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REVIEW

Frontal crash simulation of vehicles against lighting columns using FEM

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KEYWORDS

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Abstract There are many severe and fatal crashes that result from vehicles colliding with street columns such as lighting columns. These cause extremely high impact forces and deformation on the frontal area of the car. The objective of the study is to demonstrate the frontal crash simulation of vehicle against lighting columns to examine injury risk and potential of safety. In particular, various FE models are used to perform contact–impact nonlinear dynamic analysis of lighting columns with vehicle. In this paper Abaqus explicit code is used to numerically simulate the crash of the vehicle with present columns and other lighting columns fabricated from a new suggested material. The acceleration, contact force and deformed energy at the frontal region of the vehicle are traced. It is found that the lighting columns with new suggested material have impact properties to decelerate the vehicle and absorb higher energy during impact.

Contents

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1. Introduction

There are a lot of utility poles, lighting columns and signposts in streets. These may cause many severe and fatal crashes that result in vehicles colliding with lighting columns such as street columns and street traffic lights. It is not matter that the accidents occur between vehicle and vehicle or vehicles and any objects like lighting columns. It is found that the existing lighting columns are fabricated from a material of higher yield strength steel. The characteristics of this material have higher static strength and lower absorbing impact energy. This means that the vehicle must absorb the remaining kinetic energy from the crash. The resulted high impact forces on such small area of the car to lead to high risk of injury as well as endangering the lives of the vehicle occupants.

In order that the occupants of the vehicle to survive a crash of this nature, it is necessary that the vehicle must be able to absorb the energy created during the impact which already achieved in modern design cars. Although modern cars are designed with composite materials that absorb most of the developed energy resulted from the impact, yet the risk of injury is still high. A new design of lighting columns that would dramatically sustain the impact energy has been proposed. The suggested design is aimed at reducing the internal energy that the vehicle absorbs during impact is a demand. Lighting columns have been created from a variety of composite materials [1]. Passive safety lighting columns are suggested to reduce possibility of injury crash by Ferrer et al. [2]. Many companies and organizations have carried out studies to improve passive safety of lighting columns [3]. Further research indicates the importance of material selection such as fiber-reinforced polymer composite materials [4,5]. Vialn et al. [6] proposed anchorage system of non-energy absorbing system. It is permitting the vehicle to continue running after impact with a limit reduction in speed. Elmarakbi and Fielding [7] developed five different support structures including a brake away base supported with anchor bolts fixed in a concrete base. Computer simulation of vehicle collisions has improved significantly over the past few years. With the advances in computer technology and non-linear finite element method, simulation of sophisticated crash is becoming more possible [8]. Frontal collisions using various FE models are used to perform contact–impact nonlinear dynamic analysis of lighting columns with vehicle as indicated in Ref. [9]. FEM crash simulations have been primarily focused on the vehicle models and their crash characteristics. In this paper, Abaqus explicit code is used to numerically simulate frontal crash of vehicle with lighting columns. The vehicle is assumed to move in right angle against the lighting column. The shape of the road, straight or curved road is not considered in this study. Main parameters influencing maximal deceleration value are found to be column shell thickness, outer diameter and material properties. Therefore, lighting columns with different materials and shell thicknesses are investigated. The resulted accelerations, deformed energies and predicted contact forces after impact are calculated. The results of the analyses are graphically presented and the predicted trend is found to be generally satisfied.

2. Finite element model

FEM is applied to simulate performance of contact–impact nonlinear dynamic analysis. The applied FEM simulation encompasses a number of individual problems, which should be given appropriate attention. These problems are:

a. The selection of a mesh and type of element, which should be fine enough, especially at the frontal contact areas to acquire accurate results and to represent real simulation during impact.
b. Totally about 6000 elements have been generated in the entire model where the smallest size of the element is about 0.01 m in the front contact area (bumber–radiators–hood and front doors). Coarse mesh may be applied for areas located far from collision region to reduce CPU time.
c. ABAQUS/Explicit Version 6.9-4 code is used to simulate the impact of vehicles with lighting columns. The vehicle and lighting columns are modeled using four nodes, thin shell double curved elements (S4R). The contact surface during collision, elements based surfaces are applied to define contact region.

The present column (rigid) has a material yield strength steel of 355 N/mm^2 with isotropic hardening to a strength of 490 N/mm^2 at plastic strain of 0.025. Mises yield function is applied to check flow of plasticity at the yielding region. The lighting column is assumed to be fixed at its base and free to move at the top. However, the vehicle is free to move in right angle with a translational velocity along the $-X$-axis equal to 14 m/s. The velocity is applied at all nodes of the vehicle. Point masses are assumed to represent masses of mechanical and transmission components. The vehicle gross weight is taken 980 kg. This weight assumption is chosen because we are interested in comparing the effect of the collision on the different material of lighting columns with no reference to the total mass of the vehicle. Two stages of crash is passing, the first stage where maximum peak of deceleration of car is occurred while the second stage is passing with low values of deceleration up to vehicle is being stopped. In this study, the first phase of impact is considered because of being important. A dynamical explicit analysis for the time up to 0.05 s is running.

3. Discussion of results of analyses

The present lighting column has a length of 8 m and its diameters at base and top are 200 mm and 10 mm respectively, while the shell thickness (t_s) is 4 mm. Fig. 1. shows un-deformed and deformed shape of vehicle crash with the existing lighting column. It is clarified from Fig. 1. that the existing column absorbs small internal energy where, trivial deformation is shown in the column. The remaining impact energy is absorbed by the frontal area of the vehicle. Various analyses are carried out by using a new material property ($E = 2.5$ GPa, $\rho = 2500$ kg/mm^3 and $\sigma_o = 100$ MPa) and different shell thicknesses for the lighting column. Shell thicknesses of the light column are taken such as $t = 4$, 3, and 2 mm respectively. History of deformation of the lighting column is shown in Figs. 2 and 3. It is noticed that the crash against the lighting column fabricated from the new

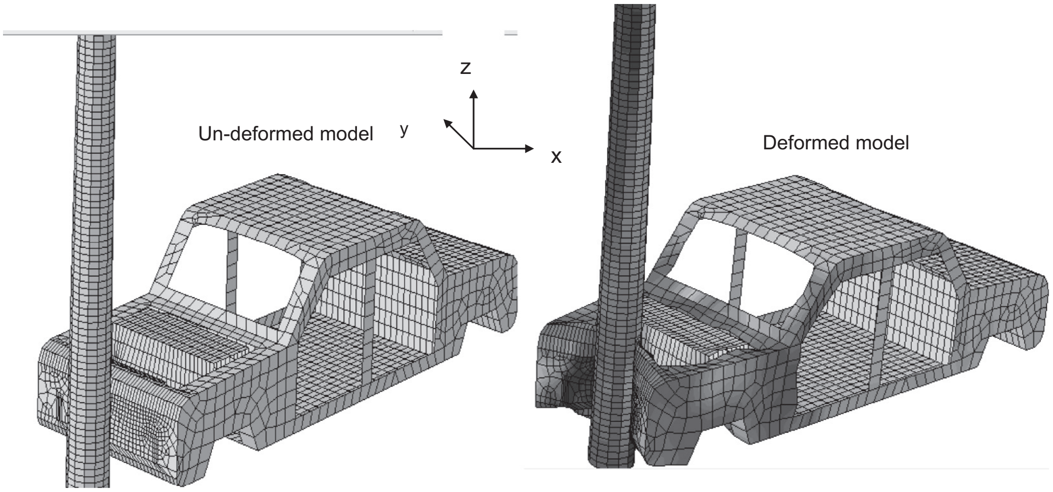

Figure 1 FE model of the present lighting column.

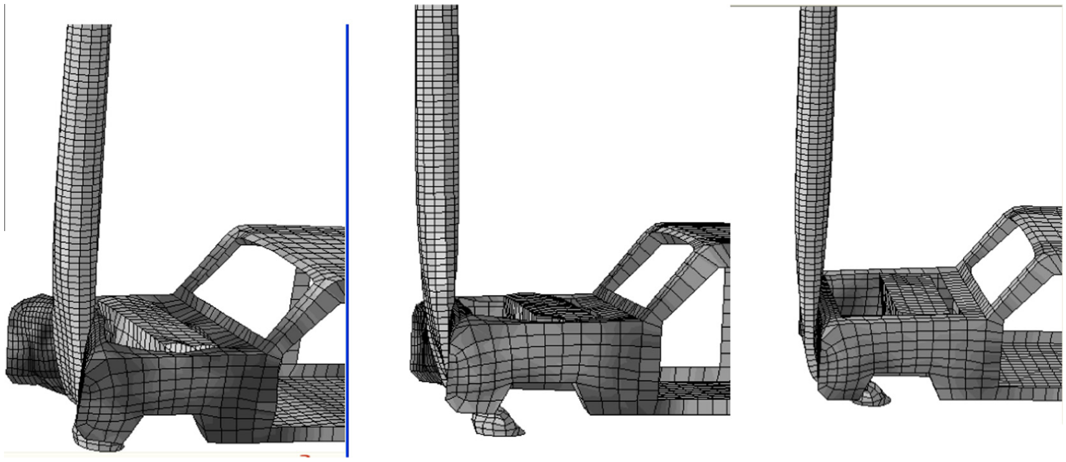

Figure 2 Deformation history of the lighting column with the new material.

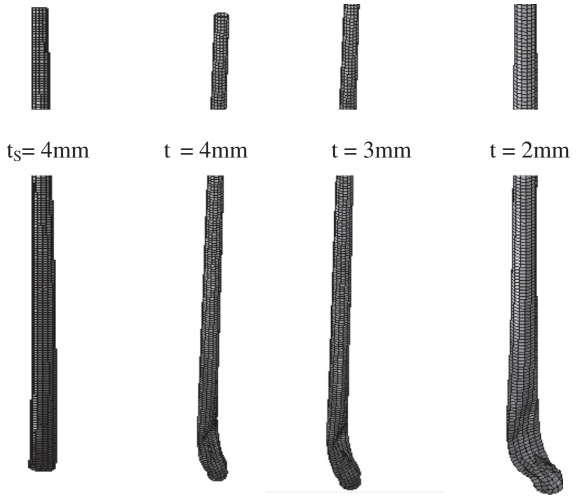

Figure 3 Deformation of the lighting column with different shell thicknesses.

soft material shows higher internal deformation, and little deformation onto the frontal area of the vehicle. The lesser is shell thickness of the lighting column, the lesser is the absorbing energy by the vehicle, or the safer occupant in the vehicle.

Fig. 4. shows acceleration–time relationship for the present and new lighting columns. The acceleration is measured at the frontal area of the vehicle. It is shown that the lighting columns with the soft material decelerate the vehicle. The column with less thickness shows maximum deceleration than other lighting columns. The results in general show the same trend, however the FE model is a bit rigid than it should be. The peak of the acceleration value is happened at a time less than that expected. This is mainly because the model lacks some of the details of the additional material parts fitted to the interior of the vehicle. Fig. 5. shows the contact force against time for all models. The force–time relationship has the same behavior for the lighting columns fabricated from the new material. Two peaks of the force values for the behavior of the present lighting column are indicated in Fig. 5.

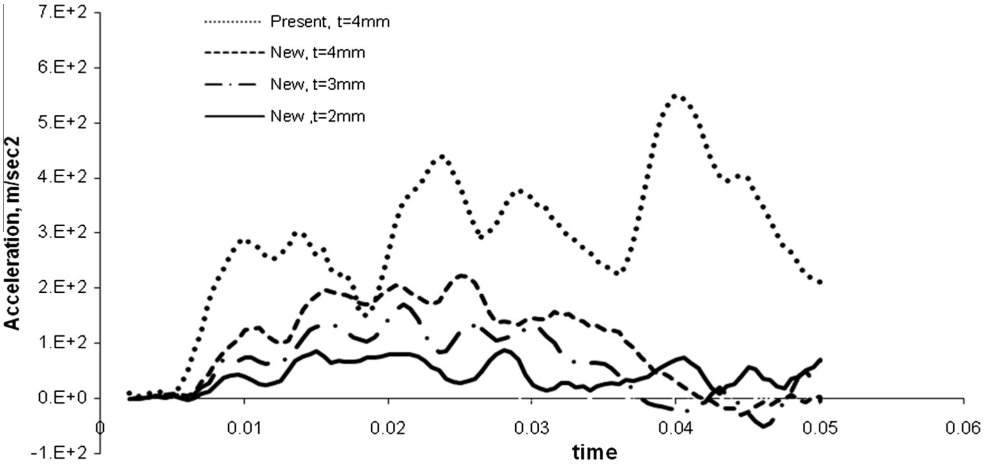

Figure 4 Acceleration–time relationship.

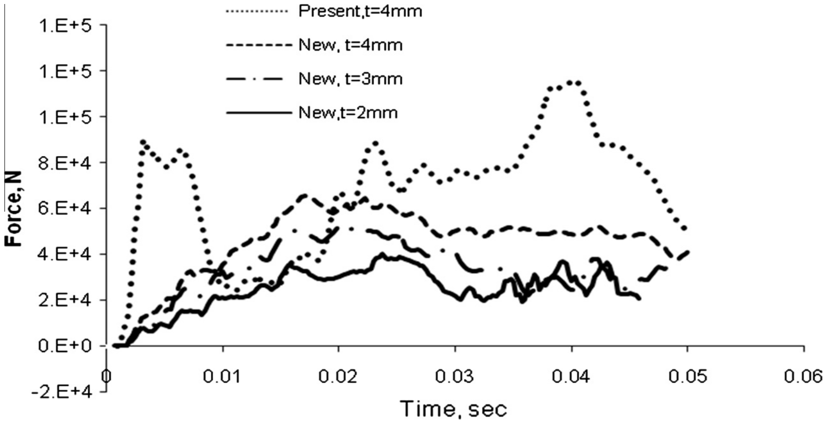

Figure 5 Force–time relationship.

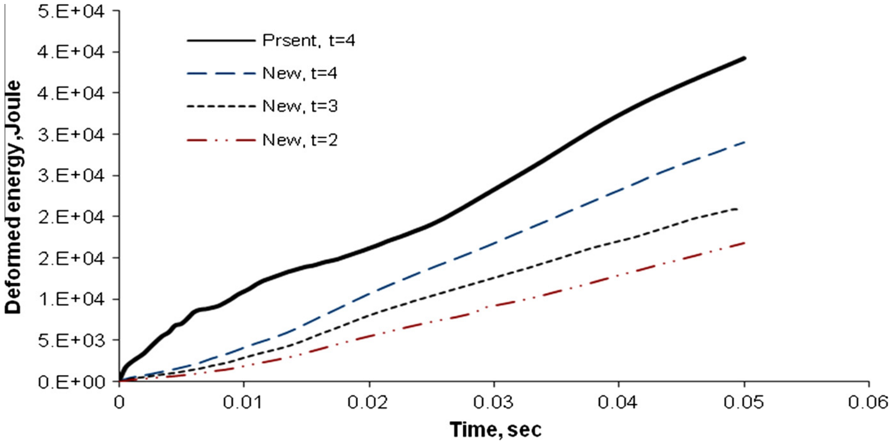

Figure 6 Deformed energy–time relationship.

Fig. 6. shows the predicted deformed energy–time relationship. It is clarified that crash with the present rigid column causes highest deformation onto the vehicle. It is seen that the lighting columns with the new fitted material

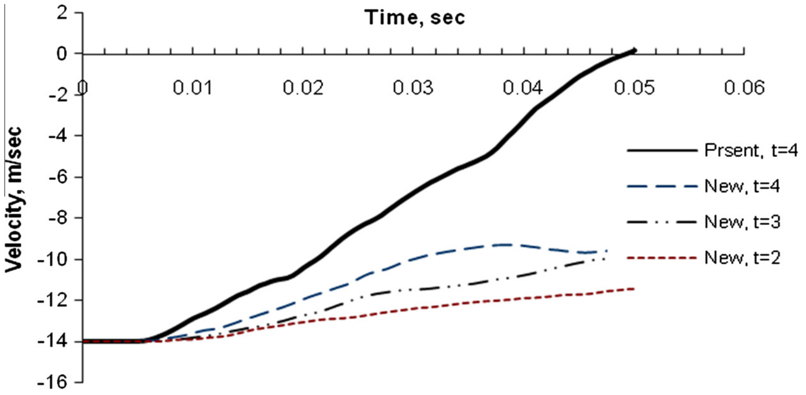

Figure 7 Velocity–time relationship.

absorb higher amount of the internal energy than the compared present column. The velocity of the vehicle reach a zero value when collides with the rigid column, while it continues running with a little reduction of speed when collides with the soft lighting columns as shown in Fig. 7. This means that the possibility of injury crash is reduced.

4. Conclusions and future works

The paper is a study for the simulation of vehicle-lighting columns impact. From the present paper the following related aspects are concluded and considered to be essential for completion of such a research work:

1. The present rigid lighting column with high yield strength of material absorbs little impact energy, in turn high injury risk is expected.
2. The lighting column fabricated from the new material decelerates the vehicle and absorbs higher impact energy, in turn increasing the safety of vehicle occupant.
3. The peak of the acceleration value is happened at a time less than that expected. This limitation is because the model lacks some of the details of the additional material parts in the interior of the vehicle.
4. Lighting columns with internal stiffening systems have to be further investigated.
5. The validation of this study has to be checked in the future with real crash colliding test.

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