DYNAMIC ANALYSIS OF HIGH-SPEED ELECTRIC LOCOMOTIVE

Václav Kraus and Michal Ranš

ŠKODA DOPRAVNÍ TECHNIKA s.r.o.
Tylova 57, 316 00, Plzeň, Czech Republic

Received: September 24th, 2001

ABSTRACT

In the paper a dynamic analysis of high-speed electric locomotive with two variants of bogie arrangement is described. After creating of computational model dynamic behavior of the locomotive was performed for each variant. On basis of the computation results better arrangement of running gear was recommended for implementation.

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

1. INTRODUCTION

Based on market requirements a high-speed electric locomotive is developed in ŠKODA DOPRAVNÍ TECHNIKA s.r.o. An extreme attention is paid to running behavior of the locomotive, especially running gear which is designed in two variants. A topic of this paper is a comparison of both arrangements of running gears from aspect of their dynamic behavior.

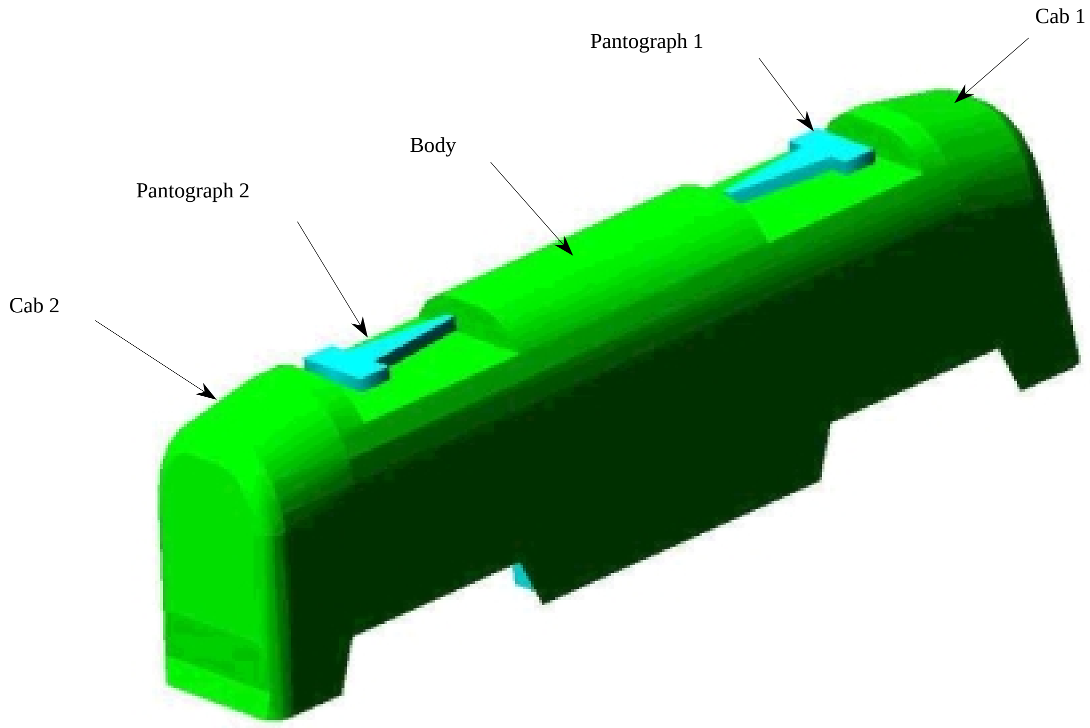
In the first alternative a drive, which consists of traction motor and gearbox, is located in the bogie frame. A torque transmission between gearbox and wheelset is achieved by hollow shaft.

In the second alternative there is used running gear, which has identical torque transmission, but location of nodal point 'motor-gearbox' is substantially different. A traction motor is placed on the body frame and gearbox is placed partly in the bogie and partly on the locomotive body. Connection of the motor and the gearbox is realized by system of rods. The torque transmission from the motor to the gearbox is achieved by cardan-shaft.

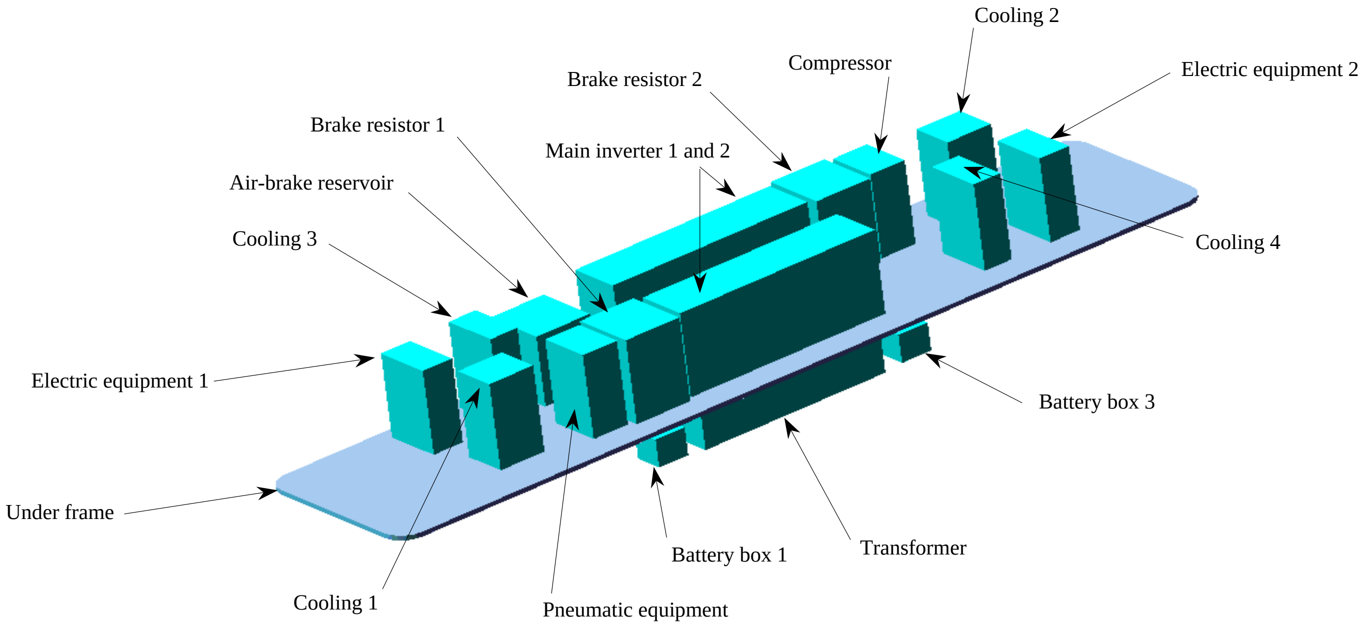
Considering the fact that each variant has some advantages but also disadvantages we decided to evaluate dynamic properties of both alternatives by means of ADAMS/Rails.

2. DESCRIPTION OF COMPUTATIONAL MODEL

ADAMS models were created for both alternatives of running gear. At first a locomotive body (see picture No.1), which is identical for both variants, was designed incl. machine room (see picture No.2).



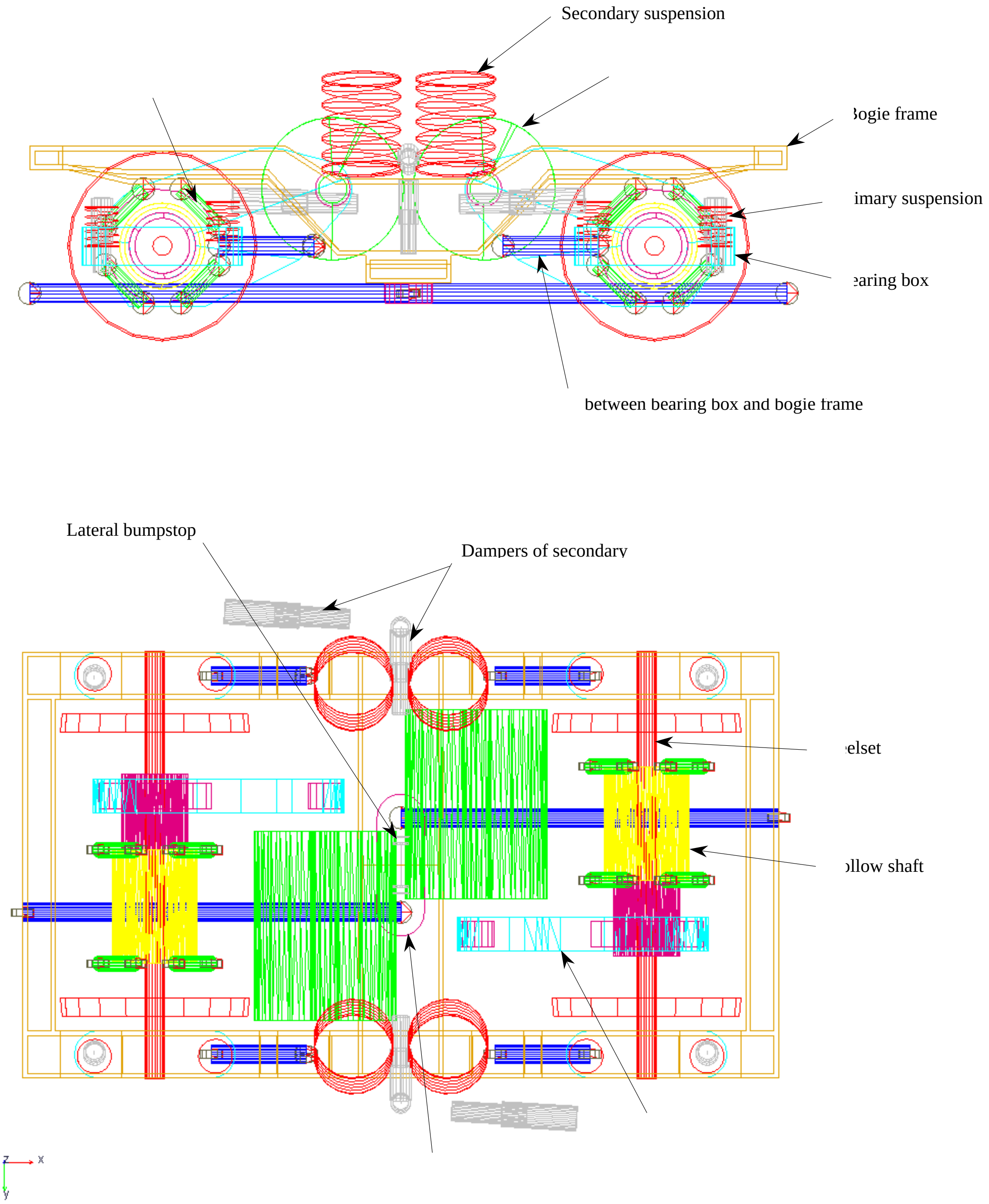
Picture No. 1 An overall view of a locomotive body



Picture No. 2 A detailed view of a machine room

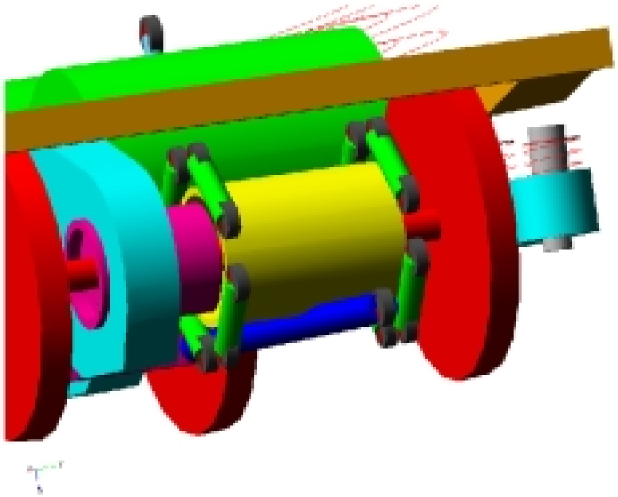
2.1. The first alternative – traction motors located in the bogie

This alternative is of standard arrangement of running gears where ‘motor-gearbox’ block is located in the bogie frame. (see picture No.3).



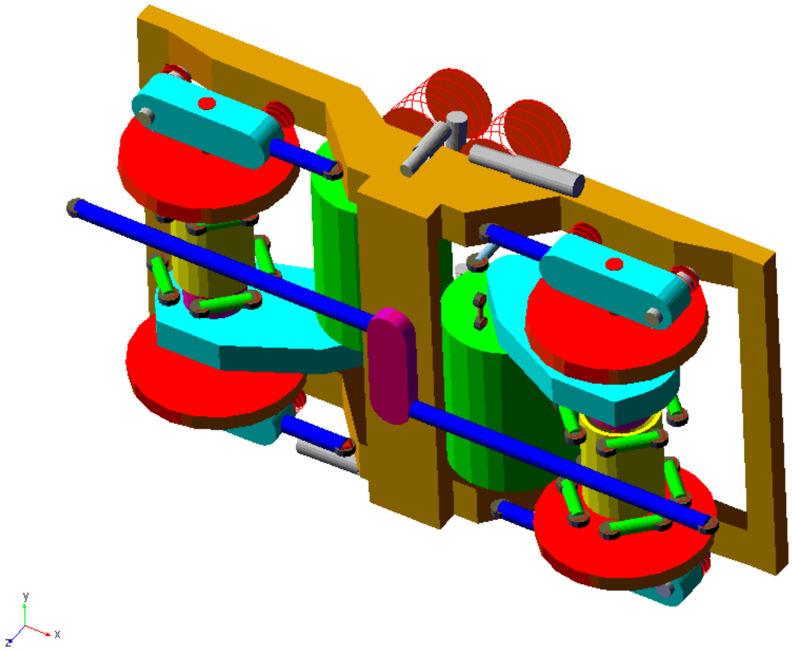
Picture. 3: A computational model of bogie - motors located in the bogie

Torque transmission between gearbox and wheelset is achieved by hollow shaft. Connection of the hollow shaft with gearbox and wheelset is realized by means of blade-type conrods with rubber-bonded metal mount on each end (see picture No.4).



Picture No. 4: A detailed view of torque transmission between gearbox and wheelset

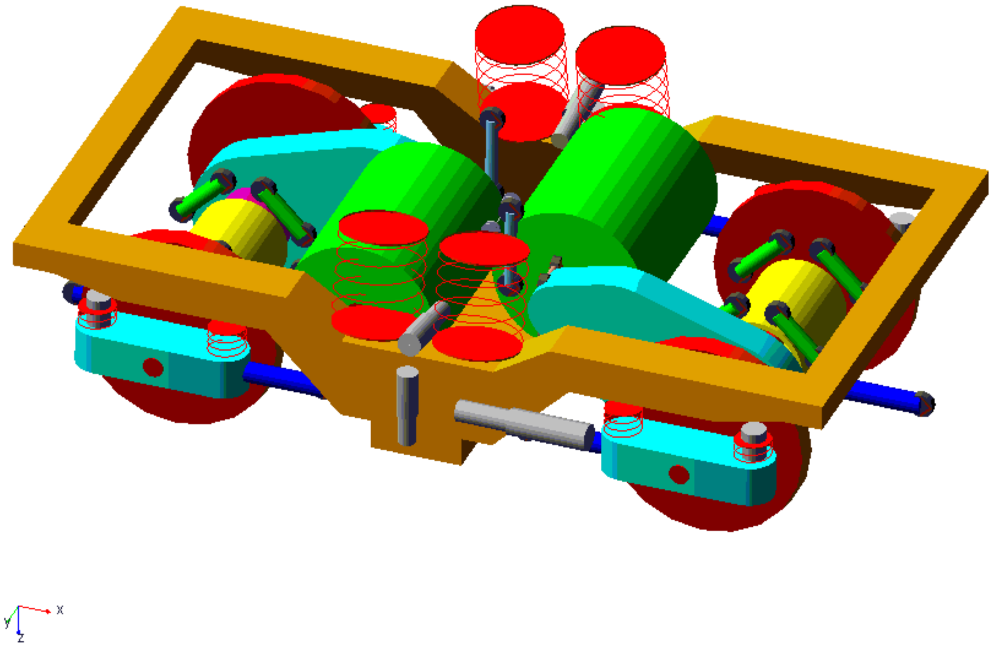
A primary suspension is realized by means of coil springs located between bogie frame and bearing boxes and dampers acting in vertical direction. A secondary suspension comprises two couples of flexi-coil strings and dampers acting in longitudinal, lateral and vertical directions. Forces from the bearing boxes to the bogie frame are transmitted by rods. Transmission of traction or breaking forces between the bogie and the vehicle body is realized by lever and rod system which is situated under center of the bogie frame (see picture No. 5).



Picture No. 5: Transition of traction and braking forces between the bogie and the locomotive body

2.2. The second alternative - traction motors attached on the locomotive body

A computational model of this alternative is shown on picture No. 6.



Picture No. 6: Computational model - motors attached on the body

In this case more complicated transmission of torque and connection of nodal point ‘motor-gearbox‘ (see picture No.7) are used. A gearbox is partly placed on the loco body frame and partly in the bogie. Connection of the gearbox and underframe of the body is performed by rod. Connection between the traction motor and the gearbox is realized by couple of rods. Torque transmission between the motor and the gearbox is achieved by cardan-shaft which also allows sliding movement in lateral direction. Torque transmission from the gearbox to the wheelset, primary suspension, secondary suspension, transmission of traction and braking forces and lateral bumpstops are the same as in the first alternative.

For modeling of coupling there were used standard elements (for example: suspension, damper, bushing etc.) from library of software ADAMS/Rails.

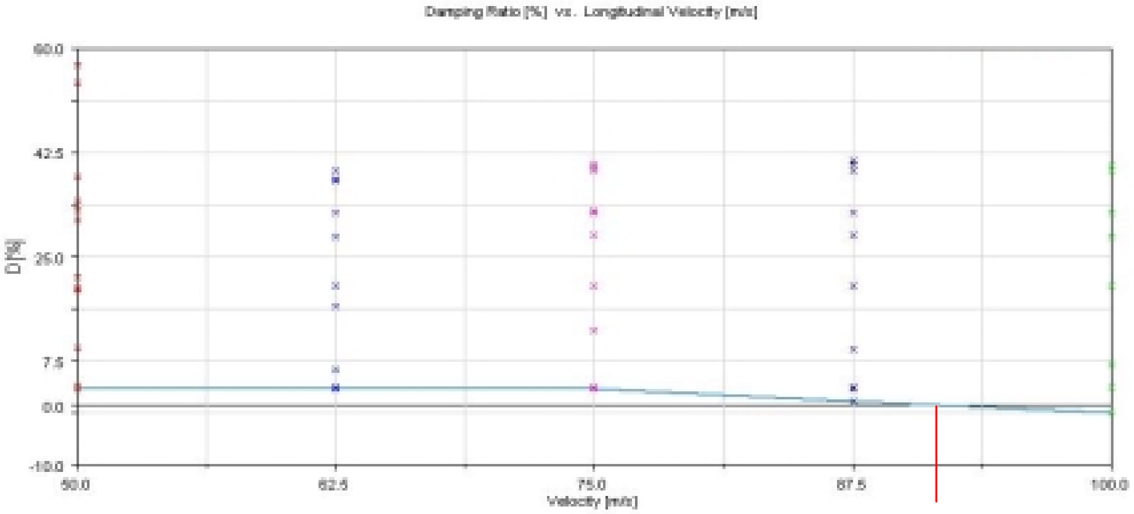
3. PERFORMED ANALYSIS

The models of both variants were debugged with help of MDI Prague. As further step a dynamic analysis was performed. At the beginning attention was concentrated on computing of natural frequencies and natural shapes including proportional damping. Values of damped natural frequency for both alternatives of bogie arrangement are practically identical with exception of body yawing. The results of this analysis are shown in table No.1.

Damped natural frequency of the body [Hz]	Motor located in the bogie	Motor attached on the body
jumping	1,2761	1,2717
swaying	0,7103	0,6698
pitching	1,4348	1,4019
tilting	0.6988	0,7026
yawing	0,8026	0,5933

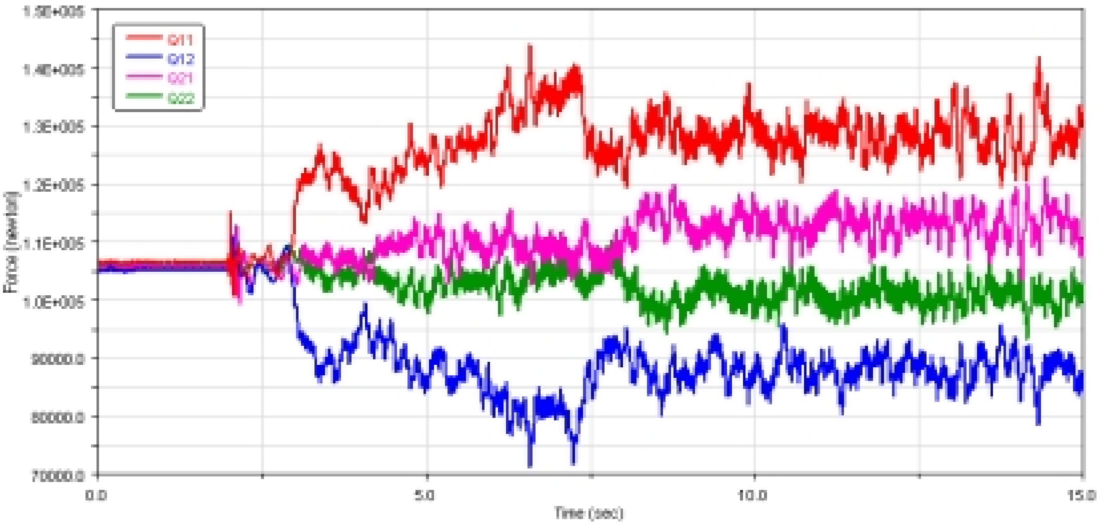
Table No. 1: Results of linear analysis

Then the running stability was solved. Value of critical speed was investigated in dependence on characteristics of primary and secondary suspensions. Basic on computation of the running behavior the suspensions were optimized (see picture No. 8).

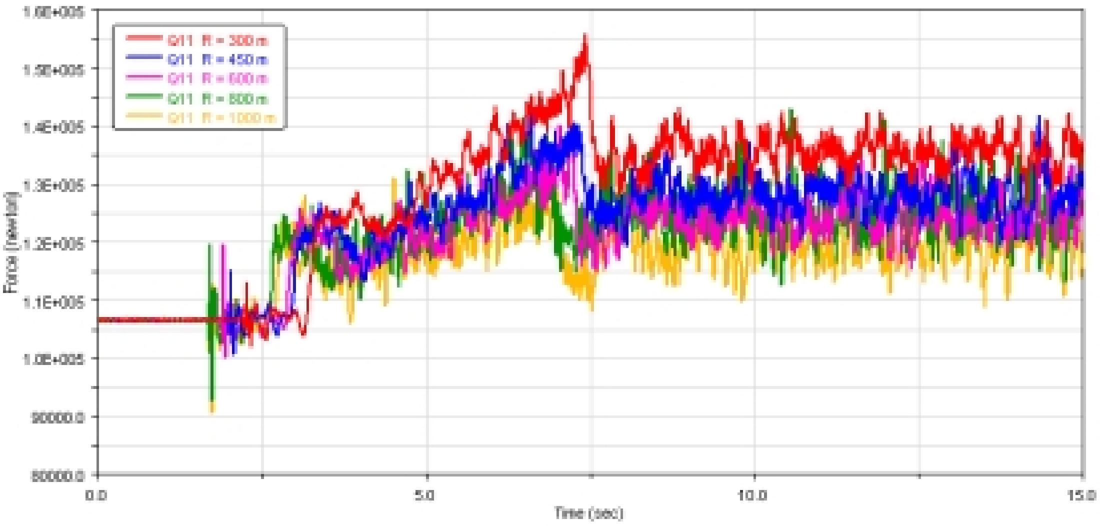


Picture No. 8: Running stability – critical speed

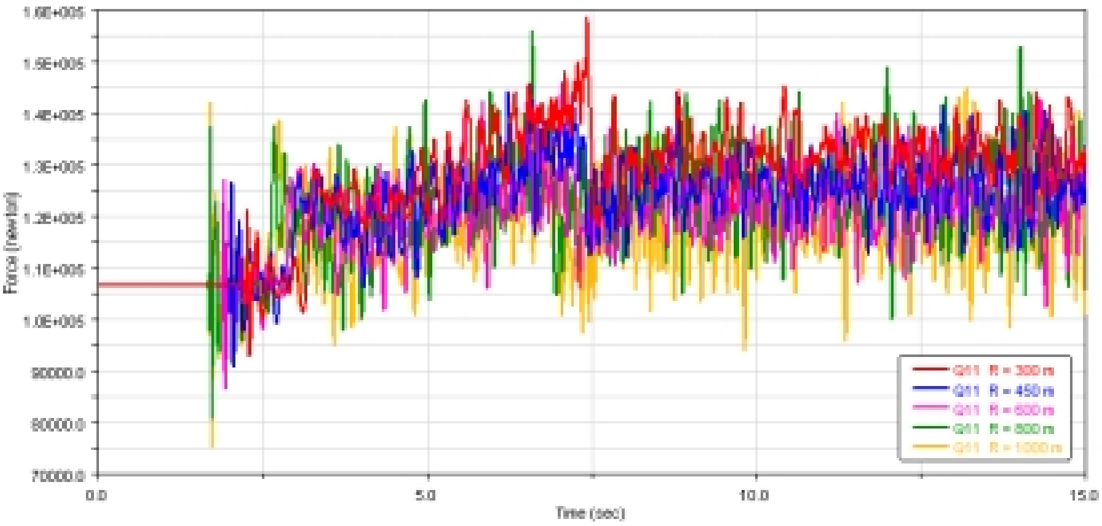
At the end movement of the vehicle along inline track and curved track with different radii was solved. The model of the track included irregularities that were measured on real track. Analyses were performed for both arrangements of running gear. Some results of the analyses are shown on pictures No.9-18 and written into tables No. 2-3. Used symbols are in accordance with rule UIC 518.



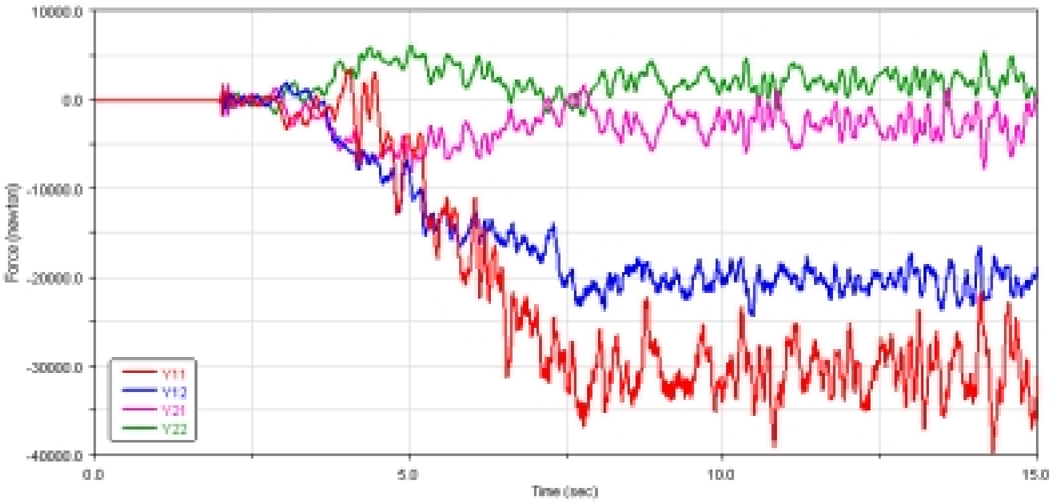
Picture No. 9: Course of vertical forces between wheel and rail (R= 450 m, p=150mm,v=28.7m/s) - motors in the bogie



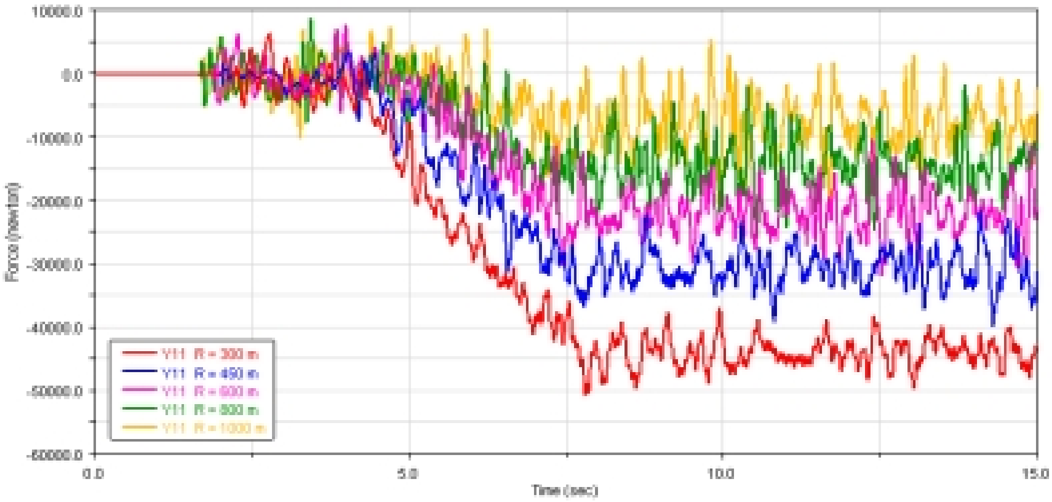
Picture No. 10: Course of vertical forces between wheel and rail – motors in the bogie



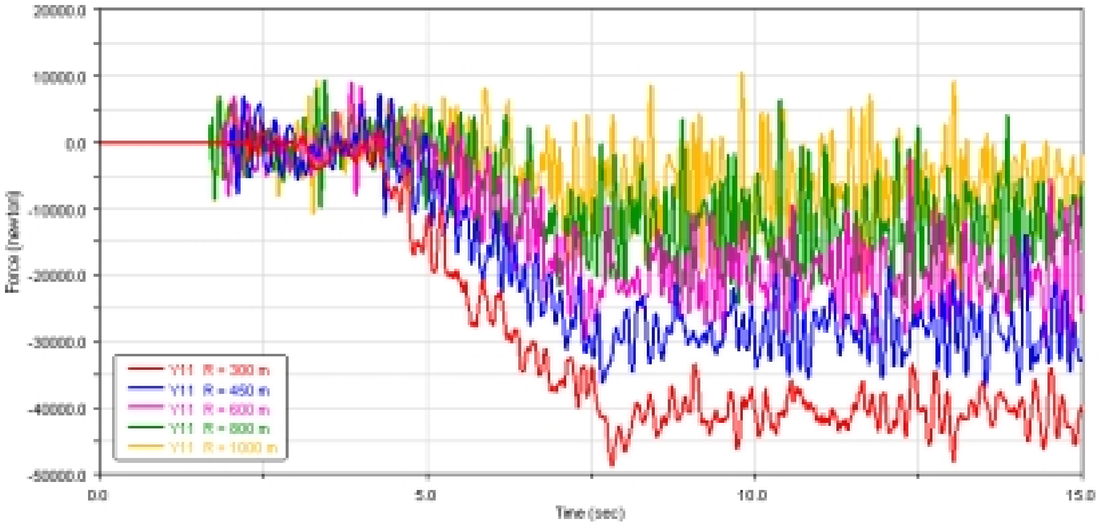
Picture No. 11: Course of vertical forces between wheel and rail – motors on the body



Picture No. 12: Course of lateral forces between wheel and rail (R= 450 m, p=150mm,v=28.7m/s) - motors in the bogie



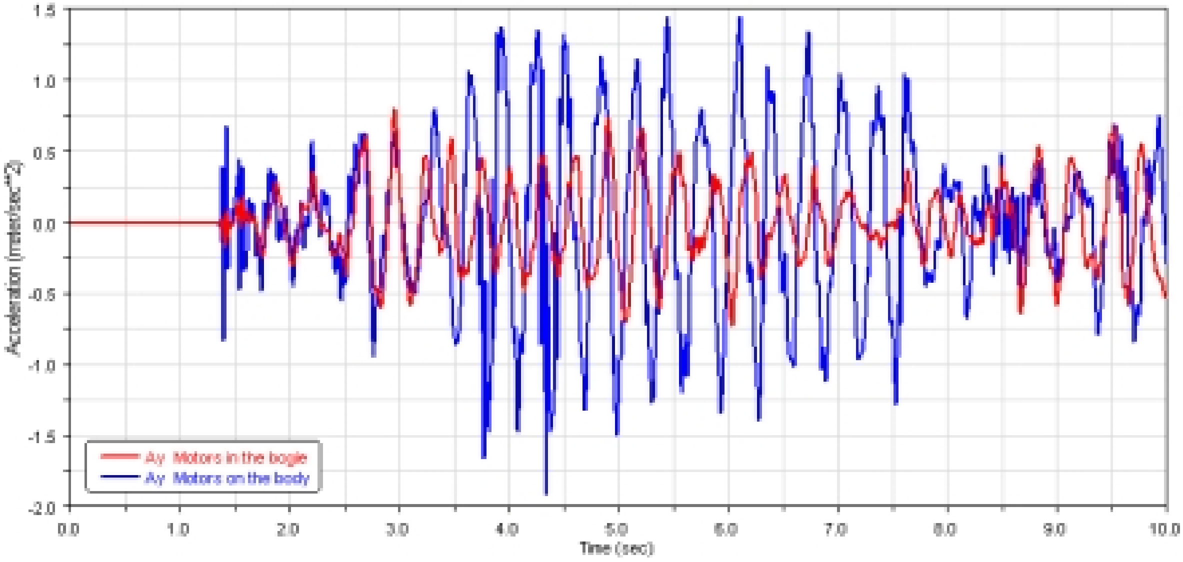
Picture No. 13: Course of lateral forces between wheel and rail – motors in the bogie



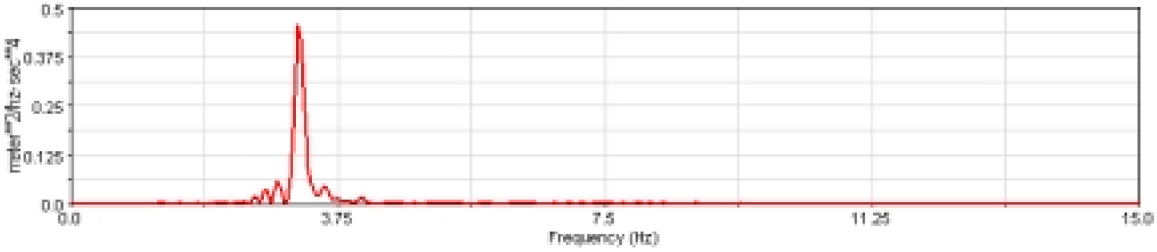
Picture No. 14: Course of lateral forces between wheel and rail – motors on the body

Q[kN]		**Motors in the bogie**			**Motors on the body**		
R[m]	**force**	**min**	**max**	**Avg**	**min**	**max**	**Avg**
300	Q11	120,6	144,8	132,5	120,6	144,8	132,5
450	Q11	123,6	143,6	132,2	111,8	141,6	126,4
600	Q11	115,4	136,7	124,2	102,6	142,9	123,5
800	Q41	120,1	139,3	128,3	102,3	159,7	129,9
1000	Q41	116,0	135,6	124,9	95,3	154,9	126,0
inline	Q41	88,8	125,3	108,0	38,4	202,9	108,1
Y[kN]		**Motors in the bogie**			**Motors on the body**		
R[m]	**force**	**min**	**max**	**Avg**	**min**	**max**	**Avg**
300	Y11	-49,6	-38,3	-44,0	-47,4	-33,1	-40,4
450	Y11	-39,8	-22,1	-31,3	-36,8	-13,9	-28,5
600	Y11	-32,2	-10,3	-21,9	-32,8	-24,6	-20,2
800	Y41	-23,3	-6,6	-14,4	-24,3	0,2	-13,4
1000	Y41	-20,0	-2,0	-12,2	-21,9	2,1	-11,5
				RMS			**RMS**
inline	Y42	-12,4	11,0	4,6	-34,7	14,4	9,4

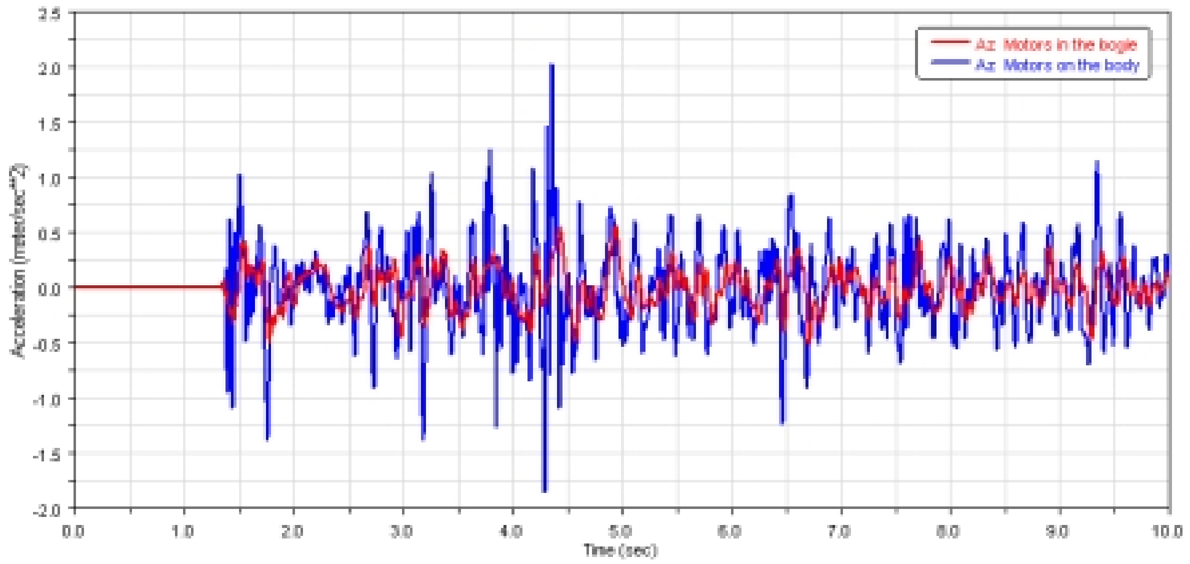
Table No.2: Values of vertical and lateral forces between rail and wheel



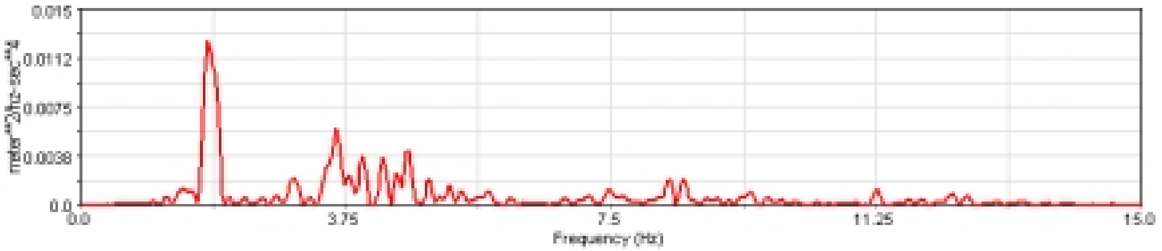
Picture No. 15: Course of lateral acceleration of front cab for both alternatives – inline track



Picture No. 16: PSD of lateral acceleration of front cab with motors in bogie – inline track



Picture No. 17: Course of vertical acceleration of front cab for both alternatives – inline track



Picture No. 18: PSD of vertical acceleration of front cab with motors in bogie – inline track

Ay[ms^{-2}]	RMS		**Az[ms^{-2}]**	RMS	
	Motors in the bogie	Motors on the body		Motors in the bogie	Motors on the body
Front cab	0,302	0,629	Front cab	0,185	0,383
Center of body	0,527	0,832	Center of body	0,286	0,444
Rear cab	0,369	0,692	Rear cab	0,23	0,353

Table No.3: Values of accelerations for both alternatives

4. CONCLUSION

.

Pursuant to acquired results it is possible to express conclusion that the arrangement with traction motors on the body does not bring significant improvement of dynamic behavior of the locomotive. With respect to this knowledge and to the fact, that this arrangement is technically much more complicated, the variant of the arrangement with traction motor located in the bogie was recommended to implementation.