Application of multibody simulation for optimisation of semitrailer

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Abstract

This paper presents multi-body dynamic analysis of a truck semitrailer, which purpose was to optimise suspension parameters in order to minimize disadvantageous influence of force distribution on high risk areas. Model contains elements of two different types: flexible and rigid bodies. Number of simulations of operational process that have influence on load case has been carried out. The target of the undertaken optimisation was to adjust semitrailers suspension stiffness coefficient and damping ratio. In this process response surface method (RSM) was used combined with parametric and structural sensitivity analysis, thanks to which influence evaluation of individual factors on values of loads, that were in region of interest has been estimated.

Keywords: multibody dynamics, dynamics, industrial problems, optimization, sensitivity

1. Introduction

Multi-body dynamic analysis is a fast way of computing internal and external forces in compound systems used in mechanics. Results achieved in this sort of computational technique are used in strength calculations as a load case for individual element. Moreover, models containing flexible bodies that were previously put to modal analysis, allow to study linear modes and predict loads that can take place during operational process with greater accuracy. Hence, it is possible to design the system in a way that minimises undesirable strain and stress, that are consequences of changeable state of load.

Sensitivity analysis allows to estimate influence of changes of selected parameters or construction structure on the elements being subject of optimisation process.

2. Problem formulation

The purpose of the multi-body dynamic analysis and of the truck semitrailer with suspension parameters optimisation was to decrease forces in high risk areas of structure: pivot connecting the truck with the articulated trailer, bolts of the tailgate and mount point of hydraulic cylinder lifting mechanism.

To fulfil the requirements, special analysis terms had to be specified. Those should be similar to working conditions of the real vehicle. There was also need to determine the most disadvantages settings of forces, which may occur in extreme situations in operational time. To complete those tasks, number of different simulations were carried out. Driving with a significant velocity along the even road with local loss of asphalt pavement, passing through strongly uneven country lane with fully loaded semitrailer or modification of the load and its character have been taken into account.

Results of above-mentioned tests were the basis for parametrical and structural sensitivity computations for the forces being in the field of interest and optimisation procedures for suspension parameters for earlier specified purpose. Pursuing those computations allowed to estimate desired values for stiffness k and damping ratio α of suspension system, thanks to which target function have been achieved.

3. Model

Variance model that was created in the implementation contains bodies of flexible and rigid type interacting each other. Tractor was treated as an element only inflicting motion with the desired parameters, such as velocity, acceleration, jerk and trajectory. Most of its mechanical properties was skipped due to simplification of its structure. Projects key target – semitrailer – is composed of the lifted box, chassis and pneumatic suspension system. Air springs and dampers have non-linear force-displacement characteristics, which was chosen on the basis of technical specification of real construction.

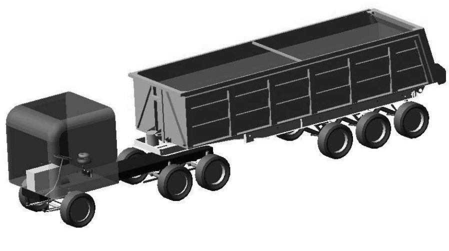

Figure 1: Truck with uniform load distributed semitrailer.

Models of the box and chassis of the semitrailer were put to modal analysis [2] in MSC Patran/Nastran environment. This led to creation of *modal neutral files* which were imported to MSC Adams/Car software for further simulations. They contains information about geometry, eigenvectors and natural frequencies used to calculate relative amplitude of modal shapes and total deformation of the structure, using the principle of linear superposition. During the multi-body simulation, flexible elements are excited thanks to proper analysis conditions corresponding to the real ones, what results in construction dynamic behaviour. This approach is more reliable and accurate, due to taking into account inevitable structure strains, which have influence on values of the considered forces. Examples of model used in simulations are presented on figure 1 and figure 2.

Figure 2: Truck with non-uniform load distributed semitrailer.

4. Analysis and results

Vehicle velocity, stiffness k and damping coefficient α of the suspension system were changed in number of attempts. Completed simulations have provided sufficient amount of data for computing sensitivity of considered forces for parameters mentioned above. Its value in function of time was estimated and analysed. Example of force – time characteristic for tailgate bolt from one of the attempts is shown on figure 3.

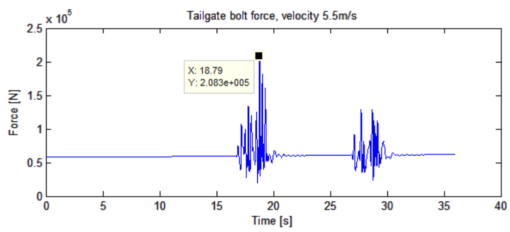

Figure 3: Tailgate bolt force value for real parameters.

The test was conducted on flat road with double local loss of pavement, for the truck velocity of 5.5m/s, with uniform load case of 32t, with suspension parameters corresponding to the original. Of figure 4 same results were presented for the model with changed (raised) stiffness coefficient *k*.

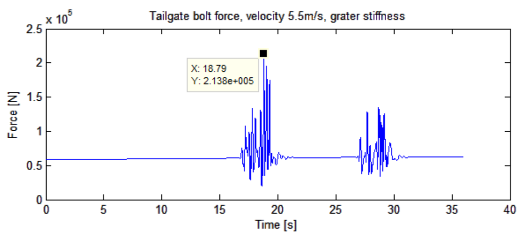

Figure 4: Tailgate bolt force value for grater stiffness coefficient.

To perform sensitivity analysis [1] the finite difference principle was used, where approximation with a forward finite difference approach. Equation (1) provides absolute value, which cannot be compared with sensitivities for the different types of parameters. If they are to be commensurable, equation (2) which provides also normalisation has to be used.

$$\frac{\Delta R_i}{\Delta P_j} = \frac{R_i(P_j+\Delta P_j)-R_i(P_j)}{\Delta P_j} \tag{1}$$

Where R_i is response quantity, and P_j is analysed model property.

$$S_n = \frac{\Delta R_i}{\Delta P_j} \cdot \frac{P_j}{R_i} \tag{2}$$

Results are presented on Pareto graph. Example for visualise influence of specific parameters for force in mount point of hydraulic cylinder is shown on figure 5. It is related to model with non-uniform distribution of total mass load of 32t.

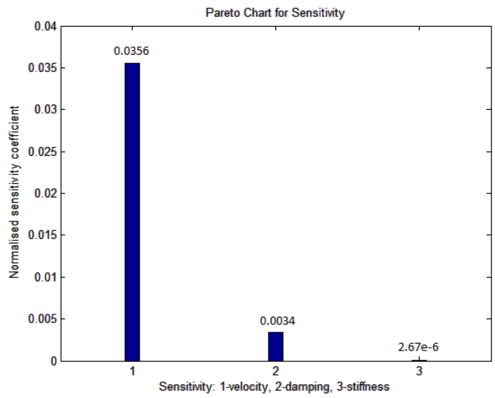

Figure 5: Pareto chart for sensitivity of loaded trailer.

For the optimisation response surface method (RSM) was used. The algorithm was implemented in MATHWORKS/MATLAB environment and allowed the estimation of most optimal suspension parameters for minimising forces in trouble spots.

5. Conclusions

In this project multi-body simulation of semitrailer was conducted. Parts being in the field of interest were set to modal analysis which preceded dynamic calculations in specially designed road and movement conditions corresponding to the real ones. Different kinds of load cases, with respect to allowable operating conditions were also implemented. Sensitivity analysis was used to find the parameters that have greatest impact on measured forces. Presented optimisation process helped to achieve new design in truck semitrailer suspension system reducing stress in critical regions of the construction.

References

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