DESIGN OF THE REAR CARRIAGE STABILIZER OF A LOW-FLOOR ARTICULATED TROLLEYBUS

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Summary During test drives with a low-floor articulated trolleybus focused on the vehicle driving stability considerable rolling of the rear carriage appeared during all the driving manoeuvres. Using a stabilizer in the rear carriage is a suitable constructional solution. Verification of the suitability of its constructional solution from the point of view of the required effect on the driving stability was performed using the computer simulations with the trolleybus multibody models.

INTRODUCTION

Computer simulations are irreplaceable in solving concrete problems of technical practice especially when experimental measurements on a real product cannot be carried out. Computer programs meant for the kinematic and dynamic analysis of mechanical systems are an important instrument in developing and improving vehicles´ properties and in improving comfort and passive safety of a driver and passengers [1].

ŠKODA RESEARCH Ltd. has been cooperating with the producer of road vehicles of municipal public transport ŠKODA OSTROV Ltd. [2] for a long time. The ŠKODA 22 Tr low-floor articulated trolleybus has been produced in ŠKODA OSTROV Ltd. since 1996. In the course of trolleybus modernization in 2002 other type of the articulation and driving axles was used in construction among others. During test drives with the modernized trolleybus focused on the vehicle driving stability considerable rolling of the rear carriage appeared during all the driving manoeuvres. Using a stabilizer in the rear carriage is a suitable constructional solution. Verification of the suitability of its constructional solution from the point of view of the required effect on the driving stability was performed using the computer simulation with the trolleybus multibody models. Multibody models of the ŠKODA 22 Tr low-floor articulated trolleybus with the HÜBNER articulation, the RÁBA driving axles and the rear carriage stabilizer [3] are created in the **alaska** software [4].

MULTIBODY MODELS OF THE ARTICULATED TROLLEYBUS

Multibody models of the both empty and loaded ŠKODA 22 Tr low-floor articulated trolleybus with the HÜBNER articulation, the RÁBA driving axles and the rear carriage stabilizer [3] were created on the basis of the data and technical documentation provided by the producer. They are formed by 47 rigid bodies, which are mutually coupled by 57 kinematic joints. The degree of freedom of the multibody models is 157. Air springs, shock absorbers and silentblocks are modelled by connecting the corresponding bodies by the force spring-damper elements. Pacejka formulae are used to describe the tires´ directional properties [4].

The proposed constructional solution considered the rear carriage stabilizer made of a steel bar of the circle cross section, the optimum diameter of which was to be determined on the basis of the computer simulations´ results. In the trolleybus multibody models the rear carriage stabilizer is not considered to be the individual rigid body, its activity is modelled by acting the external forces on the rear carriage chassis and the rear axle and their magnitude is dependent on the rear carriage roll angle.

SIMULATIONS OF TEST DRIVES

Simulations of test drives according to the experimental measurements documented in [5] were performed with the multibody models of the both empty and loaded ŠKODA 22 Tr trolleybus. Measurements were performed in the chosen sections of the trolleybus lines in Ústí nad Labem (Czech Republic) in March 2002. Originally the measurements should have been only verifying, the necessity of using the stabilizer and the application of computer simulations were not considered at that time. Time histories of steering wheel angle, speed and vehicle mass were the input data for the test drives simulations.

Simulations were performed with multibody models both without the stabilizer and with the stabilizer of the rear carriage. The monitored quantities were, like in case of experimental measurements, time histories and extreme values of the angle of mutual position of the trolleybus front and rear carriages, rear carriage roll angle and lateral acceleration of the rear carriage above the rear axle. In addition in the course of simulations with multibody models the extreme values of time histories of torsional deformations of articulated joint and relative deflections of the rear axle were monitored. Further in the course of simulations with the trolleybus multibody models with the rear carriage stabilizer the extreme values of time histories of the stabilizer vertical deformation and of forces acting between the stabilizer and the rear axle and between the stabilizer and the rear carriage chassis were monitored.

Results of the simulations were used for the evaluation of the effect of the proposed stabilizer constructional solution on the trolleybus driving stability improvements (especially on decreasing the rear carriage roll angle) and for the determination of the cause of the considerable local extremes in the time histories of the measured quantities during the test drives with he real trolleybus (it was not obvious if they were caused by exceeding the limited torsional deformation of the articulation or by rear carriage bottoming on the rear axle bump stops).

RESULTS

Comparison of the results of the simulations and the test drives with the real trolleybus without a stabilizer

Time histories and extreme values of the monitored quantities found out in the course of experimental measurements on the real trolleybus and in the course of simulations with multibody models are not fully identical. Differences are caused on the one hand by the ignorance of all the conditions of the test drives with the real trolleybus needed for more precise simulations (initial conditions when recording the experimental measurements were not fully known – distances of the rear carriage and rear axle bump stops are not known as well as the time histories of the real trolleybus speed – keeping constant speed for all the duration of the driving manoeuvre is improbable) and on the other hand by the character itself of the computer models (virtual model is always the simplification of the real construction). But in any case those facts do not affect the information abilities of simulations.

Simulations confirmed, that the cause of considerable local extremes in the time histories of the measured quantities during the test drives with the real trolleybus is in rear carriage bottoming on the rear axle bump stops. Maximum elastic torsional deformation of the HÜBNER articulation, which is 3°, was not achieved during the simulation of any test drive. Rear carriage bottoming on the rear axle bump stops was found out during the simulations of the same drives like during the experimental measurements. Extreme values of the time histories of lateral acceleration of the rear carriage above the rear axle found out in the course of the test drives with the real trolleybus and in the course of simulations with multibody models are approximately identical. Extreme values of the time histories of the angle of mutual position of the front and rear carriages of the empty trolleybus determined during the simulation are smaller and those of the loaded trolleybus are greater. Extreme values of the time histories of the rear carriage roll angle found out during the simulation are smaller. Differences are less considerable than with the angle of mutual position of the front and rear carriages.

Results of the trolleybus with the rear carriage stabilizer simulations

Simulations of test drives with the multibody models of the ŠKODA 22 Tr trolleybus with the rear carriage stabilizer were performed for various diameters of the steel rod of the circle cross section, which the stabilizer was to be made of. Time histories and extreme values of the angle of mutual position of the front and rear carriages and lateral acceleration of the rear carriage above the rear axle does not almost differ from time histories and extreme values found out during the simulations with the multibody models of the trolleybus without the stabilizer for all the verified rod diameters. Extreme values of time histories of the rear carriage roll angle and thus also extreme values of other related quantities – relative deflections of the rear axle suspension and torsional deformations of the articulated joint – decreased significantly.

CONCLUSIONS

On the basis of the results of the test drives simulations the optimum diameter of the steel rod used for the stabilizer production (0.04m) was proposed and the suitability of the complete constructional solution of the rear carriage stabilizer of the ŠKODA 22 Tr low-floor articulated trolleybus with the HÜBNER articulation and the RÁBA driving axles for improving its driving stability was confirmed. In the course of simulated drives the rear carriage roll angles decreased by 20 % to 30 % considering the original state owing to the use of the proposed stabilizer. During the simulation of any test drive with the multibody models with the rear carriage stabilizer neither the maximum permitted stabilizer deformation nor the maximum permitted forces acting on the stabilizer were exceeded.

References

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