Intelligent Safety Systems

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Abstract: - At the beginning of passive safety systems, the basic function of seatbelt was to keep the passenger in the interior of car when an impact was produced. Nowadays every car is crowded with many sensors, and some of them can provide a lot of information regarding the status of the car, such as speed, acceleration-deceleration, lateral deviance (ESP), emergency break (ABS), distance to other vehicles and obstacle, night vision, usage of belts, and other. All these data can be used in the precrash period, to prepare the passenger by impact. For these it is necessary to have an intelligent management system, which can control all passive safety systems.

Key-Words: automotive safety systems, redesign, pretensioner, retractor

1 Introduction
A typical seatbelt consists of a lap belt, which rests over the passenger pelvis, and a shoulder belt, which extends across the occupant chest. The two belt sections are tightly secured to the frame of the car in order to hold passengers in their seats. When the belt is worn correctly, it will apply most of the stopping force to the rib cage and the pelvis, which are relatively sturdy parts of the body. Since the belts extend across a wide section of the passenger body, the force is not concentrated in a small area, so it cannot do as much damage. Additionally, the seatbelt webbing is made of more flexible material than the dashboard or windshield. Safe seatbelts will only let the passenger shift forward slightly.

Car seatbelts have the ability to extend and retract. However, in a collision, the belt will suddenly tighten up and hold the passenger in place. In a typical seatbelt system, the belt webbing is connected to a retractor mechanism. The central element in the retractor is a spool, which is attached to one end of the webbing. Inside the retractor, a spring applies a rotation force, or torque, to the spool. This works to rotate the spool so it winds up any loose webbing [1]. A retractor mechanism with webbing is presented in figure 1.

When the passenger pull the webbing out, the spool rotates counter-clockwise. This turns the attached spring in the same direction. Effectively, the rotating spool works to untwist the spring. The spring tends to return to its original shape, so it resists this twisting motion. If the passenger releases the webbing, the spring will tighten up, rotating the spool clockwise until there is no slack in the belt.

The retractor has a locking mechanism that stops the spool from rotating when the car is involved in a collision. There are two sorts of locking systems in common use today: systems triggered by the car's movement and systems triggered by the belt's movement. The first sort of system locks the spool when the car rapidly decelerates (when it hits something, for example). The figure 2 presents the simplest version of this design.

The central operating element in this mechanism is a weighted pendulum. When the car comes to a sudden stop, the inertia causes the pendulum to swing forward. The pawl on the other end of the pendulum catches hold of a toothed ratchet gear attached to the spool. With the pawl gripping one of its teeth, the gear cannot rotate counter-clockwise, and neither can the connected spool. When the webbing loosens again
after the crash, the gear rotates clockwise and the pawl disengages. The second kind of system locks the spool when something jerks the belt webbing. The activating force in most designs is the speed of the spool rotation. The central operating element in this design is a centrifugal clutch - a weighted pivoting lever mounted to the rotating spool [3]. When the spool spins slowly, the lever does not pivot at all. A spring keeps it in position. However, when something pulls the webbing, spinning the spool more quickly, centrifugal force drives the weighted end of the lever outward. The Airbag Control Unit (ACU) is essentially the brain of the airbag system. It takes inputs from the crash sensors and makes the decision to fire the proper airbags at the proper force depending on the type and direction of the impact [3, 4]. Sensors feed information into the vehicle safety BUS network and communicate directly with the Airbag Control Unit. Today cars, with intelligent safety systems, are fitted with Electronic Control Unit (ECU), which contains a unit called Intelligent Management System (IMS) for seatbelts. Safety Computing Unit (SCU) is the "brain" of the intelligent system. It takes all decision regarding the function of single parts, and it store in its database diagrams of every single crash situation. It will decide when or how the airbag goes on, or the retractor blocks, pull back in seat the passenger or activate the pretensioner and the load limiter functions. The Airbag module receives information from the ECU in a car crash and activates airbag deploying.

2 Intelligent retractor

The basic idea of a load limiter is to release a little more excess belt webbing when a great deal of force is applied to the belt. The simplest load limiter is a fold sewn into the belt webbing. The stitches holding the fold in place are designed to break when a certain amount of force is applied to the belt. When the stitches come apart, the webbing unfolds, allowing the belt to extend a little bit more. This is the biggest disadvantage because the seatbelt cannot be used after a car crash.

The actual system blocking of the retractor, with ball, is not so comfortable for the passengers because when the webbing is blocked it produced noise [5]. One of solutions is a noise reducing cover. However, for this solution are appended a lot of money with injection mould and poka - yoke devices on the assembly lines. For these it is necessary to have an intelligent retractor, which can be used always and which is noiseless.

In this paper is presented the concept of a new intelligent retractor that can be controlled by the Electronic Central Unit (ECU).

The difference between a usual retractor and the presented concept is the new intelligent blocking system and load limiter. The new intelligent blocking system is different from the classic one because is electronically controlled. Intelligent load limiter is a new concept and is designed to assure a total flexibility, disregarding the passenger mass or the impact force.

2.1 Intelligent blocking system concept

For a good understanding of the new intelligent blocking system below is a short presentation of an existing blocking system.

The car sensitivity blocking system is presented in figure 3. This system is made up from components that work together for blocking command of the retractor.

Blocking sensor is composed by blocking lever (2), sensor ball (3) and sensor frame (4). Together, the three components send the signal to the steering wheel (1) that will command the lock dog to lock on the frame.

The ball is placed in a conical dwelling inside the sensor frame (4). When the car roll with a constant acceleration and with zero inclination the ball will remain placed in the conical dwelling. If during the drive a powerful deceleration occur the ball inertia force will take out the ball from the conical dwelling. The ball will move up the blocking lever (2). The blocking lever will lock the steering wheel and the steering wheel will push the lock dog on the frame tooth.

The conical dwelling geometry is designed to keep in the ball when the retractor is mounted in the correct position in the car. Therefore, each retractor with this type of sensor can be used only for a particular car and this is biggest disadvantage of this sensor. For every car pillar configuration another frame sensor configuration should be designed. That means a new mould and the growth of manufacturing costs. In addition, on the assembly lines confusion can occur.
Another disadvantage of this blocking system is the noise. The ball blocking system is very noisy. The idea for replacing the classic blocking system is to use an electromagnetic blocking system. In this way by using only one central sensor is possible to drive all retractors mounted in a car.

The new blocking system will command the blocking lever through an electromagnet. The sensor will work in the back-up mode. This means that always the sensor is supplied with electricity and the lever is retracted. When the central sensor detects a deceleration or a car inclination, the Electronic Control Unit interrupt the electricity supply and a light spring will push the lever up in the steering wheel.

In figure 4 is presented how the new blocking system works and the principal components. The components of the new blocking system are: 1 - Lock dog, 2 - Steering wheel, 3 - Thread head, 4 - Blocking lever, 5 - Electromagnet, 6 - Sensor frame.

When presence sensors from the chair detect the passenger, the electromagnet (5) is supplied with electricity. The lever (4) position is retracted, so the passenger can extract webbing from the retractor spindle.

If during the trip, an incident occurs, like a powerful brake or a big inclination of the car, the central sensor will send a signal to the ECU. The Electronic Control Unit will interrupt the electricity supply of the electromagnet and the lever will be pushed up by the spring (7).

If the power supply source is destroyed in a car crash or an Electronic Control Unit break down occurs the electromagnet will be automatic unsupplied, and the spring will maintain the lever locked in the steering wheel tooth.

2.2 Intelligent load limiter concept

Load limiters absorb the load in a crash in a very efficient way by keeping the belt force at a controlled and pre-defined level. This is accomplished by a mechanism in the retractor that allows webbing to be pulled out slightly - and in a controlled way - if the load on an occupant's body becomes too high in a violent crash [6]. The system is typically used in combination with an airbag, which then absorbs the excessive energy. This is especially important for elderly, since studies have shown that a 60-year-old person can only take half as much load on his rib cage as a twenty-year-old person [7]. The load limiter is typically integrated with the retractor, where a specially designed bar holds the spindle with the webbing. When the force from the webbing reaches a preset level, the bar will twist, allowing the spindle to turn and thereby limiting the load on the occupant's chest. Seatbelt systems with load limiters typically also have pretensioners that reduce the forward motion of the occupant by tightening the belt at the beginning of a crash [8]. The adaptive load limiter is the first load limiter offering an improved chest loading distribution. Additionally the adaptive load limiter satisfies the ECE-R16 homologation requirement and thus enabling the deactivation of the airbag module for example when a child restraint system is used [9].

The switching system is using a gas generator that has the function of altering the load path from the preset high load limitation level to the lower load limitation level. This, within the car impact, must offer also a regressive load characteristic.

Because the existing load limiters are not enough flexible for all type of passengers (mass, age and gauge) and for the size of the forces during the crash a new solution is presented in this paper. The solution founded is to replace the mechanical dumper system with a hydraulic one. The hydraulic medium is not a usual one, being hydraulic liquid with metallic powder. Through some electromagnets, the liquid
viscosity can be controlled and, in this way, can obtain the flexibility of the load limitation. The system used is nearly the same like a door dumper, but only with one sense (figure 6.a and b).

For a good understanding of how flexible load limiter works the entire process will be presented during a crash. If a car crash occurs, the Electronic Control Unit will receive information from the central sensor and will command the electromagnet locking system (4). The locking system lever will lock the steering wheel (2). If the steering wheel is locked, a relative motion between the spindle (7) and the steering wheel occurs. Because of the relative movement, the lock dog pin (1) will be guided in the cam profile from the steering wheel and than will interact with the frame teeth (6).

Depending on the crash violence, the webbing solicitation will be bigger or lower. The size of webbing solicitation can be detected with a force sensor. The force sensor will measure the force in the webbing and will send the signal to Electronic Control Unit. Depending on how big the force is the Electronic Control Unit will control the current intensity in the retractor electromagnets from the load limiter. Because of the variation of current intensity, the magnetic field around the electromagnets will be variable as well. Depending of the magnetic field intensity the liquid viscosity will be variable.

The load limiter effect is obtained by relative rotation of the spindle (5) and the locked thread head (3). The link between the two elements is the hydraulic liquid with controlled viscosity.

The rotation of the spindle is realised through the transfer liquid and a sense valve (1), which is placed in the spindle piston. When the force from the webbing (4) is bigger than a limit value, the hydraulic liquid will push the ball. The ball will push the spring, which
is calculated to be compressed only after a force limit is overtaken. This is the limit when the load limiter will be activated.

In figure 7.b is shown the load limiter in phase one, the start position of the spindle piston rotation. This is the retractor normal position without solicitation. In phase two, the retractor load limiter is in action when it is in an angular rotation relative to the thread head. A block diagram of the intelligent retractor management is presented in figure 8. As is shown, the

Electronic Central Unit receive the information from the three sensors, occupant presence sensor, car sensitivity sensor and webbing load sensor, process it and send commands to the intelligent retractor (intelligent load limiter and blocking system). The input information for the occupant presence sensor is the weight, for car sensitivity sensor is the deceleration and inclination and for the webbing, load sensor is the force that appear in the webbing during the crash.

The Electronic Central Unit transmits information to the retractor. For the intelligent flexible load limiter the Electronic Central Unit will modify the viscosity of the liquid by modifying the variation of the electromagnetic field. For the intelligent blocking system, the Electronic Central Unit will stop the electricity supply.

Using this solution, a constant behaviour of the force during the car crash can be obtained. This will help the passenger to have a low level of injuries.

Using this type of intelligent retractor is a way of cost reducing for safety systems. When a car is implied in a crash, the torsion bar with load limiter (from actual retractor) is torn. The seatbelt must be replaced by a new seatbelt in order to reuse the car again. This is the bigger disadvantage of torsion bar. After a crash, a car fitted with flexible load limiter, could be used again without further costs.

3 Conclusion

Taking in consideration that the number of car crashes grows the automotive safety is one of the important aspects that the car manufactures expand. This is why many companies build up their activities in this domain and invest a lot of money for developing new products with bigger performances than the existing one in order to limit the car crashes effects.

The electronics is used in the most of the cases to control the systems, replacing mechanical systems. Generally, a central electronic control unit controls all automotive safety systems.

Passive safety systems (seatbelts, airbags etc.) and active safety systems (ABS, ESP, AFU) works together but indirect being interconnected by an electronic control unit. The electronic control unit take the information from the active systems and if some parameters limits are exceeded, it will take the decision to send the needed information to the passive safety system.

How the complex an intelligent safety system can be is presented in figure 8 by a block diagram. This block diagram is completed with the new equipments presented in this paper. The newer parts added are only in the concept state but in the future can be implemented in the car safety systems. The concept part from this diagram is linked to the usual retractors. The intelligent retractor system is completed with intelligent locking system and intelligent flexible load limiter. The two new concepts present a high level of performance and eliminate many disadvantages of the classic systems. This new concepts can be commanded also by the electronic control unit. The two concepts will improve the performances of the classic retractor.

Another fact presented is regarding the decision to replace the classic blocking system with the ball with an electromagnetic one. The idea is to replace the ball with an electromagnet and a spring that will command
the blocking lever. The rest of the blocking mechanism is the same as in the classic retractor. 
The advantages of this solution are: 
- only one central car sensitivity sensor is used. The sensor detects the information regarding inclination and deceleration and sends it to the electronic control unit. The electronic control unit takes the decision to interrupt the electricity supply for electromagnet. The spring will push the lever to lock the retractor 
- noise reduction. The classic system produces noise when the lever gets in contact with the steering wheel teeth
- higher reaction speed in relation with the classic system
- elimination of the mounting specific angle
- back-up system
- the blocking possibilities are reduced
- lower price.
The actual types of load limiters are not enough flexible in the car crash inputs. The inputs in a car crash are the weight, the position of the occupant and the impact forces.
The solution is developing a new concept for an intelligent load limiter by replacing the torsion bar with a system that works like an electromagnetic dumper.
The biggest advantage is the possibility of this load limiter to be adaptive to many situations and after the impact, the retractor is not destroyed.

References: