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A REVIEW OF ACTIVE AND PASSIVE AUTOMOTIVE SAFETY SYSTEMS

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ABSTRACT
Safety of an automobile is one of the important areas while designing a vehicle. This paper gives an overall view of the different safety features that are taken care of while designing a vehicle. Available technologies of different active and passive safety features were analyzed. These technical features once incorporated in design not only help in avoiding the accidents but also reduces the fatigue caused to the driver which further mitigates the chances of an accident. Dissipation of the kinetic energy forms the guiding principle while designing all the passive safety features. Crumple zones situated in front and rear absorb this energy upon impact in a predictable way. Safety features such as forward collision warning systems, lane departure warning systems, electronic stability control, anti-lock braking systems, brake assist monitor, brake override, Crumple zones, seatbelts and airbags have been dealt with in detail with an overview of the total vehicle safety.

INTRODUCTION
Automobile designers today are putting more emphasis on safety aspects of vehicle (Mir Irfan Ul Haq, Ankush Anand, Tawqeer Nasir and Dhananjay Singh 2013). As per Transport Research Wing (TRW) of Ministry of Road Transport & Highways Government of India, total no of persons injured were 511394 and persons died in accidents were 142485 in 2011. Auto designers are constantly working to reduce these fatalities and injuries by incorporating in design, new technologies developed for active and passive safety systems. Government and customers both are supporting this cause of safety which has further bolstered the hand of designers. Vehicle occupant safety can be classified into two areas first one is design for crash avoidance or active safety and second one protection of occupant in case if crash occurs known as crash worthiness or passive safety (Thomas P. Wenzel, Marc Ross 2004). Passive safety systems comprises of those components of vehicle that respond to crash to protect occupants from injury, while features of active safety systems constantly act to reduce the possibility of such an event. Active safety features work silently in the background for checking the rotation speed of the tires, the location of the vehicle in its lane, or the position of the acceleration and brake pedals relative to each other. Passive safety features work to ensure that this life space is as safe as possible, and that vehicle occupants remain in this space throughout the crash. Crumple zones help to absorb and distribute crash forces before they reach the passenger and driver's seats. Similarly, seatbelts, airbags, and headrests help keep the driver and passengers stationary within the life space of the vehicle (Sieveka EM Kent RW Crandall JR 2001a, Nitin S Motgi1, P.R.Kulkarni2 & Sheelratan S Bansode3 2012b). Recently innovators have focused on developing advanced crash avoidance and active safety systems such as forward collision warning systems, lane departure warning systems, Anti Lock braking systems (ABS), Electronic stability Control (ESC), brake assist monitor, brake override etc. These devices have been developed optimized and implemented to prevent or mitigate accident severity. With the introduction of New Car Assessment Programs (NCAPs) that prescribe standardized crash tests things are getting more focused in the area of safety. In this study all these available active and passive technologies will be analyzed and there effects on the vehicle safety will be reviewed.

ACTIVE SAFETY FEATURES
Active safety features are those that help to prevent or mitigate road crashes. Active safety features will engage to either prevent the crash from occurring, or reduce the severity of an unavoidable crash. Some features like forward collision warning systems and lane departure warning systems activate a warning system when potentially dangerous situations are detected. Other safety features like electronic stability control, anti-lock braking systems, and brake assist monitor the vehicle's tires and brake systems for any signs that makes braking necessary in order to avoid a collision. All active safety features constantly monitor one or more aspects of the vehicle for potential hazards. When something problematic is detected, active safety features act autonomously to correct the situation safely. Active safety features offer an extra layer of protection on the road. While they cannot replace a safe and attentive driver, these features can be relied on to engage when they are most needed. Some of the active safety features that are in common use are discussed in below given subheadings.

Forward Collision Warning (Fcw)

These systems alerts when any vehicle is about to collide with another vehicle some distance ahead. The type of warning that the systems use are flash light, alarm sound or vibration (Ardalan Vahidi, Azim Eskandarian 2003). These systems are based on camera or radar sensors which continuously monitors the road ahead. They provide object recognition and detect relative speeds between a vehicle and object on the road. Warning systems simply warn the driver when a collision is likely to take place, but the system does not automatically apply the brakes.

Lane Departure Warning (Ldw)

These systems gives an alert whenever vehicle unintentionally drift too close to the edges of the lane. The warning type can be alarm sound or generation of vibration in driver's steering wheel or seat. Warning systems provide a warning, but corrective action is desired at the level of the driver. Preventive system if any can gently steer the car to center of the lane automatically (Joshua M. Clanton, David M. Bevly, and A. Scottedward Hodel, 2009).

Electronic Stability Control (Esc)

These systems help to maintain or regain control of vehicle in difficult driving situations (Damrongrit Piyabongkarn, Jae Y. Lew, Rajesh Rajamani, John A. Grogg, and Qinghui Yuan 2007). ESC continuously monitors tire movement and steering wheel activity to sense a loss of traction or slippage. In unexpected situations, ESC systems can reduce engine power, apply brakes independently to each wheel and correct tire suspension much faster than the driver. ESC incorporates yaw rate control into the anti-lock braking system (ABS). It also has a traction control system (TCS), which senses drive-wheel slip under acceleration and individually brakes the slipping wheel or wheels and / or reduces excess engine power until control is regained. The sensors used for ESC have to send data at all times in order to detect possible defects as soon as possible. The most important sensors are: Steering wheel angle sensor, Yaw rate sensor, Lateral acceleration sensor, Wheel speed sensor, longitudinal acceleration sensor, Roll rate sensor. ESC uses a hydraulic modulator to assure that each wheel receives the correct brake force. The brain of the ESC system is the electronic control unit (ECU). The various control techniques are embedded in it. Often, the same ECU is used for diverse systems at the same time (ABS, Traction control system, climate control, etc.).

Anti-Lock Braking Systems

Vehicle moves due to the frictional force between the tyre and road. When brakes are applied, a torque in the opposite direction as that of friction is applied and the wheel gradually comes to rest (D Peng, Y Zhang, CL Yin, JW Zhang 2008). The function of ABS is to prevent this wheel locking. ABS has Electronic control unit (ECU), Four sensors for monitoring wheel speed and a pair of valves in each brake unit. The ECU monitors the speed of each wheel. If it detects that any wheel is rotating slower speed than others (this indicates an imminent wheel lock) it redirects the valves to reduce brake pressure. Conversely if it detects a wheel faster than the others it instructs the valves to increase brake pressure. EBD (Electronic Brake Force Distribution System) is basically a subsystem of ABS and it always works in conjunction with an ABS system. The main job of EBD is to optimise brake force on each wheel individually so to get maximum breaking power without losing control. It can alter braking pressure on each wheel individually depending on the conditions and weight distribution of the vehicle at that moment.

Brake Assist

Brake assist supports unexpected braking in case of emergency. Studies show that nearly half of all drivers do not step on the brake quickly and strongly enough to stop the vehicle in case of an emergency (http://www.toyotaglobal.com 2015). When Brake Assist detects an attempted panic stop, it supports drivers by strengthening the power (Figure 1). Brake Assist will detect attempted panic braking based on the force that is applied to the brake pedal and how fast the driver is stepping on the pedal. When the system recognizes sudden braking, it will add additional pressure to the brake. When foot is released during Braking Assist, braking power lessens and regulates the brakes with ease.

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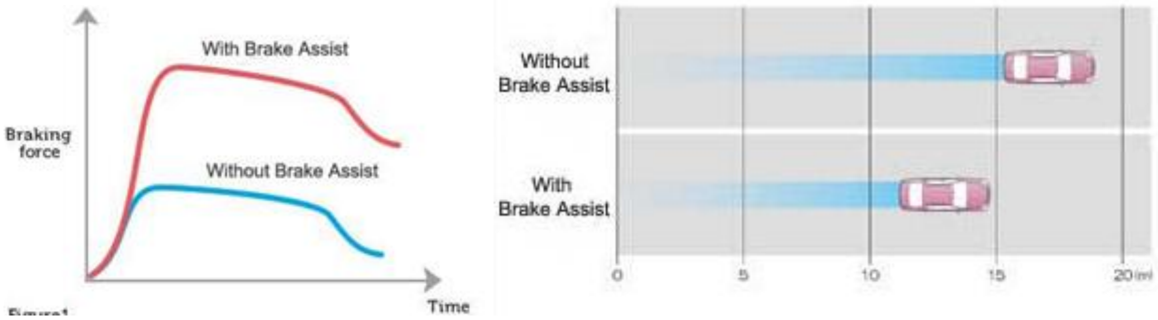

Figure 1 Comparison of vehicle with and without brake assist

Brake Override
Brake override is also known as a smart pedal. In these brake systems, sensors recognize when the accelerator pedal and brake pedal are being pressed at the same time. It understands that this has taken place by mistake. The car's central computer slow's the car down safely. The technology was first used in the BMW 750 in the late 1980s as a performance enhancement. Every BMW built since 2001 has had brake override. Chrysler was the next manufacturer to use brake override in its 2003 models. These days, several car manufacturers use the technology, with more soon to follow (wheels.blogs.nytimes.com 2015). In the case of brake override systems, the system requires sensors at the brake and accelerator pedals, a computer to make decisions for what the car should do and wiring to connect it. If it detects a problem, like the driver holding the brake while the car is speeding up, computer engage the brake override and slows the engine, through different methods given below

- Adjust the throttle position
- Reduce the amount of fuel getting to the engine
- Change the timing
  Toyota, for example, uses accelerator pedal sensors, brake light switch circuitry and vehicle speed sensors to detect when a vehicle may be going out of control.

PASSIVE SAFETY FEATURES
Passive safety features are those that help to protect vehicle occupants from further injury once a crash has occurred. The main function of passive safety features is to keep the driver and passengers protected within the vehicle from various crash forces. The life space is a protected area around vehicle occupants within which the chances of escaping a crash with minimal injuries are more. Passive safety features work to ensure that life space remains safe and that vehicle occupants remain in this space throughout the crash. Crumple zones help to absorb and distribute crash forces before they reach the passenger and driver's seats. Similarly, seatbelts, airbags, and headrests help keep the driver and passenger(s) stationary within the life space of the vehicle.

Crumple Zones
Crumple zones are the structural areas in the front and rear of the vehicle that are designed to absorb energy upon impact in a predictable way as shown in figure 2 (Hyung –il moon, young-eun jeon, Dae Young Kim, Heon Young Kim, Yong-soo Kim 2012) . Crumple zones add time to the crash by absorbing energy. Newton's second law of motion, force=mass × acceleration conveys that as the time it takes for an automobile to come to rest or change direction is increased the force experienced by the automobile (and its occupants) is decreased. Conversely too if the time to stop is shorter the force experienced is greater.

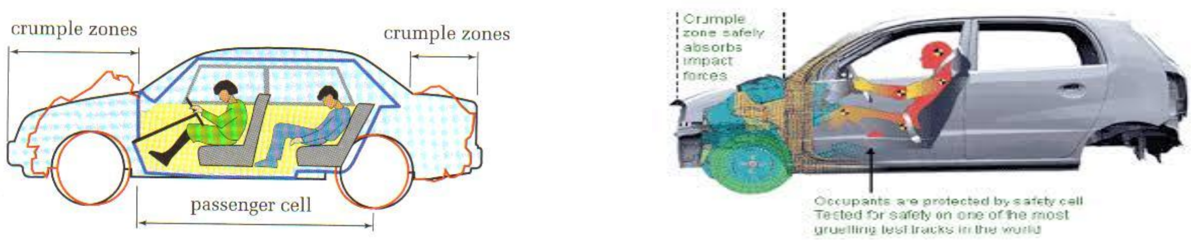

Figure 2 Crumple zone position

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When used in crumple zones, lightweight plastic components can help absorb energy and save vehicle weight at the same time. Most crumple zones are constructed with steel or titanium, high density and low density polymeric foam, spaced reinforcing fibres, spaced mechanical ribs and reinforced metal inserts with notched section for predetermined crumpling. The crumple zone will firstly have high density polymeric foam which contains more tightly formed molecules to make the foam strong; this is placed in front of the cabin. Secondly reinforced fibers are spaced between the high density polymeric foam and the low density foam, this low density foam has loosely from molecules which give the foam and greater absorbing ability then a hard breaking one. Thirdly the foam is caged in mechanical ribs made from either steel or titanium and have been specifically designed to crush downwards under the car. Lastly the front end of a car is built with steel or titanium, these metal piece are reinforced with notched metal inserts which will cause the metal to either crush upwards, downwards or to the side depending the collision therefore leaving the engine safe for movement and thus the cabin and occupants safe.

Seat Belts
Seatbelts reduce the risk of death for a front seat car occupant by about 50 percent (Peter Cummings, James D. Wells, Frederick P. Rivara, P. Cummings 2003). If the vehicle is stopped suddenly the occupant keeps on moving because of inertia and if not stopped the occupant might hit the steering or windshield which might cause injury (Sieveka EM Kent RW Crandall JR 2001). A seatbelt applies the stopping force to more durable parts of the body over a longer period of time. A seatbelt's job is to spread the stopping force across sturdier parts of body in order to minimize damage. A typical seatbelt consists of a lap belt**,** which rests over pelvis, and a shoulder belt, which extends across chest. 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. Seatbelt webbing is made of flexible material than the dashboard or windshield. It stretches a little bit, which means the stop isn't abrupt. 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. When we pull the webbing out, the spool rotates counter-clockwise, which turns the attached spring in the same direction. Effectively, the rotating spool works to untwist the spring. The spring wants to return to its original shape, so it resists this twisting motion. If webbing is released, the spring will tighten up, rotating the spool clockwise until there is no more 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
- 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 diagram (Figure 3) below shows the simplest version of this design.

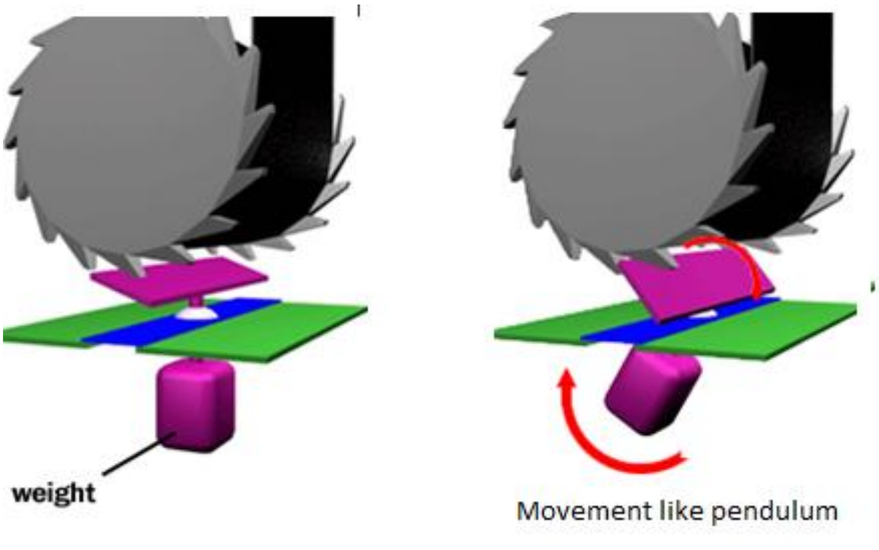

Figure 3 Engagement of the Pawl

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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 can't 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 Pretensioner

The pretensioner is to tighten up any slack in the belt webbing in the event of a crash. Whereas the conventional locking mechanism in a retractor keeps the belt from extending any farther, the pretensioner actually **pulls in on the belt**. This force helps move the passenger into the optimum crash position in his or her seat. Pretensioners normally work together with conventional locking mechanisms (Sieveka EM Kent RW Crandall JR 2001). Some pretensioners pull the entire retractor mechanism backward and some rotate the spool itself. The processor monitors mechanical or electronic **motion sensors** that respond to the sudden deceleration of an impact. When an impact is detected, the processor activates the pretensioner and then the air bag.

Some pretensioners are built around electric motors or solenoids, but the most popular designs today use **pyrotechnics** to pull in the belt webbing figure 5. The central element in this pretensioner is a chamber of combustible gas. Inside the chamber, there is a smaller chamber with explosive **igniter** material. This smaller chamber is outfitted with two electrodes, which are wired to the central processor. When the processor detects a collision, it immediately applies an electrical current across the electrodes. The spark from the electrodes ignites the igniter material, which combusts to ignite the gas in the chamber Figure 4. The burning gas generates a great deal of outward pressure. The pressure pushes on a **piston** resting in the chamber, driving it upward at high speed. A rack gear is fastened to one side of the piston. When the piston shoots up, the rack gear engages a gear connected to the retractor spool mechanism. The speeding rack rotates the spool forcefully, winding up any slack belt webbing as shown in figure 5. When the gas is ignited, the pressure pushes the piston up to rotate the retractor.

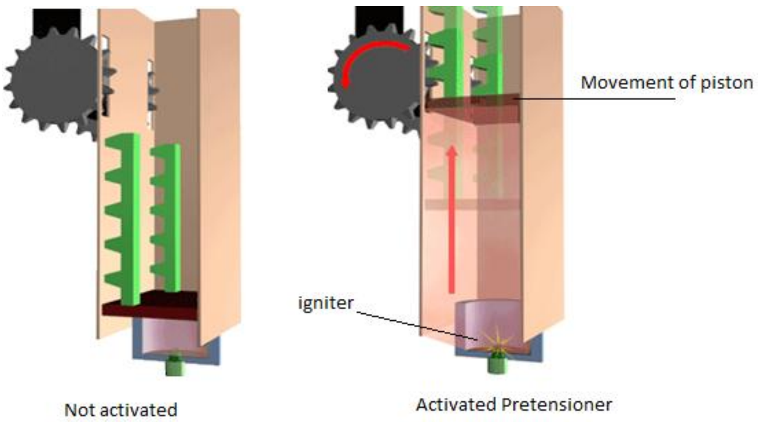

Figure 4 Working of Pretensioner

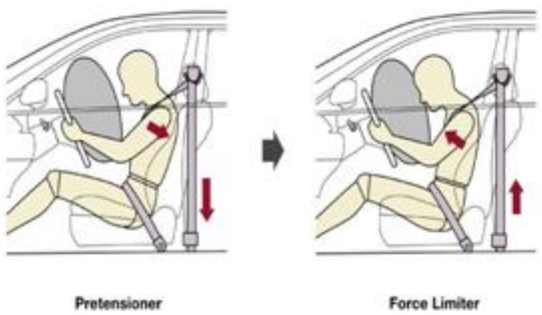

Figure 5 After actuation of Pretensioner

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Airbag

The goal of an airbag is to slow the passenger's forward motion as evenly as possible in a fraction of a second. An air bag has three main parts viz bag, sensor and inflation system for accomplishing the above task. The bag is made of a thin, nylon fabric, which is folded into the steering wheel or dashboard or, more recently, the seat or door. The sensor tells the bag to inflate. Inflation happens when there is a collision force equal to running into a brick wall at 16 to 24 km per hour. A mechanical switch is flipped when there is a mass shift that closes an electrical contact, telling the sensors that a crash has occurred. The sensors receive information from an accelerometer built into a microchip. The airbag's inflation system reacts sodium azide (NaN3) with potassium nitrate (KNO3) to produce nitrogen gas. Hot blasts of the nitrogen inflate the airbag. The main problem while designing the system are at what point airbag should inflate and once used the system has to be recharged again.

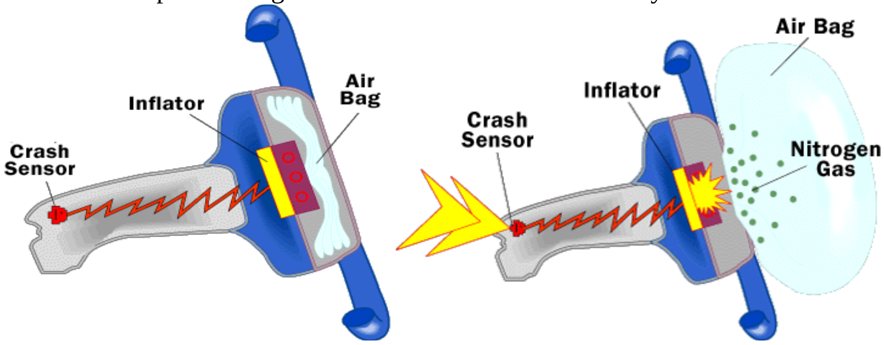

Figure 6 Functioning of Air Bag

Electromechanical sensors used in earlier front air bag applications have been replaced by multi-point electronic sensors used to discriminate collision mechanics for potential air bag deployment in front, side and rollover accidents. In addition to multipoint electronic sensors, advanced air bag systems incorporate a variety of state sensors such as seat belt use status, seat track location, and occupant size classification that are taken into consideration by air bag system algorithms and occupant protection deployment strategies. (Toomey, D., Winkel, E., and Krishnaswami, R 2015)

Head Rest

Active Headrest system is a passive safety system designed to protect the occupants from neck injuries. This system is also known as 'Active Head Restraint' system and is especially effective in the events of rear end collision. It uses the force of the occupant body against the seat back in a rear end collision to move the head restraint forward instantaneously to support the head.

Figure 7 Working of Active Head Rest System

Thereby helping to reduce the impact to the neck of a front seat occupant as shown in figure 7. The mechanism of whiplash injuries closely involves two factors resulting from the impact: the force acting to bend the neck backward and the force that causes the head to tilt rearward. Because the active restraint is effective in

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controlling these two factors it can help reduce the load on the neck at the moment of the collision. Nission has performent test on the same and reported that there is 45% reduction in force acting to bend the neck. (Hikmat F Mahmood and Bahig B Fileta 2013). Some researchers worked on inflatable head rest (Dante Bigi, Alexander Heilig, TRW Occupant Restraint Systems, Germany, Hermann Steffan, Arno Eichberger 1998) and reported that it is a promising new concept that can reduce Whiplash Associated Disorders (WAD) following rear-end impacts especially in low speed collisions. It allows a comfortable head rest position and is suitable for almost all occupant sizes without the need for adjustment. Presently BMW vehicles, headrest is actuated by pressurized gas while on Mercedes Benz vehicles, it is done by springs. According to various studies, employing the Active Headrest has significantly reduced the severity of neck injuries in rear end collisions and hence it is gaining rapid popularity.

CONCLUSION

The paper discussed the concept behind the available vehicle safety technologies which the designers have to take into considerations before presenting a safe design . Some of these technologies are being used commercially while others are in the different stages of development. However once fully developed it would help in mitigation of accidents and the injuries both to the occupants and the pedestrians.

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