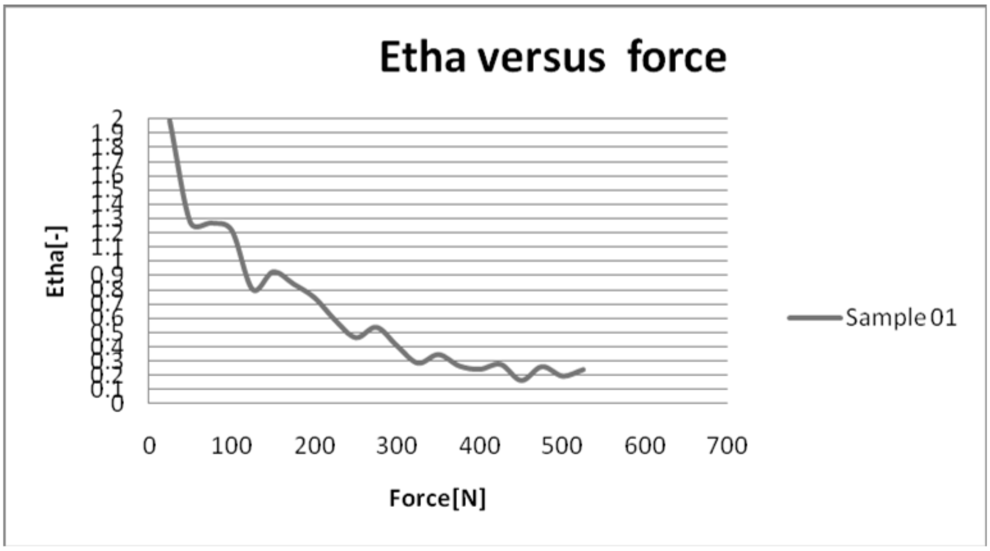

Figure: 4.1.2(a) Relationship between Etha and Force, fabric 02

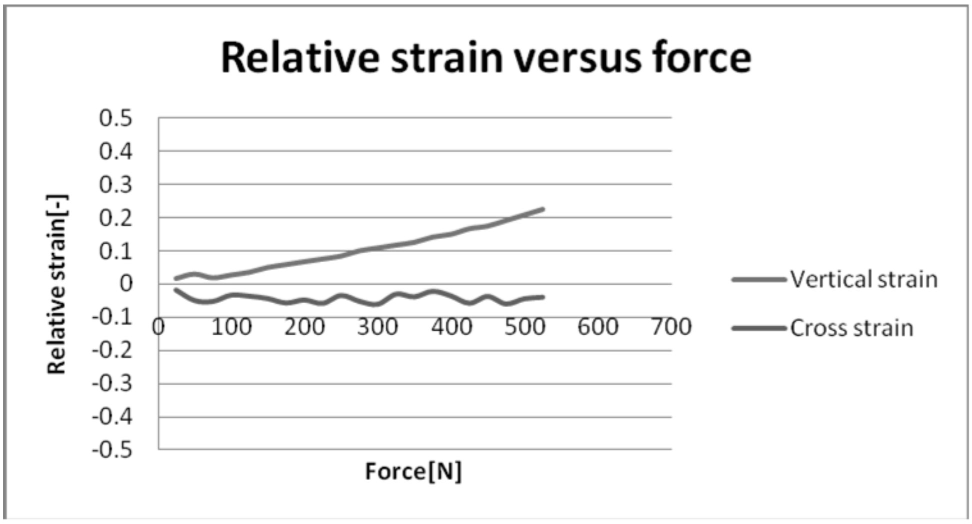

Figure: 4.1.2(b) The relationship between relative strain and force, fabric 02

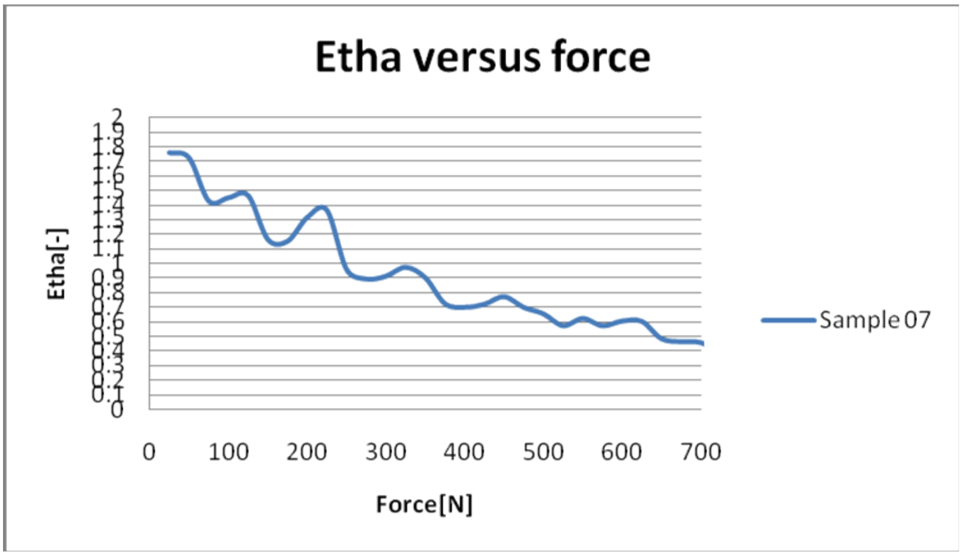

Figure: 4.3(a) Relationship between Etha and Force, fabric 03

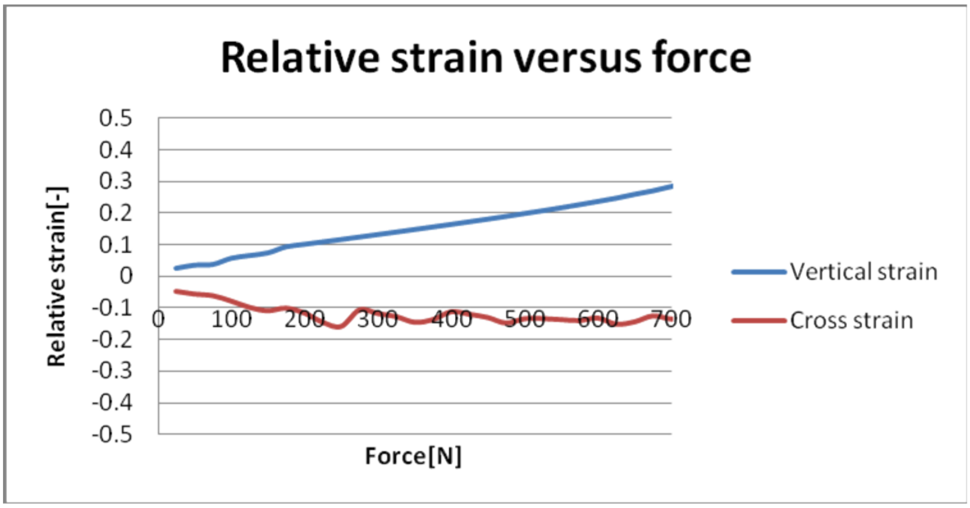

Figure: 4.1.3(b) The relationship between relative strain and force, fabric 03

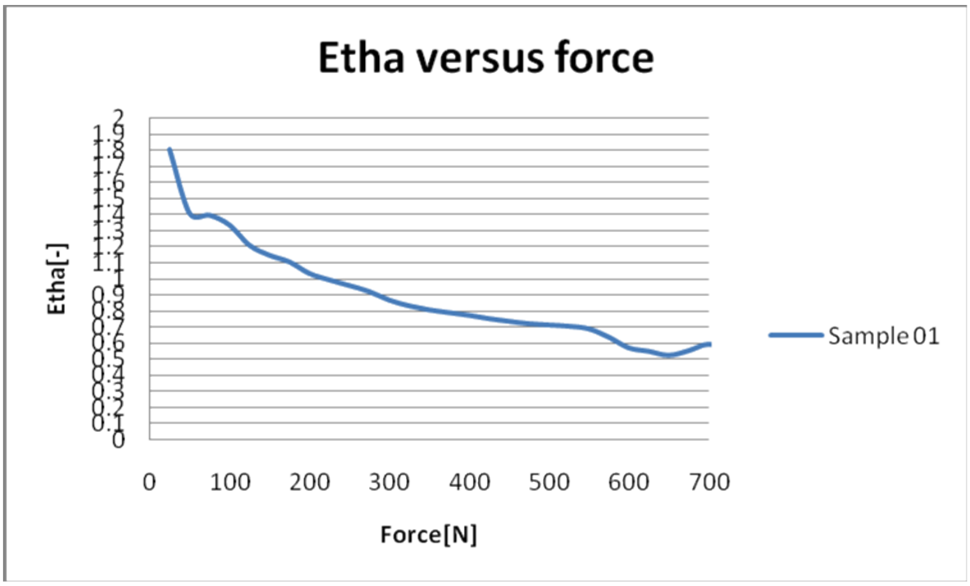

Figure: 4.4(a) Relationship between Etha and Force, fabric 04

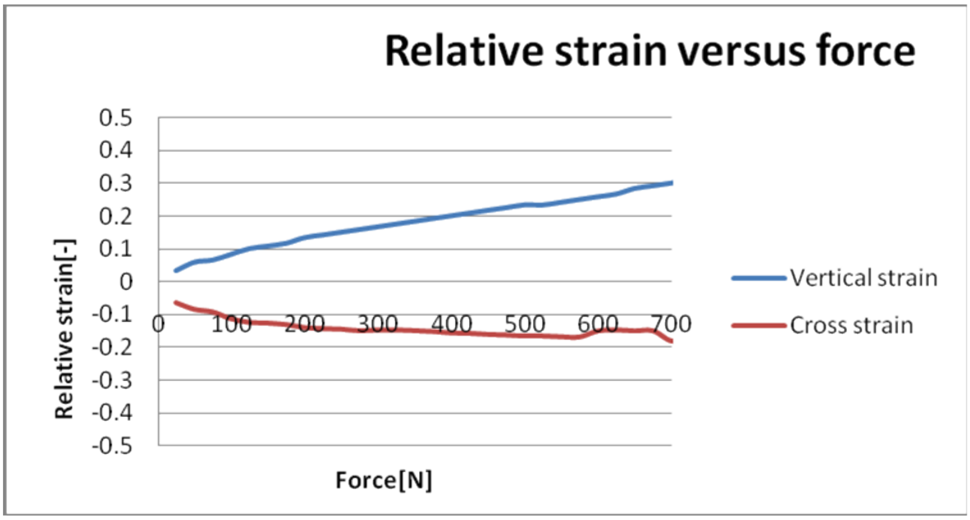

Figure: 4.1.3(b) The relationship between relative strain and force, fabric 04

4.1.1. The relationship between Etha (Poisson's ratio) and relative strain, for elongation in the weft direction

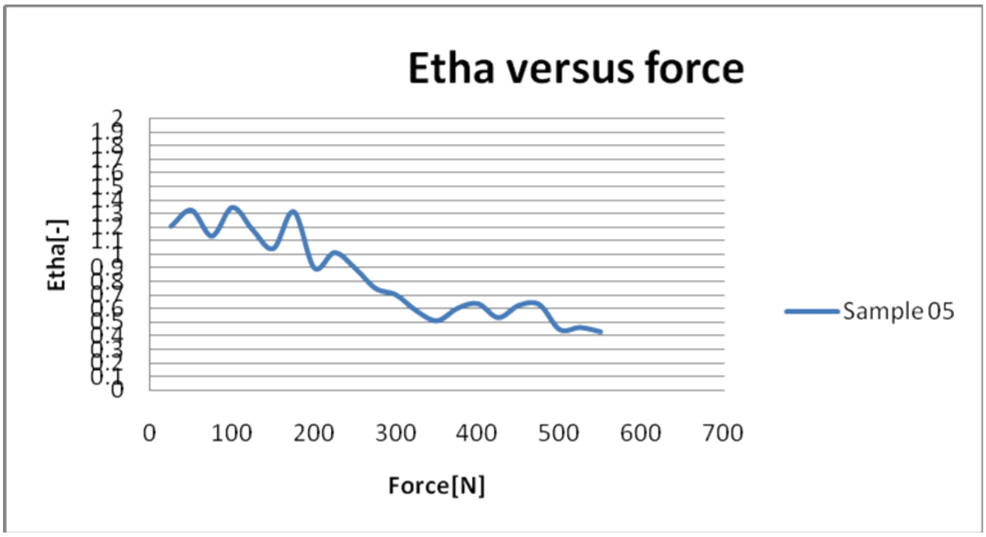

Figure: 4.1.1(a) The relationship between Etha and Force, fabric 01

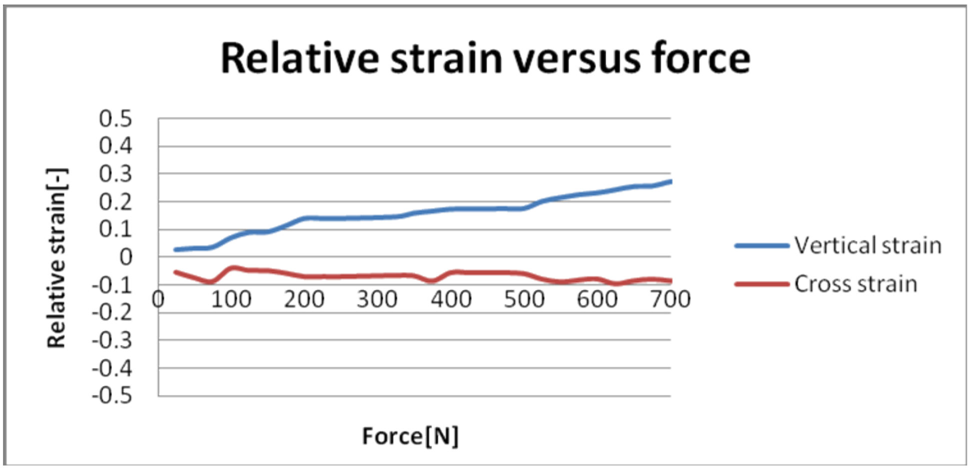

Figure: 4.1.1. (b)The relationship between relative strain and force, fabric 01

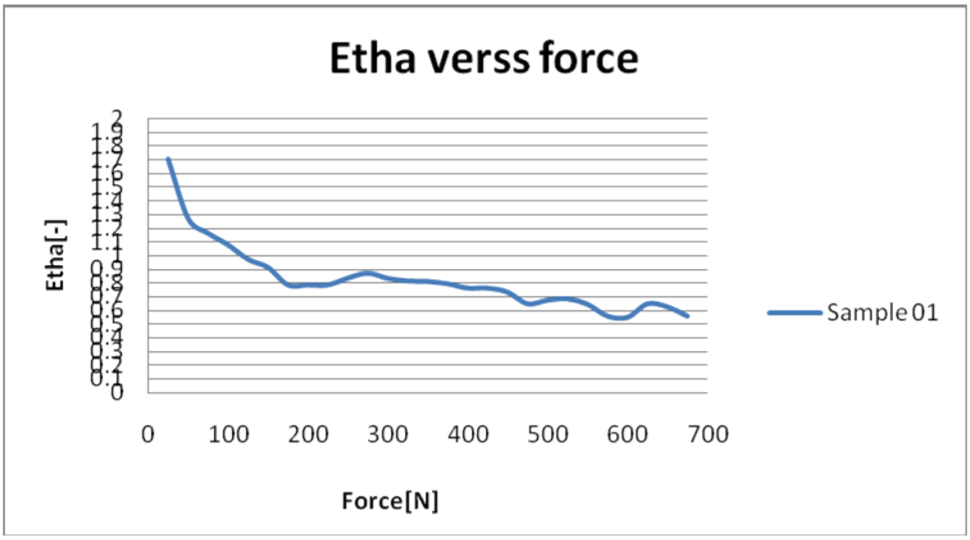

Figure: 4.1.2(a) Relationship between Etha and Force, fabric 02

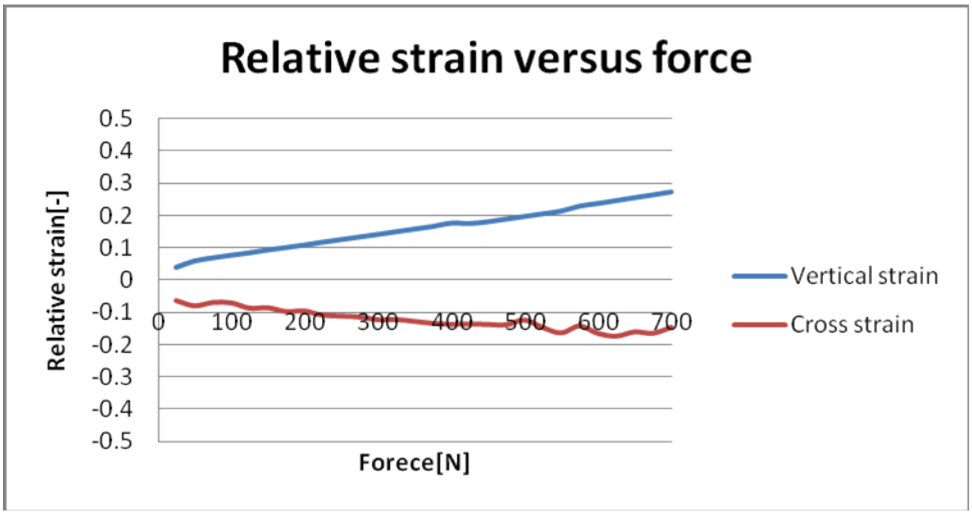

Figure: 4.1.3(b) The relationship between relative strain and force ,fabric 02

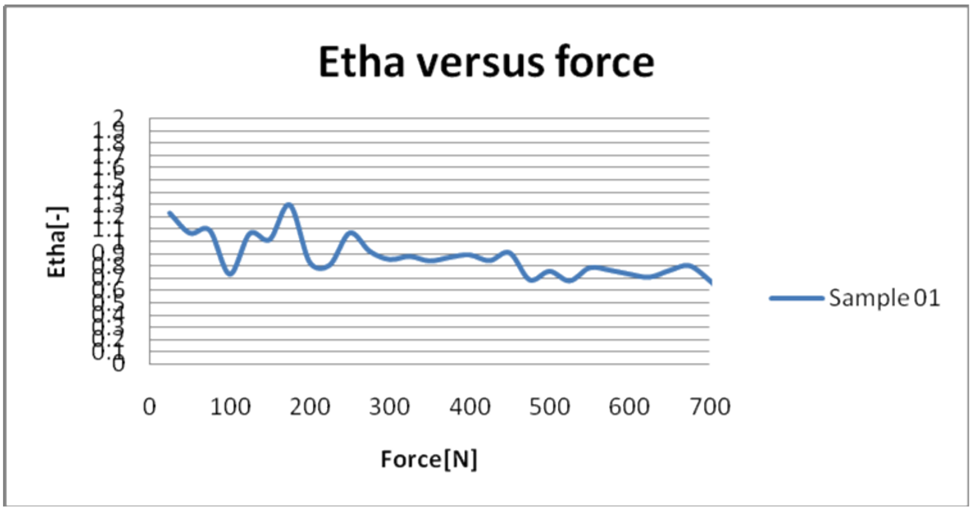

Figure: 4.1.3(b) Relationship between Etha and Force , fabric 03

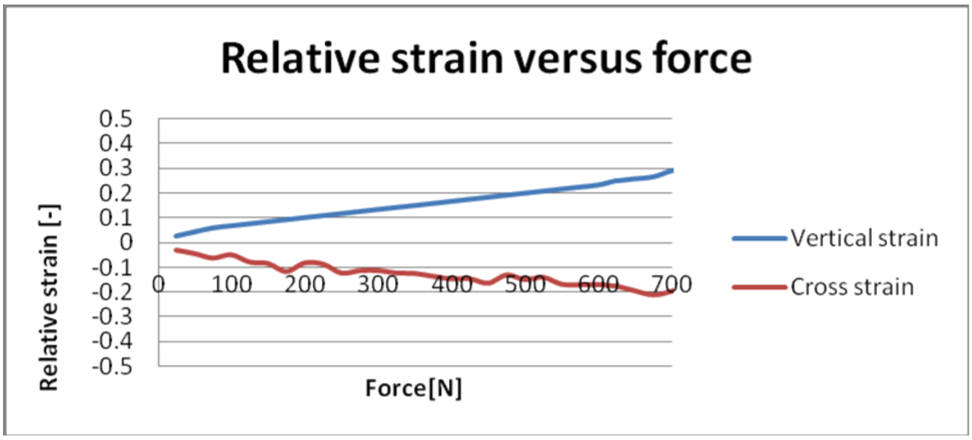

Figure: 4.1.3(b) The relationship between relative strain and force, fabric 03

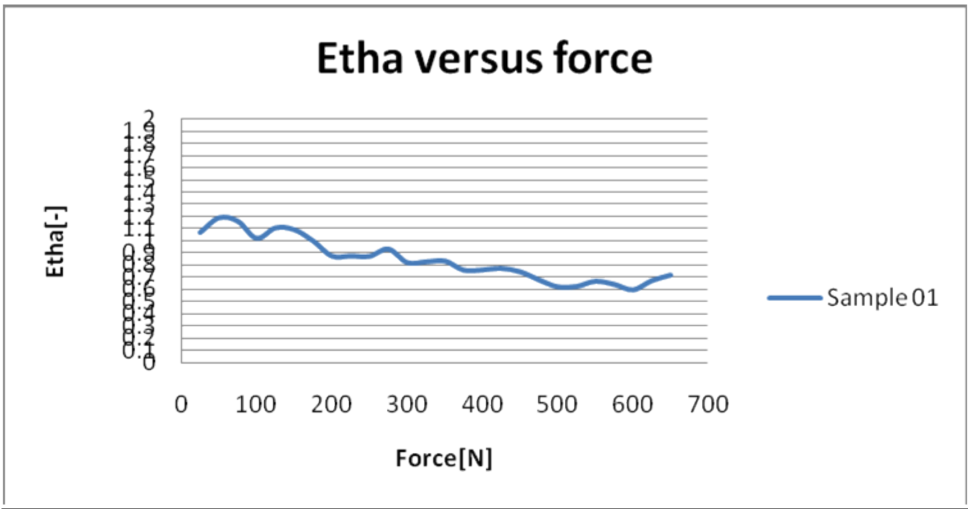

Figure: 4.1.4(a) Relationship between Etha and Force, fabric 04

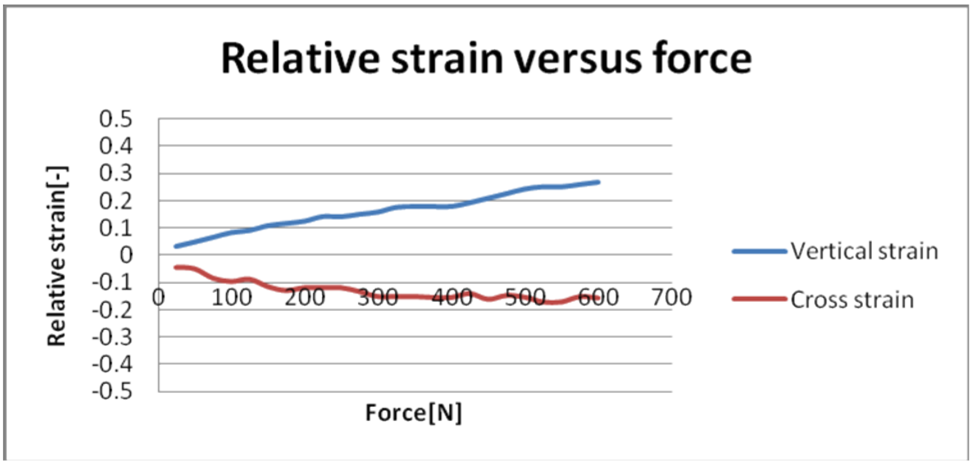

Figure: 4.1.4(b) The relationship between relative strain and force, fabric 04

4.2 Secondary and statistical evaluations

Interpolation of Etha (Poisson 's ratio) at interval of 25 forces until the maximum force at break for all samples of fabrics was done due to the fact that the samples did not break at the same force.

4.2.1 Relationship between strain and force for, elongation in the warp direction

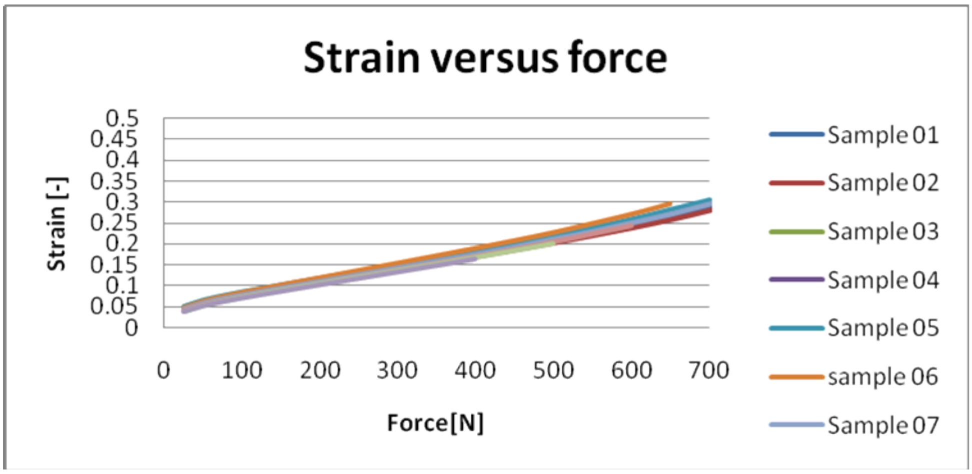

Figure: 4.2.1(a) Overall curves for strain versus force of all samples together, fabric 01

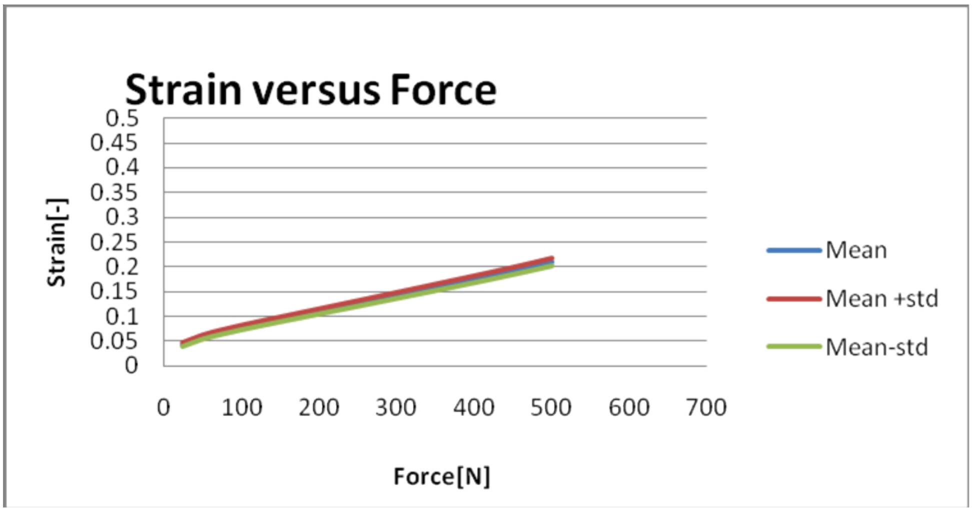

Figure: 4.2.1(b) Mean curves for strain versus force of all samples together , fabric 01

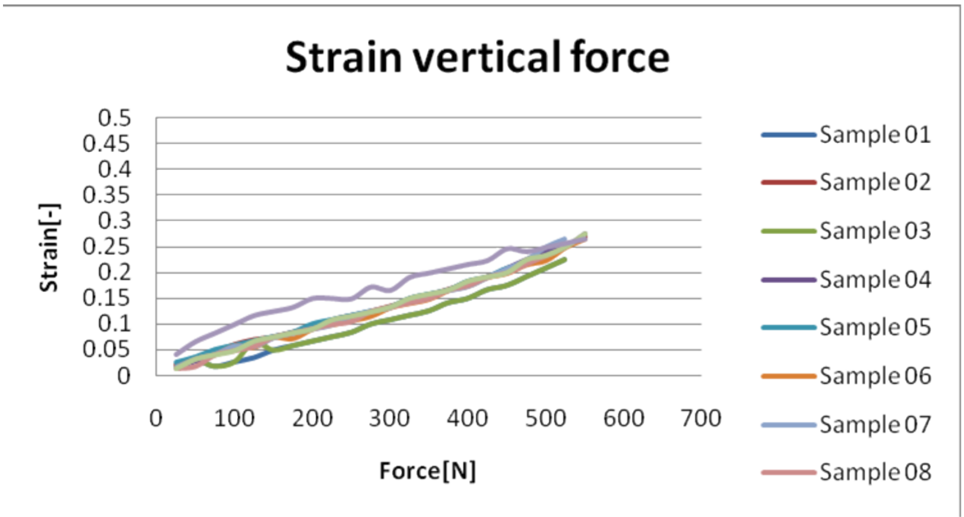

Figure: 4.2.2(a) Overall curves for strain versus force of all sample together, fabric 02

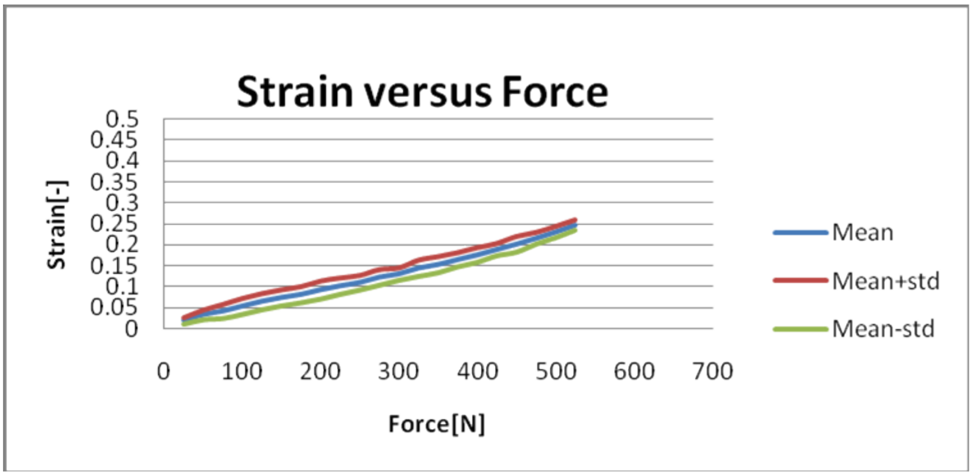

Figure: 4.2.2(b) Mean curves for strain versus force of all samples together, fabric 02

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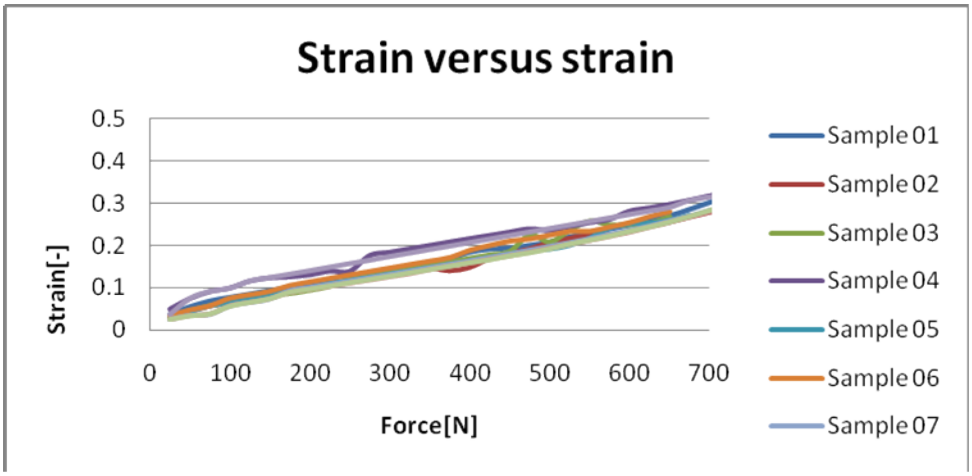

Figure: 4.2.3(a) Overall curves for strain versus force of all sample together, fabric 03

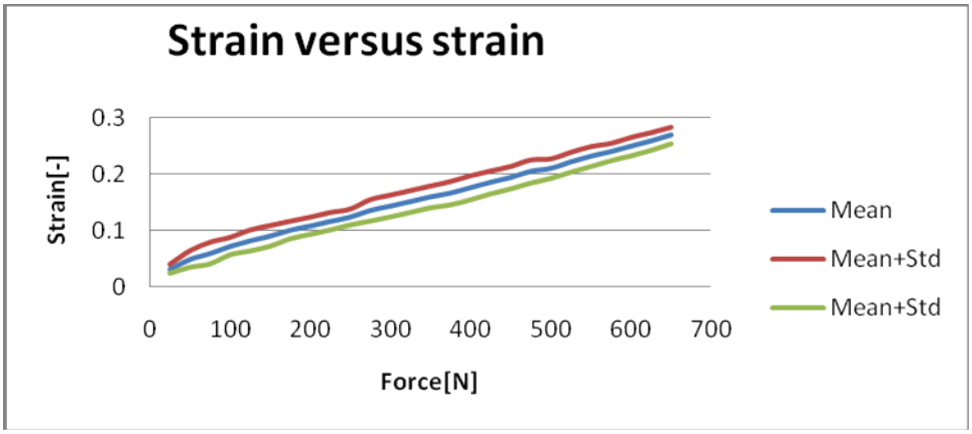

Figure: 4.2.3(a) Mean curves for strain versus force of all samples together, fabric 03

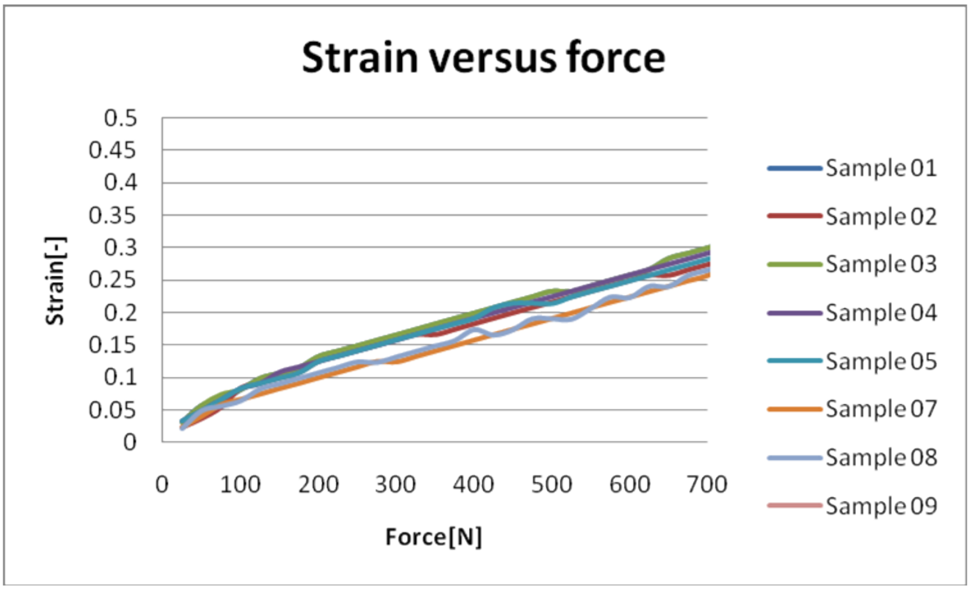

Figure: 4.2.4(a) Overall curves for strain versus force of all samples together, fabric 04

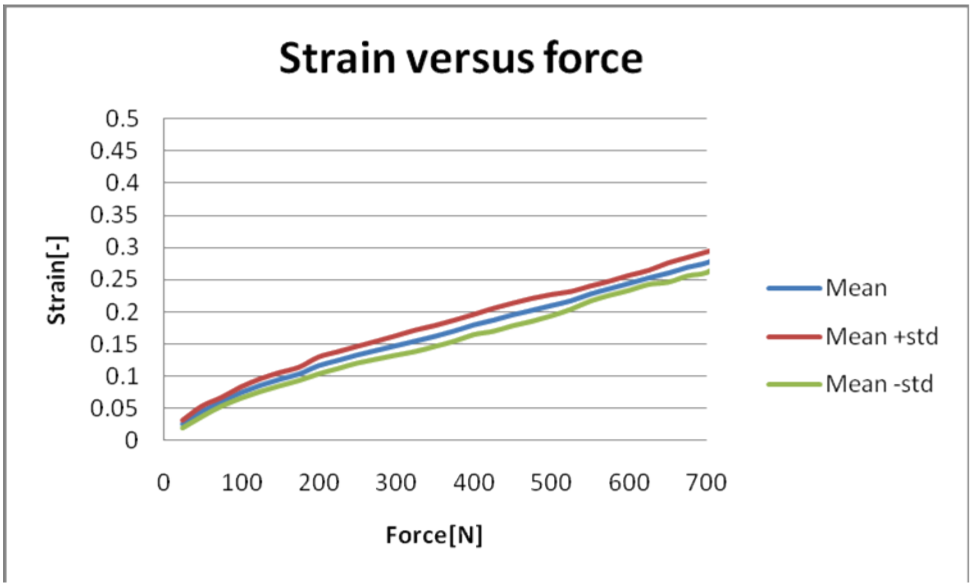

Figure: 4.2.4(a) Mean curves for strain versus force of all samples together, fabric 04

4.2.2 Relationship between strain and force for, elongation in the weft direction

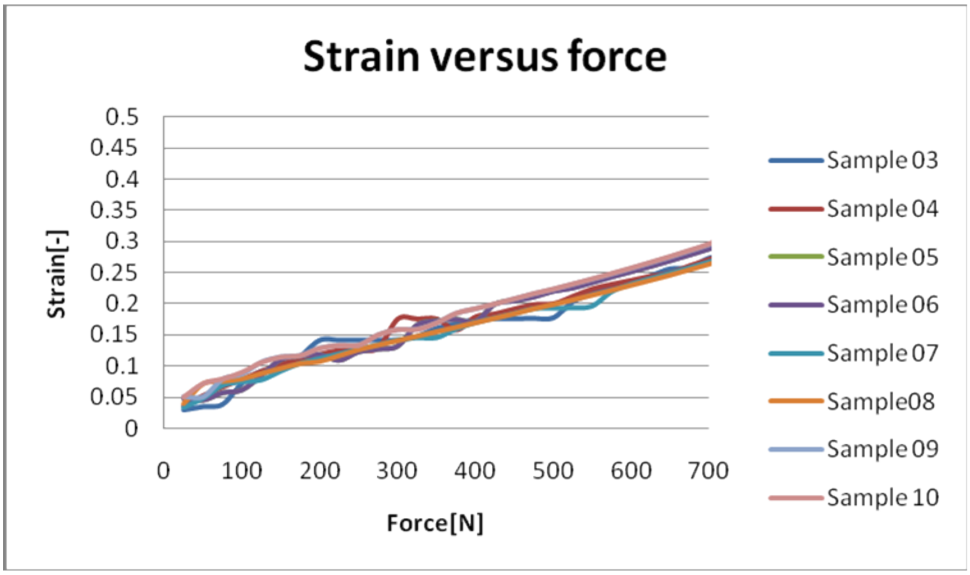

Figure: 4.2.1 .1(a) Overall curves for strain versus force of all samples together, fabric 01

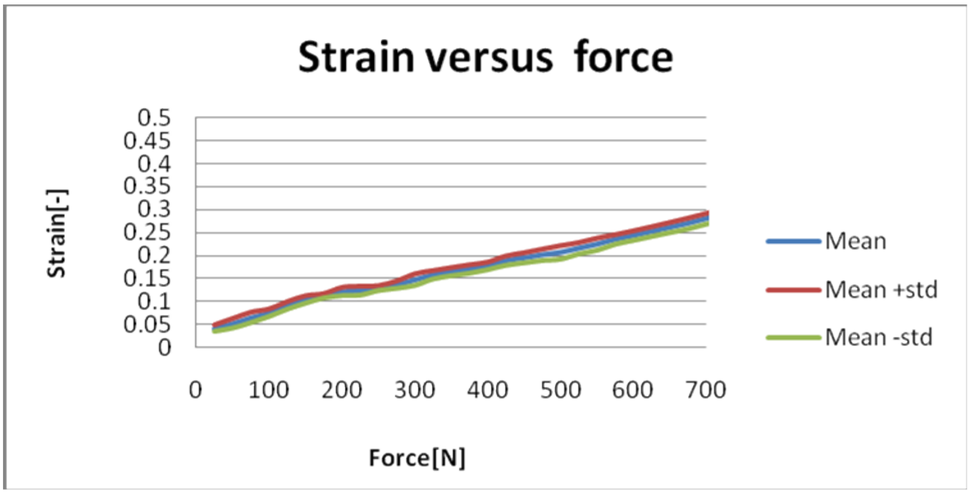

Figure: 4.2.1.1(b) Mean curves for strain versus force of all samples together, fabric 01

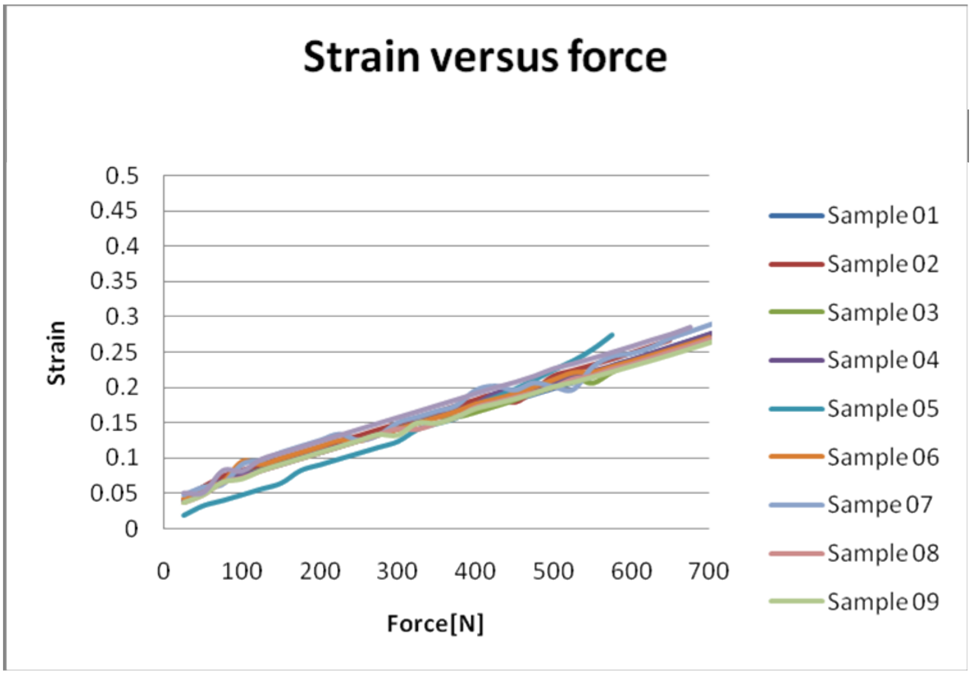

Figure: 4.2.1 .2(a) Overall curves for strain versus force of all samples together, fabric 02

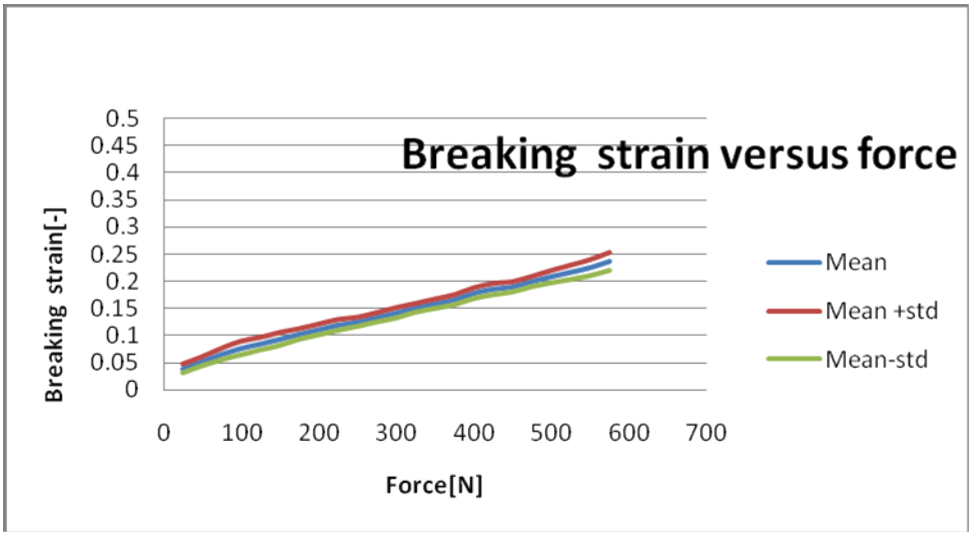

Figure: 4.2.1.2(b) Mean curves for strain versus force of all samples together, fabric 02

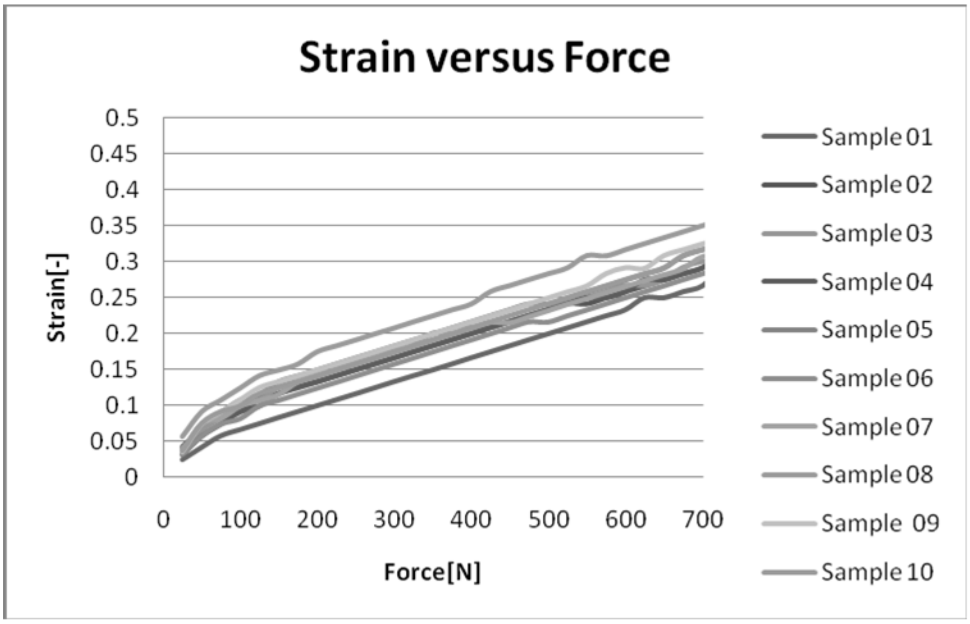

Figure: 4.2.1.3(a) Overall curves for strain versus force of all samples together, fabric 03

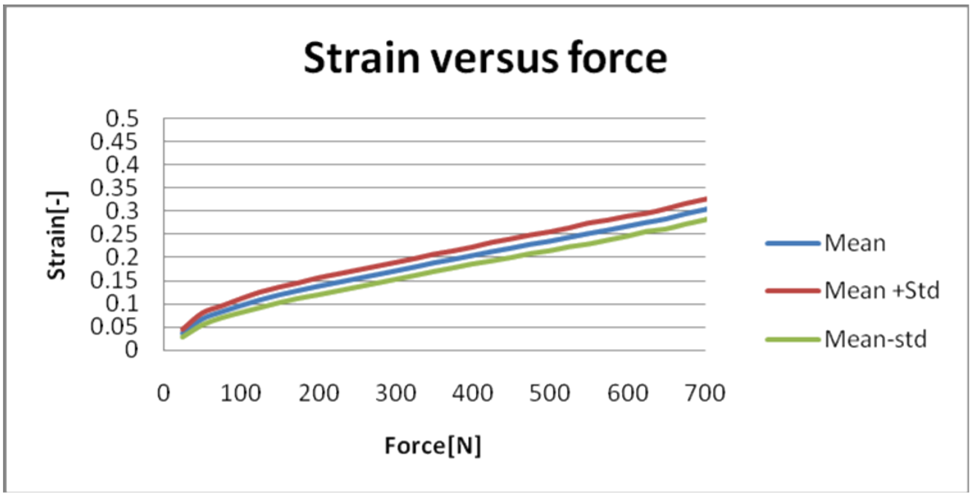

Figure: 4.2.1 .3(b) Mean curves for strain versus force of all samples together, fabric 03

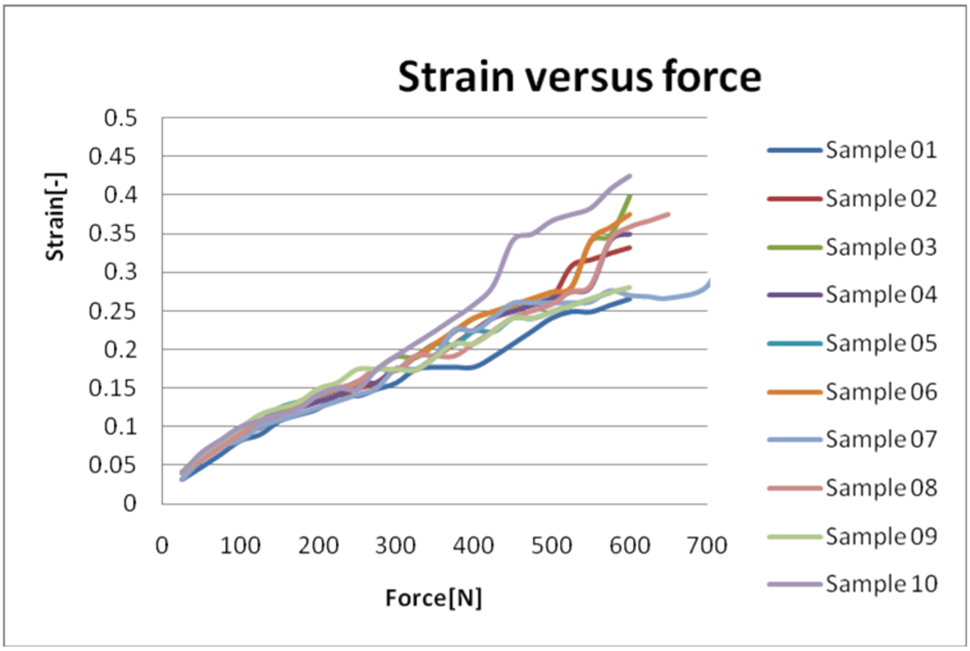

Figure: 4.2.1 .4(a) Overall curves for strain versus force of all samples together, fabric 04

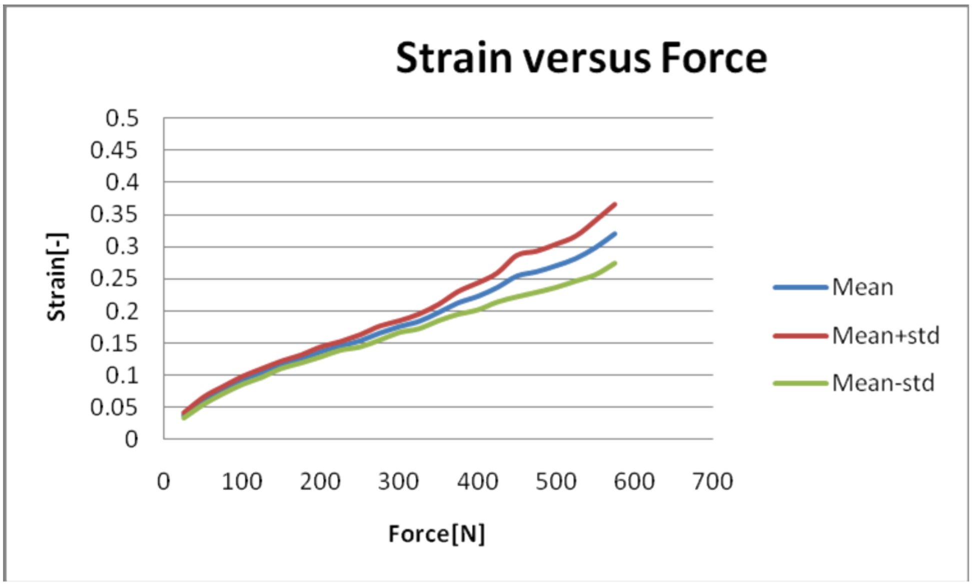

Figure: 4.2.1 .4(b) Mean curves for strain versus force of all samples together, fabric 04

4.2.3 Relationship between Etha (Poisson's ratio) and Strain; elongation in the warp direction

Interpolation of Etha (Poisson's) at interval of 25 forces until the maximum force at break for all samples of fabrics was done due to the fact that the samples did not break at the same force.

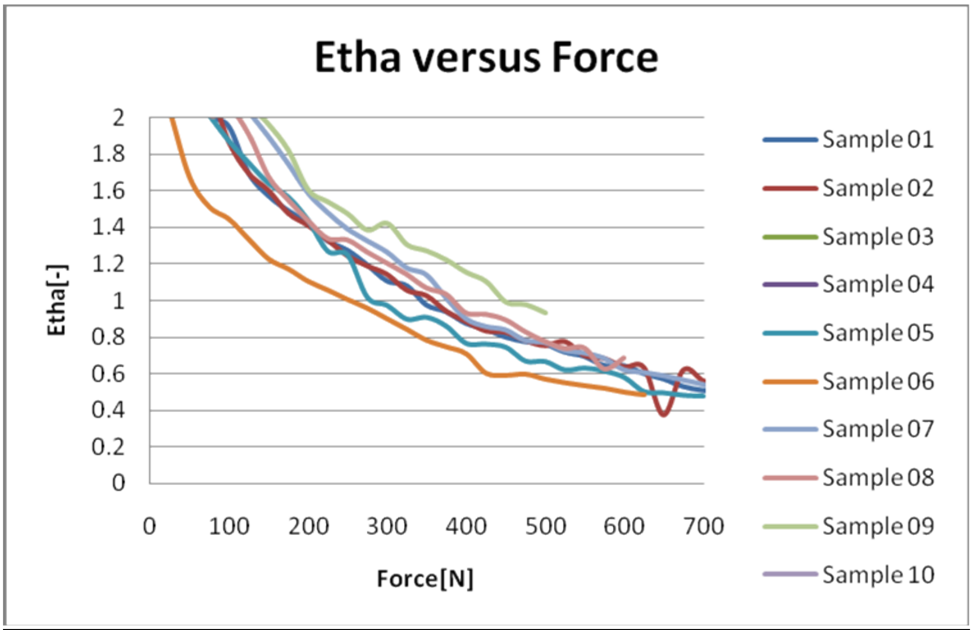

Figure: 4.2.2 .1(a) Overall curves for Etha versus strain of all samples together, fabric 01

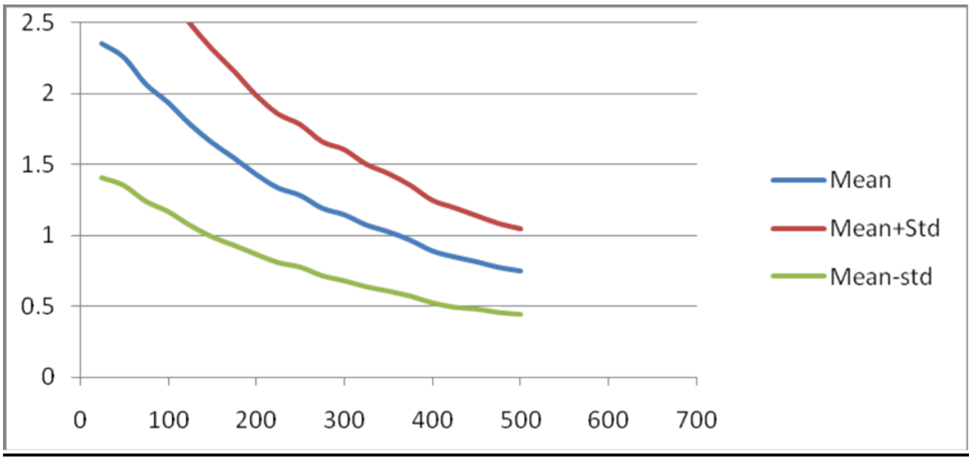

Figure: 4.2.2 .1(b) Mean curves for Etha versus strain of all samples together, fabric 01

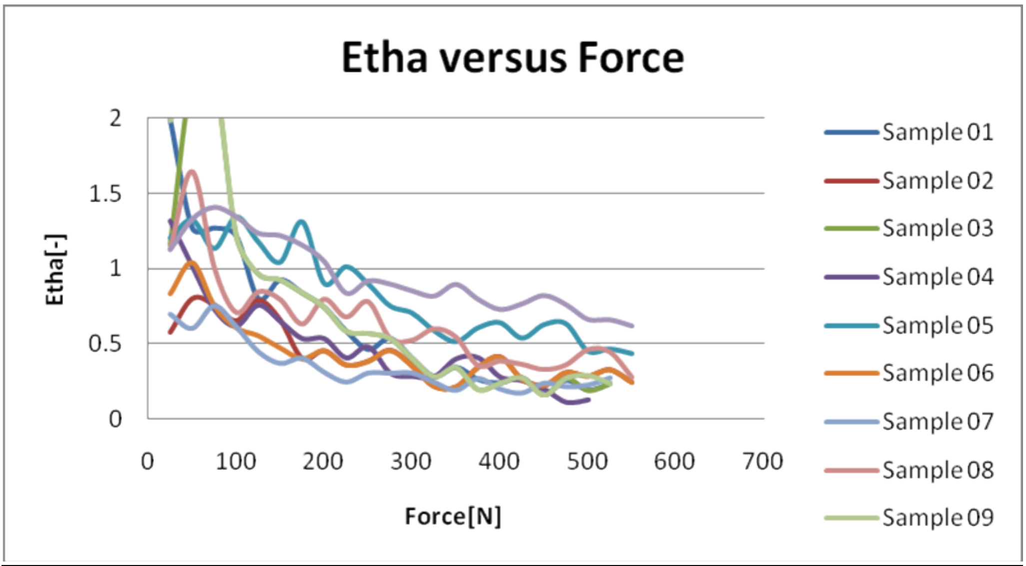

Figure: 4.2.2 .2(a) Overall of all samples together on the same curve, fabric 02

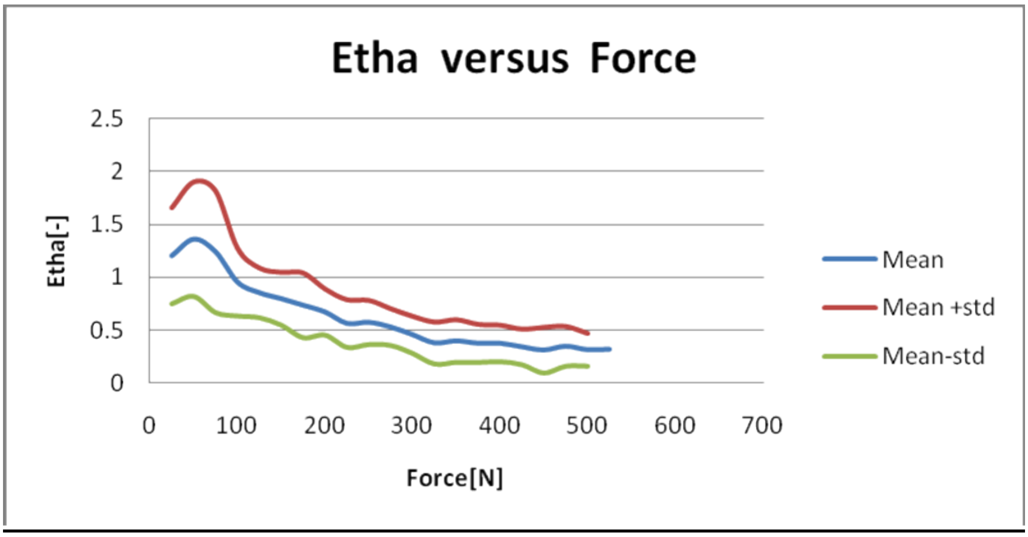

Figure: 4.2.2 .2(b) Mean curves for Etha versus strain of all sample together, fabric 02

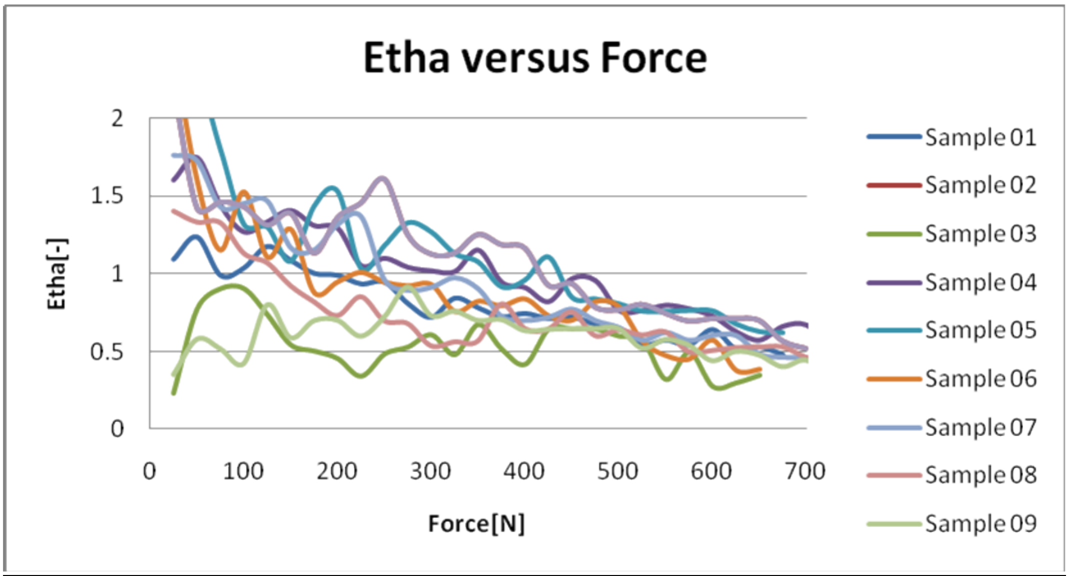

Figure: 4.2.2 .3(a) Overall of all samples together on same curve, fabric 03

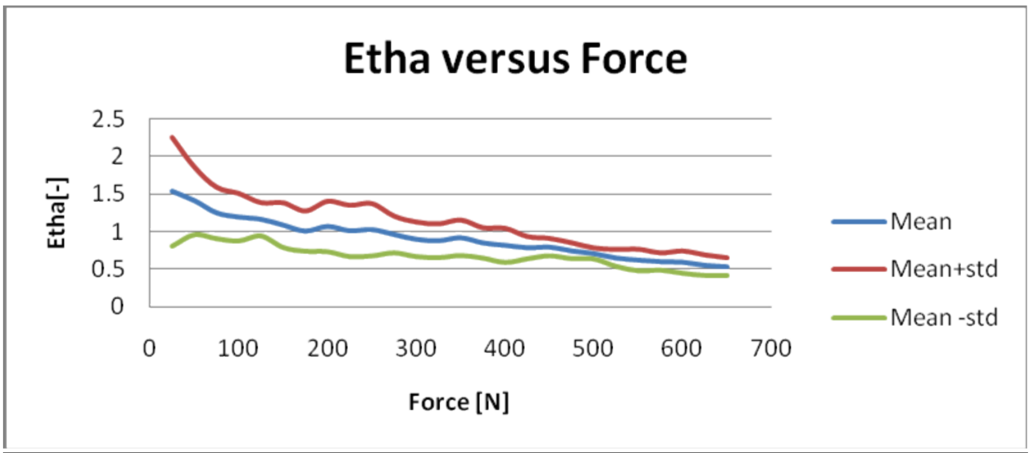

Figure: 4.2.2 .3(b) Mean curves for Etha versus strain of all sample together, fabric 03

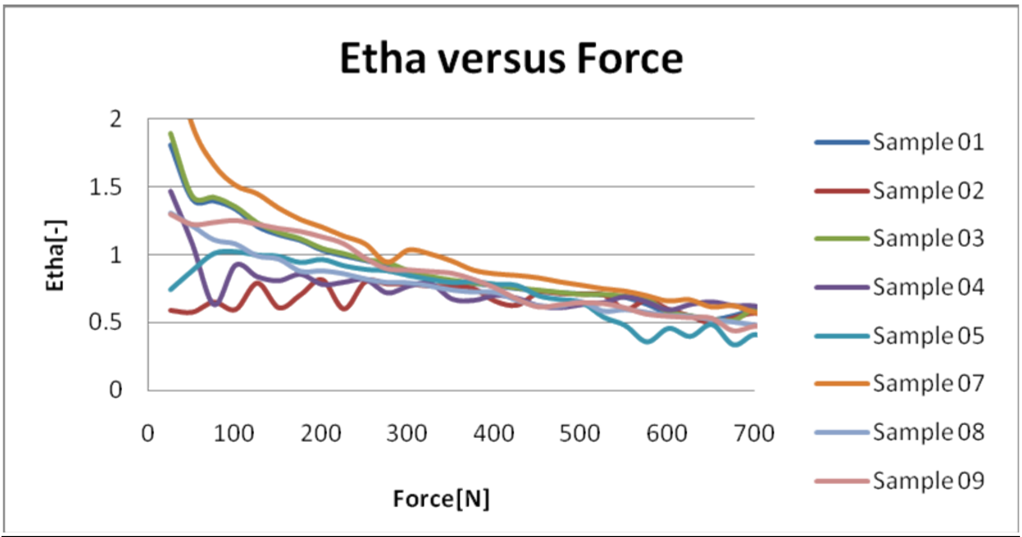

Figure: 4.2.2 .4(a) Overall of all samples together on same curve, fabric 04

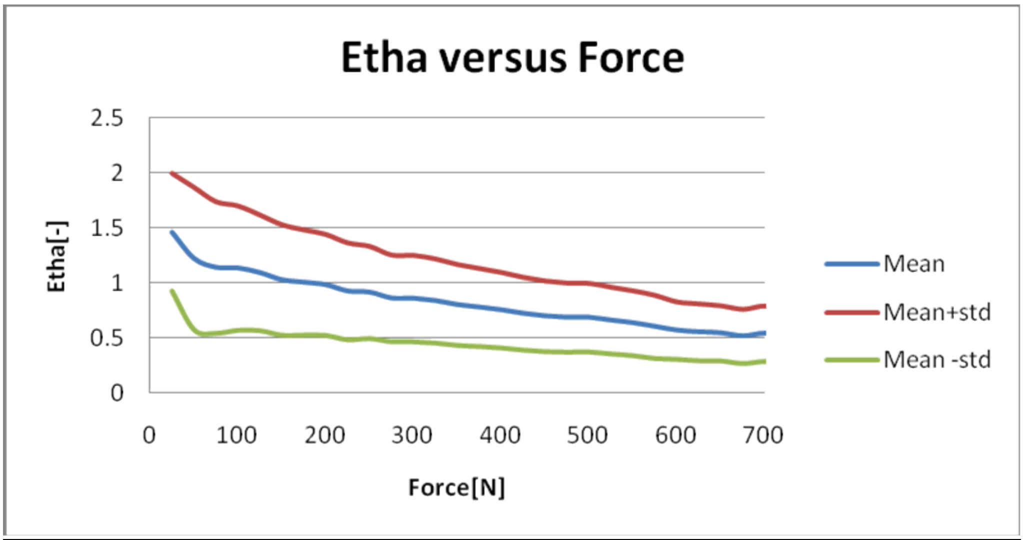

Figure: 4.2.2 .4(a) Mean curves for Etha versus strain of all sample together, fabric 04

4.2.3 (b) Relationship between Etha and Strain ;elongation in the weft direction

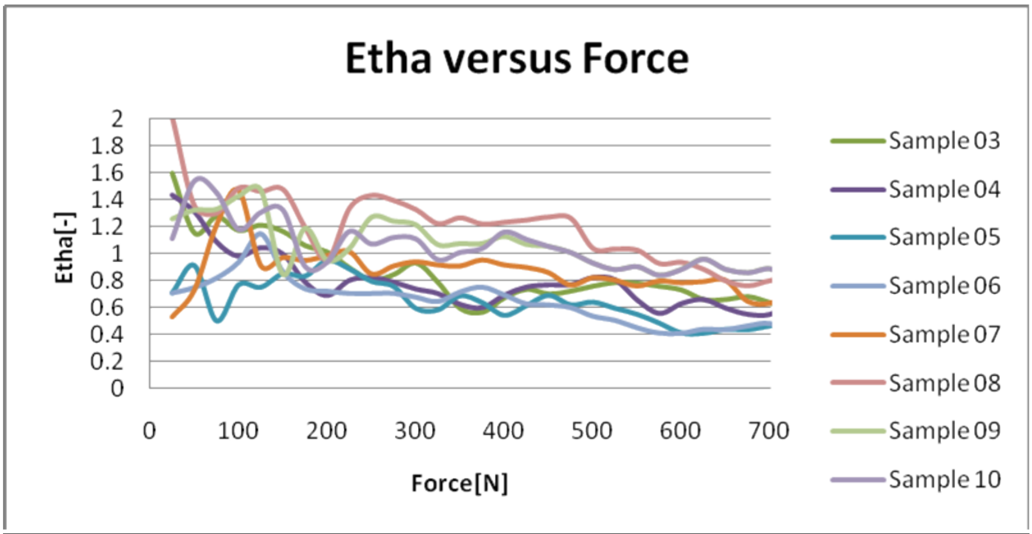

Figure: 4.2.3 .1(a) Overall curves for Etha versus strain of all sample together, fabric 01

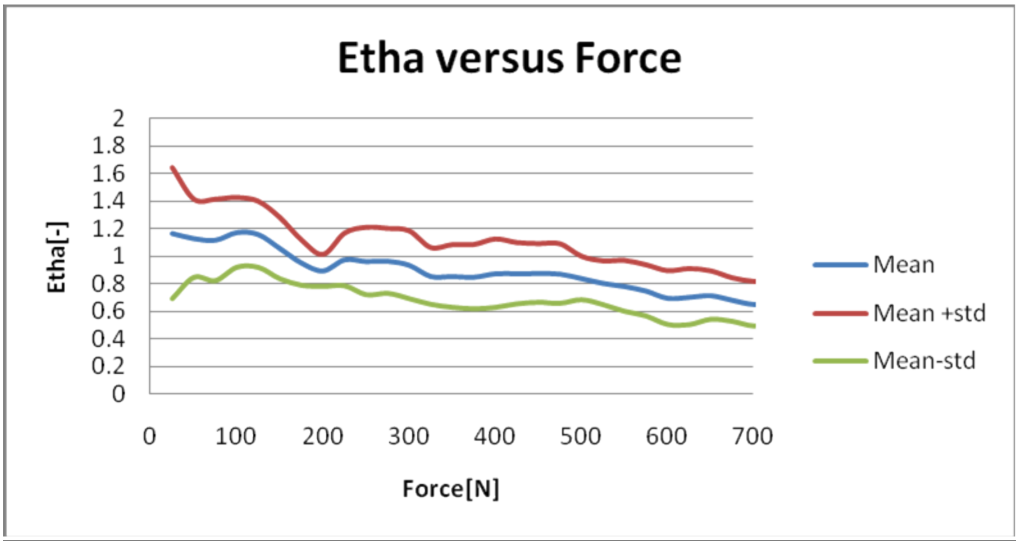

Figure: 4.2.3 .1(b) Mean curves for Etha versus strain of all samples together, fabric 01

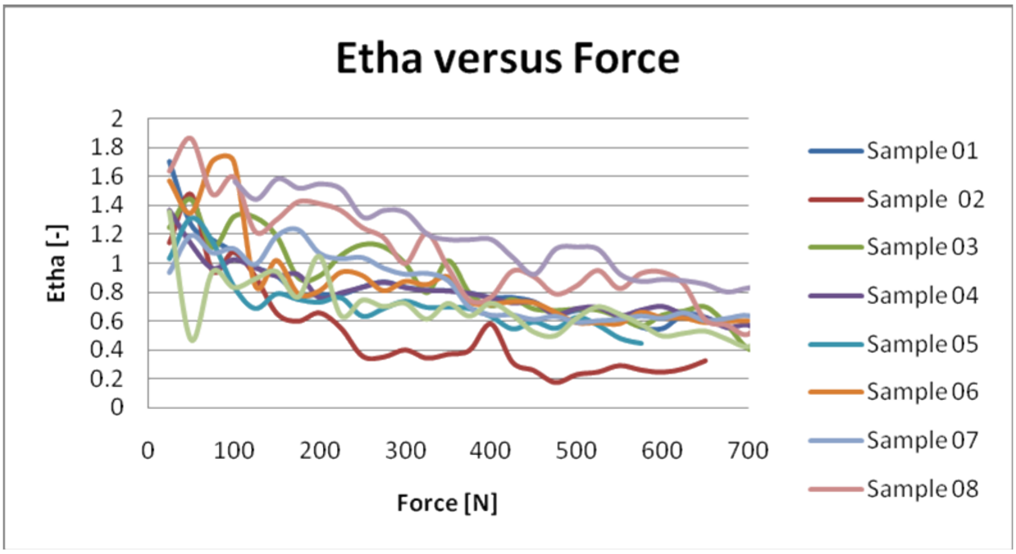

Figure: 4.2.3 .2(a) Overall of all samples together on the same curve, fabric 02

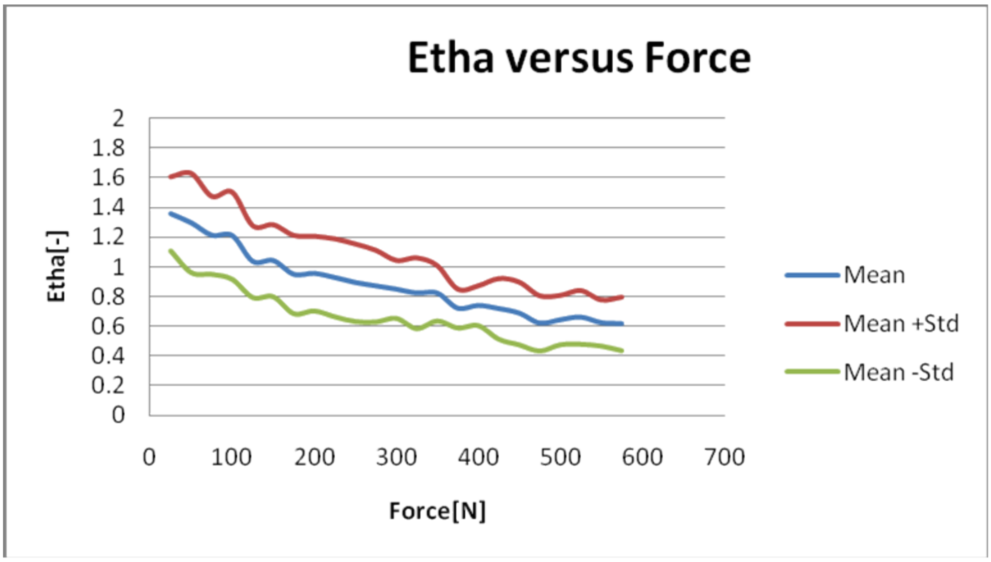

Figure: 4.2.3 .2(a) Mean curves for Etha versus strain of all samples together, fabric 03

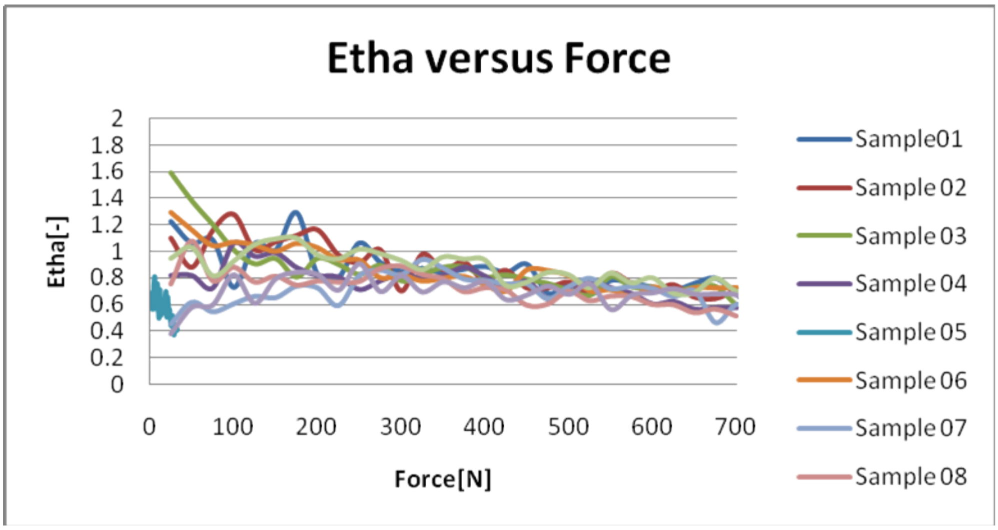

Figure: 4.2.3 .3(a) Overall of all samples together on the same curve, fabric 03

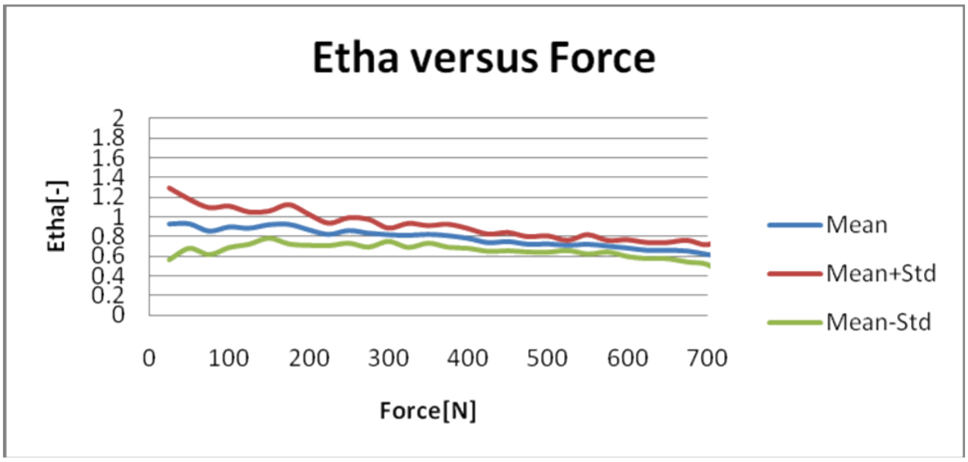

Figure: 4.2.3 .3(b) Mean curves for Etha versus strain of all samples together, fabric 03

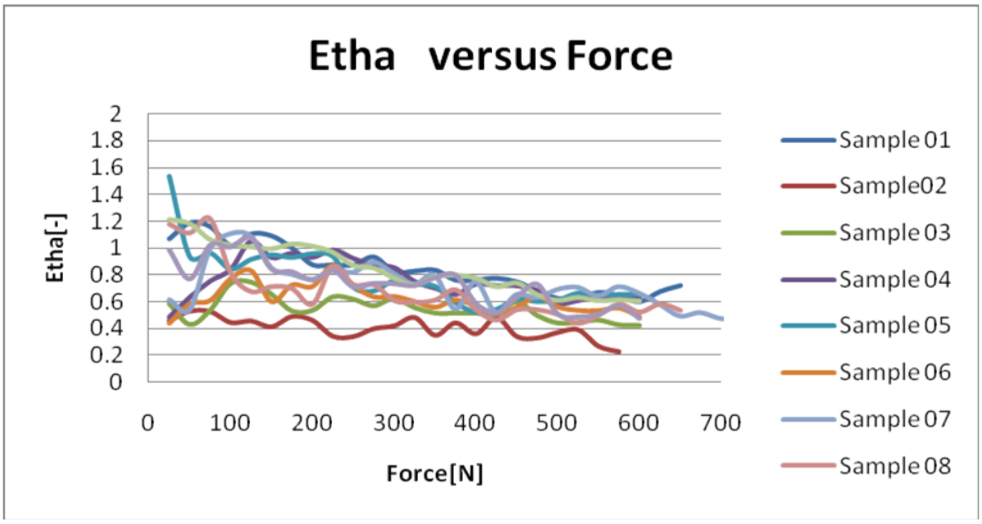

Figure: 4.2.3 .4(a) Overall of all samples together on the same curve, fabric 04

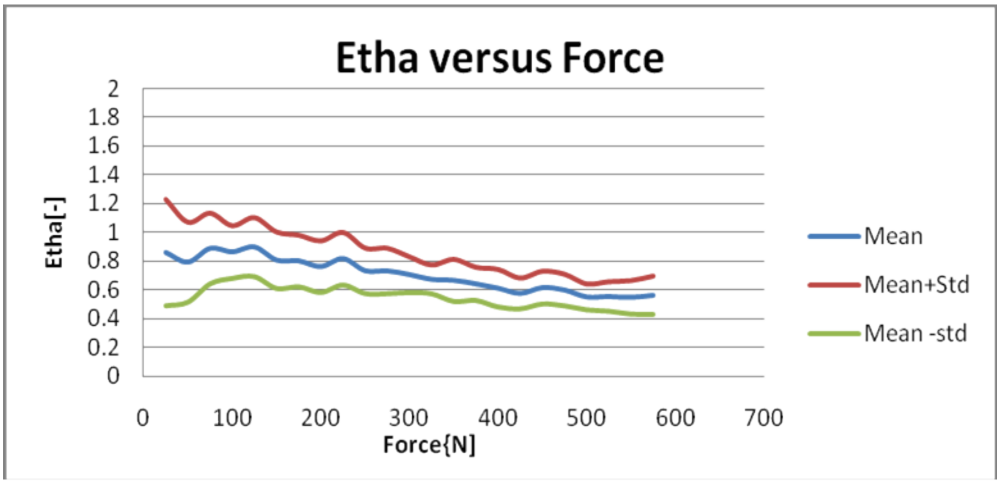

Figure: 4.2.3 .4(b) Mean curves for Etha versus strain of all samples together, fabric 04

4.3The linear regression curves for all four fabrics elongated in warp and weft direction

Table 4.3.1: The results from linearization of lnEtha and strain for fabric 01, elongated in the warp direction.

R Square value	0.994
Constant	1.193
k	-7.34
$\ln Etha = 1.193 - 7.34(\varepsilon_{verticalstrain)})$	
$\eta = e^{1.193} * e^{-7.34\varepsilon}$	

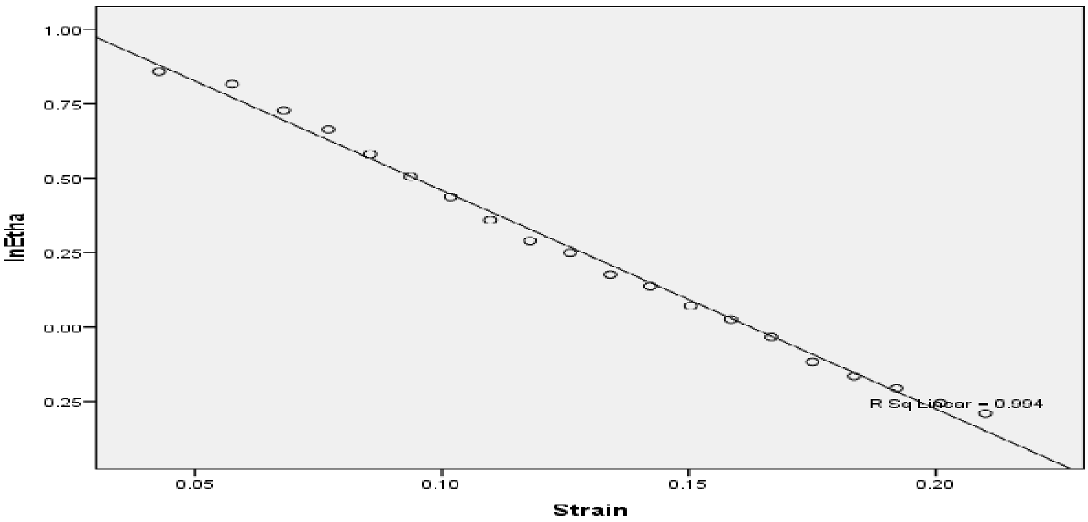

Figure: 4.3.1 (a) lnEtha versus strain for fabric 01 elongated in the warp direction

Table 4.3.2: The results from linearization of lnEtha and strain, of fabric 02; elongated in the warp direction.

R Square value	0.913
Constant	0.284
k	-6.866
$\ln Etha = 0.284 - 6.866(\varepsilon_{verticalstrain)})$	
$\eta = e^{0.282} * e^{-6.866\varepsilon}$	

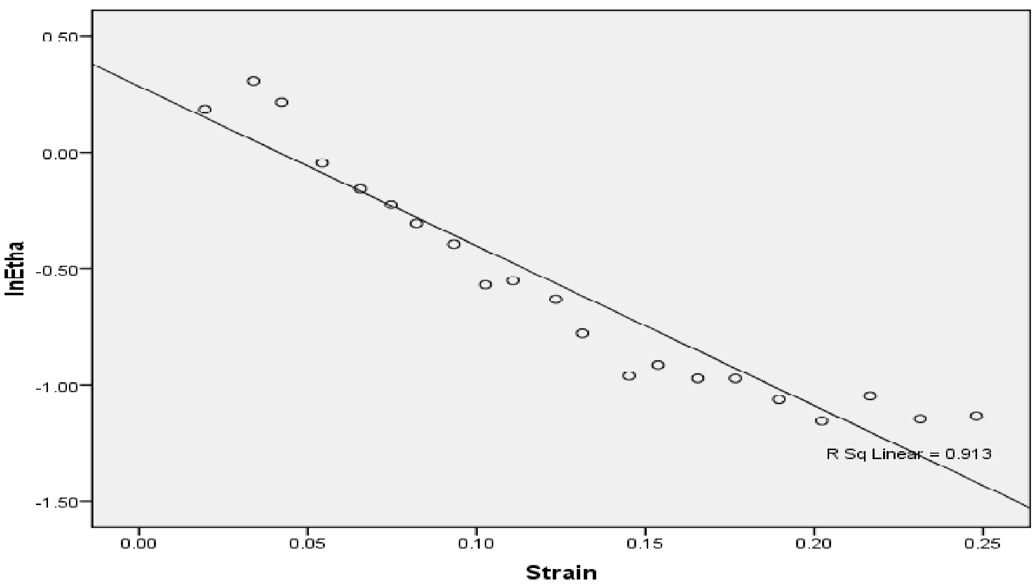

Figure: 4.3.1(b) lnEtha versus strain for fabric 02, elongated in the warp direction

Table 4.3.3: The results from linearization of lnEtha and strain for fabric 03, elongated in the warp direction.

R Square value	0.984
Constant	0.504
k	-4.12
$\ln Etha = 0.504 - 4.12(\varepsilon_{verticalstrain)})$	
$\eta = e^{0.504} * e^{-4.12\varepsilon}$	

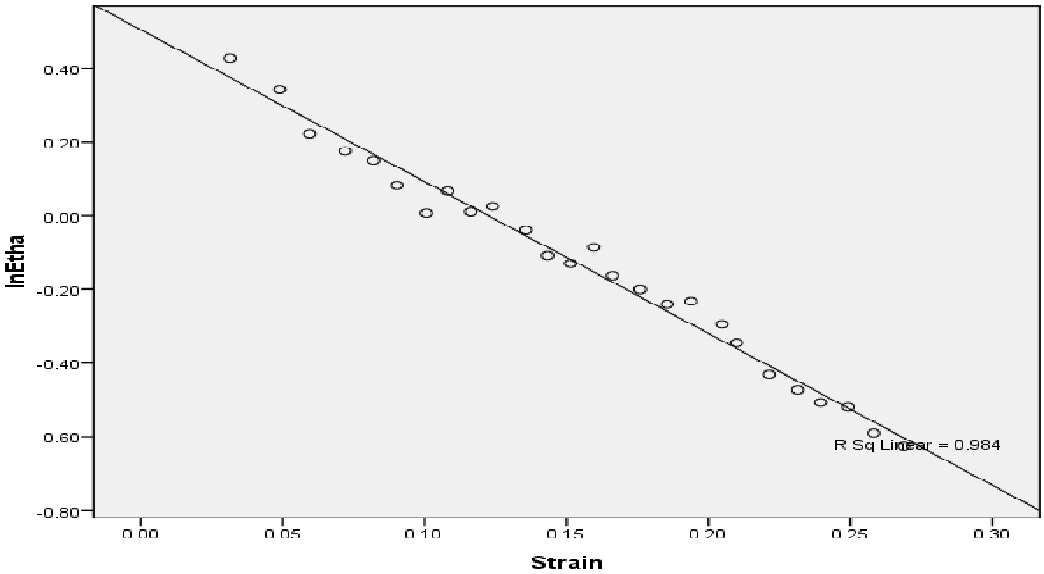

Figure: 4.3.1(c) lnEtha versus strain for fabric 03 elongated in the warp direction

Table 4.3.4: The results from linearization of lnEtha and strain for fabric 04, elongated in the warp direction.

R Square value	0.993
Constant	0.411
k	-3.850
$\ln Etha = 0.411 - 3.85(\varepsilon_{verticalstrain)})$	
$\eta = e^{0..411} * e^{-3.850\varepsilon}$	

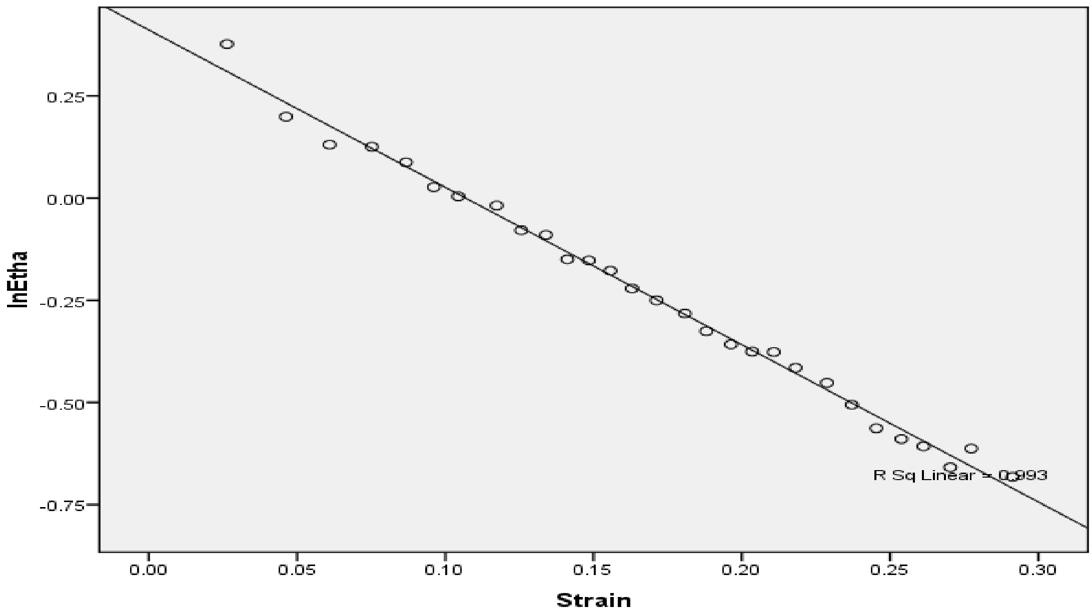

Figure: 4.3.1(d) lnEtha versus strain for fabric 04, elongated in the warp direction

Table 4.3.5: The results from linearization of lnEtha and V strain for fabric 01 , elongated in the weft direction.

R Square value	0.961
Constant	0.272
k	-2.326
$\ln Etha = 0.0272 - 2{,}326(\varepsilon_{verticalstrain)})$	
$\eta = e^{0..272} * e^{-2.326\varepsilon}$	

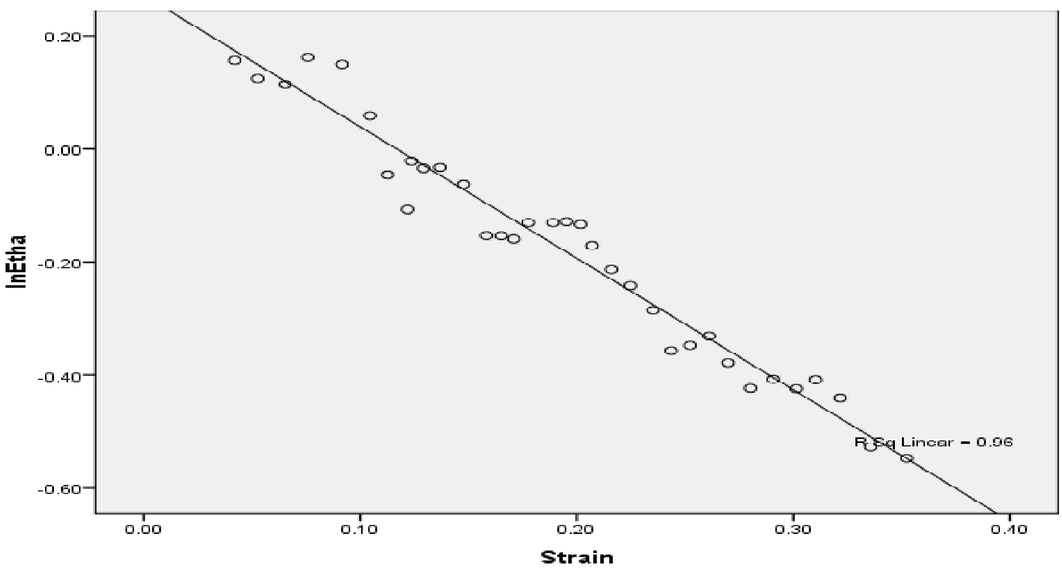

Figure: 4.3.2(a) lnEtha versus strain for fabric 01, elongated in the weft direction

Table 4.3.6: The results from linearization of lnEtha and strain for fabric 02 , elongated in the weft direction

R Square value	0.971
Constant	0.439
k	-4.196
$\ln Etha = 0.439 - 4.196(\varepsilon_{verticalstrain)})$	
$\eta = e^{0.439} * e^{-4.196\varepsilon}$	

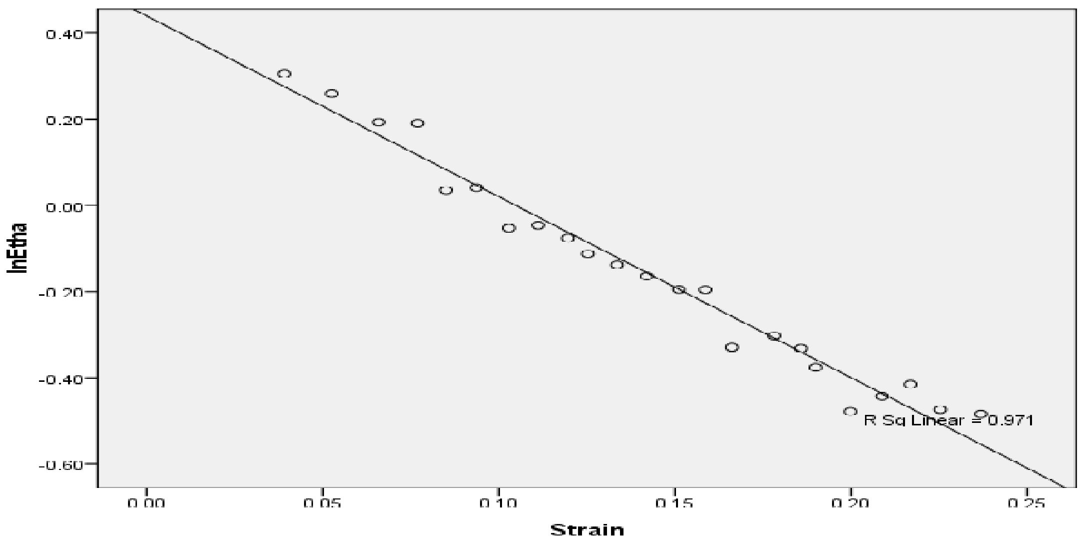

Figure: 4.3.2(a) lnEtha versus strain for fabric 02, elongated in the weft direction

Table 4.3.7: The results from linearization of ln Etha and Vertical strain

R Square value	0.916
Constant	0.063
k	-1.656
$\ln Etha = 0.063 - 1.656(\varepsilon_{verticalstrain)})$	
$\eta = e^{0.063} * e^{-1.656\varepsilon}$	

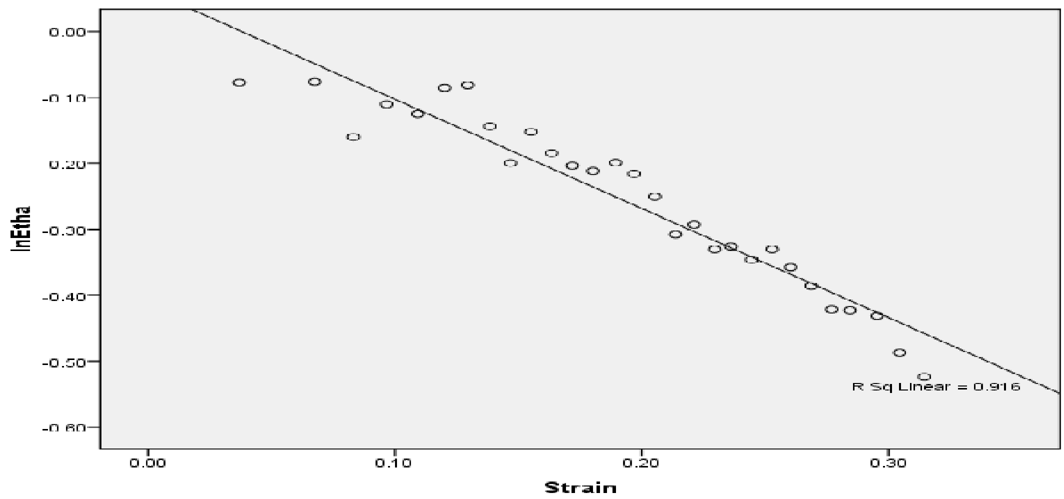

Figure: 4.3.1(b) lnEtha versus strain for fabric 03 elongated in the weft direction

Table 4.3.8 The results from linearization of lnEtha and strain for fabric 04 elongated in the weft direction

R Square value	0.905
Constant	0.002
k	-1.994
$\ln Etha = 0.002 - 1.994(\varepsilon_{verticalstrain)})$	
$\eta = e^{0.002} * e^{-1.994\varepsilon}$	

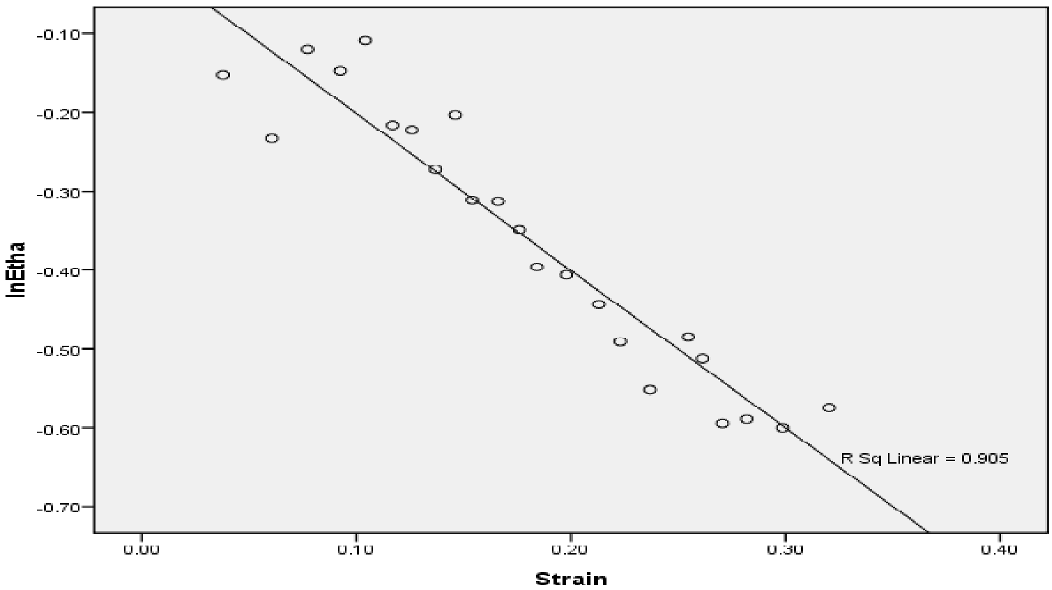

Figure: 4.3.1(d) lnEtha versus strain for fabric 04, elongated in the weft direction