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Characterization the properties of blended single jersey fabrics using different microfiber yarn cross-sections and gauges machine

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Abstract

Since the last few decades, a development of new types of fibers were appeared in order to improve the mechanical properties of fabrics besides its comfort properties, Cotton material was used as a blended material to enhance the properties of the manufactured products. The main purpose of this article is to investigate the influence of different polyester yarn cross-section and gauges on the mechanical properties of blended knitted samples. In this study two groups of knitted samples were manufactured, using gauge 24 and gauge 20, the samples were implemented with single jersey knitted structure by two different polyester microfiber cross-sections and blended cotton ratio. Some of mechanical properties were carried out for all samples such as air permeability, spray test, bursting strength and roughness. The result values recorded and tabulated, as well as statistically analysis using ANOVA Two-way Measurements were executed. The results illustrate that tests properties of blended knitted samples were significantly affected by variables except the spray test. In the same context the results clarify that trilobal cross-section improves UPF property for knitted samples. Finally, due to study the performance of each sample the radar chart was occurred, as the results revealed that Polyester Trilobal samples recorded the best sample radar area with different gauges.

Keywords: Polyester microfiber; Yarn Cross-section; Gauge; Knitted fabric; Single Jersey.

Introduction

Knitted fabric is one of the most common techniques for fabric production, which depends on creating loops by means of the overlapping between yarns using knitting needles. Two types of knitted fabric produced from applying this technique, including weft and warp knitted fabric due to the loop formative directions [1]. The knitted fabric production considered one third of the global textile market across the worldwide, as it characterized by many properties such as elasticity, stretching and comfort on wearing. [2].

Knitted fabric properties affected by many factors,including (stitch length, number of feeders, gauge, knitting tension) [3], as well as the type of yarn (count, material, cross section, kind of spinning) has a common effect on fabric properties [4]. Single Jersey or “single knit” considers as one of the weft knitted basic structures, which distinguishes with novel properties such as lightness, breathability and drapability [2].

Cotton is the most common textile materials that used in knitting fabric, especially in summer clothes and sportswear for its several properties. Recently, due to **achieving** customer’s requirements cotton fibers blended with different materials such as polyester, **polyamide** (nylon), viscose, etc. [5].

Nowadays, microfiber fabrics play a strike role in garments manufacturing, as microfiber fabrics are differentiated by their durability compared to other types of fabrics of similar weights, they are accompanied by various properties including high water permeability as they can absorb more than seven times their weight and can be dry one-third of the time spent on traditional fabrics [6], also it characterized by its softness, adequate tensile and elongation, and good durability compared to traditional fabrics [7] .

In the same context, many references stated that microfiber yarn cross-section shapes affect the surface and mechanical properties of fabrics [8,9]. Furthermore, references revealed that fibers movement within a cross-section of microfiber filaments **Figure 1. (a),(b)**, results in new and modified mechanical properties such as smoothness,

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elasticity, and dimensional stability in addition to the comfort properties e.g. moisture-wicking, air permeability, and water vapor permeability **[10,11].**

Polyester microfiber yarns are one of the synthetic fibers that can be produced by many cross-sections. In 1960, the production of the non-circular cross-section yarns released named trilobal [12]. Trilobal polyester is a triple cross-section yarn featuring by luster, which can allow being an alternative to an expensive silk shiny yarn [8]. The fabrics performed from this type of yarn characterize by good porosity and higher thickness [13] to overcome hydrophobicity property of polyester [14].

Blending is one of the best ways to get a combination of novel properties. There are many types of blending such as fiber blending and yarn blending. Cotton is the most preferable blended material. The advantage of blending cotton with other materials improves several properties for fabrics such as durability, drapability, dyeing process, and also comfort properties [15]. Therfore, using the microfiber yarn with different cross-sections and blended with cotton leads to a modified properties in knitting fabric which will be studied in this paper.

(a) (b)

Figure 1. (a) The TrilobalCrossSection, (b) The Circular Cross Section [15].

As a result for climate changes, UPF property of fabric occupies a necessary important espically in summer seasons. Polyester is one desirable defensive material against UV radiation, as it serve a good protection property for human body [16]. Thus in this article, the authors pursued to magnify the benefit of studying the impact of variables for blended knitted samples on UPF property.

2. Material and Method

Twelve knitted single jersey fabrics were manufactured using two circular knitting machine gauges (24-20). The samples were performed by two different cross-sections (circular and trilobal) polyester microfibers counted (150/288) blended with cotton (30/1) Ne. Table 1.provides the specifications of knitted samples.

2.1 Mechanical Properties of Samples

In order to study the influence of the cross-section of the microfiber filament on the structural properties, several tests occurred according to standard methods as follows:

1. The samples were placed in standard conditions during 24 hr. according to ASTM D 1776 [17] Standard Practice for Conditioning and Testing Textiles.

2. Fabric weight test according to Standard Test Method ASTM D3776 for mass per unit area (Weight) of Fabric [18], the test was executed using an electronic balance.

3. Fabric thickness test according to Standard Test Method ASTM D1777 for the thickness of textile materials [19], the test was conducted using Teclock Corporation,

4. Air Permeability test according to Standard Test Method ASTM D737 for Air Permeability of Textile Fabrics [20], the test was carried out using Toyoseiki (JIKA) instrument.

5. Spray test according to Standard Test Method AATCC 22 [21], the test was performed using the Spray Rating Tester (water repellent tester).

6. Bursting Strength test according to Standard Test Method ASTM D3786 [22], bursting strength was measured using SDL ATLAS tester.

7. Fabric Surface Roughness test was conducted at N.R.C. labs. Roughness Measuring Instrument (Surfcoder) SE1700 was used, which is manufactured by KosakaLabortaory Ltd (Japan).

For all tests, replicates and the score averages for all readings were occupied.

2.2 Ultraviolet Protection Factor (UPF)

The UV protection of the fabric was measured using UV-VIS Spectrophotometer, it was performed to measure the blocking or transmittance of UV radiation through the fabric, according to AATCC-183 [21] test method.

2.3 Statistical Analysis

All results presented and tabulated, as means values and standard deviation. Furthermore, all the inputs demonstrated by means of graphs as a line chart using Microsoft Excel. The significant effect between variables were statistically analyzed according to (ANOVA Two-way Measurements) using IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 22 for Windows, The significant difference was located at $p \leq 0.05$. The relation between samples were recorded according to the Tukey HSD test, Table 2.

3. Results and Discussion

Due to evaluate the variable of the specifications on the functional properties of the manufactured samples.The tested results were measured and tabulated

3.1 Mechanical and Physical Properties

3.1.1 Air Permeability

The results Figure 2 and Table 2 present the effect of yarn cross-section where sample 4 (100% Polyester Trilobal), achieves the highest value for air permeability property at different machine gauges. The justification return to the shape of Polyester Trilobal yarn (triangle) which contributes to creating gaps between loops resulting in more airflow. On the other site sample 5 (30% Polyester Microfiber: 70% Cotton), achieves less value which could be attributed to the blended ratio where cotton relaxation influence increasing the tightness factor (1.63) of knitted samples. Additionally, the values show that the lower the gauge, the better the breathability of knitted fabrics.

3.1.2 Spray test

The results in Figure 3 and Table 2 display that all samples attain the same value, reflecting the vast effect of structure (Single Jersey) for knitted samples on spray property than the material or blended ratio, indicating the comfortability of polyester microfiber fabric even if with cotton or not.

Table 1. Specifications of Manufactured Knitted Samples

Samples Code	Structure	Gauge	Yarn Counts	Blending Ratio	Mass per Unit Area (g/m^2)	Thickness (mm)	Loop Length (mm)	Number of Wales /cm	Number of Courses /cm	Tightness Factor
1	Single Jersey	24	150/288 polyester, 30/1 cotton	50% Polyester Microfiber: 50% Cotton	150	0.509	2.6	14	42	1.57
2				50% Polyester Trilobal: 50% Cotton	140.76	0.452	2.8	16	40	1.45
3				100% Polyester Microfiber	145.39	0.528	2.8	14	40	1.45
4				100% Polyester Trilobal	109.99	0.302	3.4	12	30	1.20
5				30% Polyester Microfiber: 70% Cotton	153.38	0.541	2.5	16	42	1.63
6				30% Polyester Trilobal: 70% Cotton	137.14	0.512	2.7	14	40	1.51
1		20		50% Polyester Microfiber: 50% Cotton	144.21	0.456	2.7	14	42	1.51
2				50% Polyester Trilobal: 50% Cotton	134.44	0.518	3.2	12	36	1.36
3				100% Polyester Microfiber	133.43	0.46	3	12	34	1.36
4				100% Polyester Trilobal	131.52	0.302	3	12	36	1.27
5				30% Polyester 6Microfiber: 70% Cotton	151.57	0.56	2.6	14	42	1.57
6				30% Polyester Trilobal: 70% Cotton	140.24	0.508	2.9	12	40	1.40

Table 2. Mean and Standard Deviation for Test Variables

Variables	Gauge	Materials						Mean	F	P
		1	2	3	4	5	6			
Air_Permeability	24	162.6^{b}	253.0^{f}	247.0^{f}	402.0^{g}	119.3^{a}	199.6^{d}	**230.6**	**27.93**	**0.000**
	20	176.0^{c}	243.6^{f}	221.8^{e}	402.0^{g}	115.5^{a}	179.0^{c}	**223.0**		
	Mean	**169.3**	**248.3**	**234.4**	**402.0**	**117.4**	**189.3**			
	F	**3078.63**								
	P	**0.000**								
Spray_Test	24	50.0	50.0	50.0	50.0	50.0	50.0	**50.0**		
	20	50.0	50.0	50.0	50.0	50.0	50.0	**50.0**		
	Mean	**50.0**	**50.0**	**50.0**	**50.0**	**50.0**	**50.0**			
	F									
	P									
Bursting_Strength	24	551.8^{cd}	561.0^{d}	910.3^{h}	851.0^{f}	526.1^{b}	498.9^{a}	**649.9**	**127.63**	**0.000**
	20	534.0^{bc}	589.9^{e}	975.1^{i}	881.1^{g}	550.6^{cd}	538.1^{bc}	**678.2**		
	Mean	**542.9**	**575.5**	**942.7**	**866.1**	**538.4**	**518.5**			
	F	**3780.49**								
	P	**0.000**								
Roughness_Face	24	15.1^{ab}	22.1^{b}	14.8^{ab}	13.3^{a}	16.3^{ab}	17.0^{ab}	**16.4**	**3.03**	**0.095**
	20	16.4^{ab}	21.7^{ab}	17.4^{ab}	17.5^{ab}	18.0^{ab}	18.0^{ab}	**18.2**		
	Mean	**15.8**	**21.9**	**16.1**	**15.4**	**17.1**	**17.5**			
	F	**3.88**								
	P	**0.010**								
Roughness_Back	24	26.1^{b}	29.0^{b}	29.3^{b}	12.6^{a}	22.9^{ab}	32.2^{b}	**25.3**	**1.90**	**0.181**
	20	24.7^{ab}	24.5^{ab}	29.8^{b}	32.4^{b}	20.8^{ab}	31.8^{b}	**27.3**		
	Mean	**25.4**	**26.8**	**30.5**	**22.5**	**21.8**	**31.0**			
	F	**4.79**								
	P	**0.004**								

$^{a\text{-}i}$ Subset for alpha = 0.05

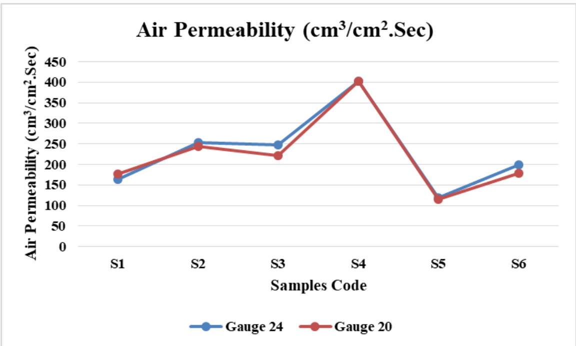

Figure 2. Air Permeability for Knitted Samples

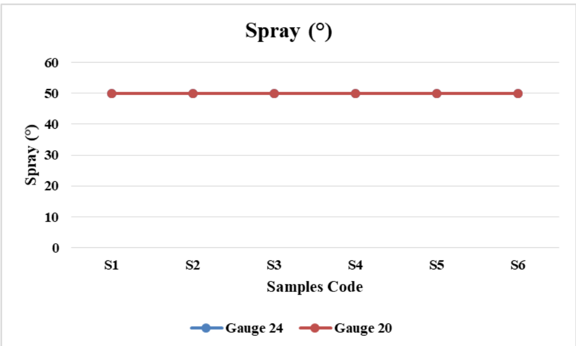

Figure 3. Spray Test for Knitted Samples

3.1.3 Bursting Strength

The results in Figure 4 and Table 2 clarify that sample 3 (100% Polyester Microfiber – circular cross-section) recorded the highest bursting property, referring to the impact of yarn cross-section where circular section improves the capability of fabric toward bursting force than trilobal section. Moreover, the results point that reducing the blended cotton ratio helps to gain more force resistance. As well, the results demonstrate increasing on gauge machine develops the bursting property of fabrics

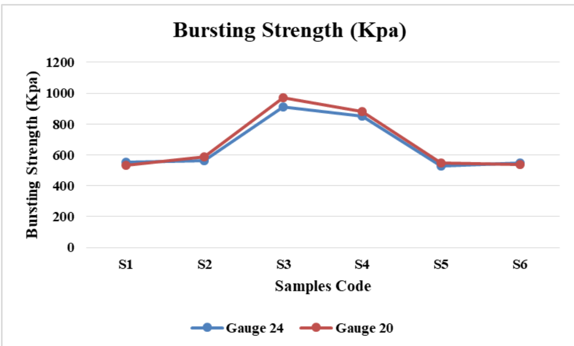

Figure 4. Bursting Strength for Knitted Samples

3.1.3 Roughness

The results in Figure 5 and Table 2 signify the effectiveness of the blended ratio and gauges on the roughness property, where the lower the machine gauge the smoother it is, and on the opposite side the higher the percentage of blended cotton the higher roughness (totally). Furthermore, the results show that the face sides of the knitted specimens are less rough than the posterior sides, which can be due to the technical overlap, during the formation of the loops, when the new loop passes through the face side of the old loop (called the technical background) a head appears only in which increase intermeshing relatively between yarns reflecting on the surface roughness.

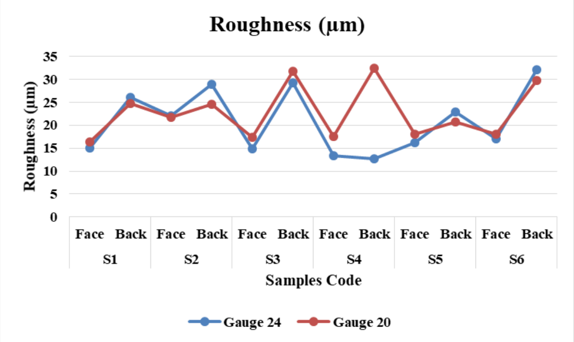

Figure 5. Roughness for Knitted Samples

3.2 Anova Analysis

According to the statistical analysis of Two way Anova, (F) test as shown in Table 2. Most of mechanical properties were significantly affected by the differences in materials, except spray test was not significantly affected at P-value (P >0.05). While for gauges differences, samples properties were significantly affected at P-value (P=0.000), except roughness at face and back sides were not significantly affected at P-value (P=0.095). (P=0.181) respectively.

3.3 Tukey Test

On the other hand, according to the Tukey HSD test and test recorded the result declared that:

3.3.1 Air Permeability

knitted samples obtain an interaction with material variable except samples 2, 3 using gauge 24 and samples 1, 6 using gauge 20 (according to the Tukey HSD test, Table 2). While, on the gauge variable samples 2, 4, 5 have not realized an interaction between samples, which indicates that the air permeability property more significantly affected by materials than gauges.

3.3.2 Spray Test

The results illuminate that there aren't any interactions between the samples and each other which refer that spray property for knitted samples insignificantly affected with different variables (materials and gauges).

3.3.3 Bursting Strength

According to the Tukey HSD test Table 2, the results specify that the bursting property of all samples significantly affected with materials variable except samples 1,2 using gauge 24 and samples 1, 5, 6 using gauge 20. At the same time, with the gauges variable the samples interact with each other except samples 1, which identifies that the bursting strength of knitted samples affected by machine gauges more than materials.

3.3.4 Roughness

The results in Table 2 designate that samples 2 (50% Polyester Trilobal: 50% Cotton) implement the highest roughness on either face side or backside. In the same context, the result pointed for roughness face side, sample 2 has the highest value but there is no interaction between sample 2 and all samples, except the interaction between samples 2, 4 using gauge 24 as it was significantly affected by the difference in gauges. For roughness for back side, sample 6 has the highest test result but there is no interaction between all samples, except sample 4 and samples 1, 2, 3, 6 using gauge 24 as it was significantly affected by different gauges.

3.4 Ultraviolet Protection Factor (UPF)

The findings in Table 3 refer that sample 4 (100% Polyester Trilobal) recorded the highest UV radiation protection compared to the rest of the samples on different gauges, moreover the values conclude to the material impact on UV radiation protection as polyester trilobal gain the highest rating rather than polyester microfiber (circular cross-section). In the same vein, the effect of machine gauges clearly shown as whenever, the gauge grow, the tightness increase subsequently more protection.

Table 3. UPF Values for Manufactured Knitted Samples

Materials	Gauge 24		Gauge 20	
	Samples Code	UPF Values	Samples Code	UPF Values
50% Polyester Microfiber: 50% Cotton	**1**	4.7	**1**	3.9
50% Polyester Trilobal: 50% Cotton	**2**	5.0	**2**	4.6
100% Polyester Microfiber	**3**	15.8	**3**	11.9
100% Polyester Trilobal	**4**	18.0	**4**	13.1
30% Polyester Microfiber: 70% Cotton	**5**	6.9	**5**	6.0
30% Polyester Trilobal: 70% Cotton	**6**	9.0	**6**	6.5

3.5 Radar Chart Analysis to Determine the Best Samples Performance

The inputs results of the mechanical and physical properties were investigated using radar chart. The radar area was calculated for all samples and the results were ordered from best to lowest. The results in table 4 declare that sample 4 (100% Polyester Trilobal) recorded the best sample radar area with different gauges while sample 5 (30% Polyester Microfiber: 70% Cotton) recorded the lowest sample radar area. Furthermore, the results point to the impact of yarn cross-section as polyester trilobal achieve the highest radar area whether in different blended ratio or machine gauges. As well as the results refer that blended knitted samples recorded the lowest performance than 100% polyester microfiber (circular, trilobal) knitted samples. In the same context, the results show that using the highest gauge 24 improves knitted sample performance with different materials. Figures 6,7,8,9 present radar charts area for knitted samples.

Table 4. Radar Chart Area Order for Manufactured Knitted Samples

Gauge 24		Gauge 20	
Samples Code	**Radar Chart Area**	**Samples Code**	**Radar Chart Area**
1	44613.81	**1**	32797.62
2	44938.11	**2**	39379.02
3	45073.08	**3**	40218.33
4	52618.19	**4**	47058.65
5	34925.65	**5**	31025.94
6	36420.88	**6**	35866.83

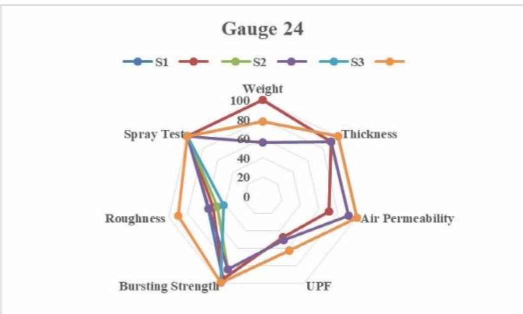

Figure 6. Radar Charts for Samples 1, 2, 3 Using Gauge 24.

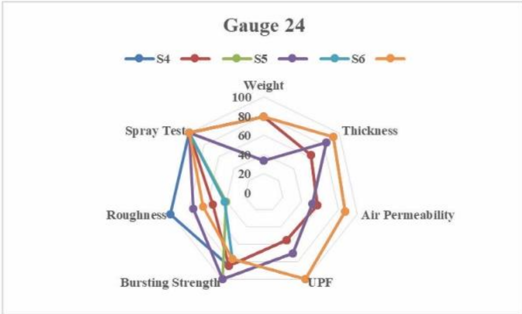

Figure 7. Radar Charts for Samples 4, 5, 6 Using Gauge 24.

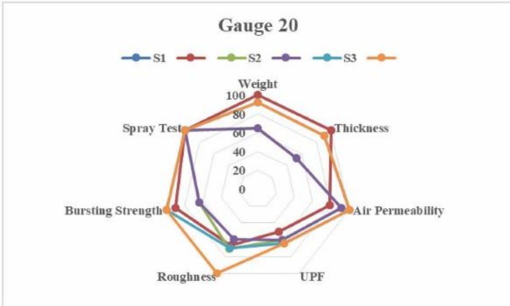

Figure 8. Radar Charts for Samples 1, 2, 3 Using Gauge 20.

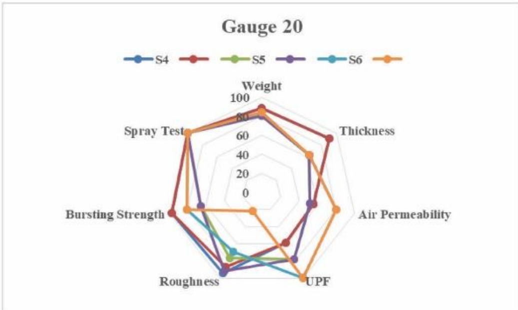

Figure 9. Radar Charts for Samples 4, 5, 6 Using Gauge 20.

4. Conclusion

The objective of this study was to investigate the influence of different polyester microfiber cross-sections and blended cotton ratio on mechanical properties. Seven laboratory tests were performed, the data results were presented, tabulated as means and standard deviation value.

The results declare that polyester trilobal achieves the highest air permeability property, while for bursting property polyester circular microfiber performs the highest strength value. In addition, The results display that all samples have the same attitude toward spray testing, while for surface roughness property, yarn cross-section and blended ratio play a strike role.

On the other hand, Two way Anova was statistically analyzed which demonstrated that all properties were significantly affected by the materials and machine gauge variables except the spray test. Moreover, The consequences refer that Polyester Trilobal recorded the highest UV protection and also whenever, the gauge grow the UPF property increase.

After data analyses and discussions, the radar chart was conducted to show the performance for manufactured samples, which revealed that Polyester Trilobal samples recorded the best sample radar area with different gauges. In the same context, the results show that using the highest gauge 24 improves knitted sample performance with different materials.

5. Conflict of interest

The authors have declared no competing interests; none of the authors have any conflict of interest or relation with any third part that bias the publication of this report.

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توصيف خصائص أقمشة السينجل جيرسي المخلوطة من خيوط المايكروفيبر باختلاف المقاطع العرضية وجوج الماكينة

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نبذة مختصرة:
إن الغرض الرئيسي من هذه الدراسة هو التحقق من تأثير المقطع العرضي لخيوط البوليستر المختلفة والجوج على الخواص الميكانيكية لعينات التريكو المخلوطة. في هذه الدراسة تم تصنيع مجموعتين من عينات التريكو باستخدام جوج 24 وجوج 20 ، وتم تنفيذ العينات بتركيب بنائي من السينجل جيرسيه بواسطة مقطعين عرضيين مختلفين من ألياف البوليستر ونسبة من القطن المخلوط. تم إجراء بعض الخصائص الميكانيكية لجميع العينات مثل نفاذية الهواء واختبار امتصاص الماء وقوة الانفجار والخشونة. تم تسجيل قيم النتائج وجدولتها ، وكذلك التحليل الإحصائي باستخدام قياسات ANOVA ثنائية الاتجاه. أوضحت النتائج تأثر خواص عينات التريكو المخلوط معنويا بالمتغيرات عدا اختبار الرش. في نفس السياق ، توضح النتائج أن المقطع العرضي ثلاثي الأبعاد يحسن خاصية UPF لعينات التريكو. أخيرًا ، نظرًا لدراسة أداء كل عينة ، تم إجراء مخطط الرادار ، حيث أوضحت النتائج أن عينات البوليستر Trilobal سجلت أفضل منطقة عينة رادار بمقاييس مختلفة.