Method for the estimation of the deformation frequency of passenger cars with the German In-Depth Accident Study (GIDAS)

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Abstract - This study that was funded by the Research Association for Automotive Technology (FAT) develops a method for the evaluation of the placement of tanks or batteries by using the deformation frequencies in real-world accidents. Therefore, the deformations of more than 20.000 passenger cars in the GIDAS database are analysed. For each vehicle a contour of deformation is calculated and the deformed areas of the vehicles are transferred in a rangy matrix of deformation. Thereby, the vehicle is divided into more than 190.000 cells. Afterwards, all single matrices of deformation are summarized for each cell which allows representative analyses of the deformation frequencies of accidents with passenger cars in Germany.

On the basis of these deformation frequencies it is possible to determine least deformed areas of all passenger cars. Furthermore, intended placements of tanks or batteries can be estimated in an early stage of development. Therefore, all vehicles with deformations in the intended tank areas can be analysed individually. Considering numerous parameters out of the GIDAS database (e.g. collision speed, kind of accident, overlap, collision partner etc.) the occurring forces can be calculated or the deformation frequency can be estimated. Furthermore, it is possible to consider the influence of primary and secondary safety systems on the deformation behaviour. The analysis of “worst case accident events” is an additional application of the calculated matrix of deformation frequency.

INTRODUCTION

The application of alternative fuels is one of the most important challenges for the automotive industry in future. Especially the safety must be guaranteed in case of an accident with vehicles operated by hydrogen, gas or electric power. The particular properties of hydrogen, gas and batteries demand strict requirements for the construction of the tanks and their placement in the vehicle.

DATASET OF GIDAS

For the present study accident data from GIDAS (German In-Depth Accident Study) was used. GIDAS is the largest in-depth accident study in Germany. The data collected in the GIDAS project is very extensive, and serves as a basis of knowledge for different groups of interest.
Due to a well defined sampling plan, representativeness with respect to the federal statistics is also guaranteed. Since mid 1999, the GIDAS project has collected on-scene accident data in the areas of Hannover and Dresden. GIDAS collects data from accidents of all kinds and, due to the on-scene investigation and the complete reconstruction of each accident, gives a comprehensive view on the individual accident sequences and its causation.
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CALCULATION OF THE DEFORMATION MATRIX AND DEFORMATION FREQUENCIES

The following chapter describes the methodology of the calculation of the deformation frequencies starting with the deformation of the single vehicle leading to the distribution of the deformation frequencies of all 20.000 vehicles.

Deformation coding in GIDAS

In the GIDAS database the measured deformations for each vehicle are coded by a defined scheme. Therefore each vehicle is divided into more than 50 zones of deformation, thereby the shape of the vehicle is considered. For each zone the maximum deformation depth is coded, which was measured at the real accident car by the accident research team. For a better understanding of this scheme of deformation coding, the next figure 1 shows an example vehicle with deformation resulting from a lateral collision with a tree onto the left side.

figure 1: example of deformation of an accident car

For this vehicle the exact deformation depth are coded in each zone. The position of the maximum deformation in each zone is exactly described by their x-, y-, and z-coordinates

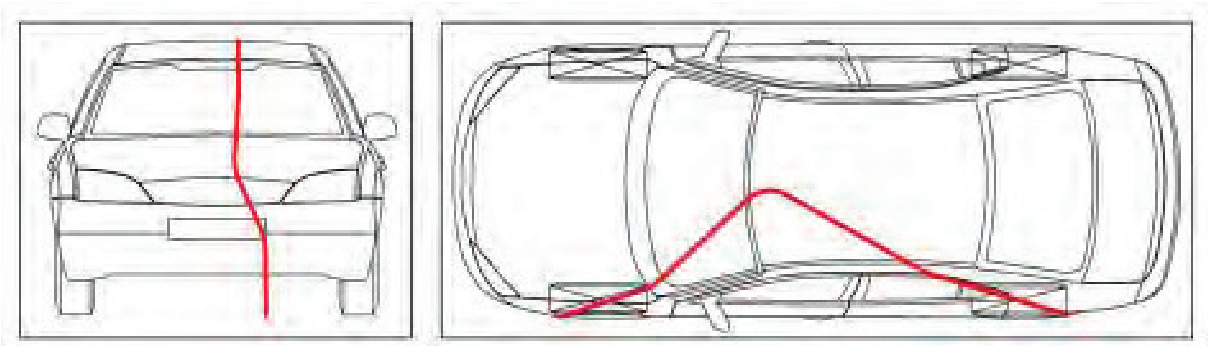

figure 2: example of deformation contour of an accident car

This way all important dimensions for all existing deformations on each side of the vehicle are known and it is possible to create a deformation contour for each single vehicle (figure 3).

Vehicle zones matrix

For the useful comparison and the statistical analysis of more than 20.000 vehicles and their deformation contours it is necessary to develop a consistent and exact basis for the deformation description. Here the different shapes of the vehicles must be considered.

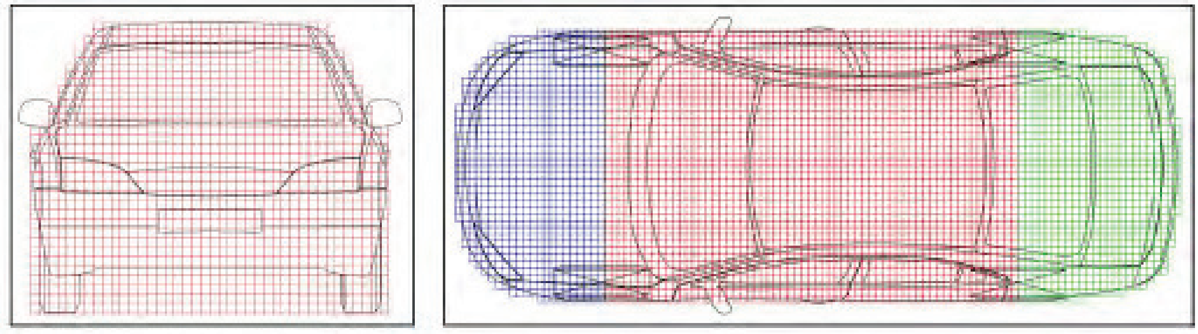

figure 4: vehicle zone matrix

Figure 3 shows the vehicle zone matrix for the limousine passenger cars. The number of cells in this matrix amounts more than 190.000 cells and is equal for each vehicle shape (station wagon, limousine, SUV, etc.) Due to this, also a common statistical analysis for all different vehicle shapes is possible.

Calculation of vehicle deformation matrix

The calculation of the vehicle deformation matrix is the last and most important step to create the 3-dimensional vehicle deformation model for each single vehicle.

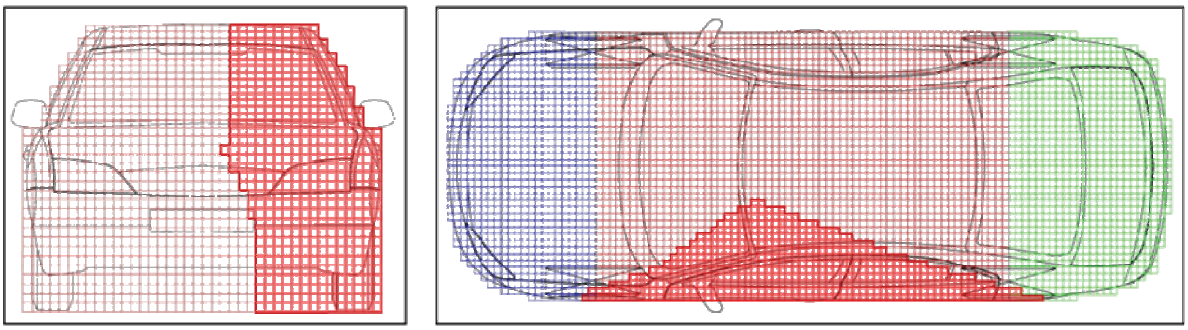

figure 5: calculation of vehicle deformation matrix

The calculation of each single cell of the deformation matrix is achieved by the mathematical interpolation of the coded deformation depth contour of each single vehicle. figure 5 shows the interpolation process in principle.

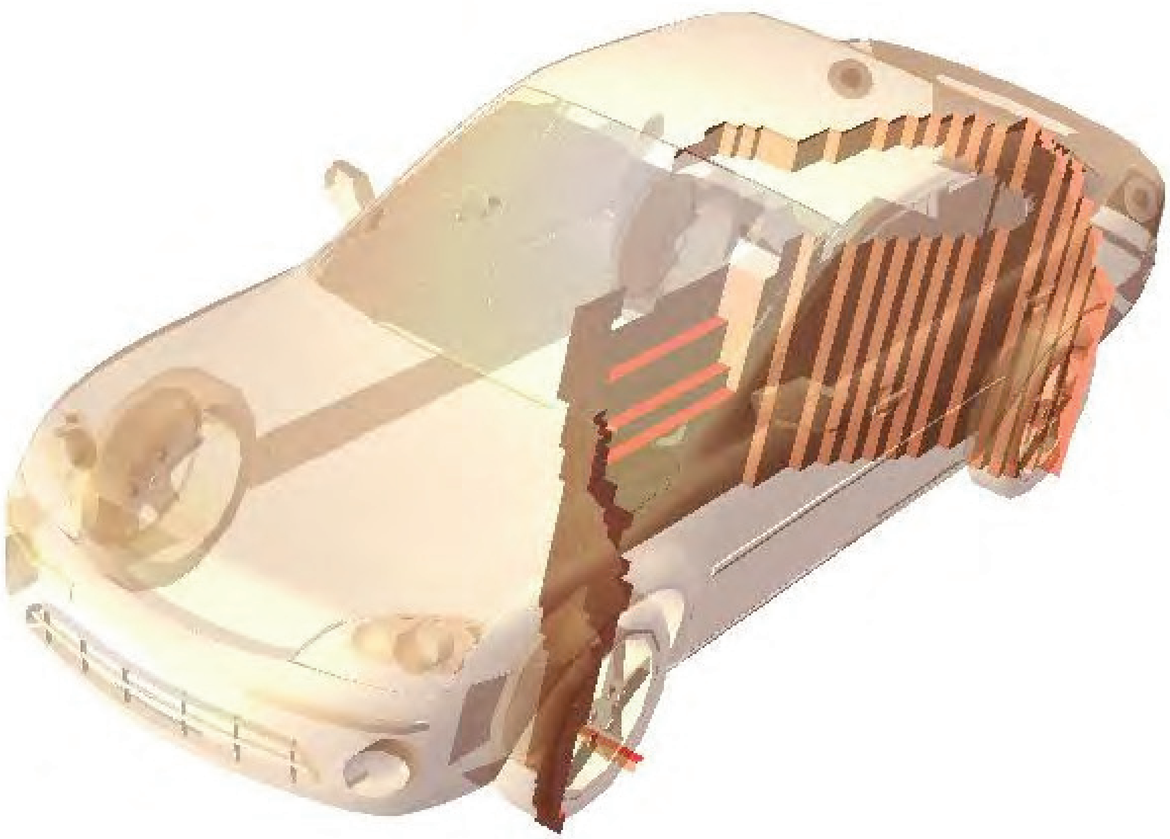

figure 6: 3-dimensional deformation model

The 3-dimensional deformation model in figure 6 shows the result of this deformation calculation process for the example accident vehicle. This kind of a 3-dimensional model is created for all 20.000 vehicles.

Determination of the deformation frequencies

For the statistical analysis of the deformation behaviour and the deformation frequencies of more than one car another description is useful.

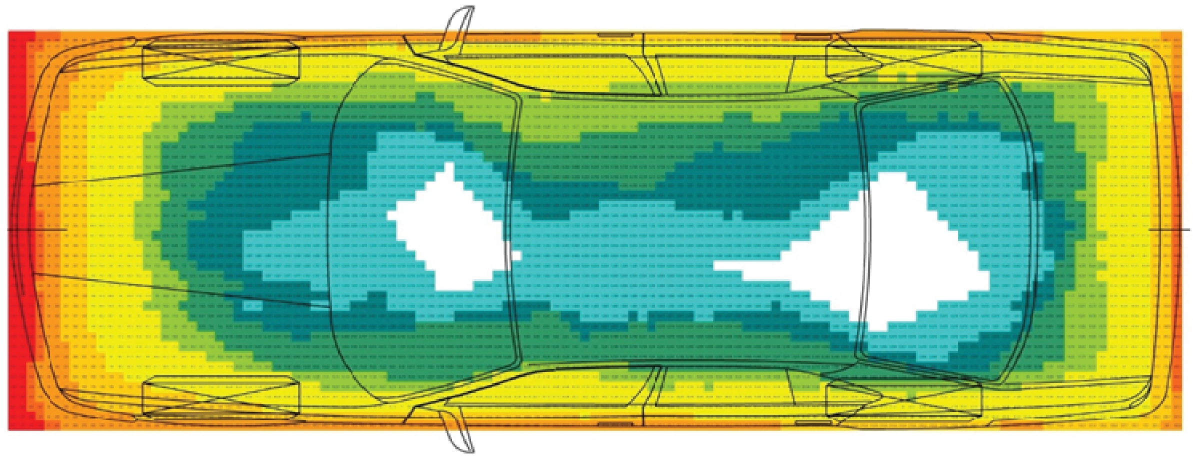

figure 7: vehicle deformation frequency matrix in height of the sill

In figure 7 the deformation frequencies of many thousand real accident passenger cars (shape: limousine) are shown. In this kind of description it is possible to alter the section height of the car in different heights, like in a computer tomography. Figure 7 shows the deformation frequency in the height of the balustrade.

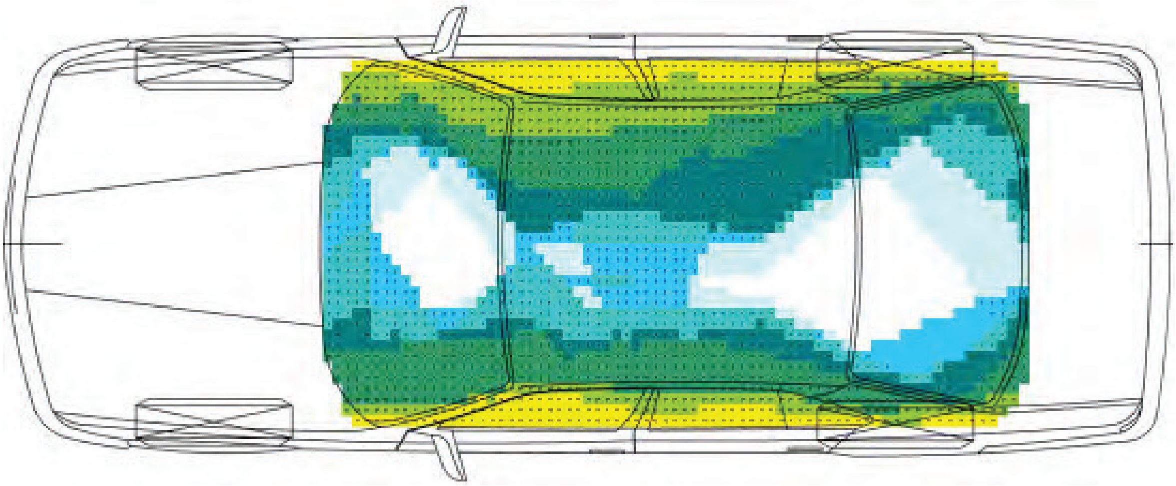

figure 8: vehicle deformation frequency matrix in height of the balustrade

POSSIBILITIES OF ANALYSING

There are several possibilities and approaches for different particular questions and analyses.

Frequency and deformation depth

The analysis of the deformation frequency matrix allows statements about the distribution of the severity of deformations in the different zones of the passenger car. It can be calculated which zones are deformed the least and therefore suitable for the placement of batteries or hydrogen tanks. In all these analyses the shape of the passenger car can be differentiated, so construction differences between a limousine and an SUV can be considered.

Definition of a section of interest

This analysis option allows geometric definition of a solid object inside the passenger car model. In the following analysis it is possible to filter all accidents and passenger cars where this defined geometric area is hit or deformed in an accident. Afterwards these filtered accidents can analysed by their frequency and all available variables of the GIDAS database. The application of this method allows the assessment of all possible sections for batteries or hydrogen tanks without the effort of a crash test.

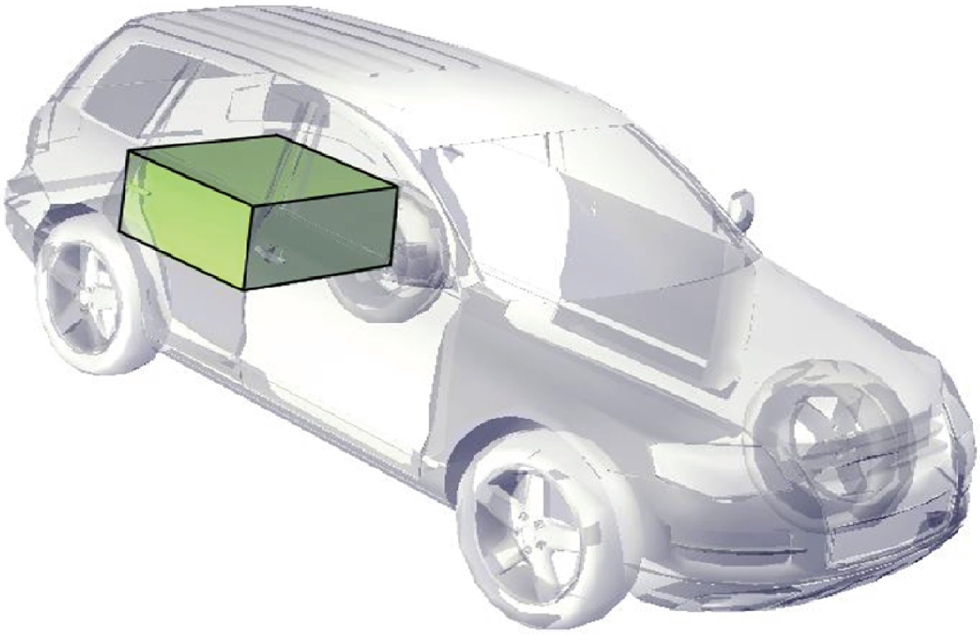

figure 8: vehicle with defined section of interest

Worst case accidents

By using the deformation frequency matrix it is possible to filter all "worst case accidents" by their deformation frequency. This way it is possible to analyse e.g. only the 1% worst deformed passenger cars. These cars and accidents can then be analysed concerning special influences like collision speed, collision partner or any other variable of the GIDAS database. In connection with the GIDAS database the influences of active safety systems in these accidents can be estimated regarding the question whether these accidents can be prevented by an active safety system.

CONCLUSION

All in all, the presented study shows, for the first time, a method for the detailed analysis of real-world accident data concerning the deformation frequency of passenger cars. Furthermore, the study relies on an exceptional high number of vehicles and finally, the use of the GIDAS database allows representative statements for the German accident scenario.