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OPTIMISATION IN THE EXPLICIT ANALYSIS OF THE ROAD BARRIERS

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Abstract: *The aim of this project was to setup a surrogate process that is able to substitute a real crash test of road barriers. As a standardized vehicle was used a typical city bus. The sensitivity analysis was performed due to detailed understanding of the parameters limits and their relations. The sensitivity study enables to check more than one crash test loadcase. Two variants of optimization were used, the standard optimization procedure and optimization with meta-model based on the previous sensitivity study. Both of them used the evolutionary algorithm. The goal was to increase a maximum internal energy of the barrier. Apart from that the vehicle maximum deceleration was improved. The optimized barrier model was verified in the thorough explicit numerical study due to investigation of the detailed interaction between the barrier model and the vehicle model. The effect of the testing vehicle on the crash barriers can be evaluated in tens of impact directions and impact velocity values. Apart from that the design of barriers was improved. The detailed numerical analysis of the "best" variant confirms a good relation between numerical simulations and real tests.*

Keywords: ANSYS, Explicit Analysis, Road barriers, OptiSLang, LS-Dyna.

1. Introduction

The safety in road traffic is a long-term problem in most countries regardless their actual state of economy or political situation. There are many types of technical resources that can help to reduce undesirable consequences of very frequent road accidents. One of the most difficulties in a production of these technical resources is to estimate their capability to decrease unfavorable results of traffic accidents. Many kinds of possible real situations lead to many analyzed loadcases.

The aim of this project was to setup a standard process of a numerical simulation that is able to substitute a real crash test of road barriers which is whenever expensive. Two points of a view are included in this project. The first is to build a simple and quick numerical model of the crash test that can be used in optimization process with hundreds of variants. The second point of view is to build the accurate numerical model as much as possible. This kind of model has to be used as a substitution of a real test. Both models can be used as a part of a development process.

2. Crash Test Configurations – Sensitivity

The simple model of the crash test, see Fig. 1, was built due to the investigation of the worst loading case that barrier has to satisfy. It brings a general overview of relations between the vehicle impact velocity, the impact angle and structural results on the barrier. A typical city bus that is most common in this area was used as a standardized vehicle. It represents a body with 13 tons of mass impacted to the barrier under defined angle.

The sensitivity analysis was performed with next input parameters:

- impact velocity,
- impact angle between vehicle and barriers,
- thickness of the barriers (two parameters).

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Next output parameters were investigated:

- internal energy of the barrier assembly,
- residual velocity of the vehicle,
- maximum deceleration of the vehicle.

More input parameters were investigated in previous analyses. Moreover during the barriers geometry design some local parts were parameterized together with global parameters of the barrier (material thickness). All parameters were evaluated in a form of correlation coefficients. It enables to exclude redundant parameters from a complex study (Saltelli, 2008). With respect to this previous investigation only thickness parameters were used in the final optimization study.

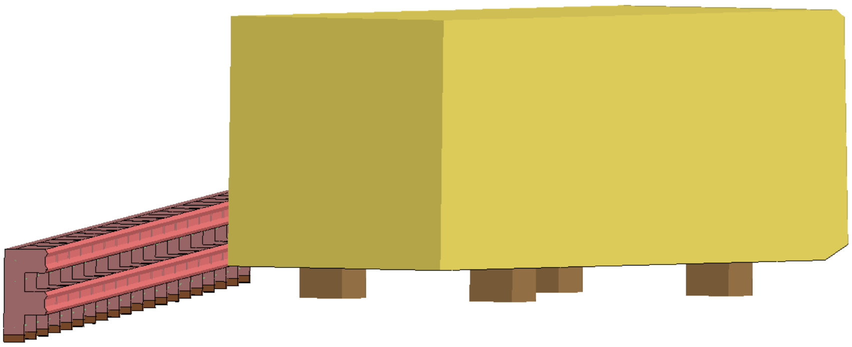

Fig. 1: Simple numerical model.

All investigated parameters were analyzed in maximal important on their limits with regards to manufacturing of barriers and all possible load cases in the crash test.

A very common approach in parameters choice is random sampling, which is called Monte Carlo Simulation (MCS). For design exploration the design variables are assumed to follow a uniform distribution with given lower and upper bounds. However this method fills the limit space not so much effectively. Many parameters sets are doubled. The better method was used, the advanced Latin Hypercube Sampling (Fig. 2). This method is able to setup parameters values more uniformly around the whole limit space.

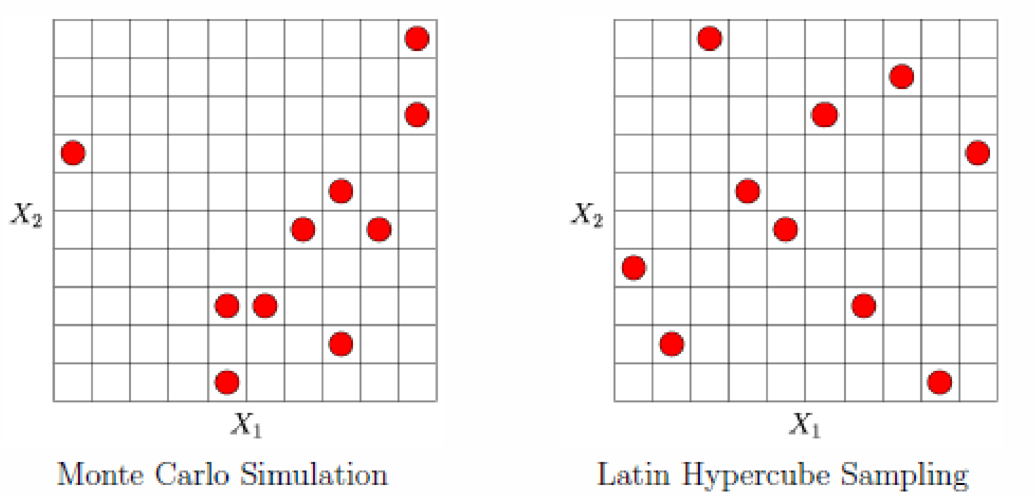

Fig. 2: Stochastic sampling schemes.

The performed sensitivity study confirms a high influence of the vehicle impact angle to all output parameters, especially to the maximal deceleration and residual velocity of the vehicle. This was quantified by correlation coefficients. The particular distribution of the influence of input parameters to output parameters was described by coefficients of importance.

3. Road Barriers Optimization

The previous sensitivity model was used as a base for next optimization. The goal was to increase a maximum internal energy of the barrier. It represents an energy that is absorbed in the barrier assembly mainly by its deformation. Not only absorbed energy but also the vehicle maximum deceleration was used as a significant goal of the optimization study. Apart of that the residual velocity of the vehicle was investigated as well.

Two variants of the optimization were used, the standard optimization procedure and the optimization with meta-model (Most, 2008) based on the previous sensitivity study. Both of them used the Evolutionary algorithm (Kelley, 1999).

Evolutionary algorithms are stochastic search methods that mimic processes of natural biological evolution. These algorithms have been originally developed to solve optimization problems where no gradient information is available, like binary or discrete search spaces, although they can also be applied to problems with continuous variables.

The prediction quality of an approximation model may be improved if unimportant variables are removed from the model. This idea is adopted in the Metamodel of Optimal Prognosis (MOP) which is based on the search for the optimal input variable set and the most appropriate approximation model (polynomial or MLS with linear or quadratic basis). Please see Fig. 2 for an optimization procedure.

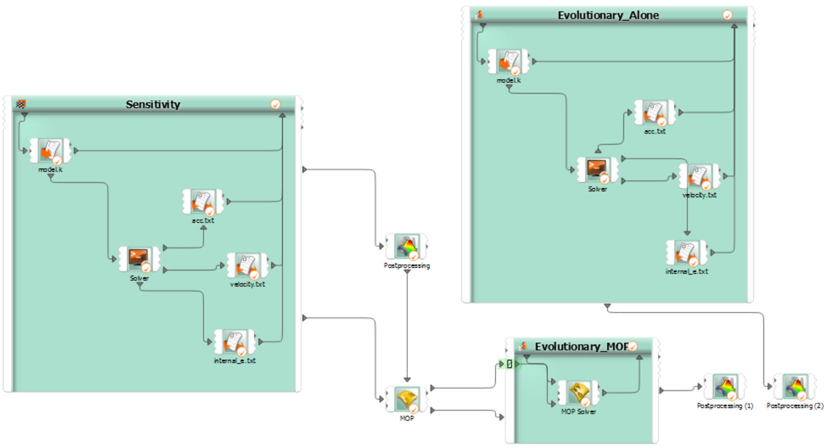

Fig. 3: Optimization procedure with MOP model.

Two thickness parameters of the road barriers were used as discrete input parameters (longitudinal part and vertical part thickness). The impact velocity and angle were fixed according standards for that kind of tests.

The optimization study used with the advance the evolutionary algorithm with two optimized objectives (Branke, 2008) – maximal energy absorbed in road barriers and the maximum deceleration of the vehicle. Those two results are naturally in the opposite. The optimization enables to evaluate a pareto front from all design points at the start, Fig. 4. Afterwards next optimization steps come near this line. It significantly improved desirable energy value.

During the optimization some steps bring good value of absorbed energy but the vehicle deceleration cross the value about 10G.

The internal energy absorbed in the road barriers was increased about 28% to 1.4e6 J (the initial kinetic energy of the vehicle is about 2.5e6 J).

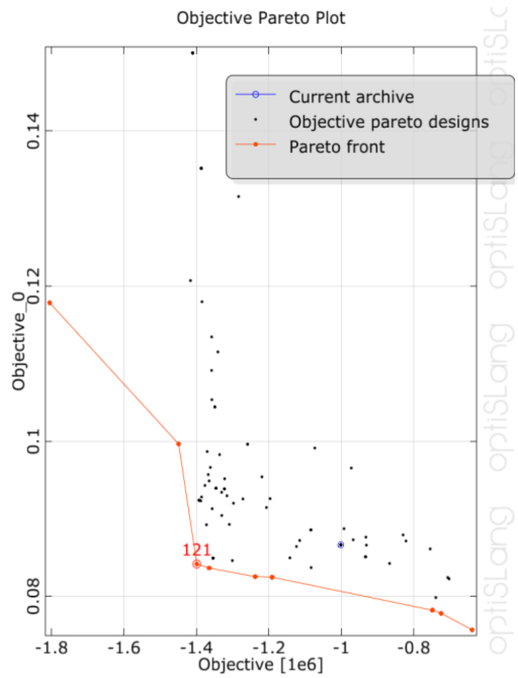

Fig. 4: Multiobjective optimization assessment.

The residual velocity in the optimized variant was kept close to the minimum value about 14 km/h (the impact velocity was defined about 70 km/h.

4. Verification Test in Numerical Simulation

The optimized barrier model was verified in the explicit numerical study due to the investigation of the detailed interaction between the barrier model and the vehicle model. This analysis was compared with the crash test of the real vehicle, see Fig. 5. More than 500k nodes were used for the modeling of the vehicle body and the barrier assembly. All materials were prescribed with parameters that enable a material erosion and plasticity behavior as well (Hallquist, 2006 and 2012).

The test results confirm supposed deformations from numerical simulation and the vehicle and barrier interaction as well.

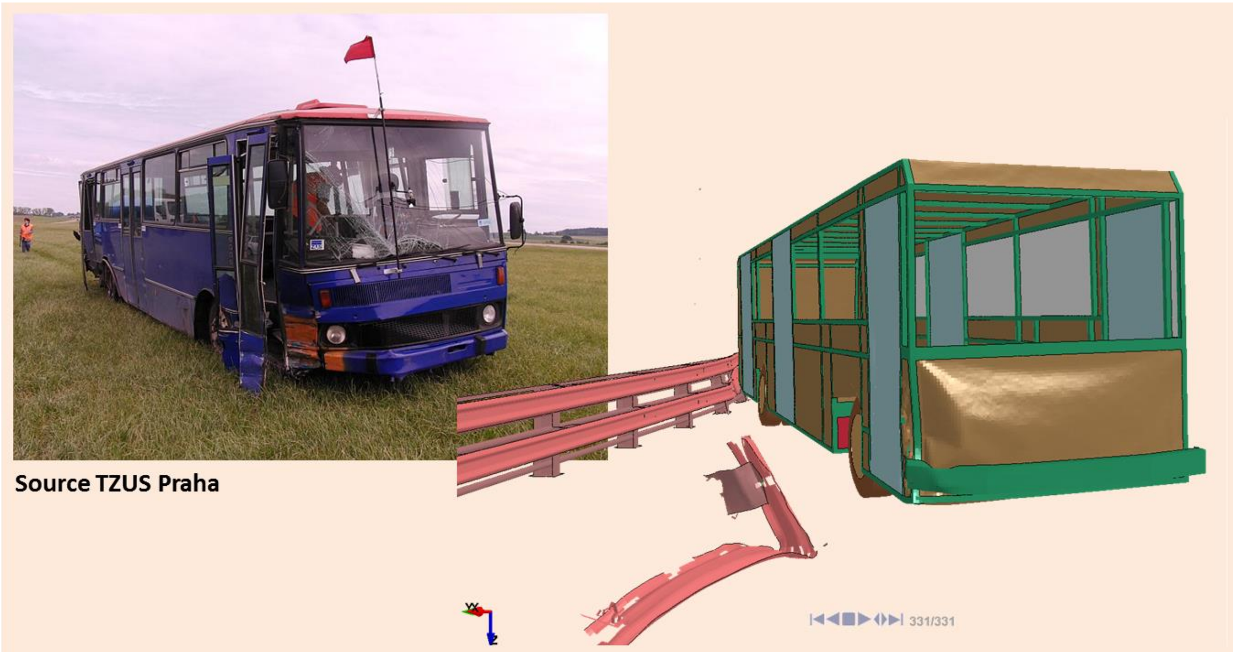

Fig. 5: Verification test of the numerical model.

5. Conclusion

The optimization brings two significant benefits in the road barriers investigation. At first, the previous sensitivity study enables to check more than one crash test load case. The effect of the testing vehicle on the road barriers was evaluated in tens of impact directions and impact velocity values. At second, the design of the road barrier was improved with the respect to the energy absorbed in barriers and undesirable deceleration in the vehicle body.

The detailed numerical analysis of the “best” variant confirms a good relation between numerical simulations and real tests.

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