Innovative Use of Thermoplastic Film Adhesives in Automotive Airbags

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1. Abstract

Side curtain airbags or headbags are a recent development in the automotive airbag industry. They aim to reduce injuries, as a result of roll over accidents.

A side curtain airbag has to stay inflated for a minimum of six seconds, and to reach this goal, silicone layers of 90g/m² and more have to be used. This technique has several draw backs.

TRW Occupant Restraint Systems, one of the worlds largest airbag-suppliers, developed together with adhesive company Collano a multi layered thermoplastic composite film to substitute silicone by a much thinner coating with excellent friction and air proof properties.

Author will demonstrate how this development was accomplished and which properties have been achieved.

2. Introduction

Invented in October 1951 (1), airbags primary goal was to reduce injuries caused by a crash. This was accomplished by driver and passenger airbags, which both had to inflate in less than 60 milliseconds, and then collapse.

A way to realise this is using a ‘silicone rubber’ (in short: silicon or silicone) coated textile bag with a defined open area (2).

The 40-50 g/qm silicone coating has a certain porosity, which doesn’t render it gas tight, but allows the airbag textile to be impermeable enough to become inflated. Another important issue of the coating is to reduce surface friction.

In order for the bag to become highly inflated, factors like velocity and pressure of the gas coming from the so called generator, the weight/sqm and flexibility of the textile, the volume of the bag and the way the bag is folded, then the surface friction is the property which defines inflation time (2) for the most part.

During the last years airbag industries were confronted with a new challenge: the roll-over or side curtain airbag (3). To reduce the severe injuries caused by roll-over accidents in vans (and, as found, even in small passenger cars this system proved to be helpful), the idea was borne to place an airbag in the edge between headliner and windows on both sides from front to rear of the car (see figure 1 on the right).

Figure 1: Side Curtain Airbag.

This was not only to protect heads, but to reduce the danger to be thrown out during a rollover-accident.
This airbags-system had to be designed with completely new properties in comparison to ‘old systems’ like driver or passenger-bag (2):
- the textile has to withstand a high gas pressure for minimum 6 s.
- low weight coating system
- very low friction
- high abrasion and puncture resistance
and of course the standard-properties
- high reliability in production and end use
- softness
- last but not least low price
plus
- high long term stability against hydrolysis and getting brittle
- heat stability 95°C/120°C and low temperature flexibility (-40°C)
- flame resistant according to airbag standards
- no solvents, if possible

The textiles used by airbag industries – in contrast to most other automotive interior textiles - are multi fibre filaments, based on Nylon 6,6 (4, 5) due to its high temperature stability.

A new development in textile technology is the so called OPW (2, 5, 6, pictures 6 and 7). This development should help, to make production of side curtain airbags less complicated, and the issue was, to find an air-tight coating for this OPW-textile, which in the region of the so called domes has very open weaving structures.

**Statement of theory and definitions**

State of the art of coating air bags involves the use of silicone rubber. A close look to this type of coating shows figure 2.
The coating is characterized by
- low friction when used as a thin layer
- stable and flexible over a broad temperature range
- high reliability in production and in airbag-end use
- open surface / relatively high air permeability

To achieve air tight coatings, as necessary for side curtain bags, first tests of coating OPW-textile with silicon showed that it is in principle possible, but 80 g/qm and more are needed and an additional top-layer to reduce friction. A microscopic view of a cross section of a heavy weight silicone coated textile shows figure 3.

For coating textiles a well known technique is laminating the substrates with films (7). A perfect control of gas permeability can be achieved in principle by a two layered film.
One layer – oriented to the textile – has to be a relatively low melting layer, used as an adhesive and the other layer has to be high melting and gas tight. This double layered films can be found for example as so called seam tapes in making seams waterproof (8) or even gas proof in military applications.

By choosing the right layers, this system seemed to be a possible way for coating airbags (7).

Thad Fredrickson (9) tested a Mylar® top layer for this application and found it ‘difficult to adhere to fabric and susceptible to pin holing upon flexing’.

As PA 6,6 has a quite high surface tension, comparable to TPUs (10), wettability with molten TPU should be good, and as TPUs usually have a high modulus of elongation and a deep glass transition temperature Tg (near –40°C), a TPU should be a good choice as thermoplastic adhesive layer. To improve wettability of the PA 6,6 fibres, plasma (11, 12) and fluorination (13) was taken into consideration. Both methods result in long term effects. Corona-treatment gives more or less short-term effects and seemed not to be useful for the planned process.

The top layer should be a high melting TPE. The melting range should be considerably higher in comparison to the TPU-adhesive, tough and easy to produce as a thin layer. Here, our own experience lead us to Polyester based TPEs.

3. Description of equipment and processes

OPW-bag-textiles with different textures, woven by BST were used. Some of the textiles were pretreated – either with Plasma or Fluor.

To produce the adhesion- and coating films different types of cast-film-and blow extruders were used – both small lab extruders and 3m-width-production lines. See figure 4.

Raw materials used for film production have been grafted with special additives externally and internally. Several laminator types were pre-tested and finally a kind of belt laminator proved to be useful. See figure 5.

To prepare first samples of laminated textiles, a simple laboratory-heated platen press was used. Airbag-production and end-testing was done by our partner BST and TRW (see acknowledgements).
To test the quality of the coating
- T-peel-tests
- surface friction tests
- fire hazard tests
- airbag-shooting tests (2)
have been performed. Testing was done before and after storage of the coated bags.

Bag materials were stored according to the different standards (GM, Daimler-Chrysler, VW, Toyota and BMW).

4. Application of equipment and processes

First pure and grafted TPU-films and PET-top-layers were produced on a lab extruder and pressed with a laboratory press on top of different OPW-textiles. This screening led to TPU- and PET-mixtures which seemed to be appropriate candidates for a big scale production in all process steps (extrusion – laminating – air-bag assembly), followed by shooting-tests before and after storage.

5. Presentation of data and results

TPU-types with melting range between 120 and 140°C coated on OPW-textile at higher temperatures gave T-peel-test values well above 1 N/mm at room temperature and still near 1 N/mm at 90°C.

Using pre treated OPWs (fluorination and plasma) resulted in 15 to 25% higher T-peel-values. Shooting tests at 90°C and –40°C showed, that, choosing the right laminating conditions and (by grafting) optimized TPUs, pre treatment of OPW-textile was not necessary to get appropriate adhesion.

As top layer, a high melting highly elastic Copolyester was grafted, so that surface-friction and adhesion to the TPU-adhesive-layer were optimised. Both layers together are below 60 g/sqm in unit weight and lead to a soft and flexible coating.

*Figure 8: shows a microscopic view of a cross section of a film-coated OPW (6).*

Some of the tested TPU-adhesives showed high peel-values immediately after lamination and failed one or two days later.

The air bags produced with this coating passed all the before mentioned tests and allowed to design a very compact, low-weight package of side-curtains.

The pressure diagram (figure 9) of a film laminated bag shows best values in comparison to silicon coated and sewed bags.

*Figure 9: pressure vs time comparison between laminated (OPW), siliconised (OPW) and sewed bag (6).*
The resulting inflation time is near 40ms and the bag stays inflated well above 6 seconds.

Figure 10: side curtain airbag in action (6). This sequence of pictures will be shown at the conference and not here, because it is not possible to integrate a film into a pdf-file.

6. Interpretation of data

The fact, that some TPUs fail a few days after laminating onto PA 66 can be explained by water migrating into the PA 66 – TPU - interface. PA 66 in equilibrium with the environmental moisture, has a water-content of 2-3.5%. During high-temperature-lamination, this water is nearly completely removed. Environmental moisture water will migrate back into the bulk and interface (14), (15) – and destroy some of the adhesive bonds (preferably hydrogen-bonds).

This, together with the fact, that some TPU films exhibit considerable high adhesion to PA 6.6 fibres, even with very low-weight indicates that a part of adhesion is caused by ´real´ adhesion-forces and not only by mechanical anchorage. But, of course, anchorage plays an important roll, as figure 8 shows.

When the melting range of the TPU-layer is high enough above the desired temperature stability and Tg is in the region near –40°C – and hydrolysis-stability is excellent, it has all properties needed for a long term bonding to PA 66 – even without pre treatment of the fibres.

The pictures illustrate, that silicone covers the exposed fibres and fills up all gaps between the fibres, whereas the film adheres mainly to the most exposed fibres.

This is the reason not only for higher weight needed by silicone rubber to get woven materials air tight but also for reduced flexibility.

A top-layer of modified high melting Copolyester TPE combines well with TPU-adhesive films and has a melting range high enough above the desired laminating temp, so that during the lamination process this top layer stays unaffected. And it is possible to steer flammability and friction into the desired range without negatively influencing the adhesive properties.

7. Conclusions

Air tight, long term stable and robust coating of PA 6,6 based airbag textiles has been proven to be possible with composite thermoplastic films.

This could be done according to airbag-standards – with lower weight and friction than possible with silicone rubber.

Especially OPW-textiles with so called ´Domes´ can be coated this way.

The film-coating is completely solvent free.

As the system was acceptable, too, concerning the costs, production was started.

Figure 11: Complete airbag module and Collano company profile
**Nomenclature**

- **a** silicone rubber = Polyorganosiloxane based rubber, heat cured produced by [www.wacker.com](http://www.wacker.com) or [www.GESilicones.com](http://www.GESilicones.com) and others

- **b** nylon 6,6 = PA 6,6 = PA 66 see [en.wikipedia.org/wiki/Nylon](http://en.wikipedia.org/wiki/Nylon)

\[
\begin{align*}
\text{HO} & \quad \text{O} \\
\text{R} & \quad \text{O} \\
\text{OH} & \quad n \\
\end{align*}
\]

A molecule of water is given off and the nylon is formed. Its properties are determined by the R and R' groups in the monomers. In nylon 6,6, R' = 6C and R = 4C alkanes, but one also has to include the two carboxyl carbons in the diacid to get the number it donates to the chain. In Kevlar, both R and R' are benzene rings.

- **c** OPW = One Piece Woven; airbag-textile, woven by a special process, that allows production of bags without seams. See pictures 6 and 7. This is a double sided textile which is designed flat and coatable and can be blown with special domes, when inflated. Dome: balloon-like deformation of inflated OPW-airbag See picture 7.

- **d** Mylar®: high melting Polyester film from Dupont [www.dupontteijinfilms.com/ datasheets/mylar/overview/h67160.pdf](http://www.dupontteijinfilms.com/ datasheets/mylar/overview/h67160.pdf)

- **e** TPU = Thermoplastic Polyurethane

- **f** TPE = Thermoplastic elastomer

- **g** T peel-test: according to german standards DIN 53530 and DIN 53539, measured with a testing device ‘Universalzugprüfmashine 1476’ from company Zwick, Germany

- **h** Surface friction tests (e) according to german standard DIN 53 375, measured with a testing device ‘Universalzugprüfmashine 1476’ from Zwick, Germany.

- **i** fire hazard tests according to IEC 60695 (1999) *Fire hazard testing, Part 11-10 50 W horizontal flame test methods*
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- Laboratory and Development Team Collano Xiro; www.collano.com

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Key Word/Phrase Index

side curtain airbag, fabric, OnePieceWoven, coating, laminating, film, Collano