OCCUPANT SAFETY RESTRAINT DEVICES
– PRESENT SCENARIO AND FUTURE SCOPE

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ABSTRACT:

Incase of accidents, passenger lives can be saved greatly by use of seat belts and airbags in the automobiles. The safety implications of these systems and the stringent safety regulations in the US and Europe have brought a growing market to these products. Present paper lays emphasis on the textile component (i.e. the fabric) of the seat belt and airbag. These fabrics have been discussed with reference to its structure, production, developments and future market potential.

1. INTRODUCTION:

There has been a significant rise in living standard and safety regulations made by the government for the people in developing nations. This has led to an increasing demand on the automobile manufacturers to introduce safety devices viz. seat belts and airbags[1] for the user.

Table 1: The Value Of World-Wide Market For Use Of Occupant Safety Restraint Devices ($ bn)

Regions	Seat belts		Airbags		Total	
	1990	1996	1990	1996	1990	1996
N.America	1.0	1.0	0.6	4.3	1.6	5.3
Europe	0.9	1.3	0.1	1.2	1.0	2.5
Japan	0.4	0.6	0.1	0.5	0.5	1.1
Other	0.1	0.7	-	0.6	0.1	1.3
Total	2.4	3.6	0.8	6.6	3.2	10.2

From Table 1, it can be seen that the market for safety restraint devices has shown a significant rise from 1990 to 1996 and is expected to grow further with rising consciousness among the consumers.

Seat belts are easy to use, effective and inexpensive means of protection in an accident. Use of airbags in a vehicle provides additional safety but it is not an alternative to seat belts. They co-exist to provide absolute safety to the passenger. This is so because the airbags provide protection against head-on collision while the seat belts provide protection irrespective of the direction of crash.

It is reported[2] that more than half of the severe injuries and deaths in automobile accidents are due to frontal collisions. Compared to seat belts alone, airbags have reduced deaths by 28% and hospitalisation by 24%.

2. SEAT BELTS:

The seat belt is an energy-absorbing device that is designed to keep the load imposed on a victim's body during a crash down to survivable limits. Fundamentally, it is designed to deliver non-recoverable extension to reduce the deceleration forces, which the body encounters in a crash.

Seat belt was invented[3] concurrently in United States and Sweden. Americans introduced belts as a strap that supports the waistline while the Swedish belts supported the body of the occupant diagonally. In present day, a combination of the two is more prevalent. Earlier seat belts were fixed and adjusted manually by the wearer. With the introduction of automatic belts today wearer has more freedom to move. Due to retracting mechanism and a special housing, seat belts now can be stored out of sight whilst not in use.

THE SEAT BELT WEBBING:

Requirements[4]:

The seat belt is required to have the following properties:

- Static load bearing capacity upto 1500 kg and extensibility upto 25-30%
- Abrasion resistance
- Heat and light resistance
- Light weight

- Flexibility for use

Manufacture*[5-7]*:

Seat belts are narrow fabrics woven from filament yarns. As per its requirements, the material used for seat belts could be either nylon or polyester. But, polyester scores over nylon because of lower extensibility and higher stiffness. Thus, polyester commands a greater share of the seat belt market whilst nylon holds a niche position.

Original seat belt webbing was woven on shuttle looms, around 1959. These looms were capable of delivering up to 200 weft insertions per minute from small weft supplies which frequently needed replenishing. The needle loom used presently is shuttleless and capable of delivering over 1000 picks per minute. Twill or satin weaves are used for seatbelts.

A typical structure of seat belt is shown in the fig 1.

A typical seat belt is made of 320 ends of 1,100 dtex polyester each. Most weft yarns made from polyester are 550dtex. Warp direction in the belt is more critical since the load is applied mostly in that direction. Commonly used seat belt webbing is a narrow fabric measuring 46mm wide. Commercial needle looms can accommodate six weaving stations simultaneously side by side. In the needle loom, the weft is inserted from one side of the warp sheet and here a selvedge is formed. The other side of webbing is held by an auxiliary needle, which manipulates a binder and a lock thread. Once these are combined with the weft yarn, a run-proof selvedge is created. Special care is taken when constructing the selvedge to ensure it is abrasion resistant. It is equally important to ensure that the selvedge is soft and comfortable to wear.

In case of nylon seat belts, the warp yarns are 180 dtex and the weft is either 470 or 940 dtex.

The woven seat belt webbing is, then transferred under tension to a dyeing and finishing range. The Grey webbing is dyed and heat set whilst webbing made from spun-dyed yarn is heat-set only. The two different routes are shown in the Fig 2.

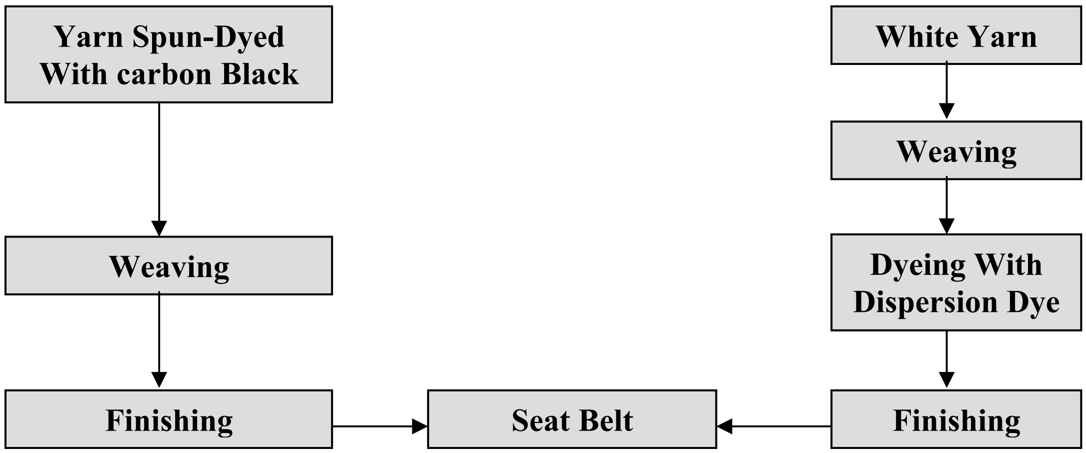

Fig. 2: Different Routes for Finishing of Seat belts

Heat-setting is undertaken to impart precise extension to the webbing and suppress its recovery in the event of crash. This is achieved by shrinking the webbing in a controlled manner which increases the weight of webbing from 50 g/m to approximately 60 g/m. In preparation for heat-setting the material is run through an Infra-Red dryer. Four lengths of webbing can be processed in parallel.

Seat belt webbing can be coloured by two methods: either by incorporating spuin-dyed yarns or by piece dyeing. The appropriate technique for piece dyeing polyester webbing is by thermosol process. Around 1978, about 80% of seat belts used spun dyed yarns that had extremely high light and rub fastness. By the early 1990s in the Western Europe, 60% of seat belts were still made from spun-dyed yarn, but 40 % were piece dyed[8]. More recently the production of piece dyed belts has increased to reflect the demand for more colour co-ordinated interiors.

European cars are fitted with black seat belts and coloured varieties are reserved for promotional model and sports cars only[9]. The Americans are more enthusiastic about coloured belts and Japanese have consistently incorporated white yarn in their seat belts to be piece dyed later.

Performance Tests And Standards for seat belt webbing*[3]*:

Tests are carried out for ascertaining the mechanical performance of the webbing as per BSI and the SAE.

- Width
- Thickness
- Breaking strength and elongation for dry and wet webbing
- Abrasion resistance at various environmental conditions and in contact with buckles and fittings
- Influence of extreme environmental conditions and temperatures
- Rubbing fastness
- Microbial resistance

Development:

The webbing will have good abrasion resistance if only short wrap floats are exposed upon its face and back. The same material has to be light, slim, smooth, so that it facilitates neat storage and runs smoothly in and out of the seat belt housing. Weave variation like the satin or pebble weaves have been tried out. The pebble weave has a two-up, two-down, configuration, which does combine the yarns in an aesthetically pleasing manner but offers limited abrasion resistance. This style of webbing has been found suitable for the replacement seat belt market where the standards are less demanding[5].

The inflatable seat belt[10] is an amalgamation of the air bag and the seat belt. This belt is held by weak stitches that burst open when the belt is inflated. Under impact the belt gives 450% more surface area than the normal flat belt. These belts could be fitted in the rear seats of the automobile to replace use of air bags in that compartment.

3. AIRBAGS:

Introduction:

An airbag is an automatic safety controls system built-into the steering wheel and various other strategic locations of the vehicle. The rise in safety consciousness in the developed nations like Australia, Europe and the US has made airbags compulsory for the safety of the occupants. It is projected by 2003 all the new automobiles will incorporate airbags [4].

General Motors first introduced Airbags in 1970. But, these were not readily accepted by the consumers then. Later, with the implementation of Federal Motors Vehicle Safety Standards (FMVSS) of US in 1984 that all automobiles should have front airbags, their market prospects improved. Accordingly, there was found to be an increase in cars with airbags in America during 1992.

Construction and Working[11]:

An airbag module consists of airbag, inflator device, mounting hardware and molded cover. The crash sensors and the diagnostics are the part of the system. The inflators are primarily sodium azide crystals, which upon combustion produce nitrogen gas. The cross-section of airbag assembly is shown in Fig. 3. Fig. 4 shows the sensor assembly of an airbag and its working is shown in Fig.5.

As per the estimate all collisions occur within 0.125 seconds; hence, the airbag system is designed to inflate in less than 0.04 seconds. The working of an airbag system in the process of a collision can be described as below:

When the frontal crash that exceeds a pre-determined severity level (approximately 16-19 km/hr), the following occurs:

'*The crash sensor is activated sending an impulse to an electric module. This module evaluates the strength of the input signal and triggers an electric impulse of similar strength. The electric impulse causes the central igniter inside the airbag to fire. Igniter burn penetrates the propellant chamber. Propellant ignites to produce and expel hot (but otherwise harmless) nitrogen gas, comprising of 78% ambient air. The gas passes through a filter and enters the system's nitrogen bag through inflator ports. The result is an inflated bag with a decorative over cover on the steering column or the instrument panel. All this occurs within 0.06 second. The inflated bag now cushions the occupant in the form of pneumatic damping. 0.12 seconds within absorbing the impact, the airbag deflates.*'

Thus, the impact of the frontal collision is averted by the use of airbag.
The stages involved in operation of air bag are shown in Fig. 6.

Types Of Airbags:

The airbags depending upon their placement in the vehicle can be classified as:

- Front driver/passenger airbag – capacity, 65 Litre fill
- Rear passengers side-impact airbag – capacity, about 100-300 Litre fill

It is reported[12] that Drivers' airbag requires about 1.5 sq.m of fabric while, the passengers' side airbag require 3.0-4.0 sq.m. It varies slightly from region to region(i.e. from US to Japan). Depending on the type of automobile, the airbag construction differs. Thus, an airbag for a car differs from that of a truck. The photographs of drivers' airbag and passengers' side airbag are shown in Fig. 7.

***Airbag Fabric Manufacure*:**

Requirements:

The airbag fabric is required to have the following properties:

- High strength
- Heat stability
- Good aging characteristics
- Energy absorption
- Coating adhesion
- Functionality at extreme hot and cold conditions.

Tear strength, packageability and reduced skin abrasion is also desired.

Most widely used raw material for the airbag fabric is Nylon-6,6 yarn in the deniers ranging from 420 to 840. The side-impact airbags use 1880 D Nylon-6,6 yarns.
NYLON-6,6 is chosen for airbags as it has a very high strength to weight ratio and is available at an economical price(in US context). Nylon in general offers advantage of performance in hostile environments. Higher elongation in nylon proves beneficial as it helps uniform distribution of stress along the circumference of the airbag.

Thermodynamically too, nylon has a higher specific heat capacity, high melting point and heat of fusion as compared to other common fibres like polyester.

Also the 4% moisture absorption capacity of nylon provides higher quenching property for the hot particulate matters(emerging from the ignitor) that can break free from the inflator. This helps to suppress burn injury to the crash victim.

These fabrics are generally woven with the following construction:

- 840 x 840 D, 98 x 98 /dm, plain weave, 60 inch width
- 420 x 420, 193 x 193, plain weave, 60 inch width

Side passenger airbags are generally uncoated. These are larger in size and pressures developed are lower and have longer inflation time. The weight per unit area of uncoated one is higher than the coated one, i.e., 244 to 257 Vs 175 g/ m^2. This is because these airbags are of coarser denier with denser weaves and thickness ranging from 0.33 to 0.4 mm[14].

There is a stringent control required on the number of defects in the fabric. The defect area should be less than 0.5 mm^2 and there should be less than 3 defects per 100 m of fabric.

Rapiers with insertion rate of 400 m/min. have been found most suitable for weaving airbags. Also, airjets with an insertion rate of 600 m/min. are being used [15].

Dornier Rapier[16-17] suitable for weaving high density, a high performance industrial fabric from filament yarns is suitable for weaving airbag fabrics. It can maintain the warp tension with absolute accuracy of 1cN per warp. This helps in maintaining a constant fabric density. Other advantageous features are: knot free weft insertion, Automatic Start-mark Prevention (ASP) etc. Even Dornier-Airjets can also be used for weaving airbag fabrics.

After weaving these fabrics are scoured, heat-set and subjected to coating(neoprene) operations. A good coating is required to have better adhesion, anti-blocking, long term flexibility, resistance to cyclic temperature changes(-40 ^{0}F to 250 ^{0}F), ozone resistance, long term stability and low cost.

When the bag is finished, it is cut into panels that are sewn together. Cutting and sewing of airbag fabrics needs careful attention as dimensional tolerance is very small. Sewing patterns and stitch types are critical for the performance of airbag. The best method of cutting both coated and uncoated fabrics is using laser. It fuses the edges of the fabric to prevent fraying, this process is also fast and accurate and reduces the cost by eliminating the cutting disc.

- The normal design of the drivers' airbag is two circular pieces of fabric sewn together.
- The passenger bag is tear-drop shaped, made from two vertical sections and a main horizontal panel[18].

The sewing thread is to be chosen properly. Nylon-6,6, Polyester, Kevlar or Aramid fibres can be used for sewing.

When sewn it is folded inside its cover. Like a parachute it is folded with extreme care to ensure smooth deployment. These folds are of various types: accordion folds, reversed accordion folds, pleated accordion folds, overlapped folds etc.

Performance Tests and Standard for Airbag Fabrics[3]:

Over fifty tests are administered upon airbag yarns and fabrics. The certification is a too costly affair. For example, the cost of validating a new manufacturing technique is $50,000 and full certification of the airbag module is $1,00,000.

Yarn:

- Fibre composition
- Yarn linear density
- Yarn twist - twist in yarn from package and from fabric

Fabric:

- Visual inspection and grading
- Fabric length and width
- Thickness
- Mass per unit area

- Air permeability
- Bursting strength
- Breaking force and extension
- Stiffness
- Abrasion resistance
- Accelerated ageing test for heat, humidity, ozone and cyclic
- Flammability.

The degree to which the standards are followed is at the discretion of the purchaser and the supplier.

Developments:

Improvements in the airbag technology are directed towards the following:

1. Smaller package size of the airbag module.
2. Cost reduction thereby
3. Improved occupant safety.

Secondary airbag injuries like abrasion, contusion, scratches and burns are equally fatal and need to be reduced for enhanced occupants' safety. Hence airbags are required to be made lighter, softer and smoother with lower coefficient of friction.

Moving towards the development of a light weight airbag fabric requires either finer denier yarn (as fabric density cannot be disturbed) or doing away with the neoprene coating. The later would also help in reducing the chances of secondary injuries, but may not ensure an effective performance of airbag. Alternative to neoprene coating are sought due to the following reasons:

1. Longer service life: The elongation of neoprene and nylon differ at 120 ^{0}C. Neoprene is not fully compatible with nylon and hence it may reduce the life of airbag fabric.
2. Use of airbags in heavy duty vehicles: The neoprene coated airbags do not meet the requirements of higher abrasion and wear resistance.

3. Need to down-size the module: The stiffness of neoprene coating primarily determines the interior volume of the module. To improve upon this either uncoated or silicone coated fabrics should be used.
4. Recyclability: With the use of neoprene coating, recyclability of the airbag becomes difficult. Recovery of nylon fabric from the coated airbag becomes difficult.

Thus the desire to make unit smaller and restraints on the weight of the vehicle assist the move towards finer denier products. More advantageous would be the development of material that performs like a coated one and is pliable like an uncoated one.

The various developments in the construction of airbags till recent times have been summarised in the Table 2

The development of non-coated airbags, although, is an attempt to meet the present day requirement for the airbag has the following lacunae on the technical and the economical front:

- Although, the weight and the thickness of the airbag fabric is reduced the stiffness of the fabric increases as compared to the existing ones.
- Uncoated airbags are easy to fold and pack in small spaces
- On the economic front, though the additional cost of coating is reduced, there is increase in the cost due to increased consumption of yarn, wastage of fabric during cutting and reduced weaving efficiency.
- The problem of excessive permeability still exists with the uncoated ones. Accident statistics show that the hot gases escaping through the open pores inflict facial burns upon the victim. Hence, certain modifications in the structure of airbags are required.

Thus, the use of silicone coated airbags has gained importance. This new silicone coated airbag weighs less than 200 g/m^2, giving 22 % saving in weight as compared to present neoprene coated airbags. The thickness of this fabric and its stiffness is also lower as compared to the present neoprene coated variety.

The comparative virtues and disadvantages of the coated and non-coated airbag fabrics are still under debate, but clearly the uncoated fabrics are likely to get an advantage. Also, the uncoated airbag is likely to have no problems caused by coating after the bag is installed. Permeability of the uncoated fabric will be influenced by yarn count, yarn twist, fabric sett, thread tension during weaving and shrinkage. It is found that the envelope facing the passenger should have less permeability than the two end sections. This would protect the passenger from particles and hot gases. To achieve this it is suggested to have a ratio of about two between the warp and weft tension.

The gas permeabilities of the inflated bag plotted against the tensile force generated cross the fabric at varying proportion of warp to weft tension show that when weft way tension is twice the warp way there is very little increase in permeability with increase in force. The graph is shown in Fig. 8. TRN Repa Gmbh of Germany has developed a different bag with variable permeability. This bag consists of a fabric envelope with two sections that, when inflated generate different gas permeabilities[19].

Another way of preventing airbag fabric from transmitting hot gases is to create a laminated structure. The patented fabric by Asahi Kasei Kogyo KK is a three-tier structure consisting of a woven face fabric, a film of olefin resin and a layer of non-woven. Only the section of bag facing the driver is manufactured in this way on economical grounds. It is found that polyethylene resin offers same defense against escaping gases as traditional coated fabrics[20].

The use of Sodium Azide gas generant in the airbag leads to the release of toxic gasses like nitrous oxide and carbon mono-oxide. These toxic gases released during deployment of airbag can be reduced or eliminated by the following ways[23]:

1. Reducing the gas combustion temperature. But this would make it difficult to retain a sufficiently high gas generant burn rate for practical application
2. Application of coatings to the airbag interior surface. The first coating of alkaline component like magnesium, sodium or calcium carbonate would help to absorb nitrous oxide and a second coating of mixture of an oxidation catalyst (manganese,

copper, cobalt or silver oxide) and Hopelite compounds to reduce carbon mono-oxide concentrations.

3. Use of non-azide based gas generants like amenable gases generated by a group of tetrazole compounds and their metal salts.

4. CONCLUDING REMARKS:

From the above discussion the following facts could be highlighted:

- The seat belt webbing has become more or less a standard product.
- The market for these has reached a maturity level in the developed nations and has also been established in the developing nations. Category of inflated seat belts is still to be explored.
- The airbag market has received a boost with the stringent safety regulations and increasing consciousness among the automobile users.
- Several attempts are being made to make airbags lighter, more compact and cheaper. This has lead to the manufacture of uncoated or silicone-coated airbags.
- To make vehicles safer for driving, certain other prime positions like door panels, roofs(for crashing wind shield) and facing rear seats, have been suggested in addition to drivers' airbag and passenger side air bag.

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Table2:Various Development In Air Bag Fabrics

Type Of Airbag	**Original Coated Type**		**Developed Non-Coated Type**				**Silicone Coated Type**
Yarn type	Nylon-6,6	Nylon-6,6	Nylon-6,6	Nylon-6,6	Nylon-6,6	Nylon-6,6	Nylon-6,6
Yarn denier	840	420	840	630	420	420	420
Fabric construction (ends/dm)	98 x 98	193 x 193	32 x 32	41 x 41	72 x 76	57 x 51	46 x 46
Weight (g/sq.m)	280	260	252	241	244	238	175
Stiffness (kgf)	1.36	1.8	0.76	1.68	1.91	3.54	0.45
Thickness (mm)	0.38	0.34	0.4	0.38	0.33	0.35	0.25