Innovative Technological Solutions for the Development of Reinforcement Woven Fabrics for Complex Lightweight Applications

Said Sobhey Badawi

Associate Professor of Weaving Technology at the Dept. of Textiles at the Faculty of Applied Arts, Helwan University, Cairo (Egypt), saidsobhey@hotmail.com.

Abstract:

The various textile industries, despite their unlimited technical development, are distinguished by their flexibility compared to many other industries, where fibrous materials are manufactured with various physical properties on a large scale. That qualifies them to participate strongly in multiple technical applications, and this is what successive generations of synthetic fibers contributed to. The first-generation (classical synthetic fibers) and the second-generation (high-performance toughness and stiffness coefficient fibers and high thermal and chemical resistance fibers) have replaced other raw materials in more than twelve branches of various applications, including areas such as packtech, mobiltech, indutech, buildtech, medtech, agrotech, geotech, protech, oekotech, ...etc. At the beginning of the first decade of the twenty-first century, the third generation of synthetic fibers appeared, which called high-functional fibers or smart fibers, because of some of their own characteristics, such as their ability to prevent the transfer of various materials and bacteria, retaining warmth and ion exchange, in addition to the ability of the fibers for biodegradation.

From all the above, the research idea was formed, which is to take maximum advantage of the physical properties of the warp and weft yarns without any interlacing between them, replacing that with touch contact between them only on the interlacing points. That leaves no chance for internal friction between them. Thus, the research paper aims to build a textile product characterized by a high tensile strength value, equal in fabric directions, dimensional stability, and a good rate of porosity that allows treatment with resins, whether natural or synthetic, and secures their penetration into the fabric structure. The research problem was identified in getting rid of the intersections between the warp and weft yarns to allow the full penetration of the resins, in addition to achieving the highest rates of fabric tensile strength even before treatment .In the executive method, bulked continuous filaments (BCF) were used as the main warp and weft yarns, which were relatively thick (den. 2000). Additional high-tenacity warp and weft yarns were used, which were relatively thin (den. 300). Their main function is interlacing with each other by using plain weave 1/1 to maintain the straightness of the main warp and weft yarns. In addition to achieving the required stability of the overall structural composition, to ensure the quality of resin processing later. In addition, the porosity of woven fabrics was achieved by using two very important operating procedures. The porosity in the longitudinal direction was achieved by drawing the main warp yarns through the odd dents of the reed (for example), while the auxiliary thin warp yarns were drawn through the even dents, and so on. On the other side, the porosity in the transverse direction between the wefts was achieved by weaving longitudinal lines like strips at regular dimensions using the real leno weave construction by using the additional thin warp and weft yarns, which helps in the formation of transverse pores between successive wefts.

By studying the results of research samples, it was concluded that the tensile strength values of the fabric without interlacing between the warp and weft yarns achieved higher and equal rates in the warp and weft directions than the corresponding samples using standard weave constructions. The lowest rates of elongation were also achieved in both directions, but they were largely equal in rate.

Keywords:

Porosity, Bulked Continuous Filaments (BCF), High Tenacity (HT), Leno, Strength, Elongation, Resin, Technical Textiles.

Paper received June 8, 2023, Accepted August 15, 2023, Published on line September 1, 2023

1. Introduction:

Food, clothing, and housing are not ordinary needs but rather the basis for a person's survival. Where textile products play a vital role in meeting man's basic needs from birth to death. Textile manufacturing is a very ancient craft with a history almost as mankind. The importance of technical textiles lies in their entering every aspect of human life. Some of the creative industries would not be the same without it as they make a vital contribution to the performance and success of products that are used in non-textile industries. Nowadays, technical textiles are used as protective clothing, medical and health care products, automotive components, building materials, geotextiles, agriculture, sport and leisurewear, filter media, environmental protection, etc. This confirms that textile technological developments have a positive impact on the various non-textile industries.

Technical textiles based on composite materials are rapidly developing as light-weight engineering materials. Fabrics constitute the reinforcement component of the composite material. The fabrics used in composites manufacture are referred to as "performance fabrics" and are especially engineered as a single-fabric system to impart reliability and performance.

The main goal of this research paper is the development of a building method for fabric structure elements for lightweight composites. Lightweight textile structures treated with resin-reinforced composites offer numerous advantages over conventional designs. Mainly because of the high stiffness and strength with light weight, the good damping and crash properties, the great variety of textile processes and structures, the cost-effective production with high reproducibility, the suitability for high-volume series production, and the fact that it is assumed to be used later in lightweight applications within different industries.

Technical textile products after resin-treatment can be used in three common ways:

1- A component part of another product that contributes directly to the strength, performance, and other properties of that product.
2- A tool in a process to manufacture another product.
3- Perform a specific function or several functions separately.

2. History

The development of man-made fibers and their new treatment materials and continuing technological development led to new products and applications. That raw material opened completely new application areas for technical textiles. Synthetic fibers offer high strength, elasticity, uniformity, chemical resistance, flame resistance, and abrasion resistance, among other important properties. Applications of new chemical treatments help designers tailor their products for special uses. New fabrication techniques also contributed to the improved performance and service life of technical textiles. The technological advances in textiles have an effect on various industries. The application of textile materials in technical textiles has given impetus to fiber technology.

2.1 Fabric porosity

The porosity of the fabric used in the composite as reinforcement plays an important role in manufacturing the composites, as well as the final properties and the voids' percentage. It is one of the important physical quantities that is used to describe textile materials, whether yarns or fabrics /1/.

The total porosity of a woven fabric consists of three components:

- The intra-fiber porosity, due to the voids within the fiber itself,
- The inter-fiber porosity, due to the voids between the fibers, and
- The inter yarn porosity, formed by the intersections between the yarns.

The pores within a fabric are also influential factors in the rate of flow of resin during composite manufacturing.

Yarn porosity, φ, due to the voids between the fibers as follows /2, 3/:

$$Yarn\ porosity\ (\varphi) = (1 - \frac{\rho_t}{\rho_m}) \times 100$$

Where $\rho_t = bulk\ density\ (g/cm^3)$,
$\rho_m = fiber\ density\ (g/cm^3)$.

Fabric porosity, $\in$, represents the fraction of the nominal bulk volume of a material that is occupied by void space as follows /4/:

$$Fabric\ porosity\ (\in) = (1 - \frac{W}{dh}) \times 100$$

Where $W = fabric\ areal\ density\ (g/cm^2)$,
$d = fiber\ bulk\ density\ (g/cm^3)$,
$h = fabric\ thickness\ (cm)$.

Porosity can range widely, depending on product design and processing techniques. The cross-sectional shapes of natural and man-made textile fibers vary widely, and the pore structure of a fiber assembly is strongly influenced by this geometrical characteristic. The manner in which fibers can pack in an assembly is largely determined by their cross-sectional shape. Pore dimensions can be described in many terms, for example, their volumes, surface areas, average diameters, and minimum diameters, frequently referred to as pore throats. Pore volume is the dominant factor that determines the capacity for liquid absorption /4/.

If we model fibers as being circular in cross-section, then the packing of uniform cylinders provides a good example of how this factor limits the lowest porosity that can be achieved. The closest possible packing of parallel cylinders with uniform radii is in rhombohedral (hexagonal) packing, shown schematically in two dimensions in Figure 1. The porosity of such a system is 9.35%, which is the minimum possible value of porosity for cylinders of equal radii. This value is independent of the cylinder radius. To the extent that this model represents an idealized two-dimensional textile material composed of identical fibers with circular cross-sectional shapes. If the fibers were not all equal in radius or if they deviated from being perfectly circular in cross-sectional shape, the minimum porosity would increase significantly. On the other hand, if the fibers were square or rectangular in cross-sectional shape, the porosity of the closest packed structure could approach zero. In contrast to cylinders, the closest rhombohedral packing of spheres with a uniform radius would produce a porosity of 25.9%. Even those fabrics that appear dense and solid will have porosities in the range of 60 to 70%. The contribution of fabric thickness to the explanation of its thermal resistance is because those characteristics influence fabric porosity. This gives the percentage of fabric volume that is occupied by air instead of textile material. In woollen fabrics, porosity ranges from 67 to 86%, while in the worsted ones, it lies between 59 and 73%, their average values being 76 and 64%, respectively /4, 5/.

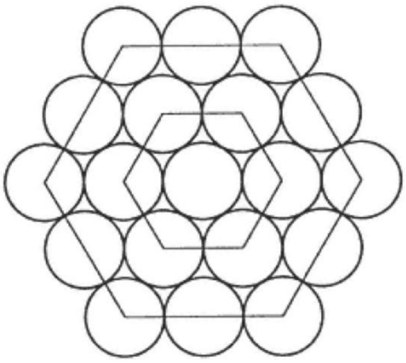

Fig. 1: 2D representation of close-packed cylinders of equal radius /4/

In quantifying porosity, it is important to distinguish between porosity values that are based on pores that are effective and those that are isolated. Effective pores are defined as those that form a continuous and interconnected phase that reaches the nominal surface of the network. Isolated pores, on the other hand, are completely enclosed by the solid material and are not a part of the continuous phase. Obviously, only the effective, interconnected pores contribute to the sorption capacity of a material. Porosity is an especially important property in connection with those textile materials that are used as liquid absorption media. Absorption can be defined as the process wherein liquid displaces the air in the void spaces or the pores in the material, either spontaneously as in wicking or under an external driving pressure. The amount of liquid that can be absorbed is a direct function of the fabric's porosity /4/.

2.2 Fabric resin-treatment

Resin is a general term for a solid or semi-solid material, often of high molecular weight, that exhibits a tendency to flow when subjected to stress and usually has a softening or melting range. There are two items of resin:

- Natural resin, natural organic substances, usually of vegetable origin and amorphous, yellowish to brown, transparent or translucent, and soluble in alcohol or ether but not in water.
- Synthetic resin, any of many manufactured products made by polymerization or other chemical processes and having the properties of natural resins.

The aim of the textile resin-treatment process is to enhance the fabrics' properties, durability, solid form, and dimensional stability by resin transfer molding, which is a variation of matched-metal-die melding in which, after placing the preformed reinforcement in the heated mold, premixed, quick-curing resin is injected while the mold is closing, or after it has closed. There is another variation of matched-metal-die molding called resin transfer molding (RTM), in which, after placing the preformed reinforcement in the heated mold, premixed, quick-curing resin is injected while the mold is closing, or after it has closed. The technique has been used to make body parts for specialty cars and aircraft components.

3. Methodology

3.1 Analysis of the Problem

The research problem is enclosed in the formation of a fabric structure with all its required characteristics, especially strength and dimensional stability, but it doesn't contain the interfacing between the warp and weft yarns. That is achieved for two main objectives: the first is making full use of the tensile strength of the warp and weft yarns without any friction related to intersection surfaces between the warp and weft yarns. The second reason is the symmetry of the tensile strength in both directions, which is very difficult to achieve using traditional fabric structures.

3.2 Theory of research method

The research procedures are based on the following orders:

- A review study of the suitable raw materials for the research's procedures.
- Study of the following fabric treatment-processes.
- Fabric design according to the research variables and required properties of the final product.
- Accurate setting for weaving machine devices, which is used in weaving experimental samples for the research study.

3.3 Weaving of Standard Experiment Samples

This essential part of the research was determined in the weaving of the experimental samples according to the previously determined structural specifications. Other woven samples were woven with the same structure specifications, but by using the standard fabric constructions.

3.4 Laboratory Measurements

The laboratory measurements were limited to measuring tensile strength and elongation tests for the woven samples in the warp and weft directions in accordance with standard procedures, which are recommended by the German Institute for Standardization and also American Standards on Textile Materials.

4. Experiments

The experimental work has been achieved on a Dornier rapier weaving machine p2, equipped with two warp beams and a dobby device, up to 24 heald frames.

Leno stripe of the construction's repeat is woven by using the manufacturing method "simultaneous bottom and top douping", in which two crossed yarns that form a leno effect are drawn through the eye of a doup needle, one operating as a bottom doup, and the other as the top doup. The crossed warp yarns are twisted around consecutive wefts to form a spiral pair, effectively setting each weft in its place.

For weaving the research samples, 9 heald frames were used as represented in Fig. 2, 6 for leno stripes (2 for top doup yarns, 2 for bottom doup yarns, and 2 for plain yarns), 1 for additional warp yarns, and 2 for the principal warp yarns (BCF).

The experimental procedures were divided into two phases:

1- Weaving of experimental samples.
2- Laboratory measurements.

4.1 Weaving of experimental samples

The experimental samples were woven according to the specifications, as represented in Table 1. The main sample of the research was woven by the main weft and warp yarns of thick BCF, which must be straight without any interlacing between each other. That was achieved by using additional, thin, and high-tenacity polyester yarns, which maintain the straightness and stability of the fabric by interlacing with each other as shown in Fig. 3. Hence, it was necessary to choose the additional yarns with the following characteristics: high tenacity and fine thickness in addition to their lower tensile strength and elongation compared to the corresponding rates in the main BCF filaments, as shown in Table 1. These properties together achieve the required dimension stability of the main sample, in addition to the weak effect of the additional filaments in creating crimps for the main warp and weft filaments and maintaining their straightness in the sample. Also, the other samples were woven with the same weave specifications by using the standard fabric construction of plain 1/1 and twill 1/3, but without the additional warp and weft yarns to compare their tensile strength and elongation.

The main elements of the woven fabric structure variables were:

1- Warp and weft yarn material:

- Principal yarns: Bulked Continuous Filaments (BCF) Polyester, denier 2000.
- Additional yarns: High Tenacity (HT) Polyester, denier 300.

2- Fabric samples' constructions:

- Non-interlaced Fabric.
- Plain weave 1/1.
- Twill weave 1/3.

The warp and weft yarns' density and arrangement system were as represented in Table 1. On the other hand, the weave diagram, draft system, and lifting plan are shown in Fig. 3, and the surface appearance of the non-interlaced construction fabric is shown in Fig. 2.

4.2 Laboratory Measurements

The laboratory measurements have been performed for the experimental samples according to standard procedures recommended by the A.S.T.M. (American Standards on Textile Materials), Designations: D 5035-06:2008, and DIN (Deutsches Institut für Normung), the German Institute for Standardization, ISO 13934-1:2013 (en). Those were limited to tensile strength and elongation tests. The measurements were carried out for all research samples in the warp and weft directions. However, for the non-interlaced fabric samples, which represent the main sample of the research, the tests were carried out in two ways: the first is the traditional method according to the standard specification, and the second is by cutting the additional warp and weft yarns after fixing the sample on the two gripping jaws of the tester device. The aim of this procedure is to study the effect of the presence or absence of additional filaments on the behavior of the sample during the test, as well as the final test results.

Table 1: Specifications of the structural elements for the experimental samples

<table>
<tr><th rowspan="3">Material</th><th>Item / Yarn</th><th>Count [Denier]</th><th>ε - F_{max} %</th><th>F_{max} N</th><th>F_{max} cN/den</th></tr>
<tr><td>PES (BCF)</td><td>2000</td><td>28.2</td><td>80.60</td><td>4.03</td></tr>
<tr><td>PES (HT)</td><td>300</td><td>17.5</td><td>21.24</td><td>7.08</td></tr>
<tr><td rowspan="9">Fabric</td><td>Fabric-Set / Construction</td><td colspan="2">Warp density [yarn/cm]</td><td colspan="2">Weft density [weft/cm]</td></tr>
<tr><td>Non-interlaced</td><td colspan="2">9 BCF / 9 HT
In the order of 1:1</td><td colspan="2">9 BCF / 9 HT
1:1 In the order of 1:1</td></tr>
<tr><td colspan="5">Notice: Leno stripes in non-interlaced fabric are arranged as 1 strip/cm that consists of 2 crossed yarns and 2 standard yarns, on the order of 1 Crossed: 2 Standard: 1 Crossed.</td></tr>
<tr><td>Fabric-Set / Construction</td><td colspan="2">Warp density [yarn/cm]</td><td colspan="2">Weft density [weft/cm]</td></tr>
<tr><td>Plain 1/1 (P 1/1)</td><td colspan="2">9 BCF</td><td colspan="2">9 BCF</td></tr>
<tr><td>Twill 1/3 (T 1/3)</td><td colspan="2">9 BCF</td><td colspan="2">9 BCF</td></tr>
<tr><td>Cover factor – Warp/weft</td><td colspan="2">14</td><td colspan="2">14</td></tr>
<tr><td>Cover factor – Fabric</td><td colspan="4">21</td></tr>
</table>

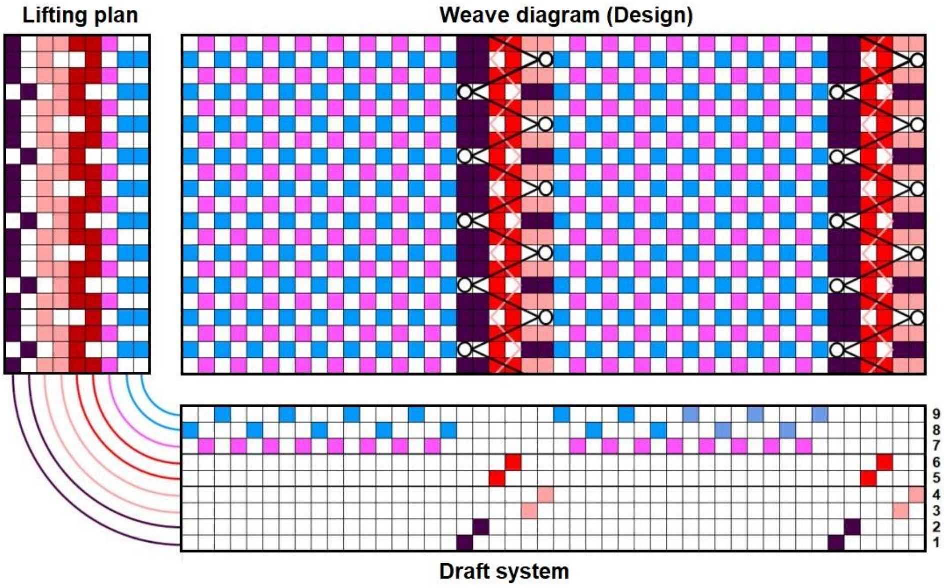

Fig. 2: The weave diagram, draft system, and lifting plan of main fabric sample (non-interlaced construction)

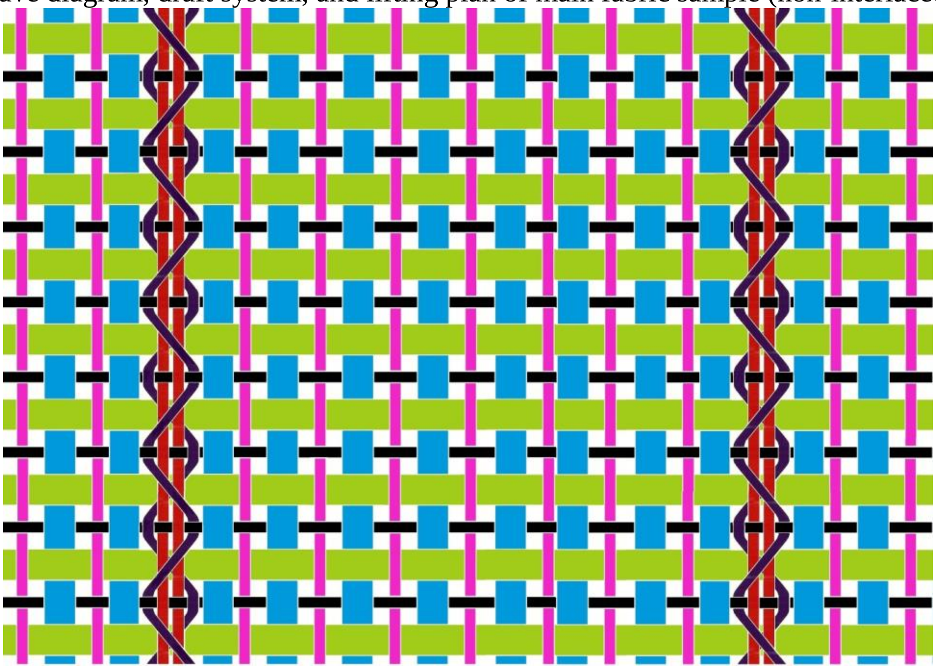

Fig. 3: Surface appearance of the main fabric sample (non-interlaced construction)

5. Results and discussions

The laboratory tests' results for the experimental samples are shown in Table 2. These results indicate the samples' tensile strength and extension at break in warp and weft directions, all in accordance with the previously mentioned specifications in Table 1.

Table 2: The tensile strength, and extension percentages at break values in warp and weft directions

Fabric Construction		Tensile Strength [Kg/5cm]		Extension at Break [%]	
		Warp	**Weft**	**Warp**	**Weft**
Non-interlaced	(A)	355	353	30.5	31.4
	(B)	356	354	30.6	31.6
Plain 1/1		321.7	321.7	41.17	43.2
Twill 1/3		301.9	301.9	39.48	41.2

A: With additional yarns
B: Without additional yarns

5.1 Description of the behavior of non-interlaced fabric samples during tensile strength and elongation tests in warp and weft directions

The study of the behavior of non-interlaced construction samples during the tensile strength and elongation tests has several reasons, the most important of which are:

1- The method applied for this test hasn't been previously indicated in any research paper.
2- Studying the effect of the absence of one of the two elements of the fabric construction (warp or weft) on the results.
3- The effect of using two different materials with different mechanical properties in the research sample during the test and also on the final results.
4- Establishing a clear technical basis when designing fabrics, especially those used in industrial applications, allows predicting in advance the mechanical properties of fabrics.

Figure 4 shows the tensile strength and elongation test curves in the warp direction for the same sample of non-interlaced construction fabric, but by two different methods. The first method was for a sample with additional warp and weft yarns that was represented by the red-black curve, and the other was without additional warp and weft yarns for the sample that was represented by the green curve. It is noted in the aforementioned figure that the curve contains three main regions that constitute the behavior of the sample during the test /6/. These regions can be identified as follows:

Initial region: As for the sample containing the additional warp and weft yarns (HT), it achieved higher tensile strength values than the other sample that was without the additional yarns. This behavior is logical as the upper vertical tension of the test device is affected by the resultant of tensile strengths for two warp yarns, which is the initial tension value of the main yarns (BCF) and the initial tension of the additional yarns (HT), even though their tensile strength value is lower. In the other sample that was without the additional yarns (HT), the initial tension value was just for the main warp yarns (BCF). As for the initial elongation, as a result of the consistency in the speed of the upper clamp movement of the test device in both cases, the elongation values in the two cases are almost equal, as shown by the shape of the two curves.

Second region: After the initial elongation of the sample, it continued to elongate for a distance of 25 mm (30–55). The warp yarns become independent and taut, and then they are extended under the effect of vertical tension. For the first sample, with additional warp and weft yarns (HT), a deformation occurred completely for all the additional yarns, and by the end of the red-distance in the curve, the effect of the additional yarns on the change rate of the sample's tensile strength during the test had ended. However, with the continuous vertical movement of the test device under the influence of the tension value of the main yarns only, the tensile strength value of the sample didn’t change for a distance of approximately 10 mm (35–45), during which the test sample achieved higher values towards the sample elongation. The color change of the tensile strength and elongation curve in the middle of that phase to black indicates the behavior of the sample at that point of the test. As for the other sample (BCF), without additional warp and weft yarns (HT), the green curve indicates the traditional form of that test, where the natural increase in the tensile and elongation rates. However, the average tensile strength was less than that of the first sample, but after the deformation of the additional yarns of the first sample and the temporary stability of the tensile strength value, it is noted that there is a beginning of symmetry in the test curve.

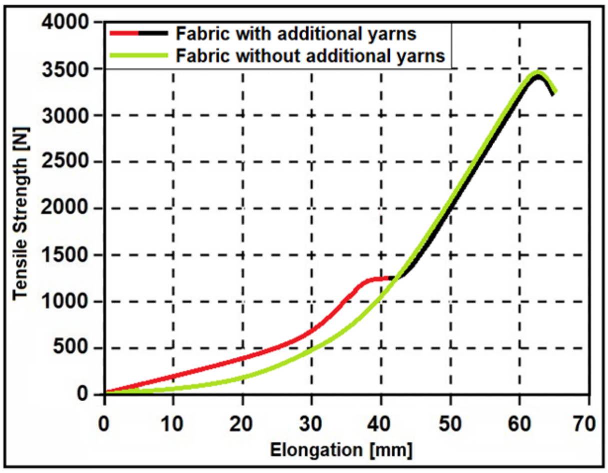

Fig. 4: Warp tensile strength and elongation curve of non-interlaced fabric

Sample deformation: The effect of tensile load and elongation at that stage is completely similar to the warp yarns of the two samples, which represented the weak points of the sample under the tension load, while the greatest value of tensile strength and elongation was recorded; the warp yarns were deformed later.

5.2 Analysis of the Influence of the research's variables on the results:

After specifying the previous item to study the behavior of non-interlaced fabric samples with/without the additional yarns (HT) during test as mentioned before. Especially, that behavior was completely unknown from the research point of view. The next important part of discussion focus on the final results and the comparison of the results of all the participating structures in the research. Therefore, the following elements show the effect of various factors on the research variables on the rates of tensile strength and elongation in the warp and weft directions

5.2.1 The influence of research variables on the rates of tensile strength in the warp/weft directions:

The tensile strength in the warp and weft directions' values of the woven fabrics varied according to the differences in the fabric constructions, as shown in Fig. 5. The highest average values of tensile strength in both directions were achieved by using non-interlaced construction, followed by plain weave 1/1, and the lowest values were achieved by using twill weave 1/3. The increase in the tensile strength rates of the non-interlaced structure is due to the lack of interlacing between the main warp and the weft yarns, where there are only touch contact areas resulting from the attraction of the additional warp and weft yarns on the main thick BCF yarns to maintain the hardness and dimension stability of the woven structural shape. It is noted that there was no significant effect of the presence of the additional HT yarns on the tensile strength rates, whether in the warp or weft direction, as the difference between the rates upon testing achieved a decrease of less than 0.3% in the absence of the additional HT yarns than in the case of their presence. That confirms that the touch contact between the thin additional HT yarns did not affect the mechanical properties of the woven fabric, despite its great influence on maintaining the consistency and dimension stability of the structural shape.

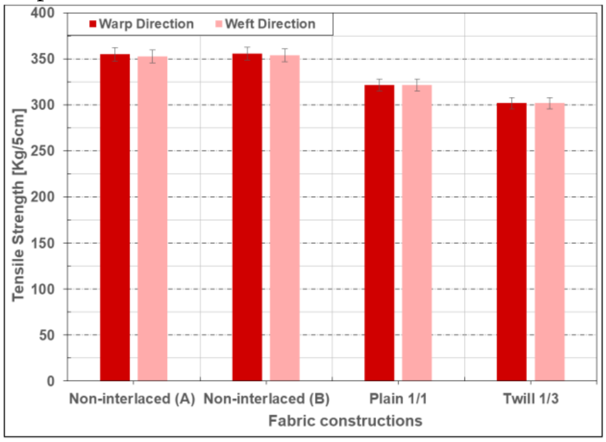

Fig. 5: Tensile strength rates in the warp and weft directions

On the other side, there was a decrease in the tensile strength rates in the warp and weft directions for the standard samples of plain weave 1/1 by about 10% and the twill 1/3 by about 15%, compared to the non-interlaced structure. These decreases in values were due to the force strength of the tester device being on all vertically parallel yarns (whether warp or weft yarns) at the same time and at regular speed, which generates a resistance force in the yarns under test to the vertical tension, and since the resultant of the force of resistance to tensile is in one direction, which makes the resultant force relatively large. While conducting the test for experimental samples that contain interlacing between the warp and weft yarns, the resultant tension force of the tester is analysed in two directions: the first is the vertical direction that is recorded on the test device and represents the tensile strength of the sample, and the second is the horizontal force exerted by the vertical yarns between the top and bottom jaws of the tester to overcome the horizontal forces resulting from the interlacing between the warp and weft yarns of the sample.

Also, the tensile strength rates of twill 1/3 samples decreased from the corresponding values for plain weave 1/1, and this decrease in tensile strength is due to the decrease in the number of intersections in the longitudinal direction from twice (two intersections) for plain weave 1/1 compared to one intersection for twill 1/3, all with the same number of wefts (4 wefts), which are interwoven with similar warp yarns in the longitudinal direction. This leads to a decrease in the contact surfaces, and thus lower rates of friction between the warp and weft yarns of twill weave 1/3, compared to plain weave 1/1, which increases the yarns' freedom and gets rid of interlacing more in the twill weave than in plain weave 1/1 Thus, the tension forces of the tester affect the filaments of the twill structure faster and more effectively than plain weave 1/1.

5.2.2 The influence of research variables on the rates of extension percentages (elongation values) in the warp/weft directions:

The extension percentages in the warp and weft directions' values of the woven fabrics varied according to the differences in the fabric constructions, as shown in Fig. 6. The lowest average values of extension percentages in warp directions were achieved by using non-interlaced construction, followed by the corresponding values for the same weave structure but in the weft direction with a slight increase of 3%. That increase is related to two factors: the first is the decrease in weft tension during weft insertion compared with the simultaneous warp tension. The second reason is the effect of the weft beating-up process, in which the reed is pushing the weft that is inserted across the warp yarns up to the fabric fell point. The higher average values of extension percentages were achieved generally in the weft direction for all woven samples, compared to their similar values in the warp direction. That is due to the two reasons that have been mentioned before. The plain weave 1/1 achieved the highest values of the extension percentages with increase percentage values of 15%, followed by the twill weave 1/3 with increase percentage values of 10% more than the non-interlaced structure, respectively.

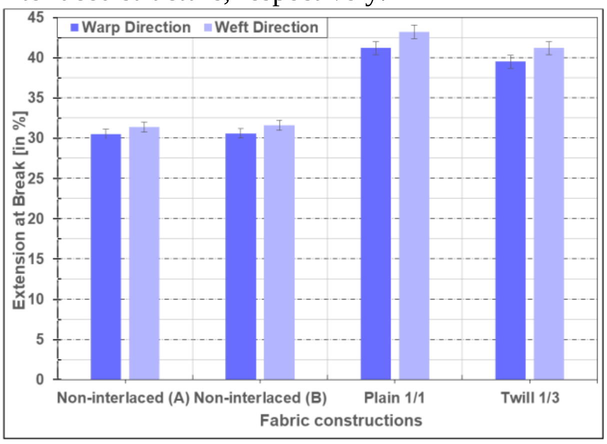

Fig. 6: Elongation rates in the warp and weft directions

The lowest average values of extension percentages in both directions were generally achieved by using non-interlaced fabric construction; as a result, there wasn't interlacing between warp and weft yarns. On the other side, there was an increase in the extension percentage rates in the warp and weft directions for the standard samples of plain weave 1/1 by about 10.5% and the twill weave 1/3 by about 9%, more than the non-interlaced structure. This increase in values of plain 1/1 and twill 1/3 weaves is related to the crimp values between warp and weft yarns of these constructions compared with non-interlaced structure shapes.

From another point of view, the higher extension percentage values of plain weave 1/1 than their similar values with twill weave 1/3 are due to the decrease in the number of intersections in any direction from twice (two intersections) for the plain weave 1/1 compared to one intersection for twill 1/3, all with the same number of yarns and wefts. This leads to a decrease in the crimp values between the warp and weft yarns of twill weave 1/3 compared to plain weave 1/1.

6. Conclusions:

Textiles have expanded greatly in the last three decades, especially in technical applications. Textiles have replaced other materials in more than twelve branches of various applications in the technical fields. As a result, successive generations of synthetic fibers appeared until the world reached the third generation of fibers, with the aim of meeting the steady demand for the use of textiles. Therefore, the research idea was to make the most of the unique physical properties of synthetic fibers. By designing a textile product characterized by homogeneity in tensile strength and elongation between the two directions of the fabric, as well as maintaining the fabric's hardness and dimension stability. In addition to that, achieving a good rate of porosity that allows the fabric to be treated with resins, whether natural or synthetic, allows for homogeneity in their penetration into the weave structure. To achieve these distinctive characteristics, the design of the fabric structure was adopted to completely eliminate, as much as possible, the crimp of the warp and weft yarns. Where yarn crimp plays a major role in the difference between the mechanical properties of fabrics in both directions. All that was done through a combination of two generations of synthetic fibers. The main warp and weft yarns of the first generation are bulked continuous filament (BCF), and the additional warp and weft yarns of the second generation are high tenacity (HT). It was to achieve the economic aspect of the final product. The executive method was summarized in the use of BCF yarns, relatively thick within the limits of Denier 2000, with additional high-tenacity yarns, relatively thin in the range of Denier 300. The function of additional yarns was interlacing with each other using the plain weave structure 1/1.

By studying the main research samples, it was concluded that the tensile properties of the fabric without interlacing between main warp and weft yarns achieved higher rates of tensile strength in the warp and weft directions than the corresponding samples using the standard weave constructions, plain and twill weaves. It also achieved equal rates of elongation in the warp and weft directions, but it was lower than its corresponding samples using the standard weave constructions, and this is what the research aimed for.

References:

1- Magdi El Messiry. (2017). Natural Fiber Textile Composite Engineering. Apple Academic Press, Inc., Florida, USA.
2- Prashansa Sharma. (2022). Fundamentals of Nano-Textile Science. Apple Academic Press, Inc., Florida, USA.
3- Mihai Ciocoiu. (2018). Materials Behavior: Research Methodology and Mathematical Models . Apple Academic Press, Inc., Florida, USA.
4- Raheel Mastura. (1996). Modern Textile Characterization Methods (International Fiber Science and Technology). CRC Pub., Boca Raton, FL, USA .
5- Subhash C. Anand, J F Kennedy, et al. (2005). Medical Textiles and Biomaterials for Healthcare. Woodhead Publishing Limited, Cambridge, UK.
6- Said Badawi. (2023). Geometrical and Mathematical Analysis of the Elongation of Woven Fabric Structures. International Design Journal, May 2023, Volume 13, Issue 3, Pages 411-422.