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Improving the Functional Performance Properties of Warp Knitted Advertising Banners with Digital Printing Technology

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***ABSTRACT**: Digital textile printing technology has come a long way since the time it was first introduced a couple of decades ago. Initially driven by the need of simplifying and optimizing the sampling process, it has evolved into a new technology with several areas of application in mass customization and luxury markets. Technology-wise it is still a complex process that requires understanding many disciplines contributing to digital textile printing. Print head design, ink chemistry, pre- and post-treatment of fabric, design and pre-flirting are all influential in achieving a great quality of digital textile print. Yet, digital textile printing is still a relatively new technology. This research aims to produce warp knitted fabrics suitable for production of some advertising banners and printing them with digital printing technology by using different parameters (Different numbers of guide bars (2 or 3)- Different warp knitted structures). Six different warp knitted samples of advertising banners were produced to achieve the best functions and performance properties. To achieve the goals of this research, the construction of warp knitting advertising banners and the parameters associated with are studied. Results of testing of advertising banners are illustrated and discussed to optimize the functional and performance properties of advertising banners design.*

***KEYWARDS:** Advertising banners, Digital textile, Functional Properties, Inkjet printing, Warp knitted fabrics.*

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I. INTRODUCTION

Textile printing can be defined as the process of transferring ink to the textile substrates by using specific printing techniques and machines. The most suitable techniques for textile substrates printing are: screen printing, digital ink-jet printing or usage of thermal transfer processes. [1]

Digital fabric printing is a very new technology with varied applications. Most available printed fabrics are rotary screen printed; single print run is several thousand yards. The high cost is due to time required to prepare screens, as each color in a design requires a separate screen. But digital printing has the advantage as it has the ability to do very small runs of each design (may be even less than 1 yard) because screens are not needed. Digital printing was first patented in 1968, in the 1990s, inkjet printers mostly been used for paper printing applications. The development in technology has now specialized wide-format printers which can handle a variety of substrates – everything from paper to vinyl to canvas and fabrics also. [2]

On the other hand, digital inkjet textile printing offers higher printing speed of short runs, flexibility, creativity and environmental benefits. In addition, it is important to note that using digital printing techniques enables better visual effects, as well as wider flexibility of print formats. Besides that, it offers better control of print quality uniformity during the production runs. [3]

The use of the fabric is the most important starting point to identify what to produce as an end-product. Most used fabrics for digital printing are polyester based fabrics. The printing process should match with type of ink e.g. low energy sublimation (dye-sub), high energy sublimation (also known as disperse direct), reactive, acid and pigment. The ink chemistry should fit the requirements of the fabric (nylon, polyester, silk, cotton). On the bases of choosing fabric and ink combination is the process followed for heat-press sublimation, infra-red fixation or steaming. [4]

Polyester fabric mostly printed with dye-sub or disperses direct ink, solvent inks, latex and UV. [5] The sublimation ink colorants bond with the fiber during fixation or sublimation, as the inks are absorbed by the fabrics, then other medium in which the ink remains with the coating and on top of the fabric, as with UV-curable formulations. Many times, latex inks on porous textiles suffer crocking or 'rub-off' issues. [6]

A warp knit fabric has a structure made of several warp threads or warps that form similar loops in a course. [7] The different stitches are knitted by changing the sideways motion or shogging movement of the guide bars during knitting. Warp knitting is a method of making a fabric by normal knitting means, in which the loops made from each warp are formed substantially along the length of the fabric. It is characterized by the fact that each warp thread is fed more or less in line with the direction in which the fabric is produced. Each needle within the knitting width must be fed with at least one separate and individual thread at each course. It is the fastest method of converting yarn into fabric, when compared with weaving and weft knitting. [8]

II. MATERIALS AND METHDS

In the experimental study, Different warp knitted samples of advertising banners were produced to achieve the best functions and performance properties. The present research aims to produce warp knitted Polyester fabrics suitable for production of some advertising banners and printing them with digital printing technology by using different parameters as following;

- Using different numbers of guide bars (2 or 3).
- Using different warp knitting structures.

2.1. Warping Process

The selected raw yarn is sent to the warping process, which is the adjustment process to supply the specified number of yarns at even tension. As the number of raw yarns differs depending on the type at the time of acceptance, it is correctly adjusted in this process and 600 yarns are wound on one beam. To produce a warp knitting fabric on the warp knitting machines its require a yarn which feed on the beams, although in some case the ends of the yarn from the cone or cheese can be feed directly into warp knitting machine using creel, mostly this method only for pattern yarn on the lace machines, however for the ground yarn always using the yarn on the warp beam.

As shown in Figure (1), warp beams produce at various warping machine, in this case for warp knitting, the warp beams produce on direct warping machines. Direct warping can be defined as produce in which ends of the yarn are wrapped in one operation from the yarn packages onto the warp beam.

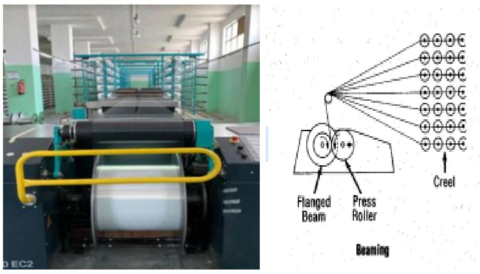

Fig . (1) Cylinder beam

Since the creel must supply the required number of the ends of the warp, there are two possibilities; either the creel can be very large or the width of the warp can be smaller. In order enable the use of moderate creel size and to simplify warp handling, section beams are warped. Each section its own flanges and number of section beams are placed on the common shaft to make up required number of ends for the warp. Most of modern warping machine, can be work with 21" beam to 42", these size of the beam mostly use on the warp knitting machine now a day. As shown in Figure (2).

Fig . (2) Warping process

As shown in Figure (3), the direct warping machine consists of the following parts:

- The warping machine or machine head which use to turn the beam so that the warp or yarn sheet from the creel are wound onto it.
- A front reed which separated a yarns and spaces to fit the width of the beam.
- Oiling device to lubricants the yarn and reduce electro static on the yarn.
- Backward device allows the beam to turn backward to repair and knots the broken yarn or remove the fluff.
- Electro static eliminator which remove the electric static on the yarn due yarn friction with others parts of warping machine i.e. reed, separator etc.
- Tension roller or roller aggregate to iron out differences yarn tension on the yarn sheet.
- An eyelet- board or back reed to gather the yarns coming off the creel.
- The creel accommodating the yarn packages.
- Yarn tension device is used to control the tension of the yarn. If the yarns are irregular or thick or thin place is in yarn then it have chance to break down due to over tension.

Fig. (3) Direct warping machine

2.2. Warp Knitting Machine

In the warp knitting process, the warped yarn wound on the beam is sent to the knitting machine by the crane vehicle or lift, and set to the machine. The beam rpm and inch are entered into the computer, and the yarn is set. The yarns are prepared as warps on beams with one or more yarns for each needle. All the samples were produced on two different warp knitting machines; HKS 2 and HKS 3M.

2.2.1. HKS 2-S Tricot Warp Knitting Machine

HKS 2-S is high-performance knitting machines capable of producing a wide range of products and extended range of patterns and articles. It is flexible enough to produce rigid as well as elastic fabrics even in finer gauge. Table (1) shows the specification of the machine while Figure (4) shows HKS 2 Tricot warp knitting machine.

Table (1) The specification of HKS 2 Tricot warp knitting machine

Model	HKS 2
Company	Karl Mayer - German
Average Speed	2200 RPM
Working width	130-186 Inch
Gauge	28
Numbers of guide bars	All bars are made of carbon-fiber-reinforced plastic
Needle bar type	Individual needle bar with compound needles

Fig. (2.4) HKS 2 Tricot warp knitting machine

2.2.2. HKS 3M Tricot Warp Knitting Machine

HKS 3M is high performance tricot machine with three guide bars from Karl Mayer with medium stroke of needle to produce wide range of applications. When equipped with an elastan device, the HKS 3-M tricot machine can also produce elastic articles. A simple and quick retrofitting of the machine with pile device is possible, because the compound sinker remains unchanged. Table (2) shows the specification of the machine while Figure (5) shows HKS 3M Tricot warp knitting machine.

Table (2) The specification of HKS 3M Tricot warp knitting machine

Model	HKS 3M
Company	Karl Mayer - German
Average Speed	2500 RPM
Working width	130-186-218 inch
Gauge	28
Numbers of guide bars	3
Needle bar type	Individual needle bar with compound needles

Fig. (5) HKS 3M Tricot warp knitting machine

2.2.3. Warp Knitted Fabrics

Table (3) shows the specification of the all produced warp knitted samples for advertising banners.

Table (3) The specification of warp knitted samples for advertising banners

Sample No.	Number of Guide Bars	Yarn Count Denier/Type	Guide Bars Movement	Thickness mm	Wight Gm/m^2	Courses/Cm
1	3	GB1:75/144 Tex Polyester microfibers	1-0\3-4	0.53	235	21
		GB2: 75/36 SD Polyester	1-0\1-2			
		GB3: 75/36 SD Polyester	1-2\1-0			
2	3	GB1:75/144 Tex Polyester microfibers	1-0\3-4	0.6	271	23
		GB2: 75/36 SD Polyester	1-0\1-2			
		GB3: 75/36 SD Polyester	2-3\1-0			
3	3	GB1:75/144 Tex Polyester microfibers	1-0\0-1	0.62	305	30
		GB2: 75/36 SD Polyester	1-0\1-2			
		GB3: 75/36 SD Polyester	3-4\1-0			
4	3	GB1:50/36 SD Polyester	1-0\5-6	0.48	243	33
		GB2: 50/36 SD Polyester	0-1\1-0			
		GB3: 50/36 SD Polyester	3-4\1-0			
5	2	GB1:50/36 SD Polyester	1-0\3-4	0.44	126	23
		GB2: 50/36 SD Polyester	1-0\1-2			
6	2	GB1:50/36 SD Polyester	1-0\0-1	0.27	80	19

		GB2: 50/36 SD Polyester	3-4\1-0			

*SD: Semi Dull Yarn
* Tex: Texture

III. RESULTS AND DISCUSSIONS

The present research aims to produce warp knitted fabrics suitable for production of some advertising banners and printing them with digital printing technology by using different parameters as following;

- Using different numbers of guide bars (2 or 3).
- Using different warp knitting structures.

Results of testing of advertising banners are illustrated and discussed to optimize the functional and performance properties of advertising banners design. For convenience, the results are presented under: -

- Air permeability test (ASTM D737 - 04(2012).
- Bursting strength test (ASTM D3786 / D3786M – 13).
- Dimensional Stability test.
- Elasticity & Recovery test (BS EN 14704-1:2005).

Six different warp knitted samples of advertising banners were produced to achieve the best functions and performance properties. Table (4) shows the laboratory tests results for all advertising banners samples

Table (4) The laboratory Tests Results for Advertising Banners Samples

No.	Air Permeability Cm³/Cm³. Sec	Bursting Strength Kg/Cm²	Elasticity & Recovery Horizontal		Elasticity & Recovery Vertical		Dimensional Stability %	
			After 1 min	After 30 min	After 1 min	After 30 min	Length wise	Width wise
1	45.86	77	100	100	100	100	- 0.8	- 0.4
2	38.5	82	100	100	100	100	-0.4	-0.4
3	28.16	86	100	100	100	100	0	0
4	4.78	82	100	100	100	100	0	0
5	29.9	64	100	100	100	100	-0.8	- 0.4
6	294.6	39	100	100	100	100	-0.8	- 0.4

3.1. The Effect of Advertising Banners Structure on Its Functional Performance Properties

The structure of a warp knit loop is very different from that of a weft knit loop. It actually contains two parts. The first is the loop itself, which is formed by the yarn being wrapped around the front or hook side of a needle and then drawn through a previously formed loop. This part of the structure is called an overlap. The second part is the length of yarn connecting each formed loop with the next succeeding loop, which is called an underlap. It is formed by the shogging or lateral movements of the yarn ends across the back side of the needles. The length of the underlap is defined by needle spaces according to the shogging movement. The longer the underlap in terms of needle spaces, the more it lies in the weftwise direction of the fabric. This increases the fabric's widthwise stability. A shorter underlap will increase the lengthwise stability.

The fabric weight is affected by the length of the underlap. While knitting with longer underlaps, more yarn is fed into the fabric. Each underlap crosses over two needle spaces instead of one. It covers more wales on its way, resulting in heavier, thicker, and denser fabric.

Figures (6), (7) and (8) show three different patterns (samples No. 1,2 &3) by using the same others manufacturing parameters (yarn count, guide bars numbers, yarn and spinning type) in the same warp knitting machine.

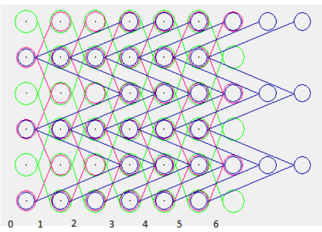

Fig. (6) Pattern (1) G1:1-0\3-4 G2: 1-0\1-2 G3: 1-2\1-0

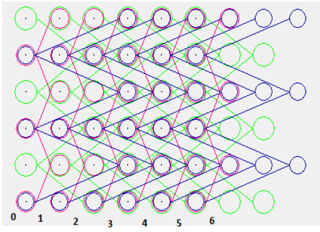

Fig. (7) Pattern (2) G1: 1-0\3-4 G2: 1-0\1-2 G3: 2-3\1-0

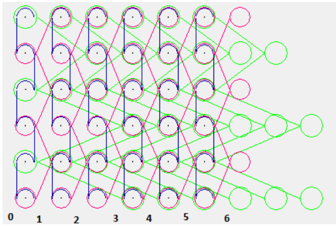

Fig. (8) Pattern (3) G1: 1-0\0-1 G2: 1-0\1-2 G3: 3-4\1-0

3.1.1. The Effect of Advertising Banners Structures on Fabric Air Permeability Property

The air permeability is mainly affected by the characteristics of pore in the fabric. The main factors affecting the porosity of the fabrics are the yarn linear density, yarn diameter, course density and wale density. The fiber morphology and deformability seem the most important factors facilitating the passage of air through the fabric. In general, the air permeability of knits seems to depend on the linear density and raw material composition. However, there exists a good relationship between area density and air permeability. Figure (9) shows the effect of advertising banners structures on fabric air permeability (cm^3/cm^2. sec).

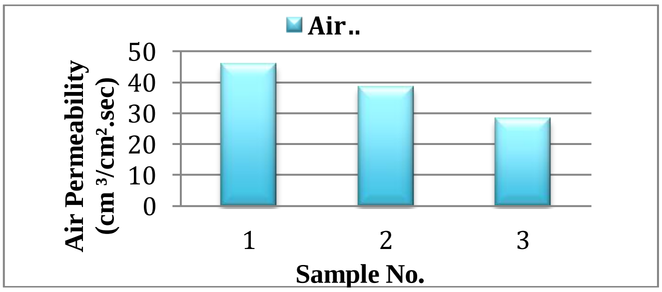

Fig . (9) The Relationship between Advertising Banners Structure and Fabric Air Permeability (cm^3/cm^2. sec)

As shown in Table (4) and Figure (9), it is observed, there is a difference in the air permeability values according to the construction of experimental samples. The air permeability values were decreased by increasing the underlap length in the structure. Open structure with shorter underlap length (sample No.1) recorded highest air permeability values compared to closed structure with longer underlap length (sample No.3). The existence of this decline is most probably a consequence of the thicker structure of long underlap length, while knitting with longer underlaps, more yarn is fed into the fabric. Each underlap crosses over two needle spaces instead of one. It covers more wales on its way, resulting in heavier, thicker, and denser fabric. Open structure of less underlap length gives the ability to the air to pass through the fabric without any obstacles due to the lower thickness of the fabric compared to closed structure.

3.1.2. The Effect of Advertising Banners Structures on Fabric Bursting Strength Property

Figure (10) shows the effect of advertising banners structures on fabric bursting strength property (Kg/Cm²).

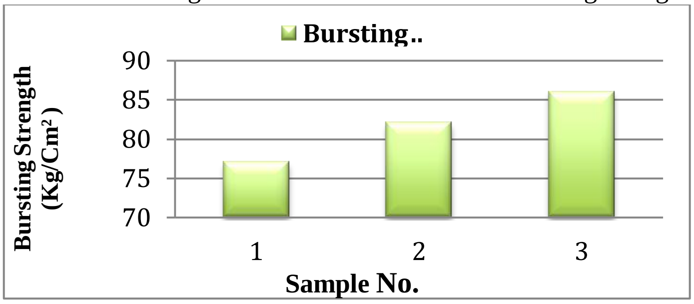

Fig . (10) The Relationship between Advertising Banners Structure and Fabric Bursting Strength Kg/Cm²

As shown in Table (4) and Figure (10), it is observed, there is a difference in the bursting strength values according to the construction of experimental samples. The bursting strength values were increased by increasing the underlap length in the structure. Closed structure with longer underlap length (sample No.3) recorded highest bursting strength values compared to opened structure with shorter underlap length (sample No.1). Each underlap crosses over two needle spaces instead of one. It covers more wales on its way, resulting in heavier, thicker, and denser fabric.

As shown in Tables (4), there is a positive correlation between stitch form, stitch density, loop shape factor, thickness and burst strength vales. As the value of stitch density rises, burst strength of the fabric rises. Finally, the weight of the fabric has a significant direct effect on bursting strength.

3.1.3. The Effect of Advertising Banners Structures on Fabric Dimensional Stability Property

This test specifies method for the preparation, marking and measuring of textile fabrics, garments and fabric assemblies change after a specified treatment, e.g. washing, dry cleaning, soaking in water and steaming. The moisture absorption of fiber is the direct factor of fabric shrinkage. The tightness of the yarn and the fabric structure is the indirect factor of shrinkage. Different raw materials of fabrics will affect shrinkage rate. Under normal circumstance, fabrics with minimum shrinkage rate are made from synthetic or blended yarns. The shrinkage rate varies according to density, yarn type, fabric type, fabric structure, dyeing and finishing process

Figure (11) shows the effect of advertising banners structures on fabric dimensional stability % in length wise while Figure (12) shows the effect of advertising banners structures on fabric dimensional stability % in width wise..

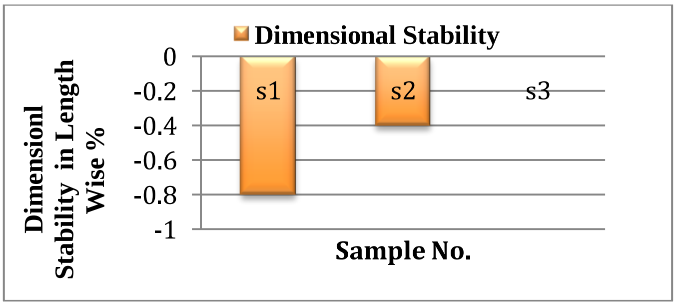

Fig. (11) The Relationship between Advertising Banners Structure and Fabric Dimensional Stability% in length Wise

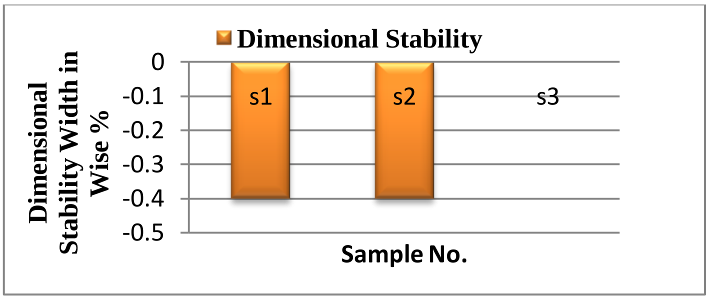

Fig (2.12) The Relationship between Advertising Banners Structure and Fabric Dimensional Stability% in Width Wise

As shown in Figures (11) & (12), the highest dimensional stability % in length and width wise is sample No.3 while the lowest dimensional stability in length wise value is sample No.1. The existence of this decline is most probably a consequence of the stitches interlacing, stitches density, the structure and the thicker of the fabric. Tighter and closed structure recorded less shrinkage rate compared with open structure.

3.2. The Effect of Used Guide Bars Number on Advertising Banners Functional Performance Properties

The guide bars are creating the necessary overlaps and underlaps to produce the delivered fabric. The pattern device initiates the movement of the guide bars, which dictates the design of the fabric. To produce different warp knit designs, one must control the shogging movements of the guide bars. More number used of guide bars offer much wider pattern scope, different effects may be obtained by altering the lapping movements and these effects may be increased still further by the use of color, mixing different yarn, linear densities or using different yarn types, such as yarns with different dyeing characteristics, textured yarns, and so on. The construction of these types of fabrics increases the versatility and enlarges the pattern scope. The increasing swinging movement of the guide bars decreases the production of these machines. However, the increased patterning possibilities offer important advantages:

- Better control of dimensional and mechanical properties.
- Greater use of color and visibility of color on the fabric surface.
- More elaborate part set threading designs to produce a wide range of fabrics.
- Improved elasticated fabrics with more patterning possibilities and less transparency of the fabric knitted.

Figures (13), (14) and (15) show three different patterns (samples No. 4, 5 &6) by using various numbers of guide bars (2 & 3 guide bars) with same others manufacturing parameters (yarn count, yarn and spinning type) in different warp knitting machine.

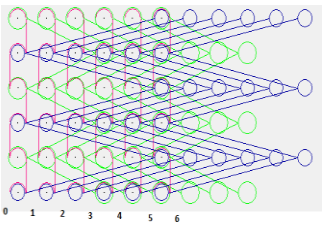

Fig. (13) Pattern (4) G1:1-0\5-6 G2: 0-1\1-0 G3: 3-4\1-0

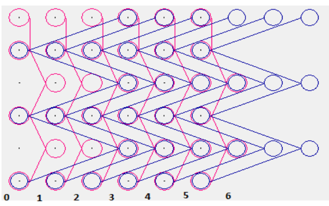

Fig. (14) Pattern (5) G1:1-0\3-4 G2: 1-0\1-2

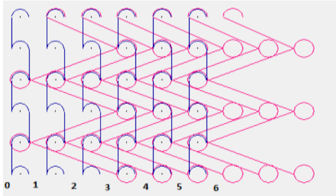

Fig. (15) Pattern (6) G1:1-0\0-1 G2: 3-4\1-0

3.2. 1. The Effect of Used Guide Bars Number on Advertising Banners Air Permeability Property

Figure (16) shows the effect of used guide bars number on fabric air permeability property (cm3/cm2. sec).

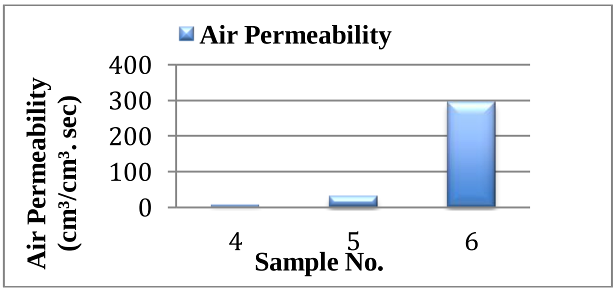

Fig. (16) The Relationship between Used Guide Bars Number and Fabric Air Permeability (cm^3/cm^2. sec)

As shown in Table (4) and Figure (16), it is cleared that; there is a difference in the air permeability values according to the used guide bars number and movement of each guide bar, sample No.6 which designed with 2 guide bars has a smaller number of courses per cm, recorded higher air permeability value compared to the sample No.4 which designed with 3 guide bars and has high number of courses per cm. More number used of guide bars offer less transparency of the fabric knitted and forbid the air to pass through the fabric easily due to the higher thickness of the fabric and its cover factor compared to less number used of guide bars.

3.2.2. The Effect of Used Guide Bars Number on Advertising Banners Bursting Strength Property

Figure (17) shows the effect of used guide bars number on fabric bursting strength property (Kg/Cm^2).

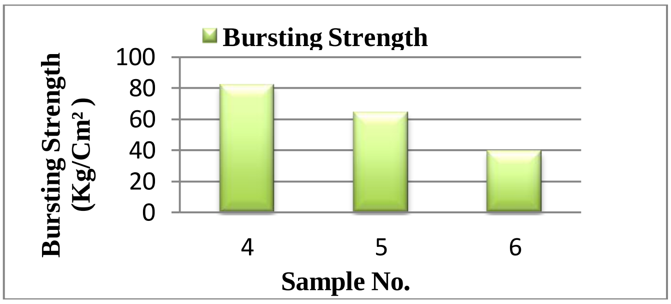

Fig. (17) The Relationship between Used Guide Bars Number and Fabric Bursting Strength (Kg/Cm^2)

shown in Table (4) and Figure (17), it is observed, there is a variation in the bursting strength values according used guide bars number. The number of guide bars and the density stitches affect the bursting strength value of produced fabric due to the different movement of each bar. The results present that the applied sample which designed with 3 guide bars and high number of courses per cm (sample No.4) recorded higher bursting strength value compared to the applied sample which designed with 2 guide bars and a smaller number of courses per cm (sample No.6). The existence of this decline is most probably a consequence of the thicker structure of the fabric. Here is a positive correlation between stitch density, thickness, weight of the fabric and burst strength vales. As the value of stitch density rises, burst strength of the fabric rises. Finally, the weight of the fabric has a significant direct effect on bursting strength.

3.2.3.The Effect of Used Guide Bars Number on Advertising Banners Dimensional Stability Property

The tightness of the yarn and the fabric structure is the indirect factor of shrinkage. Figure (18) shows the effect of used guide bars number on fabric dimensional stability % in length wise while Figure (19) shows the effect of used guide bars number on fabric dimensional stability % in width wise.

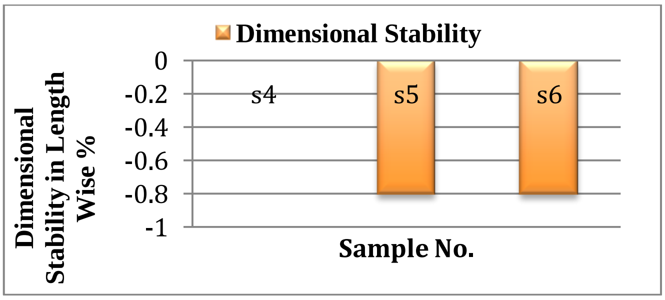

Fig (18) The Relationship between Used Guide Bars Number and Fabric Dimensional Stability% in length Wise

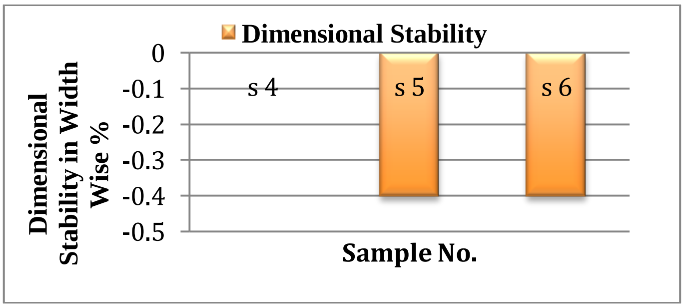

Fig . (19) The Relationship between Used Guide Bars Number and Fabric Dimensional Stability% in Width Wise

As shown in the Figures (2.18) & (2.19), the highest dimensional stability in both length and width wise ratio is (sample No.4), however the lowest dimensional stability in both length and width wise value is (sample No.5&6). The existence of this decline is most probably a consequence of the stitches interlacing, stitches density, the structure and the thicker of the fabric according to the movement of each guide bars. The tighter structure will record less shrinkage rate.

3.3. The Elasticity & Recovery % Values for All Advertising Banners Samples

According to Table (4) elasticity & recovery property for all samples recorded 100 % because of its constructions, as shown in Figures (20).

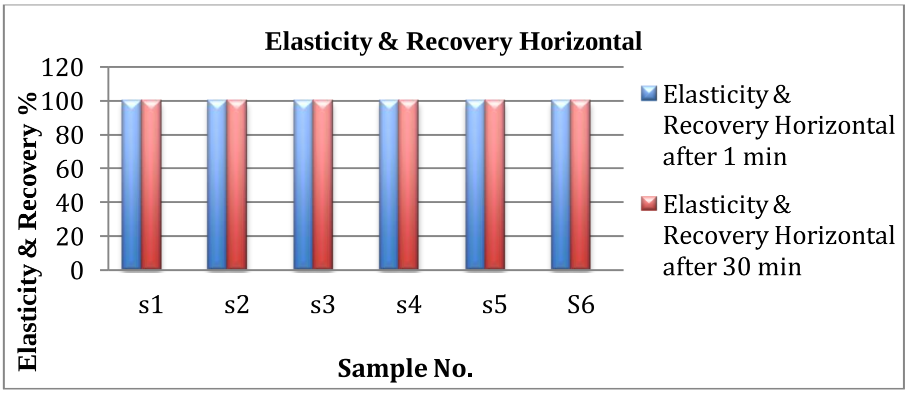

Fig. (20) Elasticity & Recovery % Values for All Advertising Banners Samples

IV. CONCLUSIONS

Digital revolution has affected every aspect of today's life. Naturally, textile printing has also adopted new technology for its needs, driven primarily by the demand for faster and cheaper sampling. Digital printing is considered to be quite a new technology. The present research aims to produce warp knitted fabrics suitable for production of some advertising banners and printing them with digital printing technology by using different parameters. To achieve the goals of this research, the construction of warp knitting advertising banners and the parameters associated with are studied. These parameters along with well-known theories and shed insight hypotheses at steps which we have followed in designing warp knitting advertising banners as given under: -

- Selection of the type of fibers or yarns that could be used to produce advertising banners, including specification of these fibers or yarns.
- Selection of the manufacturing mechanism that could be used to produce advertising banners. Applying a definite mechanism is ruled by its theories and application forms.
- Studying the required machine adjustment and the different advertising banners mechanism leads to definite design parameters (choosing the appropriate fibers, yarn type, advertising banners construction, advertising banners specification…etc.) in order to fulfill the advertising banners knitting concept. This step is guided by both the production mechanism to be used, and the characteristic properties of the raw materials.
- Testing warp knitting advertising banners (functional properties, performance and mechanical properties) to determine the feasibility of the design.

Results of testing of advertising banners are illustrated and discussed to optimize the functional and performance properties of advertising banners design. Six different warp knitted samples of advertising banners were produced to achieve the best functions and performance properties.

The structure of a warp knit loop is very different from that of a weft knit loop. The longer the underlap in terms of needle spaces, the more it lies in the weftwise direction of the fabric. This increases the fabric's widthwise stability. A shorter underlap will increase the lengthwise stability. The fabric weight is affected by the length of the underlap. While knitting with longer underlaps, more yarn is fed into the fabric. Each underlap crosses over two needle spaces instead of one. It covers more wales on its way, resulting in heavier, thicker, and denser fabric. As the value of stitch density rises, burst strength of the fabric rises. The air permeability values were decreased by increasing the underlap length in the structure. Open structure with shorter underlap length recorded highest air permeability values compared to closed structure with longer underlap length. Open structure of less underlap length gives the ability to the air to pass through the fabric without any obstacles due to the lower thickness of the fabric compared to closed structure.

The guide bars are creating the necessary overlaps and underlaps to produce the delivered fabric. The pattern device initiates the movement of the guide bars, which dictates the design of the fabric. To produce different warp knit designs, one must control the shogging movements of the guide bars. The increasing swinging movement of the guide bars decreases the production of these machines. However, the increased patterning possibilities offer important advantages. More number used of guide bars offer less transparency of the fabric knitted and forbid the air to pass through the fabric easily due to the higher thickness of the fabric and its cover factor compared to less number used of guide bars. As the value of stitch density rises, burst strength of the fabric rises. Finally, the weight of the fabric has a significant direct effect on bursting strength.

The tightness of the yarn and the fabric structure is the indirect factor of shrinkage. The shrinkage rate varies according to density, yarn type, fabric type, fabric structure, dyeing and finishing process. Tighter and closed structure recorded less shrinkage rate compared with open structure.

Yet, digital textile printing is still a relatively new technology. In the wide consumer market only parts of it have been utilized by small companies. According to studying the market only a few Internet-based companies were offering digital textile printing services to the end-users.

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