Scientific Study for the Internal Dynamic Friction between Warp and Weft Yarns of Woven Fabrics

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Abstract:
Fabrics are typically classified based on their weight, which may vary widely from light, medium to heavy-weight fabrics. On the other hand, weaving machines are also often classified into light, medium, and heavy according to the weight of the woven fabric on them. Although, this classification method of weaving machines may be incorrect in many cases, as there isn't necessarily a relationship between the weight of the woven fabric and the classification method for weaving machines in general. This is confirmed by the research in our hands. Where the research plan is based on the analysis of the internal friction forces between the warp and the wefts yarns, which are interlaced with each other within the fabric construction. Those internal friction forces have a significant impact on the force needed to beat up the wefts, based on Newton's third law "To every action, there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal and directed to contrary parts". According to the previous mechanical theory, it is expected that the required beating-up force values certainly depend on the number of interlacing rates within the woven construction repeat more than the fabric weight. The research paper revealed several important points, including determining a theoretical basis for calculating the internal friction values between warp and weft yarns within the woven fabric structure based on the warp yarns' tension during the weaving process. By determining the values of internal friction, it is possible to estimate the values of some mechanical properties of the fabrics. These calculation values can also be used to determine the appropriate machine for the weaving process with high precision.

Keywords:
Weaving Mechanism, Internal Friction, Yarn Tension, Fabric Weight, Fabric Construction, Weft Density, Yarn Friction, Plain Weaves, Twill Weave, Satin Weave, Cover Factor

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1- Introduction:

Woven fabrics are manufactured by interlacing two perpendicular groups of yarns (warp and weft yarns) to each other by crossing each over and under each other alternately. Warp and weft yarns are interlaced together by friction at the joint points, so enough interlacing points are needed to hold the fabric together in a stable status. As a result of this method of interlacing, both warp and weft yarns in both directions create crimp shapes. In addition, as the interlacing method is by friction alone, the filaments within the yarn in both fabric directions are not tightened, leaving the bundles relatively loose and open. Fabric density, yarn crimping, and the looseness of the bundle can influence composite properties.

This research paper is concerned with the study of the dynamic characteristics of the warp and weft yarns inside the fabric structure. These characteristics must be influenced by the internal friction between warp and weft yarns. From the other side of view, many factors affect these friction forces, which must be studied in this paper. The research paper assumes that the sum of the internal friction forces between the warp and weft yarns inside the woven fabric has a very important influence on the correct practical selection of the weaving machine for implementation. This choice is often made based on the fabric weight, apart from the scientific study of the mechanical properties of the structural components of the woven sample. These characteristics must necessarily be one of the most important elements for the correct technical selection of a weaving machine. Where there is no doubt that the internal friction forces within the woven structure have the greatest effect on the mechanical strength required to perform the weft beating-up process.

2- Background:

The physical and chemical properties of textile products are generally influenced by very important different elements, which are in order:

1- The structural composition of used textile fibres and their chemical, and physical properties in addition to the geometrical shape of the fibres
2- The geometry of the fabric construction, based on the product manufacture mechanism (woven, knitted, braided, non-woven, etc.)
3- Processing of preparation and treatment of the final textile product

From all these precious elements, it is concluded that the second element directly concerns the subject of this research paper. The study of the fabric geometry with its important elements affecting it, and the reflection of this effect on the internal friction force between the warp and weft yarns and hence their impact on the mechanical force rates needed for weft beating up on the weaving machines.

2.1 Geometric shape of woven fabric (Peirce's assumptions)

The geometric structure of the woven fabrics has respectable functional, operational, and aesthetic importance. The main parameters of the woven fabrics' structure are the following: weave construction, fabric set, as well as warp and weft thickness. On the other side of the view, fabrics aren't regular structures capable of description in mathematical forms based on geometry, but they can be idealized the general characters of the materials into simple geometrical forms and physical parameters to arrive at mathematical conclusions. As geometrical models are the sole solution to providing geometrical information about woven fabrics for finite element (FE) models for performance simulation /1, 2/.

Peirce's work is regarded as the beginning of modeling woven fabric geometry. Under certain assumptions, including circular yarn cross-section, complete flexibility of yarns, incompressible yarns, and arc-line-arc yarn path. In the cross-section of plain-woven fabric based on Peirce's assumption as shown in Fig. 1, the subscripts 1 and 2 are used to denote warp and weft. In this model, a two-dimensional unit of repeated fabric was built by superimposing linear and circular yarn segments to produce the desired shape. Derivation of the relationships between the geometrical parameters and such parameters as yarn spacing, weave crimp, weave angle, and fabric thickness forms the basis of the analysis. This model is convenient for calculation and has been found useful in the ordering and interpretation of observation; it is especially valid in very open structures. Peirce derived the following equations describing the geometry of plain-woven fabrics:

$$D = d_1 + d_2, \qquad (2.1)$$

and :

$$D = h_1 + h_2. \qquad (2.2)$$

$$C_1 = \frac{l_1}{p_2} - 1, \qquad (2.3)$$

and also:

$$C_2 = \frac{l_2}{p_1} - 1. \qquad (2.4)$$

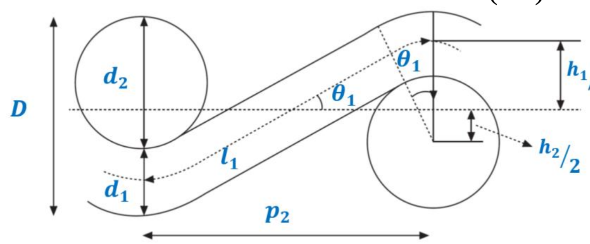

Fig. 1: Peirce's assumption for the circular cross-section of plain-woven fabric /1, 2/

Where:

1	warp yarn	2	weft yarn
c	crimp (a/b)	h	crimp ratio height of crimp wave
	Yarncirculardiameter	D	sum of circular diameters

l length of yarn axis between planes containing the axes of consecutive

p average yarn spacing for the fabric as a whole

θ maximum angle of the yarn axis to the plane of fabric in radius

2.2 Internal friction mechanics of woven fabric:

It is very important to analyze the friction forces between the warp and weft yarns within the weaving construction, based on the engineering conception of Peirce for the interlacing between the yarns and wefts.

It is assumed that the internal friction force between the surfaces of the warp yarns and the wefts are interwoven with them resists the sliding movement. That was challenged under the influence of the tensile force during the test because of the resistant effect of the internal friction in the intersecting surfaces between them.Then, by increasing the intersection surfaces between warp and weft yarns, the values of the cut strength are increased, and the results of the tensile strength test of Badawi have confirmed this assumption. Therefore, the texture of the fabric decisively and without any doubt positively influences the cutting tensile values /3, 4/.

Fig. 2 illustrated the geometrical perceptions for the plain weave 1/1 construction as mentioned before based on Peirce's studies of fabric geometry.

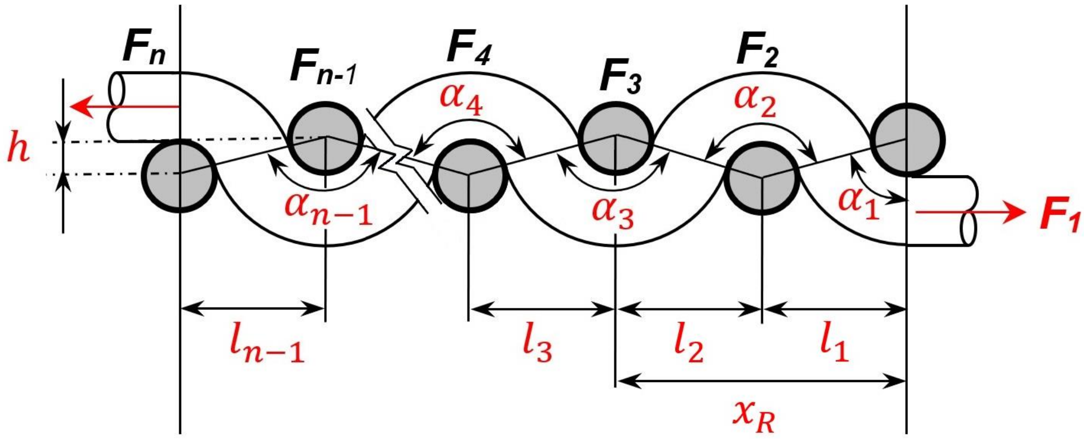

Fig. 2: The internal friction in the cross surfaces between warp and weft yarns

Referring to these geometrical perceptions, the internal friction on the cross surfaces between a signal warp yarn and wefts with different constructions can be determined as follows:

If the warp yarn is drawn with a force F_1 on the right side of the first weft, then the longitudinal friction force is equal F_2 after the first intersection

$$F_2 = F_1 \cdot e^{-\mu\alpha_1}. \quad (2.5)$$

Let:

- μ -the coefficient of friction between warp and weft yarns
- α -tangent angle of the internal friction

After the second intersection, friction force is

$$F_3 = F_1 \cdot e^{-\mu\alpha_1} \cdot e^{-\mu\alpha_2} = F_1 \cdot e^{-\mu(\alpha_1+\alpha_2)} \quad (2.6)$$

At general, the longitudinal friction force after the i -th intersections equals:

$$F_{i+1} = F_1 \cdot e^{-\mu\sum_{j=1}^{i}\alpha}. \quad (2.7)$$

From which:

$$F_1 = F_{i+1} \cdot e^{\mu\sum_{j=1}^{i}\alpha}. \quad (2.8)$$

2.3 The relation betweenfabric andweaving machine:

Over a long time, great efforts have been done to classify fabrics as a final product. Similarly, to classify weaving machines as a tool or means of fabric production. These classification methods classified fabrics and machines from different viewpoints, regarded by consumers, engineers, manufacturers, technologists, traders, and standards. With regarding all these efforts, there is a possibility of overlapping fabric/machine characteristics under these different viewpoints.

In this research, the classification method was chosen to serve the research subject. The fabrics were classified according to their weight, on the other hand, the weaving machines were classified according to the weft insertion method /5/.

2.3.1 Classification of fabrics weight:

Table 1 represents a classification of fabric weight according to square area unit (ounces per square yard or grams per square meter).

Table 1:Classification of fabrics weight according to square area unit /5/

Fabric Weight	Grade	Weight	
		[in oz/yd2]	[in g/m2]
Light weight	L1	< 1	< 33.91
	L2	1 ~ 2	33.91 ~ 67.8
	L3	2 ~ 3	67.8 ~ 101.7
	L4	3 ~ 4	101.7 ~ 135.6
Medium weight	M1	4 ~ 5	135.6 ~ 169.5
	M2	5 ~ 6	169.5 ~ 203.4
	M3	6 ~ 7	203.4 ~ 237.3
	M4	7 ~ 8	237.3 ~ 271.2
Heavy weight	H1	8 ~ 9	271.2 ~ 305.2
	H2	9 ~ 10	305.2 ~ 339.1
	H3	10 ~ 11	339.1 ~ 373.0
	H4	11 ~ 12	373.0 ~ 406.9
	H5	> 12	> 406.9

2.3.2 Classification of weaving machines:

According to the Statistics of the International Textile Industry Statistics, the ITMF has published the substitution between the shuttle and shuttle-less weaving machines during the time period from 1990 to 2020 as represented in Fig. 3. This substitution was continued in 2020, but the number of installed shuttle-less looms has shrunk for the first time from 1.68 million in 2019 to 1.64 in 2020 as a result to the negative effect of covid-19 on the global economy /6/.

In 2020, worldwide shipments of shuttle-less weaving machines were 112,000 units as illustrated in Fig.4, exceeding $1.43 billion. Shipments in the categories "air-jet" and "rapier and projectile" were 29,337 units and 21,542, respectively. The deliveries of water-jet weaving machines were 61,483.

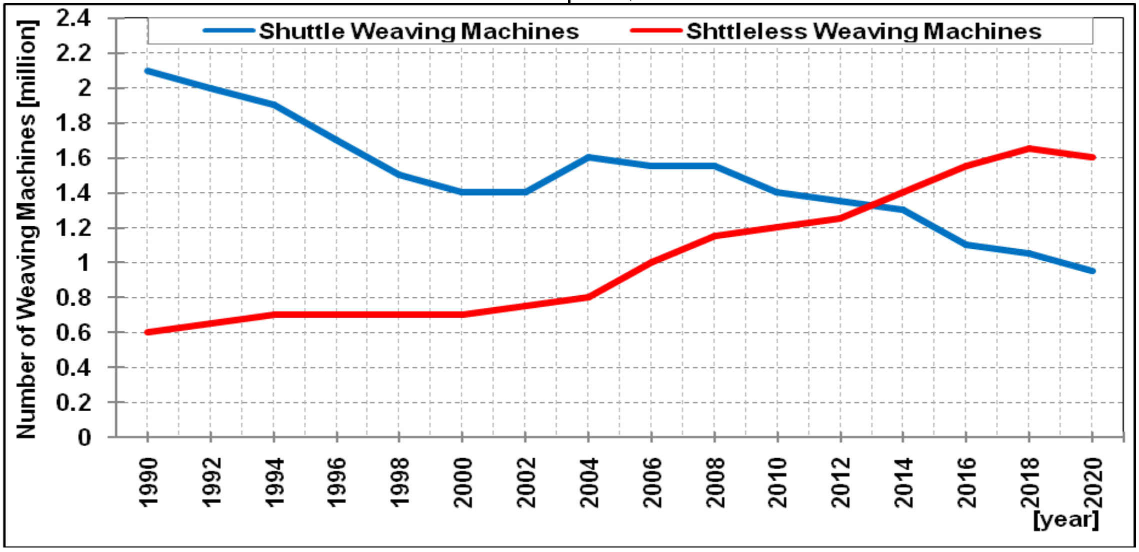

Fig. 3: Global shuttle and shuttle-less weaving machines from 1990 till 2020 /6/

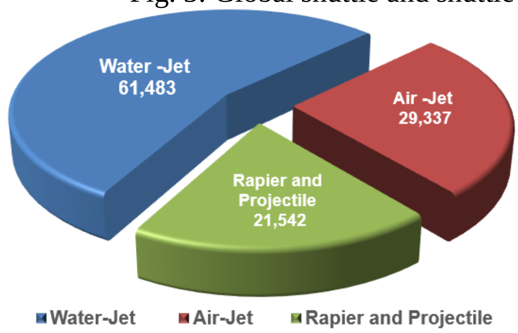

Fig. 4

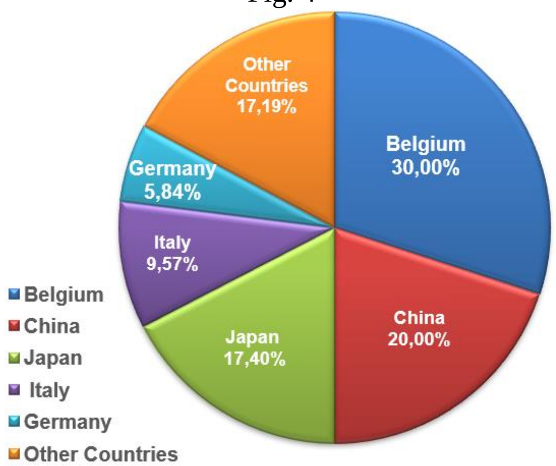

Fig. 5

Fig. 4: Worldwide shipments of shuttle-less weaving machines /7/

Fig. 5: World's largest exporters of shuttle-less weaving machines in 2020/10/

The main destination for shuttle-less weaving machines in 2020 was Asia & Oceania with 94% of all worldwide deliveries. 98%, 93%, and 81% of global water-jet, air-jet, and rapier/projectile weaving machines were shipped to that region. The main investor was China in all three sub-categories. Deliveries of weaving machines to this country cover 74% of total deliveries /7/.

The world's largest exporters of this commodity group in 2020 as shown in Fig. 5:

- Belgium - 30% of the world exports ($438 million)
- China- 20% ($296 million)
- Japan- 17.4% ($251 million)
- Italy- 9.57% ($137 million)
- Germany- 5.84% ($84 million)

3.1 Analysis of the Problem:

The research problem was limited to developing a scientific approach to measuring the internal friction forces within fabric structures. The internal friction is not only supports fabrics with all mechanical behavior, but also directly influences the choice of weaving machines for execution. The choice of weaving machine was based on the weight of the sample for several decades without the slightest concern for the required forces, which must be determined according to the internal friction forces between warp and weft yarns. For all these reasons, this paper highlights a neglected point in the field of weaving engineering.

3.2 Theory of Technology:

The used technology in this research depends on:

- The internal friction forces have a significant impact on the force needed to beat up the wefts, based on Newton's third law.
- The geometry of woven fabric samples was built according to Peirce's work's modeling method.
- Woven fabrics' specimens must be with standard structure variables.
- Fabric-set is square, and medium weight samples (M4).
- Testing methods must be related to standard methods which could be tested practically, on the other hand, the results could be measured theoretically with a mathematical method.

3.3 Weaving of Standard Experiment Samples:

This important part of the research was identified in weaving experimental samples with different elements of fabric structures. The fabric structures were limited to plain weaves1/1 and hopsack 2/2, twill weaves 2/2, and 1/3, and satin 8weave.

3.4 Laboratory Measurements:

The laboratory measurementsare limited in:

Measuring warp yarns' tensionor single yarnsof every heald frame while the weaving machine is running at beating-up point (300°-360°).Thesemeasurementvalues have been measured by using a digital yarn tension meter (Hans-Schmidt Model: DTSB-500) /8/.

4. Experiments:

The experimental work has been carried out on Dornier rapier weaving machine p2, equipped with two warp beams, adobby device with up to 24heald frames, and with a maximum fabric width of 140 cm.

4.1 Weaving of experimental samples:

The main purpose of this process is to weave standard test specimens, with different woven-fabric structure variables as represents in Table 2and Fig. 6.

The main elements of the woven fabric structure variables were:

1- Fabric construction:

- Plain weaves1/1 and hopsack 2/2.
- Twill weaves1/3, and 2/2.
- Satin weave 8.

2- Warp yarns density:20 yarns/cm.

3- Wefts density: 16, 20and 24wefts/cm.

4- Warp and weft yarn material: Polypropylene (CF) twistyarn denier 450.

Woven samples' fabric constructions were determined as represented in Table 2. On the other hand, Fig. 6 shows the design, draft system, and lifting plan of the experimental samples.

Table 2: Structure elements of the experimental samples

Material	**PES (Texture yarn)**		**Count denier**	**ε - F_{max} %**	**F_{max} Gram**	**F_{max} g/den**
			450	**24.1**	**1593**	**3.54**
Experimental samples specification						
Fabric	**Construction**	**Fabric set**	**Warp density [yarn/cm]**	**Weft density [weft/cm]**		
	Plain	1/1	22	20	22	24
		H 2/2				
	Twill	T 2/2				
		T 1/3				
	Satin	S 8				
	Cover factor (in the fabric)	Warp/weft	16.19	14.72	16.19	17.65
		Fabric		22.40	23.02	23.64

4-2 Measurement of the warp yarns tension during the weaving process:

The laboratory measurements are limited to measuring warp yarns' tension while the weaving machine is running at the beating-up point of the wefts. The tension values have been measured by using a digital yarn tension meter (Hans-Schmidt Model: DTSB-500) /6/.

These values have been individually taken for every warp yarn of the fabric repeated in the middle of the weaving width (four yarns for plain and twill structures, and eight yarns for satin 8). These values were taken from the digital yarn tension meter diagram curves and were identified at the beating-up point of the wefts (330°-360°).

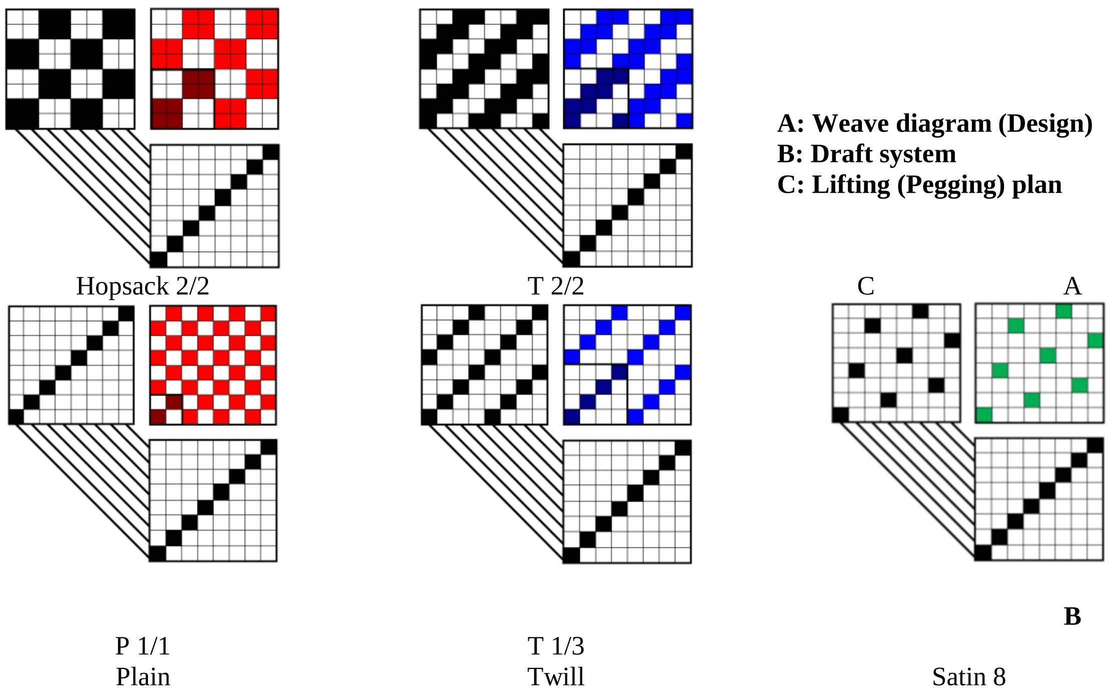

Fig. 6: The weave diagram, draft system, and lifting plan of the experimental samples

Table 3 represents the different values of warp tension for anindividualsinglewarp yarn of every heald frame for all fabric structures (from heald frame number 1 to 4 for plain and twill weaves and from heald frame number 1 to 8 for satin 8 weave). These values have been measured at the middle of the weaving width. The tests were achieved for all the experimental samples during weaving according to their woven structural variables mentioned before.The simultaneous tension values of all warp yarns of the fabric repeat multiplied by the number of constructionsrepeated in fabric width are equal to all warp yarns' tension during the beating-up process.

The technical data in Tables 3 and 4 have been achieved according to the following scientific basis:

1- The warp yarn's tension values F_t are measured by using a digital yarn tension meter.
2- The friction angle values have been determined with the aid of the geometric description shape in Fig. 7.
3- The geometric description in Fig. 7 of the internal friction between warp and weft yarns is based on Peirce's assumption of fabric geometry.
4- The Internal Friction F_n values have been calculated according to the fabric interlacing mechanic'sequation ($F_n = F_t/e^{\mu\alpha}$) as mentioned before in the background study.

Table 3: Thedifferent values of warp tension for a single warp yarn of every heald frame for all fabric structures

Fabric Construction		Heald frame Nr.	The position of warp yarn to the weft	Friction angle value			Warp Yarn	
				Degree [°]	Radian (Rad) [c]		Tension F_t	Internal Friction F_n
							at beating-up (330°- 360°) [cN]	
Plain Weave	P 1/1	1	Upper (U)	150°	$5\pi/6$	2.62c	91.2	39.45
		2	Lower (L)	150°	$5\pi/6$	2.62c	88.4	38.24
		3	U	150°	$5\pi/6$	2.62c	91.4	39.53
		4	L	150°	$5\pi/6$	2.62c	89.1	38.54
	Hop-sack 2/2	1	U	90°	$\pi/2$	1.57c	49.4	29.88
		2	U	90°	$\pi/2$	1.57c	49.8	30.12
		3	L	90°	$\pi/2$	1.57c	47.6	28.79
		4	L	90°	$\pi/2$	1.57c	48	29.03
Twill Weave	T 2/2	1	U	90°	$\pi/2$	1.57c	50.3	30.42
		2	U	90°	$\pi/2$	1.57c	50.9	30.78
		3	L	90°	$\pi/2$	1.57c	48.4	29.27
		4	L	90°	$\pi/2$	1.57c	49.2	29.76

Fabric Construction		Heald frame Nr.	The position of warp yarn to the weft	Friction angle value			Warp Yarn	
				Degree [°]	Radian (Rad) [c]		Tension F_t	Internal Friction F_n
							at beating-up (330°- 360°) [cN]	
	T 1/3	1	U	150°	$5\pi/6$	2.62c	88.7	38.37
		2	L	90°	$\pi/2$	1.57c	48.4	29.27
		3	L	30°	$\pi/6$	0.52c	28.6	24.19
		4	L	90°	$\pi/2$	1.57c	49.7	30.06
Satin Weave	S 8	1	U	150°	$5\pi/6$	2.62c	87.8	37.98
		2	L	90°	$\pi/2$	1.57c	48.3	29.21
		3	L	30°	$\pi/6$	0.52c	25.4	21.48
		4	L	30°	$\pi/6$	0.52c	25.4	21.48
		5	L	30°	$\pi/6$	0.52c	25.6	21.65
		6	L	30°	$\pi/6$	0.52c	25.6	21.65
		7	L	30°	$\pi/6$	0.52c	25.8	21.82
		8	L	90°	$\pi/2$	1.57c	50.3	30.42

Table 4 represented the average values of internal friction $F_{n.av.}$ for a single warp yarn, for a fabric construction repeat, and the sum for all warp yarns with one weft in the fabric width. All these values have been calculated according to the fabric interlacing mechanics as mentioned before.

Table 4: the internal friction F_n values for a single warp yarn (averages), for a fabric construction repeat and for all warp yarns with one weft in the fabric width.

Fabric Construction		Average value of Frictionangle		The average value of Internal Friction	Internal Friction $F_n = F_t / e^{\mu\alpha}$	
					1 Repeat	Fabric width 140 cm
		Degree [°]	Radian (Rad) [c]	$F_{n.av.} = \sum^{n=4 or 8} F_n/n$ [cN]	$\sum^{n=4or8} F_n$ [cN]	$\sum^{n=3080} F_n$ [N]
Plain	P 1/1	150°	$5\pi/6$	38.94	155.76	1199.35
	H 2/2	90°	$\pi/2$	29.46	117.82	907.21
Twill	T 2/2	90°	$\pi/2$	30.06	120.23	925.77
	T 1/3	90°	$\pi/2$	30.47	121.89	938.55
Satin	S 8	60°	$\pi/3$	23.96	167.54	737.92

5. Results and discussions:

5.1 Descriptive geometry of the internal friction for the interlacing between warp and weft yarns

The shape of weaving interlacing mechanics, as well as the number of intersections and the method of their distribution between warp and weft yarns, play a major role in determining the values of internal friction between them. The importance of determining these values lies in the fact that they clearly control the natural and mechanical properties of fabrics. However, the form of internal friction forces has not been researched widely by scientists, and those studies took the descriptive form of friction without specifying its value clearly. Therefore, this research paper focuses on studying everything related to these very important forces in woven fabric engineering. The previous geometry conceptions of the interlacing shape were studied, where it was found that Peirce's conception is the closest geometrical to the woven fabric structure, especially by using man-made fibers due to their regularity compared to other natural fibers.

Accordingly, and based on a specific microscopic test of the experimental samples, a descriptive geometry visualization of the interlacing and friction angles between the warp yarns and wefts was drawn up. A square fabric set was used, in addition to a cover factor of 16.19 for the warp yarns and wefts (that equals 23.02 for the fabric), to achieve the geometric shape of Peirce's description.

Figure 7 shows the relation between the interlacing mechanism and friction angles between the warp and weft yarns of the used standard woven structures. Figure 7a shows the shape and friction angles' values between the yarns and wefts, which achieved the highest rate of interlacing with a regular angle of 150°. Plain weave 1/1 is distinguished by this tight composition, as it contains only two intersections repeated on two yarns in both directions. That makes it the most cohesive woven structure and the most stressful on the weaving machines as well.

Figure 7B shows the shape and friction angles' values between the yarns and wefts for the plain weave hopsack and the twill 2/2, which achieved interlacing rates at regular angles of 90°. These weaves are distinguished by their composition of two intersections repeated on four yarns in both directions, which makes them less cohesive than the plain weave 1/1. However, the hopsack 2/2 is less tight than twill 2/2 due to the symmetrical movement of the two adjacent and parallel yarns and wefts, which makes them move in a group of two yarns and two wefts. While the physical behaviors of the twill structure affect the work of kinetic displacement at a rate of difference of one yarn, which makes all the traversal yarns interlaced in a single independent shape, which increases the rates of tightness compared to hopsack 2/2.

Figure 7c shows the shape and values of the friction angles between the yarns and wefts for the twill weave 1/3, which achieved irregular values for the interlacing angles of friction ranging from 30° to 90° to 150° and then 90° inside the woven structure. Despite its distinction in its composition of two intersections repeated on four yarns in the two directions, which makes it less tight than the plain weave 1/1. The tightness's physics and the variation in the angles of friction, although their sum inside the woven structure is equal to the hopsack and the twill weaves 2/2. However, this makes it not symmetrical to the apparent shape of the two sides of the woven, in addition to the strength of the shape of the twill line.

Figure 7D shows the shape and values of the friction angles between the yarns and wefts for the atlas weave 8, which achieved irregular values for the interlacing angles of friction ranging from 30° sequences five times to 90° to 150° and then 90° inside the weaving structure, despite its distinction in its composition of two sectors repeated on eight yarns in both directions, which makes it less tight than the plain weave 1/1, hopsack 2/2 and all twill weaves of all previous types, except that the nature of its cohesion and the variation in the angles of friction and its rate decreased by 33.33% compared to the hopsack 2/2, twill 2/2 and 1/3, at a rate of 60% Less than the plain weave 1/1. That makes it not symmetrical to the apparent shape of the two sides of the woven and makes it less stressful for the weaving machine in terms of operation.

5.2 Analysis of the research results:

As mentioned previously, the results of the research consist of two items, the warp yarns tension and the internal friction force between warp and weft yarns at the beating-up point. The friction force values have been measured by a specialized device and from its results, the internal friction forces have been mathematically calculated by the equations. From this point of view, it is found that there is a close correlation that combines the results of the two factors, where the internal friction values between the yarns and wefts change directly in connection with the change in the warp yarn tension force values during the weft beating up.

Certainly, the difference in fabric structure played the most prominent role in the difference in the results. The highest values were achieved by using plain weave 1/1 followed by a considerable difference with twill weave 1/3, which increased by an inconsiderable difference with twill weave 2/2 and plain hopsack weave 2/2 respectively. On the other side, the satin 8 weave achieved the lowest values by a 46% decrease than plain weave 1/1 and a 30% decrease than other weaves with four warp yarns in woven repeat as illustrated in Table 4.

Despite all the above, the most prominent role in the results was played by other sub-elements, although they are all related to the fabric structure, these elements are:

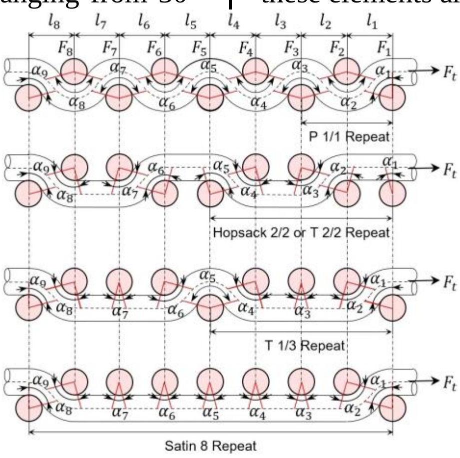

Fig. 7: The geometric description of the internal friction between warp and weft yarns is based on Peirce's assumption of fabric geometry

5.2.1 The arrangement of heald frames

The warp yarn tension and internal friction force values as shown in Fig. 8 and Table 3 are slightly increased starting from the first heald frame gradually. This increase is achieved independently for the heald frames at the same level (upper/ lower). This is due to the gradient in raising or lowering the heald frames to form a pure front shed, which leads to an increase in the stress rates on the yarns of the back heald frames compared to the front one.

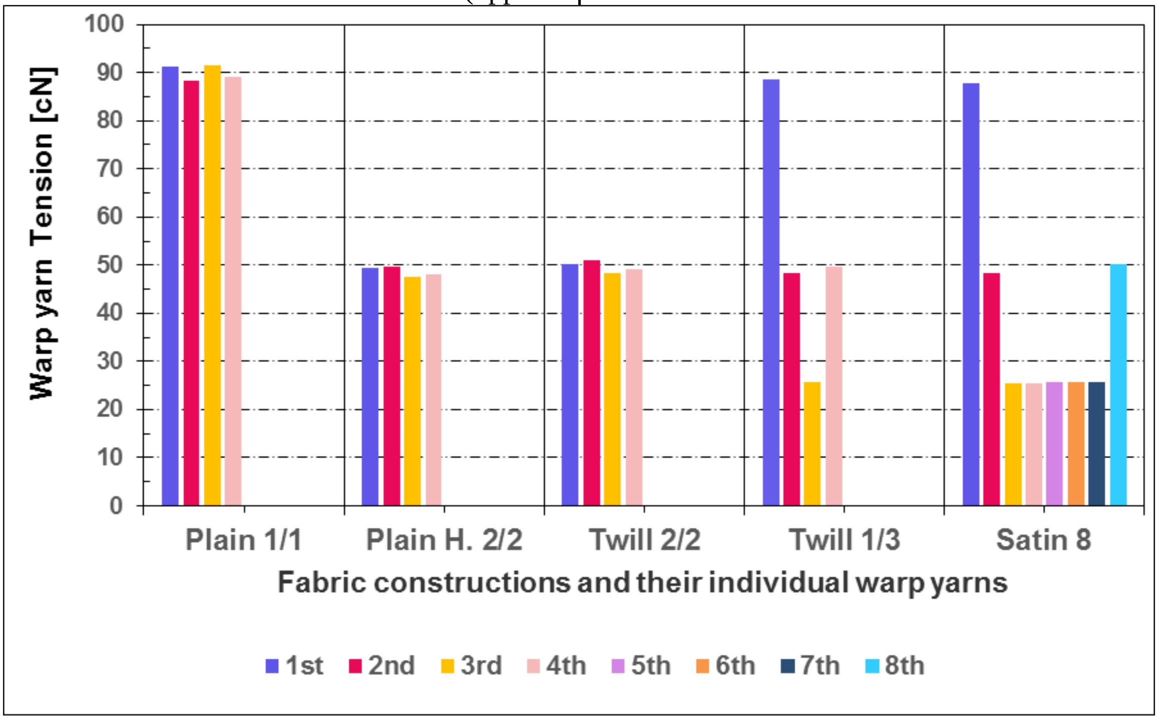

Fig. 8: The relation between the position (upper / lower) of the individual warp yarn of fabric construction repeat and its highest tension force value during weft beating-up

5.2.2 The weaving shed's type:

Both the warp yarn tension and internal friction force values are affected by the position of the heald frames for the actual weaving duration. The greater values were achieved for the heald frames that were on the upper level than the others on the lower level, as shown in Fig. 8 and Table 3. These results are because the rate of upper shed rise in all cases is greater than the rate of lower shed drop from the warp yarns line. This affects the increase in stress rates of the warp yarns in the upper shed compared to their counterparts in the lower shed.

5.2.3 The friction and interlacing angles:

Referring to the results in Table 3, the friction angle value played a major role in influencing the results, more than any other variable. According to the used standard structure elements, the plain weave 1/1 is characterized by the stability of the friction angle between all warp yarns and wefts within the weave structure and achieving a value of 150°. Therefore, high-stress rates of warp yarns and the internal friction between yarns and wefts were maintained because of achieving the highest interlacing rates at a constant rate within the weave structure. As a result, the stress rate to which the weaving machine is subjected achieves the highest rates when executing the plain weave 1/1, followed by the standard twill structures, and the lowest rates are achieved for the atlas weaves. Referring to the results in Table 4, the highest average value of friction angle was achieved by using plain weave 1/1 with a rate of 150°. The plain hopsack weave 2/2, twill weaves 2/2, and 1/3 achieved average rates of 90°. On the other side, the standard atlas weave 8 achieved the lowest average value of friction angle with a rate of 60°.

5.2 The relation between warp tension, friction focuses ad beating-up force:

Fig. 9 represents the relation between the tension force for an individual warp yarn and the internal friction force between warp and weft yarns at the beating-up point. On the other hand, the sum tension force for all warp yarns and the internal friction force between all warp yarns and a single weft at the beating-up point is represented in Fig.10.

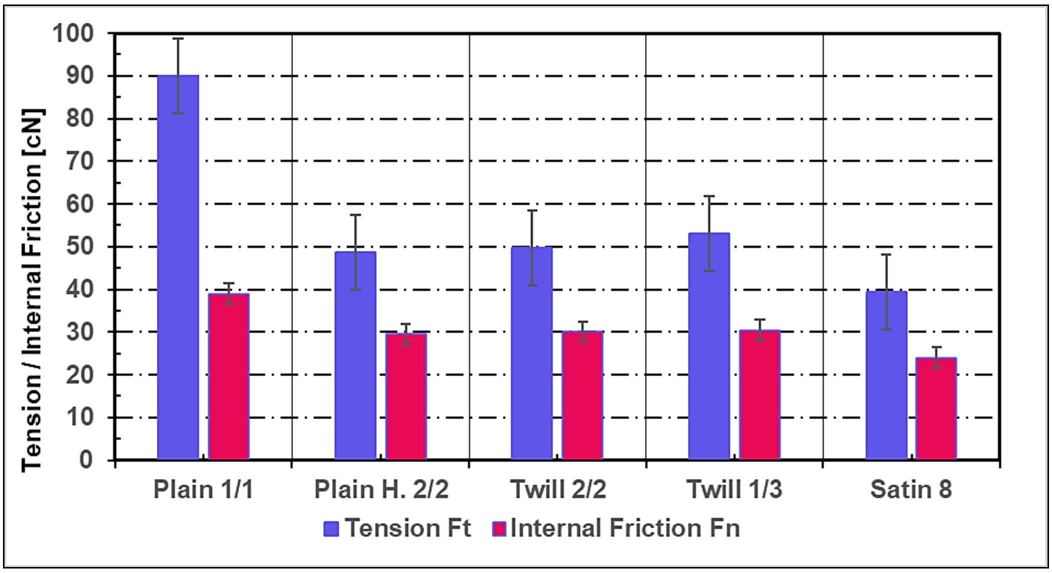

Fig. 9: The relation between the warp yarn tension force and the internal friction between weft and warp yarns

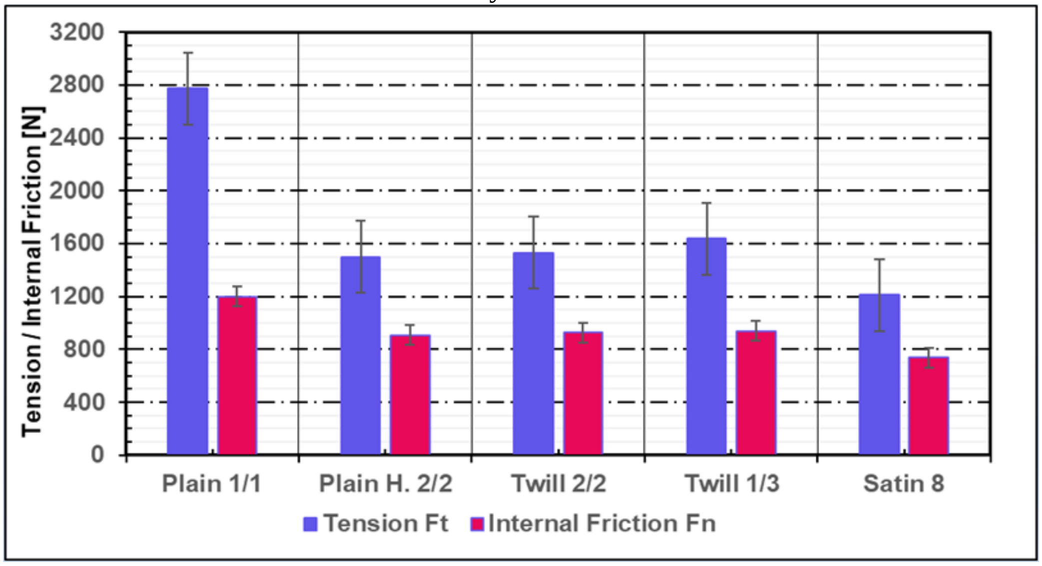

Fig. 10: The tension force for all warp yarns and the internal friction force between all warp yarns and a single weft at the beating-up point

From these relations, it is concluded that the required forces for beating up one weft varied according to the difference in weaves' constructions. The results are 1199 Newton for plain weave 1/1, 939 N. for twill weave 1/3, 926 N. for twill weave 2/2, 907 Newton for plain hopsack weave 2/2, and 738 N. for satin weave 8.

Conclusions:

Woven fabrics and weaving machines are classified into light, medium, and heavy according to the weight of the woven fabric. Although there is often not necessarily a direct relationship between the fabric weight and the classification method for used weaving machines. Unfortunately, this is a common mistake from a technical point of view, as it is assumed that the selection of the weaving machine for the operation depends on the weight of the sample, and not on the mechanical stresses during weaving. This mechanical stress of the weaving machine has always been associated with many variables, but it is noted that the study of the internal friction tension between the two main elements of woven fabrics has not gotten sufficient research study.

Therefore, the research was based on the analysis of the internal friction forces between the warp yarns and the individually inserted weft during a complete revolution of the weaving machine. The internal friction force has a significant impact on the requested force to beat up the wefts, based on Newton's third law. So, it is expected that the required beating-up force values certainly depend on the number of interlacing rates within the woven construction repeat more than the fabric weight. The research study connected the applied side in the practical measurement of the warp yarn tension rates during weft insertion, and the theoretical side in calculating the friction rates between the warp yarns and the inserted weft according to the mathematical equations. Thus, it was possible to calculate the needed force to the fabric reed for beating up the weft. This paper is concerned with the dynamic characteristics of the warp and weft yarns inside the fabric structure, which must be influenced by the internal friction between warp yarns and weft. From the other side of view, many factors affect these friction forces, which have been studied in this research paper. There was a relation between the tension force for an individual warp yarn and the internal friction force between warp and weft yarns at the beating-up point. On the other hand, the sum tension force for all warp yarns and the internal friction force between all warp yarns and a single weft at the beating-up point is concluded that the required forces for beating up one weft varied according to the difference in weaves' constructions. The plain weave 1/1 realized the highest value of the required force for beating up, followed by the twill weave 1/3, then the twill weave 2/2, then the plain hopsack weave 2/2, and the satin weave 8 realized the lowest value.

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