Review on Study of Active and Passive Safety Systems

Rahul B.Waghe[1] and S.Y.Gajjal[2]
[1,2]Department of Mechanical Engineering
NBN Sinhgad School of Engineering
Pune University, Pune

B.V.Shamsundara[3]
[3]SHL Department
Automotive Research Association of India (ARAI)
Pune

***Abstract*—Many developed and developing countrieincluding India have a serious road accident problem. This has led the Automotive Manufacturers induce more focus on safety of a vehicle. New safety systems like Antilock Braking System (ABS), Traction Control System (TCS), and Autonomous Emergency Braking System (AEBS) etc. have been invented and implemented. Safety Systems of a vehicle can be categorized as Active Safety System and Passive Safety Systems.** Active safety system **refers to devices and systems that help keep a car under control and prevent an accident. Passive safety system refers to system in the car that protects the driver and passengers from injury when an accident occurs. In this paper we have discussed working, sensors used of various active and passive safety systems in detail.**

Keywords-Active Safety, Passive Safety, ABS, TC

I. INTRODUCTION

We are at the stage of actively avoiding accidents as well as providing maximum protection to the vehicle occupants and even pedestrians. The normal approach of active and passive safety systems deliver their functionalities only at their phase specifically. Active safety features can help prevent crashes. Passive safety features prevent the occupants from injury after an accident occurs. Every technology described in this paper has a safety benefit. Some technologies have additional benefits such as improving driver and passenger comfort. Some of the more advanced technologies come at a cost but many are very inexpensive and practical to install. Approximately half of these recommended technologies can be retrofitted to a vehicle/heavy vehicle.

II. ACTIVE SAFETY SYSTEMS

A. Antilock Braking Systems (ABS)

ABS is a system which prevents the wheels of a vehicle from locking up during severe braking. Keeping the wheels rotating means they can continue to have traction on the road, which assists the driver to maintain directional stability. In most cases, ABS assists to reduce stopping distances and improving vehicle control during severe braking on dry or slippery road conditions. However on loose surfaces for gravel or snowy roads, ABS may increase stopping distances because it releases the brakes intermittently to assist in maintain directional stability. There are four main components to an ABS system: 1) Speed sensors 2) Pump 3) Valves 4) Controller

1) Speed Sensors: The anti-lock braking system needs some way of knowing when a wheel is about to lock up. The speed sensors, which are located at each wheel, or in some cases in the differential, provide this information.

2) Valves: There is a valve in the brake line of each brake controlled by the ABS. On some systems, the valve has three positions: In position one, the valve is open; pressure from the master cylinder is passed right through to the brake. In position two, the valve blocks the line, isolating that brake from the master cylinder. This prevents the pressure from rising further should the driver push the brake pedal harder. In position three, the valve releases some of the pressure from the brake.

3) Pump: Since the valve is able to release pressure from the brakes, there has to be some way to put that pressure back. That is what the pump does; when a valve reduces the pressure in a line, the pump is there to get the pressure back up.

4) Controller**:** The controller is a computer in the car. It watches the speed sensors and controls the valves. The key inputs for the ABS control module come from the wheel speed sensors and the brake pedal switch. The brake pedal switch signals the control module when the brakes are being applied. The wheel speed sensors provide information about what is happening to the wheels while the brakes are being applied.

B. Electronic Stability Control (ESC)

Electronic stability control (ESC) also known as Electronic stability program (ESP) is a computerised technology that improves safety of a vehicle’s stability by detecting and reducing loss of traction. When ESC detects loss of steering control, it automatically applies the brakes to help steer the vehicle. Braking is automatically applied to wheels individually. Some ESC systems also reduce engine power until control is regained.

C. Electronic Brake Force Distribution (EBD or EBFD)

varies the amount of force applied to each of a vehicle's brakes, based on road conditions, speed, loading, etc. Always Electronic brake force distribution, Electronic brake force limitation (EBL) is an automobile brake technology that automatically coupled with anti-lock braking systems, EBD can apply more or less braking pressure to each wheel in order to maximize the front end carries the most weight and EBD distributes less braking pressure to the rear brakes so the rear brakes do not lock up and cause a skid. In some systems, EBD distributes more braking pressure at the rear brakes during initial brake application before the effects of weight transfer become apparent. Electronic wheels dependent on tyre grip. EBD offers greater braking stability under all braking conditions and does not require ABS to be activated to operate.

D. Traction Control System (TCS)

A Traction Control System also known as Anti-Slip Regulation (ASR), is typically a secondary function of the anti-lock braking system on production vehicles, and is designed to prevent loss of traction of the driven road wheels, and therefore maintain the control of the vehicle when excessive throttle is applied by the driver and the condition of the road surface (due to varying factors) is unable to cope with the torque applied. Traction refers to the maximum frictional force that can be produced between surfaces without slipping. Typically, traction control systems share the electro-hydraulic brake actuator (but does not use the conventional master cylinder and servo), and wheel speed sensors with ABS. The basic idea behind the need of a traction control system is the difference between traction of different wheels evidencing apparent loss of road grip that compromise steering control and stability of vehicles. Difference in slip may occur due to turning of a vehicle or differently varying road conditions for different wheels. At high speeds, when a car tends to turn, its outer and inner wheels are subjected to different speed of rotation that is conventionally controlled by using a differential.

E. Autonomous Emergency Braking System

An Advanced Emergency Braking System (AEBS) or Autonomous Emergency Braking (AEB) is an autonomous road vehicle safety system which employs sensors to monitor the proximity of vehicles in front and detects situations where the relative speed and distance between the host and target vehicles suggest that a collision is imminent. AEB systems automatically apply the brakes to reduce speed when sensors on the vehicle identify a likely collision and the driver has not applied sufficient braking and is not attempting to steer away. AEB System is the safest braking system in the world. It employs state of the art radar technology specifically designed for Automotive Radars or car radars and its primary function is to avoid collisions or mitigate the impact during critical situations by applying the brakes automatically. The AEB system is designed to function on different sets of road scenarios. First, it alerts the driver of existing obstacles in front of a car. If the driver fails to act on time to avoid a collision, the AEB system will automatically apply emergency brakes with different levels of force using its intelligent algorithm for speed, trajectory, momentum, and other factors to avoid or at least lessen the impact of the collision. Some models will deploy or activate the restraint system ready for impact.

F. Roll Stability Control

Roll Stability Control (RSC) is an active vehicle safety system that automatically intervenes if a high rollover risk is detected while driving. If a rollover threat is occurring, the system intervenes and assists the driver in minimizing the rollover risk by automatically reducing vehicle speed. Roll Stability Control is designed specifically for your truck or tractor to help maintain vehicle stability and aid in reducing vehicle rollovers. RSC continuously checks and updates the lateral acceleration of the tractor and compares it to a critical threshold where rollover may occur. When the critical threshold is exceeded, RSC intervenes by reducing engine torque, and engaging the engine retarder, while automatically applying drive axle and trailer brakes. The vehicle‘s electronic control unit analyzes wheel speed, load information and transverse acceleration data to detect the likelihood of vehicle roll-over before the driver realizes there is a risk and automatically applies the brakes. It is an active safety system for passenger vehicles. It uses a roll rate sensor together with the information from the conventional electronic stability control hardware to detect a vehicle's roll condition associated with a potential rollover and executes proper brake control and engine torque reduction in response to the detected roll condition so as to mitigate a vehicular rollover. Roll stability control (RSC) and electronic stability control (ESC) systems represent two different types of automated stability control systems that actively reduce the vehicle‘s throttle and apply its brakes to decelerate the vehicle if a high rollover risk or instability threshold is detected. RSC systems address roll instability, while ESC systems address both roll and yaw instability. The idea of RSC, first documented in, was developed at Ford Motor Company and has been implemented on various vehicles within Ford Motor Company since its debut on the 2003 Volvo XC90.

G. Blind Spot Monitoring

Blind Spot Detection is a system designed to assist the driver in making lane change manoeuvres by monitoring traffic at the rear and sides of the vehicle. Using two radar sensors it detects vehicles travelling in the rear and alongside our vehicle and warns the driver of the position of any unseen vehicles around him travelling in his ―Blind Spot. The active blind spot detection system can detect traffic situations that could be dangerous if your vehicle changes lanes. The driver is informed and warned in two stages. These kinds of traffic scenarios arise, for example, when distant vehicles rapidly approach from behind. They are then in the "lane change zone" shown in the graphic. These kinds of situations are difficult for the driver to judge, especially after dark. The radar sensors work completely independently of the light conditions. The first stage of detection is called "information" and it is provided as soon as the system is switched on and a hazardous lane change situation is present. The information is provided by activating warning lights in the door mirrors. If the driver intends to make a lane change and uses the turn signal stalk to indicate this, a second, more intense stage will then be issued, the "warning". The corresponding warning light then flashes with high intensity and the steering wheel starts to vibrate. The driver must cancel the lane change and if necessary steer back into his own lane to avoid a dangerous situation.

III. PASSIVE SAFETY SYSTEMS

A. Adaptive Seat Belt

Active seat systems experience real-time seat movement due to various automotive vehicle man oeuvres. An occupant of an active seat system may be subject to real-time seat belt forces that vary in response to range and type of movement of the occupant in the seat system. The varying seat belt forces can become unpleasant to the occupant. Traditional seat systems are capable of being translated in a fore and aft direction or in an upward and downward direction relative to a vehicle frame. The system includes a seat belt extensible about an occupant of a seat system. A seat belt tension sensor is coupled to the seat belt and generates a seat belt tension signal. A seat belt actuator is mechanically coupled to the seat belt and adjusts tension of the seat belt. A controller is electrically coupled to the seat belt tension sensor and the seat belt actuator. The controller generates a seat belt tension adjustment signal in response to the seat belt tension signal and adjusts tension of the seat belt in response to the seat belt tension adjustment signal. A method for performing the same is also provided. One of several advantages of the present invention is the ability to adjust seat belt tension, during vehicle operation, to compensate for seat system movement. The ability to adjust seat belt tension decreases the potential for seat belt discomfort due to seat system movement, especially for active seat systems. Another advantage of the present invention is that in adjusting seat belt tension, vehicle dynamics, occupant characteristics, and seat system position are considered, thereby, providing seat belt tension determination system for various operating conditions and occupant characteristics. Thus, the system can potentially provide increased occupant safety by maintaining adequate seat belt tension on a vehicle occupant.

B. Inflatable Seat Belts

A Seat Belt, also known as a safety belt, is a vehicle safety device designed to secure the occupant of a vehicle against harmful movement that may result during a collision or a sudden stop. Seat belts were invented by English engineer George Cayley in the early 19th century, though Edward J. Claghorn of New York, was granted the first patent (U.S. Patent 312,085, on February 10, 1885 for a safety belt). The Inflatable Seatbelt was invented by Donald Lewis and tested at the Automotive Products Division of Allied Chemical Corp. Inflatable seatbelts have tubular inflatable bladders contained within an outer cover. When a crash occurs the bladder inflates with a gas to increase the area of the restraint contacting the occupant and also shortening the length of the restraint to tighten the belt around the occupant, improving the protection. The inflatable sections may be shoulder-only or lap and shoulder. The system supports the head during the crash better than a web only belt. It also provides side impact protection. In 2011, Ford began offering rear seat inflatable seat belts on a limited set of models, such as the Explorer and Flex. The belt is connected to vehicle sensors, used to detect a collision and give the belts the signal to inflate.

C. Under Run Protection Devices

Many times we see a passenger car going down the heavy commercial vehicle (like truck or trailer) either from rear, front or side. During a collision between such a truck and a passenger vehicle, there is a risk that the passenger vehicle will penetrate under (run under) the front or rear part of the truck and thus be jammed between the road surface and the underside of the frame or load carrier of the vehicle. The result may be that the rear part of the truck will enter the passenger compartment of the vehicle with great force, which in turn may cause serious injuries to the passengers of the vehicle. These UPD‘s are popularly classified as:

1. RUPD (rear under-run protection devices) - It prevents the entry of a small vehicle under the rear side of the truck. It is mounted on the rear side of the truck on chassis frame.

2. SUPD (side under-run protection devices) – which prevents the entry of a vehicle under the side body of the truck. It is mounted on the side rail of chassis ladder or can be mounted on truck body.

3. FUPD (front under-run protection devices) – It is designed to avoid the under run entry of colliding vehicle during head to head collision. It is at the front of the vehicle.

All the above mentioned UPD‘s have to be designed and fitted on vehicle according to respective standards of the countries. While designing them we need to consider the section of channel, material, ground clearance, fitment on vehicle using sheet metal mounting brackets etc. The device is designed to fail, but will absorb the impact energy of colliding vehicle and saves it to go under the heavy truck. Without UPD, passenger car compartment is likely to interact with stiff commercial vehicle chassis frame structures.

D. Collapsible Steering Column

Steering is the term applied to the collection of components, linkages, etc. which will allow a vessel (ship, boat) or vehicle (car, motorcycle, and bicycle) to follow the desired course. The most conventional steering arrangement is to turn the front wheels using a hand–operated steering wheel which is positioned in front of the driver, via the steering column, which may contain universal joints (which may also be part of the collapsible steering column design), to allow it to deviate somewhat from a straight line. The basic aim of steering is to ensure that the wheels are pointing in the desired directions. This is typically achieved by a series of linkages, rods, pivots and gears. A collapsible steering column is a mechanism that is used to transfer power from the steering wheel into the steering gear box, which transfers power to turn the wheels of a vehicle. Though the designs for steering columns have varied since their inception, a typical collapsible steering column looks like two interlocking shafts that attach directly to the steering wheel and the steering gear box. The steering column is the shaft directly under the steering wheel in which the ignition and automatic shift levers are often located. The safely enhanced construction of the collapsible steering column, no matter which design is used, absorbs, rather than transfers, frontal impact energy by collapsing or breaking upon impact. In this way, drivers involved in frontal impact collisions are able to avoid the dangers of non-collapsible steering parts.

IV. SENSORS USED

A. Wheel Speed Sensor

These sensors use a magnet and a coil of wire to generate a signal. The rotation of the wheel or differential induces a magnetic field around the sensor. The fluctuations of this magnetic field generate a voltage into the sensor. The number of voltage pulses per second induced in the pickup changes frequency. The frequency of the signal is proportional to wheel speed. The higher the frequency, the faster the wheel is turning.

Figure 4.1.1 Speed Sensor in an ABS

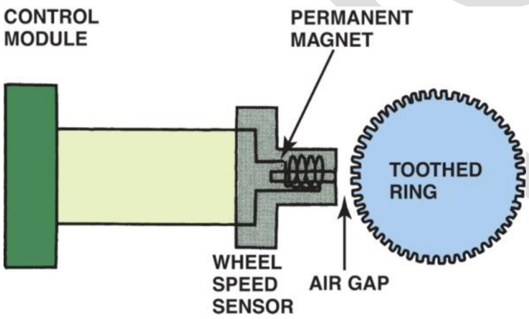

Figure 4.1.2 Working of Speed Sensor

B. Acceleration Sensor

1). Piezo-electric acceleration sensor (Up To 35g):- The heart of this acceleration sensor is a piezo-ceramic strip of polycrystalline sintered material. When electrically polarized, this material displays a piezo-electrical effect: That is, when pressure is applied, the mechanical loading results in charge separation, or a voltage which can then be picked off by electrodes. The piezo bending element comprises a bonded structure containing two inversely polarized piezo strips, the so called bi-morphous strips. When subjected to acceleration, the piezo ceramic bends by as much as 10-7 m. for signal processing, the sensor is provided with a hybrid circuit which is comprised of an impedance converter, a filter and an amplifier. These serve to define the sensitivity and effective frequency range. The filter removes the HF signal components. The lesser frequency limit of 0.6 Hz is defined by the piezo element itself. Using a supplementary test input, the sensor's electronic functions can be monitored as well as piezo-strip integrity.

2). Surface type mems based acceleration sensor (±35g to ±50g):- These acceleration sensors rely on a capacitive measuring principle. Acceleration causes the seismic mass to deflect in the x-direction. This seismic mass is suspended on wave-shaped bending springs. One electrode set is connected to the seismic mass (comb-like structure) and moves along with the particular acceleration. These movable electrodes are designed as capacitor plates and are also provided with immovable counter-electrodes which are separated from each other by a narrow air gap. The application of a capacitive differential circuit with two capacitors results in a reduction of the non-linearity of the signal evaluation. Overload stops are provided as a protection against over-acceleration. These prevent direct contact between the electrodes (combs). Mechanical sensitivity is defined by the geometrical shape of the springs. Changes in C1 and C2 are registered and changed to a corresponding voltage by a capacity/voltage converter.

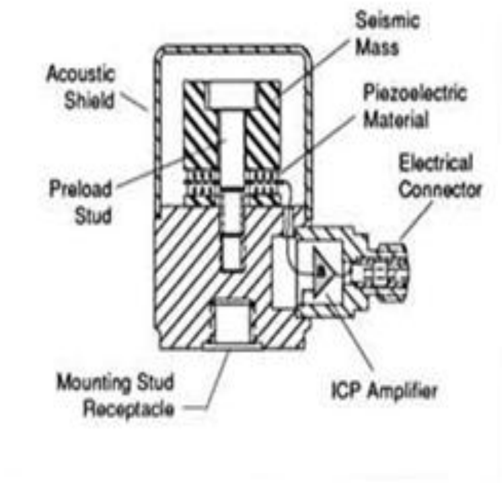

Figure 4.2.1 Piezo-Electric Acceleration Sensor

Figure 4.2.2 Surface Type MEMS Based Acceleration Sensor

C. Steering Angle Sensor

1). Electromagnetic Induction Based

(a). Basic Principle: Principle is electromagnetic induction, in which a change in a coil inductance due to shielding of magnetic flux is detected. When a plate conductor is inserted in the region of magnetic flux generated by the coil, an eddy current will flow to shield the magnetic flux, so that by changing the shielding area of the plate conductor, a change in the coil inductance is caused as illustrated in Figure 4.3.1.1, and the steering angle can be detected from this inductance change.

(b). Detection Principle : Practical configuration of the product is such that a plate conductor of changing width is situated on the coil, and the plate conductor is fixed to a rotor that rotates in synchronization with the steering shaft. As the steering shaft rotates, the shielding area of the plate conductor for the magnetic flux generated by the coil changes, thus causing a change in the coil inductance that corresponds to the steering rotation angle.

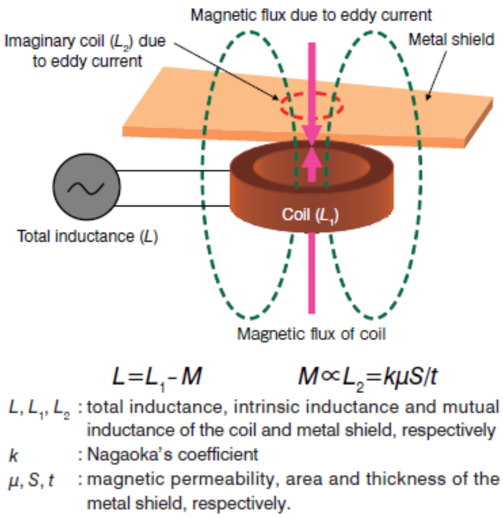

Figure 4.3.1.1- Basic Principle

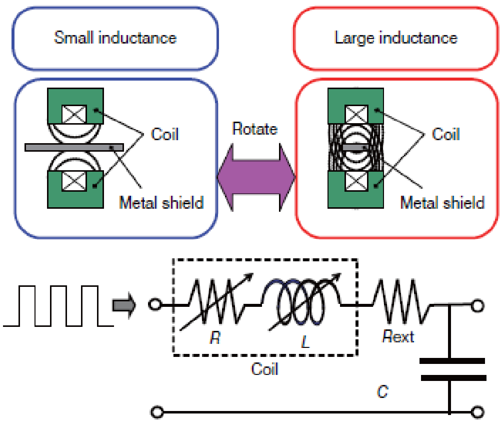

Figure 4.3.1.2- Detection Principle

2). Optical Sensor Based

(a). Basic Principle- Absolute Measuring Systems Using this measuring system, every position of the measurement range/angle is identified by a definite code on a glass or plastic disc. This code is represented on the disc in the form of light and dark regions within different tracks. This combination relates to an absolute numerical value. Thus, the position value is always directly available, counters are not necessary. In addition it is not possible to get continuously invalid values caused by interferences or loss of the supply voltage. Movements which are done while the system is turned off are immediately measured after the system is powered up.

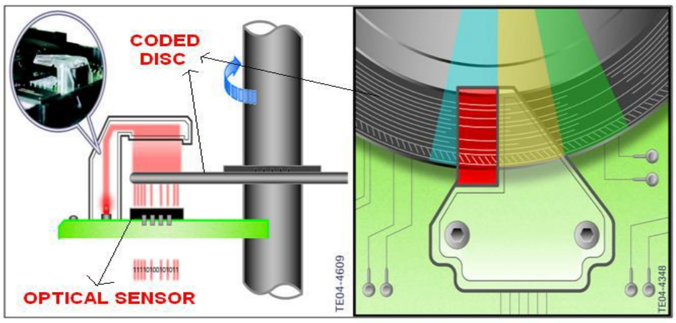

Figure 4.3.2 - Construction of sensor

(b). Detection Principle : The measuring system consists of a light source, a code disc pivoted in a precision ball bearing and an opto-electronic scanning device. A LED is used as a light source which shines through the code disc and onto the screen behind. The tracks on the code disk are evaluated by an opto-array behind the reticle. With every position another combination of slashes is covered by the dark spots on the code disk and the light beam on the photo transistor is interrupted. That way the code on the disc is transformed into electronic signals. Fluctuations in the intensity of the light source are measured by an additional photo transistor and another electronic circuit compensates for these. After the electronic signals are amplified and converted they are then available for evaluation.

D. Yaw Rate Sensor

A Yaw Rate Sensor (or rotational speed sensor) measures a vehicle's angular velocity about its vertical axis in degrees or radians per second in order to determine the orientation of the vehicle as it hard-corners or threatens to roll-over. It measures the rotation rate of the car; i.e. how much the car is actually turning. The data from the yaw sensor is compared with the data from the steering wheel angle sensor to determine regulating action. The yaw rate sensor is typically located under the driver or passenger seat, mounted on the level floorboard in order to access the vehicle‘s centre of gravity.

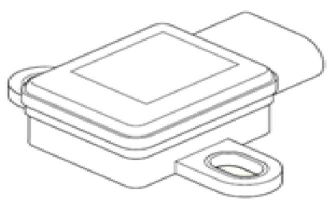

Figure 4.4 – Yaw rate sensor

E). Radar

Radar is currently the most widely adopted sensing technology for automotive ranging applications but careful design and optimization are needed for a particular sensing task (e.g. frequency, antenna type and size, range, power limitations etc.) and frequency band availability is limited. It is suitable for both short and long range applications (typically <1 to 200m) and is superior to many other technologies for vector analysis. Radar sensors are also known to have sufficient robustness to function reliably under harsh environmental conditions for extended periods of time. Their performance is affected by atmospheric attenuation (particularly molecular oxygen and water droplets and precipitation will increase attenuation, especially at higher frequencies. Radar sensors are of medium to high cost and offer poor recognition of lane markings. They rely on objects reflecting the radar waves so objects with poor reflectivity are not easily detected. The simplest type of radar system is a basic rangefinder that measures the time of flight of the transmitted radar beam from its reflection. This provides the distance between the sensor and the obstacle. Pulsed radar is frequently used in automotive applications to continuously update the position and closing speed etc. of the obstacles in the radar field of view.

$$R_{\max} = \sqrt[4]{\frac{P_{Tx} \cdot A^2 \cdot \sigma}{P_{\min} \cdot 4\pi \cdot \lambda^2}}$$

With regard to the radar equation of monostatic radar the maximum range Rmax is proportional to the square root of the effective antenna aperture size A and to the square root of the frequency denotes the reflectivity of the target, P_{Tx} the transmitted power and $P_{\min}$ the minimum power necessary for detection. Therefore, highest frequencies should be preferred to get small box volumes. But this demand is contrary to the availability of cost saving microwave technologies. The antenna size of 77 GHz LRR sensors may decrease to approx. 50 x 50 mm^2. But even when the sensitivity would be sufficient, high antenna directivity and low side lobes would still be necessary to cope with the effects of guard rails and irrelevant surroundings besides the road lanes.

V. CONCLUSION

We have studied the various active and passive safety systems in detail. The basic principles behind the technologies and sensors used in these systems have been studied. This paper can help further in developing new systems by providing basic information or working of the systems discussed.

VI. ACKNOWLEDGMENTS

The authors would like to thank the anonymous reviewers for their comments which were very helpful in improving the quality and presentation of this paper.

REFERENCES

[1] Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems, NHTSA website.

[2] *Evaluation Of The Performance Of Available Back over Prevention Technologies For Light Vehicles* Elizabeth N. Mazzae W. Riley Garrott,National Highway Traffic Safety Administration, United States Paper Number 07-0292

[3] *Collision Avoiding System (CAS)* ,Muntaser Momani Al-Balqa’ Applied University ,Faculty of Engineering Technology, 11140 P.O. Box 425530 Amman, Jordan Contemporary Engineering Sciences, Vol. 5, 2012, no. 7, 341 – 354

[4] *A Real-Time Embedded Blind Spot Safety Assistance System*, Bing-FeiWu, Chih-Chung Kao, Ying-Feng Li, and Min-Yu Tsai Institute of Electrical and Control Engineering, National Chiao Tung University, Hsinchu 300, Taiwan Hindawi Publishing Corporation ,International Journal of Vehicular Technology, Volume 2012, Article ID 506235, 15 pages,doi:10.1155/2012/506235

[5] *The Effectiveness of ESC (Electronic Stability Control) in reducing real life crashes and injuries* Anders Lie Swedish Road Administration, Claes Tingvall Swedish Road Administration, Monash University Accident Research Centre, Paper number 05-0135

[6] *Fully-Adaptive Seatbelts for frontal collisions* Timothy J. Paulitz, Donald M. Blackketter, Karl K. Rink National Institute for Advanced Transportation Technology, Department of Mechanical Engineering, University of Idaho, United States, Paper Number 05-0127

[7] Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems, NHTSA website.

[8] Driving Safety Systems Book-Bosch Automotive Technology.