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Airjet Textured Yarn Fabrics for Airbag: An Innovative Approach

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Abstract

Airbag act as safety device in vehicles, which activates when sensor detects crash or collision. Worldwide majority of airbag fabric is made of Nylon 66 yarn. The problem in airbag are repositioning of airbag, space occupied and cost. In this project attempt has been made to make airbag fabric from Nylon 66/Polyester combination airjet textured yarn to reduce the cost. Also attempt has been made to reduce fabric volume to reduce space occupied using air textured blend yarns. The 6 different type of airbag fabric has been manufactured and compared with commercially available fabric. The some of the parameters has been changed during process like Low tenacity (LT) Polyester has been replaced by High tenacity (HT) Polyester to get better properties of fabric. The fabric has been further coated to improve the air permeability and performance of the fabric. The further it has been observed that fabric properties can be match with commercial fabric. This airbag fabric can efficiently use for secondary airbags.

Keywords: Airbag • Textured yarn • Fabric volume • Air permeability • High tenacity

Introduction

Scope of study the history of Airbag starts from the invention which is credited independently to the American John W. Hetrick, whose patent was granted on 18 August 1953. Later research during the 1960s showed that compressed air could not inflate the mechanically based airbags fast enough for maximum safety, leading to the current chemical and electrically based airbags. An airbag is an inflatable cushion designed to protect passengers from serious injury in the case of an accident. The airbag is part of an inflatable restraint system, also known as an air cushion restraint system (ACRS) or an air bag supplemental restraint system (SRS) [1-4]. Airbags and the seat belts are two components of car safety device, which protect human body under the impact during accident. Different parts of airbag system are propellant, sensors, airbag cushion, and inflator assembly. The propellant is made of sodium azide and an oxidizer, a chemical that helps the sodium azide to burn when ignited. The airbag is manufactured from nylon-66 and polyester woven fabrics. The airbag cushion should have properties like bursting strength, air permeability, seam strength which are important during its performance. Hence during manufacturing proper selection of material and parameter is necessary to get good tensile, tear, bursting strength and low air permeability. The future for air bags looks promising because this type of airbag can be used in range of vehicles from aircraft to motorcycle. The next generation of air bags development more focusing on performance oriented, give better safety and will be more economical to produce.

Basic requirements of airbag

Performance of airbag fabric is dependent on type of fiber used, fabric parameters and stitching of airbag cushion. The fibers used for airbag fabrics should have considerable high strength, thermal stability and energy absorption capability, good ageing characteristics, coating adhesion and functionality under extremely hot and cold environmental conditions. Fabric properties are also dependent on type of fiber used and other requirements of better performance of airbag is the fabric should have high tensile, bursting, tearing strength, good ageing property, easily coat able and crease recovery [5-15].

Design consideration

The performance of the airbag is expected to remain essentially unchanged over the period, and reliable and predictable behavior of the proper materials selection is essential. The other factor is cost of the system, which is quite higher to be installed in an economic category vehicle. Cost of airbag module in approx. Rs 15,000 or more which is not a negligible amount. So in order to reduce cost of airbag system, cost reduction in airbag cushion is more important. Also the crease recovery of current airbag fabric is very low which makes permanent deformation at long duration [15-18]. The airbag designer needs to adjust both the airbag and textile design to meet the thermal management needs associated with particular inflators. The tools that are normally used are

1. Multi- layering of fabrics around the inflator

2. Increasing the amount of nylon yarns in the fabric

3. Fabric construction or by silicone coating.

Hence, The attempt has been made to produce airbag fabric from different airjet textured yarn made from Polyester and Nylon 66 combination to improve certain properties for better performance of airbag fabric and can be economical to produce when compared to commercial airbag fabrics. The main aim of this project is to produce the airbag using different combination of polyester and nylon 66 airjet textured yarns to reduce the volume and cost of the airbag fabric and check the performance [18-20].

Materials and Methodology

Materials

In this project Nylon 66, Low tenacity (LT) Polyester and High tenacity (HT) Polyester were used. These yarns were texturized in different combinations to study the effect in final product. Details of Parent filament yarns are given in Table 1.

The nylon-66 was procured form Shree Balaji Polyfils Ltd and polyester yarns were procured from Reliance industries Ltd. All the properties have been checked using ASTM standard.

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Experimental set up

Airjet texturing of yarn: The filament yarns were textured on ELTEX texturizing machine. The combination has been prepared by mixing nylon-66 and polyester as given in Table 2.

The texturing of parent yarn has been done using Hemajet with 10% overfeed, 7 bar air pressure and 300 m/min winding speed. The loop size, loop frequency and Instability measurement done using standard method.

Weaving of textured yarn: The airbag fabrics from textured yarn have been manufactured on Picanol-GTM loom at Nimako Synthetics Pvt Ltd, Vadodara. The different warp and weft combinations have been prepared as shown in Table 3.

The plain weave fabric construction taken 56X48 (warp and weft density), loom speed 300 rpm, fabric width of 56 inch

Finishing process: The heat setting of the fabric produced has been done. Each sample fabric was heat set at 150°C for 15 mins in stenter to relax the internal stresses of the fabric developed during the weaving process. Heat setting was done to set the stress generated during texturing process, thus reducing loop instability. Due to heat setting yarn density increases slightly this slightly decreases air permeability [21,22].

Fabric coating: Coating was done in textile chemistry department at The M.S. University of Baroda, of selected fabric has been done at lab scale by using knife coating method and curing it for 15 mins at 150°C temperature. Setting of knife is 0.10 mm from the fabric [23,24]. Coating material Elastosil NT76, was procured from WACKER Ltd. This mixture is elastic in nature upon curing and also reduces abrasion and non-toxic in nature. Fabric has been test for mechanical and performance properties as per ASTM standard [25-28].

Table 1. Parent yarn properties.

Yarn	Denier/filament	Stress (gpd)	Strain (%)
Nylon 66	210/34	5.14	16
LT Polyester	180/72	3.4	37
HT Polyester	210/34	8.4	13.64

Table 2. Texture yarn coding.

Code	Yarn	Denier
Y_{N-66}	Nylon 66	478
$Y_{LTP/N-66}$	LT Polyester+ Nylon 66	446
Y_{LTP}	LT Polyester	501
$Y_{HTP/N-66}$	HT Polyester+ Nylon 66	538
Y_{HTP}	HT Polyester	458

Table 3. Coding of Airbag fabric produced.

Fabric Set-1 Coding			**GSM**
Code	Warp	Weft	
F1	Y_{LTP}	Y_{LTP}	215
F2	Y_{LTP}	Y_{N-66}	220
F3	Y_{LTP}	$Y_{LTP/N-66}$	222
Fabric Set-2 coding			
Code	Warp	Weft	
F4	Y_{HTP}	Y_{HTP}	217
F5	Y_{HTP}	Y_{N-66}	241
F6	Y_{HTP}	$Y_{HTP/N-66}$	228

Results and Discussions

Analysis of texture yarn

The Airjet texturising helps in improve the appearance, great durability, flexibility, better covering power, high abrasion resistance, strength and bulkiness. Also improve crease resistance and dimensional stability [29,30]. In this work airbag fabric has been manufactured using airjet textured yarn in combination of PET and Nylon 6,6. The various combination of textured yarn has been prepared from PET and Nylon 66. The Nylon66, LT polyester used for SET-I and Nylon66 and HT polyester used for SET-II airbag fabrics. The five type of yarns have been prepared were given in Table 4.The two strand of yarn taken together to textured yarn [31,32].

The tensile strength of textured yarn was found little less then parent yarn due to loop structure. The Y_{N-66} gives highest strength even after texturing. $Y_{LT\ PET}$ shows lowest strength value hence for set-II $Y_{HT\ PET}$ has been selected [33]. The all yarn has been prepared at same processing parameter (overfeed-10%, air pressure-7 bar, Take-up speed-300 m/min) and shows nearer value of loop size and frequency. Also gives instability % less than 2% hence stable yarn. This textured yarn has been used in warp and weft to prepare two sets of airbag fabrics. The yarn analysis has been done as per ASTM standards [34].

Analysis of airbag fabrics

The two set of airbag fabric with different weft combination has been prepared

Set-I : The set-I has been prepared taking 100% LT Polyester airjet textured yarn in warp and Nylon66/LT Polyester combination in weft as shown in Table 5(a).

Set-II: The set-II has been prepared taking 100% HT Polyester airjet textured yarn in warp and Nylon66/HT Polyester combination in weft as shown in Table 5(b).

Breaking strength and elongation

Breaking strength of fabric depends on yarn structure, properties, fabric weave and EPI/PPI. In Set-I LT PET textured yarn was used in warp and LT PET, Nylon6,6 and Combination of both has been used in weft. It can be seen in Table 5 (a) that the warp value of breaking strength is lower than the weft of Nylon 6,6 and combination yarn. The commercial fabric (CA) sample of 100% Nylon6,6 filament shown higher values than all samples was obvious. In Set-II the PPI set was lower compared to Set-I because of the higher linear density of the weft, manufacturing on higher PPI gives distortion. Also to increase the breaking strength HT PET textured yarn has been selected. The Figure 2 shows that breaking strength of the warp has been found higher than weft Set-I. But in Set-II warp gives higher strength compare to weft due to higher EPI.

In Set-II F6 gives highest strength compare to all but F4 also give almost similar value. Hence to get better strength HT PET textured yarn can be the

Table 4. Properties of textured yarn.

Sample	Denier	Tensile strength (gpd)	Elongation %	Loop Size (mm)	Loop frequency	Instability %
$Y_{LT\ PET}$	478	3.26	32.46	4	122	1
$Y_{HT\ PET}$	446	4.1	16.23	4	125	0.5
Y_{N-66}	501	4.72	17.39	3	100	1.2
$Y_{LT\ PET/N-66}$	538	3.28	18.67	4	117	1.2
$Y_{HTPET/N-66}$	458	4	16.91	3	110	1

Table 5(a). Performance analysis of fabric Set-I.

Properties	F1		F2		F3		CA	
EPI	62		59		61		44	
PPI	52		50		50		42	
Fabric thickness (mm)	0.44		0.48		0.49		0.44	
GSM (g)	212		242		228		265	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Breaking strength (N)	844.98	994.15	1090	1230.54	976.75	1262.81	2550	2398
Elongation %	48.83	40.26	50.23	25.93	46.57	28.97	15.5	16.2
Tearing strength (N)	154.64	174.01	172.72	152.24	153.87	105.64	526.74	505.4
Bursting strength (Kg/cm2)	29.6		43.63		33.65		>60	
Air permeability (l/min)	30		17		23		3.1	

Table 5(b). Performance Analysis of Fabric Set-II.

Properties	F4		F5		F6		CA	
EPI	58		58		57		44	
PPI	48		46		46		42	
Fabric thickness (mm)	0.46		0.49		0.5		0.44	
GSM (g)	217		241		228		265	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Breaking strength (N)	1986	1882	2105	1563	2010	1984	2550	2398
Elongation %	14.64	14.9	14.54	13.2	14.64	14.3	15.5	16.2
Tearing strength (N)	264	247	270	169	265	250	526.74	505.4
Bursting strength (Kg/cm^2)	48.9		43		49.2		>60	
Air permeability (l/min)	18		16		18		3.1	

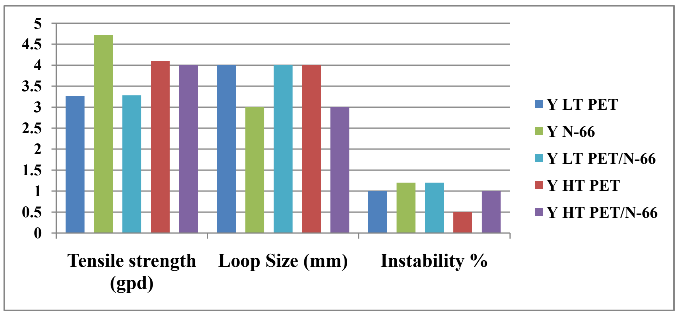

Figure 1. Properties of air jet textured yarn.

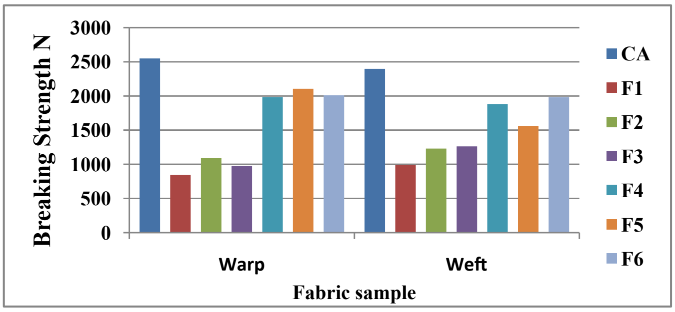

Figure 2. Breaking strength of fabrics.

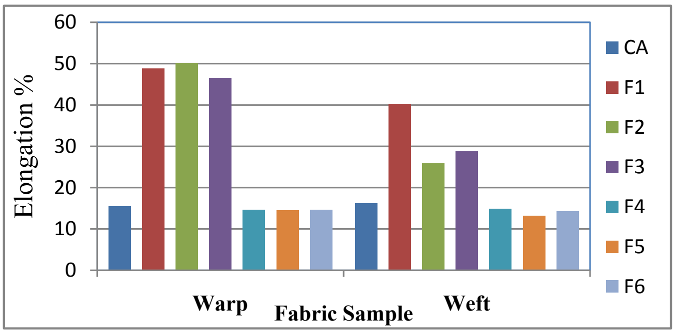

Figure 3. Elongation of fabrics.

cheaper option by designing linear density of filament higher strength nearer to CA can be achieved.

Similarly the HT PET can reduce the elongation of fabric due to its inherent properties. Its clearly observed from Figure 3 that Set-I fabrics gives higher elongation due to LTPET except nylon 66 yarn in weft. The sample F2 has highest elongation in warp direction and F1 has highest elongation in weft direction. Set-1 fabric elongation found very high compared to industrial airbag fabric and Set-II elongation decreases significantly due to HT PET. Hence Set-II gives almost similar value like CA.

Tearing strength

The fabric weave plays important factor, when it comes to tearing strength. Set-I value lies between 105 to 175 N as shown in the Figure 4. The fabric F1 has shown best tearing strength in weft direction and fabric F2 has shown best tearing strength in warp direction.

The fabric F5 has highest tearing strength in warp direction and F6 in weft direction although the difference in strength between fabrics is negligible, except nylon 66 weft. The tearing strength of fabric has been found Set-II fabrics is more than Set-I but lower than CA fabric.

Bursting strength and air permeability

Bursting strength test has been done according to ASTM standards. The Figure 5 shows bursting strength of fabric set-I and II, in which fabric F2 has highest bursting strength in set-I because of nylon 66 used in weft direction. The fabric F4 and F6 shows highest bursting strength in set-II due to HT Polyester and its combination. In fabric set-II HT polyester gives bursting strength nearer to fabric CA. Hence the bursting strength can be improved by increasing nylon66 percentage and by using HT Polyester. Also by changing the weave the result can be compared but in airbag fabric generally plain weave is used hence here data related to plain weave presented.

The threads per inch were kept constant during the process (optimized) but due to the loop structure in the yarn voids are generated give higher air permeability compared to commercial airbag fabric, this is the inherent property of airjet textured fabric. The air permeability is one of the important parameter to decide the performance of the airbag fabric.

If the air permeability is higher, during the expansion of the bag it will not hold the gases. The Figure 5 shows all fabric of set- I and II, shows the higher value of air permeability compared to standards.

Analysis of Coated Fabrics

The fabrics of set-I and II were coated using silicone base polymer. The fabric has been coated at one side, which increases the fabric thickness by 0.1 mm the main purpose of coating is to improve the properties of set-I and also improve certain important properties like air permeability the analysis of coated fabric has been done and change in performance and improvement in fabric properties has been given in Table 6.

The coating was done on one side of the fabric which blocked the air gap between the filaments but did not penetrated inside the fabric due to which the contribution of coating in fabric strength was minimal. Due to elasticity of the coating material catastrophic break was observed due to the rupture of the fabric before coating layer. Similar result can be seen in tear strength of coated fabrics. As coating material was only on the surface of the fabric, so there was no significant increase in the tear strength. The fabric C4 gives highest tear strength of all fabrics. The bursting strength of the coated fabrics in which C4 and C6 has highest bursting strength, when compared to non-coated

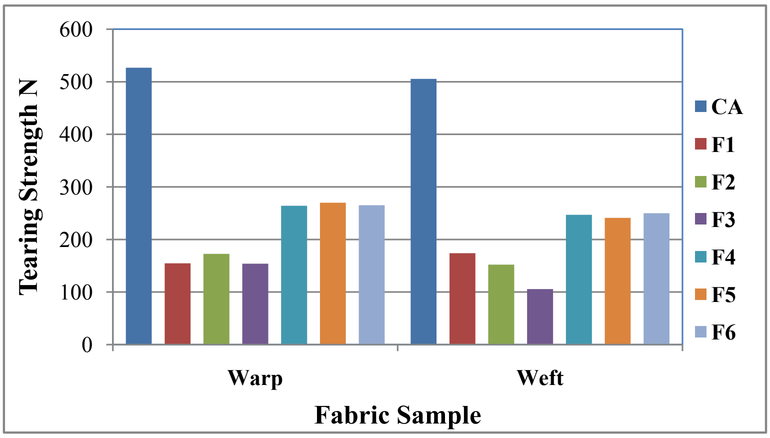

Figure 4. Tearing strength of fabrics.

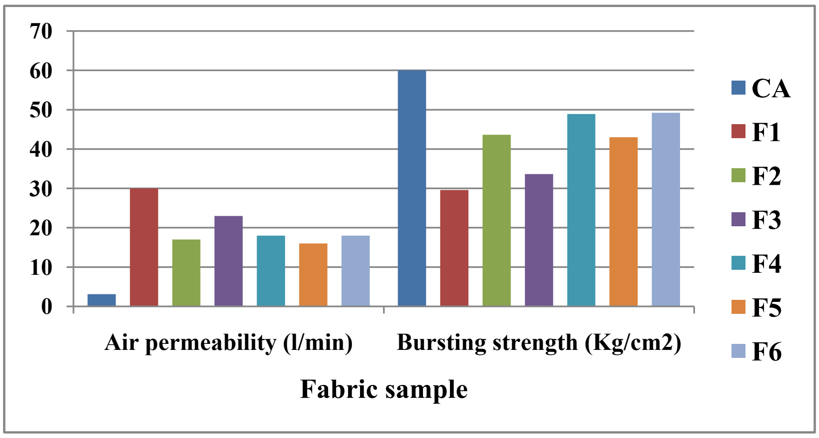

Figure 5. Air permeability and bursting strength of fabrics.

Table 6. Properties of coated fabrics.

Properties	CA		C1		C2		C3		C4		C5		C6	
EPI	44		62		59		61		58		58		57	
PPI	42		52		50		50		48		46		46	
Fabric thickness (mm)	0.44		0.65		0.58		0.64		0.56		0.55		0.56	
GSM (g)	265		310		345		334		285		310		316	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Breaking strength (N)	2550	2398	896.3	1005	1112	1267	985.6	1287	2078	2008	2201	1625	2101	2054
Elongation %	15.5	16.2	50.09	41.8	50.37	27.28	47.92	28.93	14.89	14.55	13.98	14.68	14.21	14.87
Tearing strength (N)	526.7	505	165.2	183.9	179.5	165.9	159.3	125.2	284	278	279	186	286	287
Bursting strength (Kg/cm^2)	>60		32		42		32		50.23		44.1		50.06	
Air permeability (l/min)	3.1		3.3		3.2		3.3		3.3		3.6		3.5	

fabrics there was increase of approx. 1-2 Kg/cm^2 in each fabric. This was due to elasticity of coating, which holds the yarn little more before bursting. The coating applied penetrate into the voids of textured yarn and gap between yarn, which increased cohesion between yarn and coating thus increasing bursting strength and reach to the level of commercially available fabric. The air permeability is main performance parameter as discussed before the non-coated fabric gives inferior value of air permeability, hence coating has been done. Due to coating air gap filled by silicone base polymer and improves air permeability.

Conclusion

The airjet textured yarn prepared using polyester, nylon66 and its combinations gives stable structure and good feel due to loop structure and helps in reducing volume of fabric. The airbag fabric prepared using textured yarn in warp and weft gives good quality of the fabric with better cover. The airjet fabric structure gives little less strength and high permeability due to loop structure in grey fabric. The sample (F4) manufactured using 100% high tenacity polyester give superior performance but not similar to commercially available fabric. In airjet textured fabric due to loop structure and air trapped within structure gives high air permeability hence coating is required. The coating was done in order to reduce the air permeability, whose result came out as expected and reduced air permeability drastically to 3.3 litre/min. This product can be used as side airbags.

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