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# Weave Factor for Seam Slippage Prediction of Unbalance Fabrics

## Abstract

*In this article the seam slippage characteristics of unbalanced weave fabrics are analysed. The slippage resistance of yarns at a seam in woven fabrics is a very important factor, and strong claims have been made about this property. Preliminary investigations showed that balanced and unbalanced woven fabrics must be estimated differently. Well-known factors such as the fabric structure factor  $P$  and average float  $F$  were investigated, and then a new fabric structure factor, NPR, was proposed, which best characterises the weave from a thread slippage point of view. According to the coefficient of determination, it was found that the power equation of the new weave factor for balanced fabrics shows good correlation between experimental and theoretical values. It was proved that seam slippage influences not only the weave factor in the slip direction but also in the normal direction. The weave factor in the slip direction influences seam slippage by 81%, the weave factor in opposite direction – 19%. However, this new model is unsuitable for describing warp and weft ribs from a thread slippage point of view because they comprise a separate group of weaves, with particular theories applying to them.*

**Key words:** woven fabrics, weave factor, seam slippage, fabric structure.

erley theory. In the first case it is a ratio of the surface covered by threads to the total fabric area. In the second case it is a ratio of the setting of the “square” analogue of a given fabric to the setting of standard “wire” plain weave fabric [4, 5]. This group also includes the average float length  $F$ , which was proposed by Ashenhurst, and the weave factor  $P$ , proposed by V. Milašius.

The average float length  $F$  was a very simple and widely used factor [6]. Later it was observed that this factor did not 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 are still evaluated using the same value,  $F = 2.5$ ).

The weave factor  $P$  proposed by V. Milašius [7] is calculated directly from the weave matrix. Factor  $P$  evaluates not only a single thread float, but also an interlacing of adjacent threads and can be calculated for all types of weaves. The weave factor  $P$  is a measure of the fabric structure, describing some of its properties, such as elasticity, air permeability, among others [8]. Although factor  $P$  is very good for balanced weaves, it cannot evaluate the difference between unbalanced weaves – warp rib 4/4 and weft

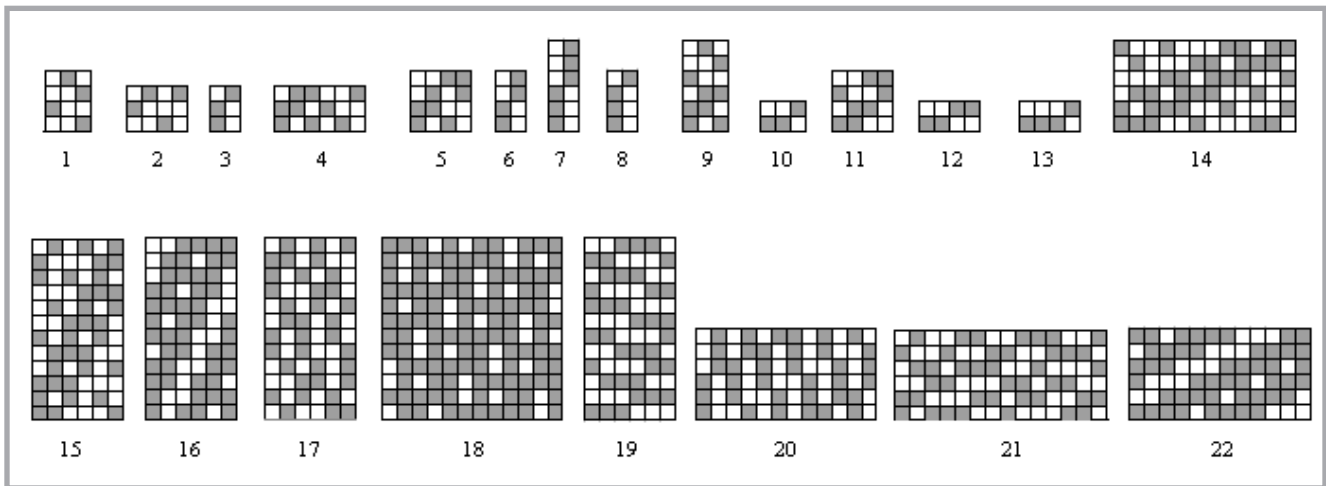
rib 4/4, giving the same value,  $P = 1.205$ . Later V. Milašius proposed factor  $P_I$ , calculated in the warp direction [1, 9], covering most of the weaves used.

In a previous work it was proved that the properties of fabrics with the same setting parameters, woven with not identical technological parameters, are different [10]. Therefore, all fabrics need to be woven with the same loom. In this way, only the weight of the fabric weave can be analysed.

The slippage resistance of yarns at a seam in woven fabrics is a very important factor, and strong claims are made for this property. It is necessary to know how the fabric structure influences seam slippage quality before manufacturing the fabric. However, the slippage of seams depends on some different factors, for example the structure of ready-made cloths and the fitting of the cloth to the human body. Moreover, knowledge of the dependence on the woven fabric structure is very important for practical purposes because it allows to design fabric with new patterns suitable for clothing that will not slip in the seams. Seam slippage is a measure of the ability of warp yarns to slip over weft ones near the seam, which extends in the warp direction, when the fabric is subjected to a given load in the weft direction (and vice versa). This load is applied so as to separate the two pieces of the fabric joined by a seam, and thus an opening, which is the result of yarn slippage, appears near the seam. It is an important parameter for fabric characterisation, especially for garment production. The dependence of seam slippage values

## Introduction

The structure of woven fabric is complex because in its evaluation we need to take into consideration many woven fabric structure parameters, such as warp and weft materials, the warp and weft linear density, warp and weft settings and the fabric weave [1 - 3]. All these woven fabric structure parameters can be evaluated together as well as separately, but woven fabric weave evaluation is the most complex because it is important to consider the nature of the float, its arrangement, the interlacing of adjacent threads etc. All seven parameters of the fabric structure can be evaluated by integrated fabric structure factors. Various scientists have 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 Bri-



**Figure 1.** Weaves used in the experiments: 1 – broken twill 1/2 B, 2 – broken twill 1/2 A, 3 – warp rib 2/1, 4 – negative broken in warp twill 2/1, 5 – negative broken in warp twill 2/2, 6 – warp rib 2/2, 7 – warp rib 3/3, 8 – warp rib 3/1, 9 – negative broken in weft twill 2/1, 10 – weft rib 2/1, 11 – negative broken in weft twill 2/2, 12 – weft rib 2//2, 13 – weft rib 3/1, 14 – weft diagonal 3,2,1,3,2,1, 15 – warp diagonal 3,2,1,3,2,1, 16 – warp diagonal 4,1,4,3, 17 – warp crepe, 18 – soleil weave, 19 – corkscrew 3/3 (in weft), 20 – corkscrew 3/3 (in warp), 21 – weft crepe, 22 – weft diagonal 4,1,4,3.

on the fabric weave makes this property an interesting case for study.

Many studies have been performed on the slippage of the yarns of woven fabric, but this question is still open [11 - 15]. The influence of weave on the slippage of yarns of woven fabric has still not been completely investigated.

In a previous work [16] we stated that the relationship between well-known structural models and weave factors are problematic and ambiguous, and therefore we made an attempt to find a new weave factor which best characterizes the fabric structure from a thread slippage point of view. Preliminary investigations with balanced woven fabrics showed that the new weave factor, *NPR*, better describes the influence of weave on slippage than other known weave factors (V. Milašius factor *P* or Ashenhurst factor *F*).

The aim of this work was to determine a new weave factor, *NPR*, for slippage pre-

diction which can be used for unbalanced weave fabrics.

## Materials and methods

Unbalanced weave fabrics were woven for the investigations, which differed only in the weave. They were allwoven on rapier looms from the same back rest. Therefore all the fabrics were woven with the same setting and technological parameters. They all had the same linear density of the warps and wefts – 12.5 tex×2, warp setting - 300 dm<sup>-1</sup>, and weft – 260 dm<sup>-1</sup>. The weaves were chosen so that they could be woven at the same loom settings (see *Figure 1*).

The slippage resistance of yarns at a seam of the woven fabrics was measured with a tensile testing machine - Zwick/Z005, according to the 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 to the Woolmark test method (TM 117 “Seam

slippage of woven fabrics”) at a 78 N force distance between yarns after the slippage has been measured.

Pieces of the test fabric were sewn together using a stitch type 301 (see *Figure 2*). 100% polyester core spun of linear density 45 tex was used for the seam, with a stitch density of 50 dm<sup>-1</sup> and needle size of 0.90 mm. The test specimens were stretched until a force of 200 N. Five specimens of each fabric were prepared for the tests.

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.

The new weave factor, *NPR*, [16] was calculated as a proportion of all the threads resisting slippage to the warp and weft repeats (*Equation 1*):

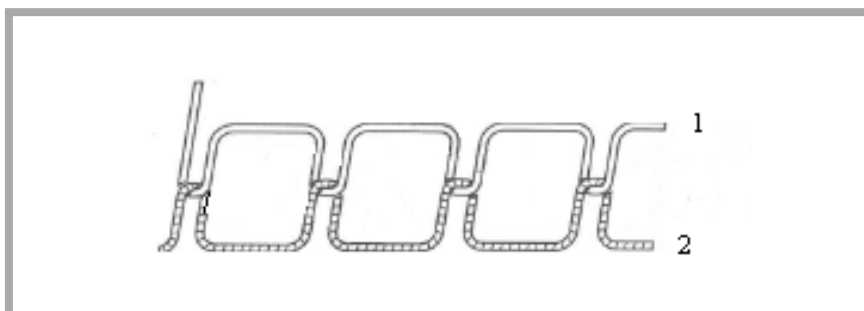
$$NPR = \frac{\sum i}{R_1 R_2} \quad (1)$$

where:  $\sum i$  – is the sum of all threads resisting slippage,  $R_1$  – warp repeat,  $R_2$  – weft repeat.

This factor is calculated directly from the weave matrix.

## Experimental results and discussion

All parameters of the fabric structure (warp and weft raw material, warp and weft linear densities, warp and weft settings and fabric weave) influence fabric



**Figure 2.** Stitch type: 1- needle thread, 2 – bobbin thread.

seam slippage. However, in this work the weight of the fabric weave on seam slippage was studied. All other parameters of the woven fabrics were the same.

Experimental investigations were made on the basis of Brierley's theory, which had to be the starting point and the overall standard. For weave estimation this starting point is a plane weave. Hence, in this work values of the properties of different weaves were compared with that of plain weave. Therefore, it was used to very popular present the "coefficient of weave influence" ( $C_w$ ), which can be calculated as the slippage resistance of the fabric/slippage resistance of plain weave fabric (only the warp rib 2/1 weave resists slippage more than the very popular plain weave). The coefficient of weave influences other parameters, which are presented in **Table 1**.

Preliminary investigations showed [16] that the coefficients of determination of well known models are small ( $R^2 = 0.7779$  with factor  $P$  and  $R^2 = 0.71$  with factor  $F$ ), and because which it was attempted to find a new weave factor which best characterises the fabric structure from a thread slippage point of view. Each warp end was analysed, and how many wefts resisted the particular thread movement were noted. Two adjacent warp ends were taken into consideration, and those wefts were eliminated which did not resist movement from one place to another. Those threads which changed location, that is to say resisted slippage, were counted. Furthermore the same adjacent wefts were counted as a square root of the adjacent equal number of wefts. Preliminary investigations with balanced weave fabrics showed that the new weave factor  $NPR$  better describes the influence of weave on slippage than

**Table 1.** Some parameters of fabrics used in experiment and values of factor  $NPR$ .

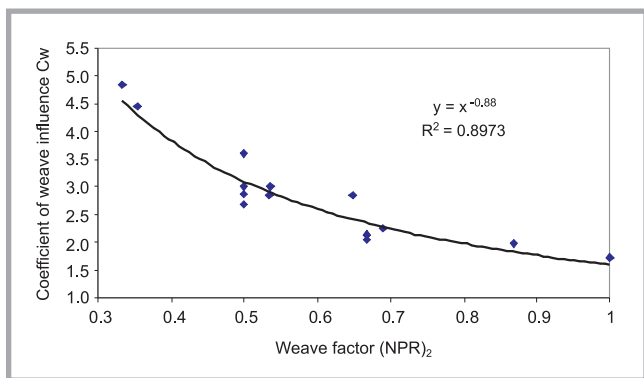
Weave	Slippage resistance of fabric, mm	Coefficient of weave influence	( $NPR$ ) <sub>1</sub>	( $NPR$ ) <sub>2</sub>
Plane	1.72	1.00	1.000	1.000
broken twill 1/2 B	2.38	1.38	0.667	0.569
broken twill 1/2 A	2.26	1.31	0.569	0.667
warp rib 2/1	1.62	0.94	0.667	0.805
negative broken in warp twill 2/1	2.58	1.50	0.667	0.713
negative broken in warp twill 2/2	2.70	1.57	0.500	0.604
warp rib 2/2	2.64	1.53	0.500	0.707
warp rib 3/3	4.04	2.35	0.333	0.577
warp rib 3/1	2.58	1.52	0.500	0.683
negative broken in weft twill 2/1	2.32	1.35	0.713	0.667
weft rib 2/1	2.32	1.35	0.805	0.667
negative broken in weft twill 2/2	2.70	1.57	0.604	0.500
weft rib 2/2	4.84	2.81	0.707	0.500
weft rib 3/1	5.26	3.06	0.683	0.500
weft diagonal 3,2,1,3,2,1	3.60	2.09	0.569	0.402
warp diagonal 3,2,1,3,2,1	2.84	1.65	0.402	0.569
warp diagonal 4,1,4,3	4.48	2.60	0.333	0.402
warp crepe	2.84	1.65	0.500	0.632
soleil weave	5.10	2.97	0.236	0.289
corkscrew 3/3 (in weft)	5.42	3.15	0.524	0.236
corkscrew 3/3 (in warp)	3.64	2.12	0.236	0.524
weft crepe	3.06	1.78	0.632	0.500
weft diagonal 4,1,4,3	4.86	2.83	0.402	0.333

other known weave factors (V. Milašius factor  $P$  or Ashenhurst factor  $F$ ). The value of the coefficient of determination is relatively high - 0.8973. That factor is calculated directly from the weave matrix. Values of factor  $NPR$  for all the fabrics investigated are presented in **Table 1**.

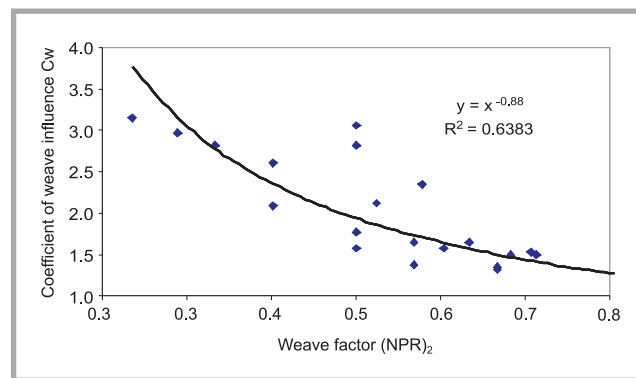
According to the coefficient of determination, it was found that the power equation of the new weave factor ( $NPR_2^{-0.88}$ ) for balanced fabrics shows a good correlation between experimental and theoretical values (see **Figure 3**). An empirical equation for weave estimation was also proposed by Brierley [4]; we also found that this kind of equation better estimates weave influence.

In the second stage of the research, the same model was used for unbalanced weave fabrics, and it was noticed that even worse results were obtained – a big dispersion occurred. The value of the coefficient of determination ( $R^2$ ) was 0.6383 (see **Figure 4**).

Preliminary investigations showed that balanced and unbalanced weave fabrics must be estimated differently. Balanced weaves have the same weave factor values in both directions – warp and weft, while unbalanced weaves have different values. It was established that the seam slippage resistance depends not only on the weave factor in the slip direction but also on that in the opposite direction. Hence the influence of the weave



**Figure 3.** Dependence of coefficient of weave influence on weave factor  $NPR$  for balanced weaves.



**Figure 4.** Dependence of coefficient of weave influence on weave factor  $NPR$  for unbalanced weaves.

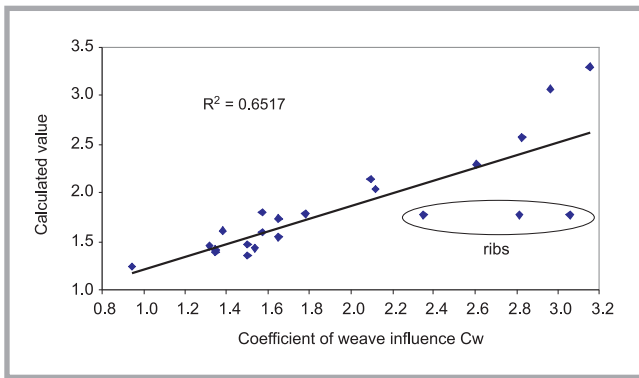


Figure 5. Correlation between experimental and calculated values.

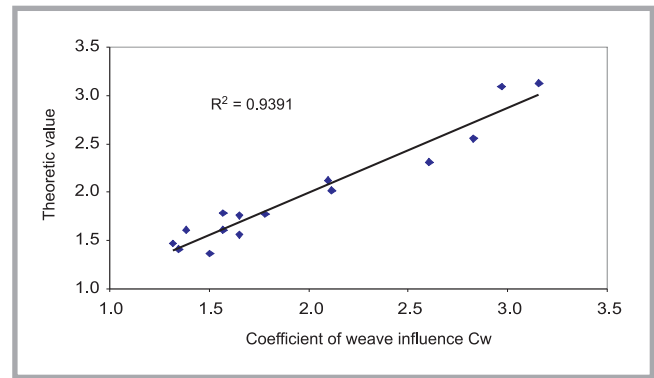


Figure 6. Correlation between experimental and calculated values (when ribs were eliminated).

factor on the slip and opposite directions was estimated  $(0.81(NPR)_2^{-0.88} + 0.19(NPR)_1^{-0.88})$  (see Figure 5).

The value of the coefficient of determination ( $R^2$ ) obtained was slightly higher, but not sufficient. The picture showed that some points are very far removed from the curve. They were analysed and it was found that these points belong to rib weave fabrics: warp rib 3/3, weft rib 2/2 and weft rib 3/1. According to the theory of Brierley, weft and warp ribs are a separate group of weaves, and particular theories are applied to them. This new model is also unsuitable for describing warp and weft ribs from a thread slippage point of view. Therefore, these fabrics were eliminated from the researches, and the value of the coefficient of determination ( $R^2$ ) was obtained as 0.9391 (see Figure 6).

Figure 6 shows a good correlation between theoretical and experimental values when ribs are eliminated. It was established that the weave factor in the slip direction influences seam slippage by 81%, and the weave factor in the opposite direction – 19%.

## Conclusions

- A new weave factor,  $NPR$ , for slippage resistance estimation has been proposed. This weave factor better describes the influence of the weave on slippage than other known weave factors (V. Milašius factor  $P$  or Ashenhurst factor  $F$ ).
- According to the coefficient of determination, it was found that the power equation of the new weave factor characterises a balanced fabric structure well from a thread slippage point

of view. The value of the coefficient of determination is high – 0.8973.

- Preliminary investigations showed that balanced and unbalanced woven fabrics must be estimated differently. Seam slippage resistance depends not only on the weave factor in the slip direction but also on that in the normal direction.
- The weave factor in the slip direction influences seam slippage by 81%, and the weave factor in the normal direction by 19%.
- This new model is unsuitable for describing warp and weft ribs from a thread slippage point of view because, according to Brierley theory, they constitute a separate group of weaves, and particular theories are applied to them.

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