THE UTILIZATION OF MSC.ADAMS IN PROCESS OF A STREETCAR DEVELOPING IN ŠKODA DOPRAVNÍ TECHNIKA

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ABSTRACT

Based on market requirements, a three-section partly low-floor streetcar with two bogies located beneath end sections was developed and manufactured in ŠKODA Dopravní technika at the end of 1997. During this development MSC.ADAMS/Rail was used for the first time. Since then the software has been used for the designing of further types of streetcars modeled from previous types. This paper describes ways of MSC.ADAMS/Rail application of this development.

Keywords: dynamic analysis of streetcar, running behavior of vehicle, arrangement of running gear

1. INTRODUCTION

At the end of 1997 a new three-section streetcar of class LTM 10.08 was developed and manufactured in ŠKODA Dopravní technika, s.r.o. (ŠKODA Transportation Systems, Ltd.). It is a vehicle for a maximum speed of 70 km/h with low-floor arrangement of middle section. This section is hung on front and rear sections, which are equipped with bogies with no possibility of turning against the tram body. Turning of sections thus ensures passing of the vehicle through the curves. Connection between streetcar sections is realized by means of spherical journals in the floor plain and pin joints in the roof plain. Movements between the sections are damped by longitudinal dampers, which prevent the yawing of sections. The body of the vehicle is manufactured of steel. An overview of the three-section streetcar is in picture No. 1.

Bogies of the streetcar are equipped with both primary and secondary suspension. The primary suspension is realized by rubber - metallic elements, the secondary suspension consists of coil springs and dampers. On the wheels of the bogies there are used rubber fillers between wheels and tires.

Asynchronous traction motors ensure the drive of streetcar with voltage fed inverters, which are equipped with IGBT elements. An electric device is located on the roof of the streetcar. Gearboxes with spur gearing transmit the torque. A shoe brake is fixed on the gearbox. Furthermore, the bogies also include electromagnetic rail brakes.

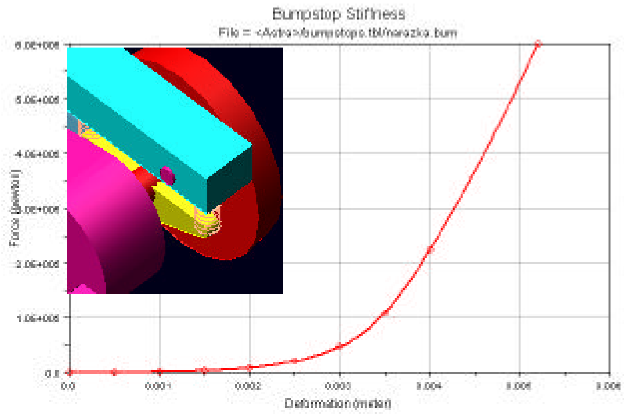
The vehicle is arranged as modular, i.e. with possibility to manufacture vehicles consisting of more module sections. On basis of this modularity a new five-section streetcar, which has four sections identical with the three-section version, is now under construction. Unlike three-section version in case of five-section vehicle the linkage between 3^{rd} and 4^{th} sections is designed by different way – only with spherical joint in level of the streetcar floor. A reason of this arrangement is to reduce a variation of loading of axles during streetcar running on concave or convex track.

Picture No. 1: An overall view of car

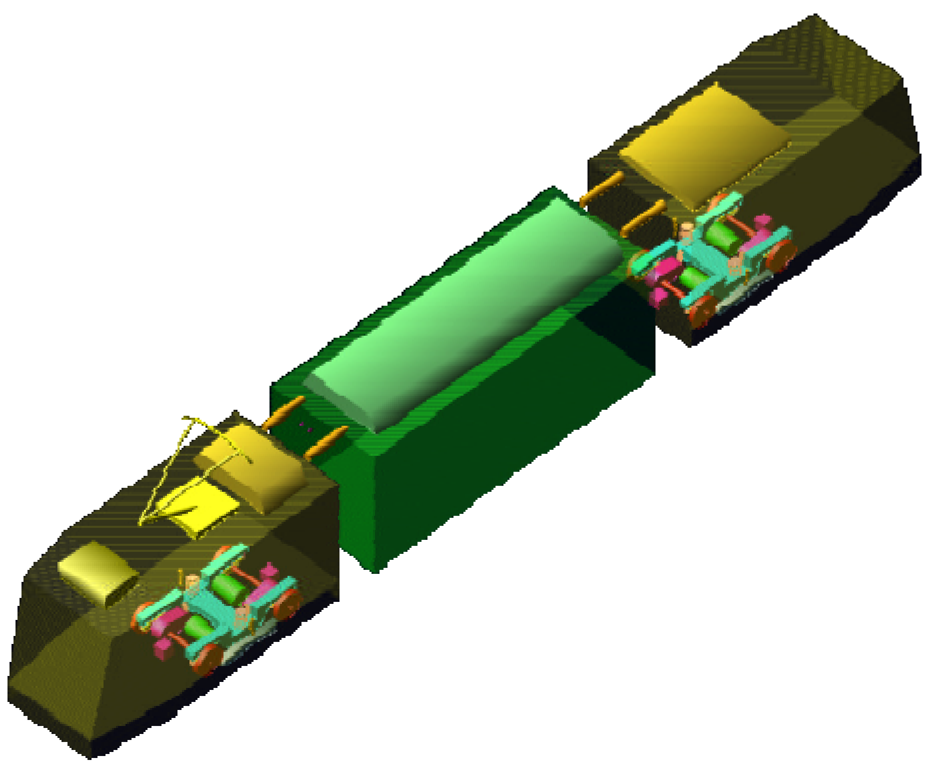
2. DESCRIPTION OF COMPUTATIONAL MODEL

After the manufacture of above described streetcar, a simulation of its dynamic behaviour was performed with ADAMS/Rail. An ADAMS model was built up at first.
Axles, bogie frame, traction motors, gearboxes and brakes were modeled. The model of the bogie was drafted as a closed shell. Then models of the bodies of the three streetcar sections were built, again as shells with mass, which corresponds to the real mass of streetcar body. On the roof there were situated blocks, which simulated the mass of the electric device.

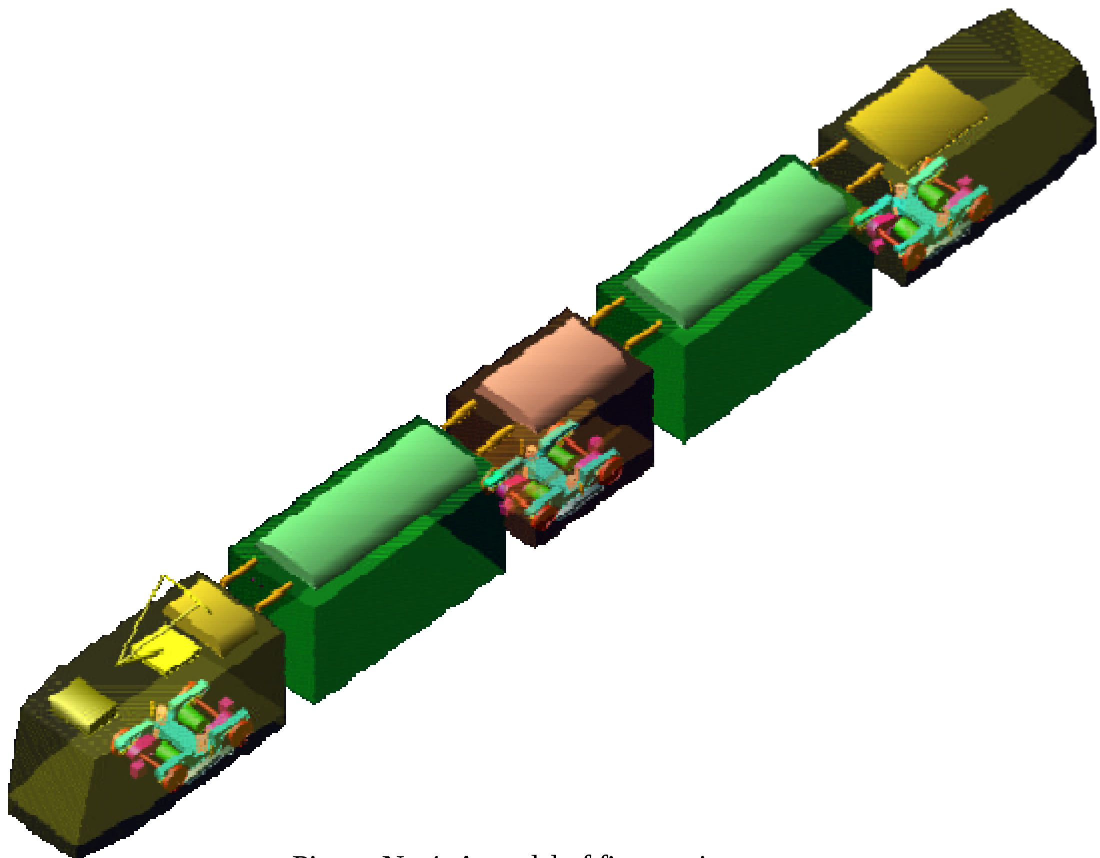
The next step was the mechanical constraints, i.e. constraints between wheel sets and bogie frame simulating primary suspension, constraints between bogies and car body simulating a secondary suspension, positioning of gearboxes in the bogie frame and constraints between the car sections were introduced into the model. Both characteristics of springing and damping elements and wheel profiles being used in the model were obtained from their measurements. The characteristics of the lateral bumpstop between bogie and body are shown in picture No.2. Types of joint connections between sections were chosen from ADAMS libraries to respect the real movements between sections. The model of the three-section streetcar is in picture No.3, and the five-section streetcar in picture No.4.



Picture No.2: A characteristic of lateral bumpstop



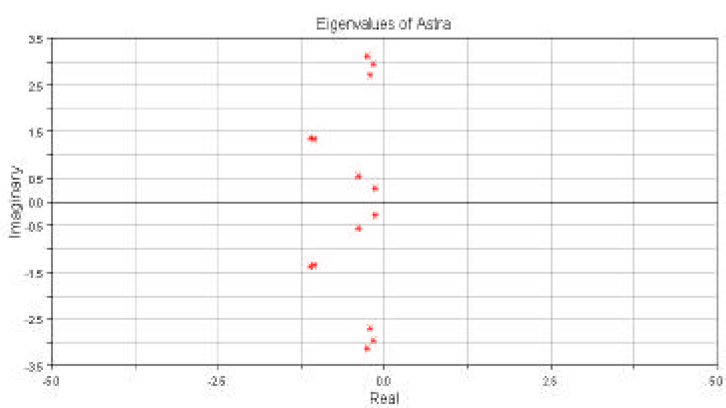
Picture No.3: A model of three-section streetcar



Picture No.4: A model of five-section streetcar

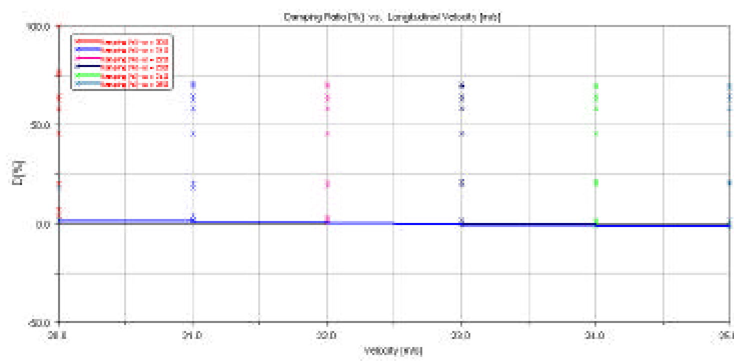
3. PERFORMED ANALYSES

As the first step modal analysis and computing of eigenfrequencies were performed. This kind of analysis was performed for both three-section and five-section streetcar. For illustration values of eigenfrequencies of the three-section car in picture No.5 are presented



Picture No. 5: Eigenfrequencies of three-section streetcar

Again for both vehicles question of the running stability was solved. Value of critical speed was investigated in dependence on characteristics of primary and secondary suspensions. Based on computation of the running behavior these suspensions were optimized. Results of this computation for empty three-section streetcar are in picture No. 6.



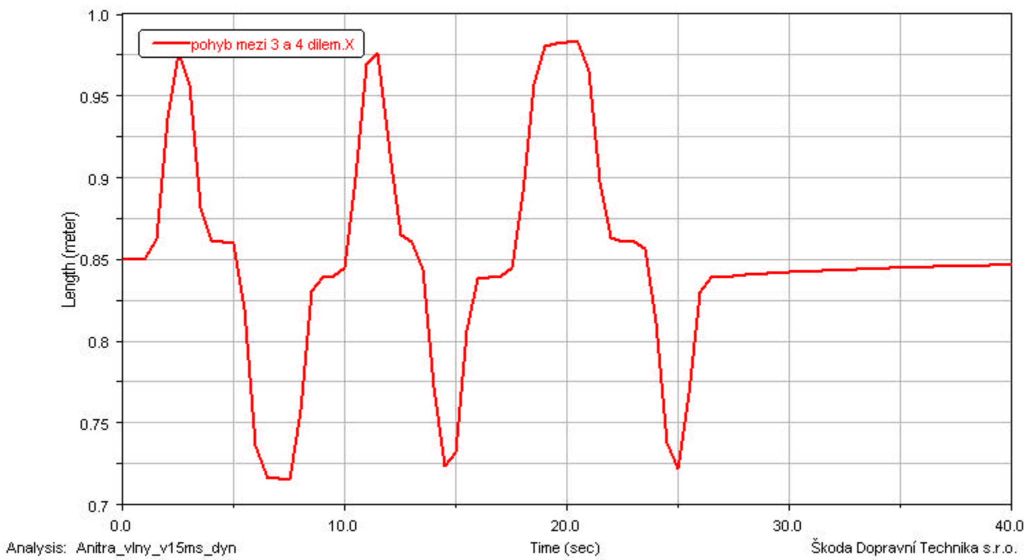
Picture No. 6: Results of stability study

For five-section streetcar analysis of axle loading was performed, with aspect of the loading of bogie beneath the middle section. Results of this analysis are introduced in table No. 1, in which change of the loading in dependence on the vehicle loading is evident. The results were further utilized for modification of arrangement of electric equipment on the vehicle roof.

Loading of empty car [kN]			**Loading by 5 persons/m^2 [kN]**			**Loading by 8 persons/m^2 [kN]**		
axle	bogie	vehicle	axle	bogie	vehicle	axle	bogie	vehicle
64.760	129.519	371.193	85.265	170.529	518.094	93.101	186.202	576.43
64.759			85.264			93.101		
58.538	117.076		85.543	171.086		96.839	193.678	
58.538			85.543			96.839		
62.299	124.598		**88.240**	176.479		**98.275**	196.55	
62.299			**88.239**			**98.275**		

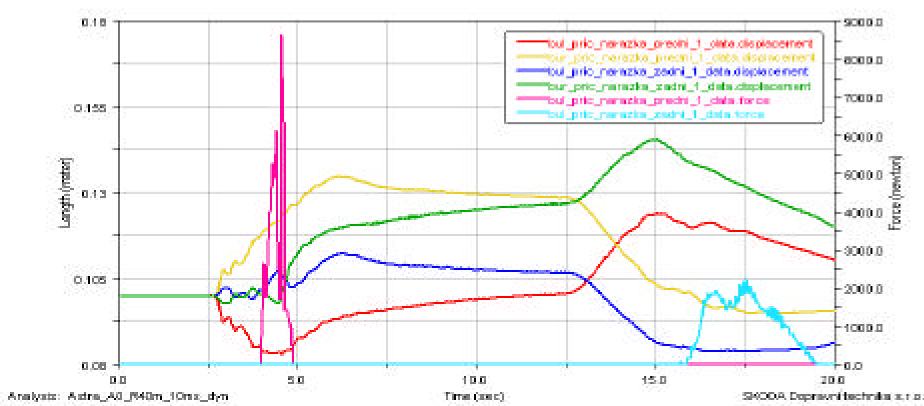
Table No. 1

For five-section streetcar a run on concave and convex track was further investigated. Aim of this analysis was to insist variation of axle loading and relative movements between 3rd and 4th sections. Just in this space, thanks to above described linkage, the relative movements are the most significant. Investigated movement in level of streetcar roof is on graph in picture No. 7.

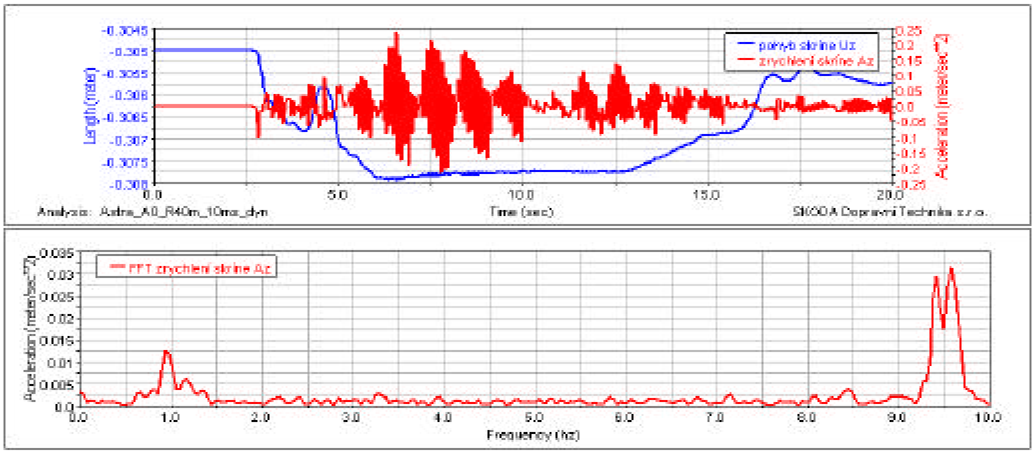


Picture No. 7: Movement between 3[rd] and 4[th] sections in longitudinal direction

At last the movement of the vehicle both along straight and curved track with different radii was solved. The model of track included irregularities that were measured on real track. Analyses were performed for both types of streetcars. Some results of the analyses are shown in pictures No.8 and 9.



Picture No. 8: Movement of lateral bumpstops of first bogie



Picture No. 9: Vertical acceleration and movement of front section of three-section car including PSD of acceleration

4. CONCLUSION

Knowledge about behavior of described streetcars obtained from the simulation by software package MSC.ADAMS/Rail were applied whether during their construction or in test operation. Thanks to this simulation manufacturing and operating cost were significantly reduced and technical as well as utility values of the streetcars were improved.

Further utilization of MSC.ADAMS/Rail in domain of streetcar vehicles depends on its further development. At present two main problems are solved:

1. Forced slew of the sections of above described streetcars. This is the question of application of force elements, which replace longitudinal roof dampers among sections and help the streetcar in smooth run through a curved track.
2. Reduction of wheel wear caused by operation of the streetcars on track with frequent occurrence of curves with small radii. In this case the simulation is supported by measured data of wheel profiles, which are periodically measured on operated streetcars.