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Implementation of statistical technique in knitting fabric of predetermined GSM and finished width: A pragmatic approach

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Abstract

The problem of knitting fabrics of specific GSM and width ordered by buyer always has been a great challenge for fabric manufacturers. Implementation of statistical technique can be a solution for this problem. This study has demonstrated strong linear relationships between different quality parameters like Machine gauge, Stitch length, Yarn count and fabric GSM of knitted fabric using correlation and multiple regression analysis. For example, from 10 observations of Machine gauge, Stitch length, Yarn count and fabric GSM, by doing regression analysis, the value of R square was found 0.982878 which means approximately 98.29% of the variation in the GSM values can be explained by using the mentioned explanatory variables. Also this study has derived some regression equations among GSM, count, stitch length, machine gauge and develop equation among fabric width, count and stitch length for each specific machine diameter and gauge.

Keywords: GSM, Fabric Width, Stitch length, Yarn count, Machine diameter, Machine gauge, Correlation analysis, Regression analysis.

1. Introduction and literature review

Ready Made Garment (RMG) sector has been the pivotal of the economy of Bangladesh over the last few decades. From the beginning of textile industry in our country in the 80s and continuing into the twenty-first century, very few amount of attention has been focused on quality improvement in textile industries in order to create an atmosphere that improves the quality of knitted fabrics. Knit section have captured large portion of RMG sector. Knit fabric manufacturers are supposed to produce fabric of certain GSM (Gram Per Square Meter) and finished width. But it is really difficult for the manufacturing personnel to produce such fabric as GSM and finished width of fabric largely depends on yarn count, stitch length and machine gauge. Knit fabric manufacturers particularly those who are involved in producing weft knitted fabrics are continuously facing the problem of adjusting different quality parameters in producing a fabric of predefined structure. Although cotton-knit fabrics have been manufactured for decades, prediction of GSM, width and shrinkage is still regarded as the most widespread and difficult problem with the performance of such fabrics. In fact, very few people in the industry know how to calculate the weight, width and shrinkage after dyeing and finishing of a given quality of knitted fabric before it has ever been manufactured. The result is that, all over the world, product development of cotton knits is carried out on a "trial and error" basis followed by adjustment and re-adjustment during successive batches of bulk production [1]. There are very few published research works that deal with the above issue. Implementation of statistics in this issue can be the best solution for the management personnel (from production floor to corporate level) of textile industries in making the organization eligible to fight and survive in the competitive world market [2] Predicting the yarn count, stitch length and appropriate machine gauge in order to produce fabric of certain GSM and finished width is of great importance in this regard. This study aims at demonstrating relationships between different quality parameters by multiple regression analysis. If the value of co-efficient of determination (R square) obtained by regression analysis is close to +1 or -1, their will be strong relationship among those [3], [4]. A zero value of co-efficient of determination indicates no relationships among the variables [3], [4].

Also this study has derived some regression equations among GSM, count, stitch length, machine gauge and develop equation among fabric width, count and stitch length for each specific machine diameter and gauge. In doing so multiple regressions analysis is performed.

2. General discussion

In this study we focused mainly on establishing linear relationship between the quality parameters of plain single jersey fabric. We collected a large amount of data about plain jersey fabric sample's GSM, count, Stitch length, width and their manufacturing machine diameter and gauge. MS Excel Auto filter Option was used for doing this Also Log books were checked manually for accuracy.

Then MS excel Data analysis tool was used to determine linear relationship among them and derive regression equation of different parameters.

2.1. Single jersey fabric

It is a plain single knit structure with face loops on one side and back loops on other. The structure is produced when all the needles of a single bed machine knit at each feed. This structure can be of technical face and technical back. [8]

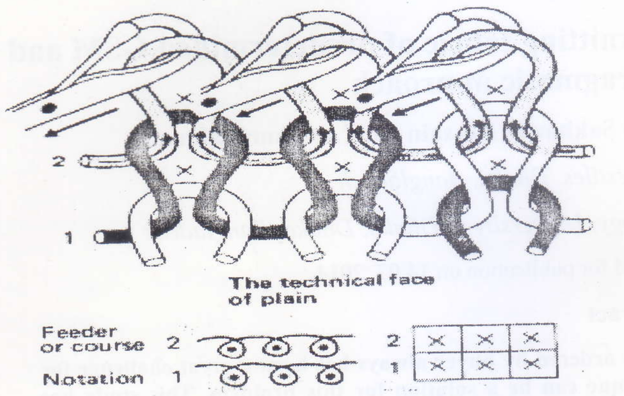

Fig. 1: Structure of single jersey knitted fabric.

2.2 Circular Knitting Machine

Most single-jersey fabric is produced on circular machines whose latch needle cylinder and sinker ring revolve through the stationary knitting cam systems that, together with their yarn feeders, are situated at regular intervals around the circumference of the cylinder. The yarns is supplied from cones, placed either on an integral overhead bobbin stand or on a free-standing creel, through tensioners, stop motions and guide eyes down to the yarn feeder guides (see Fig. 2).

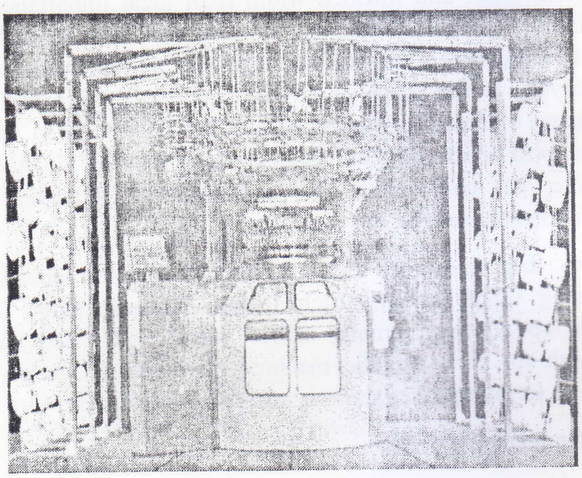

Fig. 2: Circular knitting machine

Machine Parts: 1. Yarn feeder guide, 2. Latch needle, 3. Holding-down sinker, 4. Needle cylinder, 5. Cylinder driving wheel. 6. Cylinder driving gear, 7. Sinker-operating cams, 8. Sinker cam-cap, 9. Sinker trick ring. 10. Needle-retaining spring, 11. Needle-operating cams, 12. Cam-box, 13. Cam-plate, 14. Head plate, 15. Cylinder driving pinion attached to the main drive shaft.

3. Objectives with specific aims and possible outcome

Following are the aims of this study:

- This project aims at emphasizing the importance of the linear relationship among quality parameters.
- To generate some equations among different quality parameters for readily determining yarn count, stitch length or machine gauge for producing buyer demanded fabric GSM and finished width.
- Implementing statistical methods and techniques in order to develop a linear relationship among different quality parameters in making different weft knitted fabrics.
- In doing so multiple regressions analysis will be used. If the value of co-efficient of determination (R square) obtained by regression analysis is close to +1 or -1, their will be strong relationship among those. A zero value of co-efficient of determination indicates no relationships among the variables. Here, in this experiment machine gauge, yarn count and stitch length will be treated as independent variables and gram per square meter (GSM) and finished width as dependent variable.

Following are the possible outcomes of this study:

- Strong linear relationship can be found among quality parameters by implementing the statistical method.
- We shall understand better about the relationships between the quality parameters of weft knitted fabrics.
- The result of this project will be useful in producing fabric of certain GSM and finished width and developing fabric quality.

4. MACHINE PARAMETERS

1. Machine gauge.
2. Machine Diameter.

4.1. Machine Gauge

No. of needles per inch present in a needle bed of a knitting machine is called machine gauge for that knitting machine. Selection of machine gauge depends upon the following: Yarn count, Fibre type, Yarn twist, Yarn finished. From this study of the data collected from factory we can see that the gauge increases with the English count (Ne) of the yarn.

4.2. Machine Diameter

Machine diameter is mainly diameter of m/c cylinder. It is important for fabric width. Only diameter does not determine the fabric width. It also needs machine gauge and wales space which is depends upon yarn count and loop length. This study has shown that same machine with the specific diameter can produce fabrics with different width.

5. Quality parameters of fabric

5.1. Yarn count

Count is a number that indicates length per unit mass or mass per unit length of yarn. It is expressed in two ways: Direct/Fixed length system and indirect /fixed weight system. This study has shown that fabric GSM decreases with the increase of yarn count.

5.2. Fabric GSM

Fabric weight per square meter expressed in gms is called fabric GSM. Fabric GSM decreases with increase of yarn count. This study has shown that GSM of fabric increases with the decrease of stitch length of fabric.

5.3. Stitch length

Stitch length is a length of yarn which includes the needle loop and half the sinker loop on either side of it. Generally the larger the stitch length, the more extensible and lighter the fabric and poorer the cover, opacity and bursting strength.

5.4. Fabric width

Fabric width is commonly measured in open width instead of tubular form. Although the processing of knitted fabrics in the past has been carried out mostly in tubular form, it is to be understood that processing in tubular form has its disadvantages. As Batch wise process hence reproducibility becomes difficult, high consumption of utilities like steam and water, Defect from processing in jets, rubbing and abrasion. The most important reasons for adopting open width processing of knitted goods are to produce good quality fabrics consistently with a high degree of flexibility and reproducibility and at lower costs to meet the stringent demands of customers.[7]

6. Customer specification and implementation of statistics in knitting technology

For a finished knitted fabric, the "customer" is the person or organization, which decides the final performance of the product. [1] It may be a store group, a garment maker, a converter or a retail division of a vertical company. The customer usually sets out his requirement in the form of a specification, which calls for combination of properties like-

* GSM
* Width

Sometimes this combination of properties is quite impossible to achieve in practice. It is a well-known fact that the demands of customers are often based largely upon wishful thinking rather than solid experience of the product that they have in mind. In the case of a new product this is almost inevitably the case and is to be accepted as a fact of life – part of the process of product evolution and improvement in response to market opportunities. But problem arises when the demanded weight and width values are mutually incompatible. Implementation of regression analysis can solve this problem.

7. Correlation and multiple regression analysis

There are many possible relationships between variables. Each relationship can be analyzed statistically to make predictions. Variables are related if one changes when the other does. These changes are called measures of association, or correlations. Measure of correlation between variables is done by calculating correlation coefficient. Correlation coefficient is the numerical summary of type (direction) & strength of a relationship between 2 variables. Direction indicated by a plus (+) sign for positive, and a minus (-) sign for negative (plus signs may be left off when correlations are reported).Strength is expressed as a decimal value ranges from +1.00 (perfect positive relationship) to -1.00 (perfect negative relationship. A correlation coefficient that is 0.00 means no relationship (at least not a linear one-- the two might be related in a different way).

Regression analysis involves techniques to predict or explain how people will score on a criterion, or outcome, variable based on their scores on another variable, called a *predictor variable* (or *regressor)*. Depending on how many predictor variables are studied, do a linear regression analysis or a multiple linear regression analysis. Multiple linear regression yields a *multiple correlation coefficient* [R] that tells us the relationship between the criterion variable & all the predictor variables If the value of co-efficient of determination (R square) obtained by regression analysis is close to +1 or -1, their will be strong relationship among those [3][4]. A zero value of co-efficient of determination indicates no relationships among the variables [3][4].In most research problems where regression analysis is applied, more than one independent variable is needed in the regression model [3][4]. The complexity of most scientific mechanisms is such that in order to be able to predict an important response, a multiple regression model is needed [3][4]. When this model is linear in the coefficients, it is called a multiple linear regression model. A regression equation is derived from the multiple regression analysis. Regression equation gives a forecasted output value of GSM or Width for a target shrinkage. The coefficient of variation " R-Square " value is a "goodness of fit" measure. R square is defined as: R square=SSR/SST

Where SSR= Regression sum of squares

SST= Total sum of squares

SSE= Sum of square error.

It ranges in value from 0 to 1. [3]. In our case, R square is giving a measure of the amount of reduction in the variability of GSM or Width obtained by using the regressor variables yarn count and stitch length in the model . For example, R square= 0.982878 (from Regression Summary – GSM of shown in the table 1) meaning approximately 98.29% of the variation in the GSM values can be explained by using the mentioned two explanatory variables.

8. Materials and Methods

This project was carried out at knitting shed of Viyellatex Group and GMS group. Following steps were followed in order to reach the goal of the experiment:

1) Among the four primary base structures of weft knitted fabric, Plain single jersey fabric are included here in this experiment.

2) Single jersey circular knitting machines of different machine gauges and diameter was used for producing plain single jersey and on this machines trial was carried out.

3) The grey GSM of those fabrics for different machine gauges (needle/inch), yarn counts (Ne) and stitch lengths (mm) was observed and putted on table.

4) Finished width of the fabric for same machine specification (diameter and gauge) and different yarn count and Stitch length was observed and putted on the table.

5) Correlation analysis was done on this data by the help of MS excel data analysis tools to see the correlation among different quality parameters of fabric.

6) Multiple regression analysis on MS Excel was done by using those data which were achieved for single jersey structure. It generated linear equation and strengthen the relationship between the quality parameter.

9. Result and discussion

9.1. Correlation between GSM, gauge Stitch length and count

At first grey GSM of single jersey fabrics for different machine gauges (needle/inch), yarn counts (Ne) and stitch lengths (mm) was observed and putted on table.

Table 1: Experiment data for plain single jersey fabric

GSM	Gauge	SL	Count
240	20	3.76	15
190	24	3	22
180	24	2.95	24
160	24	2.9	26
160	24	2.8	26
160	24	2.76	28
160	24	2.75	28
150	24	2.7	30
140	28	2.65	34
140	28	2.6	34
110	28	2.54	40

After that correlation analysis was done on this data by the help of MS excel data analysis tools to see the correlation among different quality parameters of fabric. The following result was found after the process.

Table 2: Summary output of correlation analysis of table 1

	GSM	Gauge	SL	Count
GSM	1			
Gauge	-0.87655	1		
SL	0.953061	-0.83875	1	
Count	-0.97	0.920275	-0.89122	1

From the above table we see that among fabric GSM, gauge, stitch length and yarn count the correlation coefficient numbers are close to 1 and -1.For example we see that correlation coefficient between GSM and count is -0.97 so we can say that they are strongly negatively correlated. That means with the increase of yarn count, fabric GSM is decreased.

9.2. Regression analysis

If regression analysis is done on the data of table 1 following result will be found:

Table 3: Summary output of multiple regression analysis for table 1 showing intercept and regression coefficients of parameters

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.991402							
R Square	0.982878							
Adjusted R Square	0.975539							
Standard Error	5.191459							
Observations	11							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	3	0829.52	3609.841	133.9397	1.52E-06			
Residual	7	88.6587	26.95125					
Total	10	1018.18						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	81.18037	5.15178	1.471945	0.184513	-49.2329	211.5936	-49.2329	211.5936
Gauge	2.192009	.749089	1.253229	0.25036	-1.94393	6.327947	-1.94393	6.327947
SL	44.44199	0.95113	4.058211	0.00482	18.54669	70.3373	18.54669	70.3373
Count	-3.56721	0.755943	-4.71889	0.00216	-5.35473	-1.77969	-5.35473	-1.77969

Consider the GSM regression model of the table 1. The adjusted R square for the model (R square adj=0.975539) is close to the ordinary R square (R square=0.982878) indicating a true goodness of fit. We also see that the p value of count and stitch length is very low which means that there are strong relation among GSM and count. From the above table we derive the following regression equation for GSM, count gauge and stitch length.

GSM =81.18037 + (2.192009* Gauge) + (44.44199 * stitch length)-(3.56721*Count).

Standard Error (Se) represents the amount of scatter in the actual data around the regression line and is very similar in concept to the SSE. Once we have Se value, we can take advantage of a rough thumb rule that is based on the normal distribution and states that we have 68% confidence the actual value of GSM or Width would be within +/-1 Se of our predictable value. Likewise we have 95% confidence that the actual value of GSM or Width would be within +/- 2 Se of our predicted value. As from the example of table 1 of section 9.1, the predicted value for GSM (when machine gauge is 24,yarn count is28 and stitch length is 2.75) is : 81.18037+ (2.192009* 24) +(44.44199*2.75) – (3.56721*28) or 156.122 [by putting input values in reg. equation GSM=81.18037+(2.192009*Gauge)+(44.44199*stitch length)–(3.56721*Count).Our 68% confidence interval would be [156.122 – 1(5.191459); 156.122 +1(5.191459)] or [150.93, 161.31] Our 95% confidence interval would be [156.122 – 2(5.191459); 156.122 +2(5.191459)] or [145.74,166.5].Following scatter diagram shows the linear relationship between fabric GSM, machine gauge, yarn count and stitch length.

9.3. Correlation between fabric width, yarn count and stitch length of same machine specifications

In this study we also observed that there is a strong linear relationship among fabric width, yarn count and stitch length of fabric knitted in machine of specific diameter and gauge. Following data were tabulated and was subjected to correlation analysis. A knitting machine of 30 inch diameter and 28 gauge was considered and different finished diameter, count and stitch length was tabulated.

Table 4: Experiment data for machine of 30 inch diameter and 28 gauge

Machine Diameter	Gauge	Finished diameter	Stitch length	Count
30	28	68	2.8	30
30	28	67	2.7	30
30	28	67	2.65	30
30	28	66	2.6	34
30	28	66	2.65	34
30	28	64	2.54	40

After correlation analysis by the help of MS excel Data analysis tool following result was found:

Table 5: Summary output of correlation analysis of table 4

	Finished diameter	SL	Count
Finished diameter	1		
SL	0.918748	1	
Count	-0.96362	-0.8107	1

From the above result we see that finished diameter, count and stitch length with same machine specifications are strongly correlated.

9.4. Regression analysis of fabric width, yarn count and stitch length of same machine specifications

After we do regression analysis of Table 4, we get following result.

Table 6: Summary output of multiple regression analysis for table 4 showing intercept and regression coefficients of parameters

SUMMARY OUTPUT

Regression Statistics

Multiple R	0.991846
R Square	0.983759
Adjusted R Square	0.972932
Standard Error	0.22478
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	9.181755	4.590877	90.86136	0.00207
Residual	3	0.151579	0.050526		
Total	5	9.333333			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	57.19893	6.36238	8.990179	0.002905	36.951	77.44687	36.951	77.44687
Stitch length	6.181057	1.935888	3.192879	0.049602	0.020197	12.34192	0.020197	12.34192
Count	-0.22081	0.043472	-5.07924	0.014742	-0.35915	-0.08246	-0.35915	-0.08246

From the above table we see that value of R square is 0.983759 which means approximately 98.38% of the variation in the GSM values can be explained by using the mentioned explanatory variables. Consider the regression model of the table 4. The adjusted R square for the model (R square adj=0.972932) is close to the ordinary R square (R square=0.983759) indicating a true goodness of fit.

We also see that the p value of count and stitch length is very low which means that there are strong relation among GSM and count. Following regression equation was derived from the data of table 4 found by Regression analysis

Fabric width=57.19893 - (0.22081*count)
+ (6.181057*stitch length)

Standard Error (Se) represents the amount of scatter in the actual data around the regression line and is very similar in concept to the SSE . Once we have Se value, we can take advantage of a rough thumb rule that is based on the normal distribution and states that we have 68% confidence the actual value of GSM or Width would be within +/-1 Se of our predictable value. Likewise we have 95% confidence that the actual value of GSM or Width would be within +/- 2 Se of our predicted value. As from the example of table 1 of section 9.1, the predicted value for fabric width (when finished diameter is 30,stitch length is 2.7 and yarn count is 30) is : 57.19893-(0.22081*count)+(6.181057*stitch length) or 67.263484 [by putting input values in reg. equation Fabric width=57.19893-(0.22081*count)+(6.181057*stitch length)].Our 68% confidence interval would be [67.263484 – 1(0.22478); 67.263484 +1(0.22478)] or [67.038704, 67.488264] Our 95% confidence interval would be [67.263484 – 2(0.22478); 67.263484 +2(0.22478)] or [66.813924, 67.713044] Following is another reading of a knitting machine of 30 inch diameter and 28 gauge.

Table 7: Experiment data for machine of 30 inch diameter and 28 gauge

Dia in inch	Gauge	Finished dia in inch	Count	SL in mm
30	24	60	38	2.5
30	24	44	30	3
30	24	52	31	2.9
30	24	52	31	2.8
30	24	52	31	2.88

Table 8: Summary output of correlation analysis of table 7

	Finished dia	Count	SL
Finished dia	1		
Count	0.864675	1	
SL	-0.92809	-0.96139	1

From the above analysis we see that there is strong correlation in between finished dia, stitch length and yarn count of fabric of same machine specification. Now if we do a regression analysis of the data of table 7 we get the following result.

Table 9: Summary output of multiple regression analysis for table 7 showing intercept and regression coefficients of parameters

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.933492
R Square	0.871407
Adjusted R Square	0.742813
Standard Error	2.868793
Observations	5

ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	2	111.5401	55.77003	6.776455	0.128593			
Residual	2	16.45994	8.229971					
Total	4	128						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	179.1985	127.189	1.408915	0.294222	-368.052	726.4488	-368.052	726.4488
Count	-0.63004	1.593551	-0.39537	0.730756	-7.48654	6.226459	-7.48654	6.226459
SL	-37.9656	27.36682	-1.38729	0.299722	-155.716	79.78428	-155.716	79.78428

From the above table we see that value of R square is 0.871407 which means approximately 87.14% of the variation in the GSM values can be explained by using the mentioned explanatory variables. Following regression equation was derived from the data of table 4 found by Regression analysis

Fabric width= 179.1985 - (37.9656*stitch length) - (0.63004*count).

10. Conclusion

The result of analysis obtained from this study is the following:

1. The value of correlation coefficient between GSM and count, GSM and gauge and GSM and stitch length is found -0.97,-0.87655 and 0.953061 respectively. Those numbers indicate the strong correlation between GSM, gauge ,SL and count.
2. The values of R square obtained for GSM is 0.982878 and for width is 0.983759.this means that this observations are correct for about 98.29% and 98.38% variations in GSM and width values.
3. A regression equation for GSM is derived from the collected data from factories. GSM=81.18037+(2.192009*Gauge)+(44.44199*stitch length) – (3.56721*Count).
4. The value of correlation coefficient between fabric width and stitch length, width and count is 0.918748 and -0.96362 respectively.
5. A regression equation for finished width is derived from the collected data from factories. Fabric width=57.19893-(0.22081*count)+(6.181057*stitch length).

End words

Although cotton-knit fabrics have been manufactured for decades, prediction of GSM and finished width is still regarded as the most widespread and difficult problem with the performance of such fabrics. From this study we have tried to find a solution for this problem and have shown strong linear relationships among quality parameters of knitted fabric and has also derived some regression equation for quality parameters. We believe that implementation of statistical technique in knitting sector is the best solution for the problem of prediction of GSM and finished width.

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