COMPARATIVE INVESTIGATION OF ACTIVE SAFETY AND PASSIVE SAFETY SYSTEMS FOR N CATEGORY VEHICLES

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Abstract : Since, both the safety systems in vehicles play vital role to prevent human from accidents or after-injuries in day-to-day travel, the designers and the manufacturers put their best effort to make the use of safety systems to its extent as per requirement. Both active safety system and passive safety system has their own importance in vehicles. In our research, we have selected three safety systems from each active and passive safety systems and comparative study of each safety systems is performed taking into consideration of various performance parameters. For the comparison, the three N-type vehicles selected are Mercedes Actros truck, Ford F-150 raptor and Volvo FH truck. After our study between those mentioned vehicles, Ford F-150 raptor is found to be the safest among all three vehicles.

IndexTerms **- Active safety, passive safety, lane change assist, hill descent control, adaptive cruise control, seatbelts, crumple zone, airbags.**

1. INTRODUCTION

Safety is something that every living being seek be it an animal or human being. India falls under one of the most affected countries in the category of road accidents. The overwhelming population, heavy traffic, rash driving, poor quality of the roads, etc. are the main factors which leads to the road accidents. The safety of the driver and the passenger in the vehicle are the major concerns when it comes to the vehicle launch and sells. According to the ministry of road transport and highways transport research wing, the total number of accidents occurred in India is 4,49,002 and the total number of persons 4,51,361 in 2019. In vehicles, there are basically two categories of safety systems namely active safety system and passive safety system.

Active safety system consists of the group of features that decreases the potent of happening accidents. These systems are designed taking into consideration of different factors such as driver's comfort and maneuverability, vehicle ergonomics, ride and handling [1] and many more. Depending on the situation and their feature installed in different active safety systems, it can be activated itself by some trigger conditions or can be activated manually by the user of the vehicle [2]. These include adaptive cruise control, brake assist system, lane change assist, lane departure warning, lane keep assist, hill descent control, park assist, tire-pressure warning, electronic stability control, etc. Hence, it is also called as crash avoidance system.

Passive safety system consists of the group of features that decreases the seriousness of the injuries and the fatalities appeared during or after the mishappening or road accidents [3]. These safety systems are designed in such a way that they are automatically activated due to sudden impacts or some triggering actions such as amount of force during collision of vehicles with any other vehicles or other objects. To sum up, we can say that these systems do not come to life until there is no call for the working. So, these systems come into action when the vehicle meet with an accident and it helps to reduce the level of injury at the time of collision [4]. These systems include seat belts, airbags, crumple zones, fuel tanks placed in correct position, fuel-pump kill switch, load-space barrier nets, etc. etc. Hence, it is also called as crash mitigation system.

2. OBJECTIVE OF OUR WORK

In this work, efforts have been made to compare the three vehicles on the basis of the active and passive safety systems employed in them on the basis of few performance parameters. The vehicles taken into consideration are Mercedes Actros truck, Ford F-150 raptor and Volvo FH truck. A comparison is made on the basis of various parameters like type of sensors used, location of the sensors on the vehicle and the working principles employed on them. The objective is to get an overall idea of effects of various parameters on the performance of passive and active safety systems.

3. RESEARCH METHODOLOGY OF OUR WORK

Under each safety systems employed in vehicles, three systems are chosen and their comparison is done using various parameters such as need, architecture and a separate table is designed to compare their performance parameters in the three different vehicles. Under active safety systems, lane change assist, hill descent control and adaptive cruise control are selected, whereas under passive safety systems, seat belt, crumple zone and air bag are taken into consideration for the comparison purpose.

4. COMPARATIVE STUDY OF ACTIVE SAFETY SYSTEMS

These safety systems work for the prevention of the accidents. These systems stay active while you drive keeping you safe from accidents. Lane Change Assist, Hill Descent Control and Adaptive Cruise Control are the chosen active safety systems under this category. Most of the active safety systems are controlled by the Electronic Control Unit. The vehicles taken into consideration for the comparative study of the three above mentioned active safety systems are as follows:

- Mercedes Actros truck
- Ford F-150 raptor
- Volvo FH truck

4.1 Lane Change Assist

This assistant system informs the driver of potential hazards while changing the lane on roads and highways with several lanes. The research shows that during lane changing, more than 6% of all accidents occurs every year. Hence, it is practically important to provide lane change assistance to the drivers for their easy and safe maneuver.

4.1.1 Need

There are blind spots in every vehicle, so we are not able to see those areas which can lead to the accidents. As of the numerical data, 25% of the accidents happen while changing lanes in Germany. Radar sensors are employed in the lane change assist systems [5] to monitor the regions alongside and behind the vehicle exactly covering the blind spots. These sensors warn the driver coherently of forthcoming collision while changing lanes. This can be shown in Table 1.

4.1.2 Architecture

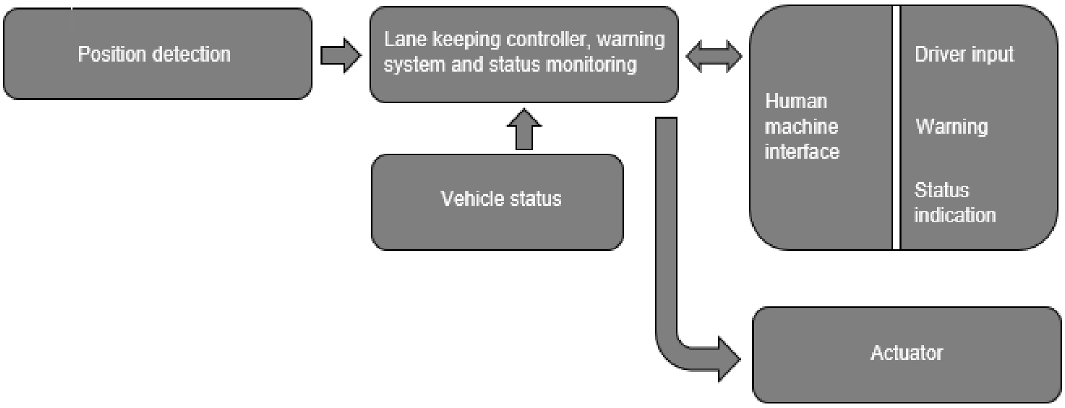

Figure 1. Architecture of lane change assist system

4.1.3 Comparison of lane change assist system employed on different vehicles at various operating parameters

Table 1. Comparison of lane change assist system employed on different vehicles at various operating parameters

Vehicle	**Mercedes Actros truck**	**Ford F-150 raptor**	**Volvo FH truck**
Model/Manufacture	2019	2020	2020
Sensors	Lateral, full range, short range radar sensor, front stereo camera, V2V communication Wi-fi	Two radar sensors on both side near the rear side of the vehicle	Video sensors Laser sensors Infrared sensors
Sensors' location	Front windshield, front bumper, front top body	Behind the windshield	Video sensors: mounted behind the windshield, typically integrated beside the rear mirror Laser sensors: mounted on the front of the vehicle [6] Infrared sensors: mounted either behind the windshield or under the vehicle
Principle	Radar-Echo principle Stereo camera-Stereophotography principle	Radar-Echo principle Stereo camera-Stereophotography principle	Hough transform and Canny edge detector to detect lane lines from real-time camera images fed from the front-end camera of the automobile
O/P actuators	Audible warning alarm, visual indicator, steering wheel vibrator, electronic power steering, brakes	Audible warning alarm, warning on instrument cluster, light blink on side mirror, electronic power steering, brakes	Audible warning alarm, warning on instrument cluster

4.2 Hill Descent Control

Hill Descent Control (HDC), is a low-speed function with enhanced engine braking. This active safety system makes it possible to increase or decrease the vehicle speed on steep downhill gradients using only the accelerator pedal, without using the foot brake [7]. It is a cruise control system where traction control technology along with anti-lock brakes is used.

4.2.1 Need

Hill descent control continuously maintains braking pressure to help prevent slippage and maintain a constant pre-set speed while going down a steep terrain. Hence, the driver can focus on the steering since there is no distraction to them for applying any brakes or downshifting the transmission. On a downhill grade, a vehicle speed between 2 and 12 mph is maintained by this safety feature [8]. Above 20 mph, the system remains activated, but the descent speed cannot be set until you are below 20 mph again. The sensors responsible for this is shown in Table 2.

4.2.2 Architecture

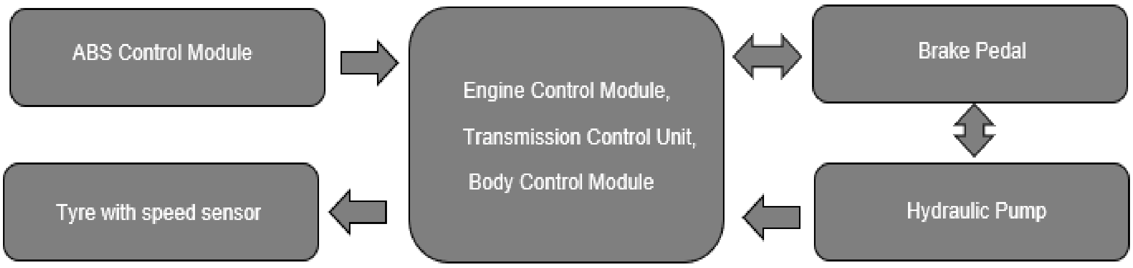

Figure 2. Architecture of hill descent control system

4.2.3 Comparison of hill descent control system employed on different vehicles at various operating parameters

Table 2. Comparison of hill descent control system employed on different vehicles at various operating parameters

Vehicle	**Mercedes Actros truck**	**Ford F-150 raptor**	**Volvo FH truck**
Model/Manufacture	2019	2020	2020
Sensors	Wheel speed sensors Throttle position sensors(TPS) ABS module	Wheel speed sensors ABS module Engine control module Body control unit Transmission control unit	Clutch travel sensor Clutch switch Gear position sensor Throttle position sensor Brake pedal sensor Wheel speed sensor Longitudinal acceleration sensor
Sensors' location	In wheels, TPS -on throttle valve shaft ABS module-In the engine compartment	In wheels, TPS- on throttle valve shaft ABS module- In the engine compartment	Placed in clutch, gear, throttle, brake pedal
Principle	Wheel sensor -generator principle TPS-Hall effect or magneto-resistive technologies	Wheel sensor-generator principle TPS - Hall effect or magneto-resistive technologies	Each wheel is braked to its traction limit. The driver sets a descent speed and the computer takes care of the rest where the speed of the car is calculated from averaging the speeds of each of the four wheels.
O/P actuators	Brakes, throttle, brake master cylinder	Brakes, throttle, brake master cylinder	Brake master cylinder

4.3 Adaptive Cruise Control

In heavy traffic, radar based and camera based Adaptive Cruise Control helps the driver keep a safe distance from the vehicle in front by controlling the accelerator and all other available brakes [9]. If there is a risk of impact, the collision warning system alerts them by bulging a light onto the windscreen in the vehicle. Hence, the emergency brake automatically activates, significantly reducing the risk of severe injuries.

4.3.1 Need

Adaptive Cruise Control customs sensory technology mounted within vehicles such as lasers, cameras and radar equipment, creating an idea of how much is one car distant to another cars or objects on the driveways. Hence, this active safety system is the foundation for future car intellect. This technology allows the car to detect and warn the driver about potential forward collisions [10]. At first red lights begin to flash, and then the expression 'brake now!' appears on the dashboard to help the driver reduce the speed. An audible warning shall also be accompanied with the system for better warning. These features can be shown under various parameter in Table 3.

4.3.2 Architecture

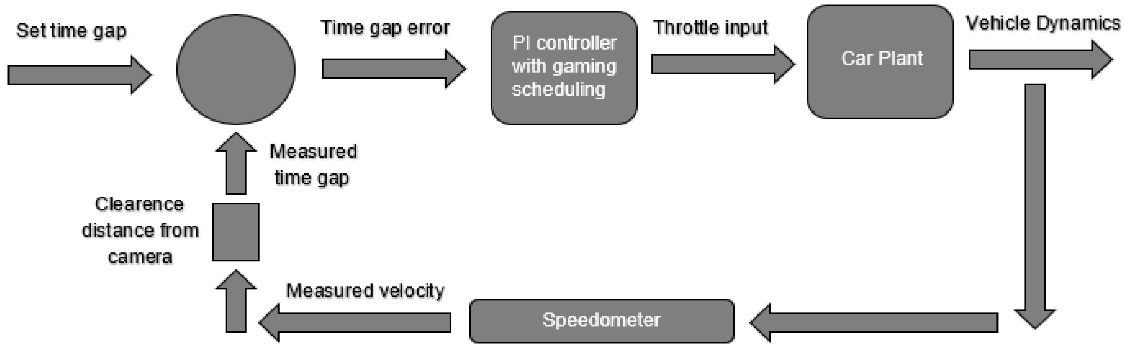

Figure 3. Architecture of adaptive cruise control system

4.3.3 Comparison of adaptive cruise control system employed on different vehicles at various operating parameters

Table 3. Comparison of adaptive cruise control system employed on different vehicles at various operating parameters

Vehicle	**Mercedes Actros truck**	**Ford F-150 raptor**	**Volvo FH truck**
Model/Manufacture	2019	2020	2020
Sensors	Accelerator and brake pedal position sensor Radar sensor Ultrasonic sensor	Radar sensor Camera	Accelerator and brake pedal position sensor Radar sensor Ultrasonic sensor
Sensors' location	Front windshield, front and rear bumper	Front windshield, front and rear bumper	Front windshield, front bumper
Principle	Radar-echo principle Ultrasonic sensors-emits and receives signal to calculate distance	Radar-echo principle Ultrasonic sensors-emits and receives signal to calculate distance	Radar-echo principle Ultrasonic sensors-emits and receives signal to calculate distance
O/P actuators	Vehicle acceleration, steering, speed	Vehicle acceleration, steering, speed	Vehicle acceleration, steering, speed

5. COMPARATIVE STUDY OF PASSIVE SAFETY SYSTEMS

Passive safety systems do not come to life until there is no call from the system work so, these systems come to life when the vehicle meets with an accident and it helps to reduce the level of injury at the time of collisions. Seat belt systems, Crumple zones and Air bags are the chosen passive safety systems under this category. The passive safety systems are deployed automatically when the car faces collision to certain impact. The vehicles taken into consideration for the comparative study of the three above mentioned passive safety systems are as follows:

- Mercedes Actros truck
- Ford F-150 raptor
- Volvo FH truck

5.1 Seat Belts

It is a safety device made to securely hold the driver or the passenger during emergency braking or during a collision. It reduces the chances of head injury and prevent the person to fall out of the vehicle.

Seat belt is a safety device that reduce the risk of the injuries at the time of road accident [11]. It is designed to absorb the force of the impact and to hold the driver or the passengers. The seat belt comprises of polyester strip, retractors, seat belt buckles, seat belt tongues and seat belt pillar loops. The different types of seat belts found in vehicles are as follows:

- Two-point seat belt
- Lap belt
- Sash belt
- Three-point seat belt

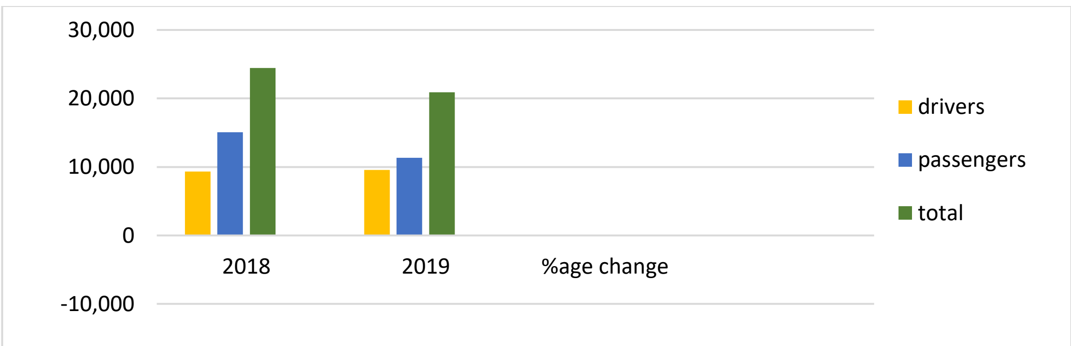

Figure 4. Data showing number of persons killed due to non-wear of seat belts

Figure 4 is the data taken from MORTH official website where the number of persons killed due to non-wear of seat belts and its change in to number of deaths in percentage is shown.

5.1.1 Need

The safest way to derive a vehicle is to buckle up the seat belt. According to the MORTH, as shown in figure 4, the number of persons killed due to non-wear of safety belts during 2019 is 20,885 which is about 14.5% less than that of 2018 [12]. From the data above, it is clear that the use of seatbelts plays vital role in saving thousands of lives every year.

5.1.2 Architecture

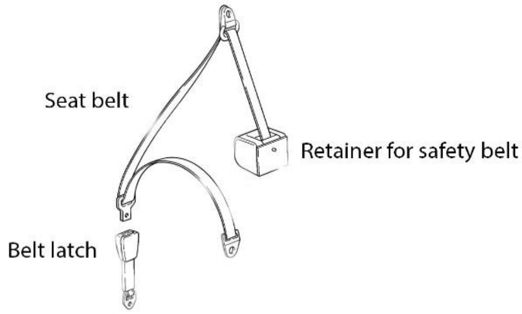

Figure 5. Architecture of seat belt

5.1.3 Comparison of seat belt system employed on different vehicles at various operating parameters

Table 4. Comparison of seat belt system employed on different vehicles at various operating parameters

Vehicle	Mercedes Actros truck	Ford F-150 raptor	Volvo FH 16 truck
Model/Manufacture	2019	2020	2020
Integrated seat belt Hight adjustment	Yes	Yes	Yes
Automatic locking mode	Yes	Yes	Yes
Safety belt warning light and chime	_	Yes	–
Crash sensors and monitoring system with readiness indicator	Yes	Yes The safety belt pretensioners at the front seating positions are designed to tighten the safety belts when activated [13].	Yes
Inflatable Seatbelt	No	Yes During a crash of sufficient force, the inflatable belt inflates from inside the webbing [14].	No
Supplementary Restraint System (SRS) mechanism	No	Yes	No
Seat belt material	Polyester	Polyester	Polyester

5.2 Crumple Zone

Crumple zone is also known as crush zone [15]. From the name, it clearly signifies that it is designed to crush when the vehicle suddenly collides with significant amount of force with objects like other vehicles, house, etc. Thus, it acts as a cushion that extends the deceleration time of the vehicle transferring less impact to the driver and the passengers.

5.2.1 Need:

During an accident, crumple zone preserves to convert the kinetic energy of the vehicle into controlled deformation. It helps the vehicle to take more time for deceleration due to which the effect of the impact force is decreased, hence increasing the possibility of the driver’s and passenger’s survival [16].

5.2.2 Architecture:

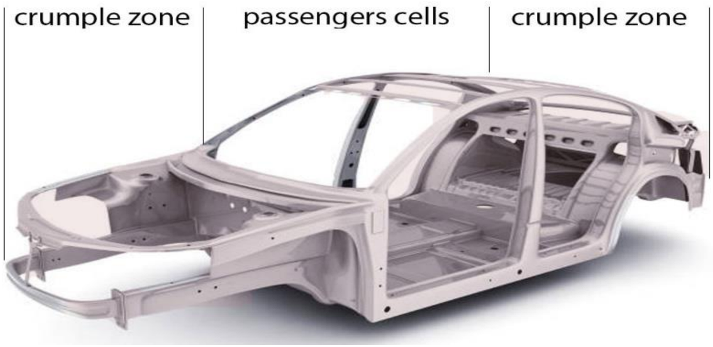

Figure 6. Architecture of crumple zone in vehicles

5.2.3 Comparison of crumple zone system employed on different vehicles at various operating parameters

Table 5. Comparison of crumple zone system employed on different vehicles at various operating parameters

Vehicle	Mercedes Actros2644 LS truck	Ford F-150 raptor	Volvo FH 16 truck
Model/Manufacture	2019	2020	2020
Chassis type	Ladder frame chassis	Ladder frame	Ladder frame chassis
Material used	Steel frame	High strength steel frame	Steel frame
Length of chassis	6867mm	220 inches	6700mm
SOS Post-Crash Alert System	No	Yes	No

5.3 Air Bag

Air bags are proven to be the quickest life-saving passive safety system that is designed so efficiently that they inflate and deflate with in no time during the collisions to save the passengers from major damage [15]. These air bags work their optimum when combined with seat belts. It consists of a fabric bag, inflation module, and an impact sensor.

5.3.1 Need:

According to the NHTSA report, from the year 1987 to 2018 [16], frontal air bags have saved 50,459 lives. When an accident is occurred, the impact sensor transfers the signal to the ECU and from there, the signal is transferred to the air bag and due to that, the air bag inflates with in few milliseconds or less than $1/20^{th}$ of a second and deflates very rapidly. If a problem is occurred in the inflation of the air bag, it could lead to death of the fatalities.

5.3.2 Architecture:

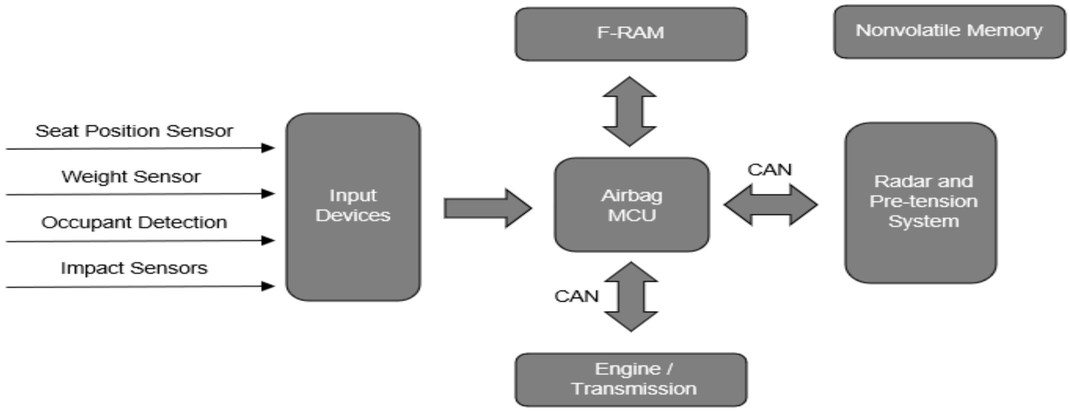

Figure 7. Architecture of air bag employed in vehicles

5.3.3 Comparison of air bag system employed on different vehicles at various operating parameters

Table 6. Comparison of air bag system employed on different vehicles at various operating parameters

Vehicle	Mercedes Actros2644 LS truck	Ford F-150 raptor	Volvo FH 16 truck
Model/Manufacture	2019	2020	2020
Number of air bags in the vehicle	2	6	2
Chemical used (Reactants)	NaN_3, KNO_3, SiO_2	KNO_3, SiO_2, NaN_3	SiO_2, KNO_3, NaN_3
Opening time	$1/20^{th}$ of a second	$1/20^{th}$ of a second	$1/20^{th}$ of a second

6. PATENTS

6.1 Patents Under Passive Safety Systems

6.1.1 seat Belt

I. US6955403B1: Seatbelt routing and restraint system (Mary A. Weaver) 2007
- A set of belt adjustments are found between the mid-section and the upper edge of the rectangular sheet for varying the location from where the shoulder-belts extend from the rectangular sheet.
- A set of belt adjustments include loops that accept the shoulder-belt which are attached to rectangular sheet.

II. US6767055B1: Vehicle seat frame and belt assembly (C. Michael Sparks) 2007
- The vehicle seat and restraint assembly and forwardly and rearwardly facing abutments of struts are flashily mating when in engaged position.
- The first strut is fixed at an angle of about 55 degrees relative to seat frame, and second strut is fixed at an angle of about 35 degrees relative to back frame.

III. US7128373B2: Seating system and method of forming same (Eric R. Kurtycz, Vikas Gupta, Charles W. Bowser, Laxman P. Katakkar) 2006
- This seating system includes a seat back with one or more plastic panels that extend across a lateral distance of the seat back.
- The seat back mostly consists of more than one path forming ribs.

IV. US6871876B2: Seat belt restraint system with double shoulder belts (Zhaoxia Xu) 2004
- The upper end of shoulder belt is extendable and retractable to the upper portion of seatback adjacent the occupant's shoulder.
- The mechanism interlocks the lower ends of both shoulder belts and the first end of middle portion belt.

V. WO2008054485A1: Seat belt system for a vehicle (John Bell, Martyn Palliser, George Gordon Milton Smith) 2002
- The lower limit of the strap defines a stop comprising a protrusion of thickness greater than the width of the first slot of the adjustable webbing guide on the strap.
- To lock the adjustable webbing guide, vertically spaced apart holes is created to the strap such that retractable projection inserts through those holes.

6.1.2 Air Bag

I. JP2018108819A: Cost-effective use of one-piece woven fabric for curtain airbag(Xiaohong Wang, Walston Bryan, Yakumo Arthur, Paranjpe Avadhoot, Hicken Paul) 2018
- An inflatable curtain has a first chamber and a second chamber that inflates toward the front of the first chamber.
- The second chamber has a height above the height [17] of the first chamber so that the lower part of the second chamber is pressed downward while being adjacent to a door of a vehicle.

II. JP6294963B2: Wrapped side impact airbag system and method (Ma Dae Hyong) 2014
- In the airbag assembly, the deployed configuration has the lower segment angled on the lower segment such that the outer surface of the inner fabric layer faces upward.
- In the deployed configuration, the second chamber is typically positioned between the vehicle occupant's head and an occupant area occupied by at least one of the vehicles.

III. DE10331133B4: Inflatable airbag deployment guide (John Sonnenberg, Bob McGee, Jim Sonnenberg, David E. Hoeft) 2003
- The airbag module comprises of an airbag cushion to be inflated by means of a gas generated by a connected inflator and thereby to be deployed from the airbag module.
- An airbag deployment guide takes the form of a vehicle installed [18] airbag module which is provided with an inflator to the inflatable airbag cushion in the vicinity of a cavity.

IV. EP1583675B1: Airbag system (Dirk Meissner, Sami Al-Samarae) 2003
- In this paper, there is minimum combination of one supplementary and main bags respectively.
- That supplementary airbag has a lower volume in order to increase the depth of deployment and/or to alter the direction of deployment of the main airbag.

V. US7144032B2: Expandable pelvic side airbag (Larry Lunt, Mark L. Enders, Kurt Gammil) 2003
- The thickness of the airbag is made to be between 2mm-25 mm when it is uninflated.
- An attachment mechanism may also be attached to the airbag designed to attach the airbag to the vehicle door.

VI. US7063350B2: Dual chamber side airbag apparatus and method (Daniel L. Steimke, Brian M. Lighthall) 2003
- The airbag module has a cushion with a pelvic chamber [19] and a thoracic chamber.
- The housing has an aperture disposed within each of the chambers such that [20], when the inflator deploys, the pelvic chamber is inflated to a relatively higher pressure [21].

6.1.3 Crumple Zone

I. US9381883B2: Front vehicle-body structure of vehicle (Yasuhiro Morita, Takahiro Hirano, Hitoshi Ochimizu) 2014
- The beam member includes a weak portion configured to be weak against a load inputted in a vehicle longitudinal direction.
- An extension portion is configured to prevent the steering member receiving the input load from sliding toward the passenger-seat side by contacting the hinge pillar [22].

II. AU2012216535B2: Support structure including a unidirectional crumple zone (Luke Adrian Mcloughlan, Gregory Nagel) 2012
- A unidirectional crumple zone is attached to the frame between the attachment end and the distal end, and defines a crumple zone face substantially orthogonal to the compression axis.
- An anvil member, such as a spacer block covers only a portion of the crumple zone face and has an edge substantially parallel to the crumple zone face.

III US7699347B2: Method and apparatus for a shared crumple zone (Stephen D. Shoap) 2008
- A first bumper is connected to the distal end of the first elongated member whereas a second elongated member has a proximate end and a distal end.
- The proximate end is proximate and approximately perpendicular to a second face of the container and a long axis of the second elongated member intersects the second face.

IV DE102006041092B4: Crumple zone of a body of a motor vehicle (Martin Kruse, Ralf Grosser, Jürgen Stegmaier, Andreas Graf) 2006
- In crumple zone, the cross member designed as a connecting component of the safety passenger compartment is assigned to the motor vehicle.
- Crumple zone contains the hollow chambers of the body component extended in the vehicle vertical direction.

V. JP4615830B2: Impact reduction front bumper device for vehicles (Yoon Joon Jae) 2003
- The plate member is having a multi-stage U-shaped cross-section which acts as the vehicular shock absorbing front bumper device.
- The multi-stage U-shaped cross-section is characterized by a three-stage U-shaped cross-section, the vehicular shock absorbing front bumper equipment.

VI DE4414432A1: Vehicle with integral crumple zone (Albrecht Dr Ing Hartmann, Joerg R Bauer) 1994

- The outer shell encloses the vehicle's front bumper and at least a greater part of a section forming the front of the vehicle from the bumper to the lower edge of the windscreen.
- The vehicle has side panels integrated into the door panels. Between the extended panels and the chassis structure is located at least part of an air-bag.

6.2 Patents Under Passive Safety Systems

6.2.1 Lane Change Assist

I. US9415776B2: Enhanced lane departure system (Oliver Schwindt, James Kim, Bhavana Chakraborty, Kevin Buckner, Brad Ignaczak) 2014

- This highlights the positions of the sensor on the host vehicle considering the parameters affecting the performance of lane departure system.
- It explains the working of the control system [23].

II. DE102014116225B4: Lane change assistance apparatus and method of operation therefor (Soon Jong Jin) 2014

- It tells us about the apparatus used in cars/vehicles.
- It tells us about the operation of different type of sensors and cameras.

III. EP1598233B1: Lane change assist system (Hikaru Nishira, Taketoshi Kawabe) 2004

- This highlights about the working of the lane change assist system
- It explains about the processing going on inside the system so that it can help the host to turn the vehicle and at a desire speed [24].

6.2.2 Hill Descent Control

I. US10597032B2: Vehicle speed control system (James Kelly, Andrew Fairgrieve, Daniel Woolliscroft) 2018

- It comprises more than one ECUs that applies torque to the required vehicles and provides the signal to locate the position of slip in the wheels.
- The ECUs further receive the target speed input from the user and maintain the speed by adjusting amount of torque and slip detection.

II. US10155513B2: Methods and systems for a vehicle driveline (Gregory Michael Pietron, Adam Nathan Banker, Dennis Craig Reed, Seung-Hoon Lee, James William Loch McCallum) 2017

- The manual input of engine stop conditions in a hill descent mode is allowed in the method.
- The manual input of driveline disconnects clutch operating mode conditions in a hill descent mode.

III. EP2139740B1: Assistance system for driving in slopes for automobiles (Philippe Blaise, Emmanuel Charpin, Damien Joucgnoux) 2008

- It includes sensors for driving assistance and correcting path for electronic calculators.
- Hill Assist Module (HAM) and Hill Descent Control Module (HDCM) falls under Hill Assist Descent Control Module (HADCM).

6.2.3 Adaptive Cruise Control

I. US10747220B2: Autonomous driving control apparatus (Naokazu UCHIDA, Taisetsu Tanimichi) 2016

- It maintains a pre-set speed input by the user relieving the load of braking.
- If the other vehicle comes near the vehicle, the driver needs to decelerate himself.

II. US9827955B2: Systems and methods to improve fuel economy using adaptive cruise in a hybrid electric vehicle when approaching traffic lights (Kenneth James Miller, Douglas Raymond Martin, William Paul Perkins) 2015

- The system controls the regenerative braking system to reduce the speed of the wheels of the vehicles.
- The system itself controls the activation and deactivation of braking according to the traffic lights changes confronted by the vehicles.

III. EP3052961B1: Adaptive cruise control with on-ramp detection (Freddy RAYES) 2014

- The system mechanically performs control of a mass vehicle longitudinally to account for merging vehicles.
- This provides techniques to automatically detect the ramp on the way of the vehicles and find a relative speed.

7. CONCLUSION

- According to WHO report, the number of deaths just because of the road accidents is nearly about 1.35 million per year. This huge number of deaths make safety issues to be the prominent one while purchasing vehicles.
- Both active safety system and passive safety system are equally important as former one alert the driver before mis-happening whereas the latter one protects the driver as well as passengers from major injuries after the accident is occurred.
- In this review study, we have discussed some of the different safety systems provided by the N-type vehicles and compared their performance parameters with three different vehicles of N-type. In active safety systems, comparing the three systems.i.e. Lane change assist, Hill descent control and Adaptive cruise control of the three vehicles, all the vehicles were having almost same parameters of performance.
- In passive safety systems, comparing the vehicles on the basis of systems as seat belts, crumple zone and airbags, Ford F-150 raptor has more features accompanied in the systems like inflatable seat belts, SRS mechanism, more number of airbags in the vehicle, etc.
- Therefore, our comparative study shows clearly that Ford F-150 raptor is the safest among all three vehicles we have chosen to compare on the basis of their various safety features.

REFERENCES

[1] Acarman, Tankut & Çayır, Burak & Yüksel, Erkan & Yürüklü, Emrah 2010 DEVELOPMENT OF AN ACTIVE SAFETY SYSTEM

[2] Wang, Y. & Zhang, Q 2013. Design of an Active Automotive Safety System Journal of Engineering Science and Technology Review 6 155-159

[3] Pandurengan, Sabarinath 2020. Passive Safety System for Side Impact in Cars Shanlax International Journal of Arts, Science and Humanities 7 115-120

[4] Hassan Nawaz Butt, Muhammad Ilyas, Masroor Ahmad and Fatih Aydogan, Assessment of passive safety system of a Small Modular Reactor (SMR) 2016. Annals of Nuclear Energy 98 191-199

[5] Nguyen, VanQuang & Kim, Heungsuk & Jun, SeoChang & Boo, Kwangsuck 2018. A Study on Real-Time Detection Method of Lane and Vehicle for Lane Change Assistant System Using Vision System on Highway Engineering Science and Technology, an International Journal 21

[6] Bian, Yougang & Ding, Jieyun & Hu, Manjiang & Xu, Qing & Wang, Jianqiang & Li, Keqiang 2020. An Advanced Lane-Keeping Assistance System with Switchable Assistance Modes IEEE Transactions on Intelligent Transportation Systems 21 385-396

[7] Luo, Yugong & Han, Yunwu & Chen, Long & Li, Keqiang 2015. Downhill safety assistance control for hybrid electric vehicles based on the downhill driver's intention model Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 229.

[8] Balasubramanian, Balaji 2015. Sensor-less hill-assist using traction control in electric LCV 1-7.

[9] Pananurak, W. & Thanok, Sunphong & Parnichkun, M 2014. Adaptive cruise control for an intelligent vehicle.

[10] Sun, Chengwei & Chu, Liang & Guo, Jianhua & Shi, Dapai & Li, Tianjiao & Jiang, Yunsong 2017. Research on adaptive cruise control strategy of pure electric vehicle with braking energy recovery Advances in Mechanical Engineering 9.

[11] Zhaoxia Xu 2003. Seat belt restraint system with lap belt adjustment device US20040140660A1.

[12] John Bell, Martyn Palliser & George Gordon Milton Smith 2007. Seat belt system for a vehicle WO2008054485A1.

[13] Stephen William Rouhana, Paul George Bedewi, Dean M Jaradi, Kirsten Marie Carr, John L. Sullivan, Tiffani Michelle Natalini-Whitmore & Sundeep Venkat Kankanala 2007. Four point seat belt system US7625048B2.

[14] Eric R. Kurtycz, Vikas Gupta, Charles W. Bowser & Laxman P. Katakkar 2003. Seating system and method of forming same US7128373B2.

[15] Luke Adrian Mcloughlan & Gregory Nagel 2012. Support structure including a unidirectional crumple zone AU2012216535B2.

[16] Oliver Schwindt, James Kim, Bhavana Chakraborty, Kevin Buckner & Brad Ignaczak 2014. Enhanced lane departure system US9415776B2.

[17] Vivekananda Maripudi, Jaime Fermin Perez, Benjamin Aguilar, James Karlow, Nicole Wiggins, John Pilchowski & William B. Cox 2011. Airbag module with deployment control flap US8231140B2.

[18] Xiaohong Wang, Walston Bryan, Yakumo Arthur, Paranjpe Avadhoot & Hicken Paul 2018. Cost-effective use of one-piece woven fabric for curtain airbag JP2018108819A.

[19] Tadahito Kataoka, Takuji Kawasaki & Yoshinori Maeda 2008. Airbag apparatus and methods EP2072345B1.

[20] Larry Lunt, Mark L. Enders & Kurt Gammil 2003. Expandable pelvic side airbag US7144032B2.

[21] Daniel L. Steimke & Brian M. Lighthall 2003 Dual chamber side airbag apparatus and method US7063350B2.

[22] Martin Kruse, Ralf Grosser, Jürgen Stegmaier & Andreas Graf 2006. Crumple zone of a body of motor vehicle DE102006041092B4.

[23] Gregory k. Qualizza 1991. Vehicle collision avoidance system US5235316A.

[24] Tasuku Maruyama & Toru Saito 2007. Lane access-assessment system DE102008029124A1.