Smart Frontal Safety System for Automobiles

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Abstract: The focus of this work is to develop a new safety system in addition to reduce accidents for innocents in automobiles. When confronted with an accident, the only safety measure which we bet our lives on is "airbags". In several cases, airbags alone may not be able to completely protect the passengers in the vehicle due to the high magnitude of the impact. In the present work, a new safety upgrade will be modeled in vehicles to absorb the sudden frontal impacts while in motion. The ultrasonic sensors are placed in the front portion of the vehicle which is set to propagate and receive ultrasonic waves while moving. The change of distance from the sensor to the obstacle is monitored continuously and in the event of an emergency, the frontal safety system in the vehicle gets activated. In such an event, the bumper or a metallic formed plate is actuated forward to a certain distance and upon striking the obstacle, the impact force is then reduced by shock absorbers or springs provided in the safety system. Hence, the impact transmitted to the passengers inside the vehicle is less when compared to the direct impact.

Keywords: vehicle safety, front collision warning, shock absorb, DC motor triggering, PID controller.

1 INTRODUCTION

Frontal crashes in car accidents are most fatal as they move at greater speeds. When the cars collide on the front side, both the vehicle speed counts. If a car hits another car from the back, only the speed of the hitting vehicle counts. In several cases, airbags alone may not be able to completely protect the passengers in the vehicle due to the high magnitude of the impact. A frontal suspension system almost reduces the impact force available in the bumper. The triggering of the bumper to a certain distance is controlled by a electric actuator called DC motor which has high speed revolution. The initial torque is attained in very low time and high revolution is achieved to eject the system. The electric actuator is coupled with a pinion and the frontal suspension system is coupled with a rack. The rack and pinion ratio is considered as 2:1 where for one revolution of pinion, twice the circumference distance of pinion is achieved by the rack. The possibilities of system pop out in 0.04 seconds to a predefined distance is shown in the simulation. The system is able to absorb most of the impact force. The mathematical expression for electric DC motor corresponds to the angular velocity and the torque is found with some related constants. The magnetic flux and electric constant are considered to derive the mathematical model. The electrical energy is converted into mechanical energy which is monitored by the controller whether the system needs to eject or not. The certain conditions are monitored and sends signal to DC motor if required.

Prediction of accidents by sensors and indication process to alert the driver are performed before the collision happens. These frontal collison warning systems are in-builded in commercial vehicle

which are upto the level of alerting system [7]. The major frontal collison system are in conventional method, where there is no active system to monitor whether the collison is occurring or not and to control the mechanical system consequently. Vehicle crash detection is a preventive system to detect the accidents in prior and avoid collisions which cause major injuries to human beings. Fujii et al [8] has developed an embedded design logic framework to upgrade the vehicle warning system inorder to workout dangerous state that considers human behaviour. The vehicle crash sensor in the warning system receives the triggering signals which senses sensing algorithm must determine and evaluate the level of crash severity prior to the occurance of any damages [9]. Collision and accident avoidance systems has very important components for the automatic control system in advanced vehicles to intensify the safety and to enlarge the highway throughput [10]. To mitigate the crash severity by deploying the safety measure was introduced in the pre-crash safety (PCS) system in the time of collision occurs. But still it is very time consuming and costly [11] . Advance safety vehicle with the concept of ITS where it can operate in rough conditions also using an image sensor for crash detection was developed by Toyota Motor Corporation. However, Due to size of the sensor the experimental system faced challenges during mass production [6]. Development of new chases model with the front and rear suspension to absorb the impact force. In all ATV vehicles, this improves the safety system to save the cabin and driver[4]. the active element to move the seat backwards when the collision happens in such period this helps the passenger to be in the safer region to avoid the most of the vibrations. The active element senses the impact force and sends the signal to a micro-controller or a micro-processor which helps to move the seat backwards to a certain distance where the dashing of passenger's head and wind-shield can be avoided [5].

This paper presents an overall idea on the development of a vehicle crash simulator and its sensing to get better with the disadvantages and to further upgrade the robustness of a detection procedure. The hydraulic shock absorbers are deployed to take the sudden impacts. The measurement of collison was calculated based on the controller and sensing element, this process is derived mathematically using the vehicle speed and the distance of two vehicles or an obstacle. The sensors are placed in intended location very strongly for the performance requirements. In the present days, the approach to address the crash detection situation is precisely formulating using algorithms and ensuring the effects of the crashes. In the highways during peak travel periods, the vehicle crashes are most severe. The approach of the paper is to fuse the control system to the mechanical system and developing a active frontal shock absorbors. The forward method to fuse the systems is done in technical softwares. It is illustrated that the real time operation can be accomplished by system analysis.

2 METHODOLOGY

2.1 Controller for triggering the frontal safety system

2.1.1 Model of a vehicle collision

This model expresses the spring and damper integration to absorb the impact forces. The mass of the body and the velocity it moves are also considered mainly to identify the force acting on the body. The spring constant, damper coefficient, andmass of the body are mentioned.

2.1.2 Controller to eject the frontal shock-absorbing system

Bang-bang controller is a hysteresis controller that switches abruptly between two states. It gives output based on set value by comparing themselves. For example: if the set value is 80 with the function of greater than, the observed value is 81 and the output shows the input value if not it shows zero. This

controller is used to satisfy the major two conditions while the vehicle in motion and sends signals to trigger the entire system forward.

2.2 Style of Triggering the frontal shock absorbers

Based on certain conditions, the frontal suspension system has to be ejected at a particular time. The major two conditions are considered to illustrate the control system. The system needs to be active only when the vehicle moves more than 60kmph. When the distance between the front vehicle and the master vehicle is less than 1 meter while the master vehicle travels at greater than 60kmph, the signal of 12V to the DC motor is given to drive out the entire system in a shorttime.

2.2.1 Sensor and motor fro triggering the frontal shock absorbers

The ultrasonic sensor or infrared sensor needs to calculate the distance between the 2 vehicles and monitoring that continuously. A bang-bang controller is used to check whether the distance is less than 1 meter or not. it allows the power of 12V to DC motor and the motor spins at a high speed coupled with a pinion which helps the rack to move outside in a short time. The rack is engaged with frontal shock absorbs which move along with it. Triggering the DC motor on certain conditions to a predefined distance in less time. The vehicle takes 0.06 seconds to cover one meter and the system cast out in 0.04 seconds to 0.5 meters.

2.2.2 Mathematical Representation to the actuator

- The concept of explaining the triggering system in mathematical representation with a different mathematical model.
- Since we are using a controller to trigger the system in a short time. The mathematical expression for the DC motor is derived whether the required torque and required angular velocity are achieved.

Electric actuator(dc motor)

An electric motor is used to eject the system at a particular time. The rack and pinion system is considered where pinion is coupled with motor and rack is coupled with frontal shock absorbers. At a certain angular velocity, the ejection of the system to the distance in less time can be achieved.
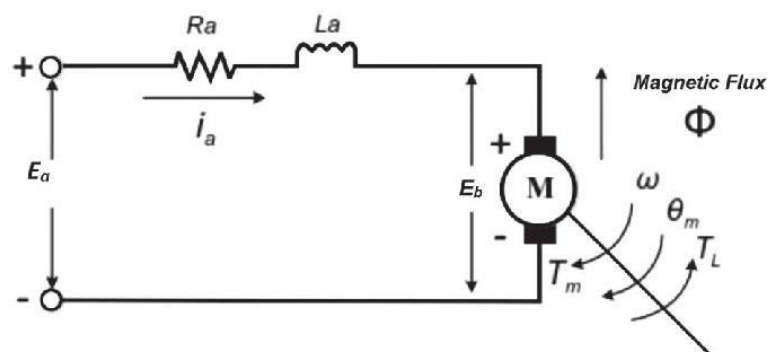

Figure 1: Electric circuit

The relation between linear velocity and angular velocity is used to find the speed of ejection to the defined distance.

Mesh equation fort the electrical circuit:

a. Angular velocity for the rack to reach the required value:

From the circuit diagram, $V_i = wk$

We know that, $V = IR$

Since the angular velocity (w) depends on input current and changes with respect to time. It is dw/dt. Equating both voltage values to evaluate the output current.

$$IR = k\ dw/dt$$

So, $I = k/R\ dw/dt$

The mesh equation for the electrical expression is formulated as

$$V_i\ (t) = Ri + L\ di/dt + wk$$

The current (i) in the differential equation always represents the output relation of a system. The derived value of current is substituted in equation.

$$V_i\ (t) = kdw/dt + Lk/R(d^2\ w)/(dt^2) + wk$$

The above equation is the differential equation for an electric actuator where current is the input factor and angular velocity and torque are the output factors.

Transfer function model:

A mathematical model requires the input and output of a system to integrate the result based action. Here, the transfer function model configures the input and output of any system. From the above differential equation, we should take Laplace transformation on both sides.

$$V(s) = k\ s\ w(s) + (Lk/R)\ s^2\ w(s) + k\ w(s)$$

Now the equation is simplified as,

$$V(s) = \{k\ s + (Lk/R)\ s^2 + k\}\ w(s)$$

The transfer function is determined as output function by input function

$$w(s)/V(s) = 1/\{k\ s + (Lk/R)\ s^2 + k\}$$

Where k is the electric constant,
The transfer function model is formulated as:

$$w(s)/V(s) = (1/k\{L/R\ s^2 + s + 1\})$$

This transfer function model gives angular velocity to the corresponding input voltage which can be converted to linear velocity by rack and pinion mechanism.

b. Torque calculation:

From the circuit diagram, **T = BI**

$$I = T/B$$

Where T is the required torque and B is the magnetic flux generated. The torque varies based on the time and depends on the input current.

$$I = (1/B)\ (dT/dt)$$

The mesh equation for the electrical expression is formulated as

$$V_i\ (t) = Ri + L\ di/dt + T/B$$

Substituting the formulated current which is related to torque.

$$V_i\ (t) = R/BdT/dt + L/B(d^2\ T)/(dt^2) + T/B$$

Hence, the differential equation for the electric actuator is derived.

Transfer function model:

Taking Laplace transformation on both sides.

$$V(s) = (R/B)\ s\ T(s) + (L/B)\ s^2\ T(s) + (1/B)\ T(s)$$

The transfer function is determined as an output function by the input function

$$T(s)/V(s) = (R/B)\ s + (L/B)\ s^2 + (1/B)$$

$$T(s)/V(s) = B / (R\ s + L\ s^2 + 1)$$

This transfer function model gives torque to the corresponding input current. Here, the mathematical calculation for angular velocity and required torque are derived.

c. Rack and pinion mechanism to drive the out.

The rotary energy from the electric actuator has to be converted into linear energy. Angular velocity from the motor is converted into linear velocity by implementing rack and pinion. The basic relation between the angular velocity and linear velocity is,

Linear velocity = Radius * Angular velocity

The ratio of rack and pinion is considered as 2:1 which makes the rack to move twice the distance covered by the circumference of the pinion. The pop-out time has to be much less than the speed of the vehicle. If the vehicle moves at 60kmph it takes 0.06 seconds to cover 1meter then the frontal shock-absorbing system needs to be popped out to the desired distance of 0.5m within 0.04 seconds. The electric dc motor with 1500rpm can achieve the movement of the system in our required time.

2.3 Simulation of the Triggering process by using MATLAB

To analyse the popping out of the system under certain conditions and simulate the electric actuator under the predefined conditions. The integration of the controller to satisfy these conditions in triggering the system forward is shown below.
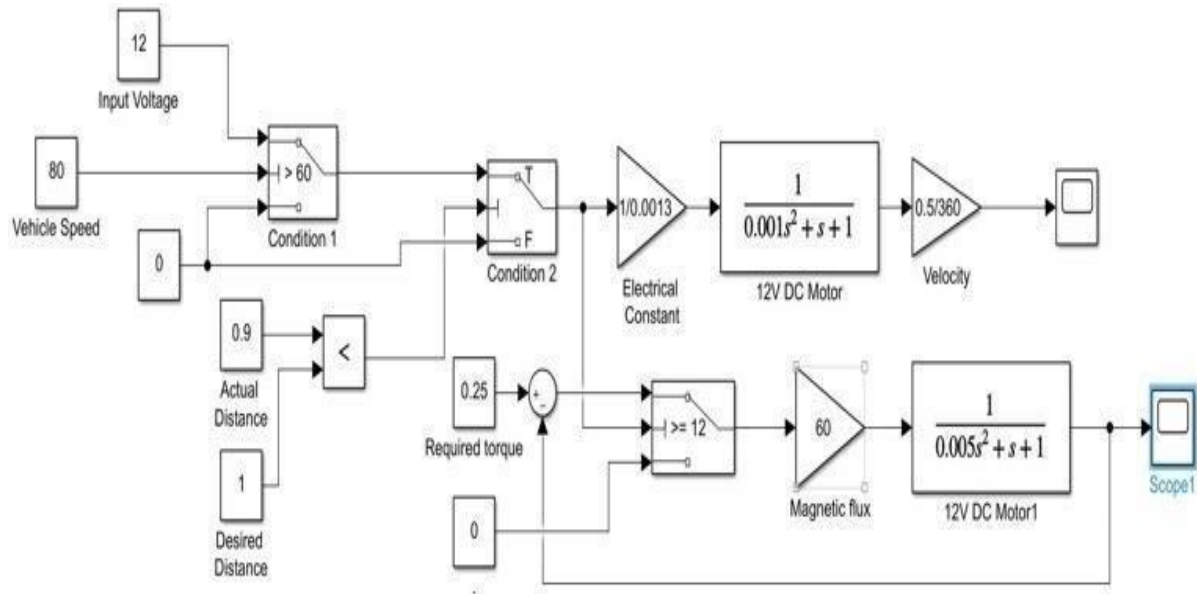
**Figure 2: Simulink model for triggering the system**

The value of the electric constant is calculated to imply with the transfer function. The constant after the transfer is converted as linear velocity by having a gain. Since the electrical actuator gives the revolution as the output, the rack and pinion mechanism is used to convert the angular velocity into the linear velocity.

3 RESULT AND DISCUSSION

This paper mainly concentrates on the controller part to trigger the mechanical system in a short time at high torque. The analysis process described in the work can reduce the failure percentage. With the measurements of elements, actual systems and their properties, the ejection speed of shock absorbers and impact force are determined. In considering the vehicle speed as 60kms per hour, it takes 0.06 secs to cover one meter. So, the system needs to eject within the consumed vehicle time. Here, we need the system to eject at 0.04 secs to 0.5 meters then the electric motor has to rotate at 1500 rpm.

3.1 TABLE(a):

TIME (s)	DISTANCE (m)
0.01	0.115
0.015	0.1784
0.02	0.2415
0.03	0.3663
0.035	0.498
0.04	0.5
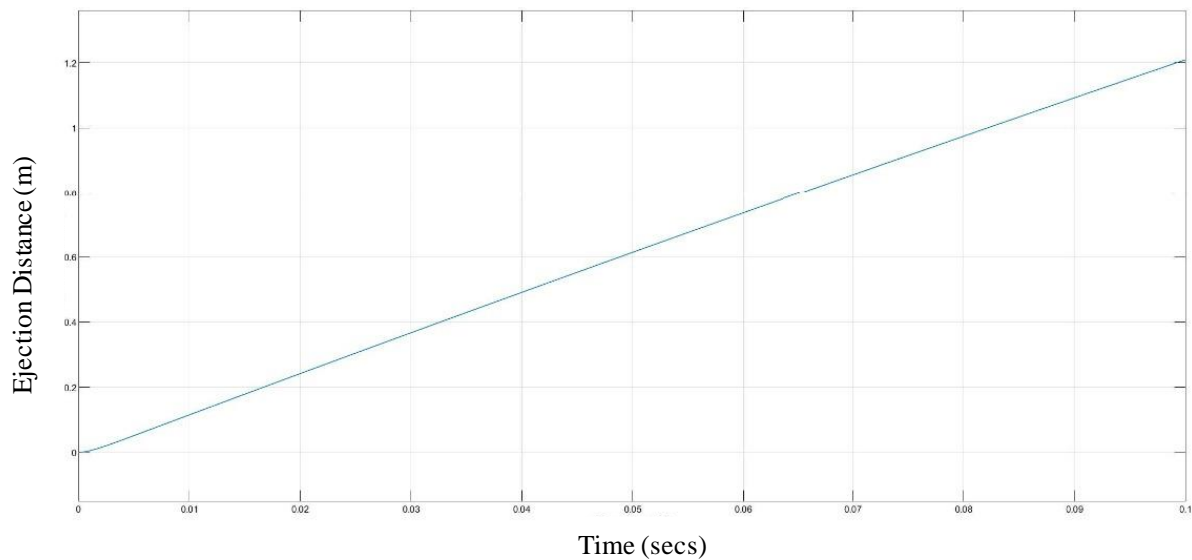
**Figure 3: The response of the system velocity (0.04 secs)**

The above table explains about the maximum distance covered by the mechanical system in the that time. The system can be extended in 0.04 sec to its fully deployed position. Hence, the accident can possibily happen only after the system is in prepared state. Moreover, the results also demonstrate that the required torque can be achieved in short time. The response shows that the system can be popped out in 0.04 seconds to a particular distance. The initial torque in the electric actuator is attained where the rack moves comfortably at high speed. In 0.01 sec itself, the required torque is crossed.

3.1 TABLE(b):

TIME (s)	TORQUE (Nm)
0.02	1.688 e-1
0.03	2.18 e-1
0.035	2.306 e-1
0.04	2.380 e-1
0.045	2.423 e-1
0.05	2.445 e-1
0.055	2.560 e-1
0.06	2.561 e-1

This table tells that the required torque is acheived to initiate the system. The mechanical payload is moved in linear motion. Here, the torque refers to the rack and pinion. So, the torque is going to move the shock absorbers at high speed. In the high speed of vehicle collision can cause severe damage to passengers and to the vehicle. Since the force exerting on the vehicle, the deformation or destruction occurs very quickly. The conventional system has no controllers to eject them at high speed. In our project, the PID controller is used to extend the system forward in a fraction of seconds. The controller can handle a adequate stability and acceleration. The mechanical system moves out before the accident confronts.

Time (secs)
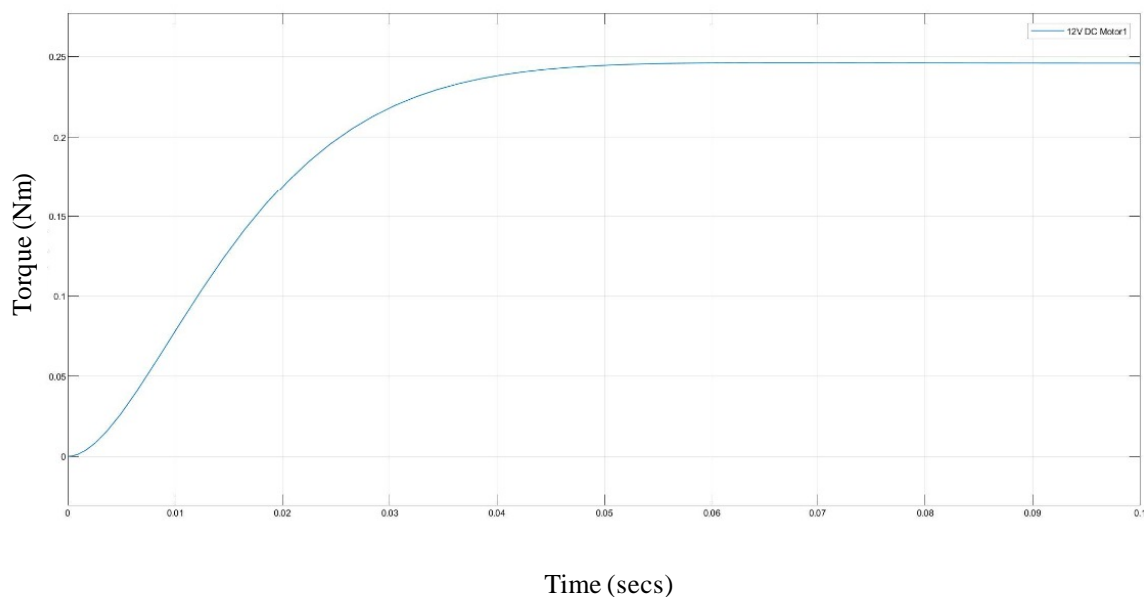
Figure 4: The response of the Triggering Torque

Every accident leads to severe injuries to passengers, the reason for this upgrade under certain premium parameters is to develop the safety system only to reduce the impact force acting on the vehicle. The vibrations are arrested by the frontal shock-absorbing system and reduces the major inconvenience to the passengers. The initial torque in 0.01 second and also the required angular velocity to simulate the system are satisfied. Some of them are discussing the frontal collision system acting in a passive method. Since there is no actuating element to trigger the system to a certain distance at a particular speed. The development of an active system for triggering the frontal shock absorbs[1].

The papers based on frontal shock absorbing system are highly concentrated on the collision warning and impact force development across the vehicle [1]. Analysis of energy absorption and vibration reduction in vehicle accidents. [2] The combination of springs and dampers in the vehicle bogies develops the complete shock absorbing when the collision occurs and the mathematical calculation gives the exact monitoring of vibration reduction. A paper based on adaptive smart front-end structure explains the dynamic model of the system and accurate prediction of the collision between vehicles [3].

Since a vehicle can move 1 meter in 0.05 seconds then the system should eject within it. The attainment of system excretion is derived in a mathematical approach and simulated based on certain conditions. The entire impact force cant be reduced to zero but almost the sudden forces and vibrations are managed to arrest. The passenger cabin experiences less impact force than the direct impact force. The triggering mechanism is explored at the required extent. Thus, in this project, effects and conditions of system ejecting is monitored and controlled.

4 CONCLUSION

This paper proposed a predictive safety system to reduce the impact force when collision occurs in vehicles. In this paper, the smart system for frontal shock absorbers was discussed and overcomed the conventional system. The combination of electrical actuator and mechanical system helps to drive out the system. The motion of the system is governed by a controller at high speed. The future work develops an entire subsystem for automobile safety upgrade and a controller assists it.

Furthermore, the applicable components will be added and functioned to get the results by using MATLAB. The methodology about fusing the control system and mechanical system will be carried out in following paper. In the development of future safety system requires a obvious practical model to minimize the errors.

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