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Analyzing the Factors by Regression Model Associated with Plain Weft Knitted Fabrics' Production

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Abstract
In this paper we studied the factors which are significantly influenced the parameters like grams per square meter (GSM), fabric width and geometric constant of weft knitted fabric. It is found that there is a significant relationships of machine diameter, stitch length, count, and geometric constant with GSM and width of the fabric. Grey diameter, finished GSM and geometric constant significantly influenced by the stitch length and resultant count. For our investigation 25 samples of plain weft knitted fabrics are produced in different settings and specifications.GSM, grey diameter, finished width, geometric constant are used as dependent variable and machine diameter, stitch length, yarn count in tex, geometric constant are used as independent variables to prepare the regression model.This research work identified the significant factors that can be used in knitting production floor of the textile industry to set the desired properties of fabrics.
Key words: *Weft knitting, GSM, diameter, geometric constant.*

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I. Introduction

The development of knitting frame from 15th century started in the hand of Williams Lee. After than continuous development in cams, needle, gauge, sinker, take-down, feeder and so on carried out throughout the century (Spancer, 2001a). Since 1978 the textile sector of Bangladesh is growing with an average 21% growth till now. And more growth happened in the knitting sector during this time. But, dimensional properties of the knitted fabric is inferior than woven fabrics. Dimensional properties mostly rely on the machine parameters, selection of yarn count and stitch length [(Khan &Rodrigues, 2015), (Lyer, Mammel, & Schach, 1992a & 1995a), (Munden, 1959)].

Though different mathematical and geometrical equations are used theoretically, the process parameters in the industrial production produced mixed results. To get desired fabrics GSM, the manufacturer must set stitch length, yarn count on the basis of machine specifications specially diameter and gauge [(Abedin, Maniruzzaman, Sina, & Khalil, 2014), (Abdel-Megied & Ahmed, 2008), (Ajgaonkar, 2006b), (Anbumani, 2007c)]. Due to the different process sequences after the take-down of the grey fabric from the machine, the characteristics of the plain weft knitted fabric change. But, all the parameters cannot be controlled during the manufacturing process. This study will try to find out the key predictors for GSM and the diameter of the fabrics. Geometric constant is suggested from geometry of plain weft knitted fabrics (Anbumani, 2007e). This study found significant relation of among the different parameters of plain weft knitted fabrics with the setting of knitting machines. This finding will help the manufacturer to use the most significant parameters that will help to set the desired properties of fabric.

Correlation and regression method is used here by manufacturing 30 plain weft knitted fabrics in a different setting, machine specification, resultant count and stitch length. First correlation coefficients are analyzed and significant factors are determined at 1% and 5% level of significance. And regression models are developed for grey diameter, finished width, finished GSM and geometrical constant. Due to unobserved parameters, and to find the combined effect of resultant count and stitch length, new variables geometric constant was also considered in this study. Here, geometric constant represents the final equation that will be helpful to determine GSM with the help of predetermined stitch length and resultant count in tex.

II. Literature Review

Weft knitted fabric became more popular than woven fabrics due to its good air permeability conductivity and insulation properties. Economic production cost with no need of ironing; high stretch and elasticity that conform body movement; excellent resistance to bursting, crease and wear with various patterning and design it draws the attention of the modern style. Thus it replaces woven fabrics day by day (Anbumani, 2007a). But, the properties of weft knitted fabrics depend on the parameters set in the machines. Due to its poor dimensional stability, many experiments have taken to establish the required parameters in the machine to limit the variation and get the desired characteristics in the finished fabrics (Kabir & Zakaria, 2012).Some of them discussed effect of yarn count and machine parameter, tightness factor, relaxation, finishing process and rate of feeding on spirality. These also influence fabric width, stitch length and GSM for various counts [(Kothari, Singh, Roy, & Varshney, 2011), (Abdel-Megied & Ahmed, 2008), (Primentas, 2003)]. Structural changes in knits during processing, the dimensional stability of plain knitted fabrics and the different properties related to machine parameters are studied to find out their relationships. Careful machine adjustment can alleviate difficulties caused by excessive shrinkage (Black, 1974). Machine gauge influences the number of wales in the fabrics also affect physical and mechanical properties of knitted fabrics [(Islam & Haque, 2014), (Abedin, Maniruzzaman, Sina, & Khalil, 2014). According to the yarn shape and yarn path different fabric structure can be produced. The dimensional stability of knit fabrics is an essential area of the knitting industry. Stitch length, yarn count, the structure of fabric influence the dimensional stability of fabric (Spencer, 2001c). So, the fabric properties like GSM, grey diameter, finished width, spirality, shrinkage varies due to those machine parameters selected(Parmer, 1999).Many researches were performed to investigate the effect of different knitting parameters on the physical and mechanical properties of knitted fabrics[(Manonmani& Cheetier, 2010), (Kavusturan, 2002)(Tao, Dhingra, Chan, & Abbas,1997)(Peirce, 1937), (Munden, 1959)]. This study is designed to determine the significant predictor for the fabric diameter/width, GSM, the geometric constant of plain weft knitted fabrics.

Terms and definitions

A. Related to Machine parameters

1. **Machine gauge:** Machine gauge can be calculated by dividing the total number of needles into the length of the needle bed. The number of needles or tricks in the needle bed per inch is expressed by E or G [(Spancer, 2001b)(Ajgaonkar, 2006b)].
2. **Machine diameter:** It varies on the type and width of the fabric requires. The distance from one needle head or butt to the just opposite needle head or butt is termed as machine diameter. Machine gauge and diameter determine the total number of needles and the fabric width (Anbumani, 2007d).
3. **Needles:** In circular weft knitting machine latch needles are widely used(Spencer, 2001c).
4. **Feeder:** Yarn guides placed close to the needles to the full circumference of the knitting zone(Anbumani, 2007d).

B. Related to Fabrics specifications

1. **Plain weft knitted fabrics:** The weft knitted fabrics produced with one set of needles (both in tubular or flat forms) are called as single jersey or plain knitted fabrics(Ajgaonkar, 2006a).
2. **Stitch length (SL):** The length of yarn in a loop(Spancer, 2001b).
3. **Stitch Density, S:** The series of loops those are connected horizontally known as course loops that intermesh vertically are known as wales. The total number of stitches per unit area is stitch density (Anbumani, 2007d).
4. **Yarn count, Tex:** The weight in grams of a 1000 meters **[**(Bayes, 1957)**,** (Spancer, An Introduction to Textile Technology, 2001a; Spancer, An Introduction to Textile Technology, 2001a)**].**
5. **Fabric width/diameter:** Fabric is takedown from the circular knitting machine in tubular form then the diameter of the fabric tube is called fabric dia. And when tube is slitten off to open width the fabric width in open form is found [(Anbumani, 2007c), (Anon, 1963b)].
6. **Grams per square meter (GSM):** Weight of fabric in unit area in gm/m^2(Anon, 1963a).
7. **Geometrical constant, Ks:** From the geometry of plain weft knitted fabrics the geometric constant, Ks is calculated according to the equation,

$$Ks = \text{Stitch density} \times (\text{stitch length})^2$$
$$\text{or, } GSM \times 100 \times \text{Stitch length}/Tex$$

III. Materials and Methods

100% cotton 25 single jersey fabrics form single ply and double ply yarn of resultant count ranges from14.76 tex to 32.81 tex using single jersey machines whose specifications are 26D×20G, 26D×24G, 30D×20G, 30D×24G, 34D×20G, 34D×24G, 36D×20G, 38D×20G and 38D×24Gwith a different stitch length ranges from 2.4 mm to 3.05 mm with available facilities. Correlation and regression model has been used to establish a linear regression equation using SPSS 23 among the variables considering 1% and 5% level of significance. To avoid the state of relaxation and other unobserved parameters geometric constant is also considered for the analysis of correlation and regression. During collection of the data the standard temperature 27 ± 2^0C and relative humidity 65±2% is considered as tropical country.

The data is analyzed using SPSS 23 software to determine the correlation among the variables and develop regression equation using the highly correlated variables at 1% and 5% level of significance. Here, regression equation is assumed to fit the linear equation as follow-

Y = bX + c; here, Y=dependent variable, X=independent variable, b=regression coefficient and c=constant.

Standards used: BS 1932:1953for fabric width (Anon, 1963b), B.S. 2471:1954 for weight per unit length (Anon, 1963a)

Variables: *Dependent variables*: GSM, grey diameter, finished width and geometric constant and *Independent variables*:Machine diameter, stitch length, yarn count in tex, geometric constant.

IV. Results and Discussion

From the data collected (in table-1) and the correlation coefficient, it is observed that, grey diameter of the fabric is depended on machine diameter, number of feeder, number of needles. But, omitting number of feeder and number of needles, the regression model for grey diameter is found as below due to presence of inter-correlation among them.

Table 1.Data table of parameters of plain weft knitted fabrics

Machine Dia and Gauge D×G	Yarn Count (Tex)	Stitch Length (mm)	Grey Diameter (inch)	Finished width (inch)	Finished GSM	Geometric constant, Ks
26x20	24.6	2.8	33	63	180	2048.78
26x20	29.53	3	32	60	200	2031.83
26x24	14.76	2.45	31	62	105	1742.89
26x24	17.37	2.4	30	64	130	1796.2
26x24	21.09	2.7	29	63	155	1984.35
26x24	29.53	3.05	32	63	240	2478.84
30x20	24.6	2.75	36	70.5	200	2235.77
30x20	24	2.8	37	70	190	2216.67
30x24	19.68	2.5	33	69	185	2350.1
30x24	22.71	2.65	31	73	165	1925.36
30x24	24.6	2.7	32	69	180	1975.61
30x24	32.81	3	46	73	250	2285.89
34x20	22	2.8	42	77	220	2800
34x20	22.71	2.75	40	75	160	1937.47
34x20	26.84	2.9	40	76	200	2160.95
34x20	26.84	2.95	40	74	190	2088.3
34x20	26.84	2.95	40	75	230	2527.94
34x24	18.45	2.75	40	76	135	2012.2
34x24	18.45	2.75	40	77	140	2086.72
34x24	22.71	2.75	40	74	160	1937.47
36x20	20.2	2.9	42	79	170	2440.59
38x20	21.09	2.8	44	77	160	2124.23
38x24	21.09	2.7	44	77	157	2009.96
38x24	21.09	2.7	44	78	160	2048.36
38x24	22.71	2.95	45	79	160	2078.38

Table 2.Correlation Coefficient

	GD	*FW*	*GC*	*GSM*
MD	0.870**	0.945**	0.183	-0.091
SL	0.431*	0.218	0.504*	0.701**
T	0.131	-0.103	-0.373	0.873**
GC	0.317	0.278	1	0.748**
GSM	0.168	-.002	0.748**	1

Here, MD- machine diameter, GD –grey diameter, FW- finished width, SL-stitch length, T- yarn number in Tex, GC- geometric constant, GSM- GSM
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 3.Regression analysis and coefficients (p<0.01)

	GD	*FW*	*GC*	*GSM*		
				(a)	*(b)*	*(c)*
(Constant)	-6.371	29.079	-38.692	-0.220	-53.141	6.997
MD	1.142	1.340				
SL			818.872	3.892		-62.657
T	0.335		-4.474	7.214		7.577
GC					0.108	0.081
R	0.907	0.945	0.506	0.873	0.748	0.999
Adj. R^2	0.806	0.888	0.189	0.740	0.541	0.998
F	50.962	191.15	3.791	35.113	29.294	3614.45
Std. Error	2.35	2.01	217.34	17.74	23.55	1.63

The coefficient indicates that grey diameter of plain weft knitted fabric is expected to be increased by 1.142 times with the unit increase of machine diameter in inch, 0.335 times with the unit increase of count in tex. The fitted line (figure-1) graphically shows the standardized predicted value from the regression model for grey diameter (GD) table 3 (p<0.01 and adj R^2 0.806).

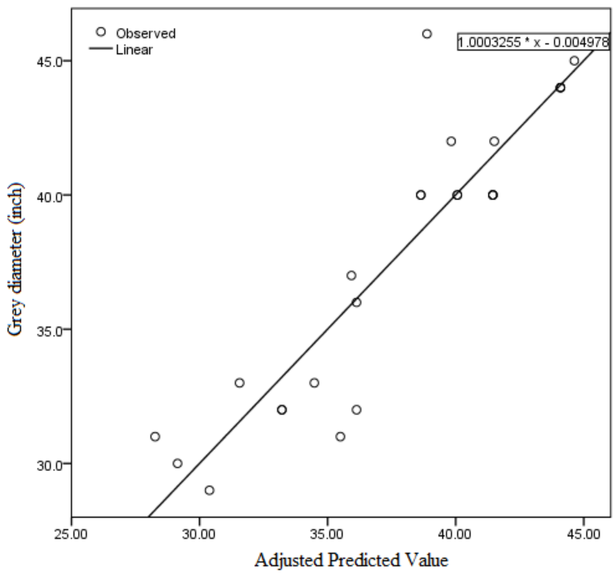


Figure 1.Predicted Value Using Linear regression model for grey diameter.

On the other hand, to predict finished width of the plain weft knitted fabric, only machine diameter is found significant to establish the regression model (p<0.01). Again, the regression model shows that finished width of fabric is expected to be increased by 1.340 times with the unit change of machine diameter in inch. The fitted line graphically shows (figure-2) the predicted values from this model (p<0.01 and adj R^2 0.888).

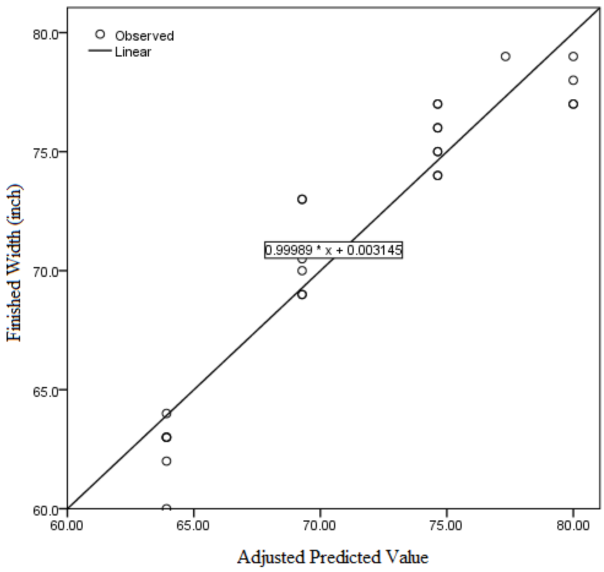


Figure 2. Predicted Value Using Linear regression model for finished width

Geometric constant is highly positively influenced by stitch length and negatively influenced by yarn count. The regression model shows that geometric constant is expected to be increased by 818.872 times with the unit change of stitch length in mm and decreased by 4.474 times with the unit change of count in tex. The fitted line graphically shows (figure-3) the predicted values from this model ($p<0.01$ and adj R^2 0.189).

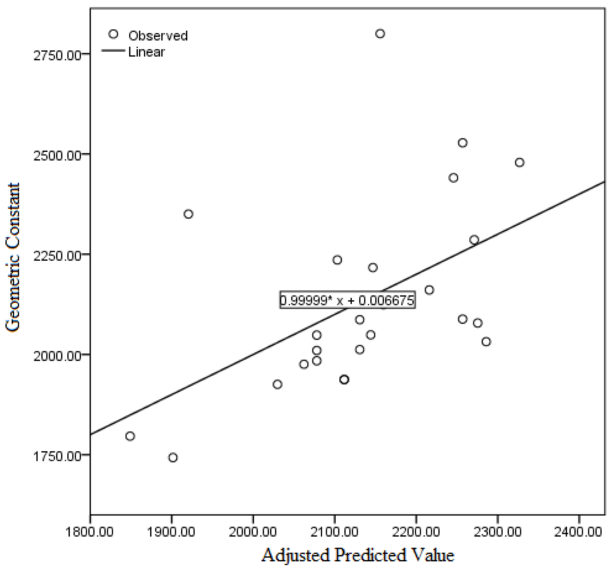
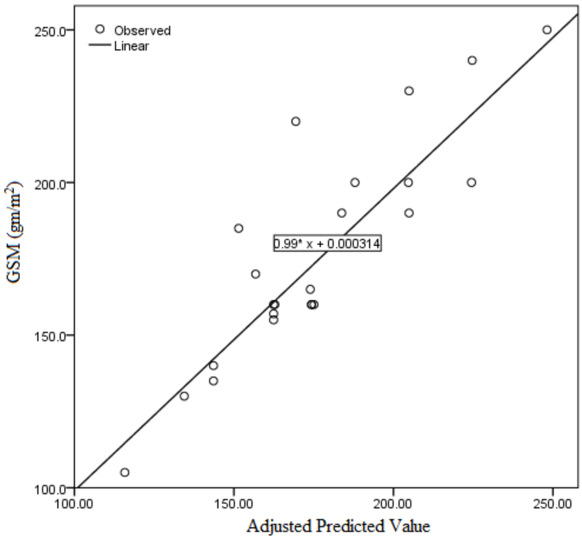


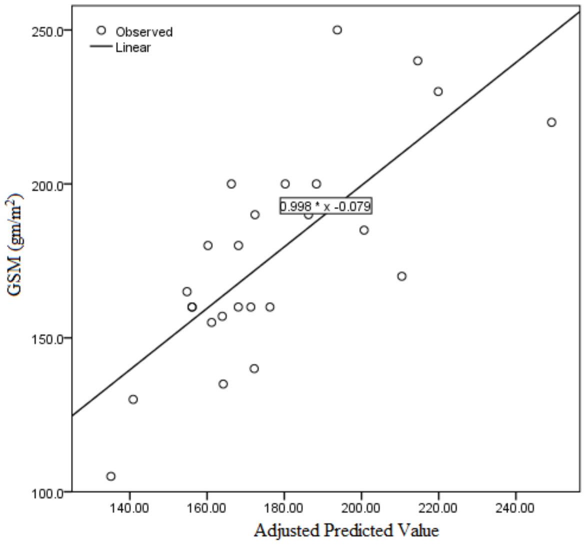
Figure 3: Predicted value using linear regression model for geometric constant, Ks

Again, it is observed that finished GSM is significantly influenced by yarn count, stitch length and geometric constant. (table 2). Geometric constant which is a composite variable and influenced by stitch length and yarn count or stitch density and loop length or GSM of the weft knitted fabrics. It can be represented as a function of stitch length and yarn count ($p<0.05$, Adj R^2 0.189).

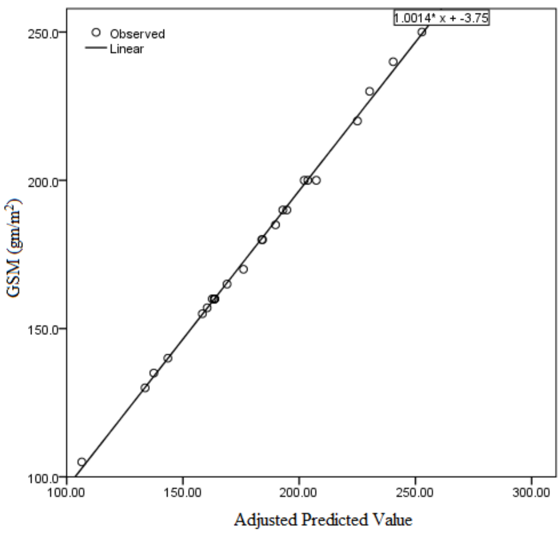
The coefficients (table 3) indicate that GSM of fabric is expected to be increased by 3.892 times with the unit increase of stitch length in mm and by 7.214 times with the unit increase of yarn count in tex while all other parameters remain as constant. But, GSM is increased by 0.108 times by unit change of geometric constant alone. If parameters stitch length, yarn count and geometric constant are used to predict the GSM considering others constant, the goodness of fit of the model increased. The predicted values by these three models are represented in the figure 3(a), 3(b) and 3(c) respectively.



(a) Stitch length and yarn count are independent variables.



(b) Geometric constant is independent is independent variable.



(c) Stitch length, yarn count and geometric constant are independent variables.

Figure 4. Predicted Value Using Linear regression model for finished GSM

From above models, following useful equations are found to be used in further study-

$$Grey\ diameter = (1.142\times MD) + (0.335 \times T) - 6.371$$

$$Finished\ width = (1.34\times MD) + 29.079$$

$$Geometric\ constant = (818.872\times SL) - (4.474\times T) - 38.692$$

$$GSM = (7.577\times T) - (62.657\times SL) + (0.081\times GC) + 6.997$$

V. Conclusion

It is a challenge to meet ever changing demands in practice for textile engineer. Every now and then, adjustments in the setting of machines are mandatory to ensure desired finished state of the knitted fabrics though it is clearly known as dimensionally unstable. This study deals with achieving desired GSM, diameter or width and geometric constant of the weft knitted fabric. Machine diameter, stitch length, count play significant impact on modification of these parameters. Established regression models in this study suggest better choice in the selection of parameters to achieve the goal. High weighted parameter, if changed, modifies the properties most. Manufacturers can use this outcome to assure and expected end product with minimal adjustments. Further study is required to set the parameters for other derivatives of single jersey fabrics as well as for double jersey fabrics. Yet, this outcome if applied properly can bring significant improvement in process control in production. Further research considering unobserved variables related to the processing or finishing of the weft knitted fabrics are required. Geometric constant is unable to establish a strong relationship with finished GSM of the fabric as other unobserved factors that are not identified or considered in this study. Further experiments considering unobserved variables are required to overcome this limitation in this study.

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