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Geometrical Modelling of Stitch class 504 and Jacquard Warp Knitted Fabric

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Abstract

This research revolves around the geometrical modelling of stitch class 504 and jacquard warp knitted fabric for the prediction of sewing thread consumption for the stitching of an article and for the prediction of yarn consumption in knitted structures and improvement of warp knitting simulation software i.e HZCAD respectively. The thread is a basic fundamental raw material for garment manufacturing industry. After considering thread's performance and appearance the major attention is to resolve the cost. The objective of this project is to develop a geometrical model for stitch class 504, to predict actual required thread consumption and its actual thread cost and to develop the garment. It was concluded that the derived geometrical formula predicted the thread consumption accurately up to 90.34%. In the same way the same geometrical modelling technique was applied on the jacquard wapr knitted favric for the prediction of the yarn consumption also the models were used to improve the warp knitting simulation software. In the industry these geometrical formula can save time and can be helpful in calculating the costing of thread/yarn. It will expand profit margin and save time.

Keywords: Geometrical Modelling; Jacquard Warp Knitted Fabric; Yarn Consumption Estimation; Formula Of Yarn Consumption; Sewing Thread Consumption; Stitch Class 504

1 Introduction

Geometric modelling is known to be a branch of applied mathematics and computational geometry that studies ways and algorithms for the mathematical description of shapes [1]. Now-a-days most geometric modelling are performed with computers and for computer-based applications. Two-dimensional models are necessary in processors typography and technical drawing [1, 2].

The sewing thread is a key supplying unit for garment industry considering it as an important material. Purpose of sewing thread is to stitch garment or used for decorative purposes. Sewing thread significantly effect on garment production and on its quality [1]. After considering thread's performance and appearance then major attention is to settle its cost. Thread cost can be define as the cost of actual thread that used in garment production, thread wastages during sewing and unused thread in stock. If the thread is faulty it rises the production cost and causes more threads

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breakages [1]. So the usage of good quality sewing thread can increase the profit of the garment industry [2]. Moreover, seam failure might occur during garment life cycle by using inappropriate sewing thread for sewing. As more precise the sewing thread consumption is define the more garment quantities we make and more we avoid unused stock.

Different types of stitches are applied on a garment to perform a sewing operation [2]. According to International Organization for Standardization (ISO) 1991 class 504 is an over edge chain stitch with complex stitch structure whose geometry is underneath deliberation. This class is mostly used for joining two or more plies together and sergeing to stop fabric fraying [2].

The yarn is considered as a basic and important material of every fabric material. Yarn significantly affect the appearance, feel, texture, balance, proportion and quality of the warp knitted fabric. After yarn selection cost of the yarn is resolved. Yarn cost can be defined as the cost of actual yarn that is used in warp knitted fabric production, yarn wastages during winding, rewinding, warping, beaming, unused yarn in stock etc [2].

The objective of this project is to develop a geometrical models for stitch class 504 and simple jacquard warp knitted fabric. The models for stich class 504 was used for the prediction of the thread consumption for the making of the garment. The models for warp knitted fabric was then utilized to predict actual required yarn quantity and its actual yarn cost. There are large research available on yarn properties which effect yarn consumption [1, 3]. This paper will talk about the geometry of the warp knitting jacquard fabric, make a mathematical formula for it and check the accuracy of the formula.

2 Problem Formulation

Geometric models are typically distinguished from procedural and object-oriented models that outline the form implicitly by an opaque algorithmic rule that generates its appearance [4]. However, these distinctions are usually blurred: as an example, a digital image can be taken as a group of squares; and geometric shapes like circles are outlined by implicit mathematical equations [6, 7]. Also, a shape model yields a constant quantity or implicit model once its definition is truncated to a finite depth [8, 9].

A stitch is a configuration made from the intra-looping, inter-looping or interlacing of yarns(s) in a specific repeated unit on the material, in a material, through the material or without the material

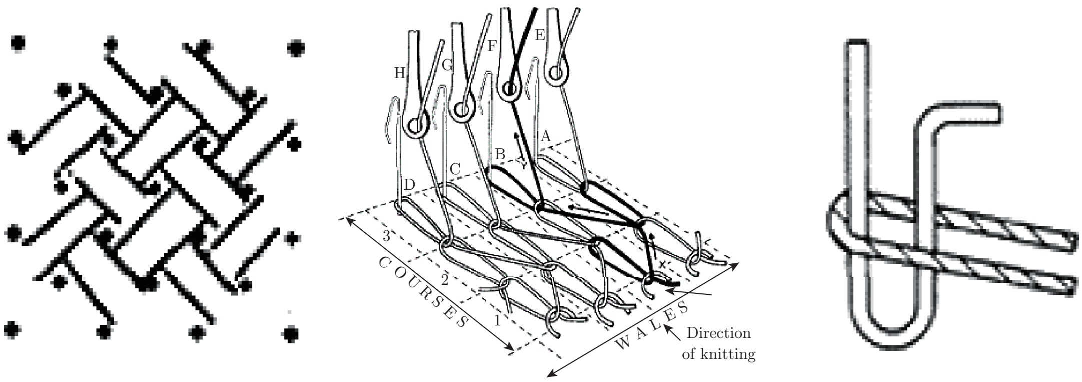

Fig. 1: Interlacing, interlooping and intralooping (left to right) [11]

[10]. The difference between interlacing, interlooping and intralooping is the configuration in which yarn(s) is/are configured to form the stitch. Interlacing is passing of yarns over and around yarn or a loop of another yarn; Interlooping involves one yarn loop passing through another loop which is made by another yarn; and in intralooping a loop is passed through another loop formed by same yarn [11]. Interlacing is often seen in the weaving of the fabric, interlooping is seen in the warp knitted fabric which can't be unravel whereas the intralooping can be seen in ravelable knitted fabric and some stitches [5].

Different Textile structure's geometrical modelling are been examined over the several ages [6]. A theoretical model was proposed for calculating sewing thread consumption. This model was established on geometrical parameters for different stitch types [7].

Three thread over edge stitch model.

The sewing thread consumption (Q_{504}) is predicted by using given formula.

$$Q_{504} = (Q_1 + Q_2 + Q_3)nL \tag{1}$$

$$Q_{504} = 2L\left(\frac{3}{2} + 4ne + nc + n\sqrt{c^2 + \frac{1}{n^2}} + 3nd(\pi - 2)\right) \tag{2}$$

Where Q_1 represents needle thread consumption

$$Q_1 = \frac{1}{n} + 4e + 2d + (\pi + 1) \tag{3}$$

Q_2 represent upper looper thread consumption

$$Q_2 = \frac{1}{2n} + 2e + 2c + 2d(\pi - 2) \tag{4}$$

Q_3 represents lower looper thread consumption

$$Q_3 = 2\sqrt{c^2 + \frac{1}{n^2}} + \frac{3}{2n} + 2e + 2d(\pi - 3) \tag{5}$$

From the result we found out that the relative error vary from 14.52% to 35% between actual and predict calculating thread consumption. Weakness of this model is that error may be increase due to negligence of important factors like thread tension, cloth compression and distortion of stitch [8, 12].

The research on warp knitting loop, earlier was done by G.L Allison who put forward a simplified model shown in the Fig. below [15]. With radius of 2d semicircle arc, with two straight lines and the third line as the circle column and extend line respectively. But the model does not consider the stretch of coil, there is no points before and after guide bar [15]. Because the model and the real structure has a lot of difference, so future generations on the basis of this model is constantly improving with more realistic and more accurate models, thus promotes the research development of the textile industry. In 1964 Grossberg (P. Grossberg) proposed the loop as an elastic rod with mathematical analysis [9, 16].

According to the grossberg's model the loop was broken down in small segment. The equation for these loops are written as following [21].

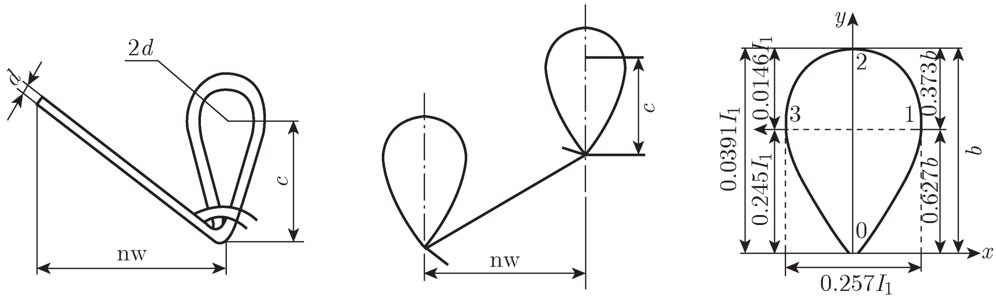

Fig. 2: Allision's loop model and grossberg's first model [9, 15, 16]

The length from 0 to 1 was.

$$0 \text{ to } 1 = 0.627b \tag{6}$$

The length from 1 to 2 was given by the following equation.

$$1 \text{ to } 2 = 0.373b \tag{7}$$

The length from point 2 to 3 was given by the following equation.

$$2 \text{ to } 3 = 0.014\,6I_1 \tag{8}$$

The length from point 3 to 4 was given by the following equation.

$$3 \text{ to } 4 = 0.024\,5I_1 \tag{9}$$

For the full length of the loop the equation proposed was.

$$b = 0.039\,1I_1 \tag{10}$$

3 Problem Solution

With the help of projection microscope, profile projector and literature review, it was known that geometry of overlock stitch is three dimensional. The three dimensional shape of stitch class 504 is shown in the Fig. 3.

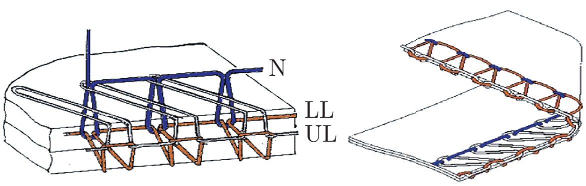

Fig. 3: Structure of stitch 504 & its appearance of face & back of fabric [13, 17]

3.1 Geometrical Model for Stitch Class 504

For the geometric modelling of the stitch class 504 it was assumed that geometry of all stitches is same. For geometrical modelling some of the curved shapes were considered as straight line for a simple model. It was seen that one stitch consists of a rectangular shaped needle thread which is interlooped with the lower looper at the wrong side of the fabric and interloped with the upper looper at the right side of the fabric. Similarly, the lower and upper looper thread intraloops at the edge of the fabric. So, the sewing thread consumed of stitch class 504 depends on three thread one by one, which is discussed one by one.

The formula for the prediction of the consumption of sewing thread to stitch 1 cm of 504 stitch is derived by deriving the formula of each thread and compiling it as a whole. Let us discuss the formula for the needle thread.

According to the Figure 1.2 the sewing thread of the needle starts from the wrong side of the fabric travels the distance of the thickness of the fabric (T) and reaches at the right side of the fabric and moves the distance of one stitch (L) then again goes down the thickness of the seam and then interloops with the lower looper. Hence the formula we got for the length of needle thread is shown in Equation (11)

$$\mathrm{PNT} = \mathrm{SPC}(2T + L + I_1) \tag{11}$$

Where PNT shows the length of predicted needle thread consumed in one cm of the seam of stitch class 504, SPC denotes stitch per centimeter, T shows the thickness of the seam, L is the length of one stitch and I_1 shows thread consumed in interlooping. The expression $(2T + L + I_1)$ denotes the thread consumed in 1 stitch and when we multiply it with SPC we will obtain the consumption of needle sewing thread in one centimeter.

Stitch density (SPC) can be changed by the stitch dial of the overlock machine. The length of a stitch is calculated by $L = 1/\mathrm{SPC}$ whereas L is length of one stitch and SPC is abbreviation of stitches per centimeter. Thickness can be calculated by multiplying the thickness of one ply of the fabric with the number of plies. Figure 4 shows the geometry of needle thread interlooping with lower looper thread.

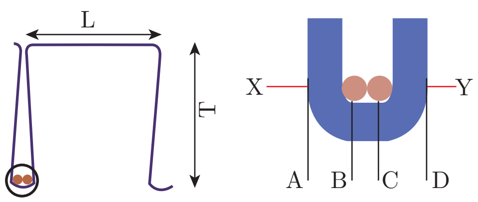

Fig. 4: Needle Thread Geometry & Geometry of interlooping of needle thread with lower looper

The interlooping of the needle thread can be divided into four segments. The part A to B & the part C and D are identical points i.e a quarter circles whose consumption is $\frac{\pi}{2}(r_l + 2r_u)$ (as the circumference of circle is $2\pi r$ where r the radius of the circle and the circumference of quarter circle is $\frac{2\pi r}{4}$) where r_l is the radius of the lower looper thread, r_u is the radius of the upper thread (needle thread), Moreover, part B to C is a straight line which is equal to the twice the radius of radius lower looper thread

$$I_1 = \frac{\pi}{2}(r_l + 2r_u) + 2r_l + \frac{\pi}{2}(r_l + 2r_u) = \pi\left(\frac{dl}{2} + d_u\right) + d_l = \frac{0.091\,7}{\sqrt{Ne_l}} + \frac{0.112\,1}{\sqrt{Ne_u}} \tag{12}$$

Replacing $\pi = 3.14 d_u = \frac{1}{28\sqrt{Ne_u}}$ and $d_l = \frac{1}{28\sqrt{Ne_l}}$ the formula for thread diameter calculation is $\frac{1}{28\sqrt{Ne}}$, the count of the thread in Tex (direct system) to change it into Ne, English count (direct system) we can use the formula $Ne = 591/Tex$. The Weight of 1 cm thread for 40 tex count is 0.000 441 grams and for 60tex count is 0.000615 grams. WPNT is the weight of predicted needle thread. WU 1 cm is the weight of the actual thread for 1 cm. It is to convert the length of predicted needle thread into predicted needle thread's weight. Hence the result formula for prediction of length of the needle sewing thread consumption is represented by Equation (13) also weight of predicted needle thread for 1 cm in grams is shown is Equ. (14)

$$PPNT = SPC\left(2T + L + \frac{0.0917}{\sqrt{Ne_l}} + \frac{0.1121}{\sqrt{Ne_u}}\right) \tag{13}$$

$$WPNT = SPC\left(2T + L + \frac{0.0917}{\sqrt{Ne_l}} + \frac{0.1121}{\sqrt{Ne_u}}\right) xWU \text{ 1 cm} \tag{14}$$

Similarly, the According to the Figure 1.3 the sewing thread of the lower looper starts from the wrongs side of the fabric where it interloops I_2 with the needle thread travels the seam width (D) and reach the cut edge of the fabric which was done with fabric knife, intraloops with upper looper I_3 moves the half of the stitch length and again intraloops with upper looper I_3, moves back to needle interlacing point I_2 with a certain angle. Again it interlacing with the needle thread I_2 and moves the distance of the stitch length (L). Considering the curved lines and straight lines we got a right angle triangle here where the hypotenuse gives us the length of the thread i.e diagonal. Hence the resultant formula we got for the prediction of length of lower looper thread is shown in Equ. (15)

$$PLLT = SPC\left(D + L + 1/2L + 2I_2 + 2I_3 + \sqrt{D^2 + (L/2)^2}\right) \tag{15}$$

Where PLLT represents the length of predicted lower looper thread, SPC denotes stitch per centimeter, D shows the seam width, L is the length of 1 stitch and I_2 and I_3 shows thread consumed in interlooping of needle thread with looper thread and intralooping of lower looper thread with upper looper thread.

When we studied the geometry of I_2 and I_3. It was same and Hence and I_2 is equal to I_3. The thread consumed in and I_2 and I_3 is calculated with the formula shown in Equation (16) Hence the resultant formula for length and weight of predicted lower looper thread for 1 cm seam is shown in Equation (17) and (18) respectively

$$PPNT = SPC\left(2T + L + \frac{0.0917}{\sqrt{Ne_l}} + \frac{0.1121}{\sqrt{Ne_u}}\right) \tag{16}$$

$$WPNT = SPC\left(2T + L + \frac{0.0917}{\sqrt{Ne_l}} + \frac{0.1121}{\sqrt{Ne_u}}\right) xWU \text{ 1 cm} \tag{17}$$

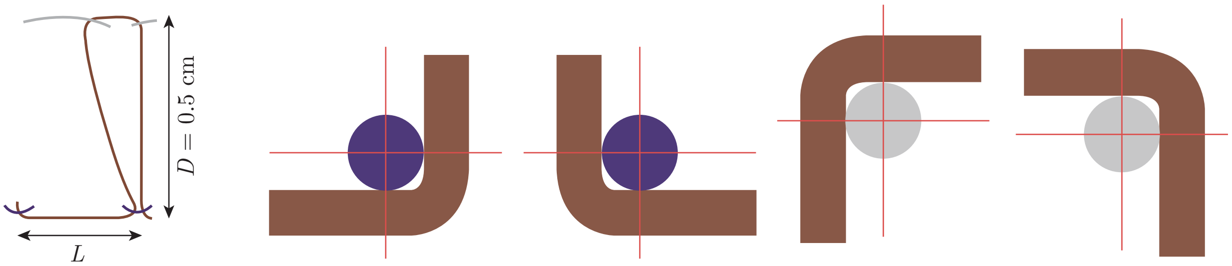

Fig. 5: Geometry of Lower Looper Thread and Geometry of interlooping and Intralooping of lower looper thread

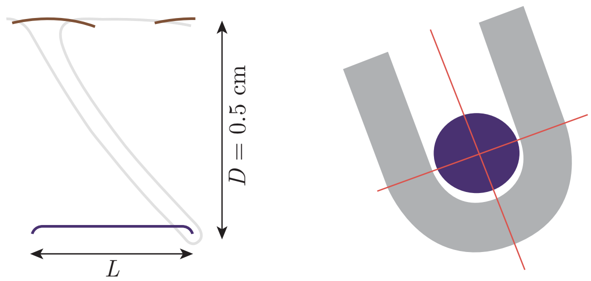

Fig. 6: Geometry of Lower Looper Thread and Geometry of interlooping and Intralooping of lower looper thread and Geometry of interlooping of upper looper thread with needle looper

Fig. 7: Black color of jacquard warp knitted fabric; left to right (a) red (b) green and (c) blue color of jacquard warp knitted fabric and the indication of major semi axis (a) and minor semi axis (b) of the ellipse [14, 22]

PLLT is the length of predicted lower looper thread and WPLLT is the weight of predicted lower looper thread. WL 1 cm is the weight of the actual lower thread for 1 cm. It is to convert the length of predicted lower looper thread into weight of predicted lower looper thread.

In the same way, according to the Figure 7 the sewing thread of the upper looper starts from the right side of the fabric where it intraloop with the lower looper thread at the left side of the stitch then travels the seam width (D) with a certain angle and reach the needle edge interloops with the needle thread at the right end and again goes at the intraloop point at a certain angle. And moves distance of one stitch length (L). Hence the resultant formula we got for the upper predicting the length of looper thread is shown in Equ. (19)

$$PULT = SPC(L + I_4 + \sqrt{D^2 + (L)^2}) \tag{18}$$

where PULT represents the predicted length of upper looper thread, SPC denotes stitch per centimeter, D shows the seam width, L is the length of 1 stitch and I_4 shows thread consumed in intralooping of lower looper thread with upper looper thread.

The I_4 is calculated with the formula shown in equation 20

$$I_4 = 4\frac{\pi}{2}\left(\frac{d_u}{2} + d_l\right) = \frac{0.112}{\sqrt{Ne_u}} + \frac{0.22}{\sqrt{Ne_l}} \tag{19}$$

Hence the result formula for length and weight of predicted upper looper thread for 1 cm seam is represented by Equation (21) and (22)

$$PULT = SPC\left(L + \frac{0.112}{\sqrt{Ne_u}} + \frac{0.22}{\sqrt{Ne_l}} + \sqrt{D^2 + (L)^2}\right) \tag{20}$$

$$WPULT = SPC\left(L + \frac{0.112}{\sqrt{Ne_u}} + \frac{0.22}{\sqrt{Ne_l}} + \sqrt{D^2 + (L)^2}\right) x\ WU\ 1\ \text{cm} \tag{21}$$

The resultant formula to predict the length of 1 cm of seam for stitch class 504 is shown is Equation (23)

$$WPT_{504} = SPC\left(2T + 3.5L + D + \frac{0.5317}{\sqrt{Ne_l}} + \frac{0.3361}{\sqrt{Ne_u}} + 2\sqrt{D^2 + (L)^2}\right) \tag{22}$$

Also the resultant formula to predict the weight of 1cm of seam in grams for stitch class 504 is shown in Equation (24)

$$\begin{aligned} WPT_{504} = & SPC\left(2T + 2L + \frac{0.3317}{\sqrt{Ne_l}} + \frac{0.2242}{\sqrt{Ne_u}} + \sqrt{D^2 + (L)^2}\right) x\ WU\ 1\ \text{cm} \\ & + SPC\left(D + 1.5L + \frac{0.112}{\sqrt{Ne_u}} + \frac{0.22}{\sqrt{Ne_l}} + \sqrt{D^2 + (L/2)^2}\right) x\ WL\ 1\ \text{cm} \end{aligned} \tag{23}$$

I have used the HZCAD warp knitting simulation software for the making of the fabric computer designs in this research. The technical route of the prediction the yarn consumption of the simple jacquard warp knitted fabric was deriving the formula of the four basic color of the jacquard i.e Black (/or white), Red, Green and Blue. Then selecting the given design of the fabric and calculating the total number of black, red green and blue color and multiply it with the derived formula to get the total number of yarn consumption for one repeat of the fabric [14, 22].

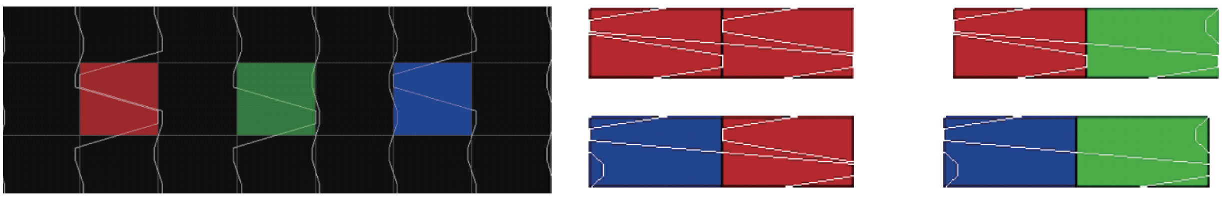

Fig. 8: Left to right red green & blue color of jacquard warp knitted fabric; comb of RGBW jacquard colors [14]

The geometrical modelling of the simple warp knitting fabric is done by making the mathematical formula of the basic four colors red, green, blue and black of the warp knitted jacquard fabric and estimating the yarn consumption of the fabric. The detail derivation of the mathematical formula is discussed in this segment. As seen in the Fig.4, the black color of the warp knitted jacquard fabric consists of one yarn only so the mathematical formula for it would be as following

$$B = AB + DF = \frac{1}{2}\left\{\pi\left(\frac{D_1}{2}\right)^2\right\} + \frac{1}{2}\left\{\pi\left(\frac{D_2}{2}\right)^2\right\} = \pi\left(\frac{D_1}{2}\right)^2 \tag{24}$$

Where B = the length of the yarn in black color of the warp knitted jacquard fabric.

D_1 = the half of the length of one course.

Length of one course $D_1 = \dfrac{\text{Total no of wales in a repeat}}{\text{total length of repent (cm)}}$

As it can be seen in Fig. 5(a), the shape of the yarn in the black color jacquard structure is almost same like a circle so the mathematical formula of the circumference of the circle is used here for the estimation of the yarn consumption. Where, is the diameter of that circle. The mathematical model for the red color jacquard warp knitted fabric sturcture was calculated by using the formula for the estimated circumference of the ellipse $\left\{2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)}\right\}$ [19, 20]. Where, a & b are the major and minor diameters of the ellipse as shown is Fig. 4.

$$R = AO + OF = \frac{1}{2}\left\{2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)}\right\} + \frac{1}{2}\left\{2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)}\right\} = 2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)} \tag{25}$$

Where

R = length of the yarn used in red color of the warp knitted jacquard fabric;

a, b = major and minor semi axis of the ellipse, respectively as shown is Fig. 4;

a = W = 25.4mm/E(guage) where W is the distance between two needles.

$\text{b} = \frac{1}{2}\left(\dfrac{\text{Total no of wales in a repeat}}{\text{total length of repent (cm)}}\right)$ as shown is Fig.4, $\text{H} = \dfrac{10\text{ mm}}{\text{Density}}$ where $\text{b} = \dfrac{H}{4}$

The mathematical formula for green and blue color of the warp knitted jacquard fabric will be the same as it is the equal but opposite in direction. The yarn consumption in the green and blue color is almost same like the red color yarn.

$$G = AD + DG = \frac{1}{2}\left\{2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)}\right\} + \frac{1}{2}\left\{\pi\left(\frac{D_1}{2}\right)^2\right\} \tag{26}$$

$$D = AD + DG = \frac{1}{2}\left\{\pi\left(\frac{D_1}{2}\right)^2\right\} + \frac{1}{2}\left\{2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)}\right\} \tag{27}$$

Where

G = length of the yarn used in green color of the warp knitted jacquard fabric;

D = length of the yarn used in blue color of the warp knitted jacquard fabric;

a, b = major and minor semi axis respectively as shown is Fig. 4;

a = Guage of the machine/2.45 as shown is Fig. 4;

$b = \dfrac{1}{2}\left(\dfrac{\text{Total no of wales in a repeat}}{\text{total length of repent (cm)}}\right)$ as shown is Fig. 4.

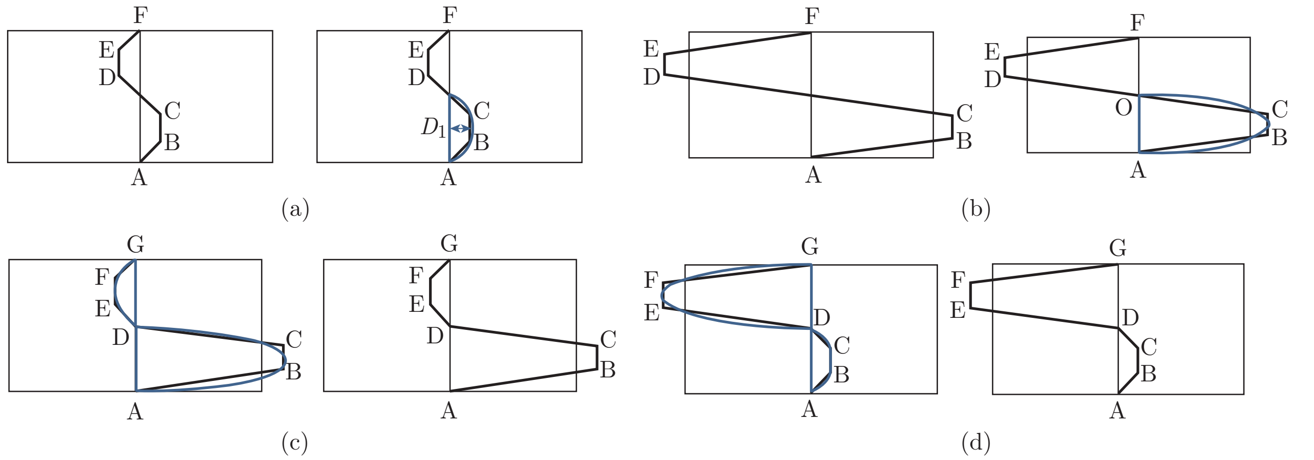

Fig. 9: Geometrical model of a. black, b. red, c. green and d. blue color jacquard

But as discussed, getting the length of the actual consumption of the fabric is really difficult as the length of the yarn may be increased due to the stresses of pulling during the process of unravelling of the yarn so the weight of the yarn is calculated. For this reason the estimated yarn was also taken in the weight formula. Hence the result formula for prediction of weight of yarn in the segment of black, red, green and blue color in grams is shown is Equation (29), (30), (31) and (32) respectively.

$$W.B = \left\{\pi\left(\frac{D_1}{2}\right)\right\} xW_b \tag{28}$$

$$W.R = 2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)} xW_r \tag{29}$$

$$W.G = \left[\frac{1}{2}\left\{2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)}\right\} + \frac{1}{2}\pi\left(\frac{D_1}{2}\right)^2\right] xW_g \tag{30}$$

$$W.D = \left[\frac{1}{2}\left\{2\pi\sqrt{\left(\frac{a^2+b^2}{2}\right)}\right\} + \frac{1}{2}\pi\left(\frac{D_2}{2}\right)^2\right] xW_d \tag{31}$$

Where

W_b = the weight (grams) of 1 cm of the yarn used for the black color;

W_r = the weight (grams) of 1 cm of the yarn used for the red color;

W_g = the weight (grams) of 1 cm of the yarn used for the green color;

W_d = the weight (grams) of 1 cm of the yarn used for the blue color.

3.2 Experimental Work

The research was done for stitch class 504, three thread one needle two looper overlock stitch. Pegasus High-speed, Overlock Machine M752-01 single needle, three thread Industrial sewing machine [18] was used for the preparation of the samples of the research. The sewing thread used in this research was two different counts of 100% polyester thread of 40 and 60 tex. The bleached woven fabric with plain weave, GSM 275 or 8.1 Ounce/yard of 5 meter in length was used for the experiment. Three variable were chosen of three levels each so 27 samples were made, i.e. Thickness of material (T) [1.095 mm; 2.175 mm; 3.28 mm], Stitch density (S_d) [7.5 spc; 10 spc; 12.5 spc] and Upper & lower sewing thread combinations (C) [40 tex-40 tex; 40 tex-60 tex; 60 tex-40 tex]

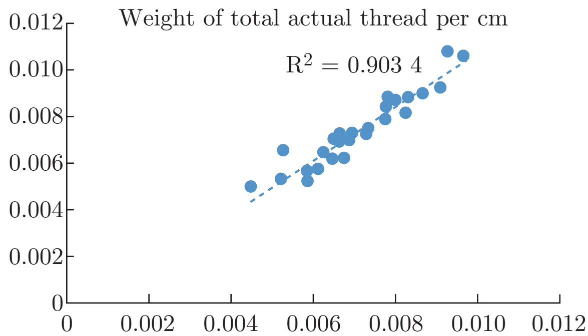

Fig. 10: Scatter diagram between actual weight and predicted weight of yarn

4 Conclusion

After formulating the formula for all the three sewing thread of stitch class 504. The model was validated for all the 27 sample. The predicted weight of each sewing thread was measured for each sample by the putting the input factors in the formula. Then, compared it with the actual weight of the thread. We have considered the measurement of sewing thread consumption with respect to weight of the thread because the length of the thread may vary due to the stress and tension during unraveling but the weight remains same. Table 1 shows the comparison between predicted and actual consumption of sewing thread with the percentage absolute relative error for stitch class 504.

The trend line of the scatter diagram plotted between the predicted weights of the stitch 504 vs the actual weight of stitch 504 shows that the model was acceptable and near to the actual measurement along the value of coefficient of determination $R^2 = 0.9034$ in figure 10. The model's accuracy is indicated by value of coefficient of determination. High value of coefficient of determination shows that geometric models proposed for the stitch class 504 has considered all the variables on which the consumption of sewing thread depends. It was seen by the experiments that the sewing thread consumption for one cm for stitch class 504 depends upon the values of sewing thread count, seam depth and stitch density.

It was concluded that the model, proposed predicts the consumption of sewing thread with 90.34% accuracy. It also concludes that the geometrical models for the stitch class is helpful for calculation of consumption of sewing thread in precise measurement. The weight of consumption of sewing thread per cm for overlock stitch (stitch class 504) varies between 0.0050 grams to 0.0107 grams. On the other hand the geometry of the four basic fundamental stitch making unit of the jacquard warp knitting fabric regarded as the black/white, red, green and blue color in the literature review of the warp knitting CAD/CAM simulation systems. We formulated a mathematical formula for the geometrical representation of the structure with the help of the technique acknowledged as geometrical modelling. It proves that this mathematical formulae can be used for the prediction yarn calculation in research and industries and for the costing calculations of the fabric order in terms of the yarn consumption. This model was also used for the improvement of the HZCAD warp knitted fabric simulation software for the algorithmic coding and make it more precise and user-friendly.

Table 1: Comparison of the predicted and actual weight with the % age absolute relative error

No. of Experiments	Predicted Weight (gm)	Actual Weight (gm)	% age Absolute Relative error
1	0.0044	0.005	10.2363
2	0.0058	0.0052	11.7572
3	0.0058	0.0056	3.4527
4	0.0059	0.0056	4.6211
5	0.0066	0.0069	4.2247
6	0.0072	0.0073	0.3004
7	0.0064	0.0070	7.5359
8	0.0082	0.0081	0.7501
9	0.0079	0.0086	8.1290
10	0.0052	0.0053	2.7555
11	0.0061	0.0057	6.4002
12	0.0067	0.0062	8.2462
13	0.0062	0.0064	3.2507
14	0.0073	0.0074	1.6748
15	0.0077	0.0079	2.0018
16	0.0069	0.0072	4.8900
17	0.0086	0.0090	3.9126
18	0.0090	0.0092	2.2459
19	0.0052	0.0065	19.648
20	0.0064	0.0061	4.5302
21	0.0068	0.0069	1.5274
22	0.0066	0.0072	8.4954
23	0.0077	0.0084	8.0099
24	0.0082	0.0088	6.0567
25	0.0078	0.0088	11.643
26	0.0096	0.0105	8.8231
27	0.0092	0.0107	14.034

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