C36 Frontal Crash Buckle Pretensioner Activation Causing Seat Belt Retractor Skip- Lock Failure

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After attending this presentation, attendees will be more informed about a parameter called webbing jerk that can have a detrimental affect on a seat belt retractor's ability to lock as intended in a frontal crash.

This presentation will impact the forensic science community by detailing how the activation of a seat belt buckle pretentioner can cause a retractor skip-lock condition. Case studies will be presented. The presentation will heighten the sense of awareness with regard to undertstanding seemingly conflicting evidence. On one hand, the seat belt assembly reveals artifacts indicating use in a crash. But, on the other hand, the injuries sustained are not those consistent with a properly seat belted occupant.

Introduction: Many modern seat belt assemblies utilize pretensioners to enhance the ability of seat belts to mitigate or prevent injury by removing excess webbing slack and cinching the seat belts on the occupants. By tightening the seat belts, the occupants are more tightly coupled to their vehicle and are able to enjoy the safety benefit of better ride down.

Seat belt pretensioners can be found in the retractor or buckle. When activated, the retractor pretensioner tightens the seat belt by rotating the retractor reel. When the buckle pretensioner is activated, the seat belt is tightened by pulling the buckle and latch plate closer to the inboard anchor.

It has been suspected that certain levels of webbing jerk (rate change of acceleration), upon activation of a buckle pretensioner, can cause retractor to skip-lock. That is, the retractor does not lock before an unintended amount of webbing payout, or does not lock at all. Thus, under certain crash conditions rather than enhancing occupant safety, the buckle pretensioner can induce a skip-lock, thereby negating the safety benefit of seat belt use.

In the past, laboratory tests have demonstrated buckle pretensioner characteristics that produce higher levels of webbing jerk can induce the skip-lock phenomenon. To augment the laboratory results, two examples of skip-lock retractor failure in the field resulting in unrestrained occupant injury patterns to seat belted occupants are presented.

FMVSS: Federal Motor Vehicle Safety Standard 209 is the compliance standard for occupant restraint systems. Section S4.3(j)(1) states an emergency-locking retractor of a type 1 or type 2 seat belt assembly, when tested in accordance with specified procedures, shall lock before the webbing extends 25 mm when the retractor is subjected to an acceleration of 7 m/s^2 (0.7g). However, it has been shown that certain seat belt assemblies, those with buckle pretensioners, fail to perform within the intent of this section, and at worse, will fail to perform as specified in the standard in real world collisions.

Case 1 Overview: A southbound Nissan Sentra, while crossing a highway, was broadsided by a westbound Plymouth Neon. After impact, the Plymouth came to rest facing westbound in the eastbound lane with no lights. Minutes later, a 2000 Ford Focus, traveling at about 59 mph, struck the Plymouth head-on. The Ford sustained an average of approximately 16 inches of crush, corresponding to a velocity change of about 30mph with a Principle Direction of Force (PDOF) of 12 o'clock. The driver's seat belt was a type 2 assembly featuring a continuous loop webbing, single emergency locking retractor, and a seat-fixed, end-release pretensioning buckle.

Upon impact the Ford's airbag did not deploy and the driver sustained facial lacerations when his head struck and broke the windshield. Inspection of the Ford's interior showed outward bowing of the windshield with bits of hair and tissue embedded in the fracture lines. The steering wheel assembly was loose due to complete separation of the shear capsules. The instrument panel on either side of the steering column was deformed forward. These artifacts, or witness marks, are generally consistent with the forward translation of an unrestrained driver in a frontal crash of this magnitude.

However, inspection of the driver's seat belt revealed that the driver's buckle pretensioner had activated indicating that it had been buckled. In addition, the plastic coating of the D-ring, the plastic opening in the B-pillar trim plastic, and the latch plate showed physical evidence consistent with the webbing rapidly moving through these components. This physical evidence indicates the driver's seat belt was worn, but the emergency locking retractor did not lock, effectively rendering the driver unrestrained.

Review of NHTSA's ODI database did not reveal any defect investigations or recalls for the front seat belts of the 2000 Ford Focus; however, 80 percent of consumer complaints that were related to seat belt or retractor performance in frontal collisions indicated that the seat belt retractor failed to lock.

Case 2 Overview: A three-vehicle collision was initiated when a pickup truck lost control on a rain-soaked highway with a posted speed limit of 70 mph. The pickup truck crossed into the oncoming traffic lane, clipped the left side of a vehicle and then collided broadside with the front of 2000 Cadillac DeVille. The resulting velocity change to the Cadillac was approximately 20 mph with a PDOF of 12 o'clock.

During the second impact, the pickup truck subsequently rode up onto the hood of the Cadillac, pushing the hood rearward toward the windshield. Because the impact was offset to the right front of the Cadillac, the collision resulted in a higher degree of deformation to the front passenger area. The pickup truck may have also engaged the windshield header of the Cadillac, as there was localized intrusion to this region. The Cadillac was equipped with front seat type 2

assemblies that are completely seat integrated, with dual emergency-locking retractors and a pretensioning buckle for the driver and front passenger.

Upon impact the Cadillac's airbags did not deploy and the front passenger sustained serious injuries including multiple facial fractures, a basilar skull fracture, and a comminuted left femur fracture. This injury pattern is consistent with an unrestrained occupant in a frontal impact of this magnitude. Inspection of the Cadillac revealed that the driver and front passenger were in fact seat belted and both their buckle pretenioners activated in response to the crash, but the passenger's emergency locking retractor did not lock, effectively rendering her unrestrained.

Cadillac Product Safety Recall: In November 2000, the passenger lap belt retractor did not remain locked during an in-house 30 mph frontal barrier test. A visual inspection of the retractor revealed a fracture of the lock pawl and shaft tooth, artifacts indicating a partial engagement of the lock pawl to the shaft, or retractor skip-lock.

From December 2000 until March 2001, the seat belt supplier statically tested thirty samples. The conclusion of these tests showed that the damage to the retractor noted in November was an effect—not a cause.

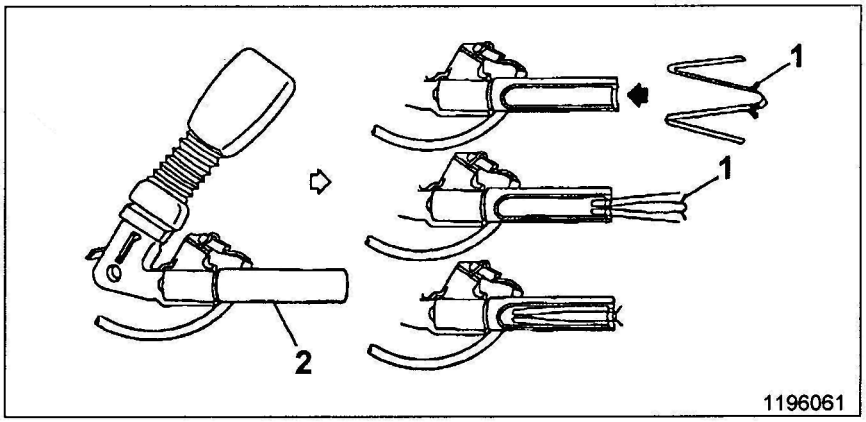
In April 2001, a driver shoulder belt retractor did not remain locked during an in-house 35 mph sled test. Visual inspection revealed a partial engagement of the lock pawl to the shaft.

From April to September 2001, the supplier modified the lock pawl processing to reduce die roll on its tip and improve the area of the lock surface. Static tests were performed to evaluate processing modifications and no significant differences in performance were noted.

In January through April 2002, a sled test series was conducted using seat mounted high-speed cameras to observe the retractor performance and loading profiles, but no suspect retractor behavior was observable. The test protocol was then modified to increase its capability to apply a controlled input to the retractor. It was determined that the velocity of the webbing alone did not duplicate the incident retractor performance. Through data analysis, focus was directed to webbing acceleration onset, i.e., jerk.

A final test series characterized the retractor lock performance over a range of locking pawl pre-positions and buckle pretensioner output (jerk) levels. A trend in retractor lock behavior was determined to be directly related to jerk. As the jerk level increases, the lock behavior transitions from lock on to the design intended tooth to a later lock which may result in a partial engagement of the intended tooth or a lock on a subsequent tooth.

The fix: A revised buckle pretensioner with a reduced micro-gas generator was introduced into the production of the 2002 Cadillac DeVille on May 15, 2002. However, over 269,000 vehicles, produced between May 1999 and May 2002, were subject to recall. Service Bulletins were sent to dealers describing a method to repair the defective buckle pretensioners. The procedure calls for a retainer to be inserted into the pretensioner cylinder (as depicted in the illustration). Once the retainer is seated, when the pyrotechnic micro-gas generator activates, the retainer slows the piston's travel within the cylinder, thereby reducing the level of jerk previously measured.



Conclusion: This study identified two cases where the physical evidence observed on the lap and shoulder belt indicated the system was worn at the time of collision. However, the resulting occupant kinematics and increased forward excursion lead to unexpected upper torso, head and facial injuries. These field examples of retractor failure augment the laboratory results that demonstrated that a jerk condition induced by buckle pretensioner activation could cause a retractor skip-lock condition that resulted in unwanted webbing payout. A vehicle product safety recall was issued for one of the vehicles.

Seat Belt Failure, Skip-Lock, Buckle Pretentioner

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