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Design and Development for Energy Absorber in Automobile for Low and Medium Velocity Impact

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Abstract - *The automotive industry has been quickly expanding as a result of new technological advancements. In addition, the number of traffic accidents and incidents has risen dramatically. The design of the bumper is one of the most important concerns for pedestrian and occupant safety. The goal of this project is to design and create a shock-absorbing bumper for the M1 category of vehicles that is simple to manufacture, environmentally friendly, and cost-effective. To reduce the transfer of impact force during a collision, several energy-absorbing materials such as honeycomb, foam, and compressive structures are tested. The bumper is modelled in CATIA, and simulation is performed with the ANSYS Explicit Dynamics Tool. Following fabrication, standard testing is carried out. With an energy absorber, the outcome demonstrates a reduction in the influence of energy.*

Key Words*: *Energy Absorber, Automobile, Bumper, Velocity Impact, Half Cylinder, Double Cylinder.

1. INTRODUCTION

Every year, hundreds of people are killed or critically injured as a result of crashes around the world. To safeguard the car's occupants, the car's structure must absorb the majority of the energy generated by collisions, prevent intrusion, and thereby prevent the compartment from deforming. To reach these conditions, both longitudinals must function together at the same time to absorb sufficient energy while keeping passengers secure. If one or both longitudinals are not loaded axially, the absorbed energy is reduced, resulting in bending. This results in two inconsistencies: the maximum energy must be absorbed by one or both longitudinals, and the energy absorbed by longitudinals in partial overlap or oblique collisions will not reach that of full overlap as indirect impact. It is required to create a rigid longitudinal member that can absorb enough energy in the event of a partial overlap and reduce or prevent bending. He also stipulated that the longitudinal be flexible in the event of an axial collision, in order to reduce too rapid deceleration.

1.1 Types of Vehicles

4 vehicle categories that are regularly engaged in real-world incidents are represented by four different vehicle front-end shapes (medium-size sedan, minibar, one-box truck, and SUV). As the medium-size sedan and SUV, the NCAC chose the Honda Accord (model year 2000) and Toyota Rav4 (model year 1997), respectively. Both models were created for frontal crashworthiness investigations, and they have to be adjusted to be used in pedestrian collision simulations.. The mass and inertia of the pieces taken from the frontal structure were aggregated into the extracted structure to make the model weights the same as the originals.

1.2 Frontal Bumpers

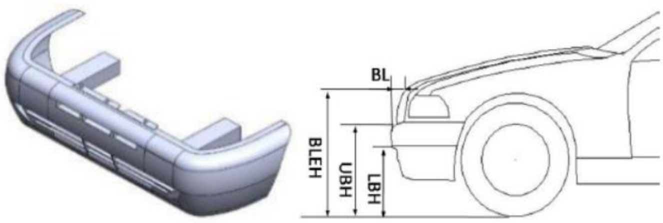

Fig -1: Terminology of Conventional Bumpers

In the diagram above, BL denotes bumper leading (cm), BLEH denotes bonnet leading edge height (cm), UBH denotes upper bumper height (cm), and LBH denotes lower bumper height (cm) (cm). A bumper system is made up of three parts: the fascia, the bumper beam, and the mounting brackets. There is usually a 70mm to 100mm gap between the fascia and the bumper beam, which can be used to increase safety by incorporating an energy-absorbing component. The goal of this project was to design and create an energy-absorbing bumper that would absorb impact energy during a collision. The fascia is the visible area of a bumper that is painted the same or different colour as the body and acts as a big portion of either the front or back of the vehicle. For strength and structural reasons, fascia is typically formed of thermoplastic olefins (TPOs), polycarbonates, Polyesters, polypropylene, polyurethanes, polyamides, or mixes of these materials with, for example, glass fibres.

1.3 Crush Boxes

The crush box is attached to the back of the front and rear bumpers. A crush box is one of the components in an automobile that absorbs the energy of a collision. The crash box will fold like a squeezebox when it collides, absorbing impact loads and reducing kinetic energy. In the event of a frontal collision, the crash box will absorb more energy by collapsing than the other body parts. It reduces the amount of damage to the bumper and mainframe, as well as saving the passengers from serious injuries. The Crush Box is a thin-walled structure that connects the vehicle's bumper construction to the side rail.

1.4 Energy Absorber

Crush boxes are less reliable in terms of safety, hence their energy absorbing efficiency is lower. As a result, in order to solve this problem, energy absorbers constructed of polymer materials are necessary. An energy absorber is a component of the bumper system that is located between the bumper fascia and the bumper beam. Metal, non-metal, or composite materials are frequently used. Only metal was used in the past. An energy absorber is a component of the bumper system that is located between the bumper fascia and the bumper beam. Metal, non-metal, or composite materials are frequently used. During the design of a car, the front bumper system may be a sophisticated energy-absorbing system that must meet both pedestrian safety and low-speed collision requirements. However, the pedestrian safety and low-speed collision design requirements for bumper systems are rather contradictory in terms of force and impact energy levels. Taking the foam bumper energy absorber as an example, the absorbers that perform well in low-speed impacts are sometimes excessively stiff when considering pedestrian lower extremity impacts because to the high force level. Things, on the other hand, are comparable. Furthermore, standard energy absorbers are typically an integrated structure constructed of thermoplastic polymer or foamed polypropylene (EPP) that may require total replacement due to area damage.

1.4.1 Need of Energy Absorber

- Energy absorbers fitted to the bumpers are one of the most effective of the new accident protection systems.
- This technology, which may be seen on the bumpers of new cars, is designed to absorb the energy from mild crashes by collapsing or crushing.
- This decreases the amount of physical damage to the car as well as the likelihood of significant injury to the occupants.
- Car bumpers are situated at a comparable height range on vehicles, ensuring that one bumper does not collide with another. In the case of trucks, a coffee bar has been installed on the back of the vehicles to create an impression. When these bars are hit, they shift a little, which reduces the amount of energy transferred to both vehicles.
- When a car collides with something at a low speed, the bumper will push backward to use the crumple zone to melt the impact since the fenders and foam absorb the energy. The crumpling of the bumper, fender, and foam reduces the amount of damage to the automobile and, as a result, the people inside it.

1.4.2 Material Limitations

Different materials are used to make the bumper absorbers. These materials differ from one another, despite the fact that they are all meant to reduce impact.

Foam: Because this is the most often utilised material for producing bumper absorbers, it's fairly easy to come by. However, because foam is softer than other materials, it does not effectively deflect energy from collisions.

Aluminium: If you're searching for something that won't add weight to your ride, aluminium bumper absorbers are the way to go. Unfortunately, because this material is difficult to weld and construct, the cost of aluminium absorbers is quite high.

Plastic: Plastic is another material utilised to make bumper absorbers. Plastic absorbers perform a good job of reducing impact, albeit they aren't as cheap as other materials. They do, however, crack with time as a result of wear and use.

1.5 Problem Statement

"To develop, analyse, and investigate the shock and energy-absorbing capabilities of an Energy observer component for low and medium velocity impacts experimentally."

A bumper system is made up of three parts: the fascia, the bumper beam, and the mounting brackets. This project focused on the design and development of an energy-absorbing bumper that may be installed inside the bumper beam to absorb impact energy during a collision. When a car collides, the frontal parts of the vehicle, such as radiator hoses, condenser arrangements, electrical wiring, and so on, are damaged and must be replaced or repaired. As a result, the cost of repairing the cost becomes more expensive for the person. As a result, an attempt is made to construct an energy absorber to overcome component failure and boost passenger safety.

1.6 Objectives

- Study of Energy Absorbing Composite Materials.
- Formation of Mathematical model for Impact Mechanism in case of Automobile

- Design and Development of Energy absorber component.
- Finite Element Analysis of Component for Low and Medium Velocity Impact.
- Selection of Cost-effective material which can be easily repairable or replaceable at low cost.

1.7 Methodology

1. Study of impact points of vehicles.
2. Study of energy absorbing components.
3. Design and development of absorber.
4. Simulation and FEA.
5. Optimization.
6. Simulation and FEA of optimized design.

2. LITERATURE SURVEY

The summarised structure of Literature Survey is the framework or synopsis of literature. In this part, all of the abstracts and points are listed and described in the order in which they appeared in the paper survey. The summary is a summary of the research data that has been collected and analysed, and it will be used to organise the dissertation. Following a thorough review of the literature, it was determined that the impact properties of glass polymers are superior to those of aluminium and metal matrix. The impact mechanisms for many aspects have been discovered, which will be beneficial to the dissertation. Different mechanisms for front and rear bumper studies are also investigated.

There has been a lot of research done on bumper placement design, but no research has been done on bumpers with energy absorbing capacity. The bumpers have been outfitted with c rush boxes provide better material energy absorbing capacity, but they do not provide better material energy absorbing capacity. Hence there is room for energy absorber design and development. This absorber of energy will have the same high energy effect as the crush boxes. Furthermore, aluminium matrix composites are used to assess impact strength. As a result, the usage of a polymer matrix can be incorporated in this scenario, and the qualities of E-glass, S-glass, and Carbon Fibre material have been discovered as a result of research.

3. MATHEMATICAL MODELLING

3.1 Methods of Energy Absorption

Honeycomb Structure: Honeycombs are superior at absorbing energy. Because the strength or energy absorbing capability of a cell varies with its size, a variety of combinations are frequently tested. A sandwich comprising two honeycombs of different sizes can also be used instead of a single honeycomb of a single cell size. This sandwich absorbs more energy than the two honeycombs on their own. Honeycomb structures come in a variety of shapes and sizes, but they all have an array of hollow cells produced between thin vertical walls. Out-of-plane compression and shear characteristics are both relatively strong. Racing Shells in sports, Aerospace Applications, and Audio Speakers are all made with these structures.

Double Cylinder Model: As an energy absorber, a double cylinder type with distinct compression stages is used. The number of stages is determined by how many cylinders are used. The two-stage compression is utilised due to space constraints and to make the energy absorber less rigid. It's easy to put together, and it can be replaced for a reasonable price if it is damaged. Although the energy capacity is less than that of Honeycomb, the model is implemented due of its inexpensive cost. Depending on the number and diameter of cylinders, the type of velocity can be changed.

Double Cylinder Model with Foam: The double cylinder type is filled with foam in this example, and two stage compression is employed to make the energy absorber less stiff. It is a low-cost method of producing the energy-absorbing component. Because it is simply a double cylinder packed with foam. The component is designed to withstand low-velocity impacts.

Double Half Cylinder Model: A single design with a double half cylinder model with 4 stage compression is considered to increase the compression stages and energy-absorbing capability. It is made up of two cylinders that have been split in half and welded together to make a double half section of the cylinder. This approach is less expensive than the twin cylinder variant, but it absorbs more energy.

3.2 Material Selection

Polymer-matrix composites (PMCs), metal-matrix composites (MMCs), and ceramic-matrix composites are three types of composites that are commercialised (CMCs). The character of the matrix material is supported by the popularity of the three fundamental types of composites (PMCs, MMCs, and CMCs). A matrix/fiber notation is used to support other categorization techniques. Aluminium reinforced with carbide, such as Al/SiC and 6061/SiC/40p-T6, and boron- and carbon-fiber-reinforced polymers (BFRP or CFRP), are also being employed. The Composites are used mostly for following advantages –

1. Light Weight - When compared to most metals, composites are lightweight. Their small weight is advantageous in aviation, because less weight equals better fuel economy.

2. Strength Related to Weight - The strength-to-weight ratio is the ratio of a material's strength to its weight. Steel, for example, is an extremely strong and heavy material. It is possible to design composite materials that are both strong and light. This feature is why composites are utilised to make aeroplanes, which require a material with a high strength-to-weight ratio.

3. Corrosion Resistance - Composites can withstand the elements as well as severe chemicals that can eat away at other materials. They can withstand harsh weather and drastic temperature changes when used outside.

4. Durable - Composite structures have a long lifespan and require little maintenance. We don't know how long composites survive because many original composites haven't reached the end of their useful life. Many composites have been in use for over 50 years.

5. Part Consolidation - An entire assembly of metal pieces can be replaced by a single piece constructed of composite materials. Reducing the number of pieces in a machine or structure saves time and reduces the amount of maintenance required over its lifetime.

The Current Study deals with the Design and Development of Energy absorber for the double cylinder and double half cylinder for polymers. Polymers, like metal matrix and ceramic composites, have a high energy absorption capability. Polymers are simple to manufacture and, because of their light weight, they lower component costs.

3.3 Impact Mechanism

3.3.1 Calculation for impact speed (S)

S = Km/h

And converting the speed into velocity,

V = S * (1000/3600)

Or

V = S * (5/18) m/s

Hence using this, velocity of object can be determined.

3.3.2 Impact Time (T)

When two or more bodies contact, an impact is a large force or shock applied over a short amount of time. A higher force delivered over a proportionally longer period usually has a bigger effect than a lower force applied over a shorter period. Impact resistance will be improved with resilient materials.

3.3.3 Vehicle Mass (m)

The kerb Weight of Vehicle = m1

No. of Passengers allowed = N = 04/05/06

Cumulative Weight of Passengers = m2

Cumulative Luggage carried by each Passenger = m3

Hence in all, the total weight of vehicle becomes, and the total mass of vehicle can be calculated as,

m= m1 + [N*(m2 + m3)]

3.3.4 Change in Kinetic Energy (K.E.)

The amount of work completed is equal to the object's change in K.E. The Work-Energy Theorem, or the relationship between Kinetic Energy and Work Done, is what this is. In other words, the change in an object's kinetic energy is the work done on it.

Mathematically we can say that,

W = Δ (K.E.)

W = 0.5 * m * v^2

Where,

M = mass of vehicle in Kg

V = Velocity of Vehicle in m/s.

3.3.5 Impact Force (F)

Impact force can be calculated as,

F = W/d

Where,

W = Work-done or Energy in Joules

d = Allowable tolerance for Displacement Produced in the Bumper in order to Ensure the safety for components and passenger.

3.3.6 Allowable Tolerance for Displacement

Between the facia and the bumper beam, there is around 80mm to 200mm of gap. As a result, the permissible displacement can be estimated to be 200mm.

In the instance of an automobile, the impact force may be calculated using the following mathematical equations for speeds ranging from 1 km/h to 120 km/h.

3.4 Selection of Impactor

The component that impacts or collides with the absorber is known as the impactor. As a result, Mahindra XYLO has been chosen as the Impactor in this circumstance. The rationale for choosing this vehicle is because it is an SUV and can carry a lot of weight. The Mahindra XYLO is available with two diesel engines. The diesel engine has a displacement of 2489 cc and a displacement of 2179 cc. It comes with a manual transmission option. The XYLO has a mileage range of 14.02 to 14.95 km/l depending on the version and fuel type.

Table -1: Specifications of Mahindra XYLO

Parameter	Value
Max Power	118.3bhp@4000rpm
Max Torque	280Nm@2400 Rpm
Overall Length (mm)	4520
Overall Width (mm)	1850
Overall Height (mm)	1905
Kerb Weight (Kgs)	1830 Kg
Gross Vehicle Weight (GVW)	2750 Kg
Body Option	SUV
Mileage (Diesel Fuel)	14.02 kmpl
Seating Capacity	8

3.5 Calculations

The Kerb Vehicle weight = m1 = 1830 Kg.
Cumulative Weight of Passengers = m2 = 80Kg
Cumulative Luggage carried by each Passenger = m3 = 20 Kg
Number of Passengers = N = 08

m= m1 + [N*(m2 + m3)]

m = 1830 + [08 * (80 + 20)]

Hence the total mass of Vehicle, m = 2630 Kg.

Consider the vehicle moving in the Direction with the speed of 25 Km/h,

∴ Impact Speed S = 25 Km/h

Velocity V= 25 * (5/18)

∴ Impact Velocity **v = 6.94 m/s**

Now, the change in Kinetic Energy can be calculated as,

K.E = $\mathbf{0.5 * m * v^2}$

K.E = 0.5 * 2630 * 6.942

K.E = 63335 Joules.

This kinetic Energy is the work done during collision, Kinetic Energy = Work Done. To overcome the amount of kinetic energy generated, there should be a displacement of car components. Since, it is a frontal impact let us constrain the maximum displacement to 200 mm for passenger and other major component's safety.
∴ Allowable tolerance for displacement, d = 200 mm = 0.2m

As we know, the work done can also be calculated as,

W= F * d
Or F = W/d
∴ Impact Force, F = 64000/0.1

F = 320 KN

Therefore, during the frontal impact the car experiences the force of 320 KN at the speed of 25 km/h. This Force is equal to 11 times the G-Force, which is fatal to human body.

Work Done (W) =64000 Joules

Table -2: Response Analysis for different Impact Speeds

No.	Impact Speed (Kmph)	Impact Velocity (m/s)	Work Done (Joules)	Impact Force (KN)
1.	25	6.94	63335.13	316.6757
2.	30	8.33	91246.4	456.232
3.	35	9.72	124239.1	621.1955
4.	40	11.11	162313.2	811.5661
5.	45	12.50	205468.8	1027.344
6.	50	13.89	253705.7	1268.529
7.	55	15.28	307024.1	1535.12
8.	60	16.67	365423.9	1827.12
9.	65	18.06	428905.1	2144.526
10.	70	19.44	496956.4	2484.782
11.	75	20.83	570563.9	2852.82
12.	80	22.22	649252.8	3246.264

4. FINITE ELEMENT ANALYSIS

4.1 Modelling of Components

4.1.1 Car Body

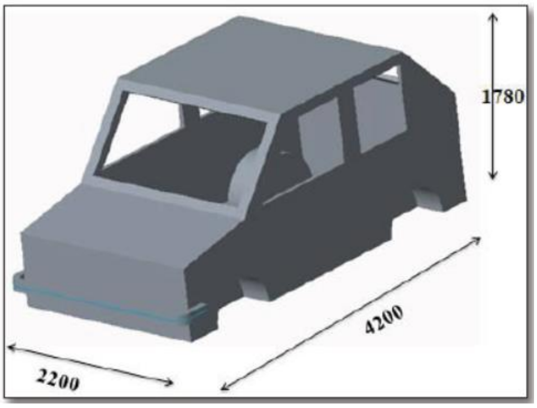

Fig -2: 3D Model of Car Body

The thickness of the body is specified as 8mm, while the length, breadth, and height are specified in Figure-2. Aluminum alloy is the material assignment for the car body, which is used for structural purposes.

4.1.2 Bumper Arrangement

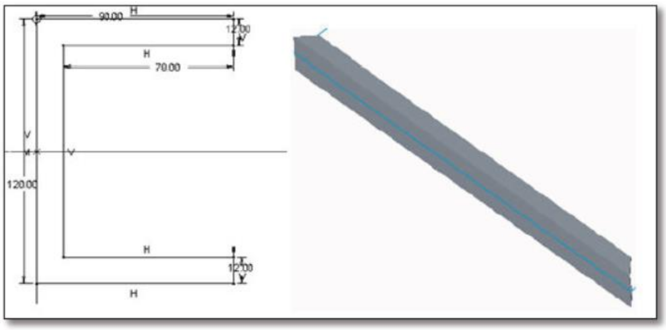

Fig -3: Specification of Bumper

The length of the absorber is kept as 2200 mm.

4.1.3 Half Cylinder Arrangement

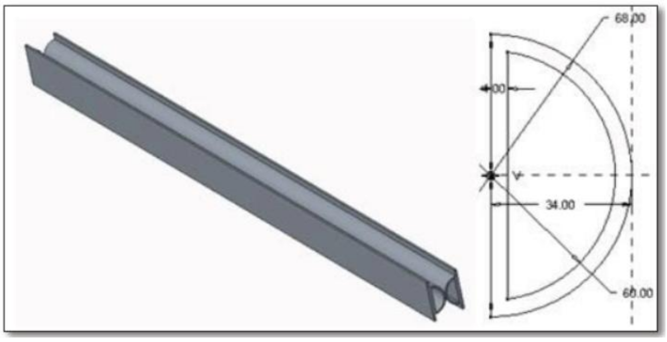

Fig -4: Specification of Half Cylinder Arrangement

The bumper is equipped with a half-cylinder energy absorbent model composed of S-Glass Polymer Fibre, with a length of 1600mm.

4.1.4 Double Cylinder

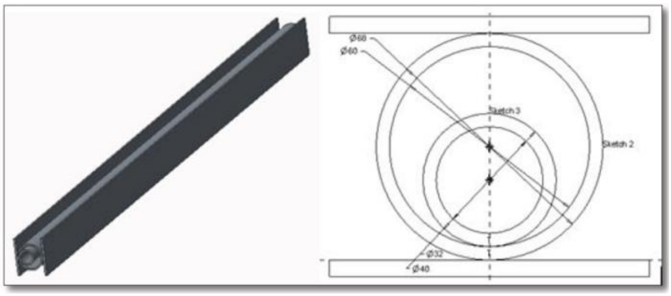

Fig -5: Specification of Double Cylinder Arrangement

4.2 FEA of Impact Analysis for Simple Car Body

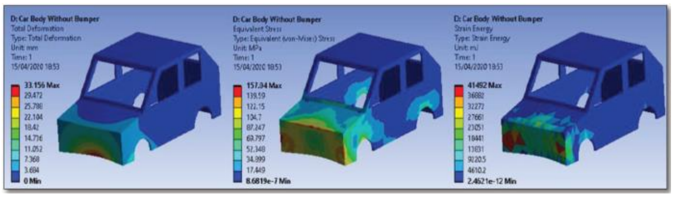

Fig -6: Analysis of Car Body at 50 km/h

The deformation states that if the car is hit with the appropriate force, it will dislocate 33mm in the direction of the vehicle, affecting other elements of the vehicle. This dislocation caused damage to the vehicle's forward components, which are particularly vulnerable. As a result, the deformation must be absorbed by absorbing the impact energy created during the contact.

4.3 FEA of Impact Analysis for Car Body with Bumper Arrangement

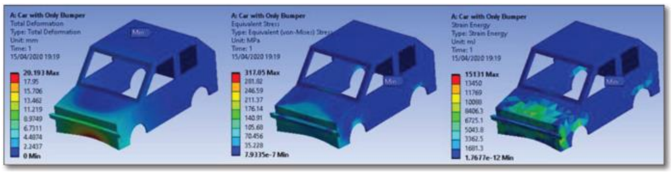

Fig -7: Analysis of Car Body using Carbon Fiber Bumper

The amount of distortion discovered is 20mm. The deformation in this conventional system is minimised as in the previous section, and the majority of the energy is absorbed by the fibre bumper, which works as a safeguard to the frontal portions in the partial efficient approach.

4.4 FEA of Impact Analysis for Car Body with Half Cylinder Arrangement

Fig -8: Analysis of Car Body using Half Cylinder Arrangement

The energy is absorbed in the component and partially reflected to the deformation in the form of 16mm in this system due to material characteristics and cross section of the absorber.

4.5 FEA of Impact Analysis for Car Body with Double Cylinder Arrangement

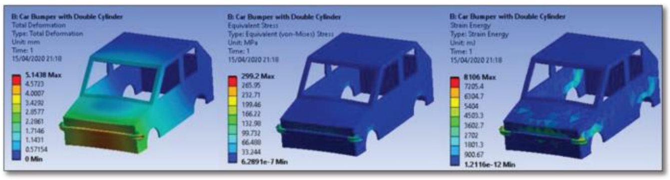

Fig -9: Analysis of Car Body using Double Cylinder Arrangement

The energy absorbed in this system is more than in prior occurrences, resulting in a 5mm deformation, which serves as the most important safety for the vehicle's frontal elements.

5. EXPERIMENTAL VALIDATION

Table -2: Experimental Validation

Impact Speed (kmph)	Deformation in mm			
	Half Cylinder		Double Cylinder	
	Experimental	Simulation	Experimental	Simulation
25	5.2	4.11	1.9	1.28
30	7.8	5.94	2.1	1.84
40	12.5	10.56	4.9	3.28
50	0	0	8.2	5.143

6. CONCLUSIONS

- The impact mechanism was created to prepare the forces of impact and impact energy, as well as to determine the strength of materials subjected to varying collision speeds.
- The double cylinder and double half cylinder models were chosen as energy absorber components because of their ease of manufacture, capacity, and low cost.
- Polymers are the best material to employ in order to acquire impact strength with minimal weight; thus, the polymers of S-Glass and Carbon Fibre have been explained with all of their features. For materials such as Carbon Fibre and S-Glass Fibre Polymer, a static analysis is carried out to determine impact strength.
- The deformation caused by the polymer composites energy absorber is smaller than that produced by a carbon fibre bumper and a body without a bumper, according to the FEA. The results of the double cylinder and half cylinder absorbers were found to be superior to those of the carbon fibre absorber.
- Under various impact speeds, a double cylinder design has been found to be a more impact resistant material. Under 40 km/h, the half cylinder failed, however the double cylinder continues to resist with slow deformation for 50 km/h.
- The double cylinder absorbs the most energy, proving that the energy does not transfer to the vehicle's front area, reducing jerks and shocks while also protecting the delicate components.
- The findings of static analysis; thus, dynamic analysis can be used to perform the results under various conditions such as concrete block, car impact, and pole crash.

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