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Examination and Analysis of Seat Belt Loading Marks

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ABSTRACT: In moderate to severe collisions, large decelerations and hence large forces are generated. Various components of the seat belt system are loaded, and physical evidence of this loading may be observed long after the collision event. Such witness marks result from interaction between different components of the restraint system, or between the restraint and portions of the vehicle interior. Detailed examination and analysis of such marks can establish whether or not the seat belt was in use, and also the precise manner in which the seat belt was worn. Such investigative techniques are critical for evaluating the collision performance of occupant restraint systems, and for positively identifying cases of restraint system misuse. This paper reviews the types of physical evidence which may be observed to determine restraint usage.

KEYWORDS: engineering, automobile seat belts, motor vehicle accidents, occupant restraint, witness marks, loading evidence, usage determination

It has become increasingly important through recent years for various interest groups to determine whether a vehicle occupant was wearing a seat belt at the time of a motor vehicle collision. Such a determination can be made through a variety of methods.

One is through examination of occupant contact points on the vehicle interior. In moderately severe collisions, an experienced investigator can usually identify the difference between a restrained and unrestrained occupant by examining the pattern of contact damage [*1*].

Another method is through examination of the occupant's injury pattern and specific injuries characteristic of restrained and unrestrained occupants [*2,3*].

A third method, which is discussed in this paper, is through examination of the seat belt restraint system for presence (or absence) of characteristic loading marks.

A large assortment of seat belt systems exist in present-day motor vehicles that prevent discussion of their individual performance in collisions. However, there is enough similarity in the loading evidence that discussion of loading marks in general can be amply applied to each individual system. The following discussion will be limited to three-point occupant restraint systems which are the type normally available to the driver and right-front passenger of most automobiles.

Generally, a seat belt is loaded by the occupant wearing the system. In a frontal impact the occupant travels forward and makes contact with the lap and torso portions of the webbing. If the restraint is positioned properly, the lap portion of the webbing will make

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contact with the occupant's pelvic region below the iliac crests. If the torso portion is positioned properly it will lie diagonally across the chest and over one shoulder.

We will discuss loading evidence on the restraint system beginning with the outboard floor anchor located adjacent to the front seat. We will discuss the evidence along the length of the webbing up to the retractor located on the lower B-pillar (in most vehicles).

Floor Anchor

The outboard lower floor anchor of the restraint system may be in the form of a bolt anchored to the stiff side beams or floor of the vehicle structure. Attached to the anchor bolt is a flat, metal plate which also holds the end of the restraint webbing. The anchor bolt fits through a hole in the plate allowing it to rotate around the bolt.

Some anchor bolts are covered by a plastic housing with a slot on top allowing the restraint webbing access to the bolt. When the system is loaded the webbing may press against the plastic housing. This interaction may cause crush of the webbing and a permanent notch may be created in the slot of the housing where the webbing pressed against it (see Figs. 1 and 2).

Sometimes the anchor bolt is covered by the floor carpet and the webbing passes through a small access hole. During collision loading the webbing may press against the carpet, rip it, and make the hole larger (see Fig. 3).

Lap Belt

From the anchor bolt the webbing passes across the front of the seat at a location approximately where the seat cushion meets with the seat back. When loaded, the webbing sometimes makes contact with the seat, usually as it passes over the top edge of the seat cushion. The seat material will usually be transferred onto the webbing. Such transfer evidence is easily rubbed off; therefore, the webbing should be handled carefully. The seat should be examined closely because such abrasions are often small.

As the lap portion of the webbing is examined the investigator can expect to see signs of precollision damage from the belt being caught between the locking bolt and the door. Sometimes the webbing becomes hooked on the locking bolt at the lower B-pillar as the occupant is exiting his vehicle. The door is shut and the webbing becomes trapped in the

FIG. 1—*Ripping of the plastic housing of the seat belt floor anchor.*

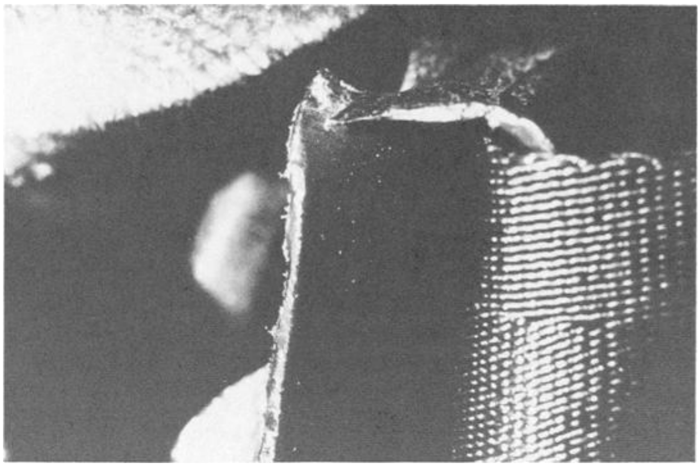

FIG. 2—*Closeup view of the deformation to the plastic housing.*

FIG. 3—*During collision loading, the webbing that passes through a small access hole in the carpet rips it and makes the hole larger.*

latch. This action causes small rips in the webbing material accompanied by black grease smears from the latch, itself. Typically, this evidence is located in an area 30 to 70 cm from the anchor bolt, however, these measurements may vary in individual cases.

Also in this region of webbing the investigator may sometimes find evidence that the occupant's body was pressing hard on the belt during the collision. Thus the webbing may contain longitudinal creases and abrasions. Traces of clothing fiber may become melted onto the webbing. If the investigator can determine the type and color of clothing worn by the vehicle occupants it is possible to determine the occupant seating positions by matching these fibers.

Tongue

At a location roughly 85 cm from the outboard floor anchor bolt the investigator may find evidence that the tongue portion of the system was interacting with the webbing.

The tongue is the metallic piece which the occupant holds and locks into the buckle when the belt is put on. The tongue may be free sliding or may be equipped with a locking bar which jams the webbing at a particular adjusted length. The type of loading evidence will depend on the type of tongue.

With a locking tongue the webbing will become creased. The crease shows up as a single line on the surface of the webbing where the top of the tongue is visible (Fig. 4) and four parallel lines on the other side (Fig. 5). The crease will usually be oriented at a diagonal to the webbing length.

Tongue loading evidence from a sliding tongue is usually in the form of a heavy transfer

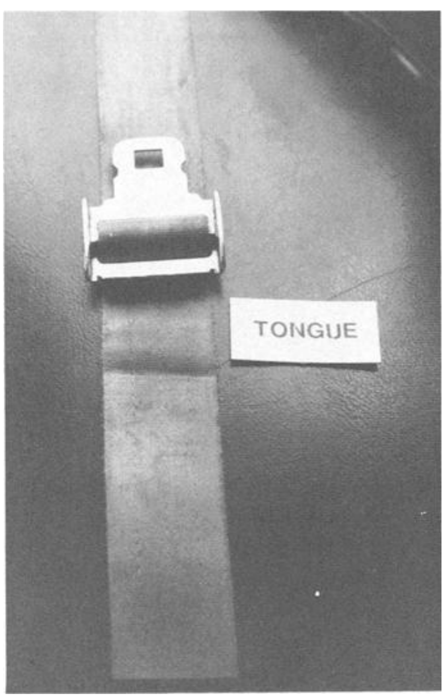

FIG. 4—*With a locking tongue the webbing will become creased. The crease appears as a single line on the surface of the webbing where the top of the tongue is visible.*

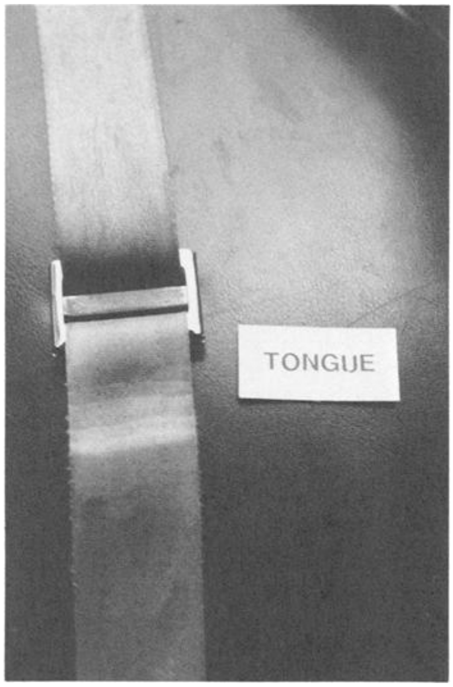

FIG. 5—*Four parallel lines on the other side of the webbing appear where the underside of the tongue is visible.*

of plastic material on the webbing. The plastic material is melted through friction as interaction occurs between the surfaces of the plastic-coated tongue and the webbing.

Caution should be taken, however, in locating actual tongue interaction evidence made during an impact and not to confuse it with an area of webbing deterioration produced through constant use of the restraint. Constant use causes the webbing material to deteriorate somewhat. Some webbing material fibers may be seen sticking up when the edge of the belt is examined. Also the webbing may become bulged from continual interaction with the tongue. Evidence of tongue interaction may develop from extensive use of the system, however, it will show as a general area of deterioration as opposed to a distinct crease (or area of transfer) produced by collision loading.

Another mark occurs when the tongue lies at one location on the webbing for a long period of time. Dust will collect in the crevices where the tongue features make contact with the webbing. As a result, the shape of the tongue-locking bar, which is outlined in dust on the webbing, could be mistaken for a loading mark. Sometimes the dust can be imbedded deeply in the webbing material; therefore the investigator should study it closely. In some instances the metal from the tongue will rust and this deposit will form on the webbing. This evidence may indicate that the restraint is infrequently, or never, used.

The investigator should also be aware that the tongue crease from loading is often located near a crease often made by the D-ring when the restraint is not in use and in a stowage position. When the restraint is stowed, the retractor will retract the webbing until it lies parallel to the B-pillar. While in this stowage position, the retractor causes the webbing to rest with some pressure on the lower bar of the D-ring. This interaction causes the above-mentioned crease which should not be confused with the tongue-loading crease.

To differentiate, the crease induced by the D-ring while the belt is in a stowage position will not be as pronounced as that caused by the tongue during collision loading. The tongue crease will show up as a sharp, narrow line. Another way of distinguishing the two is that the tongue crease will usually be oriented diagonal to the webbing width whereas the impression produced by the D-ring during stowage of the belt is normally perpendicular to the webbing length.

Torso Belt

The torso portion of the webbing also may exhibit signs of loading as a result of the interaction of the occupant's chest and shoulder with the webbing. Such evidence is usually in the form of longitudinal abrasions which occur from contact with the occupant's clothing. Transfers of skin or clothing fabric are also possible.

Some seat back types have a plastic loop or guide located on their outboard top corner. This device works to guide the torso portion of the webbing into a proper fitting position. During collision loading the webbing can force the plastic guide to pop out of its anchor or it may simply fracture (see Fig. 6). Also, because this guide is often made of plastic, it will sometimes become abraded by the webbing. Either condition may add further proof to the suspicion that the belt was worn.

Note, however, that such evidence can be misleading as shown by the example in Fig. 6. A light-colored abrasion to the seat back shows the webbing was lying flat against the seat back when it was loaded (instead of over the driver's shoulder). Such loading occurs

FIG. 6—*During collision loading, the webbing can force the plastic guide located on the seat outboard top corner to pop out of its anchor or fracture.*

when the seat back is loaded from the rear by another occupant, or by heavy cargo. The abrasion on the seat back travels too far down along the front surface of the seat back and is angled to the outboard edge of the seat instead of inboard. This loading pattern is indicative of the seat belt being in its stowage position at the time the load was applied.

In other collision situations the torso portion of the webbing can rub over the top surface of the seat back. Such action can rub off some of the plastic, vinyl, or cloth material of the seat back and this may be transferred onto the webbing (see Figs. 7 and 8). Note that in this example, the seat belt was probably in use by the driver. The shoulder belt ran across the top of the seat back and over the driver's shoulder. Thus, the abrasion was located on the top surface of the seat back (rather than on the front surface as shown in Fig. 6).

FIG. 7—*In collision situations, the torso portion of the webbing can rub over the top surface of the seat back.*

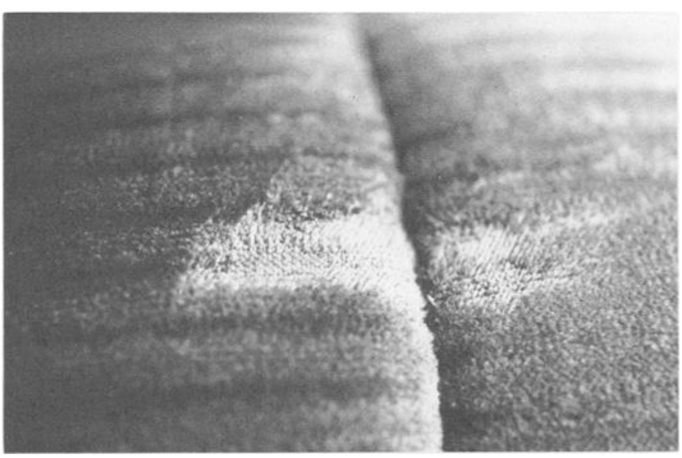

FIG. 8—*The action in Fig. 7 can rub off some of the plastic, vinyl, or cloth material of the seat back and this may be transferred on to the webbing.*

D-Ring

The D-ring is perhaps the best indicator, besides the crease produced by the tongue, of restraint system usage by an occupant during a collision. The D-ring is another guiding device that directs the webbing towards the occupant's shoulder as it is pulled in and out of the retractor at the base of the B-pillar.

Usually D-rings covered in plastic produce very good loading evidence. When the loaded webbing contacts the plastic D-ring it abrades the surface (Fig. 9), and some of the plastic becomes transferred onto the webbing material (Fig. 10).

Pieces of the abraded plastic can usually be found clinging to the D-ring at a ridge where interaction between the surfaces ceases. Also, the abraded plastic surface will exhibit lines from the weave of the webbing material (see Fig. 9). Such striations are diagnostic of collision-induced loading. If such evidence is not present, yet a smooth groove exists in the plastic, it is likely caused by constant usage of the belt over an extended time.

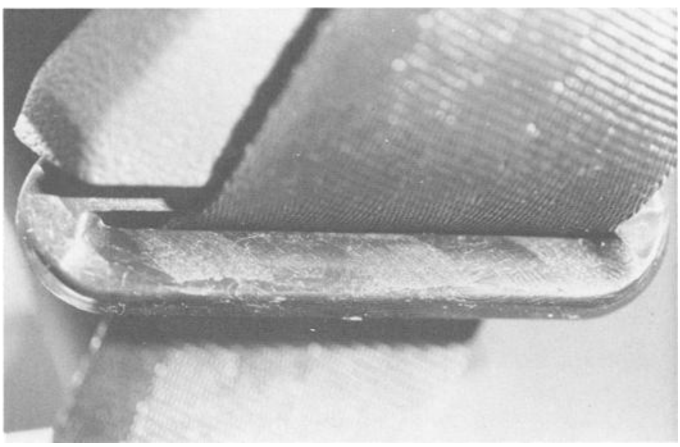

FIG. 9—*When the loaded webbing contacts the plastic D-ring it abrades the surface.*

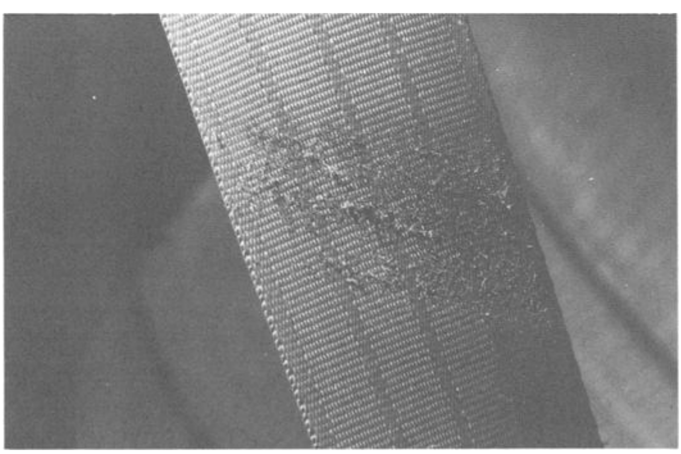

FIG. 10—*Some of the plastic from the D-ring transfers onto the webbing material.*

Typically, the transferred, D-ring material is located on the webbing at approximately 185 cm from the outboard, floor-anchor bolt. This distance should be interpreted with caution when determining proper restraint usage because many other factors influence the location of this evidence. Such factors include the size of the occupant, the adjusted position of the occupant's seat, whether the vehicle had two or four doors, and whether the restraint system was adjusted properly.

The investigator should not be surprised if loading evidence is not found at this location because some D-rings produce clearer loading evidence than others. Metallic D-rings that have no plastic covering produce poor evidence of loading either on the ring or on the webbing which interacts with them. Fortunately, metal D-rings are uncommon.

Also note that sometimes D-ring transfers on webbing are faint and difficult to locate. A method for locating transfers is shown in Fig. 11. One end of the webbing is brought to the eye and the other is extended out with a straight arm. The investigator should scan the surface of the webbing for changes in material color, contours, and texture. The webbing should be moved to different positions and angles relative to a light source until the optimum viewing conditions are obtained.

The investigator should be aware that sometimes a D-ring becomes abraded during a collision even though the restraint is not worn. For example, this occurs when a vehicle-sensitive, emergency-locking retractor has locked the webbing and the B-pillar is deformed or displaced.

In another situation, towing personnel sometimes tie the seat belt webbing to a loose door or to the steering wheel. During transportation to a holding compound the vehicle is subjected to various conditions which lock the retractor and interaction may occur at the D-ring.

Other loading evidence is created at the D-ring anchor bolt. The D-ring is anchored

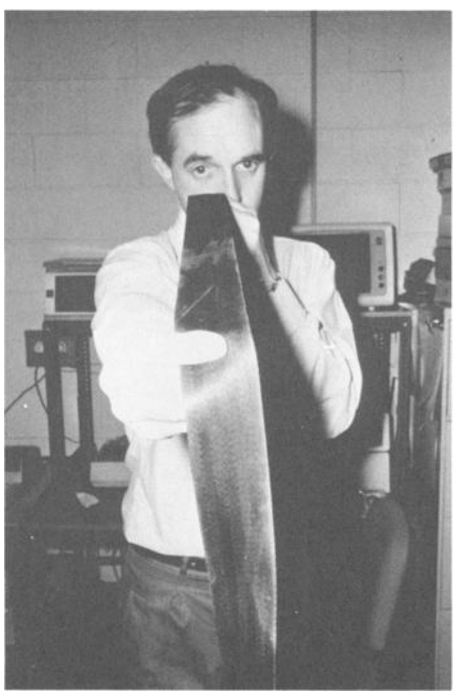

FIG. 11—*Method for locating D-ring transfers on webbing.*

by a bolt to the B-pillar. A clearance hole in the D-ring assembly allows the D-ring to rotate around the bolt since it is a loose fit. A plastic washer is located between the D-ring and the anchor bolt. When the webbing is loaded the D-ring moves against the anchor bolt thus trapping the plastic washer. Evidence of a permanent crease in the washer is sometimes an indication that a significant force was exerted on the restraint system, thus indicating the restraint was worn (see Fig. 12).

The D-ring itself should also be examined to determine the extent of its rotation during loading. This can be done by removing this component and examining the surface that faces the B-pillar. Some portions of the D-ring housing, particularly the forward and rear ends, will contact the surface of the B-pillar producing marks on the mutual surfaces. The locations of the marks may provide further information about the manner of restraint loading.

Retractor

As a final analysis, the restraint system's retractor can be examined for evidence of marking from interaction between the locking bar and teeth. Sometimes the teeth of the seat belt webbing spool, and the locking bar within the retractor, can be observed in situ. More often, it is necessary to remove the retractor assembly from the vehicle, and perhaps to disassemble the retractor mechanism, to conduct a thorough examination.

Summary

A number of locations have been identified where an investigator might find evidence of loading of the restraint system. Such evidence may well be a sign of restraint system usage in a collision, however, caution should be used to discriminate between damage caused by collision-induced loading and that occurring through wear over time.

The angle of the various loading marks on a restraint system can give the investigator clues as to the direction of that occupant's movement during the collision, and in turn, this can provide evidence regarding the forces being applied to the vehicle.

To summarize, the most common locations of evidence of restraint loading are those

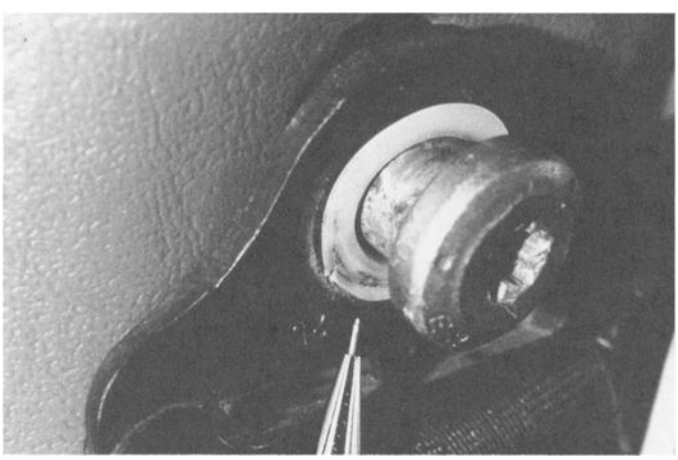

FIG. 12—*Evidence of a permanent crease in the washer located between the D-ring and the anchor bolt indicates that a significant force was exerted on the restraint system, thus indicating the restraint was worn.*

at the tongue and at the D-ring. Even at these locations, the evidence can become inconclusive due to many confounding factors. This is why when seat belt wearing is an important question to a particular agency, the restraint should be removed carefully or documented thoroughly and presented to an experienced investigator for analysis.

References

[1] Severy, D. M., Blaisdell, D. M., and Horn, L. S., "Motorist Head and Body Impact Analysis," Report SAE 850097, 1985.

[2] Green, R. N., "The Human Body in Collision," in *Proceedings of the International Association of Coroners and Medical Examiners Annual Seminar*, Toronto, Ontario, 1982, pp. 151–156.

[3] Moffatt, C. A., Moffatt E. A., and Weiman, T. R., "Diagnosis of Seat Belt Usage in Accidents," in *SAE Advances in Belt Restraint Systems: Design, Performance and Usage, Conference Proceedings*, P-141, Detroit, 1984, pp. 255–269.

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