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To develop a smart indigenous sleeping bag with active heating property for cold climates

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Abstract: Sleeping bag is made of three layer systems where inner layer is made of Micro filament polyester fabric with chemical treatment to enhance its wicking properties; middle layer is made of PU Nylon fabric for enhanced abrasion resistance & breathability with water repellence. The middle layer is constructed with different combination of non woven made of Round Polyester, Angora, wool fibres and their blends. The temperature regulated active heating system is also inserted with middle layer inside the sleeping bag. Performance of 3 layers of sleeping bag is assessed w.r.to breathability, water repellence, water absorbency, thermal insulation properties.

Keywords: sleeping bag, outer layer, inner layer, middle layer, heating system

I. INTRODUCTION

A sleeping bag is a protective "bag" for a person to sleep in, similar to a blanket that can be closed with a zipper and functions as a bed while camping, hiking, hill-walking or climbing. Its primary purpose is to entrap dead air thus, provide warmth and thermal insulation. Sleeping bags are used at high altitudes in extremely cold weather [1,2,3]. It also protects against wind chill, precipitation, rain etc. Efficacy of sleeping bag is termed as **Comfort Temperature** which gives the range of temperatures at which the user gets full night’s sleep without experiencing cold which usually is defined as an upper and lower limit of temperature [4,5]. Conventional market available, Sleeping bags are generally three layer system where outer layer and inner layer are made of polyester and cotton/polyester respectively while middle layer is a sandwich layer made of polyester batting and is responsible for thermal insulation of bag. In this paper, a sleeping bag with enhanced wicking property, superior water proof & breathability has been developed. Apart from this, active heating system is also embedded to enhance the overall thermal insulation of sleeping bag.

II. EXPERIMENTAL

2.1 Material

The microfilament Polyester fabric and Nylon fabrics were purchased from local supplier M/s Global trading company, Mumbai and the chemicals for enhancing wicking property was sourced from Archroma India Private Limited. The Hot melt PU adhesives were sourced from Jowat SE Germany.

2.2 Development of different layers of sleeping bag Methods

Details of fabrics used as inner & outer layer are given below.

2.2.1 Inner layer of sleeping bag i.e microfilament polyester

The parameters of fabric are given below.

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S.N	Fabric parameters	Measurement value
1	Nominal count of yarn	85 denier
2	Ends/cm	55
3	Picks/cm	32
4	Warp cover factor	16.4
5	Weft cover factor	13.02
6	Fabric cover factor	21.7
7	Fabric grams per square meter (GSM)	90

2.2.2 Chemical treatment of inner layer: The following recipes of chemical treatment for wicking property improvement followed by Pad –dry-cure method curing at 130 ° C for 3 minutes are given below:

Treatment	Hydroperm* SRHA liq. (gpl)	pH	Padding pick up (%)
1	15	6-6.5	50
2	20	6-6.5	50
3	30	6-6.5	50
4	60	6-6.5	50

*Archroma product

2.3 Outer layer- Nylon fabric

The outer layer nylon fabric comprises the following parameters:

SN	Parameters	Value
1	Nominal count of yarn	80 denier
2	Ends/cm	52
3	Picks/cm	36
4	Warp cover factor	9.21
5	Weft cover factor	9.21
6	Fabric cover factor	15
7	Fabric grams per square meter (GSM),max	90

2.4 Water proof & breathable coating of PU on Outer layer (nylon fabric) of sleeping bag

With PU chemicals different recipe of breathable coating were formulated for optimization of breathability & water repellnce properties. The coating treatment was given on Slot die based Hotmelt Laminating & Coating machine (Make: HipMitsu, Italy) for different trials are given below:-

Sample ID	Chemical coating (GSM)
Untreated	Nil
Treatment -1	5
Treatment -2	10
Treatment -3	15

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2.5 Fibres used as a non woven in middle layer

Fibre used	Linear density (denier)	Fibre staple length(mm)	Tenacity cN/d	Breaking extension %
Round Polyester	6	64	3.87	51
Angora	3 denier (18 micron)	45	1.61	40
Wool	5.37 denier (24 micron)	70	2.80	43

The polyester non woven samples were made from parallel-laid web through needle punching density of 150 punches/inch^2. Since the machine used was of capacity of 15 punches/inch^2, hence web was passed 10 times through the machine in order to get 150 punches/inch^2.

2.6 Constructional details of experimental non woven fabric samples

Fabric code	Fibre type	Nominal fabric weight (g/m^2)	Needling punching density (Punches/inch^2)
RP1	Round polyester	200	150
RP2	Round polyester	250	150
RP3	Round polyester	450	150
A1	Angora	150	150
A2	Angora	200	150
A3	Angora	300	150
AW1	Angora/Wool	150	150
AW2	Angora/Wool	200	150
AW3	Angora/Wool	300	150

RP1, RP2 and RP3 are non-woven of Round polyester having GSM 200, 250 and 450 respectively
A1, A2 and A3 are non-woven of 100% angora having GSM 150, 200 and 300 respectively
AW1, AW2 and AW3 are non-woven of angora/wool 70/30 blend having GSM 150, 200 and 300 respectively

2.7 Flexible heating panel

2.7.1 Heating element & Development of heating element

A flexible copper wire based heating panel (fig-1) was developed which was inserted in between the thermal insulation layer and inner wicking layer. Three heating pads were developed to control the front side and back side insulation with required warmth property. Three small heating pads were developed which were subsequently interconnected with each other and two ends of it are connected to temperature regulator (fig-1) which is finally connected with rechargeable battery. The rechargeable battery supplies the DC power to the heating pads via temperature regulator. The temperature regulator controls the required comfortable temperature for the body needs. In this way the high altitude sleeping bag was developed for giving the thermal responsive property.

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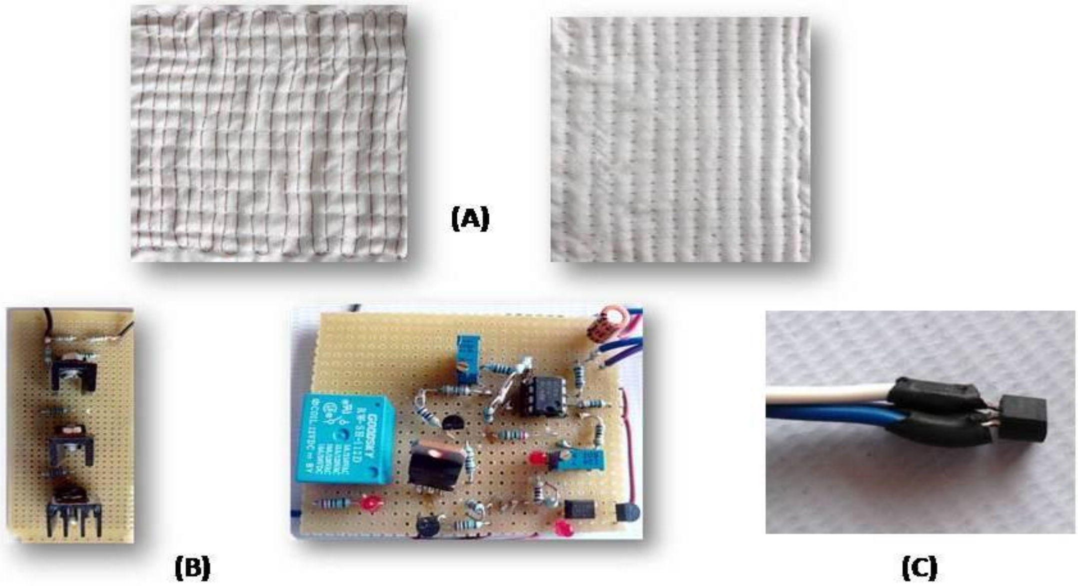

Fig no. 1 A. Flexible heating fabric, B. Thermostat, and C. Temperature sensor

III. RESULTS AND DISCUSSION

3.1 Testing results

3.1.1 Absorbency testing for microfilament polyester fabric (inner layer)

Sample treatments	S.N	Absorbency time(Second)	Avg. Absorbency time(Second)
untreated	1	41	42.33
	2	40	
	3	46	
15gpl (treatment-1)	1	18	18
	2	18	
	3	18	
20gpl (treatment-2)	1	13	12.67
	2	13	
	3	12	
30gpl (treatment-3)	1	13	12.67
	2	12	
	3	13	
60 gpl (treatment-4)	1	13	13
	2	12	
	3	14	

3.1.2 Absorbency testing for polyester fabric

The absorbency testing was carried out for polyester fabric with different recipes of chemical treated polyester fabrics. This test gives how quickly the fabric absorbs the body moisture. From the graph-1, it is seen that the untreated fabric takes more time to absorb the water molecule than the treated fabric. The treatment 20 gpl (treatment-2), 30gpl (treatment-3) and 60 gpl(treatment-4) are showing almost similar results of taking lowest time to absorb the water molecule.

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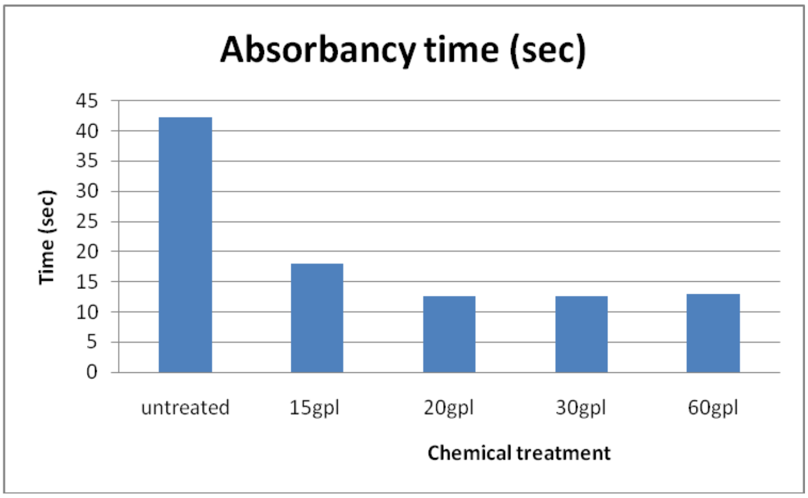


(Graph-1 shows relation between different chemical treated fabrics with absorbency time in seconds)

3.2 Testing of outer layer properties

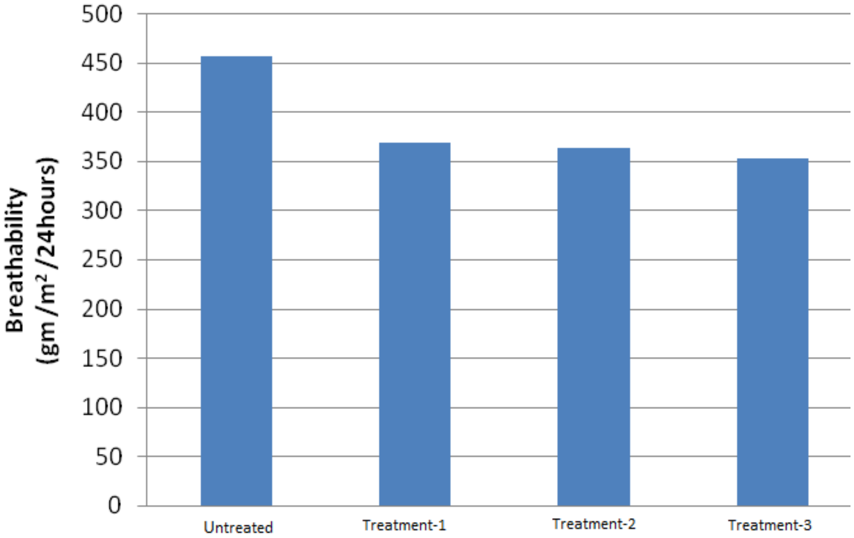
3.2.1 Breathability testing of coated nylon fabric.

The breathable coating treated nylon fabric was tested for cup test method of breathability testing.

Sample ID	Breathability testing (gm/m^2 /24 hours)
Untreated	456
Treatment -1	368
Treatment -2	363
Treatment -3	352

3.2.2 Breathability of PU coated nylon fabric

Nylon fabric was treated with different recipes of breathability coating. Different combinations of coating procedures were experimented. Cup test method of breathability testing was carried out for different trials. The following graph-2 is plotted for different treatments with their respective breathability value. In the graph-2, it can clearly seen that untreated fabric shows higher breathability than coated fabric. Fabric with treatment -1; 5 GSM, treatment -2; 10 GSM and treatment -3; 15 GSM shows almost similar results though lesser than untreated.



(Graph-2 shows the relation between breathability of outer layer with different coating recipes)

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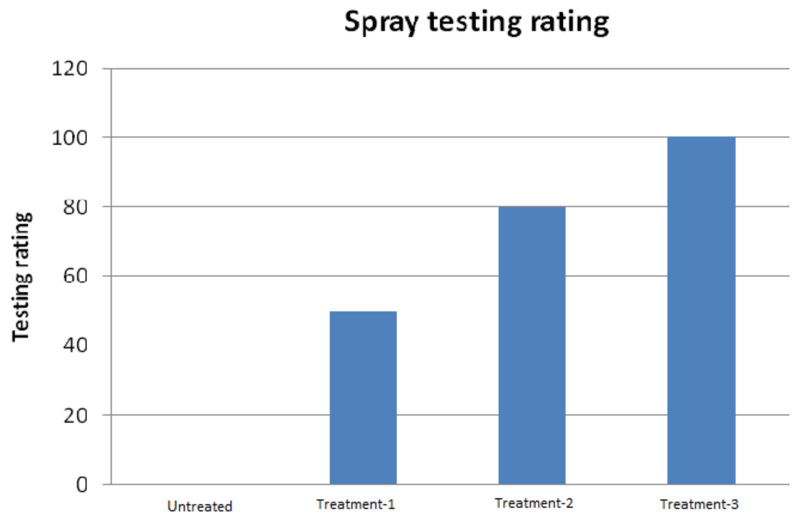
3.2.3 Spray testing /Water repellency of PU coated nylon fabric.

The PU coated nylon fabric was tested for spray testing.

Sample ID	Spray testing rating
Untreated	0
Treatment -1	50
Treatment -2	80
Treatment -3	100

3.2.4 Spray testing /Water repellency of outer layer

Spray testing was done to evaluate the water resistance capacity of the treated breathable fabric. The above mentioned different types of breathable fabrics were tested for water repellence properties. The following graph shows the relation between coated sample and its spray testing rating. The spray testing ratings are graded from 0 to 100. Rating 0 means not water repellent and 100 rating means excellent water repellent. In the following graph, it is seen that untreated fabric is not water repellent and have 0 rating. Treatment -3 gives highest water repellency properties than others. Treatment -1 gives 50 rating which is poorest among coated fabrics. Therefore, treatment-3 provides best results for outer layer nylon fabric.



(Graph-3 shows the relation between spray testing rating of outer layer with different coating recipes)

3.3 Testing of thermal insulation properties of 3 layer system (i.e outer layer + inner layer + middle layer) with and without heating system

Three layers were tested using Dry Guarded Hot Plate as per ASTM D1518 Standard Test Method for Thermal Transmittance of Textile Materials.

S.No.	Fabric code	Middle layer non woven (Fibre type)	Nominal weight of 3 layers (g/m^2)	Thermal insulation value of 3 layers without heating system (Tog)	Thermal insulation value of 3 layers with heating system (Tog)
1	FRP1	Round polyester	380	2.41	3.43

2	FRP2	Round polyester	430	3.56	4.02
3	FRP3	Round polyester	630	4.46	5.11
4	FA1	Angora (100%)	350	3.54	4.74
5	FA2	Angora (100%)	380	4.78	5.90
6	FA3	Angora (100%)	480	5.35	6.88
7	FAW1	Angora/Wool (70/30)	330	3.21	4.47
8	FAW2	Angora/Wool (70/30)	380	4.45	5.68
9	FAW3	Angora/Wool (70/30)	480	5.01	6.59
10	F(RP3 +A3)	Round polyester + Angora (100%)	930	9.38	10.98
11	F(RP3 +AW3)	Round polyester + Angora/Wool (70/30)	930	9.03	10.56

FRP1, FRP2 and FRP3 are three layers having middle layer of non-woven of Round polyester having GSM 200, 250 and 450 respectively

FA1, FA2 and FA3 are three layers having middle layer of non-woven of 100% angora having GSM 150, 200 and 300 respectively

FAW1, FAW2 and FAW3 are three layers having middle layer of non-woven of angora/wool 70/30 blend having GSM 150, 200 and 300 respectively

F(RP3 +A3) and F(RP3 +AW3) are three layers having middle layer of combination of non-woven of RP3/A3 and RP3/AW3 respectively

IV. Conclusion

In the research project, sleeping bag is fabricated by utilising of Three layers were with optimum components.

The inner layer made of microfilament polyester chemical treated of Treatment-2 (i.e 20gpl conc.) & outer layer made of Nylon with PU coating of Treatment-3 (i.e 15 GSM) have given optimum results for water absorbency and breathability & water spray test respectively.

The middle layer is used as a Combination of nonwoven layer of round polyester and angora/wool (70/30). A Flexible heating panel circuit with rechargeable DC power battery operates at voltage 15.7 V and 6 amperes current is used as active heating system which is combined with middle layer and sandwiched between inner and outer layer in sleeping bag. The combined GSM of three layers were 930 with thermal insulation value (TOG) of sleeping bag is 9.03 which can be easily increased in range of 10-11 by turning on the heating system. The developed sleeping bag will be suitable to work at -15^{0}C temperature zone.

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