Design and Fabrication of Active Hood Lift System

Rahul Nair Pappully[1], Hemanth Mandava[2], Manu Abhishek[3], Mr. Satish Kumar[4]

[1]Student, Department of Automobile Engineering, SRM University, Chennai, Tamil Nadu, India 603203
[2]Student, Department of Automobile Engineering, SRM University, Chennai, Tamil Nadu, India 603203
[3]Student, Department of Automobile Engineering, SRM University, Chennai, Tamil Nadu, India 603203
[4]Assistant Professor, Department of Automobile Engineering, SRM University, Chennai, Tamil Nadu, India 603203

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Abstract - *The majority of pedestrian fatalities and injuries are caused by traffic accidents. Many industries are striving for better protection of pedestrians by using an active hood lift system, rather than reforming the existing structure. Hence the main aim is to design and fabricate an Active Hood Lift system in an experimental model of a car.*

In this research, the active hood lift system is designed to enhance the performance for protection of pedestrians. The active hood lift system lifts the hood when the vehicle hits a pedestrian, thus mitigating head injury to the pedestrian. The hood is lifted using two double acting Pneumatic cylinders that are fixed under the bonnet/hood of the model. When the sensors that are fixed on the bumper detect a pedestrian crash, the pneumatic cylinders lift the hood instantly to a height of ten centi-meter thus creating space beneath the hood and providing a cushioning effect.
The following targets can be achieved.

1. *To reduce seriousness of pedestrian injury.*
2. *To decrease the vehicle damage during an accident.*

***Key Words*: Pedestrian Safety, Passive Protection, Future Airbag Technology, Active Hood Lift System(AHLS), Head Injury Criterion (HIC)**

1.INTRODUCTION

More than 270 000 pedestrians lose their lives on the world's roads each year accounting for 22% of the total 1.24 million road traffic deaths. Because of this problem, there has been increase in awareness of pedestrian safety and strengthening certain regulations and systems to reduce pedestrian injuries and prevent accidents. Pedestrian fatalities and injuries are mostly caused by traffic accidents. The pedestrian traffic accident is considered a social problem since it results in significant cost to society. More and more effort is still needed to ensure the pedestrian remains unhurt in case of a collision.

The primary reason causing pedestrian fatalities is head injury. In pedestrian traffic accidents, leg injury is about 60 per cent, and head injury is about 40 percent. Therefore, leg injury is 20 per cent higher than head injury. However, head injury is more serious because it causes 70 per cent of the fatalities because of obvious reasons of the brain being sensitive and that even a slight impact on the head can lead to serious circumstances.

The positions of the hood where the pedestrian head impacts are different due to the vehicle's shape/size, the impact speed, and the pedestrian's size. In general, because an adult is tall, the majority of adult cases have a head impact into the windshield and upper hood. On the other hand, because a child is small, the head impacts into the hood.

When a pedestrian traffic accident occurs, the pedestrian's head collides with the stiff points of the hood, which does not have enough deformation space to absorb the impact energy. The hood hinge, the washer reservoir, the battery terminal, the cowl, and the air cleaner housing reside below the stiff points of the hood. The injury level of the pedestrian's head at such stiff points is relatively higher than at the other points. The pedestrian's head is in grave danger at the stiff points of the hood. Therefore, the injury level must be lowered at the stiff points by eliminating the hard contact between the pedestrian's head and the hood.

The hood must absorb a significant amount of energy over a small area while precluding impact with the hard engine components, but there is limited space between the hood and critical components. The hood can be manufactured using energy absorbing materials but this again leads to extra material costs, redesigning and also due to demanding sleek design of vehicle.

Hence, the active hood lift system is one of the devices developed to reduce pedestrian fatalities and injuries from pedestrian traffic accidents.

The main role of the AHLS is to absorb the shock that would normally be transmitted to the pedestrian. This system makes the available deformation space of the hood at internal room by raising the hood for protecting pedestrian from colliding with hard structures like the engine. In particular, this system greatly reduces an injury of the pedestrian's head, which causes the majority of fatalities. This system has the advantage in that the vehicle becomes safer for pedestrians without redesigning the frontal structure of the vehicle.

The purpose of this research is development of the hood to reduce the head injuries in pedestrian accidents.

The main process involved in AHLS system for the project model fabricated is that when the sensors placed in the bumper of the vehicle detects a collision, the pneumatic cylinders placed under the hood activates and lifts it within half a second to a height of 8-10cm. This provides the cushioning effect required to reduce the seriousness of the injury.

1.1 Identification of Problem:

The accidents involving pedestrian have been rising considerately and more and more injuries are caused. Hence this kind of safety system was implemented to not only reduce the seriousness of the injury but also to decrease the damage caused to the vehicle in a pedestrian collision. Creating room under the hood is not always easy because usually there are other design constraints, such as aerodynamics and styling.

AHLS with Airbags proved to reduce the Head Injury Criterion value considerably.

Usually this system was implemented in Citroen C6 and Jaguar XK. Recently Volvo started rolling out this system with airbags i.e. Pedestrian airbags in their Volvo V40 car. Cars that have employed this system are Volvo V40, Subaru Impreza, Jaguar XF and XK and Land Rover Discovery Sport.

1.2 Major Impact Areas:

The major areas of the vehicle where the pedestrian's head usually hits are mentioned below.

- Parts of the bonnet with little deformation space beneath
- Lateral bonnet edge and transition area between bonnet and wing
- Bonnet area directly above the firewall
- Lower windscreen frame
- A-pillars
- Upper windscreen frame
- Roof frontal edge

Fig-1: Active Hood Lift System

All of these areas are characterized by stiff and hence less deformable vehicle structures. The degree of exposure of a pedestrian to these regions can differ from car to car because of differences in dimensions and styling.

1.3 Anatomy of Pedestrian Crash:

Most pedestrian crashes involve a forward moving car. In such a crash, a standing or walking pedestrian is struck and accelerated to the speed of the car and then continues forward as the car brakes to a halt. Although the pedestrian is impacted twice, first by the car and then by the ground, most of the fatal injuries occur due to the interaction with the car. The vehicle designers usually focus their attention on understanding the car-pedestrian interaction, which is characterized by the following sequence of events: the vehicle bumper first contacts the lower limbs of the pedestrian, the leading edge of the hood hits the upper thigh or pelvis, and the head and upper torso are struck by the top surface of the hood and/or windshield.

2. DESIGN OF MODEL

In order to protect the pedestrian's head from collisions with the car hood, the active hood system was implemented to soften such collisions.

This system consists of a hood that lifts at the rear when a pedestrian is struck by the car. In this case, the distance between the hood and the stiff inner parts of the car becomes wider, creating a larger degree of hood deformation when the hood is struck by the pedestrian's head. As a result, more impact energy can be absorbed and head injuries can be alleviated.

A simple approach was considered rather than implementing this system in a non-AHLS vehicle due to cost constraints. Hence, an experimental model was fabricated using Mild steel and sheet metal.

2.1 CAD Design:

The Computer Aided Design model was created using SolidWorks 2010.

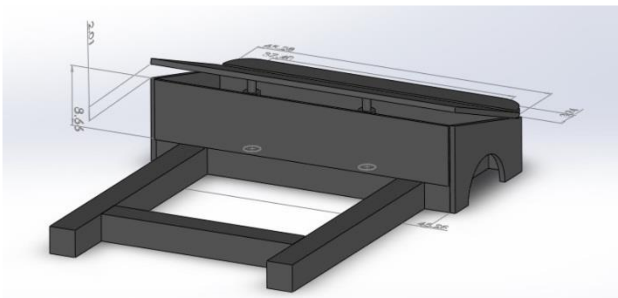


Fig-2: Rear view of the model

As we can see from the images, the hood is lifted to a certain height using two cylinders.

The front part of the model which consist of the bumper is fixed with three push type sensors which detects if the crash occurred involves a pedestrian or not. If yes, it instantly activates the pneumatic cylinders.

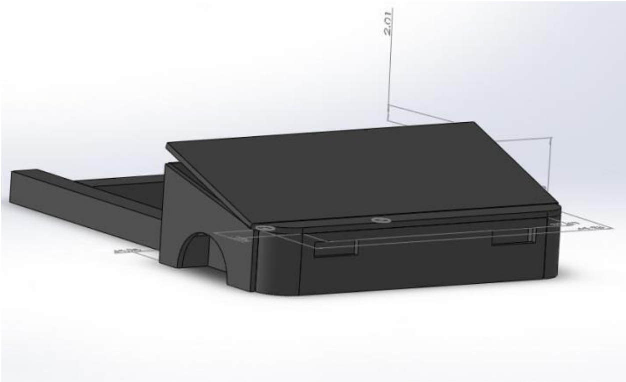


Fig-3: Front view of the model

Two long member and three shorts members are provided to support the bonnet, fenders, and bumper.
One cross member is used to support the actuators.
Specifications:
Length of the model = 1.62m
Width of the model = 1.19m
Height of the hood lifted=5cm (can be lifted to up-to 10cm)

2.2 Fabricated Model:

Considering the design prepared using SOLIDWORKS, a similar but much efficient model was fabricated using mild-steel and sheet metal.

Fig- 4: Top view of the model

Fig-5: Side view of the model

First, the chassis was fabricated by using mild-steel rods and then welded together to form shape. Then using sheet metals, the bumper and bonnet were prepared to the required dimensions. The bumper was fixed to the frontal part of the model by welding. Three holes were made to provide space for the sensors.
The bonnet was joined to the mild steel rod which is lifted by the pneumatic cylinder using hinges. Four dummy wheels are also fixed for demonstration purposes.
All the electronic parts were assembled and placed on a board which was then fixed to the model. All the wiring was done correctly and then soldered.
Two DC motors were fixed to the rear wheels and then connected to the battery and a switch. This was done so that the vehicle can move forward at a particular speed on its own by just using the switch.
Air tubes are connected form air compressor to solenoid valves and then to the pneumatic cylinders.
Air compressor provides compressed air ranging from 0.1 bar to 10 bar at 35 L/min or 210 L/min displacement.
The 12V battery provides sufficient charge for all the other electronics to function well.
A 5V regulator is provided so that none of the other components are spoilt. A 15-0-15 V,1A Transformer is provided to charge the battery using AC plug.
The wiring from sensors are connected to the connection board in the input and at the output, the wires are connected to the solenoid valve.
Hence, when the sensor gets activated, the electric signal from sensor is amplified using a 12V relay so that the required volts to activate the pneumatic solenoid valve is achieved. Due to this, the air from air compressor starts t flow into the valve and then to the pneumatic cylinder by which the pneumatic cylinders is activated and lifts the hood to a height of 10cm within milli-seconds.

3. COMPONENTS AND DESCRIPTION:

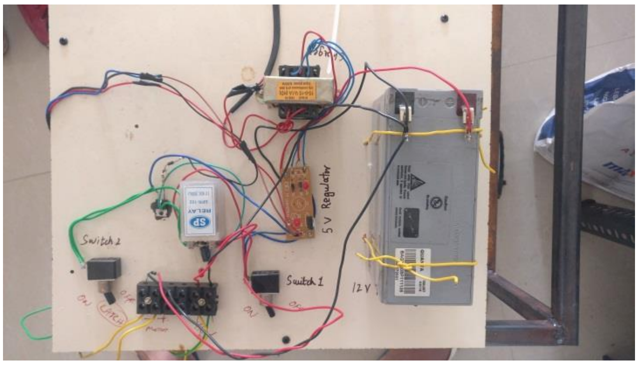


Fig-6: Electronic Circuit Set-up

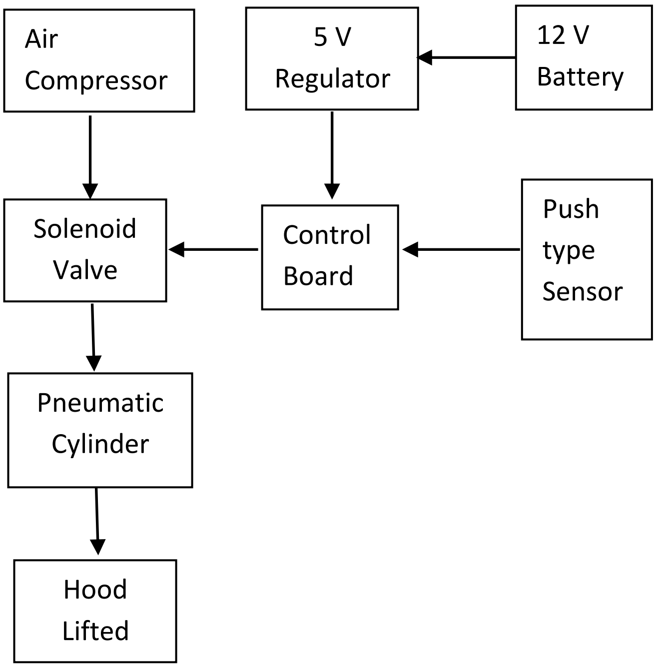
Sl.No	Part Name	Quantity
1	Pneumatic Double Acting Cylinder	2
2	12 V DC 7.2AH Battery	1
3	Solenoid Valve 3/2	1
4	Push type Sensor	3
5	Wire Connector	1
6	Switch	2
7	Relay 12V 200 Ω	1
8	5 V Regulator (IC 7805)	1
9	Plastic tube	3
10	Hose Connectors	3
11	3 Way Connector	2
12	Wheels	4
13	Board	1

Pneumatic Cylinder:
Stroke= 10cm
Bore Diameter= 20mm
Piston Diameter= 10 mm
Operating Pressure range= 1-10 bar
Operating temperature range= -20 to 70 deg Celsius
Three push type sensor are placed in the bumper.

4. WORKING MECHANISM:

The head of the pedestrian strikes the hood of the vehicle severely when a vehicle collides with the pedestrian at 30-45 kmph collision speed.
AHLS works by lifting up the vehicle's hood to obtain the space to absorb the impact energy just before the pedestrian's head hits the hood.
This system consists of three sensors fixed to the bumper covering the entire area. Two pneumatic cylinders are placed just beneath the hood at the front, allowing to open up from the windscreen side. When a crash occurs involving a pedestrian, the sensors placed in the front detect the crash and sends an electric signal to the wire connector board and instantly the hood is popped out to a height of 10cm i.e. the pneumatic cylinder is actuated. The lift height is controlled and limited so that the driver's visibility is not reduced.
A 12V Relay is provided so that the signal received from the sensor is amplified in order to activate the solenoid valve. When the solenoid valve is activated, the air from air compressor is passed on through the valve to the pneumatic cylinders, thus activating them and lift the hood. The entire process, i.e. detection of crash and actuation of pneumatic cylinder happens within milli-seconds.

The following flow charts explains the process easily



AHLS mainly works in coordination with other passive safety systems such as Pedestrian airbag, Pedestrian detection, radar, lane warning system etc.

5. CALCULATIONS

5.1 Pre-determined Parameters:

Velocity of pedestrian walking= 1m/sec to 1.8m/sec

Weight of pedestrian= Considered 70kgs

Actual weight of experimental pedestrian= 18kgs

Weight of entire model= 10-15kgs

Speed of car= 25-40kmph

Speed of experimental model= <50km/sec

Volume flow of air compressor= 35L/mi or 210L

Operating Pressure range= 0.5 bar to 10bar

5.2 Determination of Response Time:

As shown in Figure 7, the total response time (TRT) of the system which consists of triggering time and actuator deployment time should be less than the first contact time of head to the hood.

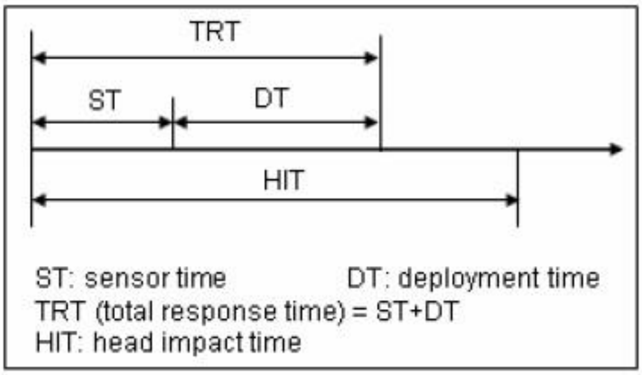


Fig-7: Total response time calculation

5.3 Time taken to lift at various Pressure levels:

Time taken for the pneumatic cylinders to lift at various pressure levels (bar) were measured using a stopwatch. The following tabular column provides us with the following figures

Sl. No	Pressure (Bar)	Time (sec)
1	0.5	Did not lift
2	1	0.042
3	1.5	0.039
4	2	0.027
5	2.5	0.016
6	3	0.014

5.4 Velocity of Pneumatic Cylinder:

Velocity of pneumatic cylinder can be calculated using the distance (stroke) and time taken to lift the hood parameters.
Hence, Velocity = Distance(m)/Time(sec)
Here, Distance= Stroke of the pneumatic cylinder i.e. 10cm
Therefore,
Velocity of pneumatic cylinders = Distance / Time
Velocity @ 1 Bar = 0.1 / 0.042 = 2.380 m/sec

Sl.No	Pressure	Velocity (m/sec)
1	1	2.380
2	1.5	2.564
3	2	3.703
4	2.5	6.25
5	3	7.14

5.5 Force exerted by Pneumatic Cylinders:

Force exerted = $P \times \pi/4\ (D^2 - d^2)$ Newtons

Consider,
Pressure, P = 1.5 Bar= 150000N/m^2
Bore Diameter, D=20mm
Piston Diameter, d=10mm
Hence,
$F=150000 \times \pi/4\ (0.02^2 - 0.01^1)$
$F=150000 \times \pi/4\ (0.0004 - 0.0001)$
F= 35.342 N
Hence, force exerted by one pneumatic cylinder is 35.342N
Therefore, force exerted by two pneumatic cylinders is 35.32 x 2 = 70.685 N

5.6 Force required to lift the hood:

Force = Mass x Acceleration due to gravity
i.e. F = M. A
Here M= Mass of the Hood= 3kgs
Acceleration due to gravity, g= 9.80 m/sec^2
Therefore, F= 3 x 9.80 N
i.e. **F= 29.4 N**
Therefore,
29.4N of force of required to lift the hood of the model to a certain height using Pneumatic cylinders.

CONCLUSION

Vehicle collisions befalls pedestrians a high fatality rate. Thus, various countermeasures to prevent accidents involving pedestrians and to lessen the severity of such accidents needs to be developed. This study focused on the injury reducing capability of pedestrian in a vehicular collision mainly focusing on head injury.

A series of tests were conducted and satisfied the criteria that the hood lifts well within the time the pedestrian's head collides. This proved to be vital as the seriousness of the injury will be reduced drastically.

Modification of the frontal structure of the vehicle can be a good solution to protect the pedestrian's head from pedestrian traffic accidents. However, satisfying the pedestrian protection regulations without modification is a better solution. Therefore, the active hood lift system has been developed to ensure sufficient space to avoid the collision of the pedestrian head with hard parts.

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