23rd International Conference
ENGINEERING MECHANICS 2017
Svratka, Czech Republic, 15 – 18 May 2017

VERIFYING THE APPLICATION OF THE MODELS OF CRASH AND COLLISION DETECTION OF INCOMPATIBLE VEHICLES

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Abstract: *The article covers the incompatible vehicle crashes. Today computer programs are widely applied in the analysis of vehicle crashes. However, it is the expert's responsibility to select the right collision model in terms of the application of the right IT tool or a selection of the right option in the computer program. Such selection must be adequate to the incident analysed, also in terms of the limitations of the models of contact between the simulation objects. The problem has been presented based on a case study a head on truck-to-car collision. The research has involved the use of VSIM simulation program. The experimental verification has demonstrated a practical application of the impact (force) crash model with the volumetric (3D) collision detection model, as most adequate to the collision analysis of incompatible vehicles.*

Keywords: VSIM, Crash model, Collision detection, Crash compatibility.

1. Introduction

The accident reconstruction identifies a problem of an applicable selection of the crash model and the detection of collision of the simulation objects in calculations. It is especially clear in the case of the incompatible vehicle crash. Papers (Gabler et al., 1996, Mendis et al, 2002, Van der Sluis, 2000 and Wicher, 2012) discuss the analytical grounds of the compatibility laws, crash test types and the term of the vehicle aggressiveness, while another paper (Yang et al., 2012) covers experimental results of crash-incompatible vehicles. Compatibility is mostly related to geometrical relationships between the bodies (shape, height) as well as mass and rigidity, which has been discussed in e.g. another paper (Aleksandrowicz, 2014) for crashes of vehicles of different categories. Truck designing strives for installing devices which would prevent a passenger car driving under a truck, which is demonstrated in other papers (Lambert et al., 2002 and Zou et al., 2001). So far there has been developed no universal crash model the application of which would be adequate in each crash case. For study reasons, vehicle crashes are usually simulated with the use of FEM (Finite Element Method). The application of such models for the reconstruction of road accidents is sporadic. In property valuer's practice the programs modelling the crash in MBS (Multi Body Systems) are most frequently applied; e.g. PC Crash, Virtual Crash. For instance, in other papers (Dima et al., 2014 and Semela et al., 2007) those programs have been validated receiving a satisfactory convergence with tests and video-recordings. One should, however, underestimate neither the simulation program model simplifications nor the effect of uncertain input data on the simulation results, which has been discussed e.g. in other papers (Bułka et al., 2007 and Wach, 2008). In Poland the most commonly applied simulation program for the vehicle crash analysis is VSIM. Its experimental verification in terms of incompatible vehicle crash modelling is not found and, with that in mind, this topic has been covered in the present article due to its cognitive and functional values.

2. Selected collision detection methods

Object-to-object crash modelling is one of the most essential elements of the simulation program. It is a vast problem, which will not be discussed here. Crash detection both identifies the collision of its objects and provides geometrical data indispensable for the IT tool to make calculations.

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2.1. 2D Model

A 2D detection model is the simplest model to study the contact between the objects of simulation. It verifies the occurrence of a common part of the objects; the areas which are projections of their stylings on the horizontal plane. The simulation objects in that model are considered vertical cuboids with the base being the projection of their styling. In general the shapes of styling projections are downloaded by the program from an external database, e.g. AutoView. Fig. 1 presents a 2D collision detection.

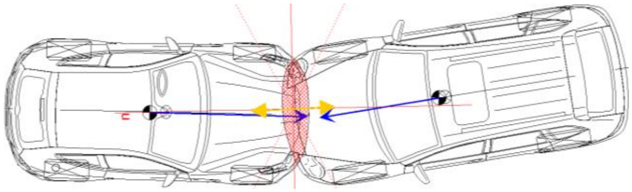


Fig. 1: 2D collision detection.

2.2. Superellipsoid – superellipsoid model

The 3D object-to-object contact model based on superellipsoids describes the simulation object or its element with a general formula (Bułka et al., 2011):

$$\left|\frac{x}{a}\right|^n + \left|\frac{y}{b}\right|^n + \left|\frac{z}{c}\right|^n = 1 \text{ for } n \geq 2 \qquad (1)$$

where:

a, b, c – length of the semiaxis and n – the order of superellipsoid corresponding to its rounding.

The contact detection involves a comparison of the distance between the centres of ellipsoid with the sum of the distance between the centre of each of them and the point on its surface and a line joining the centres of those ellipsoids. If the sum of those distances is greater than the distance between the centres, the ellipsoids analysed are in contact. Fig. 2 presents a 2D collision detection.

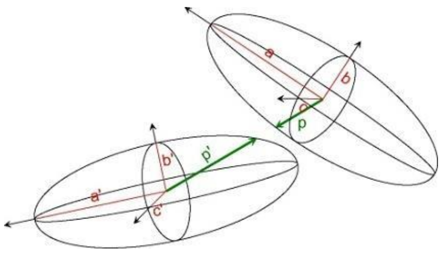


Fig. 2: Collision detection between ellipsoids.

2.3. 3D model

In the 3D model, to detect the contact of objects, three-dimensional networks of the body shape are applied, using the Gilbert-Johnson-Keerthi algorithm (GJK) (Gilbert et al., 1988). VSIM offers a unique solution with a three-dimensional map of points included in the vehicle body interior. However, the map is the same for each body type, which is a simplification in terms of the body shapes of various vehicle makes, even within the same type. Collision detection involves verifying which of the body network interior points of the simulation object are contained in the network interior of the other one. Fig. 3 presents the body network made up of VSIM program triangles.

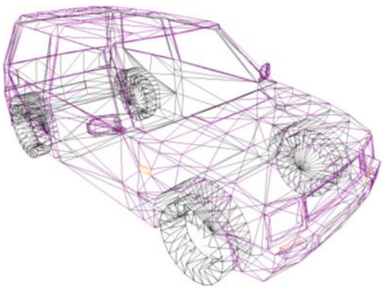


Fig. 3: Body network applied in VSIM4.

3. Case study – own research

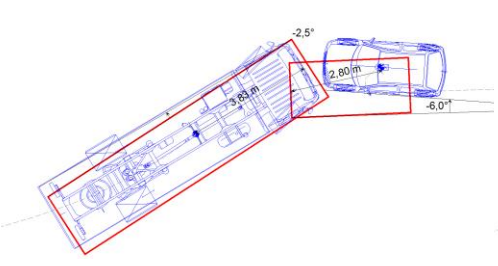
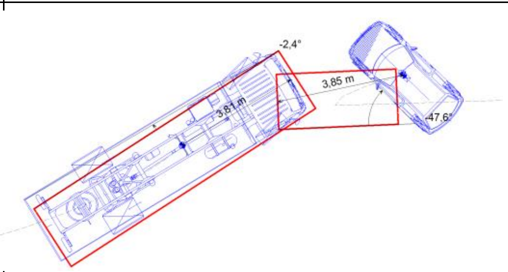
The study objects include Opel Corsa and Mercedes Actros 1840 the post-accident positions of which have been documented in photographs and the site description. The positions symbolise red rectangles and the model evaluation measure assumes the best post-accident position matching (%) to that position of the angle of rotation Ø and S distance of the centre of gravity of the simulation object. Fig. 4 presents the objects of the study.

Fig. 4: Objects of the study and their position assumed in simulation calculations.

The crash was analysed with the use of the available crash models and the collision detection in VSIM4, and vehicle stylings have been derived from AutoView database (http://www.cyborgidea.com.pl).

Tab. 1 illustrates the study results (https://www.youtube.com/watch?v=bLe0VoPvtOo, https://www.youtube.com/watch?v=O8BOxVlokSQ).

Tab. 1: Results of verifying the models of crash and collision detection in VSIM4.

<table>
<tr><th>Impulse crash model</th><th>Impact (force) crash model</th></tr>
<tr><td>2D collision detection model</td><td>2D collision detection model</td></tr>
<tr><td>
</td><td>
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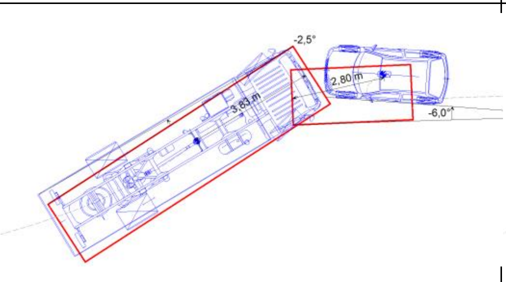
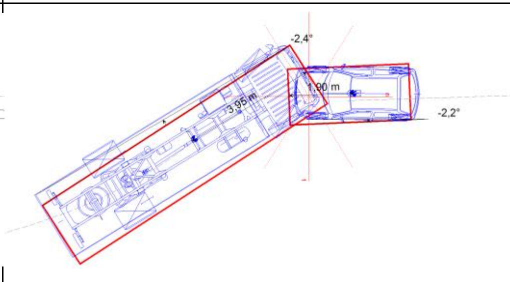
<tr><td>
</td><td>
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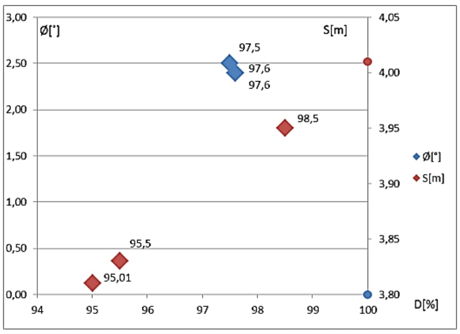
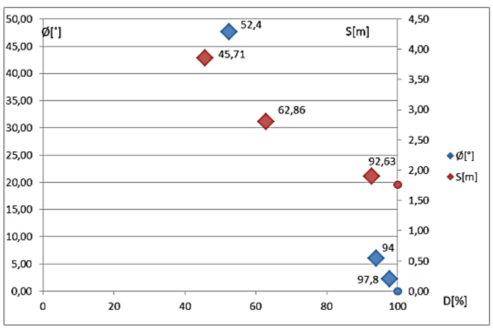
<tr><td>Mercedes matching positions Ø, S</td><td>Opel matching positions Ø, S</td></tr>
<tr><td>
</td><td>
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4. Conclusions

The analysis has demonstrated that the 2D collision detection model for incompatible vehicle crash should not be applied irrespective of the vehicle crash model selected. Especially the impact model gave a result far from the actual post-accident vehicle positions. Selecting the impulse crash model, irrespectively of the collision detection, the program generates the same result and it is also divergent from the actual state identified at the site. The impulse crash model is therefore not useful for the incompatible vehicle crash simulation. The best matching results for post-accident incompatible vehicle crash position were produced by the application of the crash (force) impact model with the 3D collision detection model: Mercedes Ø = 97.6 % and S = 98.5 % as well as Opel Ø = 97.8 % and S = 92.63 %. The discrepancies for the 2D detection model result from the assumption of considering the simulation objects as vertical cuboids with the base being a projection of their styling. The differences in the crash impact (force) model and the 3D collision detection model should be related to a simplified application of universal 3D vehicle type networks and not individually dedicated for each of them. Additionally the program simplification includes non-deformability of the 3D network of the vehicle during the crash, which should direct its development towards modelling solutions as e.g. in DyMesh convection (York et al., 1999).

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