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Innovative Textile Technology for Dilated Cardiomyopathy: "Shape Formation of Knitted Cardiac Support Mesh"

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Abstract: ***Health care sector is one of the most important sectors in our life which included the medical textiles that combined textile technology with medical science. The present work is aimed to study and evaluate the properties of weft knitted textile mesh (knitted cardiac support mesh) manufactured using two different types of yarn materials at different counts. 20 &40 denier yarn counts were used for the manufacturing nylon samples. 50 denier yarn count was used for the manufacturing polyester samples. The nylon and polyester samples were produced with three different mesh sizes. Mechanical and physical tests were performed on the produced samples to investigate fabric ability to meet performance requirements, Tests results were statistically analyzed using T-test and F-test and evaluated using radar charts. For experimental application, sample (2) using yarn count (20D) with medium mesh size, it gave the best performance during execution at the surgical operation that can be interpreted due to its good ability to stretch and recover at a moderate rate, also the textile mesh light weight give the sample the ability for not loading over the myocardium. The produced samples will be used in treatment of Dilated Cardiomyopathy, in which the mesh sample will be placed around the two ventricles to prevent further dilatation and to support and reduce left ventricular wall stress.***

Keywords: Technical textiles, Medical textile, Weft knitted textile mesh, Dilated Cardiomyopathy

1. Introduction

Medical textiles are rapidly developing at mass production rates (1), which definitively promoted this branch as one of the most potential and dynamical fields for development of the textile industry (2). It is mostly used for the production of different types of products e.g. first aid, clinical, surgical and hygiene purposes (3). Medical textiles considered the most advanced branch in technical textiles (4), it can be manufactured either by woven or knitted fabrics .The most used technology in manufacturing of medical textiles are knitting technology (3), for its different properties such as pliability, moderate elasticity and low tendency to fray (5). Modern technical textiles applied new applications using weft knitted fabrics (6). In the recent years they have been interesting materials in the new field of regenerative medicine, which revolutionizes many traditional therapies. A suitable attention were given to textiles for implantation, this is not justified because textiles are for many reasons significantly more suitable for use as implants compared to metals, e.g. some parts of human body is full of fibers(7). Implantable materials must have some characteristic according to their goals, namely, bio-compatibility, durability, impermeability or controlled permeability, flexibility, strength to the blood pressure and to the bacteria actions, positional stability, and stability in biological environments (8).

In this work an attempt has been done to manufacture nine weft knitted textile meshes (knitted cardiac support mesh) with different yarn material and counts and different mesh sizes to evaluate their performance to be used in medical textiles for the treatment of dilated cardiomyopathy.

2. Material and Methods

2.1 Materials

Three groups of samples were manufactured using two different yarn materials and three different counts, first group was manufactured using nylon yarn (20D) with (nylon/lycra) yarn (20/20D), second group was manufactured using nylon yarn (40D) with (nylon/lycra) yarn (40/20D) and third group was manufactured using polyester yarn (50D) and (polyester/lycra) (50/20D) , each group was manufactured with three different mesh sizes, Tables (1) and (2) present the structural characteristics of Nylon and Polyester knitted mesh samples respectively.

Table 1: Structural Characteristics of Nylon Samples

Sample Code	S (1)	S (2)	S (3)	S (4)	S (5)	S (6)
Machine Type	Santoni					
Gauge	28					
Number of Needles	1440					
Fabric Width	16 Inch					
Speed of Machine (pm)	80					
Material Type	Nylon – Nylon/Lycra					
Knitting Structure	Weft Knitted					
Nylon Yarn Count (Denier)	20/7			40/14		
Nylon/Lycra Yarn Count (Denier)	20/20/7			40/20/14		
Number of Wales/ 10cm	44	42	39	44	37	33
Number of Courses/10 cm	59	63	50	54	50	41
Mass Per Unit Area (g/m^2)	178.2	167	131.2	260.4	230.8	184.6

Table 2: Structural Characteristics of Polyester Samples

Sample Code	S (7)	S (8)	S (9)
Machine Type	Santoni		
Gauge	28		
Number of Needles	1440		
Fabric Width	16 Inch		
Speed of Machine (pm)	80		
Material Type	Polyester – Polyester /Lycra		
Knitting Structure	Weft Knitted		
Polyester Yarn Count (Denier)	50/36		
Polyester/Lycra Yarn Count (Denier)	50/20/36		
Number of Wales/ 10cm	41	35	30
Number of Courses/10 cm	37	38	32
Mass Per Unit Area (g/m^2)	252.8	208.4	185

2.2. Methods

All the physical and mechanical tests were carried out on the produced nylon and polyester knitted mesh samples in the textile testing laboratory at National Research Center according to the international standard test methods. Fabric weight test was carried out according to ASTM D3776-96 [9] using Electronic Balance PBC-A 1000. Fabric thickness test was carried out according to ASTM D1777-02[10] using Frazier thickness gauge. Determination of fabric voids was carried out by using Nikon Profile Projector Model V-12 instrument. Fabric bursting strength test was carried out according to ASTM D3786-01[11], using Jika-Toyoseiki Instrument. Fabric elasticity test was carried out according to British Standard (BS EN 14704-1:2005) [12] using Model Instron 3345 frame testing machine. The results of the tests were evaluated statistically and the relationship between the fabrics parameters was discussed.

3. Results and Discussion

The results of the tests done on the produced samples are shown in tables (3) and (4).

3.1. Effect of Yarn Count on Fabric Weight

Increasing yarn denier leads to increase fabric areal density, this is an expected and logic result, that is thicker yarns give heavier fabrics.

3.2. Effect of Mesh Size on Fabric Weight

Table (3) and figure (1) show that, the small mesh size for (20D, 40D) recorded the highest fabric weight followed by medium and large Mesh size. Table (4) and figure (2) show that the small mesh size for (50D) recorded the highest fabric weight followed by medium and large Mesh size. This is due to, decreasing mesh size leads to increasing the fabric proportion per unit area, and while increasing the mesh size decreases the fabric weight. This is because of, voids proportion per unit area are greater than the fabric proportion per unit area.

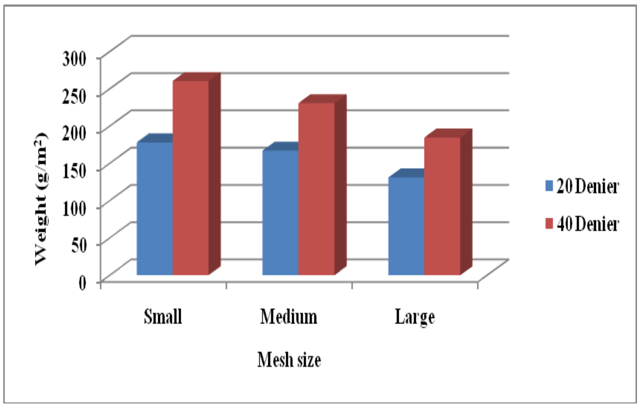

Figure 1: Nylon mesh samples weight test result

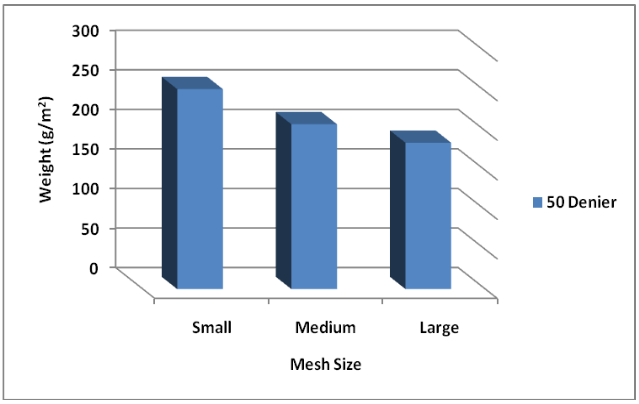

Figure 2: Polyester mesh samples weight test result

Table 3: Mean and Standard Deviation of Nylon Samples

Yarn Count	Mesh Size	Sample No.	Weight (g/m^2)	Thickness (mm)	Void (µm)	Bursting Strength (Kpa)	Elasticity (%) Machine Direction after 1 min.	Elasticity (%) Machine Direction after ½ hour	Elasticity (%) Cross-wise Direction after 1 min.	Elasticity (%) Cross-wise Direction after ½ hour
			Mean ±S.D.							
20 Denier	Small	Sample (1)	176± 2.588	1.402± 0.019	1919.2± 68.627	226.6± 46.188	79.19± 6.828	86.39± 2.387	85.71± 2.150	90.33± 4.014
20 Denier	Medium	Sample(2)	167± 4.795	1.393± 0.026	2678± 42.314	186.6± 11.547	77.11± 2.599	82.2± 4.121	82.76± 2.609	88.38± 1.245
20 Denier	Large	Sample(3)	131.2± 4.381	1.348± 0.027	3471.4± 50.406	180± 11.547	76.57± 1.240	90± 3.672	80.14± 1.454	84.34± 1.906
40 Denier	Small	Sample(4)	260.4± 5.941	1.704± 0.046	2443.2± 70.201	280± 20.00	85.59± 3.253	92.3± 3.264	90.13± 0.733	94.72± 1.955
40 Denier	Medium	Sample(5)	230.8± 3.962	1.773± 0.057	3200.2± 38.369	260± 20.00	81.55± 4.529	92.1± 1.394	88.16± 0.035	93.2± 2.530
40 Denier	Large	Sample(6)	184.6± 4.037	1.668± 0.050	3960.2± 106.182	240± 11.547	78.36± 2.829	89± 2.475	83.22± 3.294	91.65± 0.098

Table 4: Mean and Standard Deviation of Polyester Samples Manufactured on Wide Circular Weft Knitting Machine

						Weight (g/m^2)	Thickness (mm)	Void (µm)	Bursting Strength (Kpa)	Elasticity (%)			
										Machine Direction		Cross-wise Direction	
										after 1 min.	after ½ hour	after 1 min.	after ½ hour
Yarn Count	50 Denier	Mesh Size	Small	Sample No.	Sample (7)	252.8± 2.280	1.45± 0.029	3260.4± 41.560	400± 0.200	97.99± 1.734	100± 0.0	91.831± 6.549	97.519± 2.237
			Medium		Sample (8)	208.4± 5.319	1.36± 0.033	4311± 55.308	350± 0.305	95.84± 3.247	100± 0.0	87.74± 3.130	92.78± 4.770
			Large		Sample (9)	185± s3.240	1.24± 0.028	4522± 61.854	270± 0.115	93.31± 0.399	99.16± 0.969	76.24± 0.715	77.50± 2.904

Table 5: (t) Weight Test and Grouping Variables for Nylon Samples

Test Variable	t-test			p-value		
Mesh Size	S	M	L	S	M	L
Weight (g/m^2)	28.362	22.932	20.041	0.000**	0.000**	0.000**

** Highly Significant at 0.001.

From the (t) test results in table (5), it is clear that, the yarn counts (20 D) and (40 D) have a significant effect on the fabric weight with the three different mesh sizes at (p = 0.000).

Table 6: (F) Weight Test and Factors Affecting for Nylon Samples

Test Variable	F-test		p-value	
Yarn count	20D	40D	20D	40D
Weight (g/m^2)	184.871	325.269	0.000**	0.000**

From the (F) test results in table (6), it is clear that, the mesh sizes (small-medium-large) have a significant effect on the fabric weight with the two yarn counts at (p=0.000).

Table 7: (F) Weight Test and Factors Affecting for Polyester Samples

Test Variable	F-test	p-value
Yarn Count	50D	50D
Weight (g/m^2)	404.305	0.000**

From the (F) test results in table (7), it is clear that, the effect of mesh sizes (small-medium-large) have a significant effect on the fabric weight at p-value for (50 D) (p=0.000).

3.3 Effect of Yarn Count on Fabric Thickness

Table (3) and figure (3) show that samples produced by yarn count (40D) recorded the highest fabric thickness followed by the samples produced with yarn count (20D). While table (4) and figure (4) show that the samples produced with yarn count (50D) recorded high fabric thickness. This is mainly due to that, the thicker count lead thicker fabric, and vice versa.

3.4. Effect of Mesh Size on Fabric Thickness

Table (3) and figure (3) show that, smallest mesh size for (20D, 40D) gives the highest fabric thickness, followed by medium and large mesh size. Table (4) and figure (4) show that smallest mesh size for (50D) gives the highest fabric thickness followed by medium and large mesh size. This is due to that decreasing the mesh size will lead to increasing the fabric thickness, because fabric proportion per unit area is greater than the voids proportion, while decreasing the mesh size reduces the fabric thickness; this is related to that the voids proportion per unit area is greater than the fabric proportion per unit area.

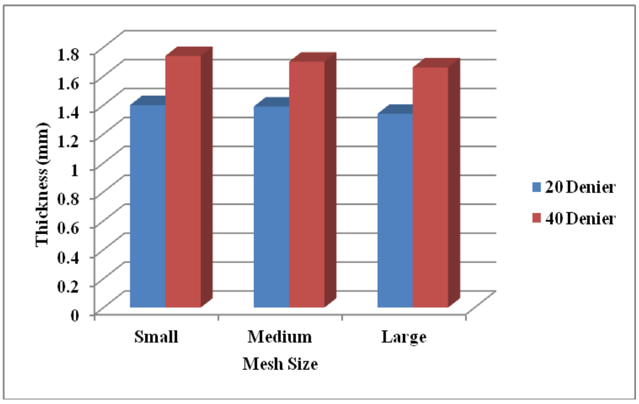

Figure 3: Nylon mesh samples thickness test result

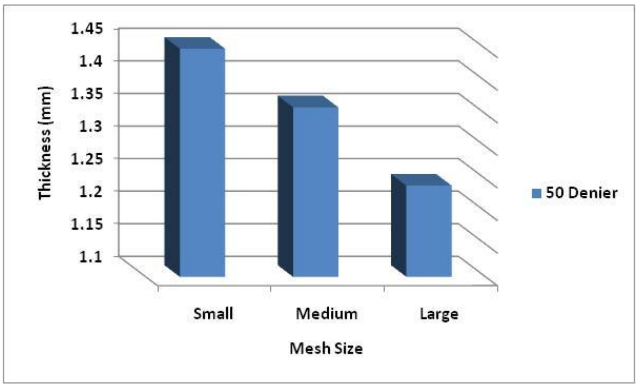

Figure 4: Polyester mesh samples thickness test result

Table 8: (t) Thickness Test and Grouping Variables for Nylon Samples

Test Variable	t-test			p-value		
Mesh Size	S	M	L	S	M	L
Thickness (mm)	19.202	18.890	17.669	0.000**	0.000**	0.000**

From the (t) test results in table (8), it is clear that, the yarn counts (20D) and (40D) have a significant effect on fabric thickness with the three different mesh sizes at (p=0.000).

Table 9: (F) Thickness Test and Factors Affecting for Nylon Samples

Test Variable	F-test		p-value	
Yarn Count	20D	40D	20D	40D
Thickness (mm)	13.839	10.633	0.000**	0.000**

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From the (F) test results in table (9), it is clear that, the mesh sizes (small-medium-large) have a significant effect on fabric thickness with two yarn counts at (p=0.000)

Table 10: (F) Thickness Test and Factors Affecting for Polyester Samples

Test Variable	F-test	p-value
Yarn Count	50D	50D
Thickness (mm)	116.367	0.000**

From the (F) test results in table (10), it is clear that, the mesh sizes (small-medium-large) have a significant effect on fabric thickness at (50 D) (p=0.000).

3.5. Effect of Yarn Count on Fabric Pore Size

It was noticed from table (3) and figure (5) that, the nylon samples produced by yarn count (40D) recorded the highest result of fabric pore size followed by samples produced by yarn count (20D). It was noticed from table (4) and figure (6) that the polyester samples produced by yarn count (50D) recorded high result of fabric pore size, This is mainly due to that, the thickest count (40D) has large number of fibers in the cross-section /per unit area which lead to increasing the pore size of fabric, while the count (20D) has a few number of fibers per unit area which lead to decreasing the fabric pore size.

3.6. Effect of Mesh Size (Number of Empty Needles) on Fabric Pore Size

It was clear from table (3) and figure (5) that, the number of empty needles (15) for samples produced with counts (20D, 40D) recorded the highest pore size followed by less number of empty needles (10), (6). Also it is clear from table (4) and figure (6) that the number of empty needles (15) for samples produced with counts (50D) recorded the highest pore size followed by less number of empty needles (10), (6). This can be interpreted due to that, increasing the number of empty needles will lead to increasing the fabric pore size, this is related to that the fabric proportion per unit area greater than the voids proportion, While decreasing the number of empty needles will decrease the fabric pore size, this is related to that the voids proportion per unit area greater than the fabric proportion per unit area.

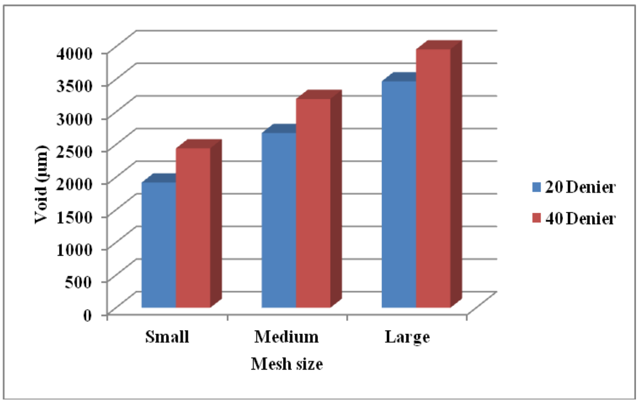

Figure 5: Nylon mesh samples void test result

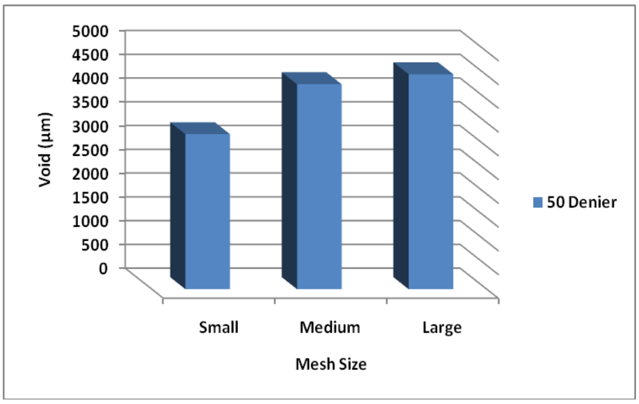

Figure 6: Polyester mesh samples void test result

Table 11: (t) Voids Test and Grouping Variables for Nylon Samples

Test Variable	t-test			p-value		
Mesh Size	S	M	L	S	M	L
Voids (µm)	11.935	20.442	9.299	0.000**	0.000**	0.000**

From the (t) test results in table (11), it is clear that, the yarn counts (20D) and (40D) have a significant effect on fabric voids with the three different mesh sizes at (p=0.000).

Table 12: (F) Voids Test and Factors Affecting for Nylon Samples

Test Variable	F-test		p-value	
Yarn Count	20D	40D	20D	40D
Voids (µm)	999.498	488.249	0.000**	0.000**

From the (F) test results in table (12), it is clear that, the mesh sizes (small-medium-large) have a significant effect on fabric voids with two yarn counts at (p=0.000).

Table 13: ((F) Void Test and Factors Affecting for Polyester Samples

Test Variable	F-test	p-value
Yarn Count	50D	50D
Void (µm)	870.309	0.000**

From the (F) test results in table (12), it is clear that, the mesh sizes (small-medium-large) have a significant effect on fabric voids with two yarn counts at (p=0.000).

3.7. Effect of Yarn Count on Fabric Bursting Strength

It was found from the results from table (3) and figure (7) that, the nylon samples produced with yarn count (40D) recorded the highest result of fabric bursting strength followed by the samples produced with yarn count (20D). It was found from the statistical analysis of the results from table (4) and figure (8) that, the polyester samples produced with yarn count (50D) recorded high result of fabric bursting strength, This is mainly due to increasing the yarn count will result in increasing the fabric bursting strength, while decreasing the yarn count will lead to decrease the fabric bursting strength. This can be interpreted due to that the thickest count has large number of fibers per unit area which lead to increasing the fabric bursting strength, while thin count has a little number of fibers per unit area which lead to decreasing the fabric bursting strength.

3.8. Effect of Mesh Size (Number of Empty Needles) on Fabric Bursting Strength

It was clear from table (3) and figure (7) that, the less number of empty needles (6) for samples produced with counts (20D, 40D) recorded the highest fabric bursting strength followed by less number of empty needles (10), (15). Also it is clear from table (4) and figure (8) that the less number of empty needles (6) for samples produced with counts (50D) recorded the highest fabric burst followed by less number of empty needles (10), (15). This means that, by decreasing the number of empty needles will lead to increasing the fabric bursting strength, while increasing the number of empty needles will result in decreasing the fabric bursting strength. This is related to that the fabric proportion per unit area greater than the voids proportion while decreasing the number of empty needles will decrease the fabric pore size, this is related to that the voids proportion per unit area greater than the fabric proportion per unit area.

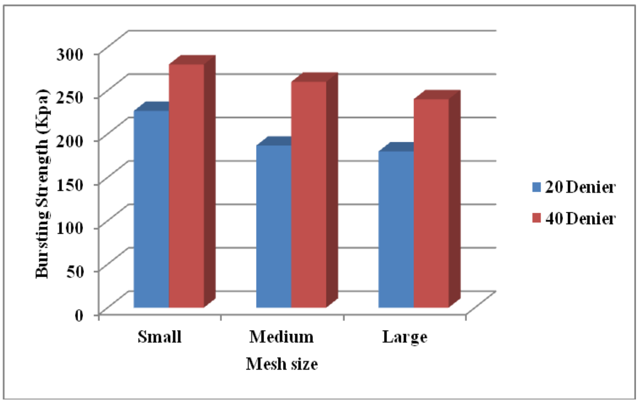

Figure 7: Nylon mesh samples bursting strength test result

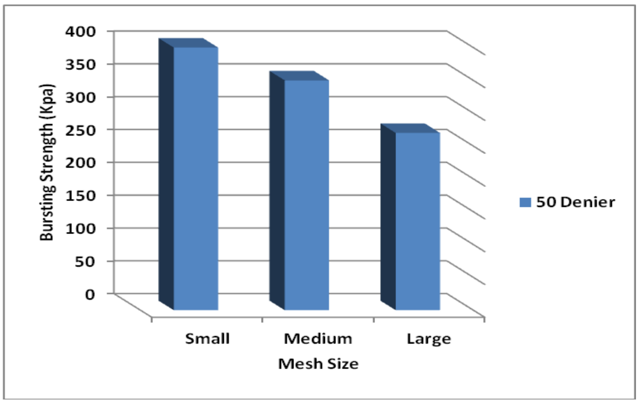

Figure 8: Polyester mesh samples bursting strength test result

Table 14: (t) Bursting Strength Test and Grouping Variables for Nylon Samples

Test Variable	t-test			p-value		
Mesh Size	S	M	L	S	M	L
Bursting Strength (Kpa)	1.835	5.500	6.364	0.140	0.005**	0.003**

From the (t) test results in table (14), it is clear that, the yarn counts (20D) and (40D) have a non-significant effect on fabric bursting strength at p-value for small mesh size but have a significant effect for medium mesh size and large mesh size.

Table 15: (F) Bursting Strength Test and Factors Affecting for Nylon Samples

Test Variable	F-test		p-value	
Yarn Count	20D	40D	20D	40D
Bursting Strength (kpa)	2.889	2.714	0.132	0.145

From the (F) test results in table (15), it is clear that, the mesh sizes (small-medium-large) have a non-significant effect on fabric bursting strength with two yarn counts at p-value for (20D) (p=0.132) and for (40D) (p=0.145).

Table 16: (F) Bursting Strength Test and Factors Affecting for Polyester Samples

Test Variable	F-test	p-value
Yarn Count	50D	50D
Bursting Strength (kpa)	25.182	0.001**

From the (F) test results in table (16), it is clear that, the mesh sizes (small-medium-large) have a significant effect on fabric bursting strength at p-value for (50D) (p=0.001).

3.9. Effect of Yarn Count on Fabric Elasticity and Recovery

It was noticed from table (3) and figure (9) that, the samples produced by yarn count (40D) recorded the highest result of fabric elasticity followed by samples produced with yarn count (20D). It is noticed from table (4) and figure (10) that that the samples produced with yarn count (50D) recorded the high result of fabric elasticity. This is mainly due to that, the thickest count (40D) has large number of fibers per unit area which lead to increasing the elasticity of fabric, while thin count (20D) has a little number of fibers per unit area which lead to decreasing the fabric elasticity.

3.10. Effect of Mesh Size on Fabric Elasticity and Recovery

It was clear from table (3) and figure (9) that, the number of empty needles (15) for (20D, 40D) recorded the highest elasticity followed by less number of empty needles (10), (6). It is clear from table (4) and figure (10) that the number of empty needles (15) for (50D) recorded the highest elasticity followed by less number of empty needles (10), (6), This can be interpreted due to that, increasing the number of empty needles will lead to increasing the fabric elasticity, while decreasing the number of empty needles will decrease the fabric elasticity. This is related to that the fabric proportion per unit area greater than the voids proportion while decreasing the number of empty needles will decrease the fabric pore size; this is related to that the of voids proportion per unit area greater than the fabric proportion per unit area.

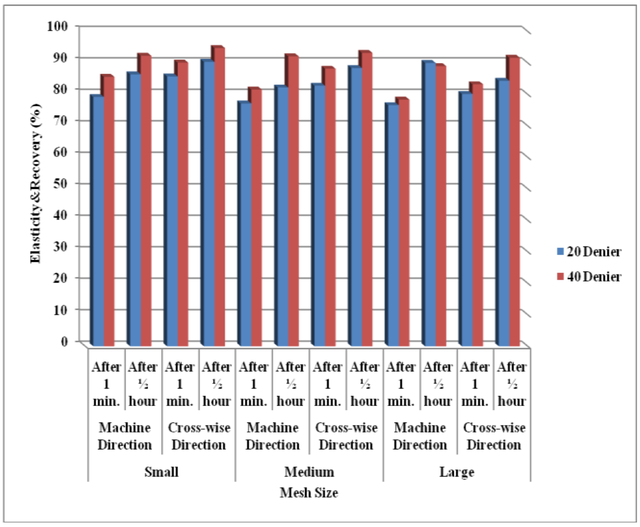

Figure 9: Nylon mesh samples elasticity and recovery test result

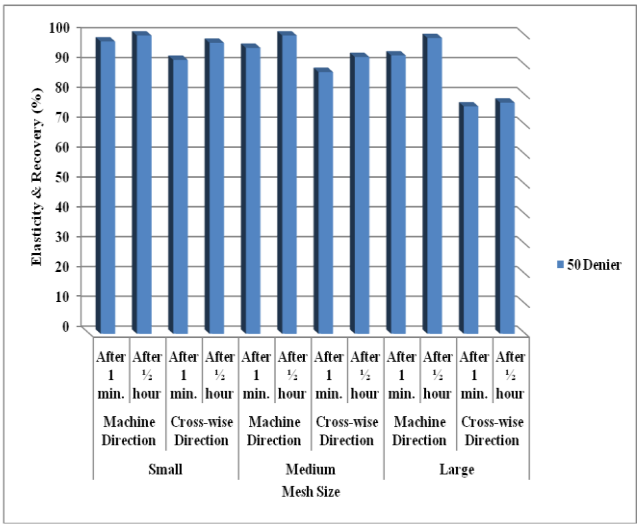

Figure 10: Polyester mesh samples elasticity and recovery test result

Table 17: (t) Elasticity and Recovery Test and Grouping Variables for Nylon Samples

Test Variable	t-test			p-value		
Mesh size	S	M	L	S	M	L
MD Elasticity after 1 min. (%)	1.466	1.336	1.007	0.217	0.253	0.371
MD Elasticity after ½ hour (%)	2.542	2.438	0.452	0.064	0.071	0.674
CD Elasticity after 1 min. (%)	3.369	3.485	1.481	0.028	0.073	0.213
CD Elasticity after ½ hour (%)	1.743	2.956	4.755	0.156	0.420	0.009

From the (t) test results in table (17), it is clear that, the yarn counts (20D) and (40D) have a non-significant effect on fabric elasticity and recovery at p-value for MD Elasticity and Recovery after 1 min. (%) including small mesh size (p=0.217), medium mesh size (p=0.253) and large mesh size (p=0.371). While for MD Elasticity and Recovery after ½ hour (%) including small mesh size (p=0.064), medium mesh size (p=0.071) and large mesh size (p=0.674). while in CD Elasticity and Recovery after 1 min. (%) there is a significant effect at p-value for small mesh size (p=0.028) and non-significant effect at p-value for medium mesh size (p=0.073), for large mesh size (p=0.213), finally for CD Elasticity and Recovery after ½ hour (%), there is non-significant effect for small mesh size (p=0.156) and a significant effect at p-value for medium mesh size (p=0.042) , large mesh size (p=0.009).

Table 18: (F) Elasticity and Recovery Test and Factors Affecting for Nylon Samples

Test Variable	F-test		p-value	
Yarn count	20D	40D	20D	40D
MD Elasticity after 1 min. (%)	0.289	3.019	0.759	0.124
MD Elasticity after ½ hour (%)	1.307	1.673	0.338	0.265
CD Elasticity after 1 min. (%)	5.164	10.032	0.050*	0.012*
CD Elasticity after ½ hour (%)	3.834	6.135	0.085	0.035

* Significant at 0.05

From the (F) test results in table (3.17), it is clear that, the mesh sizes (small-medium-large) have a non-significant effect on fabric elasticity and recovery effect on yarn counts at p-value for MD Elasticity and Recovery after 1 min. (%) including (20D) (p=0.759) and for (40D) (p=0.124), for MD Elasticity and Recovery after ½ hour (%) including (20D) (p=0.338) and for (40D) (p=0.265), while in CD Elasticity and Recovery after 1 min. (%) there is a significant effect at p-value for (20D) (p=0.050) and for (40D) (p=0.012), finally for CD Elasticity and Recovery after ½ hour (%) there is non-significant effect at p-value for (20D) (p=0.085) and significant effect for (40D) (p=0.035).

Table 19: (F) Elasticity and Recovery Test and Factors Affecting for Polyester Samples

Test Variable	F-test	p-value
Yarn count	50D	50D
MD Elasticity after 1 min. (%)	3.260	0.110
MD Elasticity after ½ hour (%)	1.000	0.422
CD Elasticity after 1 min. (%)	11.050	0.010*
CD Elasticity after ½ hour (%)	27.194	0.001**

From the (F) test results in table (19), it is clear that, the effect of mesh sizes (small-medium-large) on fabric elasticity and recovery for MD Elasticity after 1 min. (%) have a non-significant effect on yarn count at p-value for (50D) (p=0.110) and for MD Elasticity after ½ hour (%) (p=0.422), while there is a significant effect for CD Elasticity after 1 min. (%) at p-value (p=0.010) and for CD Elasticity after ½ hour (%) at p-value (p= 0.001).

4. Evaluation of Physical and Mechanical Properties of Nylon and Polyester Samples

The results of the mechanical and physical tests that were done on nylon and polyester samples were evaluated using radar charts in order to get the best performance of samples in terms of suitable quality for the end use. Figures (11-16) show radar charts for the properties of Nylon samples and Figures (17-19) show radar charts for the properties of polyester samples respectively.

a. Radar Charts for the Properties of Nylon Samples

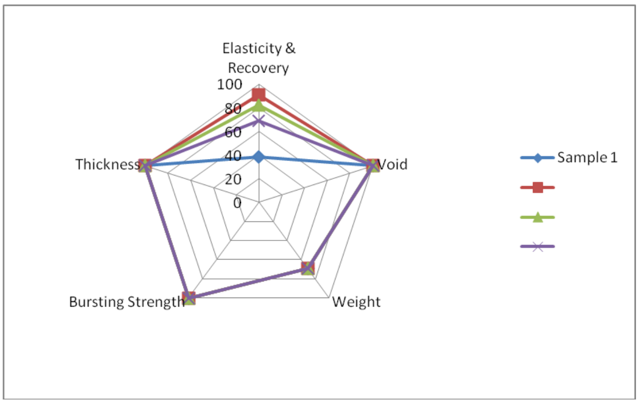

Figure 11: Sample (1) nylon mesh fabric manufactured using yarn count 20 denier

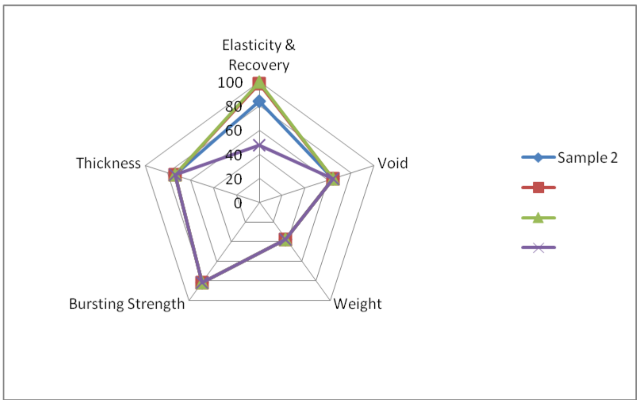

Figure 12: Sample (2) nylon mesh fabric manufactured using yarn count 20 denier

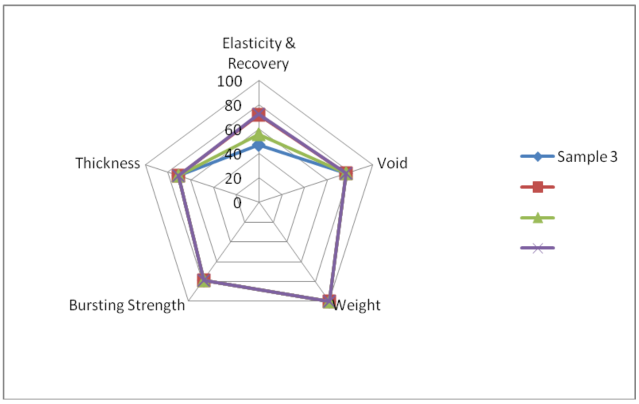

Figure 13: Sample (3) nylon mesh fabric manufactured using yarn count 20 denier

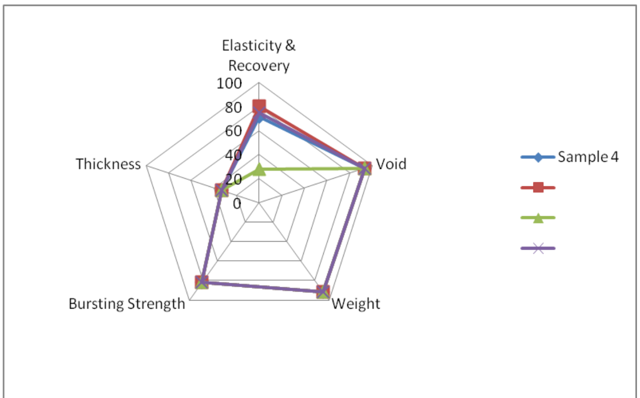

Figure 14: Sample (4) nylon mesh fabric manufactured using yarn count 40 denier

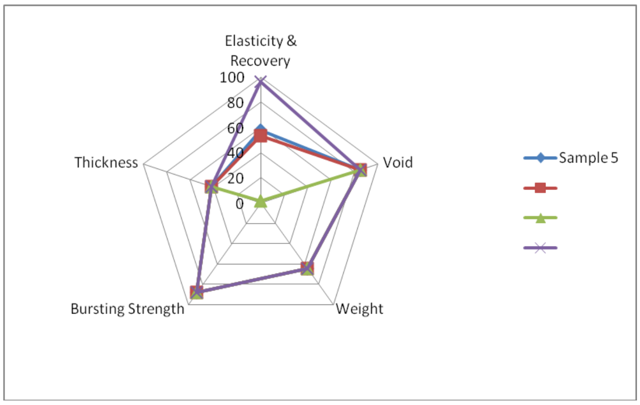

Figure 15: Sample (5) nylon knitted mesh fabric manufactured using yarn count 40 denier

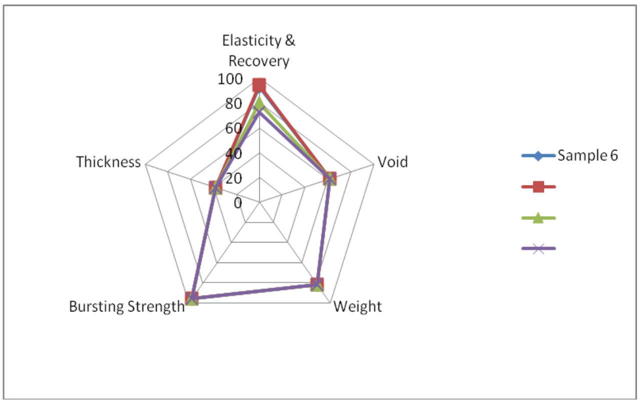

Figure 16: Sample (6) nylon knitted mesh fabric manufactured using yarn count 40 denier

b. Radar Charts for the Properties of Polyester Samples

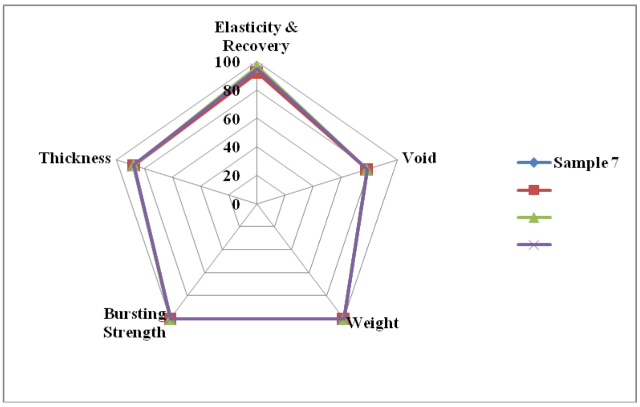

Figure 17: Sample (7) polyester knitted mesh fabric manufactured using yarn count 50 denier

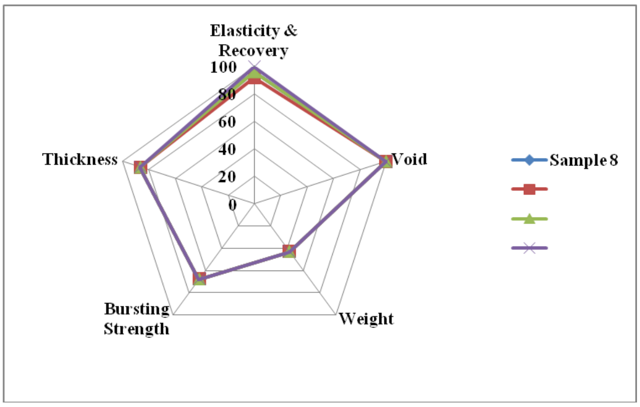

Figure 18: Sample (8) polyester knitted mesh fabric manufactured using yarn count 50 denier

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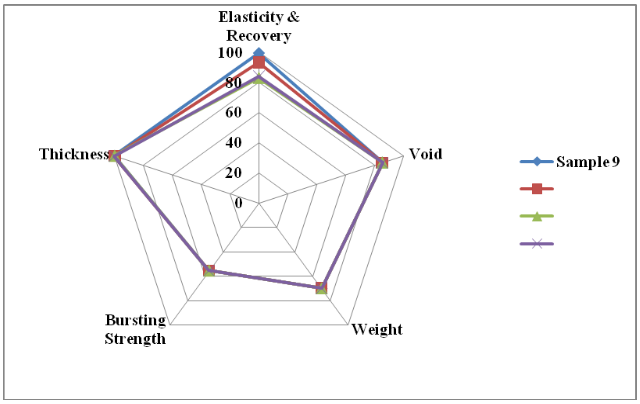

Figure 19: Sample (9) polyester knitted mesh fabric manufactured using yarn count 50 denier

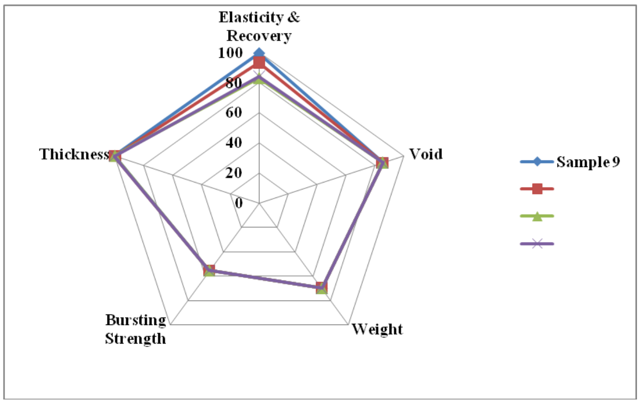

Figure 19: Sample (9) polyester knitted mesh fabric manufactured using yarn count 50 denier

5. Conclusion

In this study, the physical and mechanical properties of weft knitted mesh fabrics (knitted support mesh) manufactured using nylon yarns with count (20D) and (40D) and polyester yarns with count (50D) were investigated and evaluated.

a-The Nylon Samples Groups:

- The best performance samples evaluated by the radar chart for given properties is sample (1) manufactured with nylon material using yarn count 20 denier.
- The lowest performance samples evaluated by the radar chart for given properties is sample (5) manufactured with nylon material using yarn count 40 denier.

b-The Polyester Samples Group:

- The best performance samples evaluated by the radar chart for given properties is sample (7) manufactured with polyester material using yarn count 50 denier.
- The lowest performance samples evaluated by the radar chart for given properties is sample (8) manufactured with polyester material using yarn count 50 denier.

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Note:

Patent introduced to the Academy of Scientific Research and Technology, Egypt, "Production of Textile Meshes for Reinforcing Cardiac Hypertrophy", registered by No. 916/2015, (Under Processing).