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Study of Fabrics Properties for Intimate Apparel Application

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Abstract- This paper identifies the bra is a tool for support. It is an intimate piece of clothing. The bra gradually evolves from basic needs to body shape enhancement and personal preference on style. Bra made of layers of fabrics, these fabrics some times are not good to use to manufacture bra cup.

This paper took two kinds of mesh fiber glass and polyester, used between two layers fabrics (micro modal and polyamide microfiber), to form shape of cup. Multilayer fabrics have been widely used for clothing. The thermal and Water vapor resistances and air permeability provided by multilayer fabrics are of considerable importance in determining thermal comfort of clothing.

Firstly, study the thermal, water vapor, and air permeability transfer through each the fabrics. Secondly, study the thermal, water vapor and air permeability transfer through multilayer fabrics is presented. And study compressibility and resilience.

Keywords-*Micro Modal, Intimate Apparel, Air Permeability, Water Vapor Permeability, Thermal Resistant, Compressibility, Resilience*

I. INTRODUCTION

Previous research has shown that bra should provide good upward support, limit breast motion, and be constructed from primarily non-elastic materials that are non-allergenic, non-abrasive, and have good moisture management properties, good comfort properties. [1,2]

With the increased awareness and requirements to clothing, people have gradually shifted their focus from the coat to the underwear. As a typical representative of underwear, bra has been an essential thing in women's life. In recent years, molded-bras are booming as they can conform the breast contours for gap-free custom fit and mimic the breast shapes. Bra cup molding poses various technical problems for the manufacturers. When manufacturers experience some problems concerning material quality or processing conditions, there is no common language to communicate with each other in the absence of objective measurement date. [3, 12, 13]

In recent years, molded-cup bra sere booming as they can conforms the breast contours for gap free custom fit and mimic the breast shapes. In the intimate apparel industry, Polyurethane foam is the material most widely used in molded bra cup production.

Polyether-based Polyurethane (PU) is the cheapest of its type, has low density, good elastic recovery, heat retention and it can be cut into any thickness.

These features make polyurethane foam cups widely used in the molded-cup production. (PU) foam is soft and flexible but is easily glazed and discolored by the high temperature, time and pressure variables used in the molding processes. These production problems are now well documented but trial and error methods are common with less experienced firms [4] .because it is soft and flexible, which suits well for intimate apparel applications it canals be lined with bras in various thicknesses in order to fulfill the wearers' pursued breast contour. However, there are some major drawbacks when using this kind of material. PU has poor ability to wick moisture away and it undergoes. [3]

Three-dimensional spacer fabrics can be used to replace the PU foam because they have better heat and moisture exchange characteristics Also, since the spacer fabrics when producing conventional PU molded-cups can be produced in one operation, there is no need to carry out the laminating and bonding processes which are necessary when producing conventional PU molded-cups. [5]

Multilayer fabrics are chosen for cold weather conditions, which provide adequate thermal insulation. Generally, the usage of a multilayer clothing ensemble is better than single layer clothing in that the insulation provided by several layers can be easily adjusted. One layer is taken off or put on without disturbing the whole clothing ensemble. The body temperatures rise at high activity levels in cold climates. In these circumstances the insulation can be readily controlled by using suitable closures, for example zip fasteners, buttons, toggles, and firm adhesions. [6] Multilayer fabrics have been widely used for thermal protective clothing, which is important in hot environments to protect the wearers from solar radiation or reflected radiation. Usually thermal protective clothing consists of an inner layer, middle layer, and outer layer. [6, 7] The aim of the inner layer is to provide next to- skin comfort by wicking the sweat at the skin surface for better evaporative cooling and faster drying. The primary role of the middle layer is to provide insulation. The goal of the outer layer is to protect people against environmental conditions (i.e., heat, flame, wind, precipitation) and to allow water vapor transfer to the environment Blends in form of layering of fabrics are capable of offering the best properties of each. Knits such as polyester or polyamide- provide wicking and insulation properties in a single layer [6, 8, 9]. Multilayer fabrics are materials composed of a non-absorbent hydrophobic material on the inside-worn next to the skin-and an absorbent hydrophilic material on the outside. Usually, the hydrophobic material is polyester, and the absorbent hydrophilic material nylon. This improves the wiping action and gives the fabric a softer touch. [10, 12]

Resilience described is very important in textile applications. The thermo stating effect of the human body and the inability of humans to remain alive except within a limited range of temperatures. However, moisture content is a very important factor, and due account of the type of garment and the climate for which it is tint ended must be taken. Rates of strain and retraction are generally rather low, and it is, in general, possible to select a standard testing speed. [21]

Which will represent the service rates fairly well? The number of the cycle to consider as significant is subject to argument since clothing is generally not worn continuously. There is usually a definite rest period between cycles or between series of cycles so that secondary creep (permanent deformation) is not too important. Baggy knees and wrinkled sleeves do occur, of course; but they generally can be eliminated by proper deformation at high temperatures and moisture contents. The nature of the cycle is probably that of constant rate of strain and constant maximum strain. Are important in clothing fabrics but they should be considered as empirical methods of estimating a composite property involving both stiffness and resilience. Hence, in the case of clothing, it appears that the role of resilience is that of a factor which controls secondary heat development resulting from hysteresis or lack resilience is never a factor. [21, 22]

Nylon micro fiber: use of high thermal shrinkage property has good moisture permeability lightweight, softness and elastic synthetic polymer with a protein like chemical structure. Used to imitate silk.Very resilient, easy to care, resistant to insects, fungi and mildew.Has capability of secondary finishing. The fabric is very successfully used in mountaineering wear and other intimate apparel which employs a multi. layer structure that not only absorbs perspiration quickly but Multi layers system is a very popular high performance fabric, also trans. ports it up to the outer layer of fabric very rapidly using principle of capillary action. It is composed of coarser denier yarn on the inside surface (in direct contact with skin), and fine denier hydrophobic polyester yarn in a mesh construction on the outer surface to accelerate quick evaporation of sweat. [11, 12]

Modal fabric: cellulose fiber made by spinning reconstituted cellulose, often from beech trees. 50% more water-absorbent than cotton, can be dyed like cotton and is colorfast, resistant to shrinkage and fading, lightweight, appearance of silk, soft and smooth. [11]

II. Experimental

A. Materials

The materials applied in Bra cup, used three layers .polyamide micro fiber and modal fabrics. Table 1 shows specifications of samples, used to outer and inner layers, fiber glass net and polyester net, used between the layers of cup bra. Fig. 1 shows bra cup shape.

B. The net (layer)

Construction of net for fiber glass and polyester is plain, 3weft\cm, and 3 warp\cm. number of fiber glass is 450 deniers and polyester is 300 deniers.

Fiber contain Polyester resin (polystyrene monomer-concentration 60%), Accelerator (*Cobalt naphthenate 3%),* Hardener (Methyl ethyl ketone peroxide 3%). *Mix* the catalyst 3% *into* the resin. Add the Hardener to the polyester resin. Put the woven knit above silicon rubber knit or (silicon rubber mold). Apply layers of resin on woven knit; it will absorb the resin until reaches to the degree of saturation. See figures1, 2, and 3.

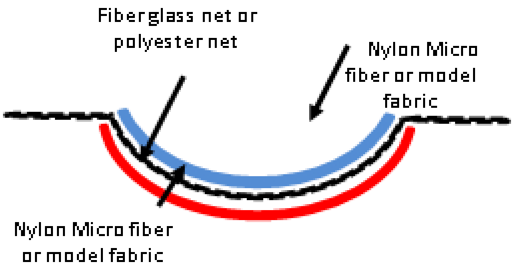


Figure 1. Bra cup

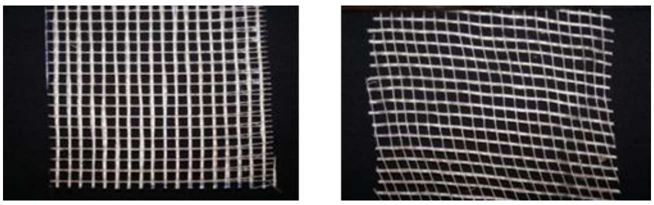


Figure 2. Layers of resin

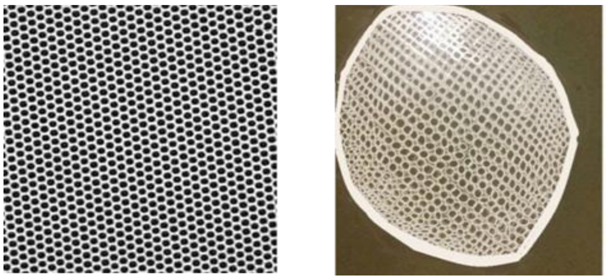


Figure 3. Layers of resin

TABLE I. SPECIFICATIONS OF SAMPLES.

samples	Nylon microfiber		micro modal	
Fabric types	*Weft knitted*		*Weft knitted*	
composition	100%		100%	
denier	70\68\2		150	
structure	Single jersey		Rib	
Density	Wales\cm	courses\cm	Wales\cm	courses\cm
	32	20	18	20

C. Measurements.

1-Weight of fabric: ASTM. Standards .D1910-64(1970).

2- Air permeability of textile fabric .ASTM - D 737

3-Water vapor permeability ISO 11092

4- Thickness ISO 5084

5-Thermal Transmittance of textile materials ASTM D: 1518

6-Compressibility BS EN 4098:1996

7- Resilience BS EN 4098:1996

All tests were carried out in National Institute for Standards after the samples were conditioned under standard atmospheric conditions(temperature 20 ± 2°C, 65 ± 2% relative humidity), according to standard ISO 139:1973. An exploratory data analysis containing central tendency and dispersion statistics was performed with the purpose of identifying outliers, normal behavior of the measured properties and also the homogeneity of variances. Then, univariate analysis of variance by using ANOVA procedure, followed by Post Hoc tests.

III. RESULTS AND DISCUSSION

The properties of each single fabric f_1,f_2.f_3.$f_4$was measured separately and then a three layer composite of the four fabrics A,B,C,D, were also measured alternatively ,and the average value of fabrics are given in Table2.Weight, thickness, the thermal comfort characteristics such as thermal transmittance, water vapor permeability ,air permeability, Compressibility and resilience were also studied.

A. weight and thickness

The porosity of a spacer fabric is a very important characteristic, which decides Permeability, moisture, and thermal comfort of fabrics. Fabric porosity is mostly influenced by the loop length, stitch density, and the thickness [24].

The three layers of cup depend on the fabric weight and thickness of fabrics that is Shown in Figure 4. The two outer layers are polyamide microfiber and micro modal.

Middle layer is fiber glass net. The composite fabrics A&C are the low results of weight and thickness when compare all results. But the composite fabrics B&D are the high results of weight and thickness.

TABLE II. THE RESULTS OF FABRICS PROPERTIES

Tested fabrics	Weight g/m2	Thickness mm	Water vapor permeability Pa.m2.w-1	Air permeability Cm3\cm2\sec.	Thermal TOG	Compressibility mm	Resilience mm
F1	158	0.50	4.82	247.7	1.22	0	0
F2	238	0.36	3.74	12.2	1.18	0	0
F3	3.49	0.87	14.8	610	0	0	0
F4	2.26	1.05	14.9	900	0	0	0
A	161.5	1.73	14.80	12.4	1.67	0.40	0.20
B	163.8	1.91	14.90	12.1	2.45	0.43	0.21
C	161.5	1.73	5.04	10.7	1.69	0.38	0.21
D	163.8	1.91	6.38	23.5	2.27	0.40	0.22

Where: f1=micro modal, **f2**=polyamide, **f3**=fiber glass net, **f4**=polyester net.
Polyamide microfiber –fiber glass net –micro modal fabric.=fabrics layers **A**
Polyamide microfiber- polyester net –micro modal fabric.=fabrics layers **B**
Micro modal fabric –fiber glass net – polyamide microfiber.= fabrics layers **C**
Micro modal fabric – polyester net – polyamide microfiber.=fabrics layers **D**

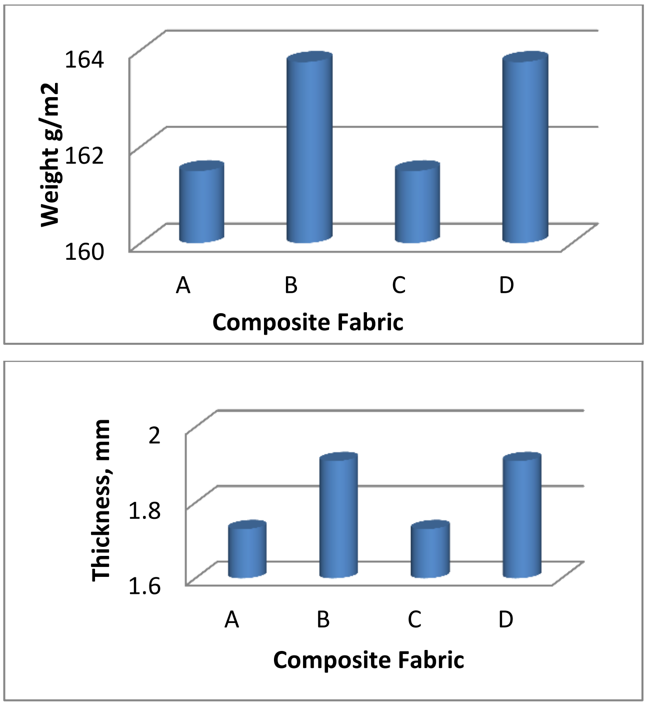


Figure 4. Weight and thickness of composite fabrics

B. Fabric air permeability

Air permeability is the rate of air flow passing vertically through a known area under a prearranged air pressure differential between the two surfaces of a material.

Air permeability and porosity are directly related to each other. If a fabric has very High porosity, it can be assumed that it is permeable [16].

As it can be seen from Figure 5, the F_1 micro modal fabric has more open structure than the others and with the increment of porosity, the air permeability values have also increased. See table 1.so composite fabric D gave good the flow through the fabrics, middle layer is polyester net gave good results, As The f_1,f_2 andf_4 results indicate that the air permeability values increase when the fabrics become looser. But T1 shows low space and all the three layers contribute the composite fabric C gave low the flow through the fabrics, middle layer is fiberglass net restriction of air flow. Although, composite fabric D and composite fabric B contain the same middle layer is polyester net and the same two outer layers are polyamide microfiber and micro modal in bra cup, But the layer micro modal F_1in contact with the skin in bra cup and middle layer polyester are giving a high feeling of comfort.

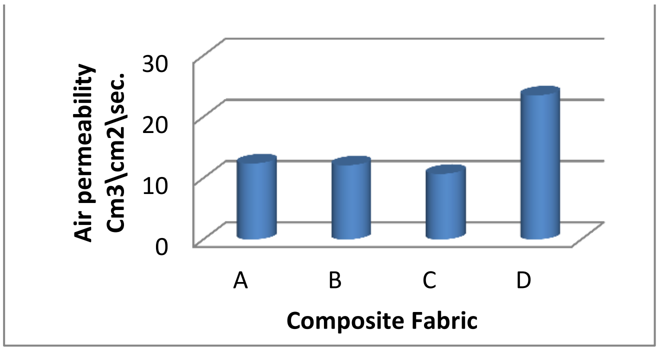


Figure 5. Air permeability of composite fabrics

C. *Fabric water vapor permeability*

Water vapor permeability is one of the most important properties that determine the velocity of water vapor transmission through a textile material. This is a vital Parameter in appraising comfort characteristics of a fabric, as it stands for the Capability of transporting perspiration. [17]

Figure 6 shows the water vapor permeability of different type of composite fabrics.

Moisture vapor transmission through largely open-knitted

Structure is predominately controlled by fabric variables that determine thickness and permeability. The thickness of fabric is a vital feature and it establishes the Distance through which moisture vapor pass through from one side of the fabric to

The other side [18] Composite A and B fabrics gave well and nearly result, but B has more water vapor diffusivity between the surfaces and layers, transfer System that draws sweat from the skin to the outer layer of the fabric. It is breathability. Composite C fabric leads to low permeability. In this case, middle layer is fiberglass net restriction of water vapor flow.

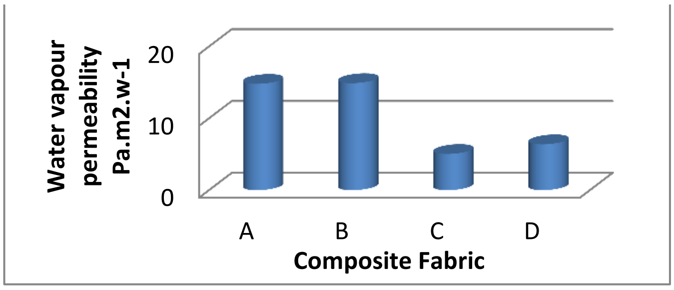


Figure 6. Water vapor permeability of composite fabrics

D. *Fabric thermal properties*

Thermal properties are explained as the amount of heat transmitted through the Thickness of the fabric in a measured surface area. Thermal conductivity and resistance are immensely influenced by the fabric structure and thickness. The long float open loop structure with higher fabric thickness produces lowest thermal conductivity. The thermal resistance shows high response for thermal conductivity and thickness of fabric. [19, 20] higher fabric thickness contributes more on thermal properties.

Figure 7 shows thermal resistance of composite fabrics. Comfort property is depending on the fabric thickness and thermal conductivity was established as a significant aspect leading to the thermal insulation of textiles, (fig.7). These results give details in the way that comparatively higher fabric thickness of a spacer fabric entraps more air within the middle layer and therefore cause higher thermal resistance with lower thermal conductivity. [18]

Even though composite B&D fabrics have higher thermal resistance and thickness than composite A&C, but composite B fabric has more thermal resistance diffusivity in between the surfaces and layers so middle layer polyester net and polyamide microfiber in contact with the skin in bra cup are giving a high feeling of comfort.

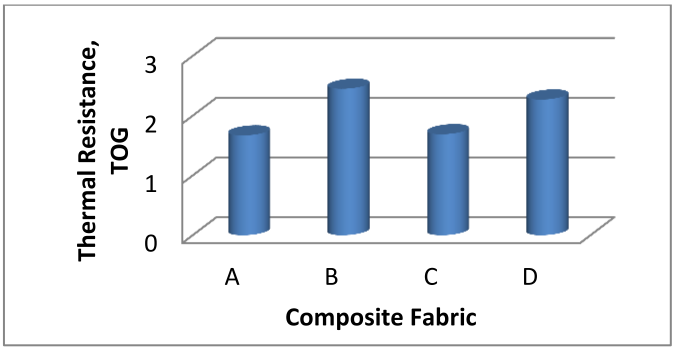


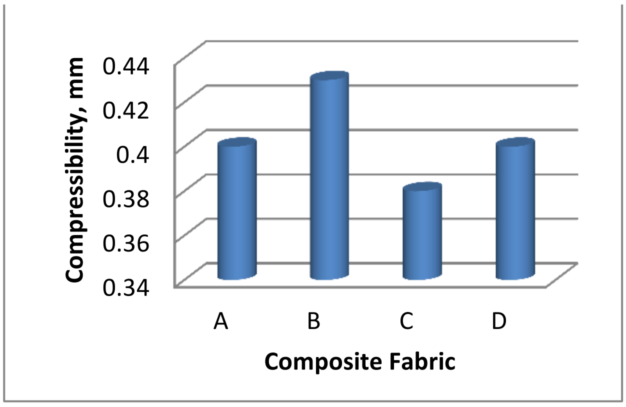
Figure 7. Thermal resistance of composite fabrics

E. *Fabric compressibility and resilience properties*

The compressibility and resilience of a fabric mainly depends on yarn packing density and yarn spacing in the fabric. Compressibility provides a feeling of bulkiness and spongy property in the fabric. Compressibility has some correlation with the thickness of the fabric; the higher the thickness, the higher the compressibility. [21] Resilience of a fabric is ability to recover from Deformation. [22]

The results of the compression and resilience properties are shown in fig. 8.

Even though composite B&D fabrics have higher compressibility and thickness than composite A&C, but composite B fabric has more compressibility, so middle layer polyester net and polyamide microfiber in contact with the skin in bra cup are giving a high compressibility. But in second diagram composite D fabric has good resilience, ability to recover from deformation.



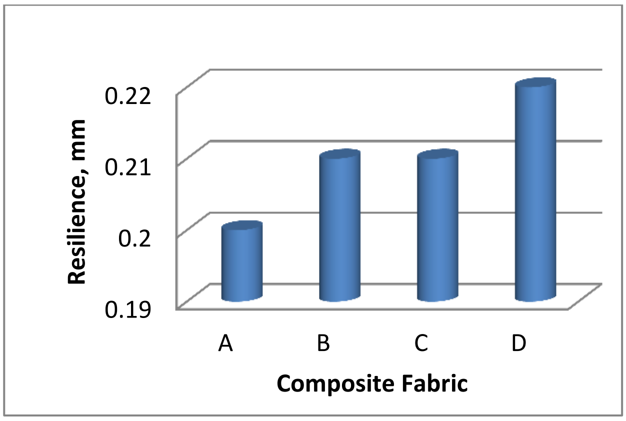


Figure 8. Compressibility and resilience properties of composite fabrics

IV. STATICALLY EVALUATION

The above-mentioned results are confirmed by analysis of variance (ANOVA), and the result is significant influence of composites fabrics on fabric properties.

TABLE III. ONE-WAY ANOVA OF COMPOSITE FABRICS PROPERTIES.

Property	*Source of Variation*	*df*	*F*	*P-value*	$F_{critical}$
Weight(g/m^2)	A,B,C,D	3	38420.5	5.7094E-17	4.066181
Thickness(mm)	A,B,C,D	3	334.3939	9.61091E-09	4.066181
Water vaporPermeability (Pa.m^2.w^{-1})	A,B,C,D	3	49401.45	2.08888E-17	4.066181
Air permeability (Cm^3\cm^2\sec.)	A,B,C,D	3	10584.75	9.90311E-15	4.066181
Thermal(TOG)	A,B,C,D	3	6337.296	7.70115E-14	4.066181
Compressibility (mm)	A,B,C,D	3	11.62182	0.002753	4.066181
Resilience(mm)	A,B,C,D	3	10.40625	0.003897	4.066181

Note: ANOVA: analysis of variance.

The results of the ANOVA are listed in Table 3, which analyses the effect of groups of fabrics samples with respect to Weight, Thickness, Water vapor Permeability Air permeability Thermal, Compressibility and Resilience proves that the changes in properties of fabrics results is highly significant differences.

Table 3 shows, there are significant differences between weight of composites fabrics A, B, C and D indication this P-value=5.7094E-17, where composites fabrics B is highest weight and then composites fabrics B and then A and C.

There are significant differences between thickness of composites fabrics A, B, C and D, indication this P-value=9.61091E-09, where composites fabrics B and D is highest Thickness and then D composites fabrics A and C.

There are significant differences between Water vapor Permeability of composites fabrics A, B, C and D, indication this P-value =2.08888E-17, where composites fabrics A is highest Water vapor Permeability and then composites fabrics B and then D and finally C. There are significant differences between air permeability, indication this P-value =9.90311E-15, where composites fabrics D is highest air permeability and then B composites fabrics A and then Band finally C.

There are significant differences between Thermal of composites fabrics A, B, C and D, indication this P-value=7.70115E-14, where composites fabrics B is highest Thermal and then composites fabrics D and then C and A.

There are significant differences between Compressibility of composites fabrics A, B, C and D, indication this P-value=0.002753, where composites fabrics B is highest Compressibility and then composites fabrics D and then A and finally C.

There are significant differences between resilience of composites fabrics A, B, C and D, indication this P-value =0.003897, where composites fabrics D is highest resilience and then composites fabrics C and then B and finally A.

The ANOVA confirmed that there are different properties between layers fabric used for bra cup also proved the significant difference among all the groups. By considering all the above cases, the Composite B fabric has more thermal resistance diffusivity in between the surfaces and layers, so middle layer polyester net and polyamide microfiber in contact with the skin in bra cup are giving a high feeling of comfort.

V. CONCLUSION

Firstly, study the thermal, water vapor, and air permeability transfer through each the fabrics. Secondly, study the thermal, water vapor and air permeability transfer through multilayer fabrics is presented. And study compressibility and resilience for 4 composite fabrics to made bra cup, middle layer polyester net or fiberglass net. These composite fabrics were manufactured by varying the different properties. In order to compare the properties of composite fabrics, the results revealed that the Composite fabric **B** has more high quality properties; it is the best bra cup. See Radar charts figure 9, so the polyester net is the best to middle layer in bra cup when compare fiberglass net. See table 4.

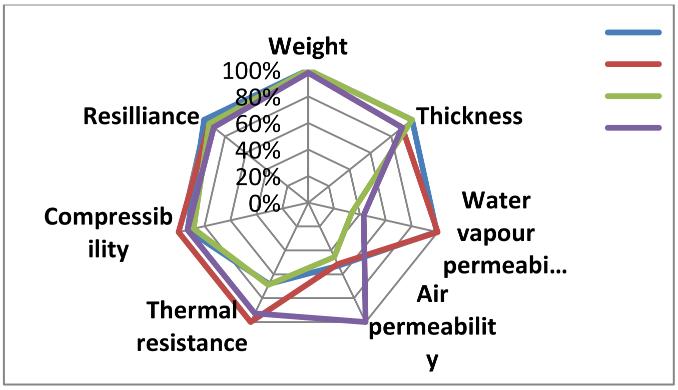


Figure 9. Radar charts of composite fabrics properties.

TABLE IV. QUALITY ASSESSMENT OF COMPOSITE FABRICS PROPERTIES

Property	Weight	Thickness	Water vapour permeability	Air permeability	Thermal resistance	Compressibility	Resilience	Quality Factor
A	100%	100%	99%	53%	68%	93%	100%	88%
B	98%	91%	100%	51%	100%	100%	95%	91%
C	100%	100%	34%	46%	69%	88%	95%	76%
D	98%	91%	43%	100%	93%	93%	91%	87%

REFERENCES

[1] SUCHITRA S.; The Bra and the Indian Woman's Notion of Sexuality, Journal of Creative Communications,267–278, 2007.

[2] Jie Zhou, Winnie Yu and Sun-pui Ng; Identifying effective design features of commercial sports bras Textile Research Journal, 83(14) 1500–1513,2013.

[3] Joanne Y., Sun-Pui N.,Study of three-dimensional spacer fabrics: Molding properties for intimate apparel application, journal of materials processing technology , 58–62, 2009.

[4] Intimate apparel journal,technology,fashion&design,market intelligence, Issue of apparel journal, May 2015.

[5] Anon.,. Bra cups made from a new spacer fabric,Kettenwirk-Praxis 2, E2–E3,2001.

[6] Clark R.P. and Edholm O.G., Man and his thermal environmentLondon: Edward Arnold, 1985.

[7] Morrissey MP and Rossi RM. Clothing systems for outdooractivities. Text Prog 2013; 45: 145–181.

[8] Ren Y.J and Ruckman J.E., Condensation in three-layerwaterproof breathable fabrics for clothing.Int J ClothingSciTechnol 2004; 16: 335–347.

[9] Zhou X., Wang X., Jiang Y., .Water vapor transfer inmulti-layered textile assemblies under the subzero climaticcondition.Sen'iGakkaishi 2006; 62: 34–38.

[10] Li Y., The Science of Clothing Comfort, Textile Progress Vol. 31, No.1/2.

[11] Anon, Active Sportswear fabrics, Japan Textile News, No. 559, January 2001.

[12] Ishtiaque, S. M., Engineering Comfort, Proceedings Smart Textiles: Their Production & Marketing Strategies, Edited by Sanjay Gupta, National Institute of Fashion Technology, New Delhi,, 29th Nov. 2000, 58-64.

[13] Xu Z, Jiang X.W,Zhang X., Study on the properties of warp-knitted spacerfabric used for bra-cup. Master Degree Paper of Xi'an Polytechnic University, 2009.

[14] Guo X., Long H. and Zhao L., Investigation on the impact and compression-after-impactproperties of warp-knitted spacer fabrics. Tex Res J 2013; 83: 904–916.

[15] Onal L. and Yildirim M., Comfort properties of functional three-dimensional knitted spacer fabrics for home-textile applications. Tex Res J 2012; 82: 1–14.

[16] Shabridh. andDas L., A Study of heat and moisture vapor transmission characteristicsthrough multilayered fabric ensembles. Fibers Polymer 2012.

[17] PalaniR., Louis S., Ramakrishna G. andMohamed Z., Comfort properties of functional warp-knittedpolyester spacer fabrics for shoe insole applications, journal of industrial textile ,2016, Vol. 45(6) 1239–1251

[18] OnofreE.i, Rocha A.M. and Catarino A., The influence of knitted fabrics' structure onthe thermal and moisture management properties. J Eng Fibers Fabrics 2011; 6: 10–22.

[19] Chidambaram P.,Govind R. andVenkataraman K.C., The effect of loop length and yarnlinear density on the thermal properties of bamboo knitted fabric. AUTEX Res J.2011;11: 102–105.

[20] Behera.B.K.,comfort andhandle behavior of linen- blended fabrics, AUTEX Research Journal, Vol. 7, No 1, March 2007.

[21] Dillon.J.H., Resilience of Fibers and Fabrics, textile research journal, April, 1947.

[22] Torstensson H.& Pal R.,Resilience in textile enterprises and supply chains Swedish School of Textiles, University of Boras, 2004.