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Analysis of Interrelation between Fabric Structure Factors and Beat-up Parameters

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In the present article there are analysed integrated fabric structure parameters and those of the beat-up process as well as the relation of beat-up process parameters and fabric's structure factors. A close relation has been determined to exist between beat-up and of a fabric structure parameters. This relation is reflected by Brierley's group factors better than by Peirce's group ones.
Keywords: weave, integrated fabric structure factors, beat-up force, beat-up duration, beat-up force impulse.

INTRODUCTION

A fabric is a complex multistage material. When new fabrics are designed the following fabric's structure parameters are calculated or selected, namely: warp and weft raw materials (the level of a polymer, composing fibre), a warp and weft linear density (thread level), warp and weft settings and fabric weave (fabric level). The evaluation of these fabric's parameters mentioned is rather simple as they are expressed by specific numbers, the only exception being fabric weave, which is a graphic fabric structure picture. Various integrated structure factors are used for a proper fabric evaluation. The beat-up is one of the most important fabric formation parts in the loom where a fabric's structure is formed. Therefore it is very important to establish a relation between fabric structure factors and the parameters of a beat-up process.

The main fabric structure parameter values are formed during the weaving process. The weft inserted during weaving is quite straight. When the beat-up is taking place, the warp and weft crimp, therefore a fabric gets narrower and shorter and the warp internal force increases.

Plate and Hepworth [1] explaining the beat-up process used the scheme shown in Fig. 1. We can see in Fig. 1 that when a thread raw material or the linear density (i.e. thread diameter) as well as the weft setting (i.e. the distance between wefts) change the thread internal force *F* described by the authors by simple mechanical equations changes as well. However, this scheme is only fit for plain weave.

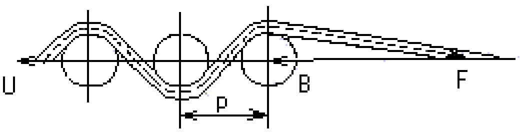

Fig. 1. Weaving model: *U* – fabric stress, *B* – beat-up force, *F* – warp stress

When weaving threads are stressed and they are strained, therefore when a fabric is taken out of a loom relaxation processes take place. The fabric width and length change when finishing operations are carried out. When a fabric is getting narrower and shorter, the settings of warp and weft change as well. The specific finishing operations such as calendering, raising, mechanical softening, etc. can change the structure of a fabric.

However, the main fabric structure formation takes place during the beat-up process when the inserted weft is beaten-up to the cloth fell. A fabric is formed as the whole during this process and the main fabric properties are given. Later the weft beat-up process was analysed by Nosek [2]. The moment when the force acting on the warp exceeds the force acting on a fabric is considered as the beginning of the beat-up process. Due to elastic deformation when the reed comes back, the cloth fell of a fabric moves together with it. The size from the extreme position of the reed to the moment when the reed separates from the cloth fell is called a cloth fell movement. When warp deformation increases, the cloth fell movement, which can be described as a beat-up duration, increases, too. Theoretically investigating the beat-up process Nosek has established that it is described best by the beat-up force impulse, i.e. the dependence integral of the beat-up force and duration, for various looms with different principles of the beat-up. So, the main beat-up process parameters are the beat-up force, beat-up duration and the impulse of the beat-up force.

INTEGRATED FABRIC STRUCTURE FACTORS

As it has been mentioned above the evaluation of weave, which is a graphic structure picture, is the most complex of all parameters. Weave can be represented graphically or analytically.

The graphic representation of weave methods is the most popular. Usually point paper is used. A square column represents the warp and a line – the weft. A marked square represents a warp float and a blank square – a weft float. Later weave was represented by analytical methods. Weave can be described as a matrix [3] where warp floats are indicated by 1 and weft floats by 0. Sometimes octal or sedecimal number systems are used for weave coding [4]. Weave coding by graphs is used very

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rarely. These methods are described in the literature [5]. However, the method of matrices is widely used for their convenience. However, the mathematical characteristics of matrices cannot reflect the weave influence on fabric properties. For this purpose specific weave matrix factors are used.

The average float length F proposed by Ashenhurst and often used for calculating: the warp and weft is equal to the repeat divided by the intersection of the warp and weft in the repeat. Galceran's weave factor Kl [7] is also similar to it. The shortcoming of these factors is that they evaluate only a single thread and do not take account of interlacing of adjacent threads.

Brierley suggested to evaluate weave by the function F^m. The power m was determined experimentally by weaving fabrics of various weaves of maximal density. It depends on a weave type [6].

Milašius [6] has marked that there is a close relation between Sklianikov's weave tightness factor c, which evaluates a mutual position of threads, and Brierley's factor F^m [6]:

$$F^m = \frac{1}{\sqrt{c}} \tag{1}$$

Milašius having calculated the factor c towards the warp and weft, suggested a new weave factor, called it as weave firmness factor:

$$P_{1/2} = \frac{1}{\sqrt{c_{1/2}}} \ . \tag{2}$$

Fabric structure factors are calculated by comparing the mathematical expression of the parameters of a fabric structure with the so-called maximal value of ‘standard’ fabrics. Newton [8] distributed integrated fabric structure factors into two groups: some of them refer to the Pierce theory, others - to the theory of Brierley. In the first case it is a ratio of a surface covered by the threads with the whole fabric’s area. In the second case it is a ratio of the setting of the “square” analog of the given fabric with the setting of the standard “wire” plain weave fabric.

The factors of the first group are used wider. Seyam and El-Shiekh [9] suggested the fabric’s structure expression which is called the fabric tightness composed of threads of racetrack shape geometry and Ashenhurst's end-plus-intersections geometry, however, their “standard” fabric in fact consists of two fabrics. The warp of one fabric is absolutely straight and on the contrary the weft of a second fabric is straight. Newton suggested that the fabric tightness should be calculated as a distance between the point corresponding to the fabric and the nearest point on the Pierce “maximal density curve” [8]. De Castellar et al applied this obvious analysis method for direct determination of the cover factor for grey and finished fabrics [10]. The main shortcoming of these factors is that they use the mean average of float length F, which does not evaluate weave exactly enough.

Brierley proposed the given fabric to compare with the “standard” plain weave “wire” fabric of maximal density [11]. The “standard” plain weave fabric is of geometrically possible setting and it is woven of “wire” threads of maximal density.

According to Brierley's formula the weft setting of an unbalanced fabric the warp and weft settings of which are not equal is:

$$S_2 = S_{sq}^{\,1+g\sqrt{T_1/T_2}}\, S_1^{\,-g\sqrt{T_1/T_2}} \ , \tag{3}$$

where S_{sq} is the “square” structure fabric setting of any weave, S_1 is the setting of the given fabric, T_1 and T_2 are corresponding warp and weft linear densities, g is the empiric coefficient.

From equation (3):

$$S_{sq} = S_2^{\frac{1}{1+g\sqrt{T_1/T_2}}}\, S_1^{\frac{g\sqrt{T_1/T_2}}{1+g\sqrt{T/T_{21}}}} \ . \tag{4}$$

On the other hand from [6] it follows:

$$S_{sq} = \frac{(MS/MD)F^m}{\sqrt{\frac{12}{\pi}\sqrt{\frac{T}{\rho}}}} \ , \tag{5}$$

where ρ is fibre density, F^m is the weave factor, (MS/MD) is the Brierley's factor of a fabric.

Brierley additionally analysed warp and weft ribs as complicated weaving changing the factor g [12]. Galuszinski has noticed that Brierley's formula needs and additional correction of the coefficient g for warp and weft ribs [13]. He has established that there is a relation between Brierley's factor MS/MD and weaving resistance. This factor can be used to establish the weavability of a fabric.

The main shortcoming these factors is the application of the function F^m for the power m which depends on the type of weave and can be established only experimentally. This disadvantage is very important because the weave of a fabric fulfils not only a technical function (i.e. it connects the warp and weft into the whole) but the aesthetic one as well, i.e. the fabric’s appearance depends on the weave. Therefore there are a lot of various kinds of weaves, the number of which constantly increases and it is impossible at least approximately to choose to which kind this or that weave should be assigned.

The method proposed by Milašius [14] as that of Brierley builds on the comparison of the given fabric’s setting with the fabric of “standard” maximal density of the “wire” “square” fabric woven by plain weave. This method differs from that of Brierley because $g = 2/3$ is for all the weaves (i.e. it does not depend on the kind of weave) and instead of F^m when equations (1) and (2) used the weave firmness factor P_1 is taken. Then the new integral fabric structure factor φ can be calculated as follows [14]:

$$\varphi = \sqrt{\frac{12}{\pi}}\,\frac{1}{P_1}\sqrt{\frac{T_{vid}}{\rho}}\, S_2^{\frac{1}{1+2/3\sqrt{T_1/T_2}}}\, S_1^{\frac{2/3\sqrt{T_1/T_2}}{1+2/3\sqrt{T_1/T_2}}} \ , \tag{6}$$

where $\rho = \frac{S_1\rho_1 + S_2\rho_2}{S_1 + S_2}$ and $T_{vid} = \frac{S_1 T_1 + S_2 T_2}{S_1 + S_2}$.

As it has been mentioned three levels should evaluate the structure of a fabric, namely: by the level of polymer, composing a filament fiber, the level of threads and the level of a fabric. So, as it was presented above all these levels are included by integrated fabric factor.

EXPERIMENTAL METHODS

A number of experiments were carried out to investigate the relation between the beating-up process parameters and fabric structure factors. The fabrics were woven by Zulcer type gripper looms, the warp and weft – PES 29.4 tex twisted multifilament yarns, the warp set 284 dm^{-1}, the weft setting was changed. The threads were drawn-in into 8 harnesses by straight draw. It was woven 12 different weaves. They are shown in Fig. 2. The weaves were selected on the base of special criteria. First of all such weaves were selected the warp repeat of which would go in 8 harnesses and could be woven without the loom resetting. A number of weaves investigated by Brierley (1, 2, 3, 4, 6, 7, 8) as well as weaves which were not investigated by Brierley (5, 9, 10, 11, 12) were selected. It was also some the so-called 'square' weaves with $P_1 = P_2$ (1, 4, 6, 7, 8, 10, 12), weaves with $P_1 < P_2$ (2, 11, 9) and weaves with $P_1 > P_2$ (3, 5) in order to make certain how fabric structure factors are fit for "square" and "non-square" weaves as Brierley investigated mostly "square" weaves with the exception of warp and weft ribs. We tried to select various weaves taking into account of practical application of them.

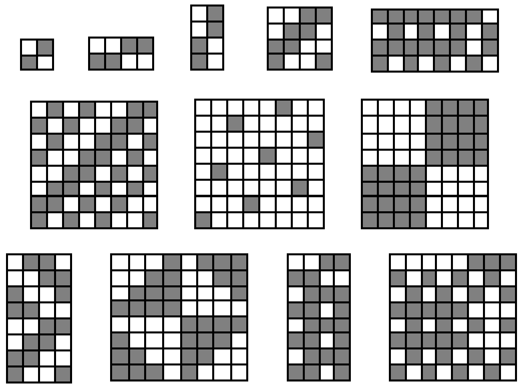


Fig. 2. Weaves used for experiment

Measurement device were connected according to the scheme presented in Fig. 3. The warp force was measured by a tensiometric gauge 1 the starting signal of which was amplified by the amplifier 2. The force was measured between the dropper and backrest. The beat-up moment was fixed by the gauge 4 acting on a magnetic principle and receiving voltage from the supply source 3. Both signals get to the analog input board 5 thanks to which it was possible to watch the measured signals in the monitor of a personal computer 6. The signals were measured with an accuracy of 0.5 degree of the rotation angle of the loom main shaft.

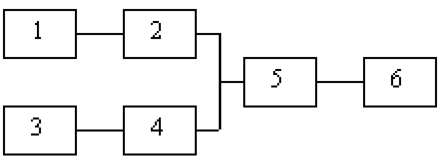


Fig. 3. The connection scheme of measurement devices: 1 – the warp force measurement gauge, 2 – the tensiometric amplifier, 3 – the voltage feeding source, 4 – the fixation gauge of a beat-up moment, 5 – the analog input board PC-20, 6 – the personal computer

For each fabric it was obtained the warp force and curves of the beat-up moment fixation, presented in Fig. 4. The upper curve shows the warp force and the lower one – the beat-up moment.

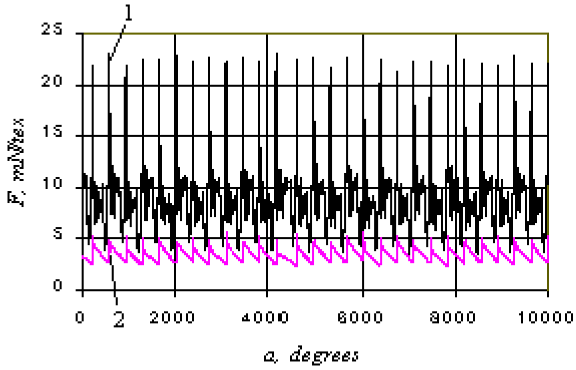


Fig. 4. The dependencies of warp stress (1) and beat-up moment fixation (2) on angle of main loom shaft

From these cyclograms it is possible to separate the change of the warp stress during one loom cycle (Fig. 5).

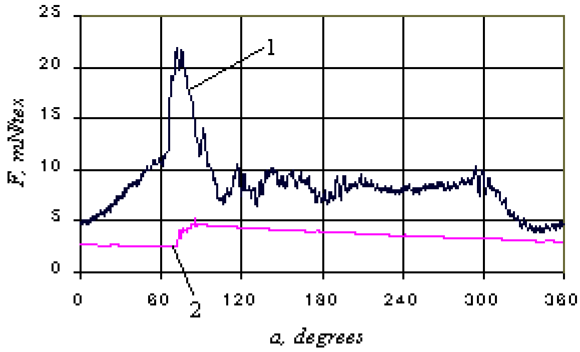


Fig. 5. The dependencies of warp stress (1) and beat-up moment fixation (2) on angle of main loom shaft during one loom cycle

From this curve it is possible to fix the beginning and end beat-up moments, which are presented in Fig. 6. This beat-up peak occupies 20° of the angle of the main loom shaft. It can be seen that in the beat-up force curve two maxima come to light. They can be bound with the vibration of the reed, but we are not going to analyze the reasons of it, because we are mainly interested in the beat-up relationship with the fabric's structure.

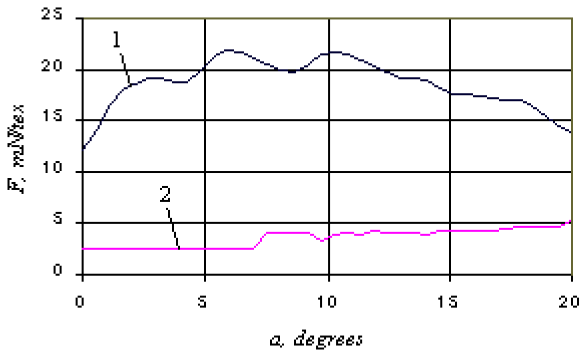


Fig. 6. The dependencies of warp stress (1) and beat-up moment fixation on angle of main loom shaft during the beat-up

In this case only a part of the warp force appearing due to the beat-up is urgent. For its establishment it is necessary to subtract from the curve of Fig. 6 a constant part of the warp force (Fig. 7). Further this force will be called the beat-up force. The main parameters of the beat-up process are also shown, namely: the beat-up force *F*, the beat-up duration *T* and the impulse of the beat-up force *I* calculated according to the formula $I = \int_0^T F dt$.

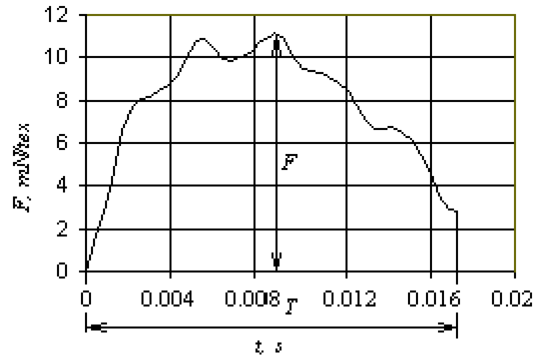


Fig. 7. The dependence of the beat-up force on angle of main loom shaft and other beat-up parameters

Further, the results of beat-up force curve summarize of 24 beat-up peaks and all the beat-up parameters of all fabrics are calculated.

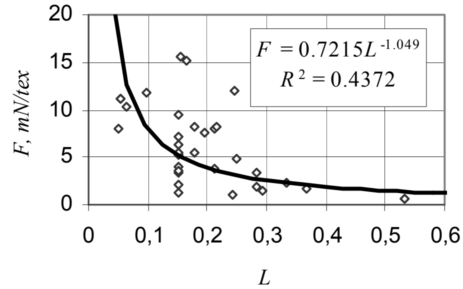
INVESTIGATION RESULTS

As an example of Pierce's group factors the dependence of the beat-up process parameters on Newton's structure factor *L* (Fig. 8) can be presented. This factor is the latest (1995). The dependences are described by power equations. Their determination coefficients are of 0.5, so the relation between the fabric structure factor and beat-up parameters is not strong.

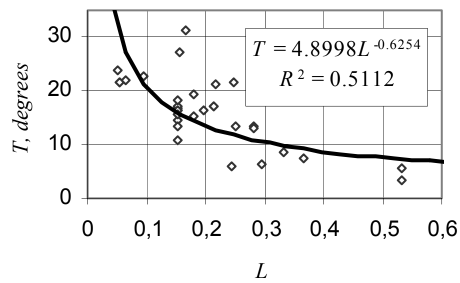
The dependence of beat-up process parameters on the integrated fabric structure factor φ is presented in Fig. 9.

The investigation results of fabric structure factors are presented in Table.

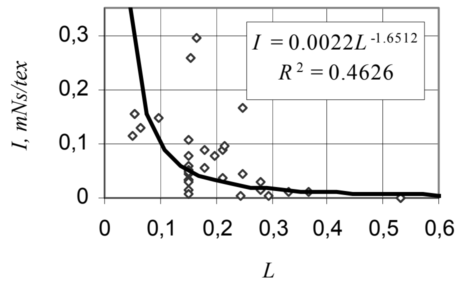
We can see that Brierley's group factors reflect beat-up parameters much better than those of Pierce's group. The determination coefficients of all this group factors are almost the same (0.7 – 0.8), however, the factor φ can be calculated for any weave using a very simple software and therefore it can be easily applied for fabrics designing.



a



b



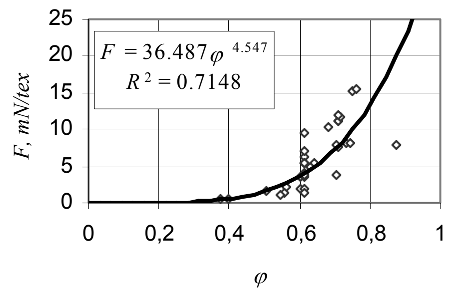
c

Fig. 8. The dependence of the beat-up process parameters on Newton's structure factor *L*: a – beat-up force, b – beat-up duration *T*, c – beat-up force impulse *I*

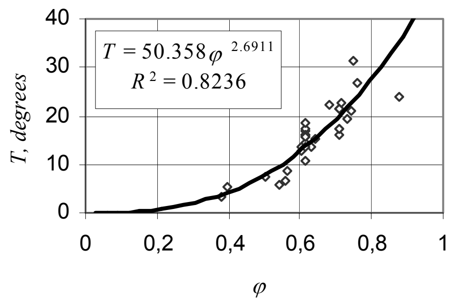
Here it should be once more emphasized the importance of weave evaluation exactness and possibilities of computer-assisted calculation because it influences not only fabric properties, but its appearance as well; therefore a lot of various kinds of weave appear.

Table. The relationship of fabric structure factors with beat-up process parameters

Group	Factor	Beat-up force		Beat-up duration		Beat-up force impulse	
		Equation	R^2	Equation	R^2	Equation	R^2
Pierce group	Newton	$F = 0.7215L^{-1.049}$	0.4372	$T = 4.8998L^{-0.6254}$	0.5112	$I = 0.0022L^{-1.6512}$	0.4626
	Seyam	$F = 6.9039(TS)^{2.6983}$	0.6007	$T = 18.577(TS)^{1.522}$	0.6287	$I = 0.0766(TS)^{4.2053}$	0.6231
	Galceran	$F = 30.406(OG)^{4.7322}$	0.5527	$T = 44.141(OG)^{2.7416}$	0.6103	$I = 0.7766(OG)^{7.3893}$	0.5755
Brierley group	Brierley	$F = 78.216(MS/MD)^{5.5194}$	0.7352	$T = 60.054(MS/MD)^{2.7779}$	0.7036	$I = 3.1741(MS/MD)^{8.5558}$	0.7683
	Galuszynski	$F = 79.303(TG)^{5.6061}$	0.7427	$T = 58.936(TG)^{2.7674}$	0.7388	$I = 3.2503(TG)^{8.6951}$	0.7753
	Milašius	$F = 36.487\varphi^{4.547}$	0.7988	$T = 50.358\varphi^{2.6911}$	0.7873	$I = 1.0832\varphi^{7.2044}$	0.8286



a



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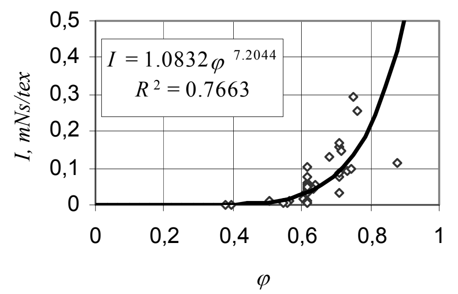

c

Fig. 9. The dependence of beat-up process parameters on the structure factor φ: a – beat-up force F, b – beat-up duration T, c – beat-up force impulse I

CONCLUSIONS

In order to describe the weft beat-up process the following parameters were selected, namely: the beat-up force, beat-up duration and beat-up force impulse. The fabric structure was evaluated by six integral factors. Having carried out experimental weft beat-up investigations, the dependence of the beat-up process and fabric structure factors has been established.

According to the values of determination coefficients it has been established that the dependencies of beat-up process parameters and fabric structure factors are better described by Brierley's group fabric factors. Because of its universality it is most convenient to use the structure factor proposed by V. Milašius.

The dependencies obtained are useful to apply for a fabric designing as according to designed fabric structure factors it's possible to establish the future technological parameter values of weaving process.

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