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TECHNICAL NOTE

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Forensic Value of Pattern and Particle Transfers From Deployed Automotive Airbag Contact*

ABSTRACT: Many automobile manufacturers began installing airbags on the driver's side in the late 1980's. Passenger side airbags followed in the early 1990's. Most airbags use a solid-propellant type of material that produces a hot gas to inflate the airbags. The gas in the driver side airbag leaves the inflator at a temperature as hot as 600°C. The hot gas escapes through the vent holes after deployment, but it can also leak through the stitching seams in the front and singe a pattern on the occupant's clothing characteristic of the seam pattern. The singe patterns from the driver and passenger side airbags will be different. Cornstarch, which is used as a lubricant in some driver side airbags, can transfer to the driver's shirt. Hairs, fibers and make-up can transfer from the driver or passenger to the surface of the deployed airbags. Two cases are presented, illustrating singe patterns and particle transfers, and how they helped determine who a driver or passenger were.

KEYWORDS: forensic science, airbags, airbag deployment, singe pattern, pattern transfer, starch particles, particle transfer

In some criminal investigations, law enforcement agencies have requested technical assistance from forensic scientists in determining the driver of a vehicle that was stolen and crashed, involved in a hit-and-run accident, or involved in a reckless homicide. In the past, evidence such as hairs, fibers, blood and fingerprints found inside the vehicle were used to help make this determination. Occupant contact with an airbag and the way that it deploys can now give investigators a new tool to help determine the driver and the passenger of a crashed vehicle, when it is in question.

Airbags are designed to supplement seat belts and reduce injuries in frontal collisions. General Motors was the first manufacturer to offer them as an option in 1975 (1). In the late 1980's, airbags were routinely installed on the driver's side of automobiles. In the early 1990's, they were routinely installed on the passenger's side of automobiles. Starting with 1998 models, federal regulations have required driver and passenger airbags on all new passenger cars (George Kirtchoff, Automotive Occupational Restraint Council. Personal communication). This requirement was extended to sport utility vehicles, vans and light trucks for 1999 models. Injuries and deaths caused by airbags have been reported in the past (2–5), but the forensic value of airbag contact has not been previously reported.

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Materials and Methods

The first commercial airbags were inflated with compressed gas. Most airbags now use some type of solid propellant pyrotechnic inflator. Sodium azide was the most commonly used solid propellant in vehicles through the 1990's. It is still in limited production, but is being phased out because of its toxicity (Airbag manufacturer, name withheld by request. Personal communication). One may still encounter vehicles that utilize sodium azide inflators, since many are still operating on the roads now. Other types of solid propellants, including guanidine nitrate, are now being used (Airbag manufacturer, name withheld by request. Personal communication). Some companies also manufacture a hybrid inflation system, which uses a stored gas, usually argon, that is heated to expansion.

A sensor in the vehicle detects a sudden forward deceleration, not necessarily a collision, and sends an electrical current to the detonator in the inflator. This causes a slow detonation of the propellant in the inflator, resulting in the production of a hot gas (N_2 in the sodium azide inflators, H_2O, CO_2 and N_2 in the guanidine nitrate inflators) that inflates the airbag. The airbag inflates in less than 1/20 of a second, at a speed of 200 miles per hour, with hot gas (6). Starting with the 1998 model vehicles, de-powered airbags, also known as second generation, were required. They inflate at 20% less velocity. One to three vent holes are usually located in the back of the airbag, so it begins to deflate immediately, making a better cushion and absorbing the impact of the occupant. Occupants who are wearing their seatbelts contact the airbags mainly with their face, chest and arms. Occupants who are unrestrained can also contact the airbags with their abdomen and legs.

Although the airbags are not packed in a "clean room," they are packed in a clean environment where possible contaminants are controlled, so their surface should be free of most debris prior to deployment (Airbag manufacturer, name withheld by request. Personal communication). Therefore, the surface of deployed airbags should be examined for the possible transfer of hairs, fibers and biological fluids from the occupants. Recovery of damaged hairs or fibers could be significant. Cosmetics may also be recovered on the surface of the airbags. Fiber transfers from the airbag to the occupant's clothing, mainly loose ones from the manufacturing process, may also be possible. Airbags are made of long, round nylon fibers, 25–30 μm in diameter, in zero-twist yarns. The sewing threads are usually nylon fibers also. By information obtained from airbag manufacturers and by personal observation, it was determined that the front and back panels of a driver side airbag can differ in construction, weave and fiber crimp. Driver side airbags are always round and 23–28" in diameter, depending on the make and model of the vehicle that they are in (Airbag manufacturer, name withheld by request. Personal communication). Passenger side airbags are always rectangular in shape and 2½ to 3 times larger than the driver side airbag.

According to information obtained from the airbag manufacturers, most driver side airbags manufactured in the 1990's have a black neoprene lining on the inner surface to prevent the hot gas from leaking through the fabric weave. These types of airbags are packed with cornstarch as a lubricant to prevent the neoprene from sticking to itself during deployment. Talc is also used as the lubricant, but not as often as cornstarch. Passenger side airbags do not contain a neoprene lining, so they are not packed with starch. The starch may be on the outer surface of the driver side airbag or it can become airborne through the vent holes, in the "cloud of smoke," when the deployment occurs. Through personal observations, some starch particles might be recovered from the shirt of the driver, while little or none may appear on the passenger's shirt. These starch particles will appear as single granules, as opposed to starch from food contamination, that will appear as agglomerates (7). Newer driver side airbags are produced with smaller neoprene lined areas, so a smaller amount of starch is used. The newest driver side airbags are now being produced without any neoprene lining, so no starch is used. These airbags use silicone as the sealant on the inside surface. The timeline of the sealant change varies by make and model, but neoprene and cornstarch have not been used for the last several years.

The gas discharged from the driver side airbag inflator can be as hot as 600°C and as hot as 700°C from the passenger side inflator (Airbag manufacturer, name withheld by request. Personal communication). The gas starts to cool immediately, but is still hot when it reaches the surface of the airbag. Since the airbags are designed to be inflated for only a short time, they are not airtight. The hot gas escapes through the vent holes in the back, as designed, but it can also be forced through the small holes from the stitching seams in the front of the airbag, which tends to be a weak point. If clothing from the occupants comes into contact with the airbag when it is at or near maximum inflation, the hot gas can cause singe patterns on the front of the clothing, characteristic of the seam patterns. This pattern appears as a series of small black dots or smears, 2–3 mm apart, in a single line or multiple parallel lines (Fig. 1), depending on the number of seam rows.

Since the driver side airbag is round with round seams, it will usually produce arc shaped singe patterns. The vent holes may cause a round singe pattern on the cuffs of the driver's shirt, if the driver is still holding the steering wheel when the airbag deploys. If the driver is wearing a short sleeve shirt, the driver might receive thermal burns on the inside of the wrists and abrasions to the forearms from the airbag deployment. Since the passenger side airbag is rectangular in shape, with straight seams, it will produce straight singe patterns on the occupant's clothing. This makes it possible to differentiate the singe patterns produced by a driver side airbag from the singe pattern produced by a passenger side airbag.

FIG. 1—*Singe pattern on shorts from driver of 1991 Lincoln Continental after airbags deployed.*

The singeing can occur on the clothing covering the chest and arms of a restrained front seat occupant. Singeing can also occur on clothing covering the abdominal area of an unrestrained front seat occupant. The size and seam patterns can differ from one airbag to another, usually by make, model and year. There may be one or two outer seams on a driver side airbag, and zero to as many as four center seams that attach the internal tethers. Because there are differences in the design of the airbags, there can be different class characteristics in the singe patterns, thereby possibly including or eliminating certain airbags as the source. Certain fibers, such as cotton and silk, singe more easily than man-man fibers, making the patterns easier to detect. The singe patterns are difficult to observe on dark colored clothing. Wearing a seatbelt will likely reduce the opportunity for clothing to become singed (Airbag manufacturer, name withheld by request. Personal communication).

Case Reports

Case 1

A 24-year old male reported to his local law enforcement agency that his 1996 Dodge Ram pick-up truck had been stolen. The truck was located about one mile from the owner's house, crashed into a tree. Both airbags were deployed. When the owner was questioned, the investigator saw some unusual impression patterns on the front of the light gray sweatshirt that he was wearing. He also noticed the smell of alcohol on the owner's breath. The owner denied any involvement in the crashed truck. The investigator collected the sweatshirt from the owner, the driver side airbag and the steering wheel, to submit to the Illinois State Police Forensic Science Laboratory in Rockford. The evidence was then transferred to a fabric impression specialist at the Illinois State Police Forensic Science Laboratory in Carbondale.

After a cursory examination, the surface of the sweatshirt and the airbag were tape lifted with clear book tape, in separate examination rooms, to remove any trace materials. The impression patterns on the sweatshirt, which was composed of 100% cotton, were examined and it was determined that they were singed into the fabric. The arc shaped patterns were in a series of small dark

FIG. 2—*Double row singe pattern on lower abdominal area of sweatshirt from the suspected driver of crashed 1996 Dodge Ram pick-up truck.*

FIG. 3—*Double outer seam area of the deployed driver side airbag from 1996 Dodge Ram pick-up truck. Some of the top seam threads are charred and slightly melted.*

FIG. 4—*Single row singe patterns on front upper left quadrant of sweatshirt from suspected driver of crashed 1996 Dodge Ram pick-up truck.*

FIG. 5—*Single central seam area of deployed driver side airbag from 1996 Dodge Ram pick-up truck.*

dots or smears, 2–3 mm apart. The manufacturer of the airbag was contacted and they stated that the hot gas that inflates the airbag can leak through the seams and produce singe patterns on the occupant's clothing (Airbag manufacturer, name withheld by request. Personal communication). With this information, the singe patterns on the sweatshirt were compared to the seams of the airbag. Some of the seam threads appeared to be charred and slightly melted. Two parallel singe lines observed on the abdominal area (Fig. 2) and left sleeve of the sweatshirt corresponded to the two outer seams of the airbag (Fig. 3). This also indicated that the driver was not likely wearing the lapbelt. Singe patterns observed on the upper left quadrant of the sweatshirt (Fig. 4) corresponded to the smaller single central seam on the airbag (Fig. 5), which attaches the inner tethers. This also indicated that the driver was not likely wearing the shoulder restraint. The 3/8 in. oblong singe pattern observed on the inside left sleeve of the sweatshirt (Fig. 6) corresponded to the single vent hole located on the back of the airbag (Fig. 7). This indicated that the driver was still holding the steering wheel when the airbags deployed.

The taping from the front outside of the airbag was examined under high magnification with a polarized light microscope. Although numerous white cotton fibers were observed on this taping, no comparisons to the sweatshirt fibers were conducted since white cotton is very common. Numerous cornstarch particles were also observed in this taping. This airbag had a neoprene lining on the inside of the front panel and used cornstarch as a lubricant, per the manufacturer (Airbag manufacturer, name withheld by request. Personal communication). The taping from the front of the sweatshirt was also examined with a polarized light microscope. Numerous cornstarch particles were observed, which were microscopically consistent with the starch from the airbag (Fig. 8). Three round colorless nylon fibers were also observed on this taping. These were consistent to the fibers that composed the back panel of the airbag, but had a different crimp than the fibers from the front panel of the airbag. At trial, the analyst testified that the owner was in the driver's seat of this truck, or a vehicle that used a similar airbag, when the airbags deployed. The owner was found guilty of several offenses.

FIG. 6—*Singe pattern on lower left sleeve of sweatshirt from suspected driver of crashed 1996 Dodge Ram pick-up truck.*

FIG. 7—*Single vent hole on back of the deployed driver side airbag from 1996 Dodge Ram pick-up truck.*

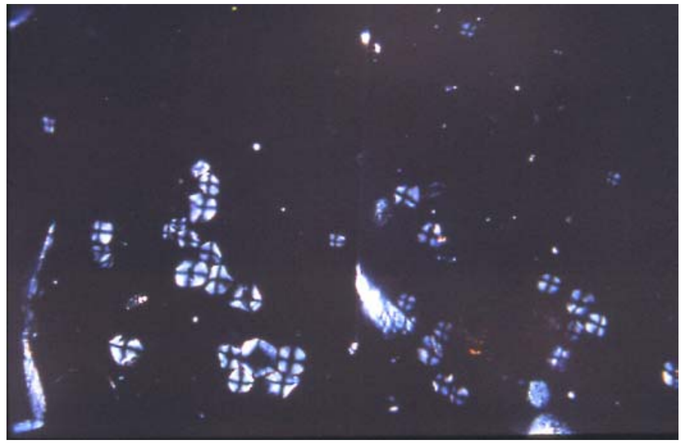

FIG. 8—*Comparison of debris taping with cornstarch particles collected from the front of deployed driver side airbag from 1996 Dodge Ram pick-up truck (left) to the debris taping with cornstarch particles collected from front of sweatshirt from suspected driver of crashed truck (right), viewed with crossed polars 400X.*

Case 2

In July of 2002, two southern Illinois musicians were returning home late from a performance, in their 1972 Chevrolet pick-up truck. As they entered an intersection, a 1996 Kia Sephia, with one black male and one white female occupant, ran through a stop sign and struck the truck on the passenger side. The truck overturned and caught fire, killing the two occupants. After striking the truck, the Sephia hit a tree on the passenger side. When emergency personnel arrived, they found the female occupant of the Sephia outside of the car and the male occupant, who had to be extricated, in the passenger seat. Some witnesses said that the male was in the driver's seat when they arrived and he crawled over to the passenger seat, although he denied being the driver. Both airbags in the Sephia had deployed. A toxicology screening was done on the male occupant. His blood alcohol level was 0.056 g/dL (the legal limit in Illinois is 0.08 g/dL) three hours after the accident. Cocaine and THC were also detected in his blood. His shirt, which was blood soaked from a large head wound, was disposed of at the emergency room.

Since criminal charges could potentially be filed, the investigators decided that they would submit evidence to the Illinois State Police Crime Laboratory in Carbondale to help them determine who was driving the Sephia. This consisted mainly of blood swabs and debris tapings from the inside of the car. The female occupant's shirt and both airbags, which contained bloodstains, were submitted at a later date.

The shirt and the airbags were first taped with clear book tape, in separate examination rooms, to remove any trace debris. Upon a more detailed examination, a diagonal singe pattern of small dots in a straight single line about 2 in. long was observed on the upper left chest area of the female's shirt (Fig. 9). Under UV light (366 nm), this row of dots and smears appeared to be about $3\frac{3}{4}$ in. long (Fig. 10). The driver side airbag had a double outer seam in a large arc shape and a double central seam in a tighter arc pattern. This was not consistent with the pattern on the shirt, so the driver side airbag was eliminated as a source of the singe pattern. The passenger side airbag seams were all in straight lines with many single and some double rows. Further comparison showed that the passenger airbag could not be eliminated as the source of the singe pattern (Fig. 11).

A damaged Caucasian head hair recovered from the front of the passenger airbag was found to be microscopically consistent with the head hair standard from the female occupant and dissimilar to

FIG. 9—*Straight single row singe pattern on upper left chest area of shirt worn by suspected passenger of crashed 1996 Kia Sephia.*

FIG. 10—*Same area as in Fig. 9 viewed under 366 nm UV light.*

FIG. 11—*Straight single seam area on deployed passenger side airbag from 1996 Kia Sephia.*

that of the male occupant. A small clump of Caucasian head hairs, with their proximal ends broken off, was recovered from the front passenger seat. These hairs were also found to be microscopically consistent with the head hair standard from the female occupant. A Negroid hair fragment, unsuitable for comparison, was recovered from the driver's seat.

No cornstarch particles were observed on the taping from the female passenger's shirt. A small area of neoprene was used on the driver side airbag from this car, so it had been packed with some cornstarch. Cornstarch was observed in the taping from the driver side airbag, but not in the taping from the passenger side airbag. Blood on the driver side airbag and driver side door matched the DNA profile of the male occupant. At trial, a Forensic Microscopy analyst testified that, because of the evidence he observed, his opinion was that the female was sitting in the passenger seat when the airbags deployed. The male occupant was found guilty of Reckless Homicide, and Aggravated Driving Under the Influence of Drugs and Alcohol, by a jury trial in June 2004.

Discussion

Since airbags have been required by federal law to be installed since 1998 on all new cars (1999 for SUVs, vans and light trucks) their deployment can provide another method to help determine who was in the driver or passenger seat of a crashed vehicle when it is in question. Not only can the airbags be examined for hairs, fibers and blood transfers from the occupants to help determine their seating position in the vehicle, but also the means by which the airbags deploy can provide a way to help make that determination. The airbag manufacturers have apparently known for some time that clothing from the front seat occupants, or the occupants themselves, can be singed by the hot gases that fill the airbags. They have dealt with injuries and legal issues from airbags for several years. Some manufacturers are now adding extra material at the seams to reduce this leaking. The manufacturers are also making other changes, mainly for the safety of the occupants. With the new two-staged systems, the airbags deploy with less force at a low speed impact. The newest advanced airbag systems have sensors that can detect the size of the occupant, how close they are sitting, the severity of the impact and whether the occupants are seatbelted, to determine the extent to inflate the airbag (8). The result of all of these changes is likely to change the degree to which the singe patterns on the clothing may be observed. The one advantage for forensic examinations is that the solid propellant materials now being used generally produce a gas hotter than that from the sodium azide-based propellants.

Forensic scientists as well as investigators and accident reconstructionists should be aware of the potential value of this evidence, and what to look for. Both driver's and passenger's upper body outerwear, if applicable, and both airbags should be collected in separate paper bags and submitted to the forensic laboratory for examination.

Note

While the airbag manufacturers that I contacted during the course of this research were very helpful when it dealt with information for the criminal cases, they preferred to have their names withheld from this manuscript because of legal issues. Some manufacturer information can be obtained from the Automotive Occupant Restraint Council (9). If you need additional contact information for a manufacturer, please contact this author.

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