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Design and FEA of Impact Damper for Four-wheeler car

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Abstract: The problem of over speeding vehicles in highway transportation is one of major problem faced in the current scenario of Indian traffic. The issue of over speeding not only damages the vehicle but the serious consequence of this is there due to loss of precious life. In real life scenario accidents in are totally unavoidable we can only have counter measures to prevent them and avoid the fatalities involved. Safety impact guard is one of the real-time counter measures which reduce the impact when the vehicle is involved in high speed impact. The proposed design which is being discussed in detail throughout this paper is for design of a re-usable safety impact damper with pressure relief valve. This design discusses the force of energy or impact that is dampened due to the action of the impact damper with the pressure relief valve. The entire objective of the project is to reduce the fatalities by designing an impact damper which provides safety against the front and rear end collisions.
Keywords: Impact, Pressure relief valve, Damper

I. INTRODUCTION

Passive Safety in vehicle is one of the critical factors that is pursued by vehicle manufacturer's world over. Occupant safety is of the prime importance and automobile manufacturing has come of age with regulations primarilyfocussing on the safety.

Bumper has been an important feature in protecting the vehicle from serious damage to the car component in a low speed collision. Especially when the collision causes damage to the expensive car parts likes fender, hood and inter-cooler.

Bumper as a component improves the performance of the car. Bumper sizeand the aerodynamic feature of the bumper are the important aspects in lowering the coefficient of drag, Cd. The efficient bumper design will also increase the down force of the car when it accelerates to give more grips to the tire and the road. This will give a good handling to the driver ever in high speed driving. In earlier design terms bumpers were meant to protect or prevent damage tothe exterior and rear end of the vehicle during low speed collision with the advancement in the design. The collision prevention technique and the crash worthiness were introduced for the bumper. Instead of being mere protectors to hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights inlow speed collisions the bumpers are now equipped with features to mitigate the impact of high speed collision to prevent mortal fatalities, it now hassafety feature intended to prevent or mitigate injury severity to occupants in the passenger cars..

Bumpers are now designed to protect occupant and designed now with multi zone stiffness this coupled with crumple zones in the structural part of the frontal chassis or the body gives robustness to the component. In the event of a collision, the bumper absorbs some of the impact, which decreases damage to the car and its occupants. It also protects the front of the car by diverting all of the car's momentum to the object with which it has collided. The bumper beam is mounted to the car's chassis with special impact / safety absorbers. The design of the impact absorber is specifically discussed in the paper in detail and the target is to minimize the impact due to damage occurring in high speed collision and protect the occupant

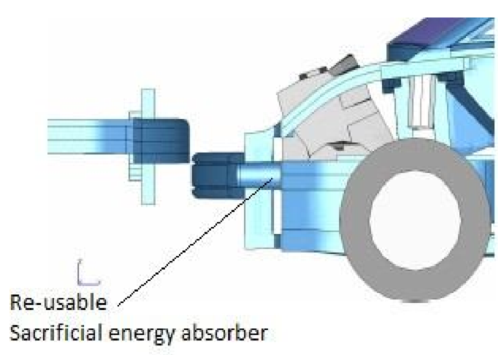

Fig 1.1Vehicle to Vehicle impact

The potential for energy absorption within the front structure of a passenger vehicle may be optimised for specific loading e.g. high-speed rigid flat barrier impact. In many vehicles, energy absorption is provided by the axial collapse of longitudinal frame members. These structural members work well when loaded as intended but may not always perform so effectively in vehicle crashes on the road. In the study described here the controlled bending rather than axial collapse of the main longitudinal members has been used to reliably manage the energy from frontal impact.

II. LITERATURE REVIEW

A. Swieskowski [1] developed an analytical procedure for the design of Belleville washers for energy capacity. He determined the stress reduction that is obtained by replacing asingle washer assembly by a nested arrangement. Also he determined the optimum stacking arrangement of Belleville spring.A theoretical study was made to obtain data to establish an analytical method for the design of Belleville washers for energy storage and to modify the conventional formulas to replace the dependent variables with the independent or known values. These modified formulas were subsequently used to establish the stress reduction of a nested spring system and to determine an optimum stacking arrangement. A simplified and direct method for the design of washers for the energy capacity was established. Final working stress is proportional to the square root of the energy requirement, and is inversely proportional to the outside diameter and the square root of the solid height. The one-parallel series of the stacking arrangement considered is the most efficient for energy storage. It was found that the final stress is inversely proportional to the outside diameter and the square root of the solid height. Therefore, these two dimensions should be as large as space requirements will allow. The final stress increases directly with the height-thickness ratio. In the practical range of the height-thickness ratio, the one parallel series offer better utilization of spring space and is preferred to the two and three parallel series. In overstressed application, where longitudinal and radial space is limited, consideration should be given for a two spring nested arrangement. The substitution of a nest for a single spring will result in 14 percent stress reduction.

B. Bairy Srinivas [2]A spring damper system was designed which was the passive safety system. The vehicles should have active safety system which will avoid the accidents asmuch as possible and passive safety system which will reduce the damage and loss of lives. Passive system will decrease the impact of accident. In this systems spring will store the energy and damper will dissipate the energy. This spring damper system reduces the impactof accident by increasing the time of collision as the spring needs some time to compress it totally. In this to check the amount of reduction in impact force when two bodies collide is analyzed with the spring damper system and without the spring damper system. The Impact force is significantly reduced with the spring damper system In the design of an automobile, the most important task is to minimize the occurrence and consequences of automobile accidents. Too many passengers die or injure every year because of accidents. Most of the vehicle manufacturing companies are unable to control these accidents. We are comingacross the many accidents which were the result of poor designing and maintenance. The vehicles should have active safety system which will avoid the accidents as much as possible and passive safety system which will reduce the damage and loss of lives. The spring damper system is a passive safety system which will decrease the impact of accident. In this systems spring will store the energy and damper will dissipate the energy. This spring damper system reduces the impact of accident by increasing the time of collision as the spring needs some time to compress it totally. In this to check the amount of reductionin impact force when two bodies collide is analyzed with the spring damper system and without the spring damper system. The Impact force is significantly reduced with the spring damper system.

A cushioning model is made to test the impact force was explored using a metal ball and varying thicknesses of polyester, it found that the collision time is increasing with thickness of sponge up to some thickness and which makes less force on the metal ball. A friction element was introduced into the bumper to improve on the impact and kinetic energy absorption capacity. Thesimulation revealed that the energy absorption capacity of the bumper was improved with the addition of a friction element. To validate these results experiments were conducted. To mitigate the degree of damage to passengers caused by automobilecollisions, a friction damper was built and used in experimental tests to test its effectiveness in impact energy attenuation. The study revealed that energy absorption capacity of a bumper can be improved with the addition of a friction damper.

With increase in damping coefficient, maximum displacement of spring is decreasing. With high damping, high acceleration is occurs. It implies that spring attains maximum displacement in less time. Variation in stiffness is having negligible effect on the maximum displacement and with increase in stiffness the spring is coming to rest within less time. Over damped system is used to reduce impact force. Low contact stiffness values lead to large rebound heights and large maximum penetration depths. Stiffness of the contact is not constant and it varies with the depth of penetration. Spring damper system reduces the impact force considerably.

C. Dharan and Bavmen [3] performed feasibility study of replacing steel disc spring with composite materials. Design equations for steels were modified for composite materials

.Several prototype disc springs were manufactured, tested. They were compared with equivalent steel springs. The results indicated that composite materials can replace steel for making disc spring. Moreover, there was considerable mass saving.

D. M. Saeki [4] proposed that the multi-unit particle dampers are the passive damping devices, those include the fine particles containing holes in the primary structure. Their main principle behind the particle impact damping is to remove or to reduce the vibration energy through losses that happen when the particles are strike on the wall of the hole. They presents the experimental results and the analytical results of the horizontal vibratory system of multi-unit particle system. An analytical method solution is based on the discrete element method which is presented. They compares the experimental results and analytical results these results shows that the accurate approximations of response of a main structure can be achieved. The results achieved show that the response of main structure is depends on the number ofenclosures and the dimensions of the enclosures.

E. Martin Sanchez [5] et al. (2013) introduced that response of a single degree of freedom of mechanical system which is containing the primary mass M, viscous damper, linear spring, and particle damper. In his study the particle damping lies in an adjustable height prismatic enclosure within which the particles are filled by means total mass Mp. He show that for small size enclosure the system does not respond the fully de-tuned mass limit in an uninteresting manner. Somewhat the system increases its effective mass up and above Mþmp before it reaches the predicted value. Furthermore he show that the same effect seems in tall enclosure where the system reaches to its limit effective masses below the expected value of M

We have studied a PD by means of simulations via a DEM. We have considered theeffective mass and effective damping of the entire SDoF system by fitting the FRF to a simple mass–spring–dashpot system. In particular, we study the effect of the height Lz ofthe enclosure. We have observed that the effective mass of the system reaches the two limits described in the literature for small and large enclosures. However, those limits arenot approached in a monotonous way and clear overshoots appear. For small gap sizes, thesystem presents effective masses above the direct sum of the primary mass M and theparticle mass mp. For large enclosures, the effective masses fall below M.

We have observed that such behavior can be explained by considering both the period oftime over which the granular bed is in full contact with the enclosure and the inertial effects due to the grains hitting the floor or ceiling in and out of phase with the spring force.

Interestingly, we found that the value of Lz at which Meff crosses M coincides with the optimum damping value described in the literature. Since the optimum Lz should be simpleto interpolate from the intersection with the horizontal M level in a plot of Meff vs Lz, we suggest that such estimation can be a more suitable approach than the search for a maximum in a plot of Ceff versus Lz. The overshoot effects described are present outsidethe range of maximal damping performance and might be considered of secondary interestin industrial applications at first sight. However, design constrains may require a PD to work off the optimum damping and in one of the overshoot regions. In particular, for enclosures somewhat taller than the one corresponding to the optimum damping, one achieves effective masses only slightly below the primary mass. This implies that the resonant frequency is almost unaltered upon addition of the particles. Moreover, such values of Lz achieve a remarkable damping (although not maximal) while still presenting a FRF with a shape very similar to the one observed for a simple SDoF mass–spring–
dashpot system. This may simplify the prediction of the behaviour of the PD under such
conditions. On the other hand, if the primary system has more degrees of freedom, the off-design resonant frequencies may fall in either overshoot regime and the side effects shouldbe taken into consideration. Although we have studied a PD driven in the direction of gravity, similar results are expected if a horizontal setup is considered. It has been shown that near the resonant frequency the response of an impact damper does not depend on therelative direction between the motion of the system and the gravity . Since the effective mass is largely determined by the response near the resonant frequency, the same general trends should be found in horizontally driven PD.

F. Vikram K. Kinra [6] et al. (2005) studied that the particle impact damping (PID) is used for the cantilever beam. The particles are filled with enclosure attached to its free end of beam. The particle impact damping used various materials for the damping of vibrations such as lead balls, steel balls, copper balls, glass balls, tungsten carbide pallets, lead dust, steel dust and sand. The objective of the study isto collect the additional data for the particle impact damping (PID). In this study studied five materials such as tungsten carbide, steel, glass, lead and sand.They studied the particle material, number of particle, effect of mass ratio and the particle shape during impact damping (PID). The

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experimentation was conductedand the experimental results showed extra advanced model of the PID should include the number of particles and particle size along with release and the restriction of the all particle moving as a one particle

Particle impact damping (PID) is a method to increase structural damping byinserting

particles in an enclosure attached to a vibrating structure. The particles absorb kineticenergy of the structure and convert it into heat through inelastic collisionsbetween theparticles and the enclosure. Additional energy dissipation may also occurdue to frictionallosses and inelastic particle-to-particle collisions amongst the particles.The unique aspect of PID is that high damping is achieved by converting kinetic energyof the structure to heat as opposed to the more traditional methods of damping where theelastic strain energy stored inthe structure is converted to heat.Viscoelastic materials have wide applications in vibrationdamping in a normalenvironment, i.e. under ambient temperature and pressure. However,they lose theireffectiveness in very low and high temperature environments and degradeover time.Particle impact damping offers the potential for the design of a better passivedampingtechnique with minimal impact on the strength, stiffness and weight of avibratingstructure. With a proper choice of particle material, this technique appears to be independent of temperature and is very durable.Earlier studies have investigated the energy loss mechanisms and characteristic ofparticle impact dampers under various excitationmodels. Saluena *et al*. [1] have studiedmathematically the dissipative properties of granular materials using particle dynamicmethod. They showed how the analysis of energy-loss rate displays different dampingregimes in the amplitude-frequency plane of the excitation force. Tianning *et al*. [2]performed numerical modeling of particle damping with discrete element method.They showed that under different vibration and particle system parameters, thecollisionand friction mechanism might play different or equivalent roles in energy dissipation.Some experimental studies have also been conducted to measure particle impactdamping at low frequencies (below 20 Hz). Papalou and Masri [3] studied thebehaviorof particle impact dampers in a horizontally vibrating single degree of freedom(SDOF)system under random base excitation. Using tungsten powder, they studied theinfluenceof mass ratio, container dimensions, and excitation levels. They provided optimumdesign of particle damper based upon reduction in system response. Cempel and Lotz [4]used a simplified energy approach to measure the influence of various particle-packingconfigurations on the damping loss factor of a SDOF system under horizontalforcedvibration. Popplewell and Semercigil [5] conducted experiments to study theperformance of a plastic "bean bag" filled with lead shot in reducing vibration. They observed that a plastic bean bag not only exhibited a greater damping effectiveness butalso"softer" impacts than a single lead slug of equal mass.Panossian [6, 7] conducted a study ofnon-obstructive particle damping in themodal analysis of structures at a higher frequency range of 300 Hz to 5,000 Hz. Thismethod consists of drilling small diameter cavities at appropriate locations in a structureand partially or fully filling the holes with particles of different materials and sizes (steelshot, tungsten powder, nickel powder, etc.). Significant decrease in structural vibrationswas observed even when the holes were completely filled with particles and subjected toa pressure as high as 240 atmosphere.Friend and Kinra [8] conducted a study of particle impact damping in the contextof free decay of a cantilever beam in the vertical plane. In their study, PID was measuredfor a cantilever beam with the enclosure attached to its free end. Lead powder was usedthroughout the study. They studied the effects of vibration amplitude and particle fillratio (or clearance) on damping. PID was observed to be highly nonlinear, i.e. amplitudedependent. A very high value of maximum specific damping capacity (50%) wasachieved in the experiment. An elementary analytical model was also constructed tocapture the essential physics of particle impact damping. A satisfactory agreementbetween the theory and experiment was observed.This work is a continuation of the work by Friend and Kinra [8]. The primaryobjective of this work is to expand the previous experiments in order to collect PIDcharacteristics of various particle materials and particle sizes. Using the same methodand experimental procedures developed by Friend and Kinra, experiments are conductedfor lead spheres, steel spheres, glass spheres, sand, steel dust, lead dust, and tungstencarbide pellets. The particle diameter varies from about 0.2 mm to 3 mm. Tests are conducted for different vibration amplitudes, clearances, and number of

particles Experiments were conducted to collect damping characteristic of various particle materials and sizes. Although many phenomena of particle impact damping observed inthe experiments still do not have satisfactory explanation yet, the experimental data collected here is offered as a damping database for future development of an analyticalmodel of particle impact damping. This research pushed the boundaries of the normal use of the laser vibrometer inan effort to make new discoveries. We learned valuable lessons such as the frequency limitations of the laser and its capability in measuring transient vibrations. We alsolearned that utilizing a cantilever beam in transient vibration to measure particle impact

damping might not be the best method. For future study, it appears that particle impact damping should be measured in forced, rather than free, vibration in order to obtain more accurate results.

G. Ahmad∗and D.P. Thambiratnam[7] This paper treats the feasibility of including a supplementary energy-absorbing device in the form of foam-filled conical tubes onto vehicular protective structures to enhance their energy absorbing capacity and hence to enhance safety for the occupants during accidental impacts. The effect of the supplementary energy absorber device was investigated for varying values of the wall thickness of the tube and the foam density of the filler. Research findings have shown the inclusion of this supplementary energy-absorbing device to be a cost-effective and beneficial solution, which promoted an enhanced level of occupant safety by enhancing the energy absorption, reducing the amount of plastic deformation sustained by the protective
structure as well as reducing the severity of the peak decelerations transferred to the occupant compartment during such an event.
In recent time protection of occupants of vehicles during accidental events has met increasing demands. The performance of existing vehicle protection systems may be complemented by using crashworthy structures like energy absorber devices in the form of thin-walled tubes. The objective of designing a crashworthy structure is to absorb energy through material deformation in a reasonably controllable manner while protecting occupants during a crash event and to mainly assure survival of occupants by absorbing sufficient energy without encroaching into the occupant compartment or by producing an undesirable level of deceleration. Energy absorbing systems have been developed for a variety of applications particularly in the fields of structural safety and crashworthiness. In many applications, energy absorbers are frequently incorporated with other structural components in the system design. It is therefore of interest to understand how individual energy absorbers behave and enhance performance when they are incorporated into an existing energy absorbing system. The use of supplementary energy absorbing devices has received widespread attention in the vehicular industry to assist with the protection of occupants during an impact event, particularly for minor frontal and sideward collisions[10]. The incorporation of such devices is to enhance the level of protection affordable to the occupant during an accident. For instance, the vehicle frontal protective structure(VFPS) acts to minimize damage to the engine bay and radiator and other essential components of the vehicle in the event of minor collisions. The energy absorber will be mounted between VFPS and front-end rail of the vehicle to provide a load path along which impact forces are transmitted from the VFPS to the vehicle. A roll over structure (ROPS) is a safety frame attached to heavy vehicles such as bulldozers or tractors to provide some protection to the operator during an accidental rollover. The role of this ROPS is to absorb some of the kinetic energy (KE) of the rollover, while maintaining a survival space for the operator. These vehicles commonly used in the rural, mining, and construction industries are susceptible to rollovers as they posses a high centre of gravity and commonly operate on sloping and uneven terrain. The performance of a ROPS has the potential to be enhanced bythe inclusion of a supplementary energy absorbing device as investigated extensively in [5, 6]. Clark et al. [6] have discovered that the inclusion of thin- walled frusta in a ROPS system is beneficial in enhancing the energy absorption capacity and structural response under rollover impact. To date, several studies have separately treated either the impact of conical tubes or the impact of ROPS/VFPS. Though some useful studies have been carried out on the dynamic response of protective structures [5, 4, 14, 15]and the enhancement of energy absorption performance by inclusion of frusta into a ROPS system [6], research in this area has only received minimal attention. To the best of the authors' knowledge, there is no research on the impact response of the combined VFPSor ROPS/foamfilledconical tube assembly reported in the literature. The present study examines the feasibility of including a cost-effective supplementary energy-absorbing device in the form of a foam-filled conical tube into the framework of (1) VFPS for a frontal collision case and (2) rollover protective structures (ROPS) for a side collision case, to enhance their energy absorption capacity and hence to enhance the safety of the occupants. The methods used in the research involve a simple hybrid analysis of VFPS/foamfilledE-conical tube (VFPS-FFCT) and an extensive finite element (FE) analysisof ROPS/foam-filled conical tube (ROPS-FFCT) assembly using the non-linear FE softwareLS-DYNA971. A hybrid analysis of VFPS-FFCT for the frontal vehicle was briefly examined to solely determine the feasible range of foam density and tube geometry in order to provide a desirable energy absorption performance. The ROPS-FFCT assembly then treated using the validated FE models of the ROPS and the foam-filled conical tubes [1, 2, 14] to determine the influenceof parameters on the energy absorption and deceleration responses by varying the tube-wall thickness and foam density for different roll slope angles. The advantages of using foam- filled conical tubes in such a system were demonstrated through the research results. The primary outcomes are research information on influence of parameters anddesign guidelines for the inclusion of foam-filled conical tubes in energy absorbing systems to enhance the energy absorption and crashworthiness performances.
The present study has investigated the feasibility of including a supplementary energy- absorbing device into vehicular protective structures, namely VFPS and ROPS, in mitigating impact loading. Validated FE models of empty and foam-filled conical tubes have been incorporated into a ROPS model to demonstrate the enhanced crashworthiness and energy absorption performances of the ROPS.

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A simplified hybrid model and detailed numerical models have been employed to examine the influence of varying the wall thickness of the conical tubes, foam density of filler and different roll slopes on the structural response of protective structures. The results from the study showed some interesting and important trends. The main finding and design guidelines from this investigation can be summarised as follows:

1) Foam-filled conical tubes are advantageous for use as energy-absorbers in ROPS system since they provide a relatively smooth load-deflection response without rapid fluctuations which promotes stable, controlled deceleration as required during an impact event.
2) Foam-filled conical tubes are effective in reducing the severity of the peak decelerations transferred to the occupants of the vehicle by increasing the contact time during the impact. The effectiveness of reducing such decelerations up to 66% was found to be most pronounced for the conical tube filled with higher density foam and at a higher roll-slope angle
3) The supplementary devices are able to absorb as much as 61.8% of the input dynamic energy of the rollover. This amount of energy absorption was found to be greatest for the thicker walled conical tube filled with high-density foam, which had more material volume available for plastic deformation
4) The effectiveness of a foam-filled conical tube as an energy absorber was most influenced by properties of the foam-filled tubes for impacts on lower gradient roll slopes
5) The inclusion of a supplementary device considerably reduces the severity of the plastic deformation sustained by the ROPS and also reduces potential for further rollover and their adverse consequences
6) Incorporation of this energy-absorbing device is a very cost-effective solution for enhancing energy-absorption capacity and safety as inclusion of a very small component has significant influence on impact response of vehicular protective structures. Overall, the inclusion of a supplementary energy absorbing device in the form of foam-filled conical tubes has proven to be a cost-effective and beneficial solution that promoted an enhanced level of occupant safety by enhancing the energy absorption and reducing the amount of plastic deformation sustained by the protective structure as well as reducing the severity of the peak decelerations transferred to the occupant compartment during an impact event. The innovation of this study is the research information for facilitating the design of foam-filled conical tube as a supplementary energy-absorbing device for this particular case as well asits application to other heavy vehicles.

H.S C Deac (8) , Protection of cars, mainly drivers and passengers in a collision are very important issues worldwide. Statistics given by "World Health Organization" are alarming rate of increase in the number of road accidents, most claiming with serious injury, human and material loss. For these reasons has been a continuous development of protection systems, especially car causing three quarters of all accidents. Mathematical modeling and simulation of a car behavior during a frontal collision leads to new solutions in the development of protective systems. This paper presents several structural models of a vehicle during a frontal collision and its behavior is analyzed by numerical simulation using Simulink.

Modeling the behavior of a car during an accident is one of the most important issues in strength design. Impact tests are complex and difficult to achieve in practical terms, requiring qualified personnel, sophisticated equipment, time and money. For these reasons was developed a mathematical model for the analysis of a collision, which can give by provided results an answer as exactly over behavior of the car, response that can replace even the experimental results. Over the years, were developed two main approaches on the behavior of the car during the collision: focus parameters method known as Lamped Mass- Spring (LMS) and finite element method (FEM). Analysis with finite element method (FEM) requires a complete and detailed description of the component geometry and material properties associated, in contrast, analysis of focus parameters method (LMS) is based on several discrete masses and springs of materials whose mechanical properties are determined by dynamic tests. The vehicle structure design process is based on determining deceleration-time history, called pulse accident, history provided by both methods. First model, relatively simple but powerful to simulate the response of a car following a frontal impact was developed by Kamal [1] in 1970. This model, known as Lumped Mass-Spring (LMS) has become widely used by accident engineers due to its simplicity and relative accuracy. The vehicle is approximated one-dimensional and includes mass-spring system, a simplification which is quite acceptable for basic modeling of some characteristics in frontal impact collision. Because of the simplistic representation of an accident, the LMS model requires a user with knowledge, understanding and experience in dynamic testing of structural materials. Several versions of the LMS models were successfully used to simulate the impact of frontal, side and rear vehicle crashes [2-4]. The purpose of this paper is to present the dynamic behavior of a car in a collision, starting from simple models with concentrated parameters (LMS) with one, two and three degrees of freedom, by numerical simulation using Simulink.

To follow the collision of two cars in Simulink, the relative displacement, relative speed and relative acceleration are introduced. When the two velocities, before the collision, are in the same direction, the relative displacement is and in the case of

the front collision, the deformation is given. Thus, practically the mechanical system can be considered with only one degree of freedom. In the diagrams given in Figures (9) and (11), it can be noticed that there is an identical behavior in the collision of two cars with the behavior of a collision ofa car with a barrier. It should be noticed that here by c t it can be understand the time after which the relative speed is zero, and the two cars arrive at an equal common velocity, followed by the restitution phase, until the moment r t , when the relative acceleration is null. Similarly, it can be calculated the restitution coefficient that will have the same expression given by the relationship (27), where the mass m will be the equivalent mass em ,the elastic constant k will be replaced by the equivalent elastic constant e k and the damping coefficient c with the equivalent damping coefficient.
A structural analysis [8], that takes into account all the components of the front vehicle:
torque box, front frame, drive line, sheet metal, wall radiator, fan and grille and transmission mount can bring a much better characterization of the behavior of a vehicle collision and sad simulation results close to real if the mechanical characteristics of these components are know. These simulations help developed new technologies in vehicle crash safety, saving several resources. In simulation can bring a much better characterization of the behavior of a vehicle collision simulation results close to real if the mechanicalcharacteristics of these components are known.

I. Zuolong, Wei (9) The study of vehicle crash process is of great importance in transportation safety. The crash pulses of vehicles during the fixed barrier impacts canreflect the crashworthiness of the vehicle structure. In this paper, a mathematical model of vehicle kinematics during the frontal crash is investigated. This work is based on theanalysis of crash response signals and vehicle structure. The proposed model usespiecewise linear functions to describe the trend of crash impulse and ignores the residual oscillations. To study the model variance, the crashes in various speeds and a full car crash in complex condition are compared. At the end of paper, the crash performance of a vehiclecrash is predicted according to the proposed model and therefore demonstrates itseffectiveness and usability.

Crashworthiness is one of the core topics in the passive safety of vehicles and plays animportant role in the condition that the impact cannot be avoided. Generally, the analysis of crashworthiness is based on the related crash responses, i.e. the displacement, velocity and acceleration, of critical parts of a vehicle in full car crash tests. However, these tests are required appropriate facilities, one or more cars with measuring devices, experienced staffand a long time to prepare. It means they are complicated, expensive, long-lasting and therefore not easy to realize [1]. This is especially true in the early stage of vehicle design. Therefore, vehicle designers and researchers made a lot of effort to build numerical models to describe the crash processes. Up to now, various technologies are used to model thevehicle crash. Typical crash models may be classified into three broad categories [2]: 1) Detailed nonlinear finite element models. These models have excellent performance in the estimation of structural crashworthiness. However, before these crash models could beused, they usually require the details of the vehicle structure and materials. This limits theuse of FE models in the design process. 2) Multibody models and multibody based lumpedparameter models. As FE models, the multibody models also suffer the complexity.Consequently, the multibody based lumped parameter models make a compromise between the accuracy and complexity. Most of these models consist of energy absorbing (EA) elements with masses connected to both ends [3]. Reference [4 and 5] are typical studies on the lumped parameter models. 3) Functional approximation or response surface models. The functional approximation method is widely used in academia and industry. And reference [6] provides an overview of its use in the research of crashworthiness. To achieve better approximation, some advanced technologies are also introduced in this area, such as wavelet [7] and neural network [8]. Most of these models focus on the crash response signals themselves and can hardly be related to the vehicle structure. So the physical meaning of these modes is not clear. In the proceeding of the study, a piecewise linear model is proposed to represent the vehicle-rigid wall frontal crash. Compared to existing models, this model is developed based on the analysis of crash responses and therefore can reflect the performance of vehicle structures in crashes.

The rest part of this paper is organized as follows: In the next section, the crashworthiness structure is introduced firstly. Afterwards, the proposed model is proposed. In this section, the modelling procedures will be presented in detail and the influences of crash condition are also discussed. After that, an estimation of vehicle kinematics is given as an application of the proposed model.

Comparing to finite element models and multibody modes, the mathematical models have advantages on conciseness and usability. For this reason, the mathematical models can be used in the early design of vehicles, as well as accident reconstruction. This paper presents a novel modelling scheme of crashes, which is based on the acceleration signals and vehicle structure. The proposed model can reflect the crash process clearly and therefore describe the crash response exactly. In addition, this model suits for the crash in various conditions by adjusting the parameters. At the end of paper, an estimation of vehicle kinematics shows the good performance of the proposed model for a frontal crash at 40km/h.

J. David Woo, (10) This study presents performance characteristics of a magneto rheological (MR)impact damper for controllable bumper in vehicle systems. Recently, several mechanisms are proposed in order to minimize the injury of vehicle occupants during frontal collision. One of the promising candidates is the MR fluid which undergoes significant instantaneous reversible changes in material characteristics when subjected to a magnetic field. Using this salient property, a new type of MR impact damper is devised inthis work. The proposed damper is integrated with bellows to induce the flow motion and the motion is operated under flow mode. The field-dependent damping force is evaluatedby computer simulation with various conditions. In order to investigate the effectiveness ofthe proposed impact damper, a lumped parameter mathematical model of frontal vehicle crash system including MR impact damper is developed and realized in order to evaluate acceleration peak reductions and transmitted force in the frontal collision.

Recently, it is essentially required that vehicle occupants are secured against vehicle collision. Therefore, bumpers are expected to absorb collision force and systems to prevent accidents. For this, research is actively advanced not only on the system that produces a braking force in advance related to breaking devices but also on the bumper that protectsthe vehicle and the driver from collision. A variety of research is available on topics, such as the security of the driver who uses air bag and safety belt, and reduction of collision through braking efficiency improvement using ABS (Witteman, 1999). Mizuno and Kajzer (1999) tried to observe both the collision characteristic from various directions in different types of cars and the collision accident analyses of pedestrians. Witteman (2005) proposed friction damper to guarantee the security of vehicle by reducing impact force and demonstrated this by means of vehicle model analysis using FEM. Wa˚ gstro¨m et al. (2004) observed that the stiffness change of the vehicle could improve the stability in various conditions through vehicle model which was combined with a one degree of freedom system using computer simulation. Jawad (1996) considered a smart bumper composed before collision controller which changes stiffness beforehand, utilizing hydraulic system. Through this, the efficiency of impact force decrement as regards different collision conditions was considered.

The research about a shock reduction is actively accomplished using smart fluid which has
reversible properties with applied electric or magnetic fields. Lee et al. (2002) suggested a magneto rheological (MR) damper to reduce shock transmitted to a helicopter. Then, they designed the controller through the mathematical model and verified controller performance. Ahmadian et al. (2002) suggested shock reduction mechanism using the MR damper when a bomb is fired. Lee and Choi (2000) and Lee et al. (2001) verified controller performance using the MR damper through application to vehicle suspension. Song et al. (2004) proposed the shock damper to reduce impact by means of acceleration decrement ofthe damper. From these researches, sufficient possibilities were presented on the reduction of impact using the smart fluid. In this study, MR impact damper is proposed to reduce transmitted force to vehicle chassis when the vehicle encounters frontal collision. The governing equation of motion of MR impact damper is derived using hydraulic model. The dynamic equation includes a damping force term which is the field dependent damping force achieved from Bingham model of MR fluid. The performance of collision mitigationis then evaluated by computer simulation using vehicle model that is included in the occupant model.

A MR impact damper was proposed and its dynamic characteristics and collision mitigation Performances were evaluated by considering variations of speed and occupants model. After verifying that the damping force can be controlled by the intensity of magnetic field, the vehicle model including occupant model was constructed. It has been simulated that VCSI and frame deformation can be effectively reduced by employing the damping force determined control strategy. The performance of MR impact damper will be experimentally evaluated for the various test conditions.

K. Hariharan Sankarasubramanian (11) During impact with an automobile, a pedestrian suffers multiple impacts with the bumper, hood and the windscreen. Optimisation of the carfront using a scalar injury cost function has been demonstrated. The results for impacts simulated in MADYMO show good co-relation with Euro-NCAP ratings for existing vehicles. Optimization of the car front to minimise the injury cost converges to vehicle profiles with features known from earlier studies to be pedestrian friendly. A method to design car fronts for pedestrian safety is evolved

Vulnerable road users, which include pedestrians and non-motorized two- w h e e l e r riders, have been found to be the major constituent in road fatalities in developing countries. Fatalities due to vehicle-pedestrian crash are found to be higher in urban areas in India (Mohan, 2010). In India, the predictions for vehicle sales for the year 2011 show an increased demand for LCVs, utility vehicles and passenger cars (SIAM, 2010). By addressing the design of the front of these automobiles one can contribute a major step inthe safety of the vulnerable road users without compromising on the safety of the occupants. In this work, the issue of vehicle-front design for safety of pedestrians is addressed. Earlier methods used optimization based on single injury measure to obtain a better vehicle profile. In subsequent levels, one additional injury measure was combined using weight factors and optimization extended.

The procedure is built upon and a single objective optimization is proposed. The objective function is derived from multiple injury parameters obtained from statistical analysis of crash and hospital data. It is a better indicator of the "actual" loss to the pedestrian in termsof cost. A direct co-relation of the individual injury severity as well as the gross effect of injuries is possible with this new measure

A larger sedan is expected to score better in head form tests indicating less severe headinjury of pedestrians as it has a larger bonnet region with comparatively low stiffness. A similar trend is observed with the "injury cost" distribution.

MADYMIZER optimized model showed a 31% reduction from the minimum injury cost observed in production vehicles. The convergence is however to a local minimum withinthe range specified.

The model optimized using genetic algorithms approach was able to operate on a wider range of dimensions and it showed a reduction of 55% from minimum injury cost observed.It was also observed that the model optimized by genetic algorithm was able to combine the benefits obtained from a longer bonnet car with better bumper and leading-edge locations to reduce injuries for pelvic and lower regions. The injury cost for torso shows the minimum observed in the whole population. Similarly, the injury cost for the pelvic and region belowis also found to be least. "Injury cost" is a hence good candidate as a unitary measure of severity of injury to pedestrian in the event of a pedestrian-vehicle crash. It can be used in the vehicle front- profile optimization for reduced pedestrian injury as it acts as a direct indicator of injury severity. Further, this method potentially allows optimisation to be carried across a population of impact cases by weighing the injury cost from each impact case.

L. Jing Zhou (12) Road traffic statistics have shown multi-event crashes typically result inhigher fatalities and injuries than single-event crashes do, especially when the initial harmful event leads to a loss of vehicle directional control and causes secondary collisions. In this work, the topic of stabilization control for vehicles involved in light vehicle-tovehicle impacts is addressed. A post-impact stability control (PISC) system is developed to attenuate undesired vehicle motions (spin-out, skid, rollover) induced by the initial impacts, so that subsequent crashes can be avoided or mitigated.

First a vehicle collision model is developed to characterize vehicle motions due to the light impact, which is based on an assumption of substantial changes of kinematic states butminor structural deformations. Colliding vehicles are modeled as rigid bodies with four degrees of freedom, and the influences of tire forces are taken into consideration to improve the prediction accuracy of collision consequences. Then a collision sensing/validation scheme is developed to detect impulsive disturbances and trigger the activation of PISC. The vehicle responses to the impulse are predicted and used to compare with subsequent measurements for collision confirmation. The stabilization controller, which is derived from the multiple sliding surface control approach, regulates the disturbed vehicle motions via differential braking/active steering. The system effectiveness is verified through CarSim/Simulink simulations for angled rear-ends collisions. When compared with the performance of existing electronic stability control (ESC) systems and four-wheel braking approach, PISC demonstrates improved capability to reject the collision disturbances and to assist the driver to regain control. For more integrated control of longitudinal/lateral/yaw/roll motions, a hierarchical controlarchitecture for vehicle handling is proposed. It consists of three coordinated stages: thegeneration of virtual control commands through model predictive control, the generation ofactual commands through constrained optimal allocation, and the tracking of wheel slips atthe actuator level. This cascade modular design allows for better tradeoff among variouscontrol objectives and explicit consideration of control input constraints at handling limits. This proposed active safety feature can be deemed as a functional extension to current ESCsystems, and constitutes a complementary module towards a comprehensive vehicle safety system. This study first addressed the vehicle-to-vehicle collision problem. A model of vehicle collision was constructed to facilitate the characterization of the post-impact vehicle kinematic states, so that the initial conditions of post-impact vehicle motions can be determined. The colliding vehicles have each been modeled as rigid bodies with four degrees of freedom, which is different from the planar model commonly used in the literature. In contrast to conventional momentum-conservation-based methods, the proposed approach took tire forces into account. Improved model prediction accuracy

was demonstrated through numerical examples. The next task is to ensure that the PISC system will be activated at the right moment whena crash has occurred, and will not get into action due to sensor defects or noises. The crash sensing criteria are based on evaluating the gradients of yaw rate and lateral acceleration. Then a model-based estimation procedure is applied to estimate crash magnitude and location, and to predict vehicle responses within a short future horizon. The crash event isconfirmed if a consistency between predictions and actual measurements can beestablished. In the next step, differential braking and/or active steering are actuated toattenuate intense post-impact motions of the vehicle, after the PISC system is activated and the crash event is confirmed. The side, timing, and magnitude of braking actuation arebased on the generation of a desired stabilizing yaw moment, which is in turn derived by adopting the multiple sliding surface control approach. The overall PISC system is implemented in Simulink and interfaced with a nonlinear SUV vehicle model in CarSim.

The simulation results demonstrate the effectiveness of the proposed system in angled rear- end collisions with varying severity and direction. In order to integrate multiple control objectives, a model-based hierarchical control framework is designed for vehicle handling and applied to the post-impact stabilization scenario. The developed control system consists of an MPC-based supervisory stage, an intermediate stage for optimal allocation, and wheel slip tracking at actuator stage. It provides the benefits of a modularized approach to accommodate control constraints and coordinate multiple control effectors in an optimal way

M. Thomas Kinsky (13) In Japan, a new leg form impactor for pedestrian protection testinghas been developed during the past 10 years. This leg form is called "Flexible Pedestrian Leg form Impactor" (FlexPLI). Compared to the existing leg form currently used in Europe, the FlexPLI is intended by its developers to better reflect the behaviour of a human leg during an impact with a vehicle. In addition to a more humanlike knee section, the new impactor provides for the possibility to also assess injuries of the pedestrian's tibia.

In the first development phase, the leg form was considered to be very bio fidelic but testing robustness was limited. In its further development, the impactor was modified to better address the needs of a certification tool: The latest version of the leg form is more robust than pre-versions, the handling is acceptable, the repeatability of test results seems to be acceptable and the leg form fits into the current sub-system test scenario of the global technical regulation (gtr) No 9 on pedestrian safety.

Common vehicle designs use a forward-moved lower structure of the bumper as a load pathto reduce the knee bending. However, these structures may cause higher strains in the tibia area of the FlexPLI (and consequently may indicate a risk for tibia injuries in real-world accidents). Therefore, for many vehicles the bumper systems designed to meet the requirements for the lower leg form currently used in Europe will need to be redesigned to fulfil the FlexPLI targets.

Nevertheless, the FlexPLI has already been proposed to be used as certification tool in gtr No 9. The study presented below provides first results of tests in a manufacturer's lab with different vehicles of different categories and identifies general concepts for optimization towards FlexPLI requirements' fulfilment. The intention of this paper is to summarize the experiences gained for use as information for future vehicle developments. About 10 years ago, experts of the Japan Automobile Research Institute (JARI) and of the Japan Automobile Manufacturers' Association (JAMA) presented a new leg form impactor for pedestrian safety testing. The new leg form is called "Flexible Pedestrian Leg form Impactor" (FlexPLI).

The European leg form impactor was never widely accepted in Japan. During the development of the first impactor and the respective test procedures, the experts of the European Experimental Vehicle Committee (EEVC; later renamed to European Enhanced Vehicle-Safety Committee) decided to prioritize knee ligament injuries while possible bone fractures were to be evaluated via the acceleration of the leg form. However, a detailed assessment of fractures of the long bones was not intended [1]. Several pedestrian safety experts, especially the experts of Japan, pointed out that the design of the EEVC leg form impactor with its rigid upper and lower part cannot simulate the human lower extremities' motion properly. Also, according to the Japanese experts the EEVC impactor may mislead the protection for the pedestrians' lower extremities since an injury assessment of the lower part of the leg is not possible [2]. Approximately 3 to 4 years ago, Japanese experts presented additional analyses of the Japanese accident statistics showing that around 87% of all leg injuries were tibia fractures [3]. The missing ability of the EEVC Lower Leg form Impactor (EEVC LFI) to assess fractures of the pedestrians' lower extremities in detail was the main reason for Japan to develop their new leg form impactor.

During the past 10 years, the FlexPLI had been presented in different build levels: version 2000, version 2002/2003, version 2004, version G, version GT and version GTR. For the later versions, which were thought to be close to a final design, additional prototypes were presented. They were referred to as version xx alpha (or xx α). To improve robustness and reliability of the tool itself, repeatability of test results, Kinsky 2

Handling of the impactor etc., the impactor was modified significantly during the development process. The latest build level, FlexPLI version GTR (or Flex-GTR), has been available in its production version since early 2010. However, the manufacturer of the leg forms still applies additional modifications during the current production to achieve further improvements and especially to be able to meet the agreed corridors for the impactors' certification [4].

Bumper systems that perform well when being tested with the EEVC lower leg form impactor do not necessarily have the same performance level with the new Flexible Pedestrian Leg form Impactor. However, first test results indicate that today's concepts, engineered to comply with current requirements for the leg form tests, may not need to be completely redesigned from sketch or "reinvented" respectively. Generally, measures like a smooth geometry of the vehicle front end with a homogenous reaction surface and a certain elasticity of the bumper structure allowing an elastic displacement of the lower bumper stiffener help to comply with the requirements of the new leg form. One focus needs to beon the design of the load paths. Structure and surface elements creating high peaks for thetibia bending moment should be avoided. Structures with multiple load supports are more promising.

However, it needs to be emphasized that the test results discussed above were produced at vehicles that already meet regulatory requirements and furthermore have a good performance in consumer metrics testing. Therefore, those vehicles are well positioned to meet the new requirements.

N. Sukru Karakaya (14) In this study the effectiveness of composite disc springs with different cross-section and hybrid type are determined by taking into account load capacities, masses, hybridization characteristics and costs of composite disc springs. Thedisc springs are analyzed with ABAQUS finite elements program by compressing between two rigid plates. The load-deflection characteristics obtained as a result of the analysis are compared with the analytic and experimental studies. Then different cross-section and hybrid composite disc springs were modeled. The trapeze A disc spring were confirmed to be more advantageous in terms of load capacity and mass by investigating the modeled disc springs. The effect of hybridization on hybrid disc springs with standard cross-section was investigated and optimum hybrid disc spring was determined according to cost and maximum loading capacity. Consequently, it is determined that carbon/epoxy plies used for outer layers are more advantageous. But the outer ply subjected to force was damaged thusthis layer should be particularly reinforced.

The use of composite materials in advanced engineering applications has been graduallyincreasing due to high strength and stable material characteristics. The composite materials, which have better light-weight, rigidity and several special characteristics, are preferred for aerospace, automotive and maritime vehicles. This applies to springs made up of metalalloys. There materials are replaced with composite springs manufactured with synthetic fibers or natural fibers. The applications frequently included in the literature for compositesprings are leaf, helical and disc spring applications. One of the significant advantages ofcomposite leaf springs is that composite leaf springs have better strength and elastic energy, in comparison to leaf springs made of steel. Besides, strength/weight ratio of composite leafsprings is more than the steel springs. The researchers design and analyze composite Springs, rather than metal leaf springs used in the past [1]. The studies conducted byresearchers managed to significantly reduce the stress on spring and structure weight. Theleaf springs produced with reinforced glass fiber used on different road conditions andachieved significant reduction in noise in the cabin and spring stiffness, in comparison toleaf spring made of metal [2]. Mahdi et al. developed an elliptic composite spring in orderto lighten the suspension systems of heavy trucks which are heavy. The effect of elliptic ratio on composite spring was examined experimentally and numerically. Besides, it wasdetermined that elliptic ratio has significant impact on spring constant and failure condition [3]. In hybrid leaf spring study, glass and other fibers were homogenously distributed in acertain cell and composite leaf springs were produced without laminating, by using glassand other fibers. A uniform stress distribution was achieved on the leaf spring produced [4].Another application related to production of springs from composite materials is helicalspring application. The study compared helical springs produced in different types and as aresult, increase in spring constant and reduction in compression failure were ensured.Sancaktar and Goweishanger conducted another study on helical springs. Spring rigidity ofhelical springs produced in glass, carbon and hybrid form was determined experimentally.The effects of coil diameter, wire diameter and coil number on spring rigidity weredetermined and also feasibility of replacing standard steel spring with composite
helical spring were examined [5–7]. The characteristics of steel disc springs were examined
analytically and experimentally studies related to disc springs which are compression springs. Besides, the weight of disc spring was reduced by using woven carbon/epoxy. Another study targeted reducing weight. The goal was to achieve a force-deflection curve, like that of a steel spring, with a lighter disc [8,9].The main purpose of this study was to determine the effectiveness of hybrid and different sectional disc springs. Load capacities, masses, hybridization characteristics and costs of the composite disc springs were taken into consideration on this study. In this study has three main parts. First, disc springs subjected to compression load were modeled by ABAQUS finite elements program. The load-deflection characteristics achieved as a result of compression analysis were compared with analytical and experimental studies. Then disc springs having different cross-section geometry were modeled. These disc springs were compared with each other according to their low mass — high load capacity. Finally, the standard cross-section hybrid disc springs made up of carbon/epoxy and glass/epoxy plies were modeled. The hybrid disc springs were compared in terms of load capacity and costs and the disc spring was confirmed to be the optimum. Failure condition of optimum hybrid disc spring was determined and results associated with this condition were obtained. Basically, the study examined disc springs with different section geometry and hybrid composite disc springs with finite elements method. Initially, it was determined whether or not analytical study and experimental study were compatible with the study conducted with finite elements method. Then disc springs with different cross-section were modeled andthe disc spring having the lowest mass-highest load capacity was determined. Finally, standard section hybrid disc springs made up of carbon/epoxy and glass/epoxy plies were modeled and these disc springs were evaluated in terms of load capacity and costs. Then failure condition of optimum disc spring was determined.

The results of the studies conducted can be listed as follows:
Disc modeled with finite elements method is in conformity with both analytical and experimental studies, if we take into consideration load-deflection curve.

1) Trapeze A section disc spring, a different section disc spring, has advantages in term of load capacity and mass, in comparison to standard section disc springs and certain other different section disc springs.
2) Hybrid disc springs made with symmetric lamination offer advantages in terms of maximum load capacity and cost.
3) Selecting a material that is more rigid (carbon/epoxy for outer plies of hybrid disc springs offers load capacity and cost advantages. The cost of disc spring increases directly as the increased number of carbon plies in the outside plies and the marginal advantage in termsof load capacity decreases
4) In case of composite disc springs, ply on the surface, where compression force is applied,is damaged. The disc spring top side subjected to force should be some other material in order to prevent such crushing damage.

O. Matthew Huang (15) Vehicle Crash Mechanics clarifies the complexities of this multifaceted area of study. It sets forth the principles of engineering mechanics and applies them to the issue of crashworthiness. It explores the three primary elements of crashworthiness, which are vehicle, occupant, and restraints, and illustrates their dynamic interactions through analytical models, experimental methods, and test data from actual crash tests. Parallel development of the analysis of actual test results and the interpretationof mathematical models related to the test provide additional insight, and case studies present real-world crash tests, accidents, and the effectiveness of air bag and crash sensing systems

P. Lakshmana Rao (16) Impact phenomena are ubiquitous in sports, musical instruments, vehicle collision, ballistics and natural disaster. A branch of physics that deals with the forces, displacement and material failure associated with impact is called as impact mechanics. The application of impact mechanics in design of engineering systems, can be termed as applied impact mechanics .This subject demands a thorough appreciation of complex processes involving contact interfaces, non-linear deformation, fracture and fragmentation. This book presents impact phenomenon as focused application of diverse topics with a balanced treatment of theory, experiment and computation. In the first part of first part the book covers fundamental ideas of uniaxial and muilti dimensional impact waves generated during the contact of colliding bodies including a concise introduction to the relevant concepts of rigid body impact mechanics. In the second part, contemporary strategies employed in experimental, theoretical and computational techniques are delineated for application to vehicle collision and ballistics.

Q. Shimoseki et al (17) while there are many books about Finite Element Methods, this is among the first volume devoted to the application of FEM in spring design. It has been compiled by the working group on Finite Element Analysis of Springs, sponsored by the Japan Society of Spring Research. The monograph considers the wide spectrum of spring shapes and functions, enabling readers to use FEM to optimize designs for even the most advanced engineering cases. It provides the theoretical background and state-of-the-art methodologies for numerical spring analysis. It also employs and explains many real-world design examples, calculated by commercial software and then compared with experimental data, to illustrate the applicability of FEM to spring analysis. Engineers already dealing with spring design will find this an excellent means of learning how to use FEM in their work, while others will find here a helpful introduction to modern spring technology and design

R. Stefan Josef Hiermaier (18) Structures Under Crash and Impact: Continuum Mechanics, Discretization and Experimental Characterization examines the testing and modeling of materials and structures under dynamic loading conditions. Readers will find an in-depth analysis of the current mathematical modelling and simulation tools available for a variety of materials, in addition to both the benefits and limitations they pose in industrial design. The models discussed are also available in commercial codes such as LS-DYNA and AUTODYN. Following a logical and well organized structure, this volume uniquely combines experimental procedures with numerical simulation and features examples from issues taken directly from the automotive, aerospace, and defence industries. Materials scientists, structural and design engineers, and physicists with an interest in crash and impact situations will find Structures under Crash and Impact a valuable reference.

S. Vladimir Kobelev (19)this book offers an advanced treatise of the mechanics of springs with focus on the springs for automotive industry. It demonstrates new and original results for the optimization of helical springs as well the design of disk springs and thin-walled springs and presents the new results for creep and relaxation of springs made of steel under high static loads. The fatigue of springs and weak link concept for cyclically loaded springsare enlightened. The closed form solutions of advanced problems allow the deeper understanding of spring mechanics and optimization of energy harvesters.

III.OBJECTIVES OF PROJECT

The specific objective of the project is

1) Improve automobile bumpers to enable them withstand impact energy of vehicles travelling at several times the speeds conventional bumpers are designed for.
2) Model and simulate impact phenomenon in order to study crash dynamics.
3) Use information from the simulation to generate design parameters for better impact attenuation bumpers.

Propose designs of a bumper that could attenuate the impact energy of vehicles travelling at speeds several times the specified speeds for the design of a conventional bumper.

IV.PROBLEM DEFINITION

Automobile bumpers are designed to withstand impact energy equivalent to 4 km/h. This corresponds to rolling impact and it would be beneficial to improve upon this design criterion. Theoptimisation criterion is used to find the solution to withstand the impact

V. METHODOLOGY

Automotive bumper system plays a very important role not only in absorbing impact energy, which is the original purpose of safety, but also in a styling stand point. A great deal of attention within the automotive industry has been focused upon light weight and sufficient safety in recent years. Therefore, the bumper system equipped with thermoplastic and energy absorbing element is a new world trend in the market.

This project is for the design of bumper system summarised as a degree of absorption of impact energy in a limited clearance between back face of bumper and body parts of vehicle Once impact takes place the system displaces the front bumper such that the spring inside damper is deflected to 60% of free length when the sacrificial damper valve is actuated to release the oil which is at pressure above the cracking pressure of valve and thus this action will action like a energy - absorber and thus the momentum force is properly dissipated without damaging the inner components of the car.

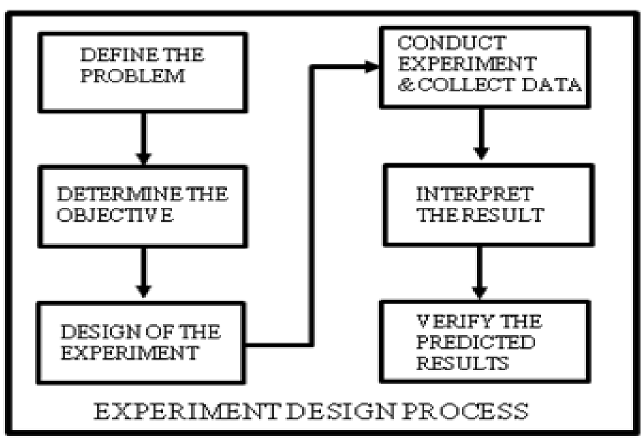

Fig 1.2 The Methodology Diagram

While experimental test is rather costly and time consuming, finite element analysis helps engineers to study design concept at an early design stage when prototypes are not available. This project attempts to show a method using computer simulation which has been broadly adapted in the various design stages of vehicle development. The analysis based on the international safety standards is done using a rigid wall impact with multiple materials. The finite element code is used for this study are Hyper mesh,

Concept of project is that when the high speed vehicle bangs against the safety impactguard the damper comprising of cylinder and piston arrangement Once impact takes placethe system displaces the front bumper such that the spring inside damper is deflected to60% of free length when the sacrificial damper valve is actuated to release the oil which isat pressure above the cracking pressure of valve and thus this action will act like an energy absorber and thus the momentum force is properly dissipated without damaging the inner components of the car and protecting the occupant from critical injury

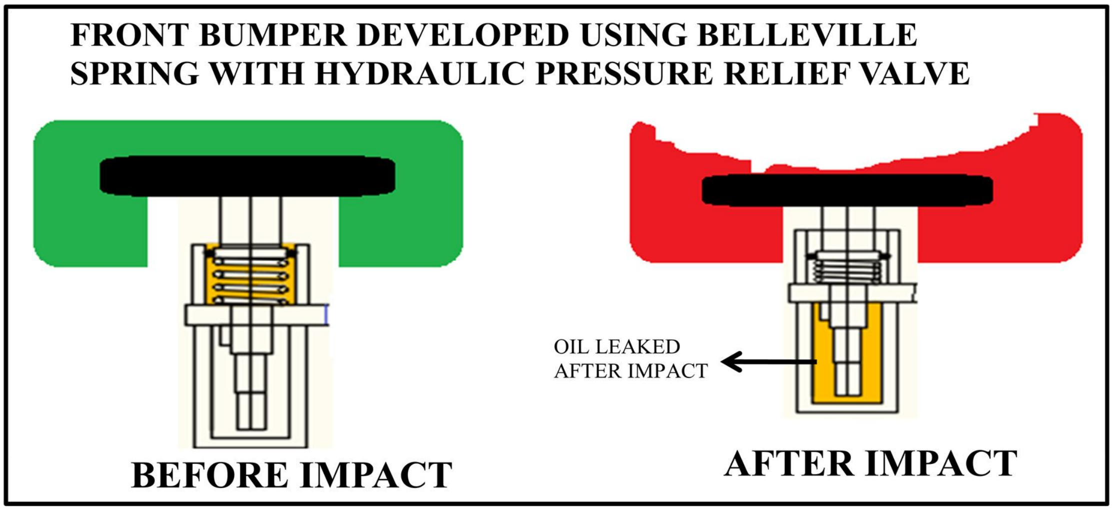

Fig 1.3 Schematic of Damper Arrangement

The structural concept used for development of the Impact Damper design is based on threebasic principles;

1) Progressive absorption of impact energy at defined load levels.
2) Multiple load paths from the vehicle front into the passenger cell.
3) A robust structural design which if it collapses does so in a controlled manner

The very front of the vehicle has been designed to offer some protection to vulnerable road users and is therefore relatively soft. Collisions involving increased mass but low speeds such as may occur in parking accidents have been used for the development of the bumper beam. At impacts up to 15km/h the bumper beam in conjunction with a sacrificial energy absorbing structure has been developed in order to minimise damage to the main vehicle structure and thereby minimise repair cost

a) Literature review: Technical papers, white papers , patent documents , etc
b) System design of robot design as for the component selection, geometry and profileselection, charge system selection, mounting & orientation
c) Mechanical design of components under given system of forces to determine functional dimensions of the components to be used using various formulae and empirical relations
d) 3-D modelling of set-up using UG NX.
e) CAE of critical component and meshing using Hyper mesh/ Ansys
f) Mechanical design validation using ANSYS critical components of the system willbe designed and validated
g) Manufacturing, assembly of the device and test-rig for experimental analysis andvalidation.
h) Testing and trial to derive performance characteristic of robot for differentplacement and orientation
i) Result discussion and thesis preparation.
j) Theoretical results will be determined using mathematical formulae.

VI. DESIGN FOR IMPACT DAMPER

In modern vehicle it takes fraction of second for a vehicle sensors to activate the protective systems in the event of an impact. The severity of the impact is more evident with each millisecond as the kinetic energy flows through the car, activating all the internal sensors of acceleration, pressure & vibration. The airbags deployment, activation of the seat pre-tensioners need to be ensured within this critical time.

The introduction of Crumple Zones allow the vehicle to decelerate and dissipate the impact kinetic energy to other structural components of the vehicle. In the event of the high speed crash the crumple zone provide a primary safety zone till all the safety systems are activated and the occupant movement is halted inside the passenger cell module and final structural level warping has finished absorbing the full impact.

The knowledge of required stopping distance of the vehicle is essential to design an effective restraint system. The paper discusses on the design of a front structure design which is stiff yet deformable to absorb the kinetic energy resulting from collision due to frontal impact and deform plastically in a manner the intrusion in the passenger compartment is reduced to the minimum

The key guidelines for the design of the system are.

Maximise the use of energy absorbing materials with the sole intention of absorbing the kinetic energy of the impact.

Increase the time over which the restraint are applied to the passenger to minimize the g level and in turn bring it to the level of tolerance level of an average human limit acceptance.

The travel of the passenger should be maximised within the passenger cell module so that the decelerating impact should be in the form of cushioning impact and this is performed bythe effective design of the crumple zone

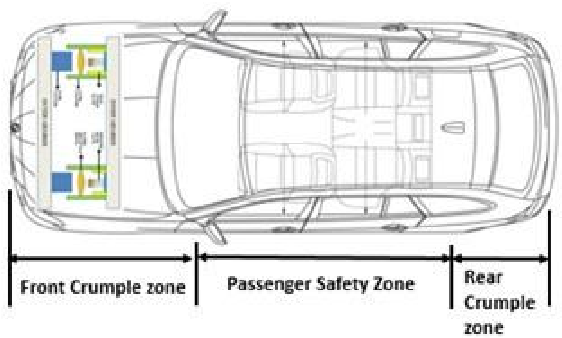

Fig 3.6 Zone Distinctions in Passenger Car

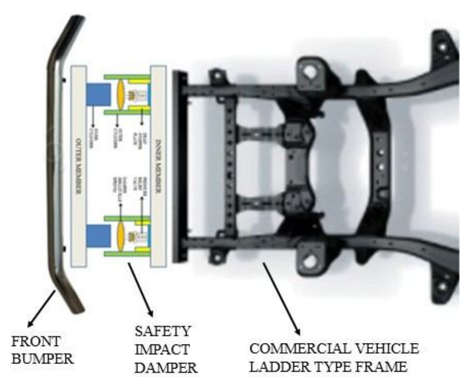

Fig 3.7 Impact Damper fitted in Commercial Vehicle

The design activity of the impact damper has been sequenced as per the key points below

Determination of impact force and system design of impact energy absorber through theoretical calculation of momentum and kinetic energy of moving vehicle and development of scaled model of the pressure relief valve as per IS standards

Design Analysis of sacrificial energy impact damper, to validate the theoretical stresses and preparation of manufacturing drawings for the impact damper and pressure relief valve.

Manufacturing of the pressure relief valve along with the critical components of the system and the test rig to test the impact damper.

Test and trial of the impact damper for different simulated conditions of vehicle speed.

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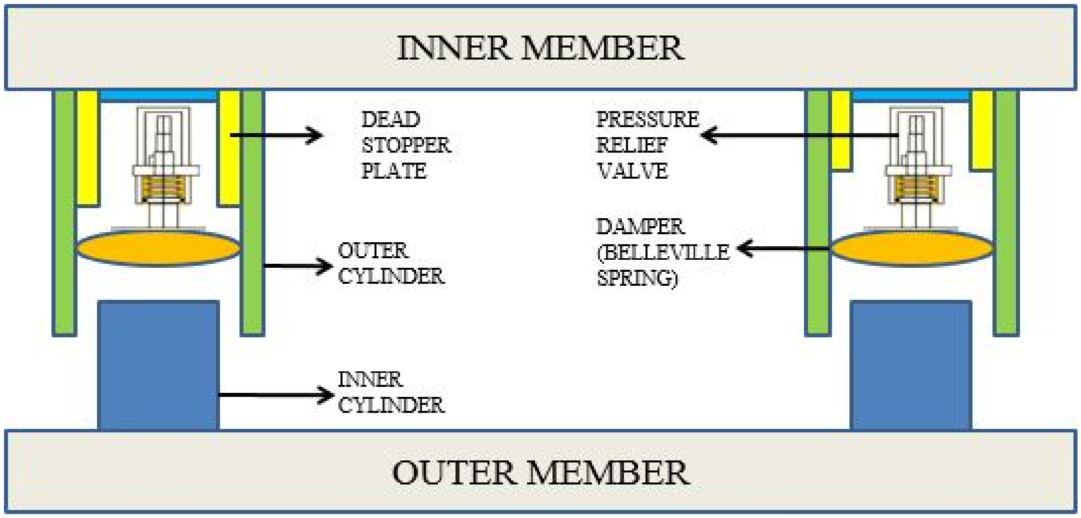
VII. KEY ELEMENTS OF THE IMPACT DAMPER

The Proposed design of safety impact guard shown in figure 4.3 is primarily designed forthe basic fact that the time of impact that is felt to the occupant needs to be prolonged .The performance of existing vehicle protection systems is complemented using crash energy absorbing structural members in the form of thin-walled tubes, called as crash tubes.



The setup is briefly explained below

1) The outer member attaches to the bumper and incase of passenger car it's replaced with the actual bumper.
2) A cylindrical tube is fitted to the main outer member its main function is to activatethe damper fitted in the cylinder ahead both of them are fitted as a telescopic arrangement with and the front tube collapses along with the damper in the eventof the frontal impact.
3) The main protection device installed is a tube fitted with nested Belleville spring atthe end of which is further fitted a pressure relief valve filled with oil. During the impact the Belleville spring undergoes local plastic yielding resulting in considerable portion of kinetic energy being absorbed through plastic deformation by buckling and folding of crash tubes& Belleville spring , this further is supportedby the pressure relief valve which gets activated and releases the oil and further absorbs the remaining kinetic energy and protecting the occupants by providing them the precious time to allow the airbags and seat restraint to further activate and help save their precious lives.
4) The inner member which fits either the chassis frame for the commercial vehicle or directly to the bulkhead in case of the passenger cars is required to maintain the damper tube in the alignment with the front crash tube.

VIII. PRIMARY DAMPER – BELLEVILLE SPRING

Disc springs are the best choice when the application requires loading in the axial direction, discs can be used as single or stack based. A Belleville washer, also known as a coned-disc spring,[1] conical spring washer,[2] disc spring, Belleville spring or cupped spring washer, is a conical shell which can be loaded along its axis either statically or dynamically. A Belleville washer is a type of spring shaped like a washer. It is the frusto-conical shape that gives the washer its characteristic spring. The "Belleville" name comes from theinventor Julien Belleville who in Dunkerque, France, in 1867 patented a spring design which already contained the principle of the disc spring.[1][3] The real inventor of Belleville washers is unknown. Through the years, a lot of different profiles for disc springs have been developed. Todaythe most used are the profiles with or without contact flats, while some other profiles, like disc springs with trapezoidal cross-section, have lost importance. Multiple Belleville washers may be stacked to modify the spring constant (or spring rate) or the amount of deflection. Stacking in the same direction will add the spring constant in parallel, creating a stiffer joint (with the same deflection). Stacking in an alternating direction is the same as adding common springs in series, resulting in a lower spring constant and greater deflection. Mixing and matching directions allow a specific spring constant and deflection capacity to be designed.

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Generally, if n disc springs are stacked in parallel (facing the same direction), standing the load, the deflection of the whole stack is equal to that of one disc spring divided by n, then, to obtain the same deflection of a single disc spring the load to apply has to be n times thatof a single disc spring. On the other hand, if **n** washers are stacked in series (facing in alternating directions), standing the load, the deflection is equal to **n** times that of one washer while the load to apply at the whole stack to obtain the same deflection of one disc spring has to be that of a single disc spring divided by **n**

Disc springs have a number of advantageous properties compared to other types of spring

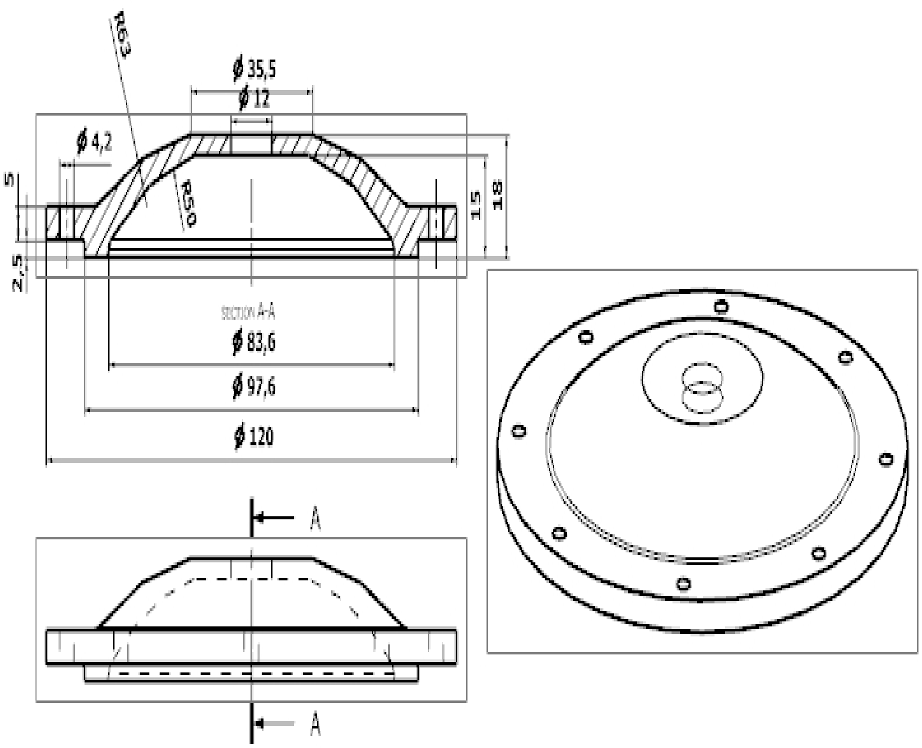
Very large loads can be supported with a small installation space, Due to the nearly unlimited number of possible combinations of individual disc springs, the characteristic curve and the column length can be further varied within additional limits,

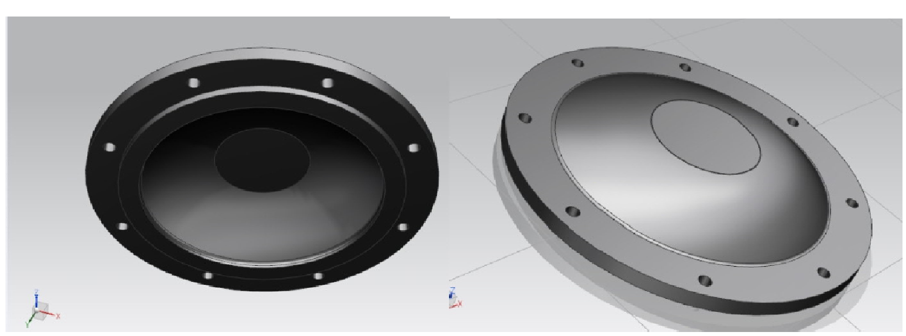
High service life under dynamic load if the spring is properly dimensioned,

Provided the permissible stress is not exceeded, no impermissible relaxation occurs,

With suitable arrangement, a large damping (high hysteresis) effect may be achieved,

Because the springs are of an annular shape, force transmission is absolutely concentric





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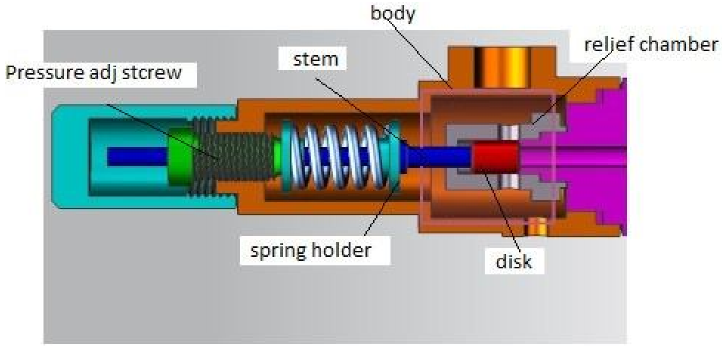
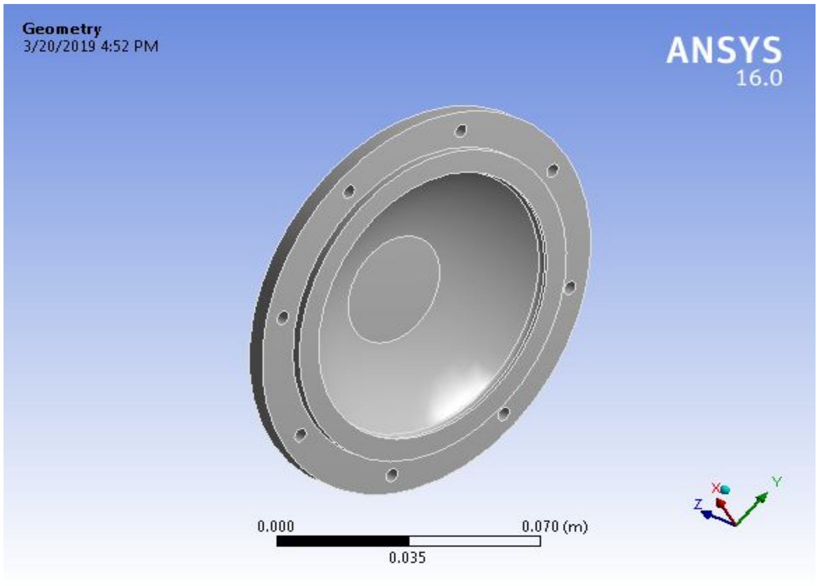
IX. PRESSURE RELIEF VALVE – SECONDARY IMPACT DAMPER

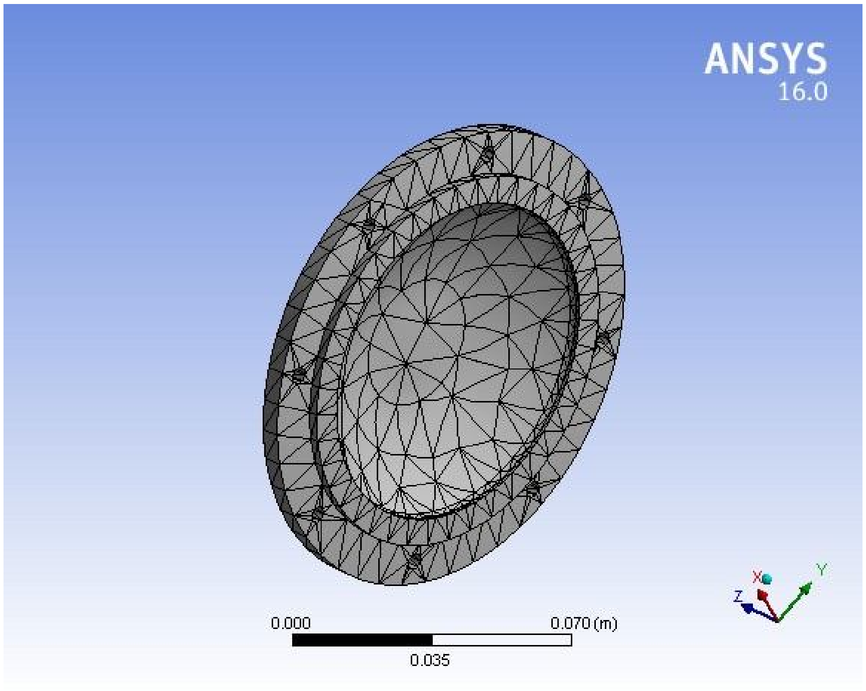


A relief valve or pressure relief valve (PRV) is a type of safety valve used to control or limit the pressure in a system; pressure might otherwise build up and create a process upset, instrument or equipment failure, or fire. The pressure is relieved by allowing the pressurised fluid to flow from an auxiliary passage out of the system. The relief valve is designed or set to open at a predetermined set pressure to protect pressure vessels and other equipment from being subjected to pressures that exceed their design limits. When the set pressure is exceeded, the relief valve becomes the "path of least resistance" as the valve is forced open and a portion of the fluid is diverted through the auxiliary route. The diverted fluid (liquid, gas or liquid–gas mixture) is usually routed through a piping system known as a *flare header* or *relief header* to a central, elevated gas flare where it is usually burned and the resulting combustion gases are released to the atmosphere.[1] As the fluid is diverted, thepressure inside the vessel will stop rising. Once it reaches the valve's reseating pressure, the valve will close. The *blowdown* is usually stated as a percentage of set pressure and refers to how much the pressure needs to drop before the valve re-seats. The blowdown can vary from roughly 2–20%, and some valves have adjustable blowdowns. The key elements of the pressure relief valve are Body of the relief valve , Pressure adjustment screw , Stem ,Spring holder, ReliefChamber & Disk The parts designed for the frontal impact damper setup The methodology of analysis for the above components is Solid model of the components were made using UG-NX
Data was transferred using STEP203 file exchange system
The Analysis was done in ANSYS 16.0.

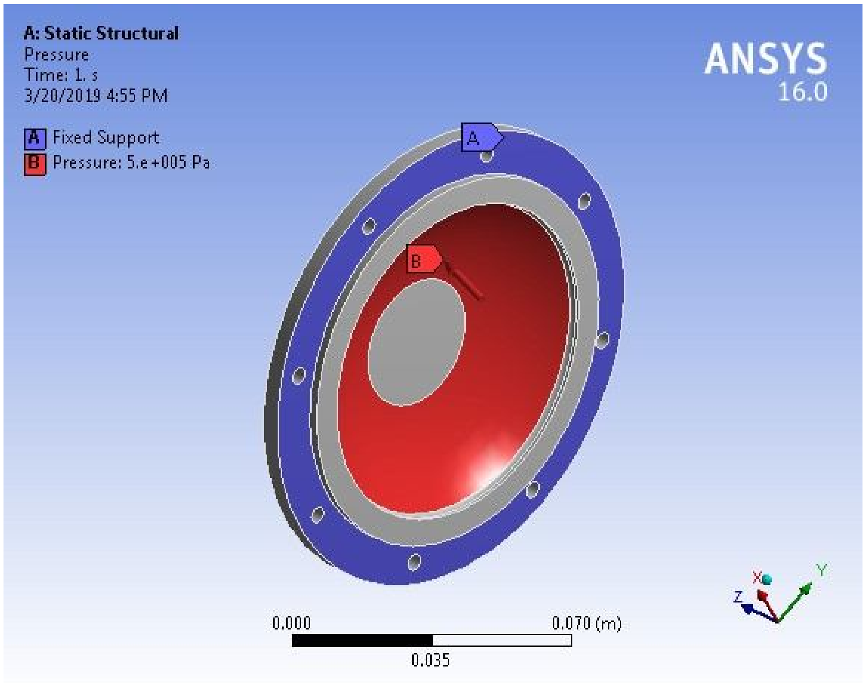
X. ANALYSIS OF TOP BELLEVILLE SPRING



Geometry was developed using unigraphix nx-8 and the step file was used as input to ansys



The meshing was done using ansys workbench



The loading was done as per the scheme shown above

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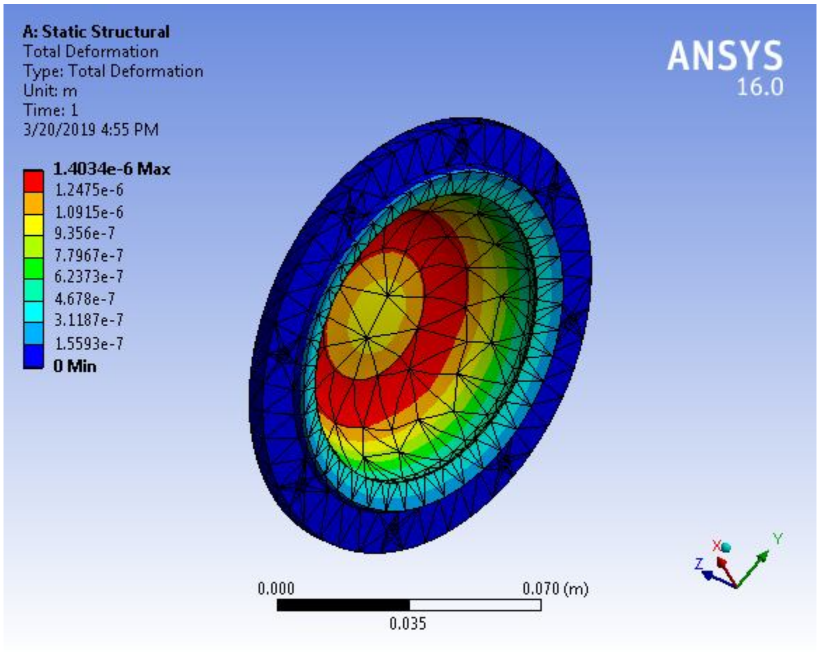
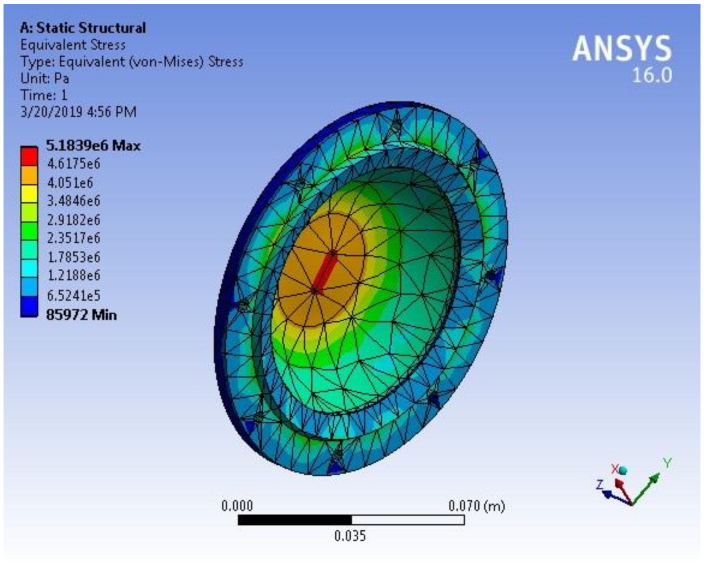


The total deformation shown is very negligible so the part is safe.



Displacement is maximum at red colored area. Maximum Von mises stress obtained is shown in Figure 4.6. As the analysis provides the results and under the loading condition, compression strength of Belleville spring is obtained. Static analysis is done by using the finite element method, in the figure blue color indicates the minimum stresses acting on the turns and red color indicatesmaximum stresses the maximum stress value is well below the allowable limit the design of the spring is safe. The total deformation shown is very negligible so the part is safe.

The maximum stress induced in the material is 5.18 Mpa which is far below the maximum value of 100 Mpa hence the spring top is safe

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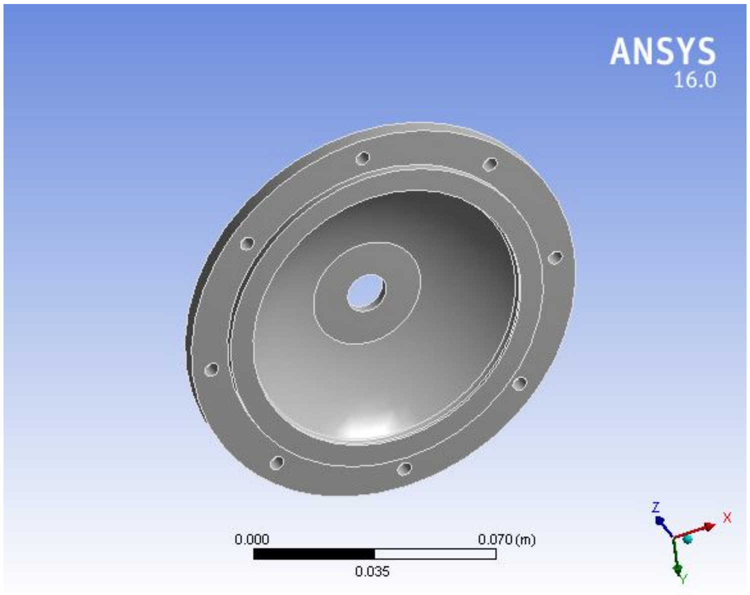
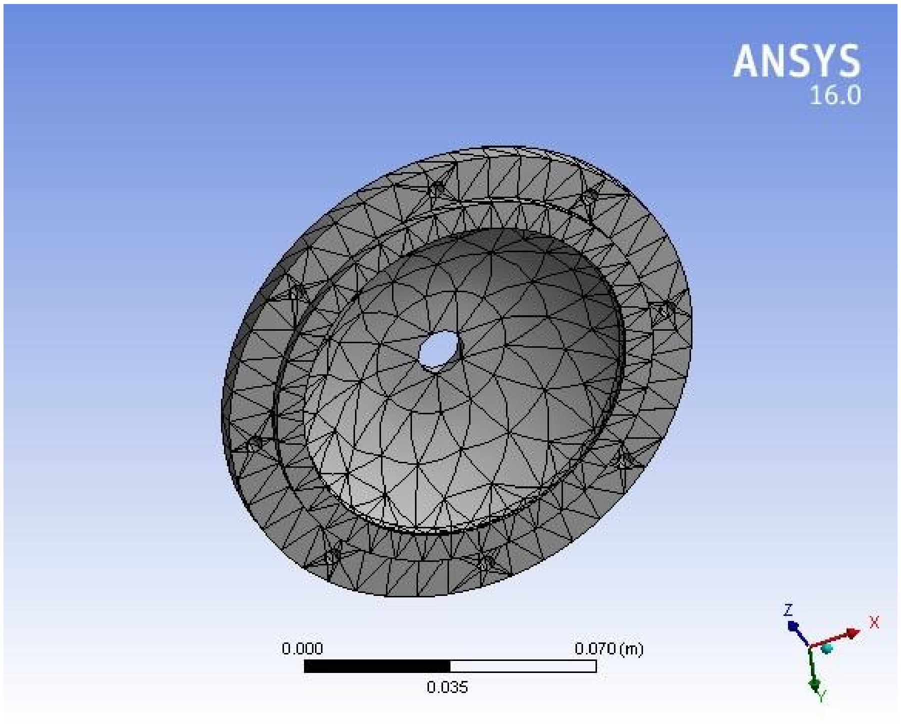
XI. ANALYSIS OF BOTTOM BELLEVILLE SPRING



Geometry was developed using unigraphix nx-8 and the step file was used as input to ansys



The meshing was done using ansys workbench free mesher

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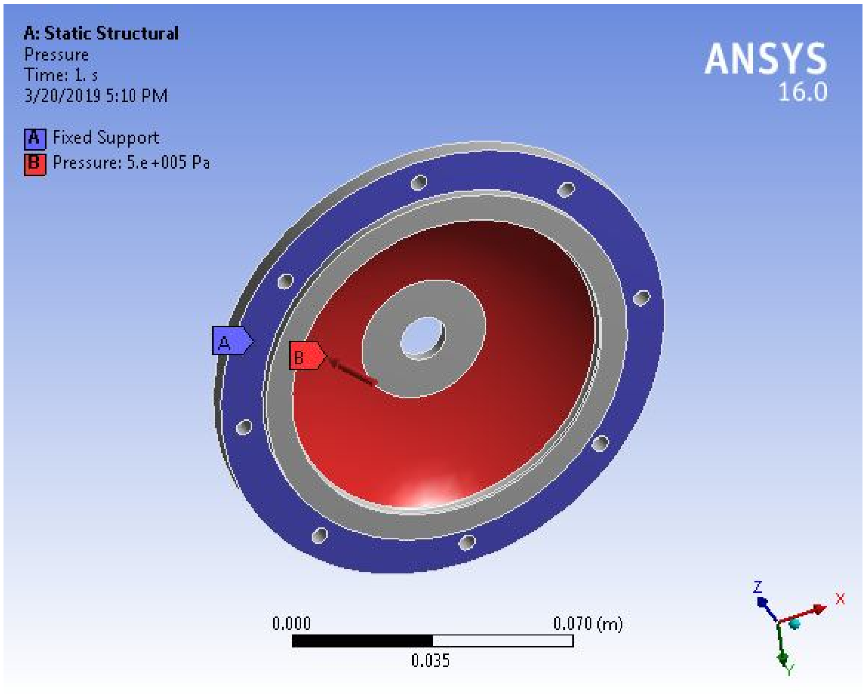
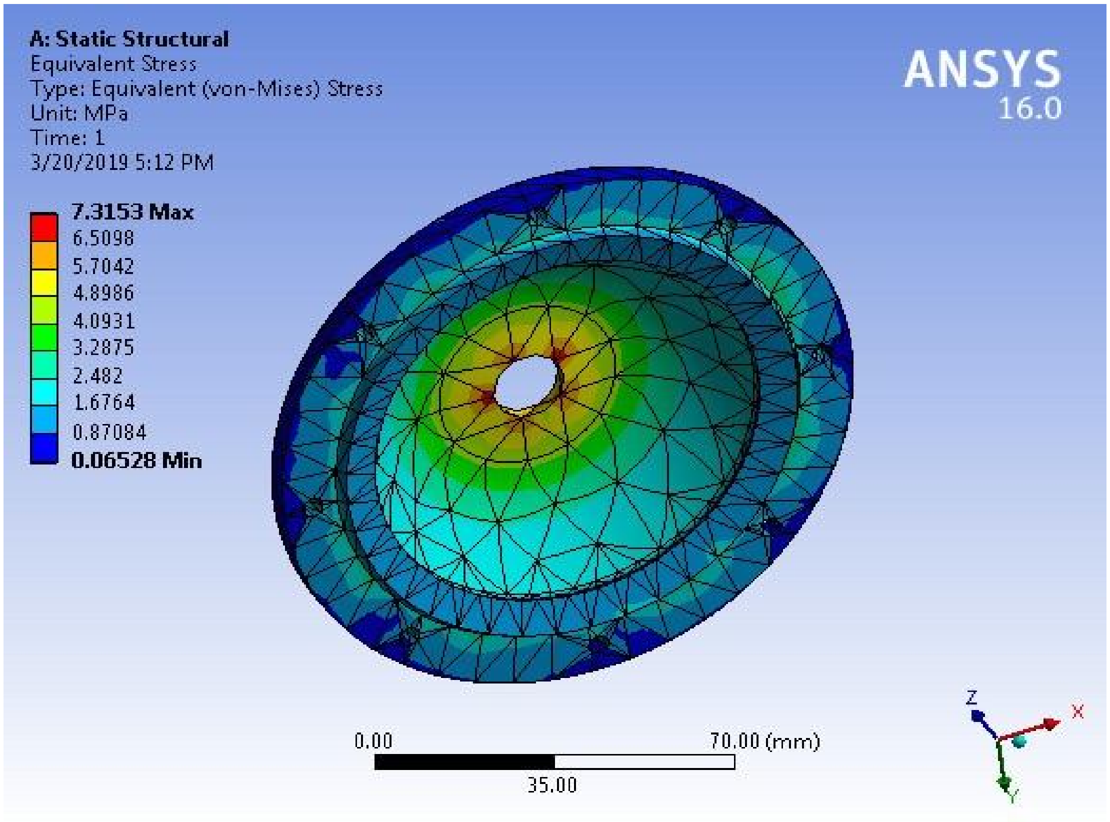


The loading was done as per the scheme shown above



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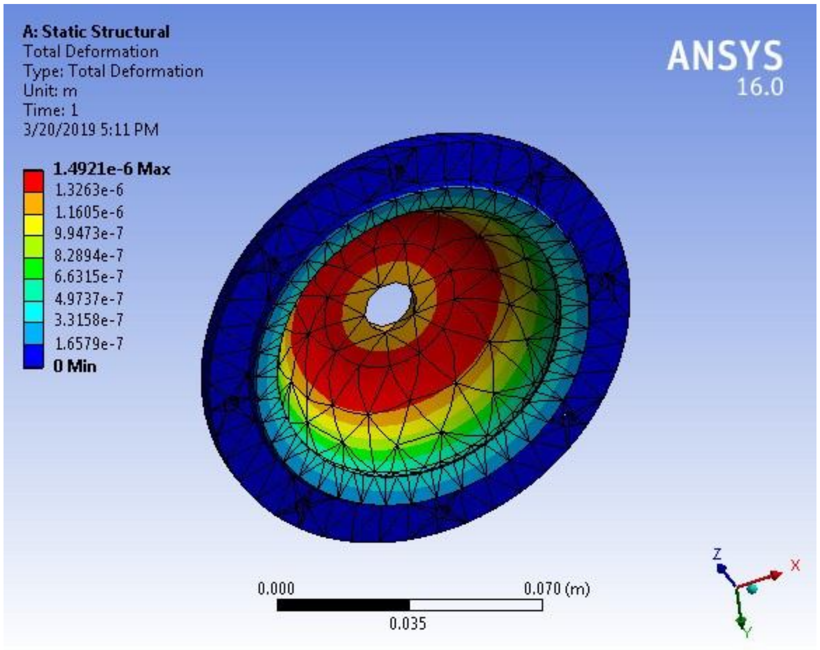
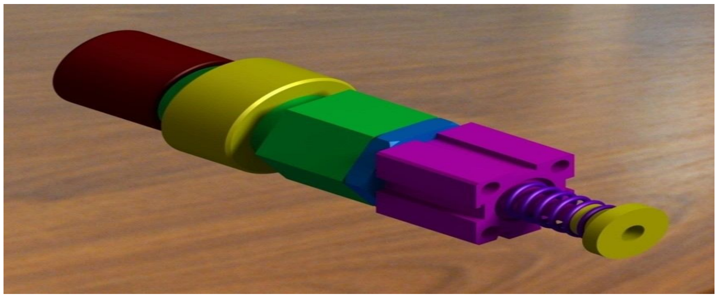
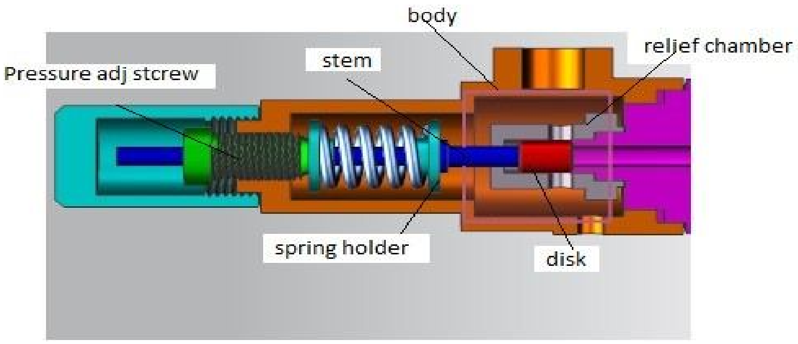


Displacement is maximum at red colored area. Maximum Von mises stress obtained is shownin Figure 4.6. As the analysis provides the results and under the loading condition, compression strength of Belleville spring is obtained. Static analysis is done by using the finite element method, in the figure blue color indicates the minimum stresses acting on the turns and red color indicatesmaximum stresses the maximum stress value is well below the allowable limit the design of the spring is safe. The total deformation shown is very negligible so the part is safe.The maximum stress induced in the material is 7.3153 Mpa which is far below the maximum value of 100 Mpa hence the spring top is safe The total deformation shown is very negligible so the part is safe.

XII. PRESSURE RELIEF VALVE





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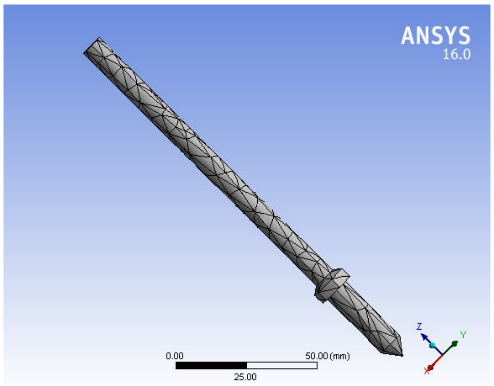
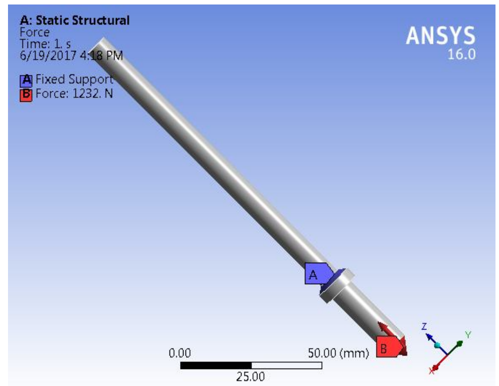
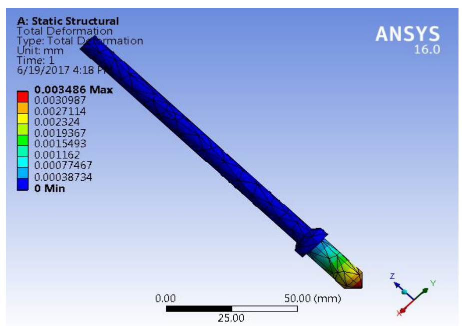
The key elements of the pressure relief valve are analysed in Ansys

1) Body of the relief valve
2) Pressure adjustment screw
3) Stem
4) Spring holder
5) Relief Chamber
6) Disk



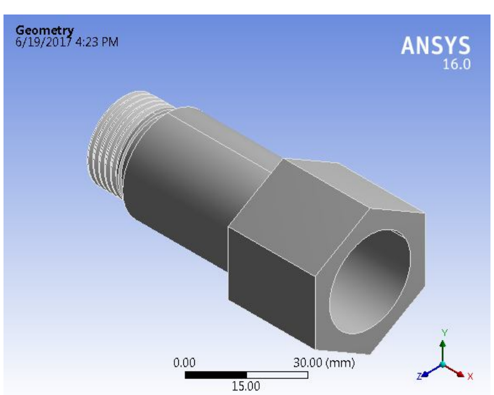


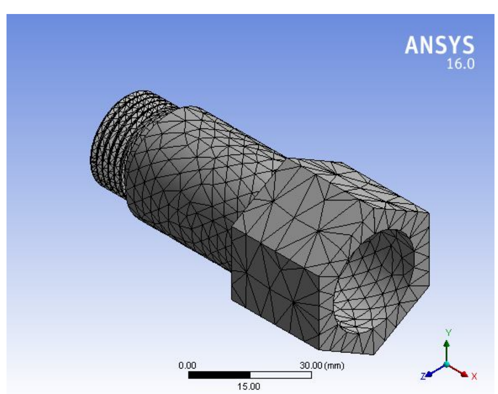


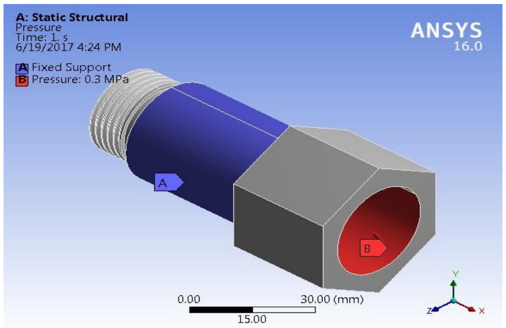
A. Analysis of Spring

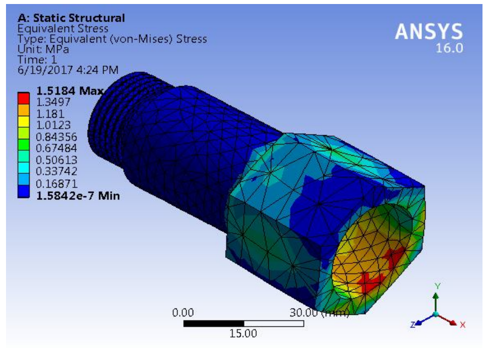
As the analysis provides the results and under the loading condition, compression strength of helical coil spring is obtained. Stress distribution of helical coil spring is as shown below in figure 4.10.In this case, static analysis is done by using the finite element method, in the figure blue colorindicates the minimum stresses acting on the turns and red color indicates maximum stresses themaximum stress value is well below the allowable limit the design of the spring is safe.

B. Analysis of Housing

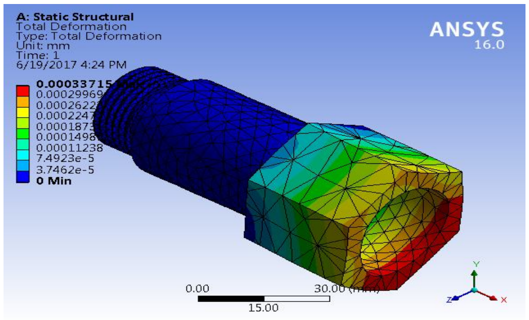


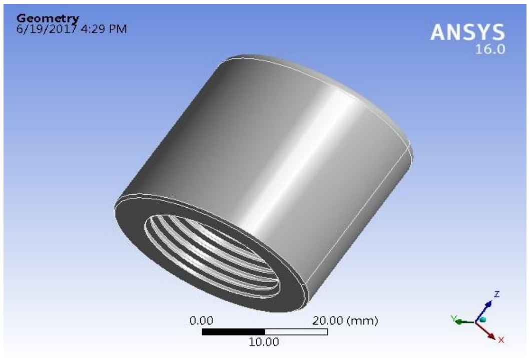


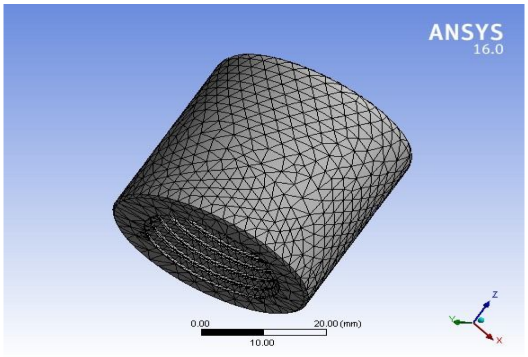


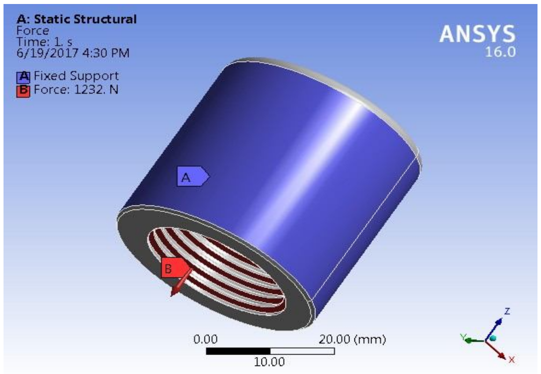


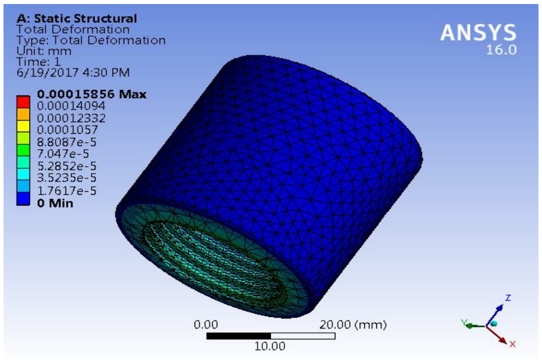
C. Analysis of Cap











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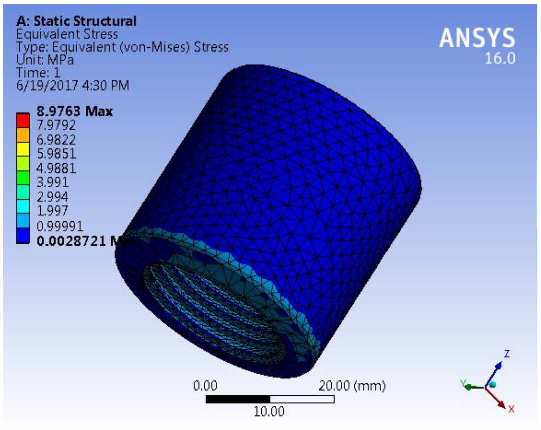
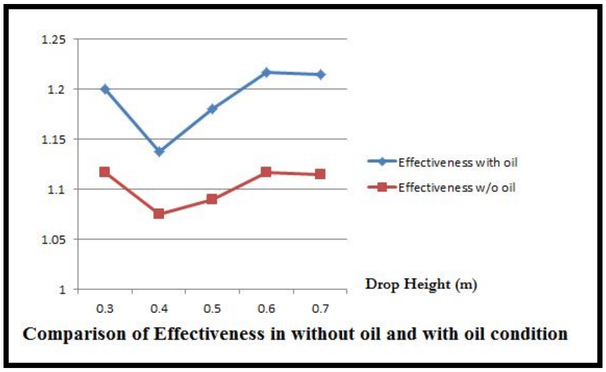


XIII. CONCLUSION



Comparision of Effectiveness with and without oil Pressure Relief Valve.

The Effectiveness Comparison shows that the damper is most effective with the oil filled condition at all drop heights hence it recommended to use the damper with oil.The graph of the percentage safety vs the drop height indicates that the maximum safety is of the order of92 percent when the drop height of 0.4 hence the corresponding speed of the vehicle will result into maximum safety when used with the composite damper

A. The collapsible bumper and hydraulic damper shows greater energy absorbed thanthe conventional system
B. Distance travelled after impact for the collapsible bumper and hydraulic damper is lesser than that of the conventional system
C. The percentage safety is more than that of conventional system.

The Project was successfully designed in two configurations namely the pressure relief spring and the disk spring model. The pressure relief valve is designed and all the parts of the system have being checked using Ansys.
The future work will be to design the disk, manufacturing of the relief valve and test of the components to develop and determine the results as per decide.
The present study has investigated the feasibility of including a supplementary energy- absorbing device into vehicular protective structures, namely, in mitigating impact loading. Validated FE models of empty and hydraulic tubes have been incorporated into a model to demonstrate the enhanced crashworthiness and energy absorption performances of the. A simplified hybrid model and detailed numerical models have been employed to examine the influence of varying the wall thickness of the conical tubes, foam density of filler and different roll slopes on the structural response of protective structures. The results from the study showed some interesting and important trends. The main finding and design guidelines from this investigation can be summarised as follows

1) Pressurised relief valve dampers are advantageous for use as energy-absorbers in ROPS system since they provide a relatively smooth load-deflection response without rapid fluctuations, which promotes stable, controlled deceleration as required during an impact event.
2) Pressurised relief valve dampers are effective in reducing the severity of the peak decelerations transferred to the occupants of the vehicle by increasing the contacttime during the impact. The effectiveness of reducing such decelerations up to 66% was found to be most pronounced.
3) The supplementary devices are able to absorb as much as 61.8% of the input dynamic energy of the rollover. This amount of energy absorption was found to be greatest for the thicker walled conical tube filled with high-density foam, which had more material volume available for plastic deformation.
4) The effectiveness of pressurised relief valve dampers as an energy absorber was most influenced by properties of the valve and Belleville spring for frontal impact mitigation.
5) The inclusion of a supplementary device considerably reduces the severity of the plastic deformation sustained by the and reduces potential for further rollover and their adverse consequences.
6) Incorporation of this energy-absorbing device is a very cost-effective solution for enhancing energy-absorption capacity and safety as inclusion of a very small component has significant influence on impact response of vehicular protective structures.

Overall, the inclusion of a supplementary energy absorbing device in the pressurisedrelief valve dampers has proven to be a cost-effective and beneficial solution that promoted an enhanced level of occupant safety by enhancing the energy absorption and reducing the amount of plastic deformation sustained by the protective structure as well as reducing the severity of the peak decelerations transferred to the occupant compartment during an impact event. The innovation of this study is the research information for facilitating the design of pressurised relief valve dampers tube as asupplementary energy-absorbing device for this particular case as well as its applicationto other heavy vehicles.

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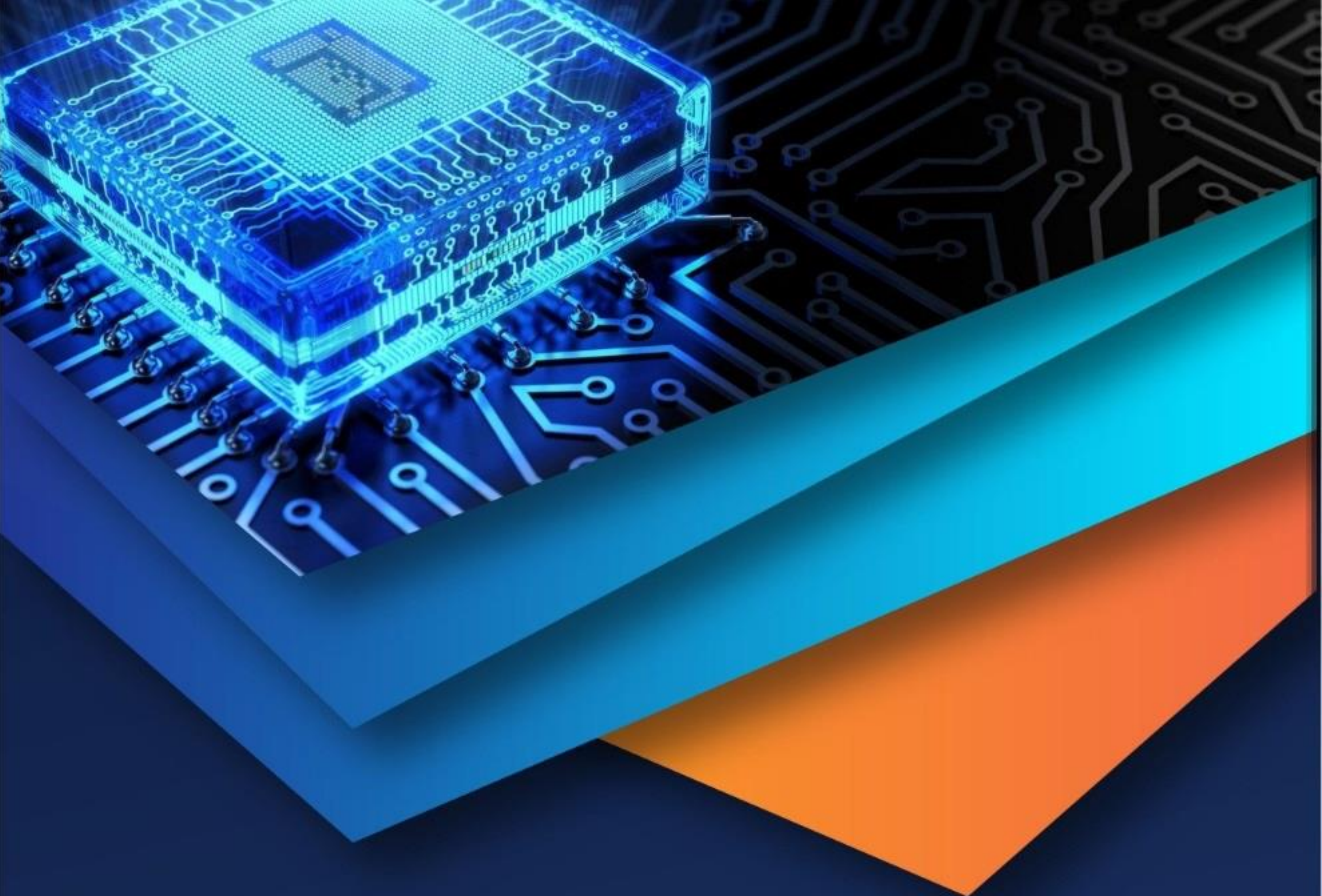

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