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SCHOOL OF MECHANICAL ENGINEERING
DEPARTMENT OF AUTOMOBILE ENGINEERING

SAU1603 – AUTOMOTIVE SAFETY

UNIT I - INTRODUCTION

UNIT I
INTRODUCTION

Design of the body for safety
Energy equation
Engine location
Deceleration of vehicle inside passenger compartment
Deceleration on impact with stationary and movable obstacle
Concept of crumble zone
Safety sandwich construction

INTRODUCTION:

- **Automobile safety** is the study and practice of design cars, construction, equipment and regulation to minimize the occurrence and consequences of traffic collisions.

CRASHWORTHINESS:

Crashworthiness is also highly dependent on how the materials, construction and design of the vehicle work together. From a collision point of view, a vehicle can be considered as two primary kinds of structure. First, there is the passenger cabin, within which the occupants should be belted to the seating. This compartment should represent a 'safety cage'. Ideally this cage will not distort or deform. Trapping feet with a collapsing firewall or having the roof structure deform onto heads is extremely poor from an injury point of view. Very strong passenger compartments are essential for these safety cages. The present material of choice for primary structural pillars is boron-containing hot stamped steels, which have very high strength and are easily manufacturable. The other important element is the crush zone that surrounds the cabin. This zone is tuned to absorb energy and provide deformation. Crash performance is improved by controlling the acceleration of an occupant's chest and minimizing a head injury criterion, which is also related to peak rates of acceleration or G-loading. Vehicle safety standards are based on these measures. To receive a 5-star crash rating, a passenger's chest should receive fewer than 48 Gs of acceleration when a vehicle impacts with a fixed rigid barrier. Therefore, from a design point of view, the crush zone should crush from its original shape to nearly zero thickness in front of the cabin compartment, ideally with a nearly constant force that is no greater than 48 times the vehicle weight while the safety cage remains undeformed. For the deforming members, high strength or stiffness is not desired, but what is important is the ability to absorb energy in a controlled manner and the ability to crush the full distance from the bumper to cabin, while the force remain near the peak value it maximizes the energy absorbed. Governmental regulation impose strict standards on occupant protection, and on various crash modes including side impact and roof crush. The mass of vehicles could be dramatically reduced if crashworthiness were not a consideration.

TYPES OF IMPACTS IN CAR ACCIDENTS:

The impacts in car accidents are of three types.

1. VEHICLE IMPACT: The initial strike involves the exterior of the vehicle crashing into something, such as another vehicle. Factors to consider here are the weight of the vehicles or objects, the speed of travel, and how fast the vehicle stopped. These factors all dictate the force exerted, with speed being the one that has the largest potential impact. The weight of a vehicle proportionally heightens the amount of force; however, speed does so exponentially, thus it greatly affects the potential severity. Older vehicles were traditionally designed to be resistant to forces in a collision, but in recent years the vehicles are instead manufactured to better absorb the force and keep the passenger

area better protected.

2. BODY IMPACT The second impact is the result of the occupant's body striking something inside of the vehicle. The body will typically be thrust toward the point of exterior impact and either be restrained by a seat belt or stopped by striking an inside object—both of which are dangerous. It is also critical to remember that any unsecured objects within the vehicle may also become potentially damaging projectiles. Examples of such objects may include a glass beverage container, a briefcase, or a tool box.
3. ORGAN IMPACT: The third impact relates to the damage occurring inside of the body, such as to the internal organs. A common example occurs when your brain abruptly strikes the skull that surrounds it. Organs that are solidly composed like the spleen or liver may be fractured and suffer harmful bleeding. Key vessels like the aorta could be damaged, which is largely responsible for blood flow, creating a potentially deadly situation.

DESIGN OF VEHICLE BODY FOR SAFETY

- The safety of a vehicle and its passengers can be improved by properly designing and selecting the material for vehicle bodies.
- The vehicle body structure is subjected to static and dynamic service loads during the life cycle. It also has to maintain its integrity and provide adequate protection in survivable crashes.
- At present there are two designs of vehicle body constructions: 1. Body over frame structure and 2. Uni- body structure.

Necessary features of a safe vehicle body:

- Deformable yet stiff front structure with crumple zones to absorb the crash kinetic energy from frontal collisions
- Deformable rear structure to safeguard rear passenger compartment and protect the fuel tank
- Properly designed side structures and doors to minimize intrusion in side impact and prevent doors from opening due to crash loads
- Strong roof structure for rollover protection
- Properly designed restraint systems with working in harmony with the vehicle structure
- Accommodate various chassis designs for different power train locations and drive train configurations.

Design techniques/strategies:

The following design techniques/strategies are to be followed while designing a car body (especially front structure) to reduce the impact of crash and increase the safety of the car and passengers.

Desired dummy performance:

- Dummy is a physical model representing humans inside a car.
- To model a car for safety, it should be modeled for proper crash energy management.
- As the human beings are to be safeguarded, the interaction of the human beings with the restraint system during a crash has to be studied first. This branch of study is widely known as bio-mechanics.
- The reaction of a human being for a crash pulse has to defined and studied in depth. The following steps are involved in this procedure

Stiff cage structural concept:

- Stiff cage is the passenger compartment structure which provides protection for the passengers in all modes of survivable collisions.
- The necessary features of a good stiff cage structure are: 1. sufficient peak load capacity to support the energy absorbing members in front of it, 2. High crash energy absorption. The stiff cage structure should withstand all the extreme loads and the severe deformation.

Controlled progressive crush and deformation with limited intrusion:

- To make the impact of crash less, the crush event has to be controlled and the deformation should be made such that the intrusion of other components into the passenger compartment is less.
- Axial mode of crush is preferred to bending mode of crush as bending mode has lower energy content.
- To achieve this objective three different crush zones are identified:
  - Soft front zone: Reduces the aggressively of crash in pedestrian / vehicle and vehicle / vehicle collisions
  - Primary crush zone: It consists of the main energy absorbing structure before the power train. It is characterized by a relatively uniform progressive structural collapse.
  - Secondary crush zone: Lies between the primary zone and passenger compartment and sometimes extends into the passenger compartment up to firewall. It provides a stable platform for the primary zone and transfers the load to the occupant compartment as efficiently as possible.

Weight efficient energy absorbing structures:

- The architecture of the structural frame (structural topology) design depends on the ability to design the primary crush zone for bending, folding, mixed folding and bending.
- For a given vehicle package different topologies have to be studied for the same crush energy absorption. The steps followed are:
    - Create a simple model of vehicle front end system
    - Determine the design loads of structural members

ENERGY EQUATION

- The application of the conservation of energy principle provides a powerful tool for problem solving.
- Newton's laws are used for the solution of many standard problems, but often there are methods using energy which are more straightforward.
- The basic reason for the advantage of the energy approach is that just the beginning and ending energies need be considered; intermediate processes do not need to be examined in detail since conservation of energy guarantees that the final energy of the system is the same as the initial energy.
- The work-energy principle is also a useful approach to the use of conservation of energy in mechanics problem solving. It is particularly useful in cases where an object is brought to rest as in a car crash or the normal stopping of an automobile.

- Kinetic energy is energy of motion. Objects that are moving, have kinetic energy (KE). If a car crashes into a wall at 5 mph, it shouldn't do much damage to the car. But if it hits the wall at 40 mph, the car will most likely be totaled. Kinetic energy is similar to potential energy. The more the object weighs, and the faster it is moving, the more kinetic energy it has. The formula for KE is: KE = 1/2*m*v2 where m is the mass and v is the velocity.
- The kinetic energy increases with the velocity squared. This means that if a car is going twice as fast, it has four times the energy. It may be noticed that the car accelerates much faster from 0 mph to 20 mph than it does from 40 mph to 60 mph. Let's compare how much kinetic energy is required at each of these speeds. At first glance, you might say that in each case, the car is increasing its speed by 20 mph, and so the energy required for each increase must be the same. But this is not so. We can calculate the kinetic energy required to go from 0 mph to 20 mph by calculating the KE at 20 mph and then subtracting the KE at 0 mph from that number. In this case, it would be 1/2*m*202 - 1/2*m*02. Because the second part of the equation is 0, the KE = 1/2*m*202, or 200 m. For the car going from 40 mph to 60 mph, the KE = 1/2*m*602 - 1/2*m*402; so KE = 1,800 m - 800 m, or 1000 m. Comparing the two results, we can see that it takes a KE of 1,000 m to go from 40 mph to 60 mph, whereas it only takes 200 m to go from 0 mph to 20 mph.
- There are a lot of other factors involved in determining a car's acceleration, such as aerodynamic drag, which also increases with the velocity squared. Gear ratios determine how much of the engine's power is available at a particular speed, and traction is sometimes a limiting factor. So it's a lot more complicated than just doing a kinetic energy calculation, but that calculation does help to explain the difference in acceleration times.

ENGINE LOCATION

Front engine:

- The large mass of an engine at the front of the car gives the driver protection in the event of a head on collision.
- Engine cooling is simpler to arrange and in addition the cornering ability of a vehicle is normally better if the weight is concentrated at the front.

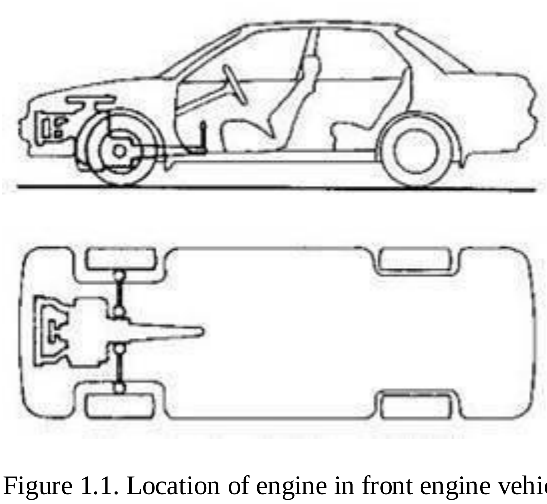


Figure 1.1. Location of engine in front engine vehicle.

- Advantages:
    - Better axle load distribution
    - Better road grip
    - Comfort riding
    - Better cooling
    - Less noise (long exhaust pipe)
    - Use a long engine

Rear engine:

- It increases the load on the rear driving wheels, giving them better grip of the road. Most rear-engine layouts have been confined to comparatively small cars, because the heavy engine at the rear has an adverse effect on the 'handling' of the car by making it 'tail-heavy'.
- Also it takes up good deal of space that would be used on a front-engine car for carrying luggage.
- Most of the space vacated by the engine at the front end can be used for luggage, but this space is usually less than that available at the rear.

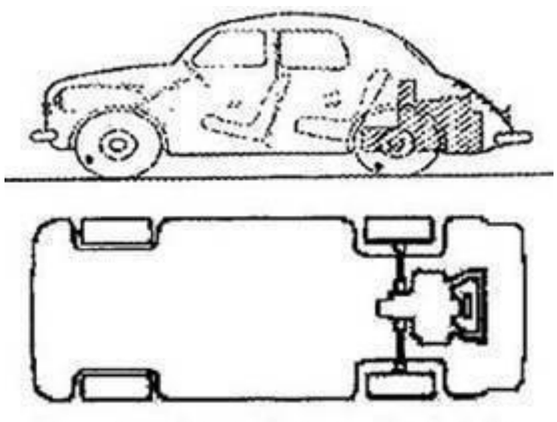


Figure 1.2. Location of engine in rear engine vehicle.

Central and mid-engine:

- These engine situations generally apply to sports cars because the engine sitting gives a load distribution that achieves both good handling and maximum traction from the driving wheels.
- These advantages, whilst of great importance for special cars, are outweighed in the case of everyday cars by the fact that the engine takes up space that would normally be occupied by passengers.
- The mid-engine layout shown combines the engine and transmission components in one unit. The term mid-engine is used because the engine is mounted in front of rear axle line.

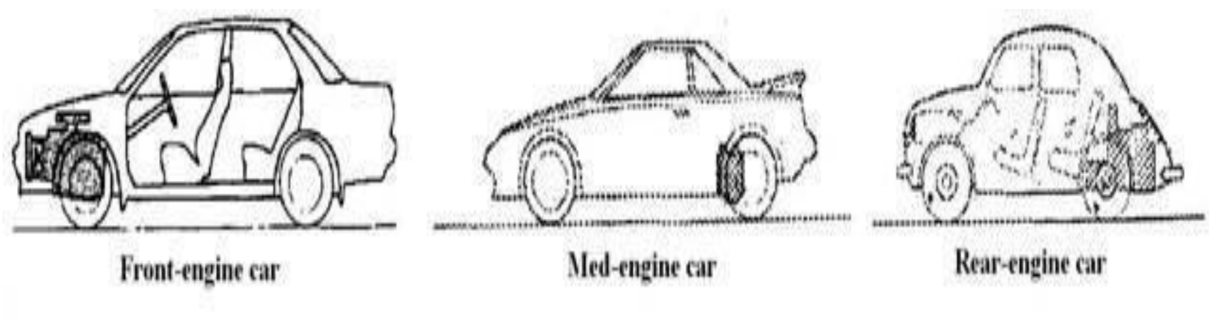


Figure 1.3. Location of engine in different types of cars.

DECELERATION OF VEHICLE AND PASSENGER COMPARTMENT ON IMPACT WITH STATIONARY AND MOVABLE OBSTACLE

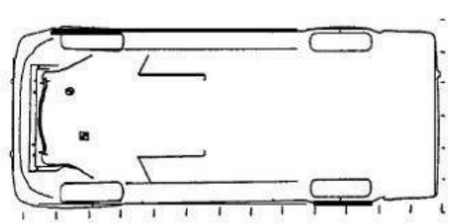
It is important to study the deceleration inside passenger compartment to know the effect of crash completely, so that the crash avoidance systems can be suitably designed. For example, if the deceleration of the passenger after crash is very high, the air bag system and the seat belt system has to be so designed that the activation time for them is reduced to a lower value. Otherwise it may lead to injuries and fatalities.

Usually tests are conducted to know the deceleration behavior after the crash with a stationary obstacle. The tests are conducted at the following speeds:

1. 15 mph (miles per hour)
2. 20 mph
3. 40 mph
4. 50 mph

15 mph test:

The following pictures show the body deformation and acceleration graph after crash. The body deformation is less as the vehicle speed is low. The crash occurs at time 0 seconds. From the graph, we can know that after the crash, deceleration occurs which is shown in the negative (lower) portion. Its value is up to 20g. After some time the acceleration slowly comes to zero (the car stops)



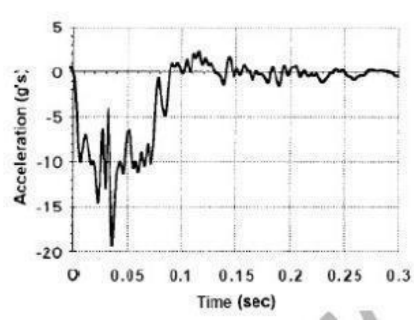


Figure 1.4. Deceleration characteristics in car after impact with stationary object (at 15 mph speed testing condition).

20 mph test:

In the 20 mph test, the body deformation is more than 15 mph test. Moreover, the acceleration has reduced to a further lower value (up to 35 g) in the negative direction. In this case the maximum deceleration is obtained in 50 milli seconds whereas for 10 mph test it was 35 milli seconds. The rebound velocity for this case is1.7 mph whereas for 10 mph it is 1.3 mph.40 mph test: In the 40 mph test, we can see that the acceleration curve goes down (deceleration) then suddenly goes up in the positive region (acceleration). This is due to the fact that, at 40 mph, the deformation is more and the accelerometer (sensor) mounting area has buckled and resulted in an increase in acceleration value. The body deformation is also high such that the accelerometer mounting area is also damaged. So, we have to carefully analyze the graph to study the situation.

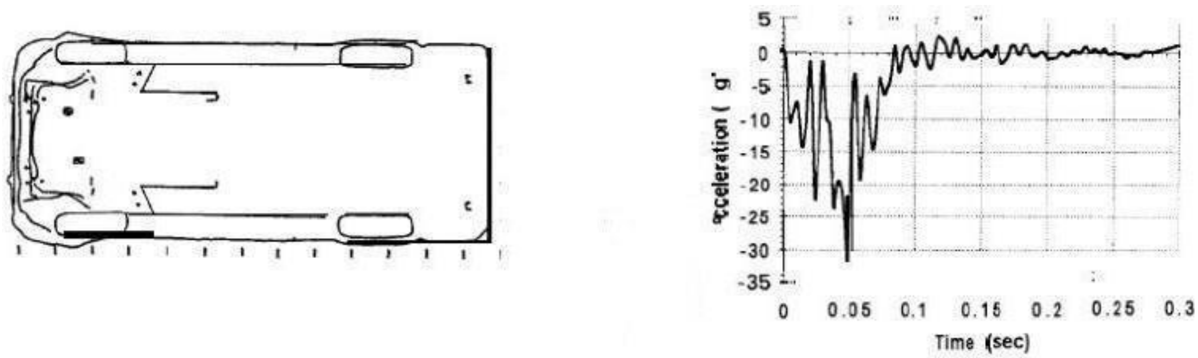


Figure 1.5. Deceleration characteristics in car after impact with stationary object (at 20 mph speed testing condition).

40 mph test:

In the 40 mph test, we can see that the acceleration curve goes down (deceleration) then suddenly goes up in the positive region (acceleration). This is due to the fact that, at 40 mph, the deformation is more and the accelerometer (sensor) mounting area has buckled and resulted in an increase in acceleration value. The body deformation is also high such that the accelerometer mounting area is also damaged. So, we have to carefully analyze the graph to study the situation.

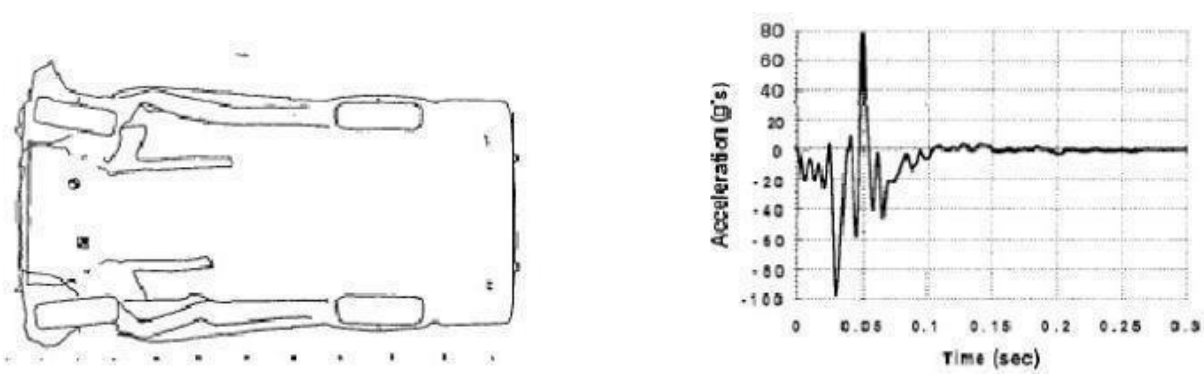


Figure 1.6. Deceleration characteristics in car after impact with stationary object (at 40 mph speed testing condition).

50 mph test:

The body deformation is very high as the speed is more. The acceleration curve shows that the maximum deceleration is around 35g and happens in time duration of 45 milli seconds. The rebound velocity is 1.6 mph.

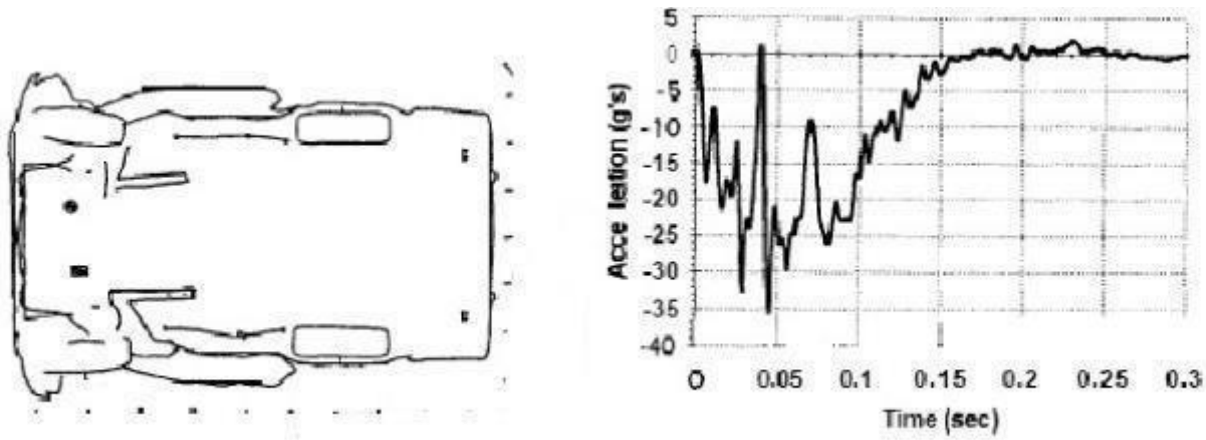


Figure 1.7. Deceleration characteristics in car after impact with stationary object (at 50 mph speed testing condition).

DECELERATION ON IMPACT WITH A MOVABLE OBSTACLE:

A movable obstacle can be another car or any other vehicle. Let us consider a car is impacting with another car. We shall study for the two cars; one car which is impacting the second car, the other car is which is being impacted. In this case the test is conducted at 40 mph.

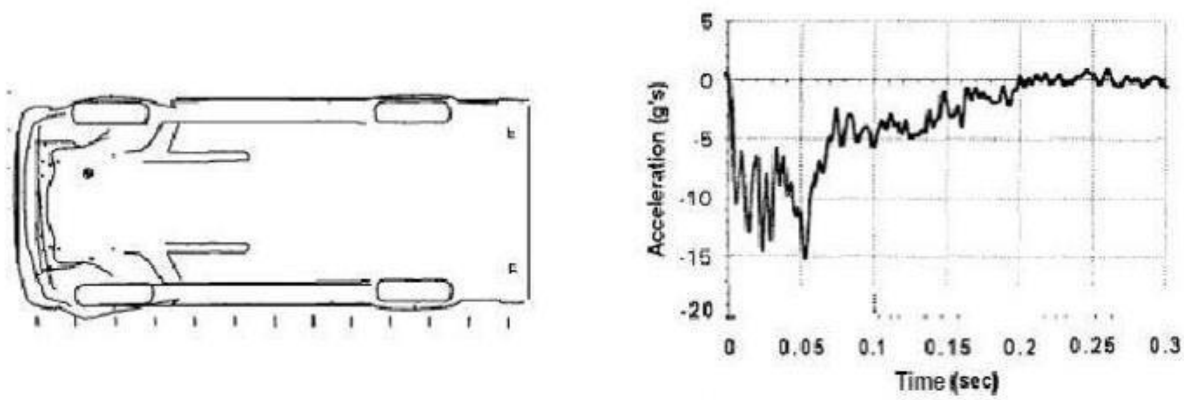


Figure 1.8. Deceleration characteristics in car after impact with movable object (at 40 mph speed testing condition).

The impact velocity was 40.6 mph with a separation velocity of 18.0 mph for a total velocity change of 22.6 mph. A maximum of 15g's deceleration was achieved at about 50 milliseconds. The total impact duration was approximately 195 milliseconds

Impacted vehicle:

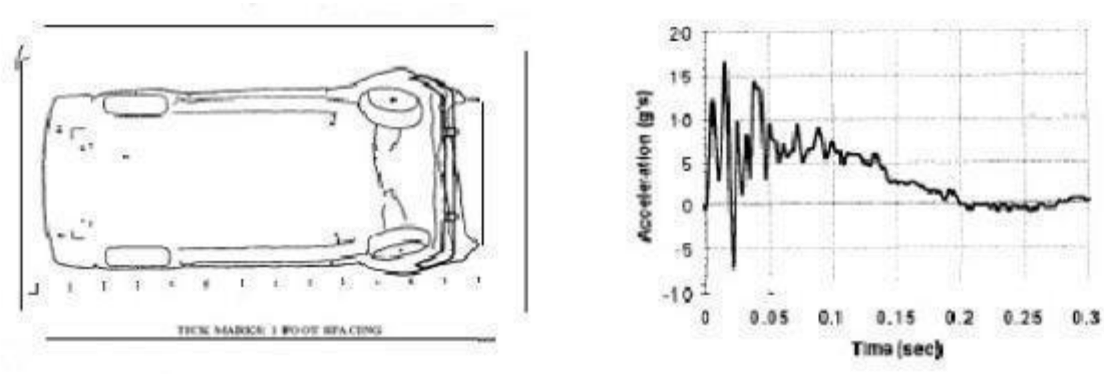


Figure 1.9. Deceleration characteristics in car after impact with movable object (at 18 mph speed testing condition).

The pre-impact velocity was 0.0 mph with a separation velocity of 22.8 for a total velocity change of 22.8mph. A maximum of 16.5g's acceleration was achieved at about 15 milliseconds. The total impact duration was approximately 195 milliseconds.

CONCEPT OF CRUMBLE ZONE

- Crumple zones are designed to absorb the energy from the impact during a traffic collision by controlled deformation.
- The crumple zone of an automobile is a structural feature designed to compress during an accident to absorb energy from the impact. Typically, crumple zones are located in the front part of the vehicle, in order to absorb the impact of a head-on collision, though they may be found on other parts of the vehicle as well. Some racing cars use aluminum or composite honeycomb to form an 'impact attenuator' for this purpose.
- It was an inventor Bela Barenyi who pioneered the idea that passengers were safer in a vehicle that was designed to easily absorb the energy from an impact and keep that energy away from the people inside the cabin. Barenyi devised a system of placing the car's components in a certain configuration that kept the kinetic energy in the event of a crash away from a bubble protecting the car's occupants.
- Mercedes obtained patent from Barenyi's invention way back in 1952 and the technology was first introduced into production cars in 1959 in the Mercedes-Benz 220, 220 S and 220 SE models.

Auto safety has come a long way in the last few decades, and one of the most effective innovations is the crumple zone. Also known as a crush zone, crumple zones are areas of a vehicle that are designed to deform and crumple in a collision. This absorbs some of the energy of the impact, preventing it from being transmitted to the occupants.

Of course, keeping people safe in auto accidents isn't as simple as making the whole vehicle crumple. Engineers have to consider many factors in designing safer cars, including vehicle size and weight, frame stiffness and the stresses the car is likely to be subjected to in a crash. For example, race cars experience far more severe impacts than street cars, and SUVs often crash with more force than small cars.

Function:

- Crumple zones work by managing crash energy, absorbing it within the outer sections of the vehicle, rather than being directly transmitted to the occupants, while also preventing intrusion into or deformation of the passenger cabin.
- This better protects car occupants against injury. This is achieved by controlled weakening of sacrificial outer parts of the car, while strengthening and increasing the rigidity of the inner part of the body of the car, making the passenger cabin into a 'safety cell', by using more reinforcing beam sand higher strength steels. Volvo introduced the side crumple zone; with the introduction of the SIPS (Side Impact Protection System) in the early 1990s.
- The purpose of crumple zones is to slow down the collision and to absorb energy. It is like the difference between slamming someone into a wall headfirst (fracturing their skull) and shoulder-first (bruising their flesh slightly) is that the arm, being softer, has tens of times longer to slow its speed, yielding a little at a time, than the hard skull, which isn't in contact with the wall until it has to deal with extremely high pressures.
- Seatbelts restrain the passenger so they don't fly through the windshield, and are in the correct position for the airbag and also spread the loading of impact on the body. Seat belts also absorb energy by being designed to stretch during an impact, so that there is less speed differential between the passenger's body and their vehicle interior. In short: A passenger whose body is decelerated more slowly due to the crumple zone (and other devices) over a longer time, survives much more often than a passenger whose body indirectly impacts a hard, undamaged metal car body which has come to a halt nearly instantaneously.
- The final impact after a passenger's body hits the car interior, airbag or seat belts, is that of the internal organs hitting the ribcage or skull. The force of this impact is the mechanism through which car crashes cause disabling or life threatening injury. The sequence of energy is dissipating and speed reducing technologies - crumple zone - seat belt - airbags - padded interior, are designed to work together as system, to reduce the force of this final impact.
- A common misconception about crumple zones is that they reduce safety by allowing the vehicle's body to collapse, crushing the occupants. In fact, crumple zones are typically located in front and behind of the main body (though side impact absorption systems are starting to be introduced), of the car (which forms a rigid 'safety cell'), compacting within the space of the engine compartment or boot/trunk.
- The marked improvement over the past two decades in high speed crash test results and real-life accidents also belies any such fears.
- Modern vehicles using what are commonly termed 'crumple zones' provide far superior protection for their occupants in severe tests than older models, or SUVs that use a separate chassis frame and have no crumple zones.

SAFETY SANDWICH CONSTRUCTION:

- Sandwich panel constructions using metallic and polymeric honeycombs and foams have been used for many years in the competition and high performance sectors of the automotive industry, and there is considerable knowledge and confidence in their static, dynamic and crashworthiness properties.
- Sandwich panels have only been used to produce extremely limited numbers of product and have been essentially hand-worked.
- The potential advantages of polymer composites for automotive parts (high specific strength and stiffness, corrosion resistance) are well known. Further benefits are available from the use of sandwich construction, in which a relatively stiff, strong skin is bonded either side of a much thicker, lightweight core.
- Sandwich panels have been widely used for structural applications in the marine, aerospace and performance automotive industries for several decades.
- Lightweight core materials have included balsa, polymer foams and metallic, paper or polymer honeycombs. These have been used in various combinations with skins of carbon, glass and/or aramid fiber-reinforced polymer, as well as aluminium.The principle of sandwich construction is that bending loads are carried by the skins, while the core transmits shear load.
- They enable large gains in structural efficiency, since the thickness (and hence flexural rigidity) of panels can be increased without significant weight penalty.
- In high performance car construction, most sandwich panel elements are vacuum bag/autoclave molded on a contact tool, usually in several stages (e.g. first skin; core to skin bond; second skin).
- Although this permits complex shapes to be produced on low cost tooling, it is necessarily a time consuming and labor intensive process.
- A high degree of cleanliness and sophisticated process control are required, and inspection is notoriously difficult.
- Sandwich panels are also available as flat sheet, stock material.
- Hexcel Composites, for example, supply arrange of honeycomb cored sheets of varying specifications which is widely used for building cladding, aircraft flooring, luggage bins and bulkheads.
- The use of a stock material is attractive, since primary material quality and specification becomes the responsibility of the supplier, not the manufacturer.
- Several techniques are well established for the shaping and assembly of structural components from flat sandwich panel. Panels may be bent to required angles by removing a defined strip of material from the inner skin, then folding and adhesively bonding the joint.

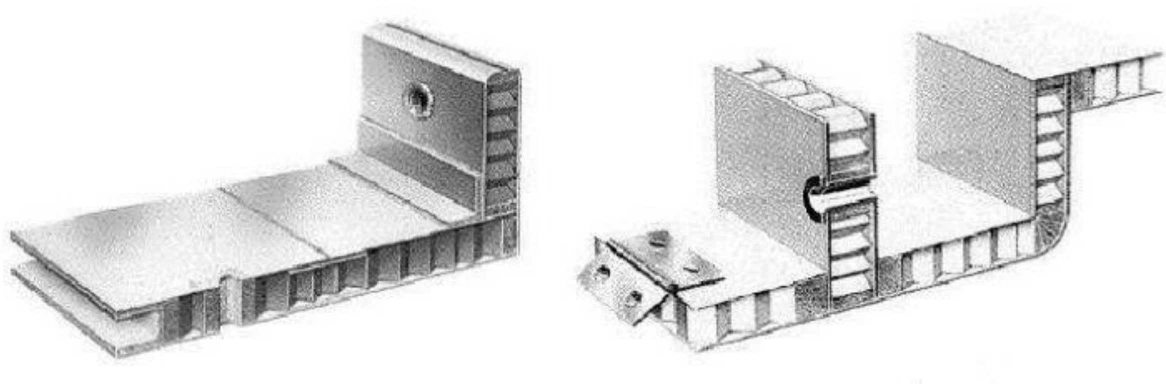


Figure 1.10. Safety structures – Sandwich composite materials.

- For additional strength, reinforcing material can be added at the skin joints. It is emphasized at this point that the process of shaping a panel requires no tooling, and assembly can often be arranged so that parts are self-jigging.
- The panels can be machined with hand tools a major attraction of these techniques is the potential they offer for computer control and automation.

Importance of ergonomics in automotive safety:

Ergonomics is the interaction between a person and the things they use. For example, the products usability and the comfort level. The things to keep in mind are that many demographics are now using vehicles such as women driving SUVs, elderly people, differently abled or special needs people who need to drive vehicles. There are mainly five aspects of ergonomics - safety, comfort, ease of use, productivity and aesthetics. While spending for aesthetics is a stretch, spending for safety is something that customers don't have any qualms about. It is the one aspect that no one wants to compromise on. Usually there are standard features for safety such as airbags in every car. However, extra care needs to be taken if optimum safety is to be ensured.

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SAU1603 – AUTOMOTIVE SAFETY

UNIT II – SAFETY CONCEPTS

UNIT II
SAFETY CONCEPTS

Active safety: driving safety, conditional safety, perceptibility safety, operating safety
Passive safety: exterior safety, interior safety,
Deformation behavior of vehicle body
Speed and acceleration characteristics of passenger compartment on impact.

Passenger safety occupies a prime spot in the automobile sector today. Stakeholders across the automobile value chain acknowledge the importance of passenger/occupant safety and are constantly upgrading their offerings to provide fail safe safety technologies that will protect passengers and pedestrians. Proactive policy implementation and consumer awareness has played a key role in making automotive safety systems popular. However the penetration of these lifesaving technologies differs from country to country. Economically developed countries tend to have a high penetration of these technologies across various passenger and commercial vehicle segments. Traditionally Automobile Safety Systems can be classified in to two segments, namely Active Safety Systems and Passive Safety Systems.

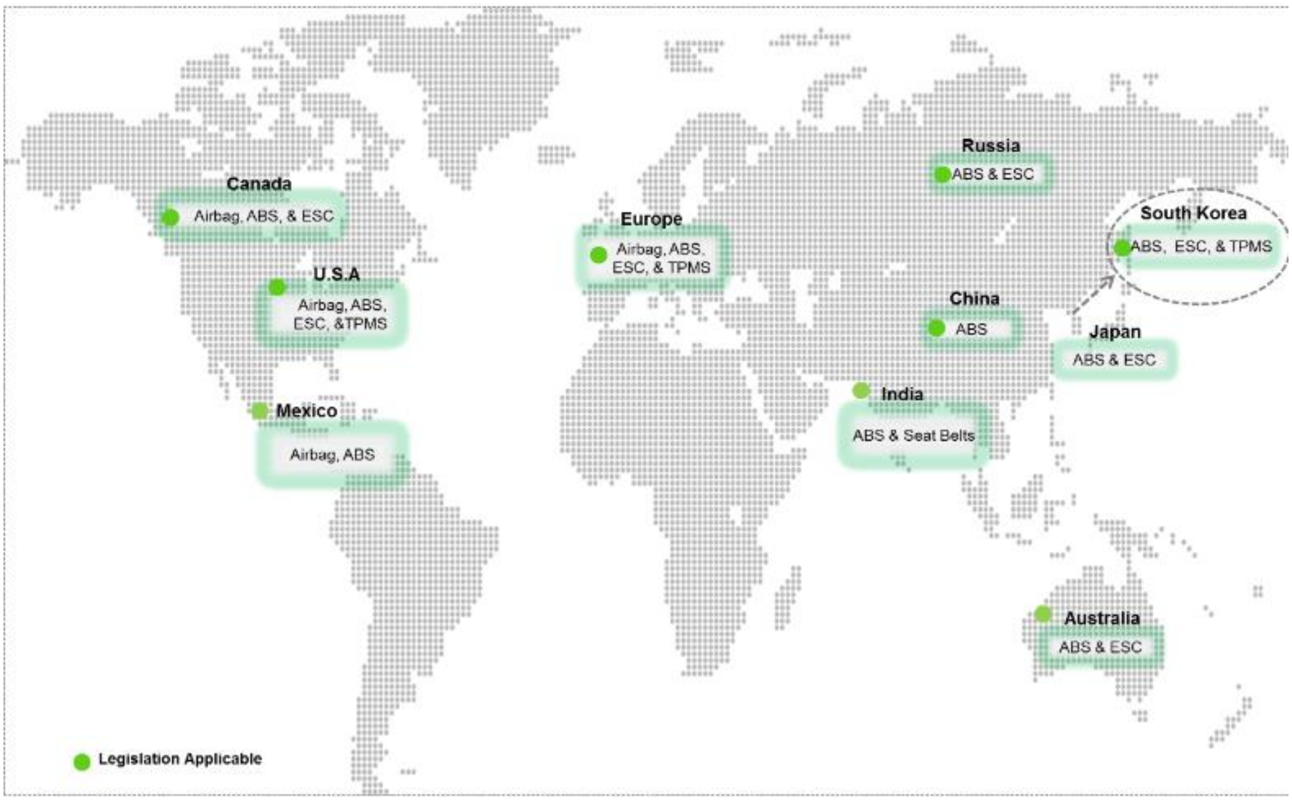

Figure 2.1. Distribution of automotive safety systems in various countries.

Active Safety Systems as the term suggests play a preventive role in mitigating crashes and accidents by providing advance warning or by providing the driver with additional assistance in steering/controlling the vehicle. Head-Up Display (HUD), Anti-Lock Braking Systems (ABS), Electronic Stability Control (ESC), Tire Pressure Monitoring System (TPMS), Lane Departure Warning System (LDWS), Adaptive Cruise Control (ACC), Driver Monitoring System (DMS), Blind Spot Detection (BSD) and Night Vision System (NVS) are common Active Safety Systems. Passive Safety Systems play a role in limiting/containing the damage/injuries caused to driver, passengers and pedestrians in the event of a crash/accident. Airbags, Seatbelts, Whiplash Protection System etc. are common Passive Safety Systems deployed in vehicles these days. An emerging trend witnessed in the global automotive safety system market is the increasing demand from the countries like India, China, Russia and Brazil. Since the market for the safety systems like Airbags and ABS in developed economies is maturing and becoming saturated, OEMs and suppliers are focusing on increase demand from emerging markets. The demand is becoming higher in emerging markets primarily because of the improving road safety standards/supporting legislation and consumer awareness. Rapidly increasing vehicle population in emerging markets such as China, Thailand, Brazil and India is also driving up the risk of road fatalities and supporting demand for safety systems in passenger and commercial vehicles. Further, programmes like New Car Assessment Programe (NCAP) a government car safety evaluation programme which provides ratings, based on the safety performance of cars have become a catalyst for encouraging significant safety improvements initiatives from original equipment manufacturers, that drive consumer confidence and hence demand for Active and Passive Safety Systems.

ACTIVE SAFETY:

- Active safety systems help prevent accidents and thus make a preventive contribution to safety in road traffic.
- Active safety systems are designed to help you avoid a crash in the first place.
- One example of an active driving safety system is the Antilock Braking System (ABS) with Electronic Stability Program (ESP) from Bosch, which stabilizes the vehicle even in critical braking situations and maintains steerability in the process.

Driving safety

- It is the result of a harmonious chassis and suspension design with regard to wheel suspension, springing, steering and braking, and is reflected in optimum dynamic vehicle behavior.

Conditional safety

- It results from keeping the physiological stress that the vehicle occupants are subjected to by vibration, noise, and climatic conditions down to as low a level as possible. It is a significant factor in reducing the possibility of miss actions in traffic.
- Vibrations within a frequency range of 1 to 25 Hz (stuttering, shaking, etc.) induced by wheels and drive components reach the occupants of the vehicle via the body, seats and steering wheel. The effect of these vibrations is more or less pronounced, depending upon their direction, amplitude and duration.
- Noises as acoustical disturbances in and around the vehicle can come from internal sources (engine, transmission, prop shafts, axles) or external sources (tire/road noises, wind noises), and are transmitted through the air or the vehicle body.
- The sound pressure level is measured in dB(A) (see Motor-vehicle noise measurements and limits).Noise reduction measures are concerned on the one hand with the development of quiet- running components and the insulation of noise sources (e.g., engine encapsulation), and on the other hand with noise damping by means of insulating or anti-noise materials.
- Climatic conditions inside the vehicle are primarily influenced by air temperature, air humidity, rate of airflow through the passenger compartment and air pressure (see Environmental stresses for additional information).

Perceptibility safety

- Measures which increase perceptibility safety are concentrated
- Lighting equipment (see Lighting),
- Acoustic warning devices (see Acoustic signaling devices),
- Direct and indirect view (see Main dimensions) (Driver's view: The angle of obscuration caused by the A-pillars for both of the driver's eyes binocular must not be more than 6 degrees).

Operating safety

- Low driver stress, and thus a high degree of driving safety, requires optimum design of the driver surroundings with regard to ease of operation of the vehicle controls.

Table 2.1. Active Safety Systems.

Technology	Acronym	Definition
Anti-lock Braking System	ABS	ABS allows the wheels on a motor vehicle to maintain tractive contact with the road surface based on driver inputs while braking. This prevents the wheels from locking up (ceasing rotation) and avoids uncontrolled skidding. This automated system works on the principles of threshold braking and cadence braking.
Electronic Stability Control	ESC	ESC system improves vehicle's stability by detecting and reducing loss of traction (skidding). This system prevents crashes by reducing the danger of vehicle skidding or driver losing control as a result of over-steering. This system becomes active when a driver loses control of his or her car.
Adaptive Cruise Control	ACC	ACC is an intelligent form of cruise control that slows down and speeds up automatically to maintain a safe distance from the vehicles ahead. The control is based on sensor information from on-board sensors.
Tyre-Pressure Monitoring System	TPMS	TPMS is an electronic system designed to monitor air pressure inside pneumatic tires on various types of vehicles. TPMS report real-time tyre-pressure information to the driver of the vehicle, either via a gauge, a pictogram display, or a simple low-pressure warning light.
Lane Departure Warning	LDW	LDW system is a mechanism designed to warn a driver when the vehicle begins to move out of its lane on freeways and arterial roads. These systems are designed to minimize accidents by addressing causes of collisions such as driver error, distractions, and drowsiness.
Night Vision System	NVS	NVS extend the perception of the driver beyond the limited reach of headlights through the use of thermo graphic cameras, infrared lights, heads up displays, and other technologies to prevent accidents.
Blind Spot Detection	BSD	Blind spots are areas outside of a vehicle that the driver is unable to see. These can be caused by window pillars, headrests, back seat passengers, and other objects. A BSD system is a vehicle-based sensor device that detects other vehicles located to the driver's side and rear.
Driver Monitoring	DM	This safety system uses infrared sensors to monitor driver attentiveness. Specifically, a driver monitoring system includes a Closed-Circuit Camera (CCD) camera placed on the steering column that is capable of eye tracking via infrared Light-Emitting Diode (LED) detectors. If the driver is not paying attention to the road ahead and a collision is eminent, the system flashes lights and warning sounds for the driver.
Road Sign Recognition	RSR	Road sign recognition notifies and warns the driver of enforced restrictions on the road.
Automatic Emergency Braking	AEB	This system slows the vehicle and potentially reduces collision severity in an unavoidable situation. If the driver's braking is not enough to avoid a collision, autonomous emergency braking applies maximum brake pressure to reduce speed and impact of collision.

Active Safety Features:

Active safety features are designed to keep in full control of the vehicle at all times using advanced technologies. These technologies attempt to avoid accidents in the first place, and they are always on, alerting commuters. Thus, these safety features are always "active."

Here are some of the features they include:

Active Brakes – These brakes help make driving easier in a number of different ways by applying added braking pressure when emergency braking, automatically drying themselves when it's wet, and decreasing erratic driving.

Dynamic Stability Control – Using advanced sensors and the strategic delivery of torque and brake pressure to the wheels, this system is able to help you stay stable on the road.

Head-Up Display – Keep your eyes on the road to avoid a collision while still getting access to important information like your speed, navigation directions, and radio.

Cornering Brake Control – When you're taking a corner at speed, this system applies the brakes automatically to help you stay in control.

Adaptive Cruise Control – This feature is able to automatically maintain a safe distance between your car and the one in front of you.

PASSIVE SAFETY:

- A passive safety system helps to protect from injury if a crash is unavoidable.It refersto components of the vehicle (primarily airbags, seatbelts and the physical structure of the vehicle) that help to protect occupants during a crash
- Passive safety systems serve to protect the occupants against serious or even fatalinjuries.
- An example of passive safety is the airbags, which protect the occupantsfollowing an unavoidable impact.

Exterior safety

The term "exterior safety" covers all vehicle-related measures which are designed to minimize the severity of injury to pedestrians and bicycle and motorcycle riders struck by the vehicle in an accident. Those factors which determine exterior safety are:

- Vehicle-body deformation behavior,
- Exterior vehicle body shape.

The primary objective is to design the vehicle such that its exterior design minimizes the consequences of a primary collision (a collision involving persons outside the vehicle and the vehicle itself).The most severe injuries are sustained by passengers who are hit by the front of the vehicle, whereby the course of the accident greatly depends upon body size. The consequences of collisions involving two-wheeled vehicles and passenger cars can only be slightly ameliorated by passenger-car design due to the two-wheeled vehicle's often considerable inherent energy component, its high seat position and the wide dispersion of contact points. Those design features which can be incorporated into the passenger car are, for example:

- Movable front lamps
- Recessed windshields wipers,
- Recessed drip rails,
- Recessed door handles.

Interior safety

The term "interior safety" covers vehicle measures whose purpose is to minimize the accelerations and forces acting on the vehicle occupants in the event of an accident, to provide sufficient survival space, and to ensure the operability of those vehicle components critical to the removal of passengers from the vehicle after the accident has occurred. The determining factors for passenger safety are:

- Deformation behavior (vehicle body),
- Passenger-compartment strength, size of the survival space during and after impact,
- Restraint systems,
- Impact areas (vehicle interior),
- Steering system,
- Occupant extrication,
- Fire protection.

Laws which regulate interior safety (frontal impact) are:

- Protection of vehicle occupants in the event of an accident, in particular restraint systems
- Windshield mounting
- Penetration of the windshield by vehicle body components
- Parcel-shelf and compartment lids

Rating-Tests:

- New-Car Assessment Program (NCAP, USA, Europe, Japan, Australia),
- IIHS (USA, insurance test),
- ADAC, ams, AUTO-BILD.

Passive Safety Features:

Passive safety features are designed to mitigate the impact of a collision when it does occur. So, they remain passive unless called upon.

Passive features on MINI cars include:

Smart Airbags – New MINI vehicles come with up to eight smart airbags.

Crash Sensor System – This feature automatically unlocks the doors, turns on the hazard lights, and cuts the fuel pump when the airbags go off.

Breakaway Engine – This feature helps the engine and gearbox absorb as much of the impact as possible in case of a forward collision.

Rollover Protection Bar – This mounted safety bar can deploy in just seconds to provide added protection if the vehicle rolls over.

Engine Immobilizer – This system automatically immobilizes the engine without the key.

Table 2.2. Passive Safety Systems.

Technology	Acronym	Definition
Airbag	AB	Automotive airbags consist of flexible fabric bag or a cushion designed to inflate rapidly during a collision. Its function is to cushion its occupants during a crash when they hit objects inside such as the steering wheel or a window. Modern vehicles comprise of multiple airbag modules in different side and frontal locations of the passenger seating positions which offer maximum protection during collision.
Seat belt	SB	Seat belts are safety belts installed on the passenger seat of a vehicle to secure the occupant against harmful movements that may result due to collision, jerk, or sudden braking.
Occupant Sensing Systems	OSS	It is a system of sensors that detect who is sitting in the passenger seat. Occupant sensing systems eliminate the need for an on/off switch for airbags in most cases, because they use sophisticated technology to identify whether an adult or a child is in the seat. The sensor assembly is installed in the bottom cushion of the passenger seat and is used to suppress or enable the passenger's airbag, based on the classification of the occupant.
Whiplash Protection	WLP	In a WHIPS equipped seat, the entire backrest is designed to protect the front occupant's neck in case of rear impact. WHIPS utilizes a specially designed hinge-mount that attaches the back rest to the seat bottom, which has a pre-determined rate of rearward movement in the event of certain types of rear impacts. The seatback also has a series of springs that allows the cushion to move slightly backward on impact, thereby cradling the body within the seat. This, combined with high-mounted head restraints, to limit the "whipping" motion of the head that often occurs during a rear-end impact.
Child Safety Systems	CSS	Child safety systems are specifically designed seats that protect children from injury or death during collisions. Generally, these seats are installed based on end-user requirements.
Pedestrian Safety System	PSS	This system prevents vehicles from colliding with pedestrians by sensing the situation and provides guidance to make decision. In most of the advanced vehicle, this system automatically decreases vehicle speed to avoid collision with pedestrians.

Head up display:

The automotive HUD finds application in the majority of the passenger car segments. Given the increasing adoption of HUD in the automotive sector, it has become a standard feature for various models in the luxury car segment. Additionally, the increasing demand for comfort and safety has compelled automakers to incorporate this feature in premium and mid segment models as well. The market in growing regions such as Asia-Pacific, and North America indicate promising growth potential for the automotive HUD market. The Asia-Pacific automotive market in particular presents high-growth opportunities; the region includes Japan, China, and India, with the latter two having huge production capabilities. The European HUD market is primarily driven by the growing awareness regarding driver safety and convenience. Europe has many luxury/premium car manufacturers. Major high-end car OEMs such as Audi AG (Germany), BMW (Germany), Mercedes-Benz (Germany), Bentley Motors (UK), Maserati (Italy), Ferrari (Italy), and Bugatti Automobiles (France) have their headquarters in Europe. The automotive HUD comes as standard safety feature in the majority of European automobiles. The region therefore has a wide customer base for this technology.

Windshield head up display technology and combiner head UP display technology:

The windshield head up display projects a virtual image with the necessary information needed by the driver. This information is projected in accordance with the drivers eye gaze. In this technology type, the windshield of the car plays an important role as there are chances that the image produced by the device can be distorted. The conventional HUD uses TFT displays which projects images on the windscreen. With the advancement in technology there have been improvements in the display technology. One of the differentiating factors between the two types of HUDs is the space requirement and image resolution. The Combiner HUD type has a smaller screen which displays the necessary information but lacks the picture quality as compared to the other type. The Combiner HUD has an adjustable positioning system which enables the driver to adjust the screen according to their convenience.

Augmented Reality head up display technology:

Augmented reality (AR) is an upcoming trend in the head-up display market. Augmented HUD is a real time technology which enhances the safety and driving experience. Augmented reality-based HUD technology provides full-colour advanced driver assistance system (ADAS) including lane departure warning system and advanced driving information. The AR-HUD sense the exterior environment of the vehicle, analyses this information and virtually display the traffic condition. For example, if the driver has set a destination on the navigation system, the AR-HUD projects a virtual route that is to be followed. It also detects the distance between itself and the vehicle in front and alerts the driver. The differentiating factor for AR-HUD is that it projects information which appears to be part of the driving situation itself.

DEFORMATION BEHAVIOR OF VEHICLE BODY

Due to the frequency of frontal collisions, an important role is played by the legally stipulated frontal impact test in which a vehicle is driven at a speed of 48.3 km/h (30 mph) into a rigid barrier which is either perpendicular or inclined at an angle of up to 30° relative to the longitudinal axis of the car.

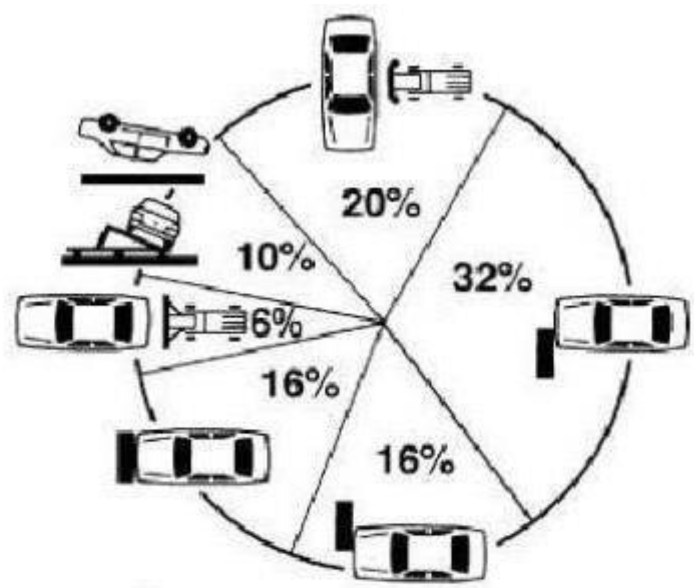

Figure 2.2. Distribution of various types of impacts in car accidents.

- Because 50 % of all frontal collisions in right-hand traffic primarily involve the left-hand half of the front of the vehicle, manufacturers worldwide conduct left asymmetrical front impact tests on LHD vehicles covering 30 ... 50 % of the vehicle width. Distribution of accidents by type of collision, Symbolized by test methods yielding equal results in a frontal collision, kinetic energy is absorbed through deformation of the bumper, the front of the vehicle, and in severe cases the forward section of the passenger compartment (dash area). Axles, wheels (rims) and the engine limit the deformable length. Adequate deformation lengths and displaceable vehicle aggregates are necessary, however, in order to minimize passenger-compartment acceleration.
- Depending upon vehicle design (body shape, type of drive and engine position), vehicle mass and size, a frontal impact with a barrier at approx. 50 km/h results in permanent deformation in the forward area of 0.4 0.7 m. Damage to the passenger compartment should be minimized. These concerns primarily dash area (displacement of steering system, instrument panel, pedals, toe- panel intrusion), underbody (lowering or tilting of seats), the side structure (ability to open the doors after an accident).

- Acceleration measurements and evaluations of high-speed films enable deformation behavior to be analyzed precisely. Dummies of various sizes are used to simulate vehicle occupants and provide acceleration figures for head and chest as well as forces acting on thighs. Head acceleration values are used to determine the head injury criterion (HIC). The comparison of measured values supplied by the dummies with the permissible limit values as per FMVSS 208 (HIC: 1000, chest acceleration: 60 g/3 ms, upper leg force: 10 kN) are only limited in their applicability to the human being.
- The side impact, as the next most frequent type of accident, places a high risk of injury on the vehicle occupants due to the limited energy absorbing capability of trim and structural components, and the resulting high degree of vehicle interior deformation. The risk of injury is largely influenced by the structural strength of the side of the vehicle (pillar/door joints, top/bottom pillar points), load-carrying capacity of floor cross-members and seats, as well as the design of inside door panels (FMVSS 214, ECE R95, Euro-NCAP, US-SINCAP).In the rear impact test, deformation of the vehicle interior must be minor at most.
- It should still be possible to open the doors, the edge of the trunk lid should not penetrate the rear window and enter the vehicle interior, and fuel-system integrity must be preserved (FMVSS 301).Roof structures are investigated by means of rollover tests and quasi-static car-roof crush tests(FMVSS 216).
- In addition, at least one manufacturer subjects his vehicles to the inverted vehicle drop test in order to test the dimensional stability of the roof structure (survival space) under extreme conditions (the vehicle falls from a height of 0.5 m onto the left front corner of its roof).

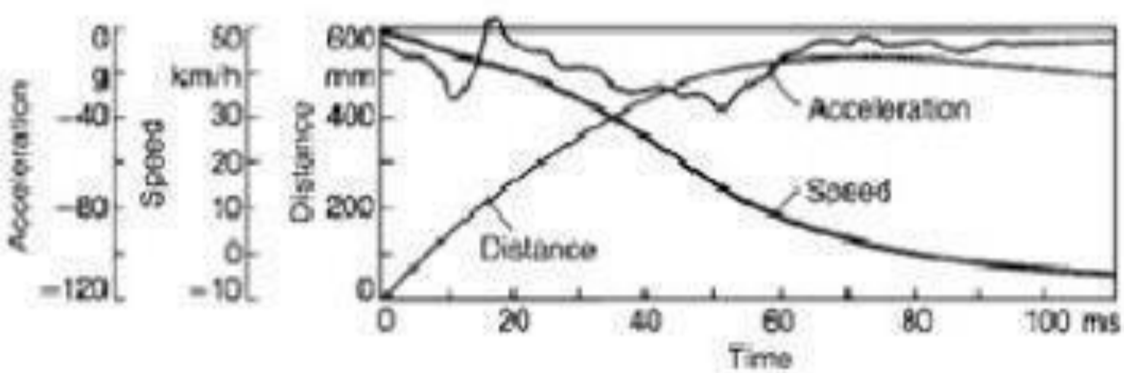

Figure 2.3. Acceleration, Speed and distance travelled during a car accident.

Acceleration, speed and distance traveled, of a passenger compartment when impacting a barrier impacting a barrier at 50 km/h.

SPEED AND ACCELERATION CHARACTERISTICS OF VEHICLE BODY:

Velocity graph for 15 mph barrier test:

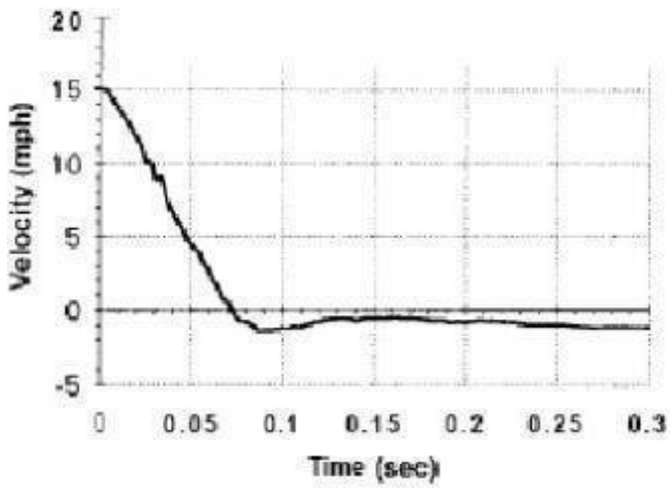

Figure 2.4. Velocity graph during a barrier test conducted at 15 mph.

Velocity graph for 20 mph barrier test:

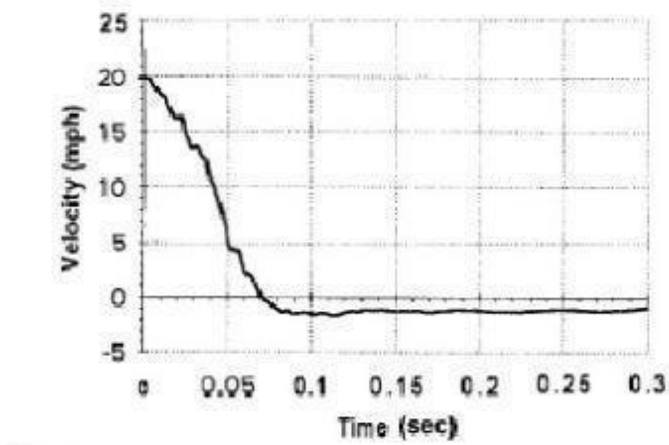

Figure 2.5. Velocity graph during a barrier test conducted at 20 mph.

Velocity graph for 40 mph barrier test:

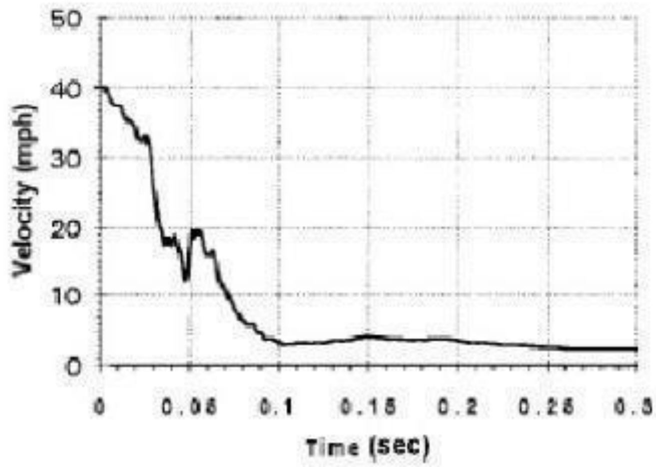

Figure 2.6. Velocity graph during a barrier test conducted at 40 mph.

Velocity graph for 50 mph barrier test:

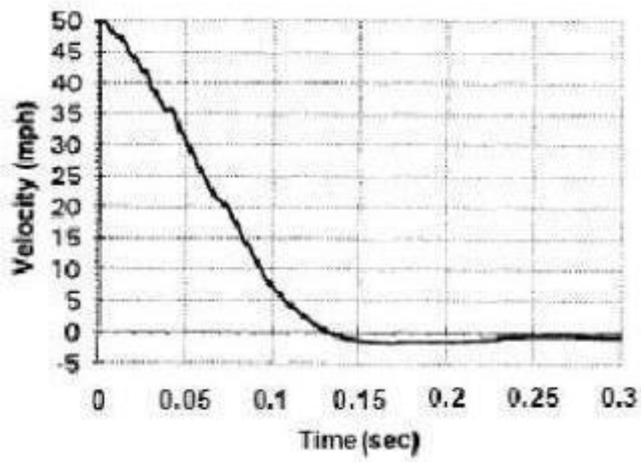

Figure 2.7. Velocity graph during a barrier test conducted at 50 mph.

- All the graphs show the reduction in velocity (speed) of passenger compartment on impact. For 15 mph and20 mph barrier test, we can see that the velocity comes to zero, crosses zero line, stays in the negative region afterwards.
- Velocity in negative region means that the car is moving in opposite direction (i. e.) after the collision it moves back. But for 40 mph test, the velocity comes close to zero and lies in the positive region. It means that after the impact, the car does not bounce back much, because most of the energy of the crash is taken by deforming the body metal.
- But in 15 mph and 20 mph tests, as the speed is low, the kinetic energy to deform the body metal is also less and hence the body metal does not deform and stands rigid. So, the car bounces back and velocity is slightly in the negative region.

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SAU1603 – AUTOMOTIVE SAFETY

UNIT III – SAFETY EQUIPMENTS

UNIT III
SAFETY EQUIPMENTS

Seat belt, regulations, automatic seat belt lightener system
Collapsible steering column, tilt able steering wheel
Air bags, electronic system for activating air bags
Bumper design for safety

SEAT BELT

- A seat belt, sometimes called a safety belt, is a safety harness designed to secure the occupant of a vehicle against harmful movement that may result from a collision or a sudden stop.
- As part of an overall automobile passive safety system, seat belts are intended to reduce injuries by stopping the wearer from hitting hard interior elements of the vehicle, or other passengers (the so-called second impact), are in the correct position for the airbag to deploy and prevent the passenger from being thrown from the vehicle.
- Seat belts also absorb energy by being designed to stretch during an impact, so that there is less speed differential between the passenger's body and their vehicle interior, and also to spread the loading of impact on the passengers' body.
- The final, so-called 'third impact' after a passenger's body hits the car interior, airbag or seat belts, is that of the internal organs hitting the ribcage or skull.
- The force of this impact is the mechanism through which car crashes cause disabling or life threatening injury.

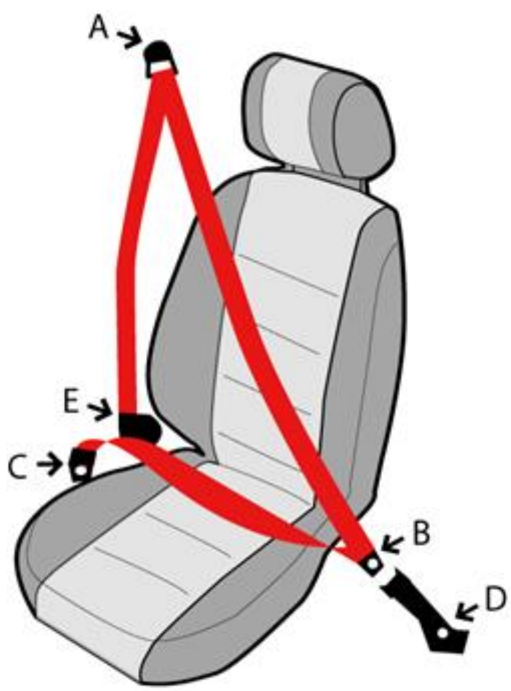

Figure 3.1. Three points seat belt.

- The sequence of energy dissipating and speed reducing technologies - crumple zone - seat belt - airbags - padded interior, are designed to work together as system, to reduce the force of this final impact

Types of seat belts

- Lap seat belt
- Three points

seatbelt Lap:

- Adjustable strap that goes over the waist. Used frequently in older cars, now uncommon except in some rear middle seats. Passenger's aircraft seats also use lap seat belts to prevent injuries.

Sash:

- Adjustable strap that goes over the shoulder. Used mainly in the 1960s, but of limited benefit because it is very easy to slip out of in a collision.

Three-point:

- Similar to the lap and shoulder, but one single continuous length of webbing. Both three-point and lap-and-sash belts help spread out the energy of the moving body in a collision over the chest, pelvis, and shoulders. Volvo introduced the first production three-point belt in 1959. The first car with three point belt was a Volvo PV 544 that was delivered to a dealer in Kristian stad on August 13, 1959. The three point belt was developed by Nils Bohlin who earlier had worked on ejection seats at Saab. Until the 1980s, three-point belts were commonly available only in the front seats of cars; the back seats had only lap belts or diagonal belts. Evidence of the potential for lap belts to cause separation of the lumbar vertebrae and the sometimes associated paralysis, or "seat belt syndrome", has led to a revision of passenger safety regulations in nearly all developed countries requiring that all seats in a vehicle be equipped with three-point belts. Since September 1, 2007, all new cars sold in the U.S. require a lap and shoulder belt in the center rear.

Seat belts and seat-belt tighteners

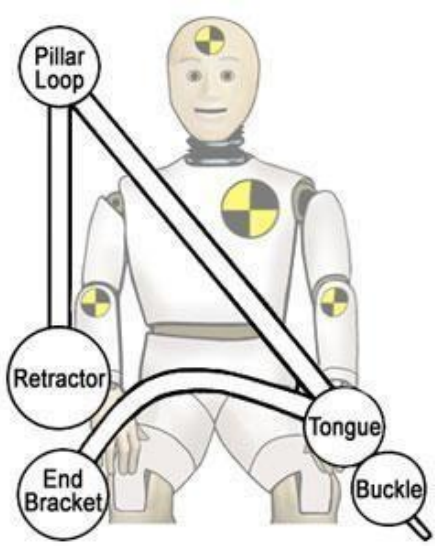

Figure 3.2. Parts of Seat belt.

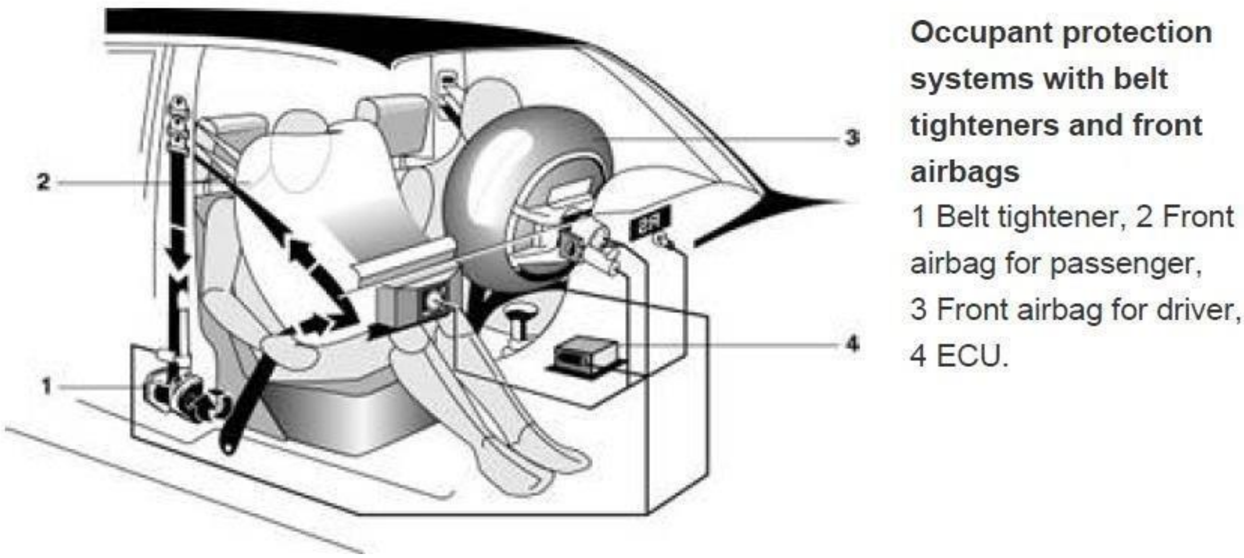

Figure 3.3. Occupant protection systems with belt tighteners and front airbags

FUNCTION:

- The function of seat belts is to restrain the occupants of a vehicle in their seats when the vehicle hits an obstacle.
- Seat-belt tighteners improve the restraining characteristics of a three-point inertia-reel belt and increase the protection against injury.
- In the event of a frontal impact, they pull the seat belts tighter against the body and thus hold the upper body as closely as possible against the seat backrest.
- This prevents excessive forward displacement of the occupants caused by mass inertia.

Operating concept:

- In a frontal impact with a solid obstacle at a speed of 50 km/h, the seat belts must absorb a level of energy comparable to the kinetic energy of a person in free fall from the 4th floor of a building. Because of the belt slack, the belt stretch and the delayed effect of the belt retractor ("film-reel effect"),three-point inertia-reel belts provide only limited protection in frontal impacts with solid obstacles at speeds of over 40 km/h because they can no longer safely prevent the head and body from impacting against the steering wheel or the instrument panel. An occupant experiences extensive forward displacement without restraint systems.
- Deceleration to standstill and forward displacement of an occupant at an impact speed of 50 km/h.1 Impact, 2 Firing of belt tightener/airbag, 3 Belt tightened, 4 Airbag inflated. without/ with restraint systems. In an impact, the shoulder belt tightener compensates for the belt slack and the "film-reel effect" by retracting and tightening the belt strap.
- At an impact speed of 50 km/h, this system achieves its full effect within the first 20 ms of the impact; and thus supports the airbag which needs approx. 40 ms to inflate completely. The occupant continues to move forward slightly until making contact with the deflating airbag and in this manner is protected from injury.
- A prerequisite for optimum protection is that the occupants' forward movement away from their seats remains minimal as they decelerate along with the vehicle. This is

achieved by triggering the belt tighteners immediately upon initial impact to ensure that safe restraint of the occupants in the front seats starts as soon as possible.

- The maximum forward displacement with tightened seat belts is approx. 1 cm and the duration of mechanical tightening is 5...10 ms. On activation, a pyrotechnical propellant charge is electrically fired. The explosive pressure acts on a piston, which turns the belt reel via a steel cable in such a way that the belt rests tightly against the body.

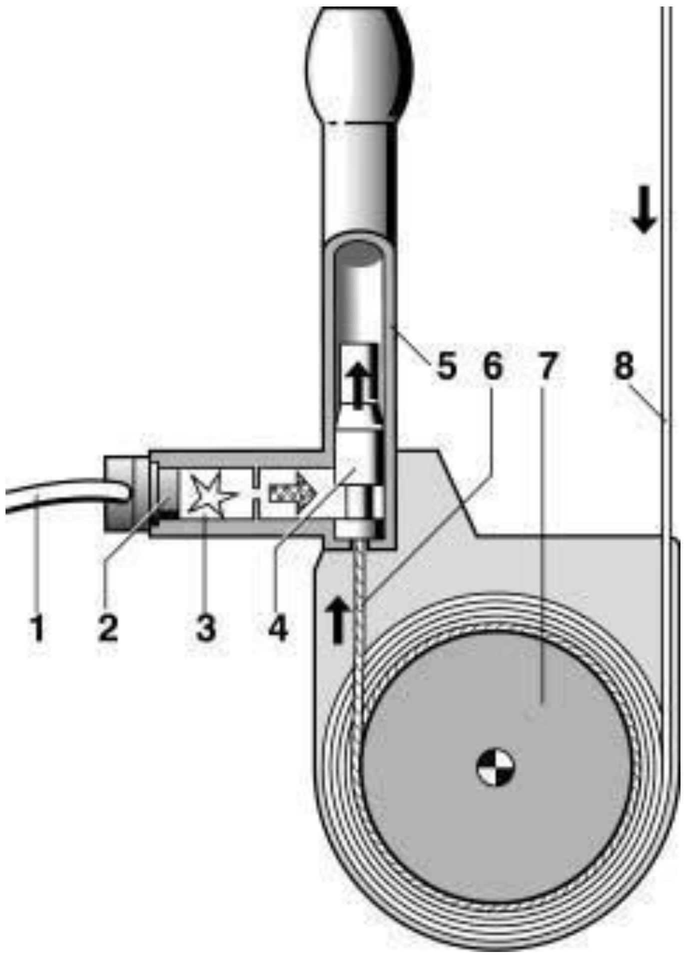

Figure 3.4. Shoulder-belt tightener

1.Ignition cable, 2 Firing elements, 3 Propellant charge, 4 Piston, 5 Cylinder, 6 Metal cables, 7 Belt reel, 8 Belt strap.

COLLAPSIBLE STEERING COLUMN

- The collapsible steering column, like shoulder harnesses or air bags, is a device that greatly increases driver survivability in the event of a head on collision. During a head on crash, the steering column can be pushed into the passenger compartment with tremendous force.
- At the same time, drivers obey Newton's first law of motion and continue to travel at the same speed of the automobile until something acts on the driver to slow or stop them. Too frequently, it was the steering wheel that caused drivers to stop, sometimes with horrific consequences.
- In fact, years ago it was not unheard of for drivers to be impaled on the steering shaft. As a result, engineers began to investigate ways in which driver survivability could be increased for those unlucky enough to slam into the steering wheel. The goal was to develop a system in which the driver could safely slow down or decelerate during a front end collision. What they developed is now known as the collapsible steering column. Its design was so successful that nearly all of today's steering columns are designed to deform under pressure from impact.
- Collapsible steering columns come in a number of designs. Some columns integrate a series of telescoping tubes that collapse when impacted by the driver. Others use break points in the column that will allow the bend more easily. Still others have a special joint near the steering gear that allows the column to snap down during impact. While air bags have become more prominent over the past few years, collapsible steering columns continue to play an important role in enhancing driver safety. But rather than being a primary safety feature, steering column designs have come to represent the last ring of safety behind shoulder harnesses restraints and air bags. Together, more drivers are walking away from crashes that would have certainly resulted in death, just a few years ago.

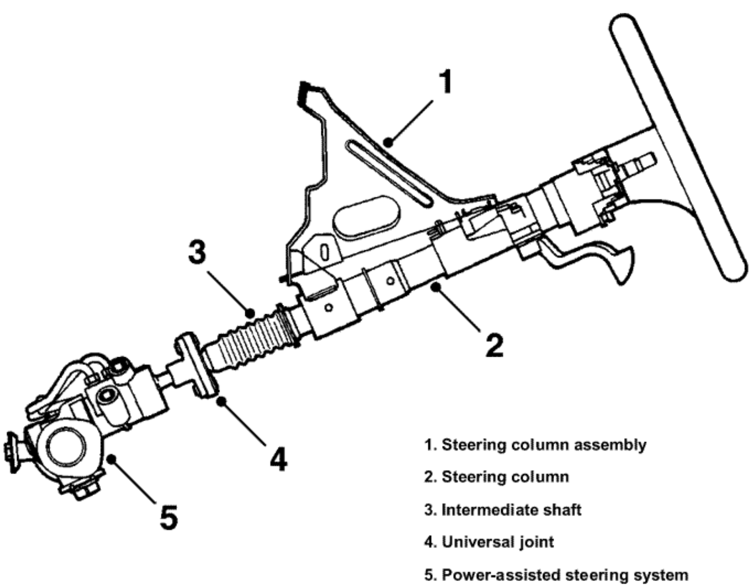

Figure 3.5. Parts of conventional steering column assembly

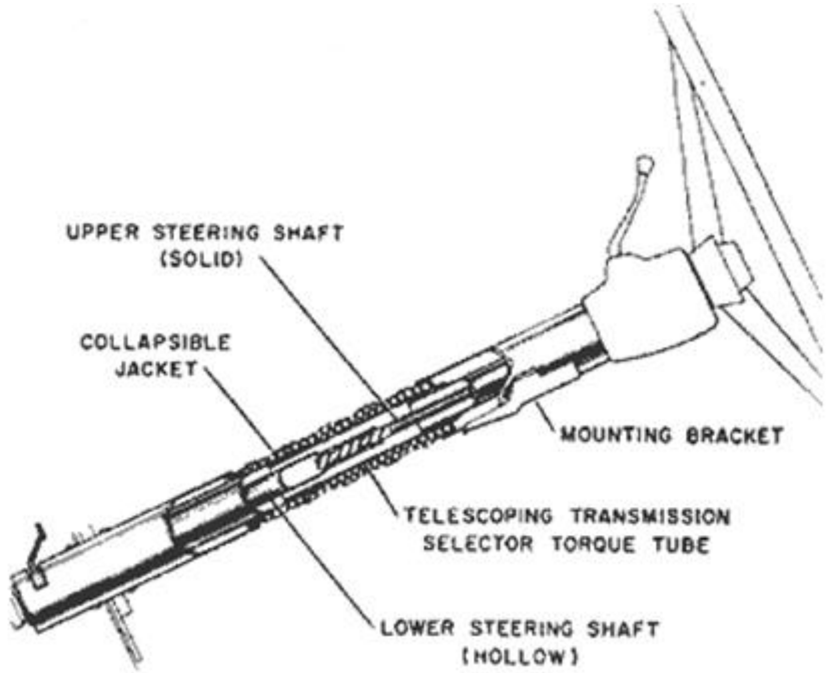

Figure 3.6. Parts of standard crushable steering column assembly

AIR BAGS, ELECTRONIC SYSTEM FOR ACTIVATING AIR BAGS:

Front airbag

Function:

- The function of front airbags is to protect the driver and the front passenger against head and chest injuries in a vehicle impact with a solid obstacle at speeds of up to 60 km/h.
- In a frontal impact between two vehicles, the front airbags afford protection at relative speeds of up to 100 km/h. A belt tightener alone cannot prevent the head from hitting the steering wheel in response to severe impact. In order to fulfill this function, depending on the installation location, vehicle type and structure-deformation response, airbag shave different filling capacities and pressure build-up sequences adapted to the specific vehicle conditions.
- In a few vehicle types, front airbags also operate in conjunction with "inflatable knee pads", which safeguard the "ride down benefit", i.e. the speed decrease of the occupants together with the speed decrease of the passenger cell.
- This ensures the rotational forward motion of the upper body and head which is actually needed for optimal airbag protection, and is of particular benefit in countries where seat-belt usage is not mandatory.

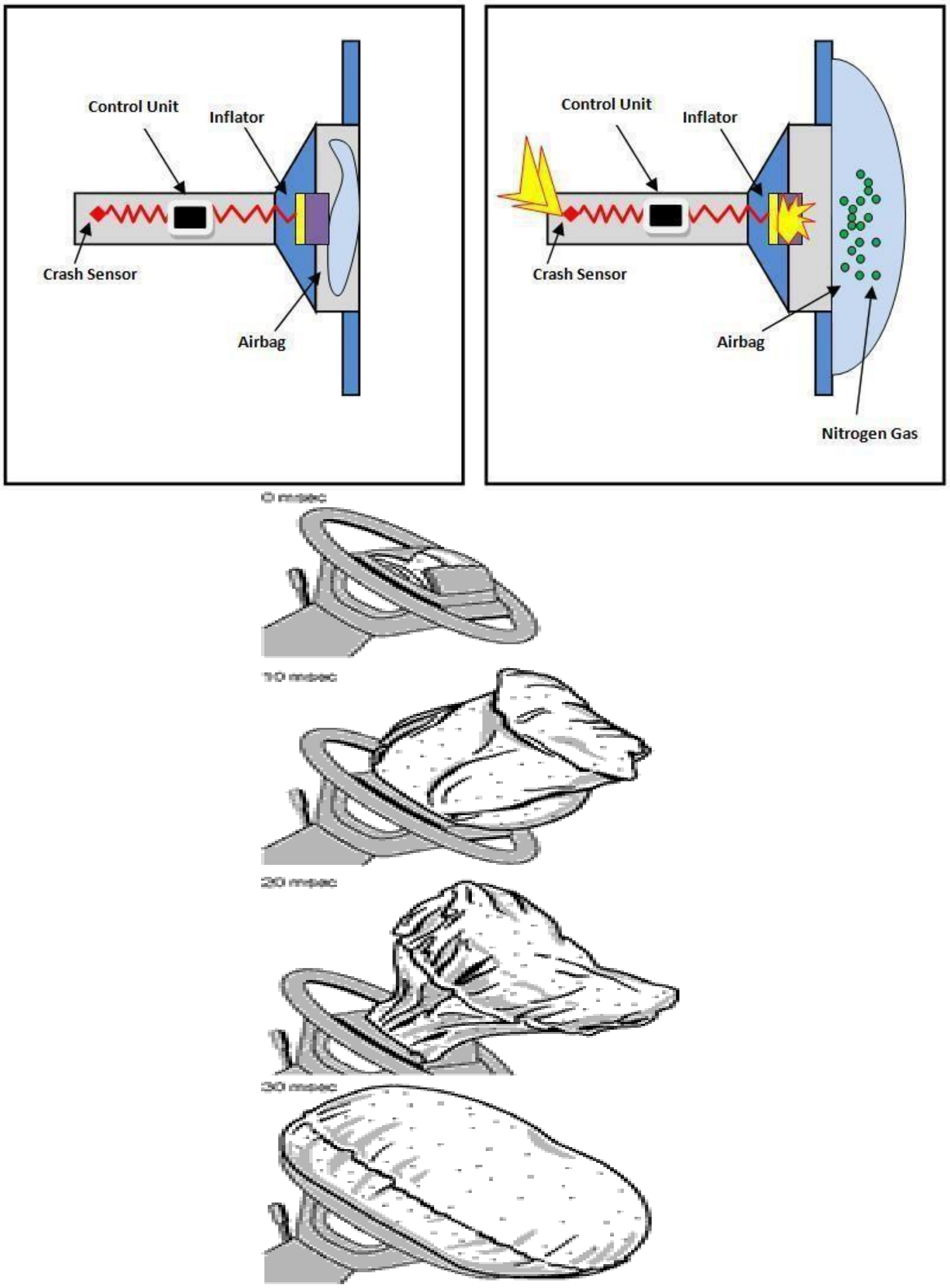

Figure 3.7. Construction and working of airbag.

Operating concept:

- To protect driver and front passenger, pyrotechnical gas inflators inflate the driver and passenger airbags in pyrotechnical, highly dynamic fashion after a vehicle impact detected by sensors.
- In order for the affected occupant to enjoy maximum protection, the airbag must be fully inflated before the occupant comes into contact with it.
- The airbag then responds to upper-body contact with partial deflation in a response pattern calculated to combine "gentle" impact-energy absorption with non-critical (in terms of injury) surface pressures and decelerative forces for the occupant. This concept significantly reduces or even prevents head and chest injuries.
- The maximum permissible forward displacement before the driver's airbag is fully inflated is approx.12.5 cm, corresponding to a period of approx. 10 ms + 30 ms = 40 ms after the initial impact (at 50 km/h with a solid obstacle) (see Fig. "Deceleration to standstill"). It needs 10 ms for electronic firing to take place and 30ms for the airbag to inflate.
- In a 50 km/h crash, the airbag takes approx. 40 ms to inflate fully and a further 80...100 ms to deflate through the deflation holes. The entire process thus takes little more than a tenth of a second, i.e. the batting of an eyelid.

Impact detection:

- Optimal occupant protection against the effects of frontal, offset, oblique or pole impact is obtained through the precisely coordinated interplay of electrically fired pyrotechnical front airbags and seat-belt tighteners.
- To maximize the effect of both protective devices, they are activated with optimized time response by a common ECU (triggering unit) installed in the passenger cell. The ECU's deceleration calculations are based on data from one or two electronic acceleration sensors used to monitor the decelerative forces that accompany an impact. The impact must also be analyzed. A hammer blow in the workshop, gentle pushing, driving over a curbstone or a pothole should not trigger the airbag. With this end in mind, the sensor signals are processed in digital analysis algorithms whose sensitivity parameters have been optimized with the aid of crash-data simulations.
- Depending on the impact type, the first trigger threshold is reached within 5...60 ms. the acceleration characteristics, which are influenced for instance by the vehicle equipment and the body's deformation performance, are different for each vehicle. They determine the setting parameters which are of crucial importance for the sensitivity in the analysis algorithm (computing process) and, in the end, for airbag and belt-tightener firing.
- Depending on the vehicle-manufacturer's production concept, the trigger parameters and the extent of vehicle equipment can also be programmed into the ECU at the end of the assembly line ("end-of-line programming" or "EoL programming").In order to prevent injuries caused by airbags or fatalities to "out-of-position" occupants or to small children in Re board child seats, it is essential that the front airbags are triggered and inflated in accordance with the particular situations.

- The following improvement measures are available for this purpose 1. Deactivation switches. These switches can be used to deactivate the driver or passenger airbag. The airbag function states are indicated by special lamps.2. In the USA, where there have been approx. 130 fatalities caused by airbags, attempts are being made to reduce aggressive inflation by introducing "depowered airbags".
- These are airbags whose gas-inflator power has been reduced by 20...30 %, which itself reduces the inflation speed, the inflation severity and the risk of injury to "out-of-position" occupants. "Depowered airbags" can thus be depressed more easily by large and heavy occupants, i.e. they have a reduced energy-absorption capacity. It is therefore essential above all with regard to the possibility of severe frontal impacts for the occupants to fasten their seatbelts.3. "Intelligent airbag systems".
- The introduction of improved sensing functions and control options for the airbag inflation process, with the accompanying improvement of the protective effect, is intended to result in a step-by-step reduction in the risk of injury.

Acceleration sensors:

- Acceleration sensors for impact detection are integrated directly in the ECU (belt tightener, front airbag)and mounted at selected points on the left and right body sides (side airbag) or in the vehicle's front-end deformation area (upfront sensors for "intelligent airbag systems").
- The precision of these sensors is crucial in saving lives. They are generally surface-micromechanical sensors consisting of fixed and moving finger structures and spring pins. A special process is used to incorporate the "spring/mass system" on the surface of a silicon wafer.
- Since the sensors only have low working capacitance (≈1 pF), it is necessary to accommodate the evaluation electronics in the same housing so as to avoid stray-capacitance and other forms of interference.

Gas inflators:

- The pyrotechnical propellant charges of the gas inflators for generating the airbag inflation gas (mainly nitrogen) and for actuating belt tighteners are activated by an electrically operated firing element.
- The gas inflator in question inflates the airbag with nitrogen. The driver's airbag integrated in the steering-wheel hub (volume 35...67 l) or the passenger airbag installed in the glove box (70...150 l) is inflated approx. 30 ms after firing.

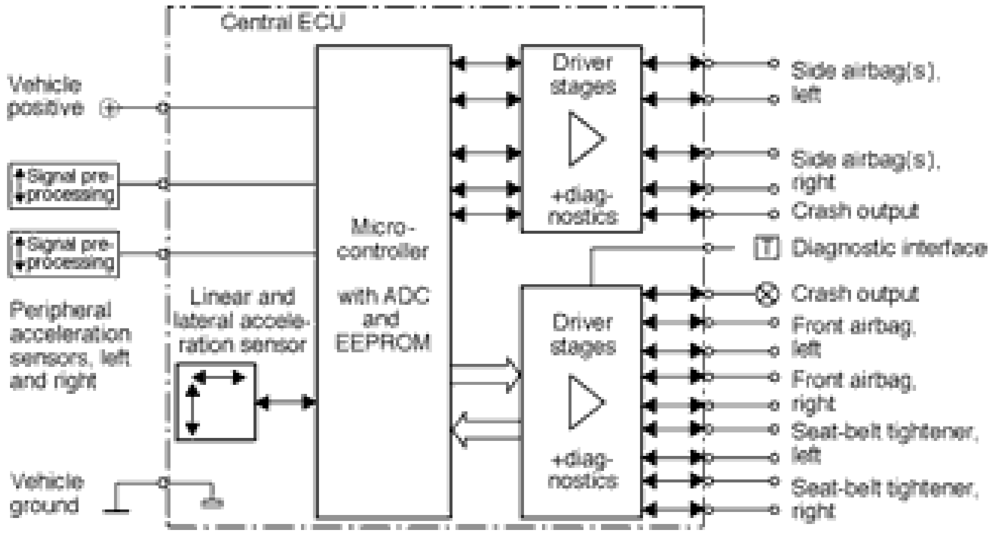

Figure 3.8. Combined ECU for belt tighteners and front/side airbags

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BUMPER DESIGN FOR SAFETY

- A **bumper** is a shield made of steel, aluminum, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low speed collision occurs, the **bumper** system absorbs the shock to prevent or reduce damage to the car
- The front and rear of the vehicle should be protected in such a manner that low-speed collisions will only damage the vehicle slightly, or not at all. Prescribed bumper evaluation tests (US Part 581, Canada CMVSS 215, and ECE-R 42) specify minimum requirements in terms of energy absorption and installed bumper height.

Figure 3.9. Front bumper of a car.

- Bumper evaluation tests in accordance with US Part 581 (4 km/h barrier collision, 4 km/h pendulum tests) must be passed by a bumper system whose energy absorber is of the no-damage absorber type.
- The requirements of the ECE standard are satisfied by plastically deformable retaining elements located between the bumper and the vehicle body structure. In addition to sheet steel, many bumpers are manufactured using fiber-reinforced plastics and aluminum sections

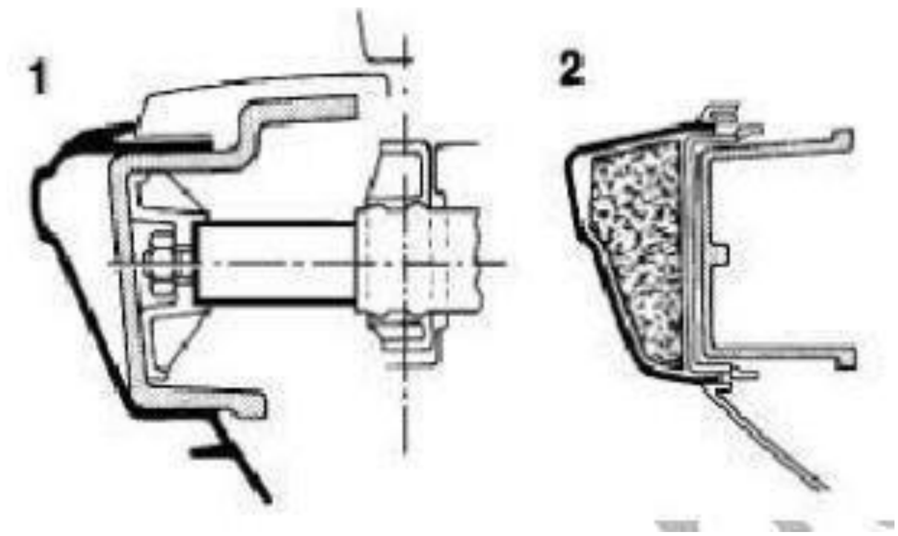

Figure 3.10. Cross sectional view of bumpers 1. Shock-absorber system, 2 Energy-absorbing PUR-foam systems

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SCHOOL OF MECHANICAL ENGINEERING
DEPARTMENT OF AUTOMOBILE ENGINEERING

SAU1603 – AUTOMOTIVE SAFETY

UNIT IV – COLLISION WARNING AND AVOIDANCE

UNIT IV
COLLISION WARNING AND AVOIDANCE

- COLLISION WARNING SYSTEM
- CAUSES OF REAR END COLLISION
- FRONTAL OBJECT DETECTION
- REAR VEHICLE OBJECT DETECTION SYSTEM
- OBJECT DETECTION SYSTEM WITH BRAKING SYSTEM INTERACTIONS.

1. COLLISION WARNING SYSTEM

- Collision Warning with Auto Brake is an active safety system that helps the driver to avoid or mitigate rear-end collisions.
- It uses forward-looking sensors to detect obstacles ahead of the vehicle.
- When a high risk for a rear-end collision is detected the system helps the driver by providing a warning and brake support.
- If the driver does not react in time and a collision is judged to be unavoidable, the system will automatically brake the vehicle.
- This may not avoid the accident, but the consequences can be reduced.
- This system is introduced in two steps. The first generation, called Collision Warning with Brake Support, is currently on the market in the new Volvo S80 allowing activation on vehicles that are moving or have been detected as moving. The second generation, called Collision Warning with Auto Brake
- Collision Warning with Auto Brake where the area in front of the vehicle is continuously monitored with the help of a long-range radar and a forward-sensing wide-angle camera fitted in front of the interior rear-view mirror.
- A warning and brake support will be provided for collisions with other vehicles, both moving and stationary.
- If the driver does not intervene in spite of the warning and the possible collision is judged to be unavoidable; intervention braking is automatically applied to slow down the car. This aims at reducing impact speeds and thus the risk for consequences.

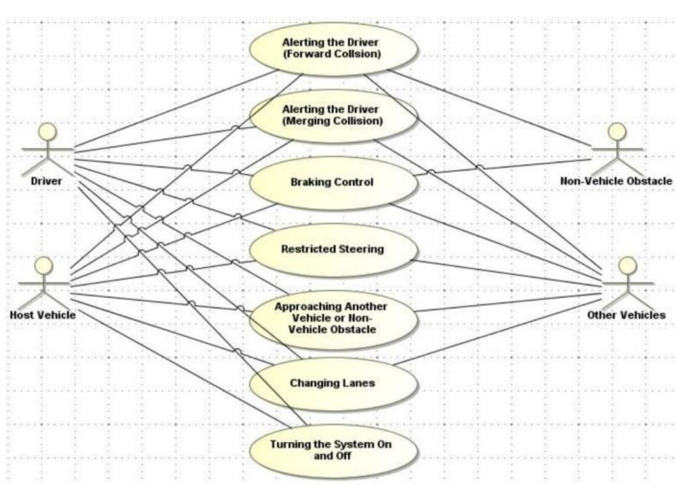


Figure 4.1. Schematic of collision warning system.

Components of collision warning system:

- **Sensor System**
  - Information about the traffic situation in front of the host vehicle is obtained from two sensors:- A 77-GHz mechanically-scanning forward looking **radar**, mounted in the vehicles grille, which measures target information such as range, range rate and angle in front of the vehicle in a 15 degree field-of-view.
  - A 640*480 pixel black and white progressive scan CMOS **camera**, mounted behind the windscreen, which is used for classifying the objects, e.g. as vehicles, in a 48-degree field-overview. Since the camera is used for reporting both vision objects and lane markings, the field of view was chosen to work for both.

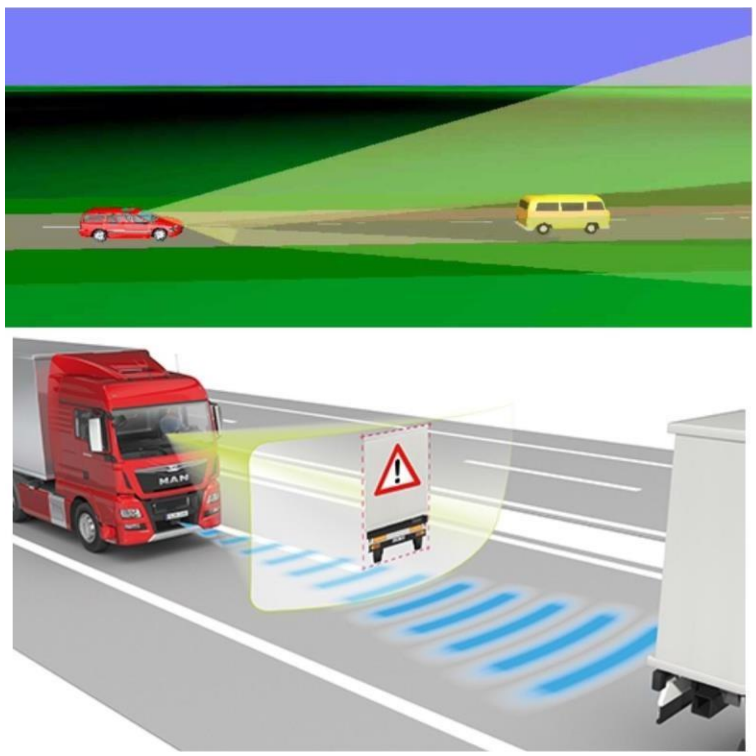


Figure 4.2. Collision warning system in vehicles.

- **Collision Warning**
  - The Collision Warning (CW) function is targeting to avoid or mitigate collisions by means of warning the driver ahead of a possible collision.
  - The system requires high usability, low number of nuisance alarms and an efficient Human Machine Interface (HMI).
  - The Collision Warning system should provide a relative late warning in order to reduce nuisance alarms and to reduce the possible misuse where an early warning system may build a trust that is falsely interpreted by the driver to allow for execution of non-driving tasks. The activation of the Collision Warning will therefore approximately occur when the driving situation is considered to be unpleasant.
  - However, it shall allow the driver to brake to avoid or mitigate an accident

provided the following distance was initially longer than the warning distance.

Functions:

Threat Assessment

- The aim of the threat assessment is to understand if the information from the forward sensing system shows that there is a risk for collision
- The first step is to approve a lead vehicle as staying in the forward path within a given time to collision utilizing intra-vehicle and yaw-rate information.
- Given an approved lead vehicle a second step calculates a total warning distance, i.e. the predicted distance required for avoiding a collision.
- The total warning distance base calculation is derived from a sum of three distinct distance calculations.
- The first is the driver reaction distance which is obtained from the predicted driver reaction time multiplied by vehicle speed.
- The second is the system reaction distance which is obtained from the system reaction time multiplied by vehicle speed.
- The third is the braking distance to avoid impact using the current physical states of the lead vehicle and the host vehicle using the constant acceleration model for the behavior of the host and the target vehicle closely mimicking the CAMP late warning algorithm.
- The sum of above provides a total warning distance.
- If the distance to the forward vehicle becomes lower than the total warning distance a warning is to be issued.

Collision Warning HMI

- An efficient HMI(Human Machine Interface) for a warning system is characterized by a low driver reaction time, as this is crucial for improving the possibility for the driver to mitigate or even avoid a collision.
- An efficient HMI puts requirements on low false and nuisance alarm rates, since there is a risk for overexposure that may lead to drivers deactivating the system.
- The warning interface is a dual modality warning incorporating visual and audible channels.

- The visual warning is a flashing red horizontal line located in the lower part of the windshield in the forward direction of the driver.
- The sound consists of tone burst with harmonics content.
- When the audible warning is active the sound system is muted. The Collision Warning can be turned off by a main switch.
- The system includes a warning distance setting using three levels. The levels have been defined by balancing driver behavior in late brake situations versus normal driving behavior.
- The warning distance settings are differentiated by the deceleration level used in the different settings the predicted brake ability by the driver.
- They also reduce warnings in normal driving situations to different levels.

Figure 4.3. Collision Warning head-up display

Driver Over ride:

- The objective of the driver override function is to inhibit a brake intervention when the driver has the situation under control. However, this is difficult or even impossible to measure and therefore driver inputs as steering and braking activities are considered instead, as these are the natural countermeasures in a collision event.
- The release of the accelerator pedal is considered, as this indicates that any further acceleration is undesired, and it can be assumed that the driver is thereby acknowledging a collision risk.
- Since the level of action that is required to activate a steering or brake override depends on the driver and on the traffic situation, the decision threshold is empirically determined through extensive testing in real life traffic situations with a large number of drivers.

Auto Brake

- *It is beneficial to the driver to get support in the upcoming collision event. This can be achieved by reducing the collision energy by optimizing driver initiated braking or through automatically putting on the brakes prior to the collision event.*
- When providing autonomous interventions that override or complement the driver's actions, one has to ensure that customer satisfaction is not negatively affected by false interventions.
- Customer acceptance is crucial in order to increase take rates and thus to increase the overall real- life safety benefit of the system. It is therefore necessary to implement a decision making strategy that reduces the amount of false interventions while not missing collision events where the driver needs support. Therefore, an intervention decision should be based on two main information categories: traffic situation data and driver actions. *The traffic situation data is used to quantify the risk for a collision event, in other words a threat assessment is performed*.
- This assessment will never be perfect as sensor information is usually a subset of the totally available information and mostly affected by latencies. So, a collision may appear to be unavoidable but is in reality avoidable. Hence, a driver that takes distinct steering and/or braking action is judged to be in control of the situation and should be trusted. The driver override function is to detect these distinct driver actions.
- As soon as *the support system has performed the threat assessment and driver override detection, the outcome can be weighted by the brake intervention strategy and a decision on an autonomous brake intervention can be taken*

Functions of collision warning:

System functionality:

- Alerting the driver
- Braking control
- Restricted steering Driver functionality:
- Changing lanes
- Turning the system on and off
- Approaching another vehicle or Non vehicle obstacle

2. REAR-IMPACT COLLISION WARNING SYSTEM (RICWS):

1. Common factors that contribute to rear-end collisions include by **driver inattention** or **distraction, tailgating, panic stops**, and **reduced traction** due to weather or worn pavement.
2. Rear impact crashes are the most frequent type of bus accidents.
3. Transit buses are particularly susceptible to rear impact collisions because of their **frequent stops**, which often occur in traffic lanes.
4. The majorities of bus collisions occur while the bus is **decelerating or stopped**.
5. The preponderance of crashes occurs with buses stopped during daylight hours, in good weather conditions, while traversing a straight path, and with the striking vehicle attempting no avoidance or corrective action.
6. Rear-end collisions are common accident scenarios and a common cause of these accidents is **driver distraction** and thus not reacting in time.

3. FRONTAL OBJECT DETECTION

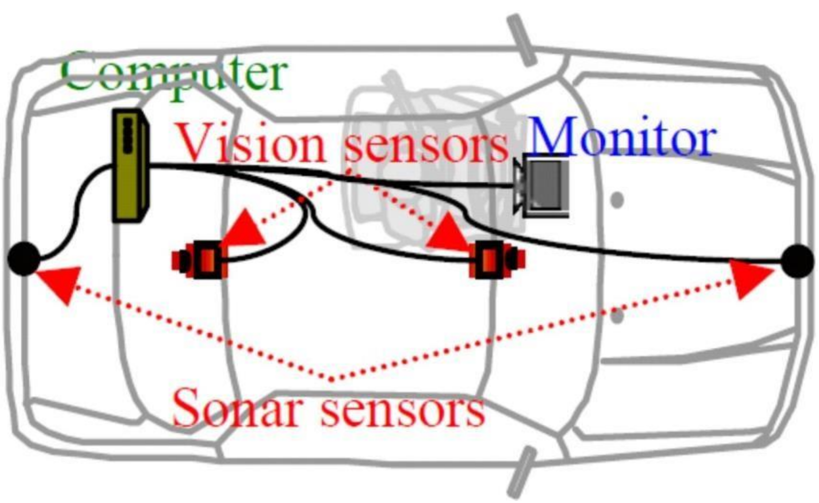


Figure 4.4. System overview of frontal object detection

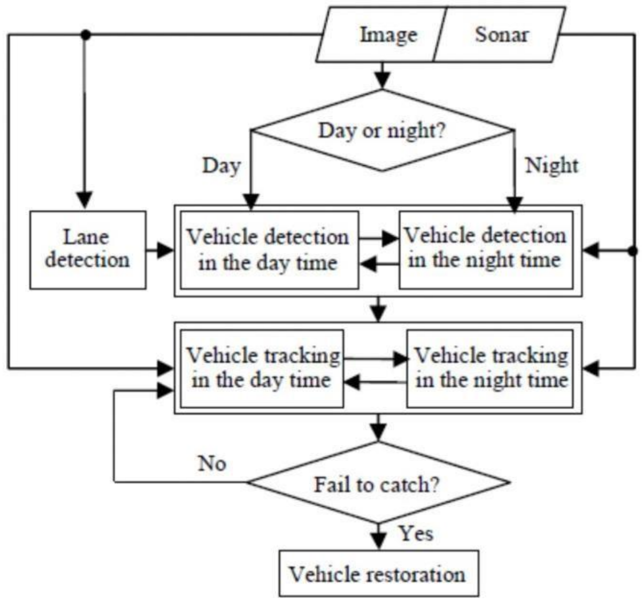


Figure 4.5. Schematic of frontal object detection system

SYSTEM OVERVIEW

- The Sensor system has two cameras that can detect vehicles in the medium and far range are installed by the side of a rear-view mirror and at the ceiling above the back seat and the two sonar sensors that can measure the distance in the near range are installed at the front and rear bumpers.
- Because the environment of the vehicle changes relatively fast as the speed ofa ego-vehicle is high, we acquire 2 images of 1 field with 640×240 for avoiding the motion flow and use 320×240 image by sub-sampling and acquire 2 signals of sonar sensors successively.

Determination Of The Day And Night Times

- The environment of a moving vehicle greatly varies, it is difficult to detect vehicles using a single feature or pre-established vehicle templates.
- Various features or templates can be used for various environments, and by applying the appropriate algorithm to the current environment the day or night time can be determined.

Vehicle Detection in the Day Time

- The detection system in the day time consists of 4 parts, the **preprocessing module** working on the input raw image, the **vehicle candidate extraction module** by a shadow region and a template, the **validation module** by a prior knowledge, and the **fusion module** for fusing sonar and image data.
  1) *Preprocessing*:
  2) *Vehicle Candidate Extraction*:
  3) *Vehicle Candidate Validation*
  4) *Vehicle Detection Using Sonar Sensors*

Figure 4.6. Determination of the light condition

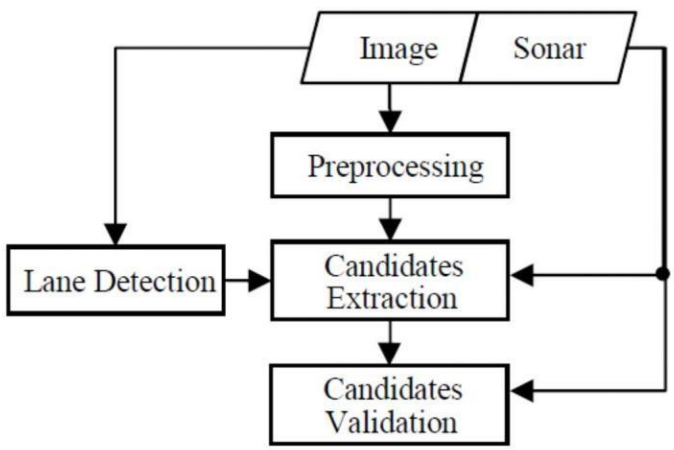
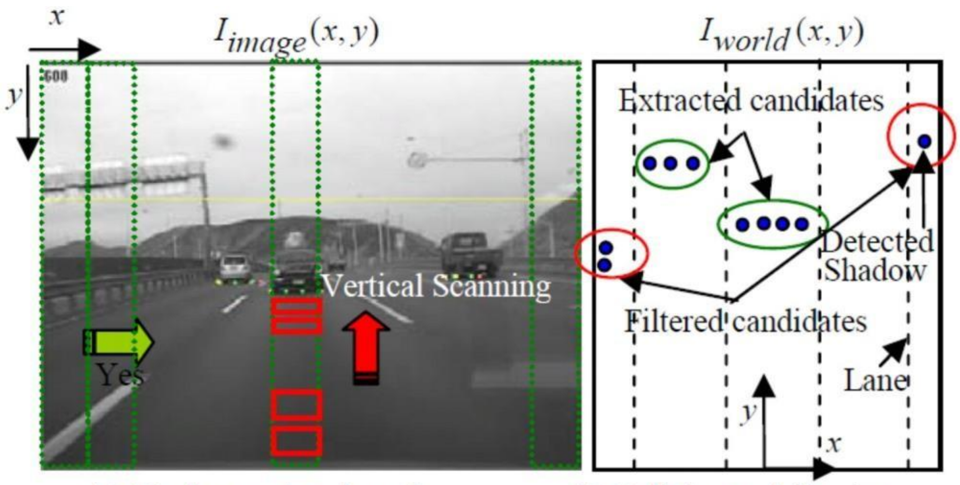
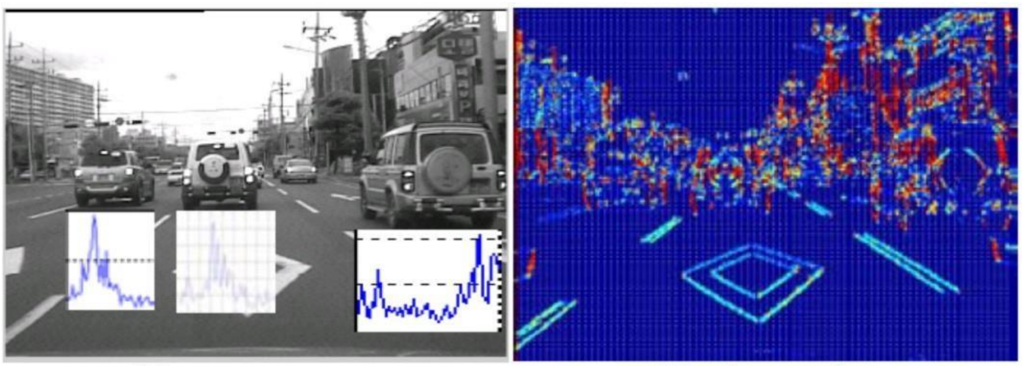


Figure 4.7. Schematic of Vehicle Detection System in the day time



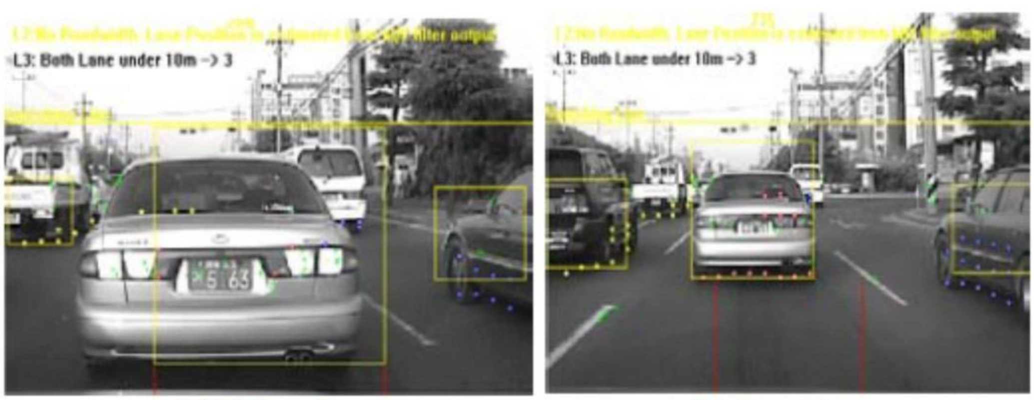
(a) Shadow region detection (b) Splitting and filtering

Figure 4.8. Vehicle Candidates Extraction



(a) symmetry rate (b) edge angle map

Figure 4.9.The symmetry rate and edge angle map



(a) Below 3m (b) 3m~10m

Figure 4.10. Vehicle detection at near distance

4. REAR VEHICLE OBJECT DETECTION SYSTEM

- Rear object detection systems monitor a specific area behind a commercial motor vehicle, detect objects, and provide warnings to drivers when they are approaching an object behind the vehicle while in reverse. These systems assist the driver in avoiding collisions during backing or parking maneuvers.
- Rear object detection systems detect moving and stationary objects located within a specific area behind a commercial motor vehicle while it is backing up. Currently available systems can detect objects within a range of approximately 10 to 20 feet behind a vehicle.
- They can be integrated with other sensors, such as side object detection sensors to cover other blind spot areas around a vehicle.
- Audible and/or visual distance-based alerts that vary depending upon the closeness of the vehicle to an obstacle are the types of warnings that can be provided to a driver through a processing and/or display unit in the cab.
- The sensor units located on the back of the vehicle can consist of different types of detection technology, such as radar or sonar.
- **Ultrasonic technology or sonar** (Sound Navigation And Ranging) determines the range of objects by emitting a transmitter pulse of ultrasonic energy.
    - The resultant echo is detected by a receiver as it is reflected from the detected object.
    - The emitter is a membrane that transforms mechanical energy into a chirp (inaudible sound wave) and sends this sound out toward the target area.
    - When the sound encounters an object, it is reflected back to the receiver circuit that is tuned to the frequency of the emitter, which then transfers the data to a driver display unit.
- **Radar (Radio Detection and Ranging) technology** is also used for rear object detection systems. Radar typically operates in the ultra-high-frequency or microwave range of the radio- frequency spectrum.
    - These radio frequency waves are transmitted from the vehicle at defined intervals within a specific coverage area.
    - The sensor collects echoes from electromagnetic waves that bounce off objects behind the vehicle. These echoes are sent to a signal processing unit and communicated to a driver interface.
    - Some processing units utilize algorithms for object detection, object tracking, and angle measurement to provide specific distance information.
- Rear object detection systems provide audible and/or visual alerts to warn drivers when objects are detected. Some systems indicate the vehicle's distance from a detected object. For example, the driver interface may consist of a graphical or digital visual display that shows the distance from the vehicle to a specific object. Other visual alerts could consist of a series of lights which change color or light up as objects are detected. These visual alerts can be used in combination with audible alerts that vary in tone and frequency as the vehicle moves closer to an object.
- Rear object detection systems can be activated manually when needed or automatically for continuous operation. Some rear object detection systems are connected directly to the

vehicle's backup lights, which activate automatically when the vehicle is shifted into reverse. Other systems are activated when the key is put into the ignition or the vehicle is put into operation. When the systems are activated, their operation is "hands-free," and the driver can focus on safely operating the vehicle.

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SAU1603 – AUTOMOTIVE SAFETY

UNIT V - COMFORT AND CONVENIENCE SYSTEM

UNIT V
COMFORT AND CONVENIENCE SYSTEM

- Steering and mirror adjustment
- Central locking system
- Garage door opening system
- Tire pressure control system
- Rain sensor system
- Environment information system

STEERING AND MIRROR ADJUSTMENT

- Electrically-adjustable steering columns are also seeing increased use as yet another means of enhancing driver comfort.
- The adjustment mechanism, consisting of a single electric motor and self-arresting gear set for each adjustment plane, forms an integral part of the steering column.
- The gear set for telescopic adjustment must be capable of absorbing any and all impact forces (crash forces) which might be applied to the steering column.
- The adjustment can be triggered in either of two ways, using the manual position switch or with the programmable seat adjustment. Also available is a provision for tilting the column upward to facilitate driver entry and degrees.

CENTRAL LOCKING SYSTEM

- Either pneumatic or electric actuators can be used to power central locking systems for vehicle doors, luggage compartments and fuel-filler flaps.
- In pneumatic systems, an electric motor drives the reversible dual-pressure pump which provides the required system pressure (positive or vacuum).
- The system can be switched on and off by a central position switch inside the vehicle and by the ignition switch. As an optional feature, the system can be operated from a number of points (driver door, front-seat passenger door, and trunk lid).

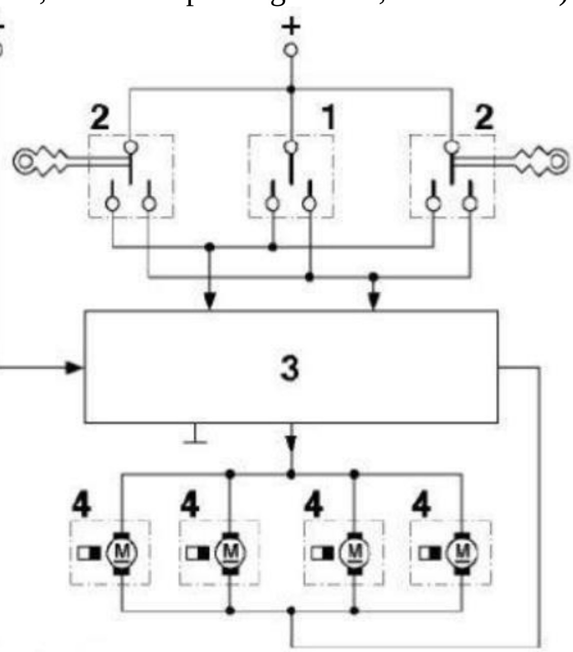

Figure 5.1. Central Locking System.1 Central switch, 2 Contacts in door-lock mechanisms, 3 Control unit, 4 Servomotors

More widespread than the pneumatic systems are those which depend on electric motors for central locking. Although various technologies are used, according to function range and lock type, the basic principle remains constant: a small electric motor featuring a reduction-gear drive unit powers the actuating lever responsible for opening and closing the lock.

Provision must be made to ensure that the door can always be unlocked with the key and the interior handle in the event of a power failure. Central locking systems incorporating special theft-deterrence features must be designed to preclude deactivation of the security system using any means other than the vehicle key.

Ultrasonic or infrared remote control provides increased convenience. Such systems permit remote operation of the central locking system when the driver is still some distance away from the vehicle.

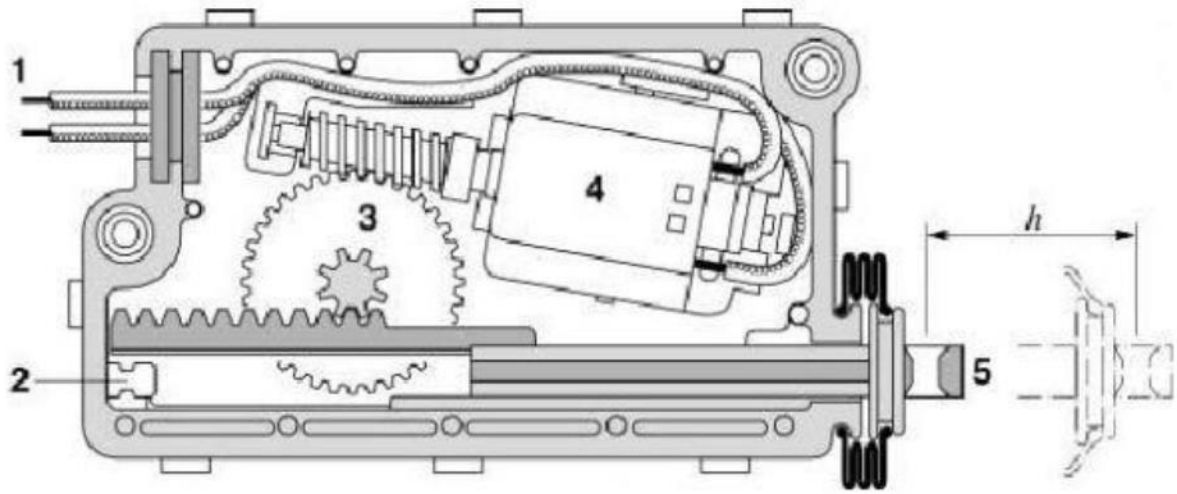

Figure 5.2. Cut section of central locking system. 1 Wiring connection, 2 Flexible end-position coupling, 3 Gear unit, 4 Electric motor, 5 Actuating lever, h - Travel range

Garage door opening system

- A garage door opener is a motorized device that opens and closes garage doors.
- Most are controlled by switches on the garage wall, as well as by remote controls carried in the garage owner's cars. The typical electric garage door opener consists of a power unit that contains the electric motor. The power unit attaches to a track.
- A trolley connected to an arm that attaches to the top of the garage door slides back and forth on the track, thus opening and closing the garage door. The trolley is guided along the track by a chain, belt, or screw that turns when the motor is operated.
- A quick-release mechanism is attached to the trolley to allow the garage door to be disconnected from the opener for manual operation during a power failure or in case of emergency.
- Limit switches on the power unit control the distance the garage door opens and closes once the motor receives a signal from the remote control or wall push button to operate the door. The entire assembly hangs above the garage door.
- The power unit hangs from the ceiling and is located towards the rear of the garage. The end of the track on the opposite end of the power unit attaches to a header bracket that is attached to the header wall above the garage door. The power head is usually supported by punched angle iron.

- The first garage door opener remote controls were simple and consisted of a simple transmitter (the remote) and receiver which controlled the opener mechanism. The transmitter would transmit.on a designated frequency; the receiver would listen for the radio signal, then open or close the garage, depending on the door position.
- The garage door remote is low in power and in range, it was powerful enough to interfere with other receivers in the area. The second stage of the wireless garage door opener system deals with the shared frequency problem. To rectify this, systems required a garage door owner to preset a digital code via dip switches on the receiver and transmitter.
- These switches provided garage door systems with 28 = 256 different codes they were not designed with high security in mind; the main intent was to avoid interference with similar systems nearby. The third stage of garage door opener market uses a frequency spectrum range between 300-400 MHz and most of the transmitter/receivers rely on hopping or rolling code technology.
- This approach prevents perpetrators from recording a code and replaying it to open a garage door. Since the signal is supposed to be significantly different from that of any other garage door remote control, manufacturers claim it is impossible for someone other than the owner of the remote to open the garage.
- When the transmitter sends a code, it generates a new code using an encoder. The receiver, after receiving a correct code, uses the same encoder with the same original seed to generate a new code that it will accept in the future.
- Because there is a high probability that someone might accidentally push the open button while not in range and desynchronize the code, the transmitter and receiver generate look-a-head codes ahead of time. The fourth stage of garage door opener systems is similar to third stage, but it is limited to the 315 MHz frequency.

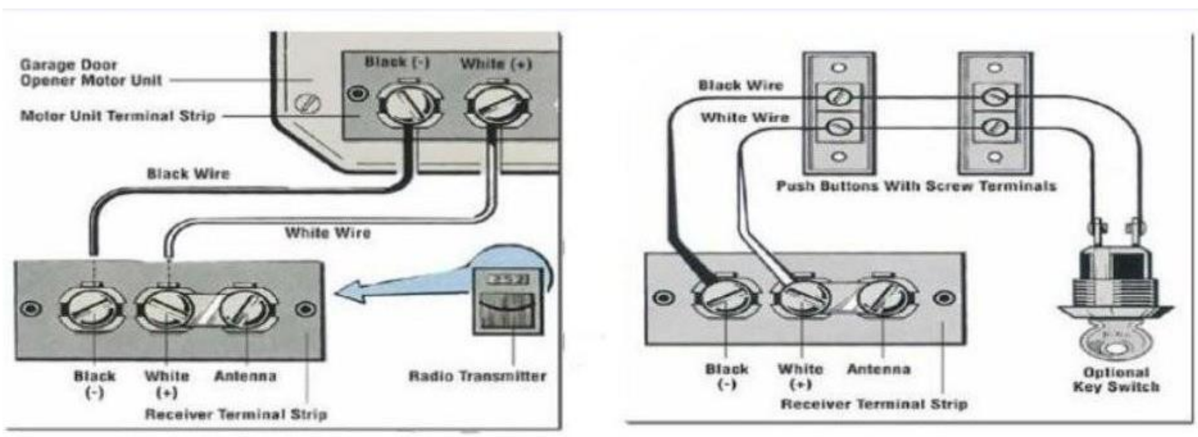

Figure 5.3. Garage door opening system

Tire Pressure Control system

- Another interesting electronic system that is slowly finding use in automobiles is a warning system for low tire pressure that works while the car is in motion. This application is motivated in part by an act of Congress that among other things requires that new vehicles have tire pressure monitoring capability by the 2004 model year.
- A potentially dangerous situation could be avoided if the driver could be alerted to the fact that a tire has low pressure. For example, if a tire develops a leak, the driver could be warned in sufficient time to stop the car before control becomes difficult. There are several pressure sensor concepts that can be used.

- A block diagram of a hypothetical system showing the scheme of working where, a tire pressure sensor continually measures the tire pressure. The signal from the sensor mounted on the rolling tire is coupled by a link to the electronic signal processor. Whenever the pressure drops below a critical limit, a warning signal is sent to a display on the instrument panel to indicate which tire has the low pressure.
- The difficult part of this system is the link from the tire pressure sensor mounted on the rotating tire to the signal processor mounted on the body. Several concepts have the potential to provide this link. For example, slip rings, which are similar to the brushes on a dc motor, could be used. However, this would require a major modification to the wheel-axle assembly and does not appear to been acceptable choice at the present time. Another concept for providing this link is to use a small radio transmitter mounted on the tire. By using modern solid-state electronic technology, a low-power transmitter is mounted in the tire valves. The transmitter sends a signal to a receiver in the car body.
- The distance from the transmitter to the receiver is a few feet, so only very low power is required. One problem with this method is that electrical power for the transmitter would have to be provided by a self-contained battery. However, the transmitter need only operate for a few seconds and only when the tire pressure falls below a critical level. Therefore, a tiny battery could theoretically provide enough power. The scheme is illustrated schematically for a single tire in the following figure. The sensor switch is usually held open by normal tire pressure on a diaphragm mechanically connected to the switch. Low tire pressure allows the spring-loaded switch to close, thereby switching on the micro transmitter. The receiver, which is directly powered by the car battery, receives the transmitted signal and passes it to the signal processor, also directly powered by the car battery.
- The signal processor then activates a warning lamp for the driver, and it remains on until the driver resets the warning system by operating a switch on the instrument panel. One reason for using a signal processing unit is the relatively short life of the transmitter battery. The transmitter will remain on until the low-pressure condition is corrected or until the battery runs down. By using a signal processor, the low-pressure status can be stored in memory so the warning will still be given even if the transmitter quits operating.
- The need for this feature could arise if the pressure dropped while the car was parked. By storing the status, the system would warn the driver as soon as the ignition was turned on. Still another scheme for monitoring tire pressure is to have a transmitter/receiver mounted on the car. In this scheme, the tire pressure sensor is a form of passive transponder that is interrogated by the transmitter/receiver system.

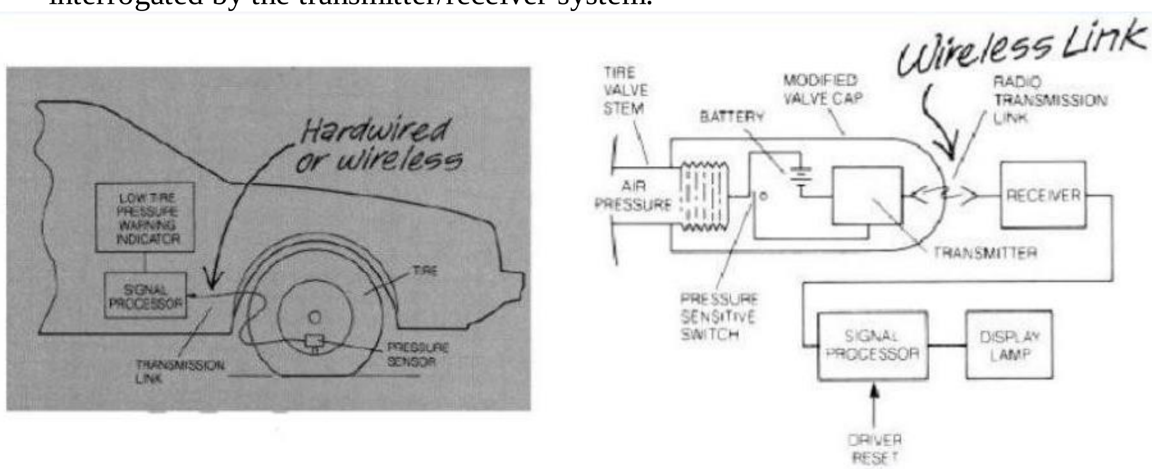

Figure 5.4. Schematic of pressure control system.

Rain Sensors

The rain sensor recognizes rain droplets on the windshield, so that the windshield wipers can be triggered automatically.

The unit thus frees the driver to concentrate on other tasks by making the various control operations used to activate conventional wiper systems redundant. For the time being the driver can still use the manual controls; if desired, the automatic system must be manually selected when the vehicle is started. The sensor consists of an optical transmission and reception path (similar to the dirt sensor). In this application, the light is directed toward the windshield at an angle. A dry outer surface reflects (total reflection) it back to the receiver, which is also mounted at an angle. When water droplets are present on the outer surface, a substantial amount of the light is refracted outward, thus weakening the return signal. This system also responds to dirt once the activation threshold is exceeded.

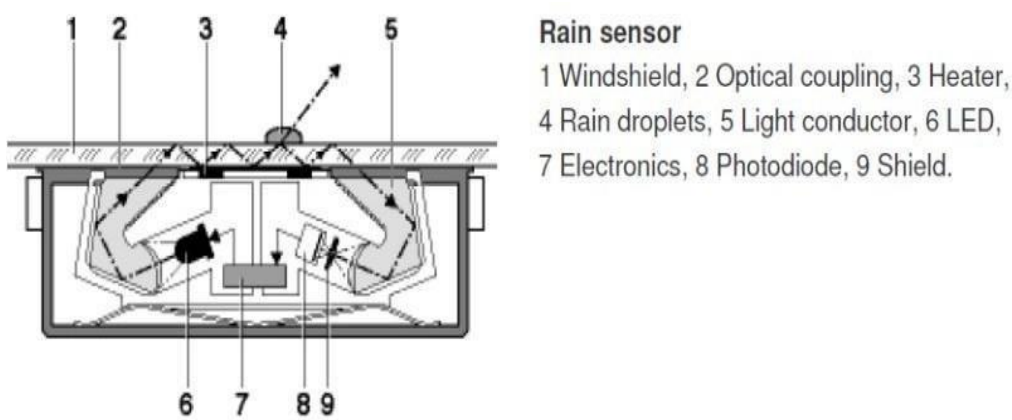

Figure 5.5. Sectional view of rain sensor system.

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