Research on Collision Safety for Self-Driving and Electric Cars

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Research on Collision Safety for Self-Driving and Electric Cars

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1 Research goal

With the concern of environment issues and the rapid development of artificial intelligence (AI) technology, conventional fossil fuels vehicles will gradually lose the market-leading position, and electric vehicles, self-driving vehicles, and self-driving electric vehicles is taking over. No matter how the vehicle' mechanical control or body structure changes, the vehicle safety always is a top concern for users. A common design approach to enhance the crashworthiness of a vehicle is to make the energy absorbing device absorb kinetic energy as much as possible hence improving the safety of the driver or passengers when crash occurs. This approach also is considered to apply the technology to the application of daily necessities. Another approach to enhance the vehicle safety of a vehicle is to improve the prevent collisions of adopting AI technology in advanced driver assistance system (ADAS) to provide a driver with essential information during driving process.

2 Summary of the chapters

Chapter 1 Introduction

This chapter describes the background of this thesis, including the importance of energy-absorbing structures, the superiority of origami engineering and collision avoidance system, and then outlines the previous research results on the crash deformation mode and energy absorption performance of the strength member of vehicle and daily necessity helmet, and finally describes the purpose and research contents of this thesis.

Chapter 2 Crash energy absorbing member of the lightweight electrical vehicles by using truss core panel

In the electric vehicle, when the mechanical power systems such as propeller shaft or piping route are unnecessary and the front floor will be in flat shape, a new lightweight structure based on truss core panel (TCP) is designed to meet this requirement. To solve the problem of vertical bend during TCP was crash and improve the crash energy absorption as much as possible, the insert members on the both side are included in the proposed structure based on the TCP. Next, the response surface methodology (RSM) is used as the optimization technique. And then, in order to verify the superiority of the proposed lightweight structure based on TCP, the structure based on honeycomb core panel (HCP) is optimized and used to be compared. According to the simulation results, the structure based on TCP is capable of absorbing energy more than the one based on HCP at the same mass of structures.

Chapter 3 Crash energy absorbing member of the electrical vehicles by using pairing origami structure

In the electric vehicle, if the existing box-type is still used as the side member, there is a problem that though this side member has ideal collapse mode without Euler buckling, it cannot be collapsed more than 70% of its length because of its bulk and moreover, its initial peak load is sometimes too high. To solve these problems, two pairing origami structure, one is Tachi-Miura polyhedron (TMP), which has been studied extensively by the folding behavior for mechanical energy; another is Nojima polyhedron (NP), which is invented from a hexagonal origami shape independently. The geometrical characteristics of two pairing structures are discussed by parameters for the first time. In order to investigate the energy absorption performance of TMP and NP, these pairing structures are characterized by extracting geometrical parameters. By using the optimization method of Response Surface Methodology, the shapes of TMP and NP are numerically optimized respectively to seek the maximum energy absorption. As a result, in the bending mode comparison of TMP and NP, relative to the mirror symmetry structure of NP, there is a big vertical bend in TMP during the collapse deformation process, so the energy absorption amount of NP is more than that of TMP; in the comparison of NP and existing box-type side member, due to NP regularly deforms from the front to the end and the deformations reach 89%, NP the has relatively better energy absorption characteristic and the very smooth force is received; in the comparison of NP and RSC, even the energy absorption amount of RSC is more than that of NP, but NP has the advantage of manufacture cost, so an excellent energy absorbing member based on NP is the future challenge.

Chapter 4 Application to daily necessities by vehicle crash technology and origami structures

The goal of safety helmet is absorbing the impact energy and decreasing the impact force as much as possible, which is similar to the crash analysis of strength member of vehicle. In order to seek the requirements of being folded save and satisfying the safety performance, three type origami structures (cover structure, reversed spiral cylindrical (RSC) structure and honeycomb structure) are introduced to the design of safety helmet. Though geometric analysis, impact simulation analysis and structural optimization, the combination helmet structure composed of cover structure, RSC structure and honeycomb structure is improved. The proposed helmet made of cardboard totally satisfies the safety standards of working helmet with lightweight and can be put into a very small box of 300mm (length) ×150mm (width) ×50mm (height), where the helmet could be kept to save space. The validity of the analysis models is confirmed by discussing the differences between the analysis and the experiment, where the error is within 10% in the presence of irregularities in manufacturing and mounting.

Chapter 5 Preventive safety for self-driving vehicles by deep learning

From the previous chapters, the collision characteristics for self-driving and electric vehicle have been studied from the design of car component--energy-absorbing structure by using origami structures to improve the safety of protecting driver and passengers. However, from the perspective of preventing collision, except design of car component--energy-absorbing structure, the advanced driving assistant system (ADAS) has been practically applied in self-driving vehicles to help the driver in the driving process. Among them, the driver monitoring system (DMS) uses sensors to monitor driver attentiveness. In DMS, the driver's facial recognition is fundamental. Considering the superiority of convolutional neural network (CNN) in image classification, in order to improve the processing speed and identification accuracy, the deep learning which learns information directly from drivers' images is used to detect drivers' state instead of the machine learning which learns information based on facial feature points extraction. Because the deep learning needs large amount of image data to study the information for classification, however, it is difficult to get so many images like driver in the painful case, so an effective image processing method is developed to increase image data from existing facial expression data. The proposed method is trained by the AlexNet and GoogleNet in the Deep Learning GPU Training System (DIGITS) and shows the plasticity of improving the accuracy of facial expression recognition.

Chapter 6 Conclusions and future works

Finally, to sum up the above discussions, the research on collision characteristics for electric and self-driving vehicle is not just in crashworthiness of absorbing-energy structure design invented from origami-engineering by FEM analysis; in crashworthiness of monitor driver attentiveness by the driver's facial recognition with deep learning. And collision analysis method is used in the application of daily necessity safety helmet. The future works of the research are as followings:

(1) To extend the application of the foldable safety helmet by considering be used as the bicycle helmet.

(2) To improve the image recognition for automatic driving through the following two ways:

- One widely applicable database (Extended Cohn-Kanada Dataset) is introduced into test to confirm the applicability of the proposed data processing method.
- The DMS is developed by using correction method for shadows in the face and deep holographic neural networks (D-HNN) for modeling the normal/abnormal driver's face status under different lighting conditions and driver's appearances.