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Improving Safety Features during a Head on Collision inside a Car Cabin

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Abstract*— The core theme of this research is directed towards the idea of providing more safety features inside a driver cabin when the car or the vehicle encounters a head on collision either with another vehicle or any other object. With the observations at various incidents, a survey states that one out of ten thousand vehicle under observation shows a case of air bags failure due to some glitch, when the air bags does not open even during a collision this leads to various injuries and sometimes death due to the air bags failure. During a collision there is a transfer of momentum which is the product of mass of the object and the velocity. It is sometimes also measured as the product of force and the time of application also known as impulse. Hence, greater the mass and velocity more will be the momentum. With the research it has been inferred that if we increase the time in which the momentum transfers from one body to another, it will produce lesser injuries and sometimes even no injuries at all even if the air bags takes more time than usual to open. This research will prove out to be a substantial solution for the air bag failure conditions and will make the driver safety more efficient.

***Index Terms*— Air bag system, collision, momentum.**

I. INTRODUCTION

According to a report by Association for Safe International Road Travel, on annual global road crash statistics nearly 1.3 million people die in road crashes each year, on average 3,287 deaths a day and around 20-50 millions are injured. Road crashes cost USD $518 billion globally, costing individual countries from 1-2% of their annual GDP. So what can be done to reduce this huge loss to both property and personnel? One of the solutions is to make design modifications in the driver cabin and also provide better safety devices and equipment to reduce the impact of the collision on the operator. This paper is directed towards fomenting a notion about the same. When an object with mass has velocity then product of both mass and velocity is known as momentum. Similarly, when a vehicle travels at some velocity, it attains some momentum. Now, according to the Newton's first law of motion a body will remain in the same state until and unless a force is applied on it to change its state and position. Hence during a collision, either with an object moving towards the vehicle from the opposite direction or with a still object, there is a transfer of momentum between the objects. The greater the mass more will be the momentum and the more the velocity the more the momentum. Presently to save the drivers and the passengers to receive any substantial injuries during the collision air bags are used. The air bags consist of a gas generator, polystyrene bag a controller which consists of two deceleration sensors. One of the sensors is automatic sensor known as the G-sensor and another one is mechanical. The air bags open up after receiving an output from the microprocessor and the controller. The sensors records the statistics of the decelerations of the car and have a threshold value, once the decelerations surpasses that value the air bags inflates and prevent any fatal injuries to the passengers thereby saving the lives of the passengers. But this paper intends to extrapolate this process. The impact of the collision can be reduced either by reducing the momentum and transferring it to any other object which is not feasible and practically possible or by increasing the time of momentum transfer thereby reducing impact of the collision on the human body.

A. How to prevent injuries during a crash?

During the mid 1960’s, the safety of a driver was quintessentially increased due to the introduction of air bags inside the cabin. The air bags open when the car hits an object or a moving vehicle. The air bags assembly consists of a gas generator, deceleration sensors, a microprocessor, and a flexible fabric cloth. The when the car hits an object the deceleration sensors senses a sudden and drastic deceleration. One of the sensors is automatic known as the G-sensor and the other one is a mechanical sensor. The Air Bag Control Unit process the various attribute of the impact and then send the signals accordingly. The Air bag system uses a gas generator which provides the gas that inflates the air bag. The gas generator contains the solid propellant that produces an inert gas which inflates the bag. The solid propellant has to be ignited for which various pyro-electric techniques are used. The pyro-electric technique refers to use of a conductor wrapped around a combustible material. When the conductor becomes hot, it ignites the combustible material which provides necessary heat for spark needed for ignition. Airbag systems

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contain a mixture of sodium azide (NaN_3), KNO_3, and SiO_2. Air bags on the side of the vehicle have approximately 50-80 g of NaN_3, with the larger passenger-side airbag containing about 250 g. Within around 40-45 milliseconds of impact, these three reactions take place producing nitrogen gas.

(1) $2\ NaN_3 \rightarrow 2\ Na + 3\ N_2\ (g)$

(2) $10\ Na + 2\ KNO_3 \rightarrow K_2O + 5\ Na_2O + N_2\ (g)$

(3) $K_2O + Na_2O + 2\ SiO_2 \rightarrow K_2O_3Si + Na_2O_3Si$ (silicate glass)

Hence, the inflated bag saves the driver and the passengers from receiving injuries and is one of the best safety features provided inside a car.

B. What happens during a collision?

When a vehicle encounters a collision its velocity declines drastically in a very short span of time generally in about (0.5-1 seconds). Hence, the kinetic energy as well as the momentum decreases. The following figures illustrate the graphical representation of the various changes occurring in these factors during an impact.

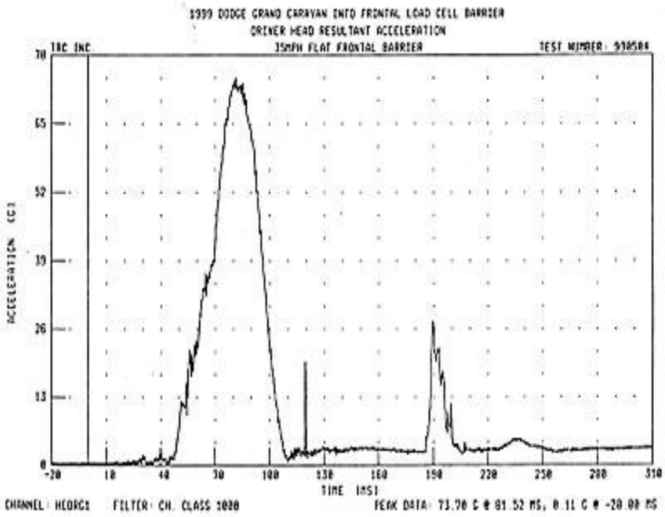

Fig 1 Crash test human head acceleration

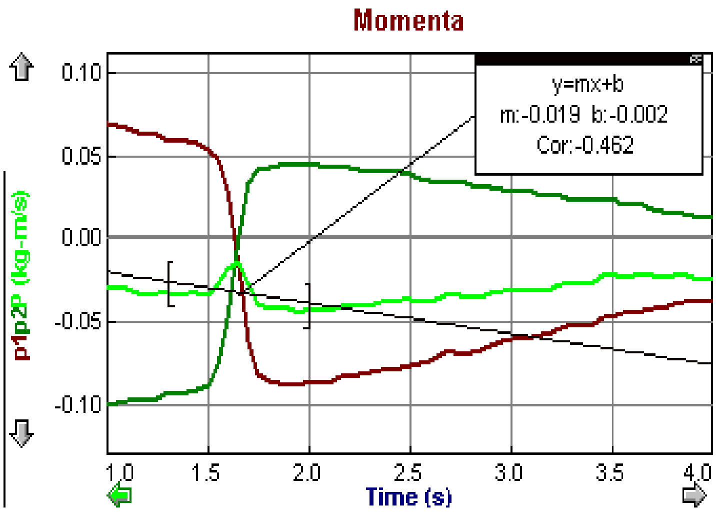

Fig 2 Momentum versus time graph during collision

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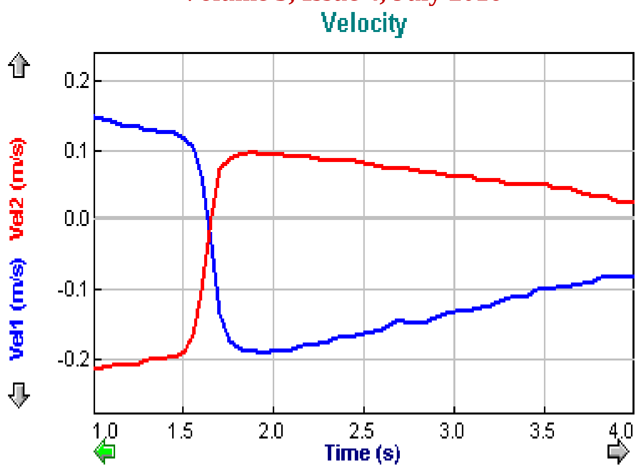


Fig 3 Velocity versus time graph during collision

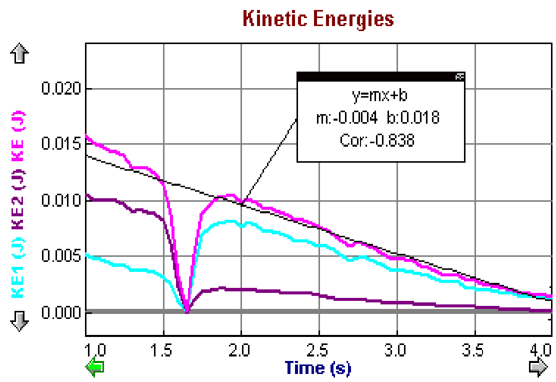


Fig 4 Kinetic energy versus time graph during collision

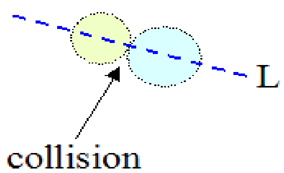
C. Mathematics of the collision

Let the car C_1 has a mass (m_1) and a velocity (v_1) and another car C_2 moving in the direction towards the car C_1 has a mass m_2 and velocity v_2. Let v be the final velocity after an inelastic collision, then: Initial momentum $P_1 = m_1 v_1 + m_2 v_2$

Final Momentum $P_2 = (m_1 + m_2)\, v$

Then according to the law of conservation of linear momentum considering one dimensional motion: $P_1 = P_2$: or $m_1 v_1 + m_2 v_2 = (m_1 + m_2)\, v$

Or $v = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$



L is the line of impact.

Fig 5 Collision of two objects showing line of impact

Kinetic energy equation: Initial Kinetic Energy ($K.E_i$) = $\frac{1}{2} m_1 v_1^2 - \frac{1}{2} m_2 v_2^2$

Final Kinetic energy ($K.E_f$) = $\frac{1}{2} (m_1 + m_2)\, v^2$

Hence, the loss of kinetic energy is given by: $K.E_i - K.E_f$

i.e, $[\frac{1}{2} m_1 v_1^2 - \frac{1}{2} m_2 v_2^2] - [\frac{1}{2} (m_1 + m_2) (\frac{m_1 v_1 + m_2 v_2}{m_1 + m_2})^2]$

For an inelastic collision, a factor known as the coefficient of restitution is used which is calculated along the line of impact. The coefficient of restitution is given as

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e = v2f - v1f / v1i - v2i
v1i is the component of the initial velocity of car 1, resolved along the direction of L.
v2i is the component of the initial velocity of car 2, resolved along the direction of L.
v1f is the component of the final velocity of car 1, resolved along the direction of L.
v2f is the component of the final velocity of car 2, resolved along the direction of L.

D. Limitations of Air bag System

The air bags deploy only once and deflate quickly after the initial impact so they are not an effective way to protect the passengers during a series of collision. The air bags sometimes get deployed by just a small impact which does not even damages the body of the car. Once deployed the air bag assembly has to be replaced they cannot be reused again. One of the major issues with the air bags is that after the deployment they do not effectively position the occupants in a proper and comfortable positions leading to sudden blows to the face.

E. What can be done to provide better security features inside the vehicle?

During a crash there is a transfer of momentum between the two bodies and also some amount of kinetic energy is also lost. The impulse defined as the product of average force and the time it is exerted is called the impulse of force. From Newton's second law Faverage = maaverage= m $\frac{\Delta v}{\Delta t}$
So, Impulse = Faverage Δt = m Δv
Overall the impact of a collision depends upon the average force and the time for collision. Furthermore, to reduce the effect of the collision either the average force has to be decreased or the time has to be increased. A real life example is when someone jumps from a height if the jumper bends his knees he will feel a very negligible impact after collision with the ground. The jumper uses the simple law that if the time of impact is increased, it allows the body to transfer the momentum for a longer time there by decreasing the chances of severe injuries and wounds. Hence, if there is a way we can allow the body of the occupant in the car to increase the time of collision with any surface the impact of the momentum can be reduced drastically.

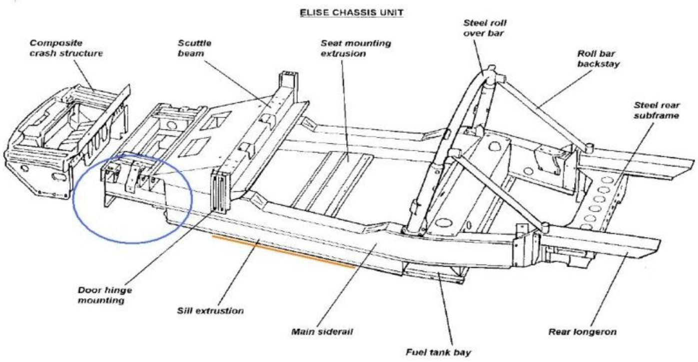

Fig 6 Skeletal structure of a car cabin

To attain this, a frame grooved with guide rails will have to be fitted on the chassis of the vehicle. The assembly uses two deceleration sensors the same as used in air bags system, a microprocessor, a receiver unit and a slider crank unit.

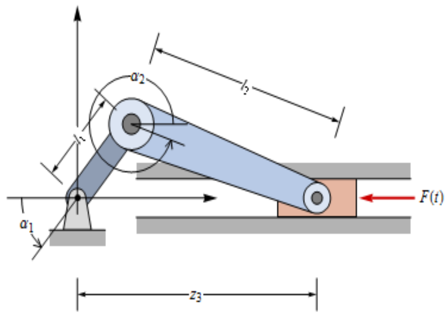

Fig 7 Slider-crank mechanism

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The threshold deceleration values of these sensors are kept higher than that of air bag sensors so that the backward and forward motion cycle can complete before the air bag deployment. Just before impact when the sensors sense rapid deceleration occurring in the vehicle, a signal is sent to the microprocessor unit. The microprocessor processes the whole data accordingly and then defines the limit to which the seats are to be moved backwards. After the processing of data, a signal is sent to the receiver unit which moves the slider-crank mechanism connected to the seats over the guide rails present on the frame. Milliseconds before the impact the seats move backwards on the guide rails. The motion of the seats is calibrated in such a way that when the seats move in the forward direction after going backwards, the air bags are deployed once the seat reaches its original position.

Fig 8 Position of the seats during operation

II. RESULTS

This allows longer time period for the momentum transfer and subsequently saving the occupants from receiving any substantial damage. The core concept is to provide longer time before the body comes in contact with any surface on the dashboard.

III. CONCLUSION

With the increased time of impact the injuries can be reduced and the human lives can be saved more efficiently. With this new design feature chances of occupants receiving substantial damage during a collision can be reduced.

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