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Theoretical and Empirical Estimation of Plain-Stitch Fabric Slurgalling

Abstract
Theoretical and empirical estimation of PA and viscose-PAN plain-stitch fabric has been carried out using computer image analysis. The border values of relative difference in the height of fabric courses εB_{gr} and the relative changes in the length of thread in the stitch at which slurgalling occurs have been defined, whereby they have been verified by means of a model dependence $\varepsilon B=a\cdot\varepsilon l$. The usefulness of computer image analysis as a tool for the objective and direct estimation of fabric slurgalling has been confirmed.

Key words: *slurgalling, knitted fabric, plain-stitch fabric, computer image analysis, flat knitting machine.*

The faults of slurgalling on course fabrics are most frequently caused by different needle push depths and by different tension of threads in the area of stitch creation in particular working areas of the machine [1]. As a consequence, both different thread lengths in stitch l for particular courses of the fabric and (at the same time) different values of their height B, are obtained, which can be noticed on fabric surface as slurgalling faults [2]. The assessment of such faults then takes on a subjective character. The relative difference of thread length in a stitch εl defined by measuring the thread knit-in in the technological process, or by thread unstitching from particular courses of the fabric, is the estimator of fabric non-uniformity which is commonly used in practice [3]. The method of directly measuring the height of a single course in computer image analysis proved very useful in respect of estimation of plain-stitch fabric slurgalling [4]. This method allows a new slurgalling estimator to be used, namely the relative difference in height of fabric courses εB. Investigations of knitted fabrics made from PA silk proved that slurgalling (low-contrast stripes) occur when the border values of εB_{gr} equal -9.7% and +7.5%, which correspond to border values of εl_{gr} equal to -5.3% and +3.2%. Using computer image analysis, a similar investigation has been carried out for plain-stitch fabric with programmed slurgalling and made from viscose-PAN 32 tex×2 yarn on a computer-controlled flat knitting machine manufactured by the Universal company. The yarn used for the production of the knitted fabric is characterised by high uniformity and good contrast of outlines in the images of the knitted fabric investigated (Figure 1).

In order to determine the border values for the changes in needle push depth ΔZ_{gr}, below or above which more than low-contrast stripes appear, and in order to determine the values of εl_{gr} and εB_{gr} at the same time, a subjective analysis of slurgalling faults was carried out. The results of the investigation are presented in Table 1, while the diagrams of the regression equations $\varepsilon l=\varphi(\Delta Z)$ and $\varepsilon B=f(\Delta Z)$ have been presented in Figure 2, where border values are given in bold letters.

***Table 1.** The list of border values of the relative difference of thread length in a stitch εl_{gr} and relative differences of the course height εB_{gr}, at which the slurgalling fault occurs on plain-stitch fabrics from viscose-PAN yarn.*

ΔZ_{gr}, pitches	εl_{gr}, %	εB_{gr}, %
-6	-12.2	-22.6
4	8.4	17.5

As in the case of PA plain-stitch knitted fabrics, the εB values are about twice as large as the εl values. Thus, taking into account the simplifying assumption that the increment of thread length in a stitch Δl causes an increment of course height alone, the following can be formulated:

$$\Delta l = 2\,\Delta B \qquad (1)$$

and is presented as a scheme in Figure 3.

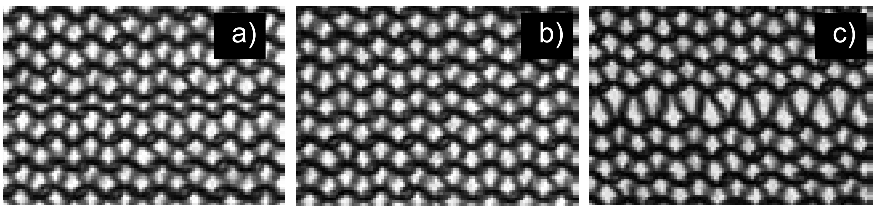

***Figure 1.** Examples of images of knitted fabrics made from viscose-PAN yarn with preset slurgalling for the changes in needle push depth by: a) ΔZ= –10, b) ΔZ= 0, and c) ΔZ= 10 (pitches).*

***Table 2.** The list of border values of the relative difference of thread length in a stitch εl_{gr} and the relative difference in course height εB_{gr} and $\varepsilon B_{gr}(m)$ values.*

Parameter, %	PA knitted fabric		Viscose-PAN knitted fabric	
εl_{gr}	-5.3	3.2	-12.2	8.4
εB_{gr}	-9.7	7.5	-22.6	17.5
$\varepsilon B_{gr}(m)$	-12.4	7.5	-26.1	17.9

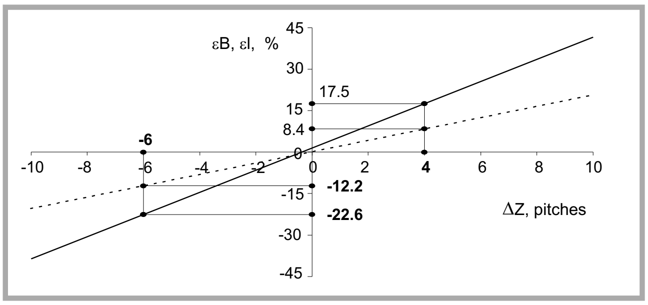

Figure 2. Dependence of the relative difference of the course height εB (continuous line) and the relative difference of thread length in a stitch εl (dash line) in the function of the changes in needle push-depth ΔZ for viscose-PAN knitted fabrics (border values are marked in bold).

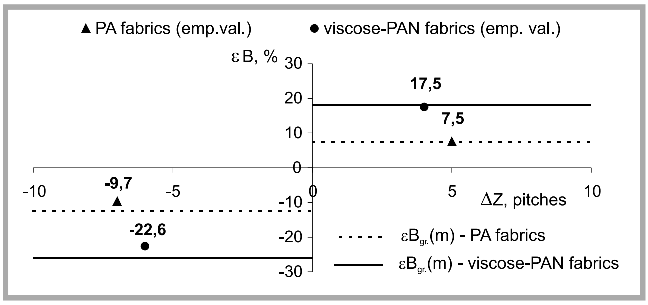

Figure 4. Border values of the relative difference in course height εB_{gr} determined by measurement in computer image analysis and model values $\varepsilon B_{gr}(m)$ for plain-stitch fabrics from PA yarns and viscose-PAN yarns.

By converting dependence (1), the following is obtained:

$$\varepsilon l = 2\ \frac{B_0}{l_0} \cdot \varepsilon B \qquad (2)$$

and upon taking into account the dependence determining the course knit-in coefficient for background stitches W_{r0}, we obtain the following:

$$\varepsilon B = \frac{W_{r0}}{2}\ \varepsilon l \qquad (3)$$

Treating the course knit-in coefficient W_{r0} of background stitches as a constant value for particular raw-material versions of knitted fabrics, the model dependence can be presented in a simplified way as follows:

$$\varepsilon B(m) = a \cdot \varepsilon \qquad (4)$$

The value of the W_{r0} coefficient for PA knitted fabrics is W_{r0}=4.66, while it is W_{r0}=4.27 for viscose-PAN knitted fabrics. Thus, with the assumption (1), the model border values of εB_{gr} (m) can be calculated for the border values of εl_{gr} determined empirically. These values and their empirical values are presented in Table 2 and illustrated in Figure 4.

A theoretical and empirical analysis of slurgalling on plain-stitch knitted fabrics has shown that the assumption taken for model (1) and dependence (4) resulting from such an assumption are correct in the case of positive values of εl_{gr} in respect of both PA and viscose-PAN knitted fabrics, while in the case of negative values of εl_{gr} obtained by reducing needle push-depth, the model values εB_{gr} (m) are lower than the empirical values εB_{gr} by 2.7% for PA fabrics, and by 3.4% for viscose-PAN fabrics.

Research carried out under the same conditions on the geometry of uniform plain-stitch knitted fabrics with distinct outlines of stitches has shown that the relative border value of indirect measurement error referring to the dimension of 1 mm is equal to approx. 1.5%, which confirms the usefulness of the method for estimating slurgalling faults in respect of the determined border values of εB_{gr} [5].

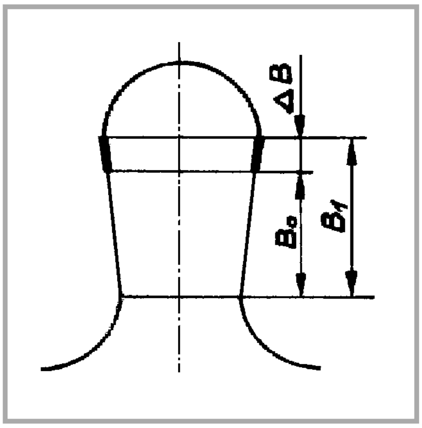

Figure 3. Schematic drawing of a knitted fabric stitch, with the absolute difference of course height ΔB=0.5Δl marked on it.

Conclusions

- Estimating the slurgalling of viscose-PAN plain-stitch fabrics by means of computer image analysis allowed the definition of the border values of the relative difference in fabric course height εB_{gr} at which stripes appear defined on a 5-grade quality scale as 'low-contrast' stripes. These values amount to -22.6% and +17.5% and, in comparison with border values of the relative difference in thread length in a stitch εl_{gr}= -12.2% and +8.4%, they are approximately twice as great. A similar investigation of plain-stitch knitted fabrics from PA silk has confirmed this proportion (εB_{gr}= -9.7% and +7.5%, while εl_{gr}= -5.3% and +3.2%).
- The results of the research allowed us to make the assumption that the change in thread length in a stitch l exclusively causes the change in course height B. The theoretical and empirical estimation of slurgalling has confirmed the assumption to be correct, especially in the case of knitted fabrics, where the slurgalling fault occurs as a result of the increase in the thread length in a stitch.
- An investigation of the geometry of the uniform knitted fabrics has shown that the relative border value of measurement error during computer image analysis as related to a 1-mm dimension for the knitted fabrics with distinct outlines of stitches, amounts to approximately 1.5%. This confirms the usefulness of the method used for estimating the slurgalling fault for the determined border values εB_{gr}.

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