Laser Ablated Removable Car Seat Covers for Reliable Deployment of Side-torso Airbags

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Abstract

In the event of a collision, the safe and reliable deployment of side-torso airbags through removable car seat covers that use tear-seam technology has been recently questioned. It is well known that a side-torso airbag system in automotive seats can reduce injuries and prevent fatalities in the event of a collision. Removable car seat covers suitable for side-torso airbag systems are popular accessories in the automotive industry from the perspective of upholstery protection and aesthetics. This study demonstrated a better-suited technology in which laser ablation down the side panel of removable car seat covers, produced a pre-determined strength within a weakened zone that allowed a reliable airbag deployment in the event of a collision. This paper investigates the effect of laser power as a key factor in the laser ablation process and its influence on the bursting strength of the car seat cover materials. The laser-ablation of the removable car seat covers can ensure the consistent airbag deployment under environmental conditions ranging between as ambient (22 ± 2°C), cold (-35 ± 2°C) and hot (85 ± 2°C). The durability and deployment performance of these car seat covers after UV exposure were also investigated.

Keywords

Laser ablation, textiles, car seat covers, side-torso airbags, bursting strength

Introduction

Airbags in passenger vehicles are a supplementary restraint system to seat belts that further mitigates the injuries suffered in serious crashes. The use of airbags can help to minimise the chances of fatalities from an external collision, and limit passenger impact with the inside of the car. Airbags were first introduced in passenger cars by Ford in 1971 to protect the driver and front passenger in frontal collisions. Since then, the number of airbags in modern cars has increased to 5 and in some cases to 9, covering a wide range of accident scenarios. Side airbags were first introduced into vehicles around 1995 to help protect passenger car occupants from serious injury in struck side crashes. International studies have shown that side airbags are effective in reducing the risk of death in near side impact situations, and mitigate injuries in vehicle rollovers (Braver & Kyrychenko, 2004). A driver involved in a side impact has twice as high fatality risk as driver involved in frontal impacts (Farmer, Braver, & Mitter, 1997). In 2014 in Australia, 1299 passenger vehicles were involved in police-reported fatal crashes. These crashes resulted in 763 deaths (BITRE, 2014).

Airbags in front occupant car seats are generally concealed in a moulded plastic enclosure contained within the side upholstery of the seat as either a head-and-torso or torso-only system. The seat upholstery through which the side airbag would deploy involves a tear-seam technology that facilitates the inflation of the airbag during a collision. For a moving vehicle, airbags primarily deploy for crashes at speeds greater than 30 km/h (Toyota, 2015). When an internal accelerometer senses a possible collision, a microprocessor senses the vehicle deceleration and other relevant parameters and initiates the deployment of the airbag (Huffman, 2011). At the time of deployment, the airbags release by rupturing the moulded plastic enclosure within the seat, followed by bursting of the tear-seam of the upholstery of the fitted seat. The airbag deployment is executed with an enormous velocity of 200 – 320 km/hr (Braver & Kyrychenko, 2004; Farmer et al., 1997)

The use of removable car seat covers over the standard upholstery is a popular accessory used to protect the upholstery as well as to give aesthetic appeal. Similar to the car seats, the removable seat covers also include a tear seam along the side gusset to enable the deployment of the airbag during a collision. It is imperative that the seat cover never obstructs the full deployment of the airbag.

Our research has identified that current seat cover designs that employ tear-seam technology have issues of reliability and predictability during airbag deployment, due to various technical and design deficiencies in the tear-seams. Several factors such as fabric stretch, the strength of sewing thread used at the tear-seam, the length of the tear-seam, the placement of the tear-seam, the type of stitch, and stitch density can affect the behaviour of airbag deployment. As a consequence, ballooning of the seat cover material prior to the failure of the seam can occur which increases the time taken for the airbag to deploy, thus reducing its effectiveness.

Laser processing in the automotive industry for applications such as cutting, drilling, marking, welding and the surface treatment of materials such as ceramics, and plastics is well established (Roessler, 1989). In the textile industry, laser processing has been used extensively for cutting of fabrics (Jackson, Preston, & Tao, 1995); engraving designs on fabrics (Yuan, Jiang, Newton, Fan, & Au, 2011) and carpets, surface modification of fabrics (Chow, Fibers and Polymers 2011), decorative finishes on denim (Ortiz-Morales, Poterasu, Acosta-Ortiz, Compean, & Hernandez-Alvarado, 2003), and wool felting (Nourbakhsh, Ebrahimi, & Valipour, 2011). The lasers technologies used in these industries usually employ CO_2 and neodymium-doped solid-state lasers. In textile manufacturing, CO_2 lasers are predominantly used with typical operating power efficiencies in the range of 5 – 15 % and maximum continuous power outputs well over 10 kW. For comparison, solid-state lasers are characterised by much lower power efficiencies and are operated in a pulse mode. The wavelength of the emission from a CO_2 laser is about 10 μm, whereas the neodymium-doped laser is often characterised by an emission wavelength centred at 1.06 μm, a factor of 10 shorter than that from CO_2 but still in the infrared region.

The use of laser processing to facilitate cutting in a predetermined pattern for strategic weakening of car interior door panels that cover the exit points for airbags has been explored by Riha et al. (2006). Similarly, Bauer (2001) researched the use of a controlled laser beam to weaken the back of the cover layer of trims of a car interior by wholly cutting through the substrate and partially through the cover layer to produce grooves of a precise depth and width. Costin (2000) investigated the application of laser technology to impart patterned designs on thin fabrics and leather by using an electronic controller to direct the drive mechanism for controlling the speed of etching.

The concept of using lasers to pre-weaken the side panel of a removable car seat cover has not been explored until now. Laser processing for such applications required the development and demonstration of pre-weakened fabrics to allow for reliable, predictable and timely deployment of airbags through the tearing of the fabric cover. While many of the above authors have attempted to modify fabric surfaces using laser to allow for deployment, the concept of pre-weakening a precise zone to a known bursting strength has not been demonstrated.

There are several challenges that can be encountered when using the pre-weakening concept on removable car seat covers. Unlike fixed trims and face fabrics that are adhered to the foam of the car seat (as in the case of OEM car seats) removable car seat covers can distort and result in significant misalignment from the actual deployment zone which can create serious performance issues. The objective of this research was to develop a pre-weakened and predetermined zone having a known bursting strength for facilitating reliable side airbag deployment from a car seat.

Experimental

Fabric material

100% polyester weft knitted textile fabrics supplied by Who-Rae Pty Ltd were used for the experimental investigations. The fabric properties are as shown in Table 1.

Table 1 Fabric material specifications

Parameters	**Details**
Yarn used	100 % Polyester
Yarn count	100 denier
Mass per unit area	100 g/m^2
Courses/cm	9
Wales/cm	10

Laser ablation of fabric

Laser ablation of fabric was performed using a commercial CO_2 laser in atmospheric conditions. The generated wavelength of the laser beam was set at 10.6 µm and the laser power was set at 80 - 150 W. The applied laser etching software was LaserCut® and laser engraving on the fabrics involved pattern files designed using Adobe Photoshop® graphics design software. The JPEG files were created in grayscale. The fabrics were placed in an etching cabinet for the laser treatment at different intensities by varying the process parameters.

The controlled laser has three operational parameters that were varied to control the ablation of lines of weakness on the fabric, namely power, the distance between the ablated lines and the angle of the lines. The intensity of the laser was optimised by changing the scale of power incrementally from 1 to 20 %; where the intensity of the ablation increased with higher laser power; and adjusting the distance between the lines.

Performance assessment of the laser ablated fabric material

Bursting strength

The bursting strength of the laser ablated fabrics were evaluated using a SDL Atlas Autoburst® M229 hydraulic bursting strength instrument in accordance with ASTM D3786 standard test method (ASTM, 2001). Ten specimens of each of the experimental fabric samples were tested. The specimen size was 15 cm x 15 cm.

Accelerated UV exposure

A UV exposure test was conducted in accordance with SAE J2412/ J2413 (SAE, 2012). A Ci400 Weather-Ometer was used for this test. Laser ablated fabrics were exposed to 263 kJ/m2 of UV radiation. The UV exposed samples were subsequently tested for bursting strength.

Static airbag deployment testing

Static airbag deployment testing was conducted at a NATA accredited airbag testing facility APV Engineering and Testing Services, Melbourne. The airbag deployment testing was carried out under different environmental conditions which included ambient (22 ± 2° C), cold (- 35 ± 2°C) and hot (85 ± 2°C) temperatures.

Results and discussion

Airbag deployment tests for tear-seam technology based seat covers

Random batch testing of to determine the reliable airbag deployment through seat covers, is a standard industry practices from a quality assurance perspective. Such tests are based on static airbag deployments and are commercially undertaken through an accredited laboratory. Results obtained from 2010 to 2014 are shown in Figure 1, and indicate that over 40% of side torso airbags failed to deploy through the tear-seam car seat covers. Investigation of the these seat cover designs have issues of reliability and predictability, due to various technical and design deficiencies in the tear-seams, such as fabric stretch, strength of sewing thread used in the tear-seam, length and placement of the tear-seam, type of stitch, and stitch density.

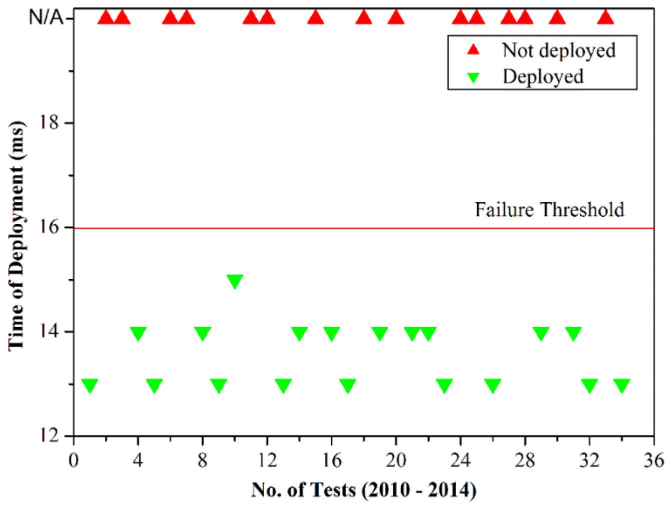

Figure 1 Airbag deployment testing of car seats covers with tear seam technology

Effect of laser power on the bursting strength of fabric

Figure 2 shows the effect of power intensity of the laser on the bursting strength of the ablated polyester fabric. As the power intensity increased from 7% to 13%, the bursting strength of the fabric was decreased.

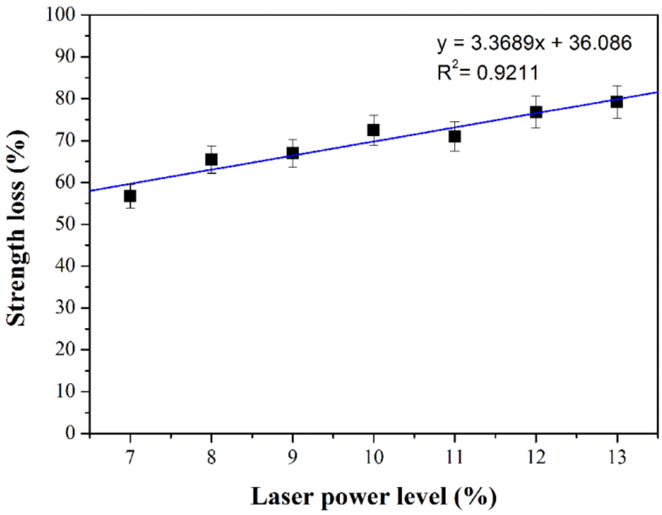

Figure 2 Relationship between laser power and bursting strength

In order to determine the optimal bursting strength of the laser ablated samples acceptable for timely deployment of an airbag, laser ablated fabrics of different power intensities were integrated into the cut-and-sewn car seat covers as side panels. These seat covers were subjected to static airbag deployment testing, initially at standard atmospheric conditions. Figure 3 shows a magnified image of the laser ablated pattern before (a) and after fabric bursting test, and Figure 4 shows the typical airbag testing before and after deployment.

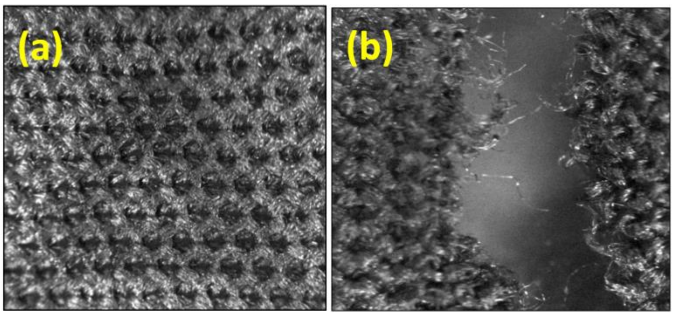

Figure 3 (a) laser ablated weakened area, (b) fabric tear at weakened area

Figure 4 Airbag deployment testing (a) side view before deployment (b) side view after deployment (c) front view before deployment (d) front view after deployment

Effect of bursting strength of laser ablated area on the airbag deployment time

Figure 5 **Error! Reference source not found.**shows the relationship between the bursting strength of the laser ablated area in the pre-weakened zone of the polyester fabric and the airbag deployment time. The average time of deployment for a standard side-torso airbag to extend 50 mm, 150 mm and full extension can estimated to be around 3 ms, 7 ms, and 15 ms respectively (Balavich, Soderborg, Lange, & Pearce, 2011). The industry-accepted failure threshold for side airbag systems is set at 16 ms, during which time an airbag is expected to be fully deployed. To pass the acceptable threshold therefore, the deployment time through the seat upholstery and the additional seat cover must be below this failure threshold to ensure reliable deployment of the airbag.

From Figure 5 it can be observed that the timely airbag deployment can be achieved when the strength of the laser ablated fabrics is reduced by approximately 70% from the original strength of non-ablated fabric. The airbag deployment time however exceeds the failure threshold of 16 ms when the bursting strength reduction is less than 60%. If the reduction in bursting strength is greater than 80% the durability of the fabric is compromised and premature tearing of the side panel may occur. According to Figure 5, if the strength is reduced by 60% from the original, the samples may pass the standard but the fabric may not be sufficiently weakened for a deployment if the temperature in the car exceeds 22 ^{o}C.

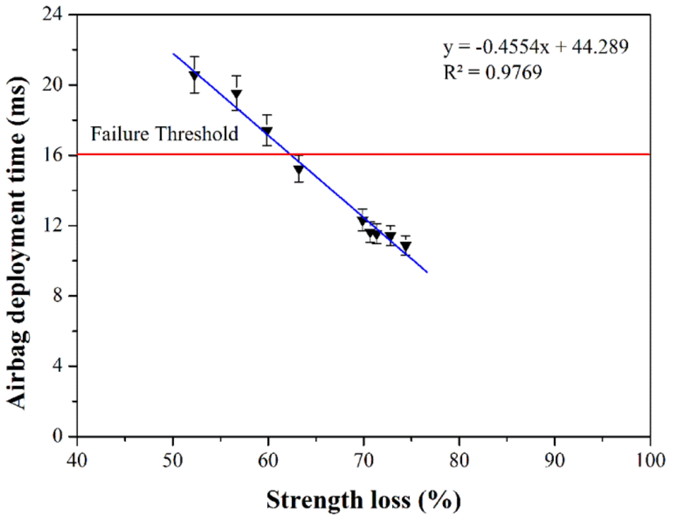

Figure 5 Relationship between bursting strength of laser ablated area and airbag deployment time @ ambient conditions

The laser ablation showed an obvious effect on the bursting strength, when the strength reduced to approximately 25 % of its original.

Effect of environmental condition on airbag deployment time

Car seat covers are used in different geographical locations where the environmental conditions can be extreme. In order to investigate the performance of the car seat covers with the laser ablated pre-weakened side panels, the seat covers were subjected to hot (85 °C), cold (-35 °C) and ambient (22 °C) environmental testing conditions. Figure 6 shows the effect of different environmental conditions on the deployment efficiency and time of the car seat covers having pre-weakened laser ablated side panels. The results showed a slight increase in the deployment time with increase in temperature but were within the failure threshold. This change could be attributed to the change in the fabric elasticity where the stretch of the fabric can be reduced with decrease in temperature.

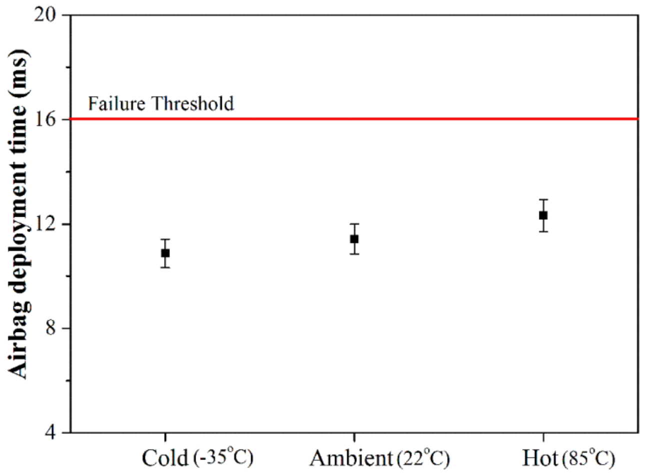

Figure 6 Effect of environmental condition on airbag deployment time of laser ablated car seat cover

Effect of UV exposure on bursting strength of laser ablated area

Based on the requirements of the automotive industry, an assessment of the performance of upholstery and removable car seat covers when exposed to UV radiation must be made to determine the lifetime durability. This parameter was investigated in accordance with the SAE J2412/J2413 standards. Figure 7 shows the effect of UV irradiance on the bursting strength of the laser ablated pre-weakened side panel. The laser ablated fabric panels exposed to UV irradiance intensities of 38 kJ/m^2, 75 kJ/m^2 and 263 kJ/m^2 were tested for bursting strength and static airbag deployment respectively. The fabrics exposed to 263 kJ/m^2 UV radiation showed less than 10% reduction in the bursting strength. This is deemed to be acceptable because the strength of the fabric is expected to degrade over time due to the ageing effects of heat and UV.

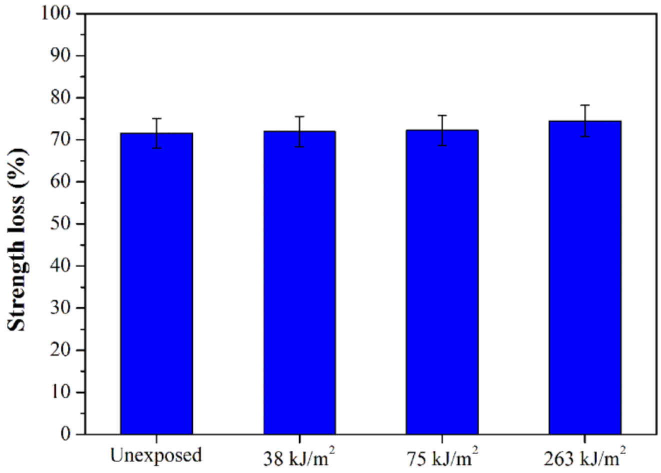

Figure 7 Effect of UV irradiation on the bursting strength of laser ablated area

Conclusions

Laser ablation can be applied in the development of a pre-weakened zone in a car seat cover for reliable deployment of airbags. Laser ablation offers the advantage of being able to adjust the level of weakness of the deployment zone to guarantee 100 % efficiency. Tear-seam technology relies on the quality of the sewing operation and the materials used, and as a consequence this may result in as many as 40 % of tear seams not performing as required. For the chosen fabric, the current research has shown that for timely and efficient deployment, the optimum bursting strength of the laser ablated fabric should be reduced to 25% of its original. This is likely to change for different fabrics and therefore it is recommended that the optimal bursting strength of individual fabrics be determined. The performance of the laser ablated car seat covers tested under various environmental (-35°C, 22°C, and 85°C) conditions, showed an increase in deployment time as a function of increase in temperature, but did not compromise the effective operation of the pre-weakened zone. Laser ablated fabrics exposed to UV irradiance of 263 kJ/m2 showed a reduction of less than 10 % in bursting strength which means its life-time should only be marginally compromised.

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