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Influence of Weave into Slippage of Yarns in Woven Fabric

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Slippage resistance of yarns at a seam in woven fabrics is a very important factor and very strict claims are raised for this property. It is necessary to know how fabric structure influences on seam slippage quality before manufacturing the fabric. The purpose of this work was to establish which of the weave factor is most suitable to describe balanced weave fabrics seam slippage. It was investigated seam slippage characteristics in the fabric and the factor was offered, which characterizes best fabric structure from the thread slippage point of view. Fifteen wool fabrics, which differ only on weave were weaved for investigations. The test was carried out according to LST EN ISO 13936-1standard. First of all, the well known factors such as fabric structure factor *P* and average float *F* were investigated and then a new fabric structure factor was offered, which the best characterizes the weave from thread slippage point of view. The proposed model shows good correlation between experimental and theoretical values of the new weave factor.
Keywords: woven fabrics, weave factor, seam slippage, fabric structure.

1. INTRODUCTION

Woven fabric is a sophisticated structure material and its characteristics are influenced by its structure. There are seven parameters influencing woven fabric structure: the raw material of the warp and the weft, the linear density of warp and weft, the warp and weft setting and the weave of the fabric [1 – 3].

All seven parameters of the fabric's structure can be evaluated by integrated fabric structure factors. Various scientists proposed different evaluations of all these fabric parameters. According to the methods of evaluation of these parameters, two groups of integrated factors are distinguished: the first is based on the Peirce theory and the second on the Brierley theory. Peirce's group factors express the covering of a fabric surface with threads, and Brierley's group factors are defined as a ratio of analysing fabric density with standard fabric density [4, 5]. This group also includes average float length *F*, which was offered by Ashenhurst and weave factor *P* offered by V. Milašius.

It is well known factor – the average float length *F*, which was offered by Ashenhurst [6, 7]. It was very simple and widely used factor. Later it was observed that this factor didn't describe all the properties of a weave, which are important from a technological and end-use point of view. This factor could not evaluate the difference between types of weaves (it is well known that the weaves twill 7/1, satin 8/3 and panama 4/4 have a different tightness, but are still counted with the same value, $F = 4$) and unbalanced weaves, whose average warp float is different from the average weft float (warp rib 4/4 and weft rib 4/4 behave very differently during weaving but still evaluated using the same value, $F = 2.5$).

Weave factor *P* offered by V. Milašius is calculated directly from the weave matrix. Factor *P* evaluates not only a single thread float, but an interlacing of adjacent threads too and can be calculated for all the types of the weaves. Weave factor *P* describes beating-up process very well [8] and it measures fabric structure describing some of its properties, such as elasticity, air permeability and other [1 – 3].

However, factor *P* is very good for balanced weaves but it cannot evaluate the difference between unbalanced weaves – warp rib 4/4 and weft rib 4/4 have the same value, $P = 1.205$. Later V. Milašius proposed factor P_1, calculated in the warp direction [1]. It covers most of the weaves used.

Such technological and constructional parameters as position of back rest, heald levelling advance, geometry of shed, weft and warp yarns stress in general meaning, may influence on fabric structure. It was measured in previous work, that properties of fabrics with the same setting parameters, but weaved with not identical technological parameters, are different [9]. Such properties of fabrics as air permeability, strength, elongation, etc. were investigated by many authors. Many studies have been performed on the woven fabric structure influence on different fabric properties. Investigations showed that woven fabric structure influences on fabric properties. When weave of fabric is different, the properties are different, too [10 – 12]. Therefore, all fabrics need to be weaved with the same loom. So all the fabrics were weaved with the same setting and technological parameters. In this way, only the weight of fabric weave can be analysed.

Slippage resistance of yarns at a seam in woven fabrics is a very important factor and very strict claims are raised for this property.

The slippage-based opening at the seam line occurs on the woven fabrics due to movement in the fabric of the weft yarns over warp yarns (or warp yarns over weft yarns) at a sewn seam during wearing. Many studies have been performed on slippage of yarns of woven fabric, but this question is still open [13 – 15]. Influence of weave on

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slippage of yarns of woven fabric is not still completely investigated.

The aim of this work was to establish which of the weave factor is most suitable to describe slippage resistance of yarns at a seam in woven balanced weave fabrics.

2. MATERIALS AND METHODS

Fifteen wool fabrics were weaved for investigations, which differ only on weave. They all were weaved with rapier "Vamatex" looms from the same back rest. So all the fabrics were weaved with the same setting and technological parameters.

They all have the same linear density of warps and wefts – 12.5 tex×2, warps setting is 300 dm^{-1}, wefts – 260 dm^{-1}**.** The warp ends were drawin-in on 12 heald frames straight pass and fifteen balanced weaves, which can be weaved on 12 heald frames were chosen. The weaves were chosen in such a way that they could be woven at the same loom settings (see Fig. 1).

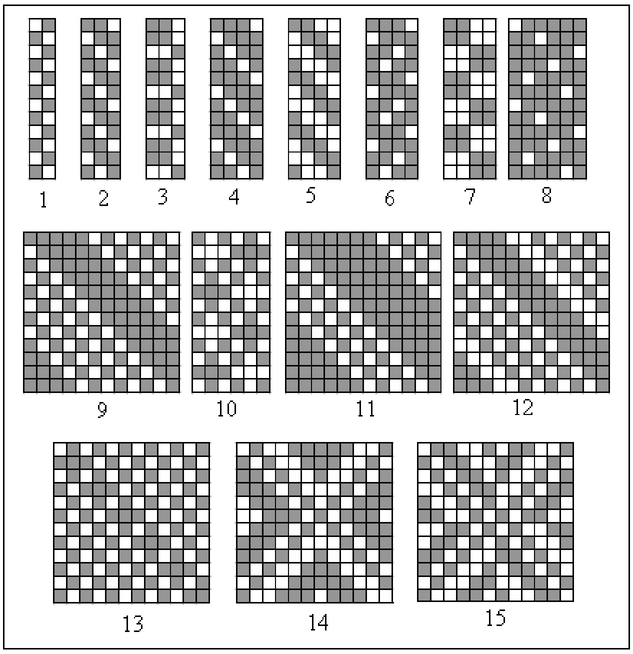

Fig. 1. The weaves used for experiments: 1 – plain weave, 2 – twill 2/1, 3 – basket 2/1, 4 – twill 3/1, 5 – twill 2/2, 6 – warp satin (4 healds), 7 – basket 2/2, 8 – warp satin (6 healds), 9 – twill 5/1 1/1 1/1 1/1, 10 – leno 3/3, 11 – twill 7/1 1/1 1/1, 12 – twill 4/2 1/1 1/1 1/1, 13 – weave based on plain weave, 14 – diamond specular broken twill 1/1 3/2, 15 – diamond negative broken twill 1/1 2/2

Slippage resistance of the yarns at a seam in woven fabrics was measured with a tensile testing machine Zwick/Z005, according to international standard "Determination of the slippage resistance of yarns at a seam in woven fabrics – Part 1: Fixed seam opening method" (LST EN ISO 13936-1: 2004) and according Woolmark test method (TM 117 "Seam slippage of woven fabrics") at 78 N force distance between yarns after slippage has been measured.

In this research only tests of seam slippage in the weft direction were carried out (warp yarns slipping over weft yarns). All results were statistically processed.

Weave factor P proposed by V. Milašius was calculated by the following equation:

$$P_{1(2)} = \sqrt{\frac{3R_1R_2}{3R_1R_2 - \left(2n_{f1(2)} + \sum_{i=1}^{6} K_{1(2)i} n_{f1(2)i}\right)}}, \qquad (1)$$

where: R_1 and R_2 are the warp and weft repeat of the weave, respectively, n_f - the number of free fields, n_{fi} - the number of free fields belongs to group i, K_i - elimination factor of group i.

The Ashenhurst's weave factor F, alternatively called the average float length was calculated by the following equation:

$$F_{1(2)} = \frac{R_{2(1)}}{t_{1(2)}}, \qquad (2)$$

where: $R_{1(2)}$ are repeats of warp and weft, respectively, $t_{1(2)}$ are the numbers of intersections of warp and weft, respectively.

3. RESULTS AND DISCUSSIONS

All parameters of the fabric structure (warp and weft raw material, warp and weft linear densities, warp and weft settings and fabric weave) influence on fabric seam slippage, but, exactly the weight of fabric weave on seam slippage was studied in this work. All other parameters of the woven fabrics were the same.

First of all, well known and investigated factors were analysed – weave factor P proposed by V. Milašius (for balanced weaves $P_1 = P_2 = P$) and average float length F offered by Ashenhurst (for balanced weaves is the same in both directions warp and weft $F_1 = F_2 = F$).

Experimental investigations were made on the basis of Brierley's theory under which it must be the starting point – standard. For weave estimation this starting point is a plane weave. So, in this work values of properties of different weaves were compared with the value of plain weave. Therefore, it was not used obtained slip rate in the studies, but in proportion with the size of plane weave (there are no weave, which resist against slippage more than plain weave). This proportion we named as "coefficient of weave influence" which can be calculated as: slippage resistant of fabric / slippage resistant of plane weave fabric. The coefficient of weave influence and other parameters are presented in Table 1.

On the first stage of research weave factor P proposed by V. Milašius was analysed, because it describes beating-up process very well and it measures fabric structure describing some of its properties, such as elasticity, air permeability and more. It was checked, how this factor characterizes the weave from the thread slippage point of view.

Simple models were considered: linear, power and polynomial of second order equations and calculated coefficients of determination between experimental and theoretical values.

The value of coefficient of determination (R^2) of linear equation was obtained 0.7448, of power – 0.7392 and of polynomial of second order equation – 0.7779 (see Fig. 2).

Table 1. Weave factors

Weave	Factor *P*	Factor *F*	Slippage resistance of fabric, mm	Coefficient of weave influence
plain	1.00	1.00	1.72	1.00
twill 2/1	1.16	1.5	2.14	1.24
basket 2/1	1.19	1.5	3.02	1.76
twill 3/1	1.33	2.00	2.88	1.67
twill 2/2	1.27	2.00	2.70	1.57
warp satin (4 healds)	1.30	2.00	3.02	1.76
basket 2/2	1.36	2.00	4.46	2.59
warp satin (6 healds)	1.55	3.00	4.84	2.81
twill 5/1 1/1 1/1 1/1	1.21	1.50	2.06	1.20
leno 3/3	1.39	2.00	3.60	2.09
twill 7/1 1/1 1/1	1.10	1.29	2.86	1.66
twill 4/2 1/1 1/1 1/1	1.19	1.50	2.14	1.24
weave based on plain weave	1.03	1.09	1.98	1.15
diamond specular broken twill 1/1 3/2	1.24	1.71	2.84	1.65
diamond negative broken twill 1/1 2/2	1.23	1.38	2.26	1.31

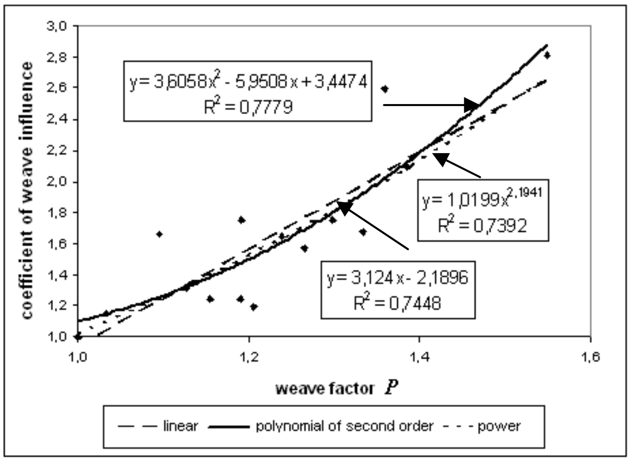

Fig. 2. Dependence of coefficient of weave influence on weave factor *P*

It was found that polynomial of second order equation describes slippage the best but its coefficient of determination is not enough high, only 0.7779.

On the second stage of investigation the average float length *F* which was offered by Ashenhurst was analysed. The same simple equations as with weave factor *P* (linear, power and polynomial of second order equations) were checked and noticed that the results were obtained even worse – even bigger difference between the experimental and theoretical values were obtained. The value of coefficient of determination (R^2) were approximately 0.71 (see Fig. 3).

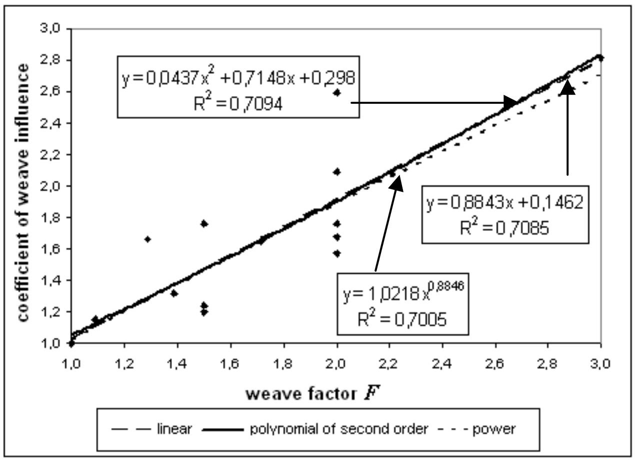

Fig. 3. Dependence of coefficient of weave influence on weave factor *F*

This factor could not evaluate the difference between types of weaves. It is well known that the weaves twill 7/1, satin 8/3 and panama 4/4 have a different tightness, but are still counted with the same value, $F = 4$. So this factor is not good. It is unsuitable for describing the weave from thread slippage point of view.

Because of small coefficients of determination of studied models, on the third stage of the research it was attempted to find a new weave factor, which characterizes best fabric structure from the thread slippage point of view. It was analysed each warp end and it was noticed, how many wefts resist to that particular thread move. It was taken two adjacent warp ends, eliminated those wefts, which do not resist to move from one place to another and counted these threads, which change location that is to say resist to slippage. And further the same adjacent wefts were counted like square root of adjacent equal number of wefts (see Fig. 4).

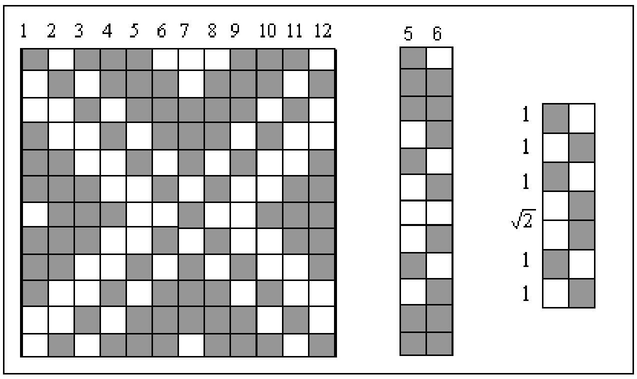

Fig. 4. Example of calculation of new weave factor

It was decided that the same adjacent wefts were counted like a square root of adjacent equal number of wefts because of theory of Hamilton, under which threads have possibility to close up – ready to change their cross-section [16] (see Fig. 5). This theory was confirmed in previous work where it was also found that floats of warps and wefts not only close up, but also can go ones under another [17].

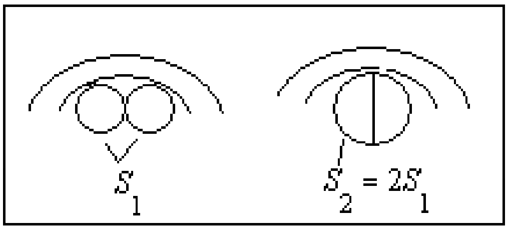

Fig. 5. Two different possibilities of yarns shape in fabric cross–section

Table 2. Values of factor *NPR*

Weave	New weave factor *NPR*
plain	1.000
twill 2/1	0.667
basket 2/1	0.536
twill 3/1	0.500
twill 2/2	0.500
warp satin (4 healds)	0.500
basket 2/2	0.354
warp satin (6 healds)	0.333
twill 5/1 1/1 1/1 1/1	0.667
leno 3/3	0.500
twill 7/1 1/1 1/1	0.648
twill 4/2 1/1 1/1 1/1	0.667
weave based on plain weave	0.868
diamond specular broken twill 1/1 3/2	0.535
diamond negative broken twill 1/1 2/2	0.690

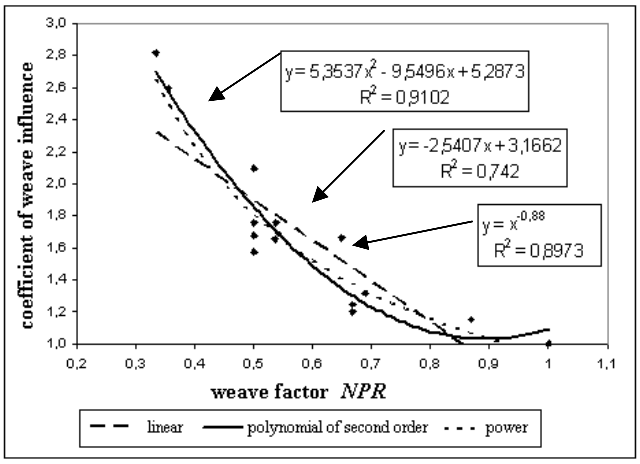

Fig. 6. Dependence of coefficient of weave influence on weave factor *NPR*

Two possible marginal positions of yarns are shown in Fig. 5. It is evident, that if $S_2 = 2S_1$ and $S_2 = d_2^2\pi$, and $S_1 = d_1^2\pi$, then $d_2 = d_1\sqrt{2}$.

Therefore that the same adjacent wefts were counted like square root of adjacent equal number of wefts.

New weave factor is calculated like proportion of all threads, which resist to slippage with the warp and weft repeats (equation 7):

$$NPR = \frac{\sum i}{R_1 R_2}, \qquad (3)$$

where: $\sum i$ – in the sum of all threads which resist to slippage, R_1 – warp repeat, R_2 – weft repeat.

That factor is calculated directly from the weave matrix. Values of factor *NPR* for all investigated fabrics are presented in the Table 2.

The same simple equations as with the weave factor *P* and average float length *F* were checked and noticed that polynomial of second order equation of new weave factor describes slippage the best and have enough high value of coefficient of determination $R^2 = 0.9102$ (see Fig. 5). It shows good correlation between experimental and theoretical values of the polynomial of second order equation of the new weave factor. The power equation shows good correlation as well.

4. CONCLUSIONS

- Polynomial of second order equation of weave factor *P* decribes weave from the thread slippage point of view better than linear and power equations. However, coefficient of determination is not enough high ($R^2 = 0.7779$).
- The average float length *F,* which was offered by Ashenhurst does not characterize fabric structure from thread slippage point of view.
- The new weave factor *NPR* for slippage resistance estimation has been proposed. This weave factor better describe the influence of weave on slippage then other known weave factors (V. Milašius factor *P* or Ashenhurst factor *F*).
- According to the coefficient of determination, it was found that a polynomial of second order equation of new weave factor the best characterizes balanced fabric structure from thread slippage point of view. The value of coefficient of determination is high – 0.9102.

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