IJARESM
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ENGINEERING, SCIENCE & MANAGEMENT

INVESTIGATING QUALITATIVE AND ECONOMICAL EFFICACY OF POLYLON YARN FOR AIRBAG FABRIC MATERIAL

Dr. (Mrs.) Tasnim N. Shaikh[1], Dr. Satyajeet Chaudhari[2] and Mr. Hiren Rasania[3]
Associate Prof., Textile Engg., Faculty of Technology & Engg., Vadodara, Gujarat, India[1]
Associate Prof., Textile Engg., Faculty of Technology & Engg., Vadodara, Gujarat, India[2]
ME Student, Textile Engineering, Faculty of Technology & Engg., Vadodara, Gujarat, India[3]

Abstract: The deaths among drivers using both airbags and seat belts are quite lower than among drivers using seat belts alone. Thereby installation of airbags for occupant as well as passenger becomes mandatory in the newly produced cars. This has boosted up airbag markets. Continuous research is going on for making airbag fabric material qualitatively and economically efficient to meet budget of major end users. Important requirements for the airbag fabric are low air permeability, a low fabric weight, a low fabric thickness (to save space in the automotive vehicle), high fabric breaking strength and breaking extension (to absorb the energy in the explosive unfolding of the airbag).

Early from the development stage, Nylon 6, 6 has occupied most favourable position in this regard, but its higher cost always remains debatable. Optional materials are high performance fibres like; Glass, Aramid, Carbon, etc. They are also not cost competitive. Nylon 6 and high tenacity Polyester can be possible options. However, they have failed as an individuals during experimentation in fulfilling all requirements of this end use. But they can serve as a good compliment for each other. Looking at these out comes only, their core-sheath composite; Polylon yarn was designed. Core of the yarn was engineered out of 70% high tenacity Polyester, possessing better surface resistance in adverse atmospheric conditions and 30% sheath with better impact resistant holder Nylon 6.Such a unique combination yarn was verified for its feasibility in serving as an airbag fabric. Comparative analysis was carried out for its physical, mechanical and thermal characteristics with Nylon 6, 6; the most versatile material in this area.

Polylon has shown superiority over Nylon 6, 6 in terms of percent extension, initial modulus, melting point, specific heat and cost. However, it is lagging in terms of tenacity and density. Nylon 6, 6 yarn can be substituted by this new polymer having enough strength in terms of quality and cost for automobile safety restraint system.

Key words: **Airbag, Economy, Initial Modulus, Melting point, Polylon, Toughness**.

I. INTRODUCTION

Airbags are designed to act as the supplemental safety device in addition to the seat belt. They have been commercially available since late 1980’s. There is a significantly higher reduction in moderate to serious head injuries for people using airbags and seat

belts together than for people using only seat belts, when compared to drivers using no restraining safety equipment [2, 3, 11].

Nylon 6, 6 remains the material of choice for airbag fabric since long although costly. Nylon 6 can be a good option due to, its favourable properties especially impact resistance. However, it is inferior to high tenacity Polyester fibre in humid heat resistance, light resistance, shape stability as well as cost for the purpose being. Impact analysis of both the yarns failure has indicated that Nylon 6 is superior in the limitation areas of high tenacity Polyester and vice versa. So, their composite yarn was made out of 70% high tenacity Polyester at core and 30% Nylon 6 at sheath to get beneficial properties together [4, 8]. Quality parameters were investigated for the newly engineered composite polymer. This can help in identifying its acceptability as an optional material for airbag fabric.

II. EXPERIMENTAL

Airbag material has to play a vital role in the success of safety restraint system of automobiles. Prize reductions along with improved performance are the two major constrains for this fast growing industry. Implementation of new efficient but cheaper material and simplicity in the airbag production process are two way solutions possible. Verification of newly engineered composite yarn strengths for airbag fabric application is the step put forward in the direction of first option.

A. Materials

Nylon 6,6, with the fineness ranging from 420 denier/ 68 fils. to 840 denier/148 fils., is the most versatile material used in airbag fabric manufacturing[1, 3, 8]. So, Polylon yarn fineness value was also selected identical, viz; 420denier/ 200 fils. for giving a valid ground of comparison. However, filament fineness of both the yarns were not same. This difference was intentionally retained as per pack-ability requirements of an air bag within small gap available in today's modern compact car steering [3, 6]. Accordingly yarn having individual filament fineness less than three can enhance air bag fabric performance by increasing cover factor and fold ability [7, 12]. Experimenting with fine denier filament Polylon yarn can only provide a true picture in defining its feasibility as replacer as per modern car needs.

B. Methods

Polylon is the newly introduced material in the market. Its quality parameters important for this application were measured as per standard test methods [5, 10, 11]. They are broadly divided into three groups as follows:

Physical Properties: Yarn fineness and Filament Fineness

Mechanical Properties: Tenacity and breaking extension

Thermal Properties: Density (kg/m^3), Specific Heat Capacity (kJ/kg/^{0}C), Melting Point (°C), Softening Point (°C) and Energy to melt (kJ/kg).

Kamal Metal Industry's manually operated 1 meter circumference wrap reel along with LIBROR AEL-40SM with 0.0001gm accuracy were used for measuring yarn fineness. Average of ten readings for 90 meter skein were taken into consideration. Numbers of filaments were counted by using a magnifying glass (10X). Then filament fineness (dpf) was calculated by equation 1

 ISSN : 2394-1766

$$\text{Denier per filament(dpf)} = \frac{\text{Yarn fineness (denier)}}{\text{No of filaments}} \quad \ldots\ldots\ldots \quad \textit{Equation 1}$$

Mohalo's Star Moisture meter working on the electrical resistance principle was used for moisture measurement. Average of hundred readings was considered. Proportion of Polyester and Nylon in the Polylon yarn was defined by the solvent method.Hemtech Melting test apparatus was used for measuring softening and melting point.Thermal characteristics of the samples were analysed on PerkinElmer Differential Scanning Calorimeter 6000-Series (DSC 6000) in heat- cool-heat mode[10].The experimental Heat of melting (ΔHm) in kJ/kg and melting point were measured by using software. Specific Heat Capacity (kJ/kg/^{0}C)of the yarns was measured as per following relationship.

$$\text{Specific Heat Capacity}C_p = \frac{\text{Heat of melting } (\Delta Hm) \text{ in kJ/kg}}{\text{Heating Rate in } {}^0C/_{min}} \quad \ldots\ldots\ldots \quad \textit{Equation 2}$$

Free Shrinkage of yarn at 177^{o}C was measured by using chemical oven. Yarn of 500mm length (l_o) measured at tex/2 ± 10% tension was cut. It was hanged freely in chemical oven set at 177^{o}C temperature and standard humidity for 15 minutes. After 15 minutes its length (l_f) was measured at the same tension. Difference in the length was expressed as the percentage of original to calculate percent free shrinkage. The tensile strength and extension of yarn was measured on a computer aided Lloyd tensile tester –LRX model, working on CRL (constant rate of Load) method. The test specifications used during test were gauge length: 200 mm and cross-head speed: 200 mm/min.

The quality parameters of Nylon 6, 6 yarns used in commercial air bag fabric and meeting the suggested standards of MERCEDEZE BENZE were obtained from earlier researches [2, 6, 12]. They are used as reference values in present experiment.

III. RESULTS & DISCUSSION

Yarn performance analysis was done as per three categories defined in previous section.

A. Physical Properties:

Yarn as well as filament fineness values provided by the manufacturer were confirmed by test results. They are reported in table 1.

Table 1: Comparison of Yarn Physical Properties

Type ofYarn / Yarn Properties	Commercially used Nylon 6, 6 in airbag		Experimented Polylon
Yarn fineness (d)	840	420	420
Filament Fineness (d)	5.68	6.18	2.10

B. Mechanical Properties

Mechanical properties measured for Polylon yarn and reference value of Nylon 6, 6 yarn are reported in table 2.

 ISSN : 2394-1766

Table 2: Comparison of Yarn Properties

Type of Yarn / Yarn Properties	Experimented Polylon	Commercially used Nylon 6, 6 in airbag
Specifications	420d	420d
Tenacity (g/d)	5.88	7.9
Breaking extension (%)	25.04	21.00
Initial Modulus (g/d)	45.82	50-60
Elastic Recovery	100% at 8%	100% at 8%

Strength (tenacity) of Nylon 6, 6 is found superior over Polylon yarn. However, the suitability of the material can be judged on the basis of toughness of fabric made out of it, rather than yarn strength. Airbag made out of low toughness fabrichas low resistance in absorbing the momentary expansion impact of the inflator having a high temperature and high pressure. Such fabric for an airbag can easily be torn when the airbag is unfolded [5, 6].
Toughness of fabric represents the cross sectional area of the tenacity-elongation curve of the fiber and the fabric [5, 7].The fabric said to be have higher toughness as the tenacity and the elongation of the fiber that is used to the fabric becomes higher. Contrary to tenacity value, percent extension executed by Polylon here is high [table 2]. So, until yarn is realized into fabric and checked for toughness, prediction about material suitability for air bag fabric application will be error some.
Elastic recovery and initial modulus of Polylon has shown very close resemblance with Nylon 6, 6 [table 2]. These properties define extent of material stiffness. Material with low values offers a uniform biaxial stress distribution along perimeter seams in an airbag due. Thereby when the airbag deploys and the seams come under stress, low stiffness allows it to extend fast under low force. This allows the force to be widely distributed, thereby enhancing fracture resistance at the highest stress points[5, 12].Polylon with comparatively low stiffness value [table 2], thereby occupies a favorable position in air bag fabric material over Nylon 6, 6.

C. Thermal Properties:

Air bags are working in the hostile atmospheric conditions at the point of collision; very high temperature due to explosion of hot gases during deployment [1, 3, 9]. So, the raw material needs to be evaluated in terms of their thermal characteristics. Test results obtained from Hemtech Melting test apparatus and Perkin Elmer DSC- 6000 are reported in table 3.

Table 3: Comparison of Thermal Properties of Yarns

Type of Yarn / Yarn Properties	Experimented Polylon	Standard Nylon 6, 6
Specific Heat Capacity (kJ/kg/^{o}C)	2.35	1.67
Melting Point (°C)	285	260

 ISSN : 2394-1766

Softening Point (°C)	240	220
Free Shrinkage at 177°C (%)	8	9- 10
% Moisture Content at 65% R.H.	3.2	4.0
Density (g/cc)	1.216	1.140

Polylon has shown higher values for melting point, specific heat capacity and softening point but lower value of free shrinkage than Nylon 6, 6[table 3]. Polylon with higher melting temperature and specific heat capacity requires more amount of energy (approx. 35% higher) to melt. Hence in any inflation event that uses a pyrotechnic or pyrotechnic-containing inflator, cushions made from Polylon yarn are thereby expected to less susceptible to burn or melt through in the body of the cushion or at the seam [5, 8].

Contrarily, lower thermal shrinkage expectedly brings about 15 to 20% reduced air permeability for Polylon yarn fabric as compared to Nylon 6, 6 one [6,7]. This can be a negative credit for Polylon in meeting basic requirements for airbag fabric.

Moisture properties of the yarns are required to be considered along with thermal characteristics as inflated hot air bag surface makes direct contact with the skin of the occupant at the point of collision [7, 8].That's why percent moisture content values are accommodated along with thermal properties [table 3].

Although having higher proportion polyester on cover, moisture content of Polylon is 3.2%, very close to Nylon 6, 6. So, it will offer the beneficial additional quenching characteristics of Nylon at the point of hot gas deployment. Similar to Nylon, it can typically absorb near about 4% water by weight. Thereby helps in preventing burn-through from hot particulates that potentially can break free from the inflator and travel into the inflating airbag [4, 5]. Thus similar to nylons, it will also require more heat before it begins to lose its properties. This can makes Polylon better suited material for the air bag in terms of occupant's burnt injury against the blast of hot gases during deployment.

Polylon has higher density as compared to Nylon 6, 6 [table 3]. As a result of which the cushion made out of it can have added 6% mass and cost. However, cost/kg of 420d/ 68 fils. Nylon 6, 6 yarn ranges between Rs. 350- 380, whereas Polylon yarn of 420d/ 200fils. ranges between Rs.180 -200, as per market survey. Thus added 6% cost of cushion on added mass can be easily off set by much lower basic cost of Polylon material by approx. 64%. But the added mass of economically effluent material can adversely affect the kinetic energy of impact on the occupant in out-of-position situations thus reduces safety. So, higher density of Polylon makes it inferior to Nylon 6, 6 in terms performance.

IV. CONCLUSION

- Polylon is the newly designed composite polymer of complimentary materials, viz; 70% high tenacity Polyester and 30% Nylon 6.Polylon with equivalent yarn size but finer constituent filaments was checked for its feasibility as an airbag fabric material. The yarn values were compared with Mercedes Benz standards met by equivalent size Nylon6, 6 yarns.
- Polylon yarn has shown lower tenacity of 5.88 g/ denier, but exhibited higher extension of 25.04 %, to the standards. It is compatible with standards in terms of elastic recovery and initial modulus. However its significance in expected application area can be realized only after fabric formation and analysing it for fabric toughness.

- Higher density of Polylon (1.2160 g/cc) as compared to Nylons (1.14 g/cc),adversely affects the kinetic energy of impact on the occupant, especially in out-of-position situations.Even it adds to the mass of airbag fabric made out of it by 6%. But lower basic cost of the new material prevail it in the economy race.
- Higher melting point, softening point and specific heat of Polylon, supersede it over Nylon 6, 6 in terms of susceptible to burn or melt through in the body of the cushion or at the seam. This favourable thermal behaviour is further supported by possessing almost identical 3.2% moisture regain required for subsidizing burn injury similar to that of Nylons.Free shrinkage of Polylon at 177^0C is low (8%) against the desirable standard (9-10%). This can negatively attribute to its permeability behaviour at the point of collision.
- Innovative composite yarn has shown upper hand over Nylon 6, 6 in main targeted thermal characteristics. Its short fall in terms of tenacity and free shrinkage can be well judged only after fabric formation, making airbag and exposing collision test condition.

REFERENCES

[01] C. Bastien, M. V. Blundell, D. Stubbs, J. Christensen, J. Hoffmann, M. Reisinger and R. Van Der Made, Correlation of Airbag Fabric Material Mechanical Failure Characteristic for Out of Position Applications" PROCEEDINGS OF ISMA 2010 INCLUDING USD2010, pp 1679-1683.

[02] Dupont Airbag End-Use Technology, "Marerial selection for Air-bags", March 2003, pp 1-8.

[03] E. W. Kenneth, "Bags, Buckles, and Belts: The Debate over Mandatory Passive Restraints in Automobiles",Journal of Health Politics, Policy and Law, 1983**,**Vol. 8, No.1, pp: 44-75.

[04] G. W. Nelb, "Global Trends in Airbag Fibers and Fabrics", International Fiber Journal, Dec 1998.http://www.fiberjournal.com/issue/december98/story1.html.

[05] MADYMO Theory Manual Release 7.2 on Jan. 2010, pp 253-298.

[06] R. Keshavaraj, R. W. Tock, and Dan H, "Analysis of Fabrics used in Passive restraint systems", Journal of
Textile Institute. (U.K.), pp. 1-5, March 2009.

[07] R. Keshavaraj, R. W. Tock, and Nusholtz G. S., "Evaluating airbagfabrics, Automotive Engineering", Vol.103, 11, pp 55-58, 1995.

[08] S. K. Mukhopadhyay and J.F.Patridge, "Automotive Textiles", Textile Progress, The Textile Institute, 29(172), 1997.

[09] T. N. Shaikh, S. B. Chaudhari and H. Rasania, "Air Bag: A safety Restraint System of an Automobile", Int. Journal of Engineering Research and Application www.ijera.com Vol. 3, Issue 5, Sep-Oct 2013, pp.615-621.

[10] T. N. Shaikh, S. B. Chaudhari and H. Rasania, "Study the Thermal Behaviour of POLYLON: An Emerging Composite Filament", International Journal of Advances in Management, Technology & Engineering Sciences, Vol. IV, Issue 3 (I), Dec. 2014, pp: 31-33.

[11] W. Fung and M. Hardcastle 'Textiles in automotive engineering' Woodhead Publishing Limited, pp 231-234, 2001.

[12] "What do you know about air bag?"- National Highway Traffic Safety Administration (NHTSA) Publication, Nov. 2002. www.nhtsa.dot.gov.

