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# Statistical Study of the Influence of Some Knitting Parameters Variation on the Fabrics Quality

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**Abstract:** In this study, we statistically studied the influence of the variations of the knitting parameters: loop length, taking-down and carriage speed on the knitted cloth characteristics: stitch length and basis weight, in the two extreme relaxation cases which are the industrial relaxation using the relaxlab and the dry relaxation. Then, we pointed out the contribution of the Digital Stitch Control System (DSCS) made by Shima Seiki to the knitted cloth characteristics. Results prove that the use of DSCS reduces the number of parameters that affect the studied fabric characteristics, which lead to a better control of the fabric quality. The used yarn is acrylic high bulk, $N_m$ = 15. The bonding is the 1 and 1 rib.

**Key words:** Knitted fabrics, digital stitch control system, factorial analysis, relaxation, basis weight, length of absorbed yarn

## INTRODUCTION

Professionals consider the shape modifications of knitted fabrics during different steps of fabrication and use as an unavoidable problem. That's why, many fundamental researches treated the stability of the knitted clothes and machine constructors are continually developing systems aiming to control and reduce the bad impact of the dimensional variations, especially concerning the length of the absorbed yarn, on the fabrics.

The literature reports some of the parameters that have the main influence at different levels on the geometric properties of relaxed knitted fabrics, e.g. stitch length, the yarn physical properties (Chen, 2002).

The effect of some knitting parameters on the mechanism of loop formation (Knapton, 1966a, b). They proposed some modifications on the cam system geometry to ameliorate the knitting conditions. Shanahan (1970) established different relaxation conditions that were more or less drastic and tried to analyse theoretically the structure of the knitted fabric in terms of the loop configuration. Some researchers tried to improve the dimensional stability of the fabrics by chemically treating the fiber (Cortez, 2002).

Even if its known that it is difficult in practice to obtain a perfectly relaxed fabric (Shanahan, 1970) we tried out to study, by statistical means the influence of some knitting parameters in the two extreme cases of relaxation which are dry relaxation and industrial one using the relaxlab. The fabric is made by a non-dyed High Bulk Acrylic yarn.

## MATERIALS AND METHODS

The fabrics were made with the 122FF Shima Seiki knitting machine equipped with DSCS and Parameters variations are done automatically using a PC which monitors all the machine components.

Dry relaxation consists on conditioning the fabric during one week at room temperature (25°C) and constant relative humidity (about 60%).

Industrial relaxation using the relaxlab consists on vibrating the fabric for 15 min in presence of water-steam. The digital stitch control system helps to knit a prototype or a test piece of a pattern.

The data for a particular pattern are based on the loop length and the number of stitches in each row. The interest of the DSCS is to treat each stitch as a single data, with whole share.

During the knitting of each row, the machine's computer monitors and regulates the stitch length, referring to the data sent from the DSCS, in order to maintain it constant on following rows, with a high degree of accuracy, whatever are the knitting conditions such as the nature of the yarn or the external parameters (yarn tension, humidity).

**Factorial design:** Table 1 shows the factors which will be taken in account to investigate their influences on the variables to be studied. These latest are the length of the absorbed yarn (called LFA) and the basis weight. The different values of the factors, also called the explanatory variables, used in this study are indicated in the third column. The softwares used are SPSS 9 and

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Table 1: Explanatory variables: names, types and levels

| Factors or explanatory variables | Type of factors | The levels of factors |
|---|---|---|
| Loop length | Continuous | 3 levels (18; 22; 26) |
| Taking-down | Continuous | 3 levels (28; 34; 39) |
| Carriage speed | Continuous | 2 levels (0.5; 0.8 m $sec^{-1}$) |
| Operation state of the DSCS | Non continuous | 0: DSCS off<br>2 levels 1: DSCS on |
| Kind of relaxation | Non continuous | 0: dry relaxation<br>2 levels 1: industrial relaxation |

Minitab 14, 18, 22 and 26 are equivalent respectively to 0.925, 1.02 and 1.11 cm/loop.

## RESULTS AND DISCUSSION

**Length of the absorbed yarn:** According to the statistical tests, the results below are obtained:

- $p>\alpha = 0.05$, where p is the value given by the normality test of Anderson Darling
- Average of the residues = 0.000
- Test of Durbin Watson, D.W. = 1.65: a value which can be statistically considered close to 2.

So the data follow a normal law and the coefficients of the explanatory parameters can be estimated by the ordinary least squares method.

In addition, Fig. 1 shows that the loop length is the most influent factor. The carriage speed and the interaction (carriage speed/DSCS) are influencing the considered answer, too.

Further we are trying to find out the operation state of the DSCS in which the speed has the greatest influence on the LFA?

According to Table 2, we can say that, whatever is the type of relaxation applied to the knitted fabric, we obtain the following results:

- Without using the DSCS, the parameters that influence the stitch length, by descending order and by accepting a risk of error of 5% in the estimation of the explanatory variables coefficients, are the loop length then the speed of the carriage. The variation of one of these two factors is proportional to that of the stitch length.
- By using the DSCS, the factor speed looses its significance (t test<1.96) and the taking-down remains always a non significant factor.

That is due to the fact that the DSCS regularizes the positions of the stitch cams in each passage of the carriage, in order to ensure a constant consumption of the yarn whatever are the yarn tension around the spool and the flow of the yarn.

In the other case, when the operation state of the DSCS is off, it can be said that the carriage is directly related to the spool and in our experimental conditions, a considerable increase in its speed generates a greater delivery of the yarn. Consequently, the quantity of yarn absorbed by needles will be greater.

**Basis weight:** The same steps of study were carried out for the answer basis weight and confirmed that the values of the variables follow a normal law and the validity of estimating the coefficients of the explanatory factors by the ordinary least squares.

The diagram of Pareto showed that the basis weight is influenced primarily by the following factors, arranged in descending order: Relaxation, loop length, Interaction (relaxation/taking down) and Interaction (DSCS/carriage speed/relaxation).

The basis weight is largely influenced by the industrial relaxation and the loop length. In fact, during the industrial relaxation, the acrylic high bulk yarn, in view of its structure, shrinks in a remarkable way in the directions of column and row. So that the stitches' density will be greater, which explain the considerable increase of the surface mass of the knitted fabric.

The more the loop length increases, the more the basis weight decreases (negative coefficient of regression of the loop length). That's due to the fact that the quantity of yarn consumed, per unit of area, by a loose knitted fabric is less than that consumed by a sleazy one.

The effect of the taking-down is meaningful only when the knitted fabric is relaxed dry ($p<0.05$). In the other case, the factor taking down loses an important share of its significance. Therefore, the relaxation using the relaxlab could hide the information which the variable taking-down can carry about the basis weight. That's because the steam and the vibrations in which the fabric was subjected during its relaxation on the relaxlab cancelled all the mechanical interactions and stresses within the stitches. These internal interactions represent the effect brought by the taking-down (Table 3).

In the previous results concerning the stitch length, we found that the carriage speed is proportional to this response when the DSCS is not in operation and considering that the increase of absorbed yarn generates the reduction of the basis weight, it can be said that speed is inversely proportional to the basis weight. However, according to the statistical results showed on the Table 3, in the case of DSCS off, the increase of the stitch length generated by the increase of the carriage speed doesn't have a significant effect when the knitted fabric is not relaxed by the relaxlab ($p>0.05$). In the other case, the variation of the carriage speed can have a significant influence with 5% errors risk.

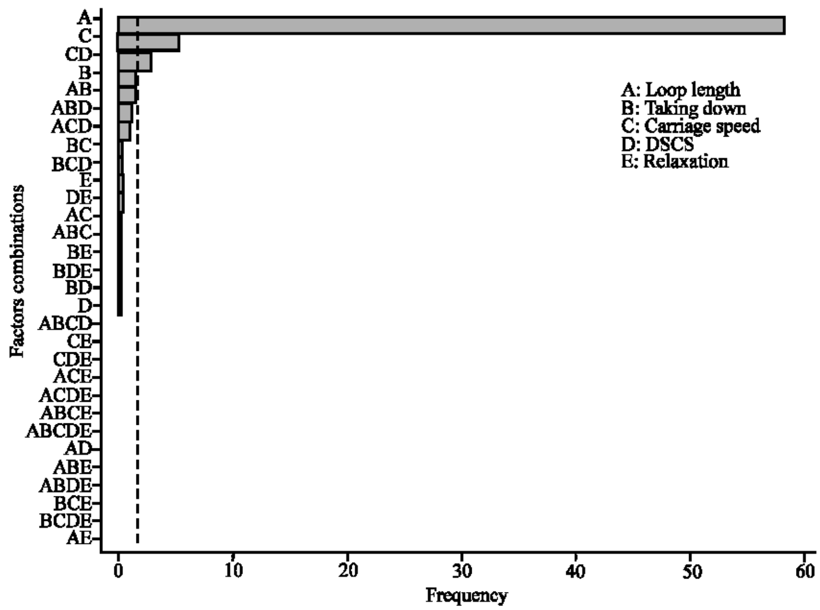


Fig. 1: Pareto diagram of the main effects using α = 0.05

Table 2: The results estimation of the explicative model for each combination (DSCS, relaxation); stitch length = f (loop length, taking-down, carriage speed)

| Response: Stitch length | | DSCS off+dry relaxation | DSCS off+industrial relaxation | DSCS on+dry relaxation | DSCS on+industrial relaxation |
|---|---|---|---|---|---|
| Loop length | Coefficient of contribution $\alpha_i$ | 0.985 | 0.986 | 0.991 | 0.991 |
| | t-test | (35.05)*** | (38.38)*** | (29.57)*** | (29.57)*** |
| | p-value | 0 | 0 | 0 | 0 |
| Taking-down | Coefficient of contribution $\alpha_i$ | 0.031 | 0.048 | 0.031 | 0.031 |
| | t-test | (1.1)* 1.1 | 1.861 | 0.929 | 0.929 |
| | p-value | 0.53 | 0.125 | 0.6 | 0.6 |
| Carriage speed | Coefficient of contribution $\alpha_i$ | 0.136 | 0.129 | 0.036 | 0.036 |
| | t-test | (4.856)** | (5.031)** | 1.079 | 1.079 |
| | p-value | 0.03 | 0.03 | 0.32 | 0.32 |
| | $R^2$ (adjusted) | 98.7% | 98.9% | 98.1 | 98.1% |

*Significant to 10%; **Significant to 5%; ***Significant to 1%

Table 3: The results estimation of the explicative model for each combination (DSCS, relaxation); basis weight = f (loop length, taking-down, carriage speed)

| Response: Basis weight | | DSCS off+ dry relaxation | DSCS off+ industrial relaxation | DSCS on+ dry relaxation | DSCS on+ industrial relaxation |
|---|---|---|---|---|---|
| Loop length | Coefficient of contribution $\alpha_i$ | -0.962 | -0.963 | -0.989 | -0.971 |
| | t-test | (-21.928)*** | (-17.446)*** | (-32.65)*** | (-19.68)*** |
| | p-value | 0 | 0 | 0 | 0 |
| Taking-down | Coefficient of contribution $\alpha_i$ | -0.211 | -0.089 | -0.096 | -0.077 |
| | t-test | 64 (-4.807) *** | -1.612 | (-3.164)*** | -1.553 |
| | p-value | 0 | 0.13 | 0.007 | 0.143 |
| Carriage speed | Coefficient of contribution $\alpha_i$ | -0.047 | -0.152 | -0.019 | -0.13 |
| | t-test | -1.068 | (-2.751)** | -0.631 | -1.829 |
| | p-value | 0.303 | 0.016 | 0.538 | 0.12 |
| | $R^2$ (adjusted) | 96.7% | 94.8% | 98.4% | 95.9% |

*Significant to 10%;**Significant to 5%; ***Significant to 1%

This result can be interpreted as follows: since dry relaxed knitted fabric shrinks little in the columns and rows directions and considering the increase of the stitch length per unit of area, generated by the carriage speed, is not so important to influence significantly the basis weight, there will not be a significant variation of our dependant variable. Whereas, in the case of an industrial relaxation, the important shrinking of the fabric, generates an accumulation of the amount of yarn added by the carriage speed effect. Thus, this accumulation will have a significant effect which is inversely proportional to the basis weight. This last result confirms the results obtained for the first output variable.

## CONCLUSION

Obtained results show the contribution of the digital stitch control system to the stability of the knitted fabrics and their regularity. In addition, the factorial design allowed us to establish the relationship between all treated parameters and their interactions either in contribution model or in estimating one. We showed in that research only the first models.

Nevertheless, the results obtained in this study can be followed by controlling other parameters during knitting operation like the tension of the yarn, relative humidity and temperature of the knitting room, rugosity of the yarns.

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