Experimental Development of Active Control Systems of Railway Vehicle Bogies

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Abstract
Předmětem našich aktivit je vývoj systémů, které pomocí členů aktivního řízení integrovaných do mechanizmu vedení dvojkolí pozitivně ovlivňují jízdní chování kolejových vozidel. Vyvíjený systém je nejprve teoreticky navržen a následně testován na modelovém kladkovém stavu ČVUT. Hlavními sledovanými parametry chování vozidla jedoucího v simulované koleji jsou příčné síly v kontaktu kola s rotující kolejnicí a parametry příčného kmitání podvozku. U testovaného systému akční člen na základě řídícího signálu natáčí obě dvojkolí kolem jejich svislé osy. Tímto způsobem lze on-line řídit jak příčné kmitání vozidla během jízdy v přímé trati, tak snižovat velikosti vodících sil v oblouku. Předmětem výzkumu je rovněž aplikovatelnost systému na podvozky vybavené vzájemně volně otočnými koly.

Keywords
Active bogie control, roller-type test set, floating wheels

1. Introduction
The requirements concerning the running behaviour of new railway vehicles are continuously rising. The classic concepts of railway bogies show their limits as regards the vehicle dynamics. It is possible to improve the running characteristics of the vehicles and thus exceed these limits by integrating power elements into the bogies and by means of feedback controls responding to the current state of the vehicle. Owing to the technology development these systems are more and more available to the railway services as regards the price, reliability as well as the system weight. For this reason, in our opinion, it makes sense that attention should be paid to the development of these systems and the best way should be sought of how to improve the vehicle dynamics or how to minimise negative impacts on the rail by using these means. Some of the railway vehicle manufactures have been carrying out research into this.
At our institute we have set the goal of both theoretically defining the control system and testing its functioning by means of experiments. For this purpose the original CTU model roller rig is used. [1]

2. Active Control Objectives
Main tasks of the active control system are as follows:
- to stabilize the vehicle dynamics
- to reduce the vehicle resistance of motion

The first point is important especially as regards the high-speed vehicles. Limitation or elimination of the lateral harmonic motion of a vehicle running along the lines contributes considerably to a higher riding luxury and reduces considerably stress on the vehicle parts and the railway superstructure.
The second point involves especially the vehicle running round a bend. By introducing suitable forces or moments into the bogie running round a bend it is possible to achieve

reduced angles of attack between wheels and rails and thus to reduce the slip forces between the wheel and the rail. This reduces train resistance and also the wear of wheels and track.
A special case is the application of the control systems within the bogies equipped with independently turning wheels (IRW). These bogies literally ask for application of the controls as only through them it is possible to exploit all the advantages of these undercarriages and eliminate their disadvantages.

3. Choice of the Suitable Control Method

Figure 1 shows three control principles which were taken into account in relation to the system being developed. The basic condition for choosing the method was its applicability within the conditions of a CTU laboratory.

- to introduce the torque on the wheelset vertical axis
- to introduce different torques on the right and left wheels – only as regards IRW
- to introduce a torque tie between the right and left wheels – only as regards IRW

The first method was chosen due to the fact that it is expected that the system for both classical wheelset and IRW will be developed.

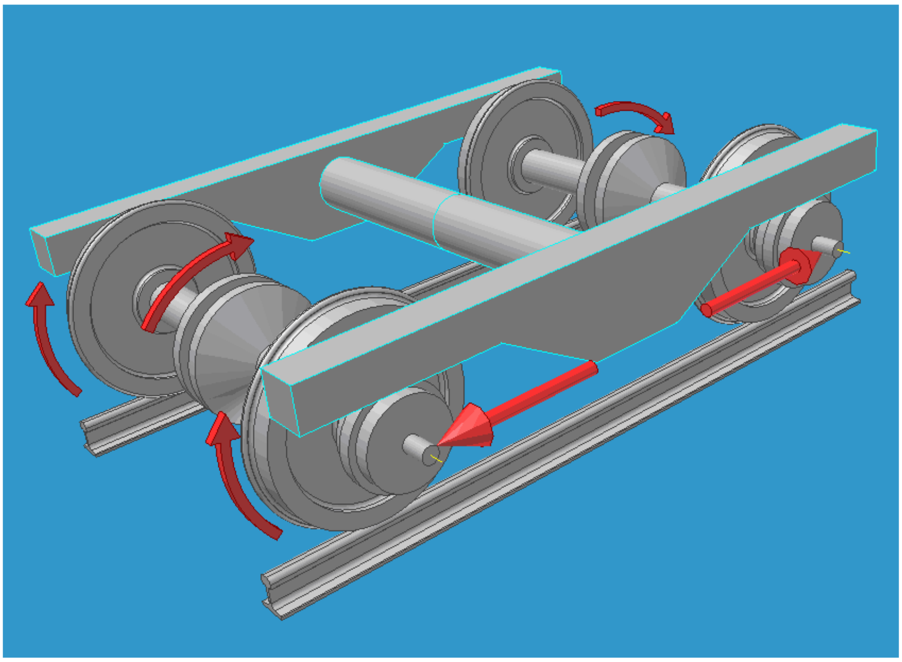

Fig1. Possibility of introducing regulating force effects

4. Proposing the Control System Parameters

For the purposes of designing the control system a 2D mathematical model of a two-axle bogie was prepared. It is a linearized model of motion equations dealt with in Matlab – Simulink. Weight parameters correspond to the bogie installed on the CTU model roller rig.
The mathematical model is completed with feedback regulation branches simulating the active control. The main task of the model is to design the control algorithm. At present we use only the proportional control of the action element with input quantities. On the basis of this model it is possible to specify the maximum control forces in the mechanism and the necessary speed of the control system response.

5. Structural Design

Subsequently, the structural design was made of the mechanism introducing the control torque into the wheelset. The mechanism consists of a power unit which brings the couple of forces through the conical gearbox and the rod system to the axel box of the wheelset.

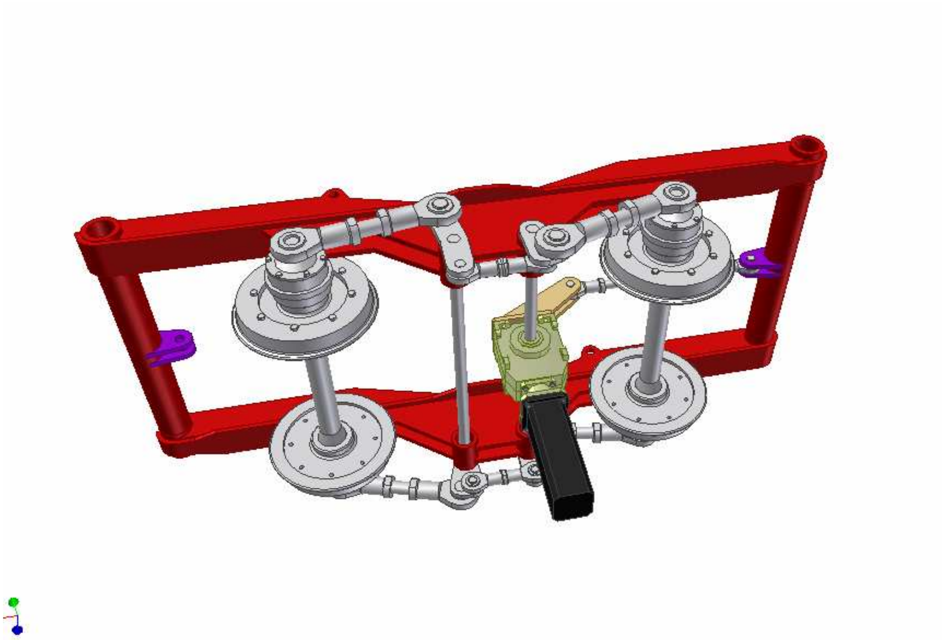

Fig2. System controlling both wheelsets by means of one common action element

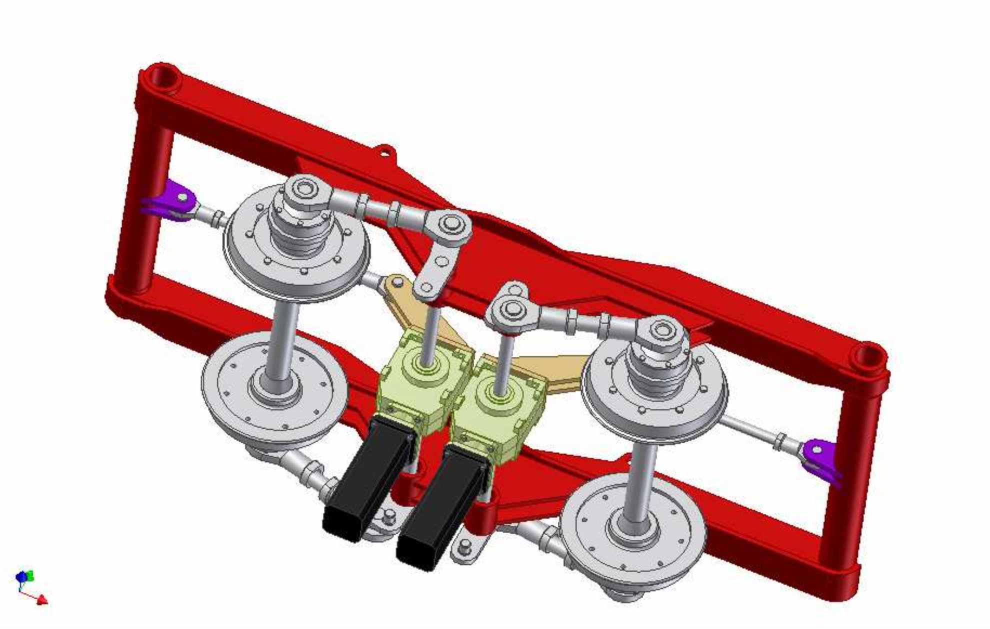

Fig3. System controlling each wheelset with a separate action element

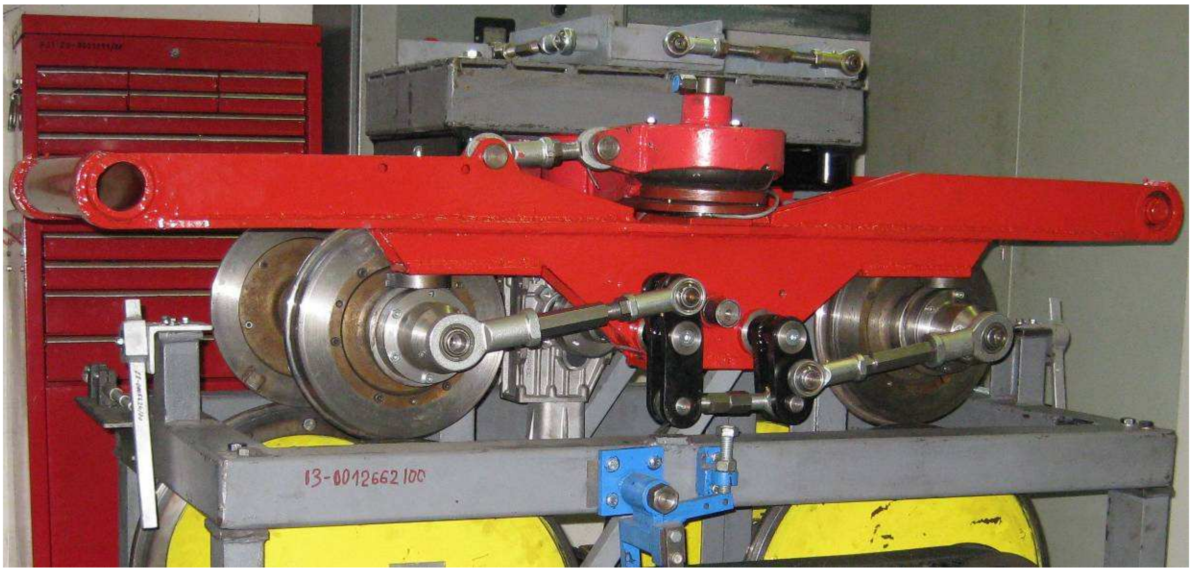

Fig4. Control system installed on the roller rig

6. Experiment Preparation

The basic condition of a successful experiment is the assessment of the effect of deviations of particular parameters of the experimental mechanism from nominal values on the general characteristics. The parameters which appear as critical from this point of view must be thereafter set with increased accuracy. As regards the railway roller rig the greatest attention must be paid to the contact between the wheel and the roller. Both as regards their mutual geometry and as regards the required kinematics. The following subchapters contain some of the measures ensuring sufficient accuracy of the experiment.

6.1. Contact Geometry Verification

The mutual contact of the wheel operating surface and the roller causes force effects which determine dynamic characteristics of the vehicle. By changing the contact geometry profile the intensities and directions of contact forces are changed as well. It is thus clear that the description of the shape of real driving profiles is necessary for the purposes of assessing the experimental bogie characteristics. For these purposes a profile meter was designed and manufactured with sufficient accuracy.

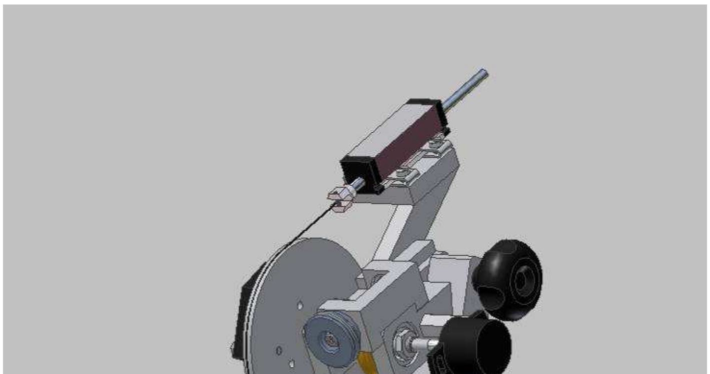

Fig5. Profile meter design

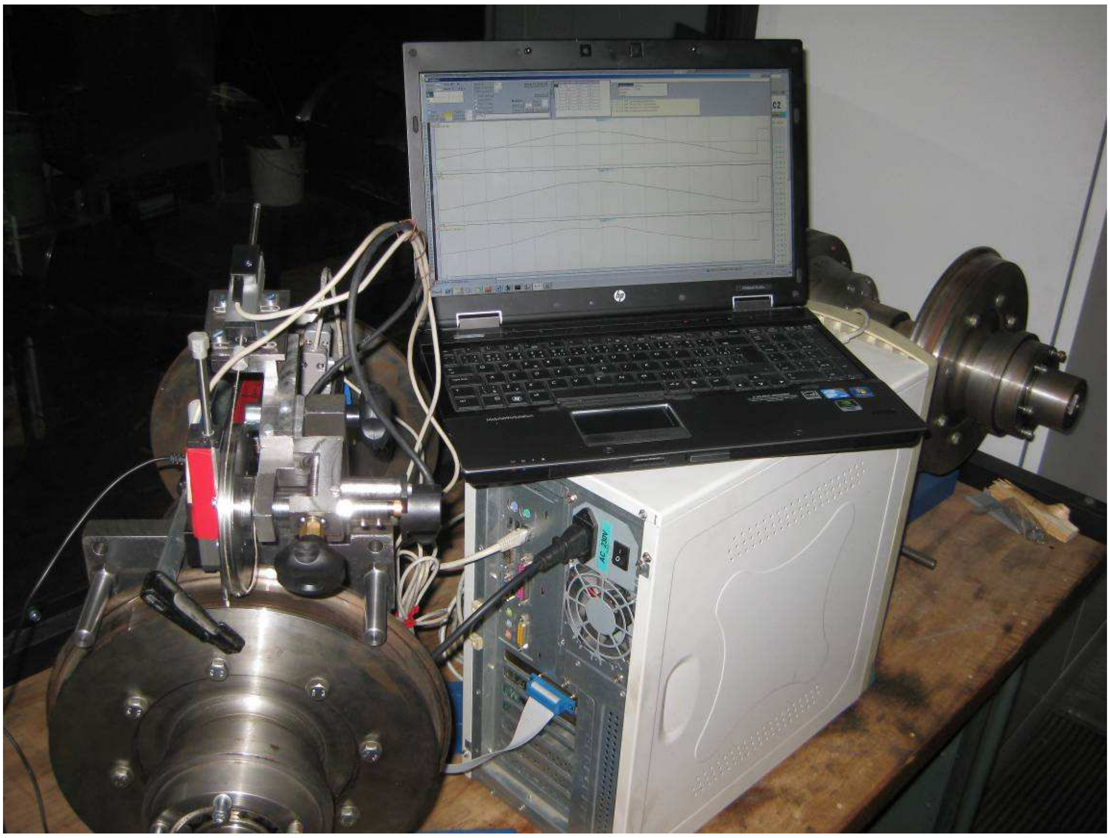

Fig6. Profile meter application

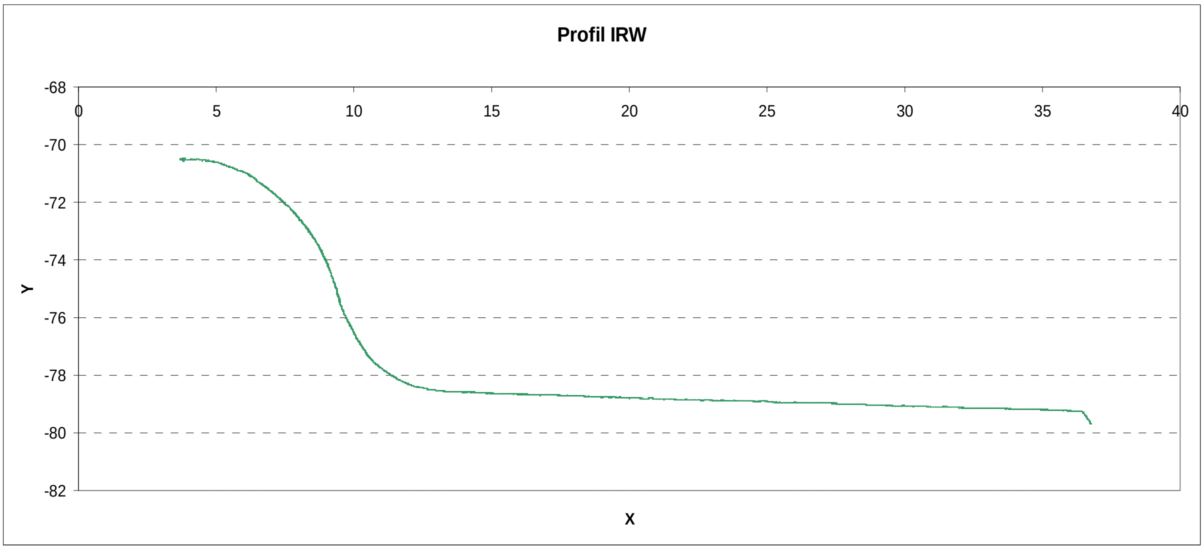

Fig7. Measured profile of the pulley

6.2. New Means of Driving Round a Bend Simulation

Simulation of the conditions under which a vehicle runs round a bend must follow especially the following two factors:

- directional curvature of the track
- different length of the trajectory theoretically covered by the inner and outer wheel of the wheelset.

The first point is implemented by turning one of the couples of rollers on the vertical axis into the radial position with respect to the simulated bend. The second point is simulated by setting different revolutions of the right and left rollers. Both the changes must be implemented with sufficient accuracy and as far as possible continuously and in real time. The first point was set by a motion screw driven by a servomotor. In order to ensure the precise difference of the right and left rollers a planetary gearbox with the gear ratio adjustable by the servomotor was inserted between the shafts of the rollers.

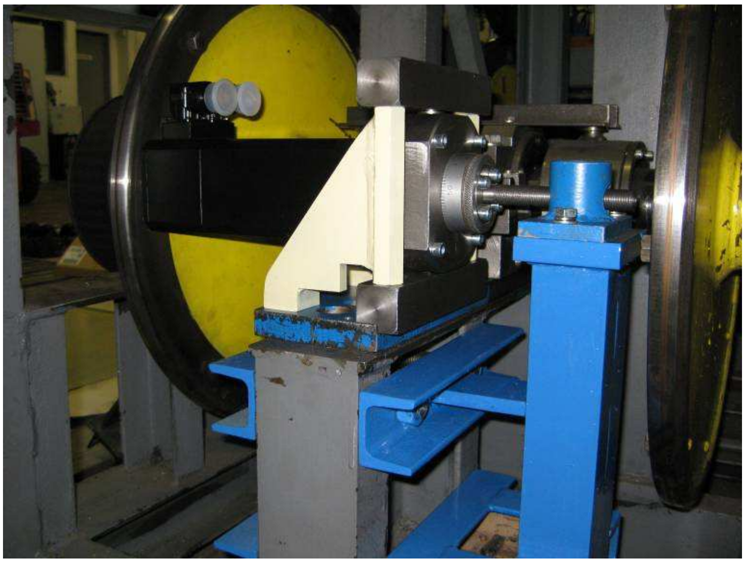

Fig8. Drive turning the pulleys

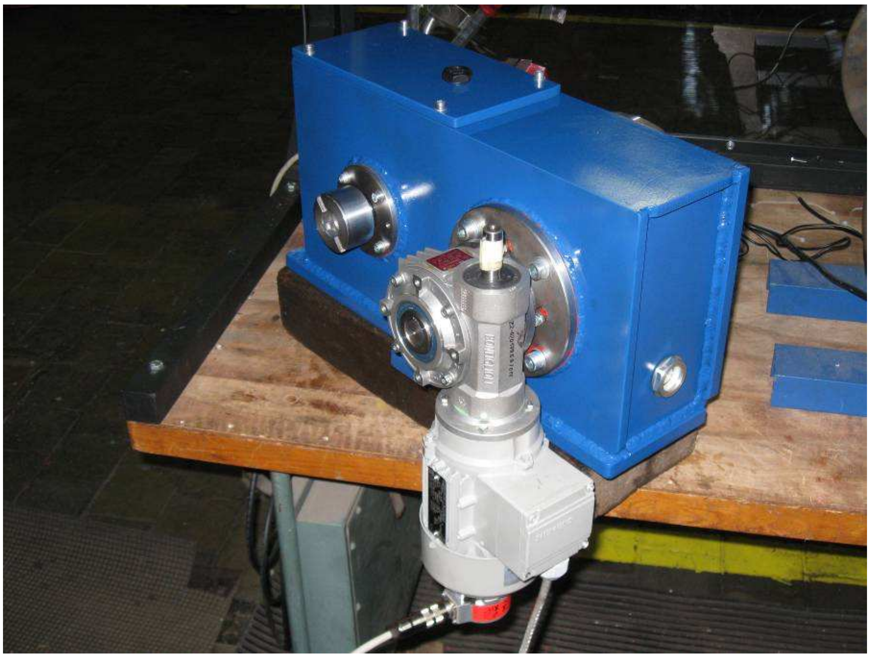

Fig9. Planetary gear controlled by servo motor

6.3. New Method of Measuring Lateral Forces of the Contract between the Wheel and the Roller

The new controlled drives of the tested mechanism resulted in the increased number of frequency converters and therefore also in the electromagnetic pollution emitted by them. This had a negative impact on the functioning of the measuring chain. For that reason the measuring chain was gradually converted into a system more resistant to the external noise

absorption. New sensors, new amplifiers and also a new digitizing card for data collection were acquired.
One of the important measured quantities is also lateral guiding force between the wheel and the roller. The original measuring method showed little response and great hysteresis. Therefore measurement of lateral forces from the roller deformation was proposed. Tensometers are attached to the roller disk and signals are transmitted by means of the wireless transmission into the measuring computer.

7. Conclusion

The active control system implemented on the CTU model roller rig has already been put into operation and a number of experiments have been carried out. The revealed drawbacks of the equipment and their removal are described in Chapter 6 herein. Nevertheless, the control system functionality has been proved and it is necessary to find a suitable control algorithm.
At present the final installation and debugging of new systems are taking place. It will be put completely into operation towards the end of April and at the beginning of May 2011.

8. Bibliography

[1] BAUER P., KOLÁŘ J. WŮDY T., *Experimentální ověřování jízdních vlastností kolejových vozidel,* Současné problémy v kolejových vozidlech, XVII. Mezinárodní konference, Česká Třebová 2005 (Experimental verification of railway vehicle characteristics, Current problems of railway vehicles, XVII International Conference, Česká Třebová 2005)