A Study of Relation between Force and Acceleration Signals in Airbag Control by Single Pendulum Model

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Abstract

This paper uses a pendulum collision model to study collision in airbag system design and testing which overcome the disadvantages of the current airbag system testing process. The pendulum model used in this study can change the hardness, mass of the vehicle, collision velocity. In addition, the model can measure acceleration and force during the collision. The paper investigated the dependence of force and acceleration according to factors such as collision mass, collision speed, and equivalent stiffness of the vehicle to evaluate the model. These results can also be used in other studies to determine airbag control algorithm for different vehicles and collision conditions.

Keywords: Airbag, force sensor, acceleration transducer, collision acceleration.

1. Introduction

The current airbag studies are often focused to investigate the change of force and acceleration in the collision process to control airbag system and to study and select sensors, transducers and controllers could be found in [1],[2]. Control algorithms of the airbag system to improve the accuracy and speed of the operating system to ensure the exploding time within the allowable limits were presented in [3]-[5]. The force and acceleration parameters of the collision process play a very important role in airbag studies, since they are two parameters that directly determine the damage caused to the driver and the passenger [6],[7]. Therefore, the force and acceleration are also two parameters that are measured and included as the airbag control threshold. The process of measuring these two parameters play a vital role in the precise control of the airbag system. Therefore, the paper will focus on studying the change of force and acceleration in the collision process to determine the control threshold of the airbag system. In addition, actual full-scale crash tests to assess crashworthiness of vehicle is expensive and space consuming since they require the use of sledges or moving barriers to simulate the impact studies of airbags in real vehicles. In this paper, the study proposed a method to study the role of the force and acceleration signals in the collision process by using a single pendulum collision model. This paper presents the contents including how to build a single pendulum airbag research model, survey research process, results of the dependence of force and acceleration of collision according to the survey parameters and conclusion and research orientations in the future.

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2. Research Methodology

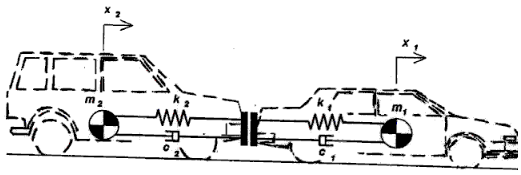

Fig. 1. Crash model

The collision process of the vehicle is described in equation (1):

$$\begin{cases} m_1 x_1'' + c(x_1' - x_2') + k(x_1 - x_2) = 0 \\ m_2 x_2'' + c(x_2' - x_1') + k(x_2 - x_1) = 0 \end{cases} \quad (1)$$

$$c = \frac{c_1 c_2}{c_1 + c_2} \quad k = \frac{k_1 k_2}{k_1 + k_2}$$

Because the collision process depends mostly on factors such as vehicle weight and chassis rigidity. These factors will determine whether the collision is soft or elastic collision. Therefore, studying accurately and calculating this process accordding to formula (1) is very complicated. In fact, airbag testing process is often simplified by the impact process of a vehicle with a hard wall. But this is still very complex and expensive, so the authors have proposed research based on a single pendulum collision model with parameters measured by the sensors through the testing process. Model is described in Fig.2. When using a single pendulum model, m_1 is converted to the weight of the vehicle, c is the body stiffness, m_2 is the mass of the second vehicle in collision, 1 and 2 stands for the load cell stands and the acceleration transducer, respectively.

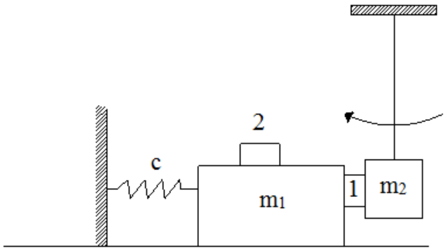

Fig. 2. Building a pendulum crash model

In this model, the body weight and stiffness are easily changed, the collision speed is changed through the collision angle (α) of the pendulum according to the formula (2) and L stands for the length of the pendulum :

$$v = \sqrt{2gL\left(1-\cos\alpha\right)} \quad (2)$$

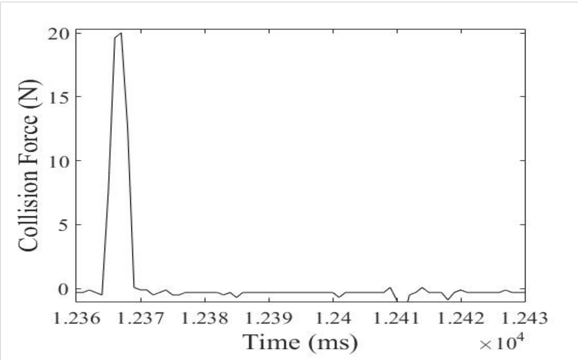

Fig. 3. Results of a force measurement

The force and acceleration values during the collision process are determined by experimental methods. In which, the impact force is measured by the loadcell sensor, the crash acceleration was measured by utilizing transducer MPU6050 No. 2. To obtain the ACU input threshold for the controller [8,9], the testing process will be carried out to collect and analyse data results. According to the various cases, the force and acceleration are investigated according to the crash speed, spring stiffness and impact mass m_2. During the experiment, the results will be sent to the computer as a set of data plotted as shown in Fig.3 and 4.

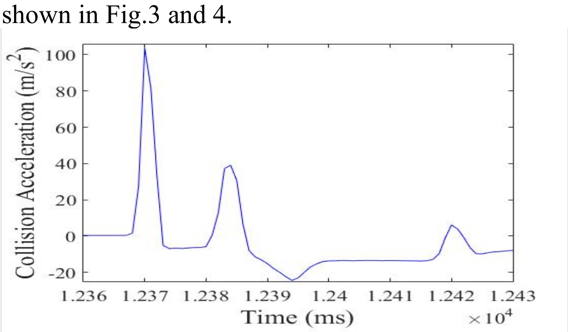

Fig. 4. Results of a acceleration measurement

From this investigation, the force and acceleration of collisions in the experiments will be sent to the computer and analyzed to observe the relationship of the force parameters and the acceleration of collisions with the investigation elements.

3. Results and disscution

The collision process is a complex process, so it is difficult to assess the accuracy of the two parameters used in controlling the activation of the airbag as the impact force and the impact acceleration measured during the experiment. In the process of designing the model, there was a problem that the force and acceleration depends on many external factors. This leads to the results of measurements using the simular parameters is diffirent. Therefore a method is still needed to evaluate the physical model used in the experiment.

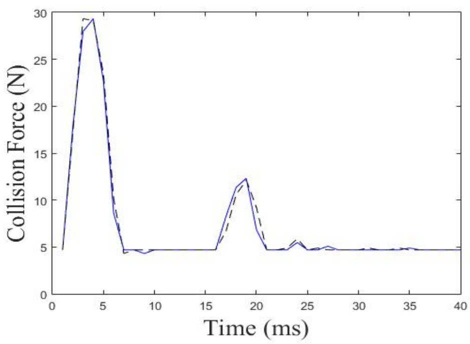

Fig. 5. The change of force with similar parameters

In order to assess the accuracy of the model, the paper conducted experiments several times at the same parameter *c*, m_2 and collision speed and then analyzed the variation of the output parameters, the results showed that between measurements, when the parameters of mass, stiffness and velocity are not changed, the results are similar in both the maximum and the profile values of the force graph and acceleration. The results are shown in Fig.5 and Fig.6.

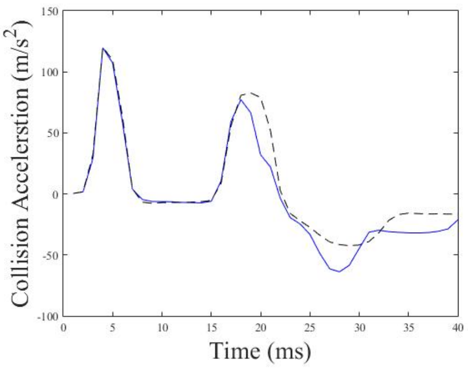

Fig. 6. The change of acceleration with similar parameters

In addition to studying the force and acceleration in collision processes, the paper investigated the dependence of two parameters according to the crash angle of the pendulum, spring stiffness and m_2 impact mass. These results are shown in Fig.7. To evaluate the more general relationship between force and acceleration of collision, the paper proceeds to arrange data sets according to the increasing force values and expressing on Fig.8.

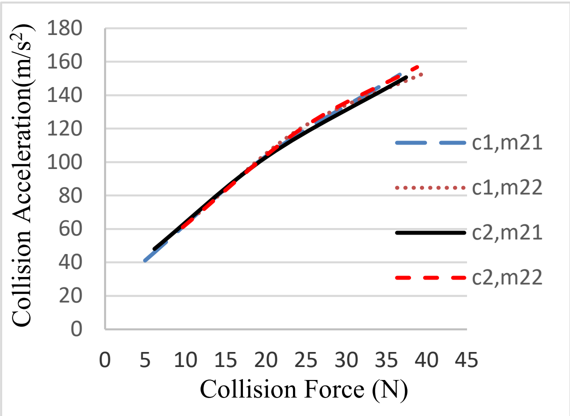

Fig. 7. The relationship of force and acceleration

From the plots shown in Fig.7 and Fig.8, it can be seen that the acceleration values depend almost linearly on the collision force values. Some points in the region of large force and acceleration do not fully follow this regulation, but it is not significant. These results also show that the relationship between force and acceleration does not depend on m_2 and c.

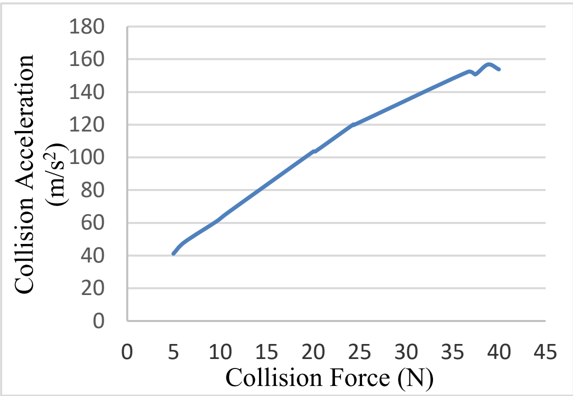

Fig. 8. The relationship of force and acceleration

The force and acceleration of collisions were also investigated when changing the stiffness and mass parameters then measured at different collision angles. After getting the force plot in accordance with different collision angles shown as in Fig.9.

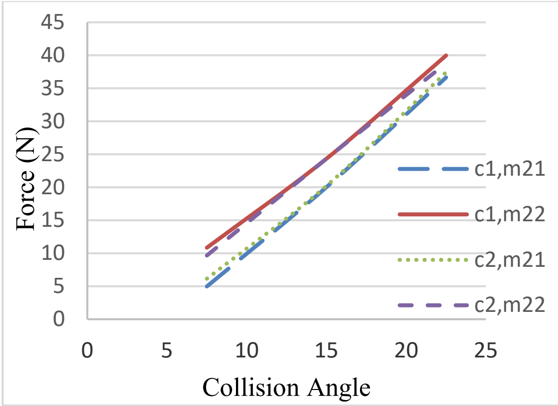

Fig. 9. The survey of impact force

The results show if the mass and collision angle increase, the impact force increases and if the stiffness increases the impact force changes negligibly. The effect of mass on the impact force is much larger than the stiffness. At small collision angles, the effect of mass and stiffness on impact force is much larger than collision angles.

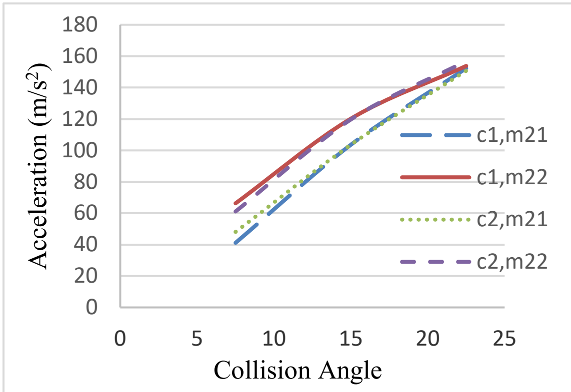

Fig. 10. The survey of impact acceleration

Collision acceleration also is quite similar to the impact force. Collision mass affects acceleration more than stiffness. At a small impact angle, stiffness significantly affects the acceleration and the increasing impact angle reduces the influence. This result is shown in Fig.10.

4. Conclusion

The results of the paper show that the model accurately reflects the relationship between force and acceleration in the collision process.The study illustrates the mass affects on accelerations and forces more than stiffness. In addition, the collision speed has linear effects on force and acceleration. The study also show that it need to research further to change the position and role of sensors in airbag control to improve accuracy of system. The model and results can be used to simulate the collision process with a certain percentage in studies which evaluate the dependence of force and the acceleration of collisions according to factors including frame stiffness, vehicle mass and collision velocity in airbag system studies.

Acknowledgments

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