Opponent's Review for the Dissertation Defence

Dissertation Title: **ANTI-SLIP CONTROL OF TRACTION MOTOR OF RAIL VEHICLES**

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Dissertation Thesis is focused on problems of wheel slip protection usable for traction rail vehicles. Directly on slip and anti-slip control system for traction tram drive. Many research institutes and vehicle producers are involved in long-term to research issue of traction power transmission and to achieve maximum traction forces between wheel and rail with regard to external conditions.
Efforts of these teams to achieve maximum adhesive values are from point of increasing safety requirements in public transport (especially braking ability), as well in obtaining the necessary operation traction properties of vehicles under varying external conditions (water, ice, mud ..), and with the requirements to reducing vehicle weight while maintaining the components long live and reducing their wear. These necessary parameters at slip drive controllers achieved thanks to new developments in this field area, thanks to introduction of new regulation and control algorithms. For this reason, I think that the topic that Ing. Zirek dealt in your dissertation work is still active. The presented work is very interesting with its conclusions and findings.
PhD student Ing. Zirek deals with the problems of slip control both from the point of view of mathematical simulations which according to the submitted work verified the functionality and properties of the slip control solutions he has chosen (chosen control scheme).
These control schemes were subsequently verified by experimental works in DFJP laboratories. For this verification he used a wheel-rail test bench with traction PMSM and loading induction motor. According to the submitted research work he also created numerical models for these validations. Subsequently, it monitored and compared the effects of different settings of each type of regulators with respect to the speed of the rail vehicle.
Doctoral thesis is divided into 6 chapters. As is customary, the opening chapters of the dissertation deal with the theoretical analysis of the issue. These introductory chapters contain very clear and concise information on the issue and physical equations and incursions. In 4 chapter are describe 5 chosen methods of slip controls schema (Wheel Slip Control Based on a Single Threshold; Wheel Slip Control Based on Multiple Thresholds; Wheel Slip Control Based on Angular Acceleration of wheel; PI Wheel Slip Control; Sliding Mode Wheel Slip Control). This chapter describes the differentiation in control schemes. From my point of view is main thesis chapter no. 5 "Results and Discussion" In this chapter student demonstrate their results from Matlab simulation and from validation measuring. This chapters have great technical value. With this chapter are connected many trend graphs in thesis appendix chapter. From my point of view it is a pity that they are not mentioned more in the main chapter. Similar is a pity from technical point of view that in thesis are not more describe Matlab algorithms. From my point of view Matlab algorithms and his describes are for separate thesis chapter. Last 6th chapter is conclusion with plan for future works. This chapter create clear summary of thesis and student doctoral study of the student.

After getting acquainted with the dissertation, I can state that its thematic sequence is well designed and that the work is transparent. Linguistically I do not allow to evaluate the work, because its language is not my mother tongue. Figures, tables and formulas are clear. In thesis introduction is list of symbols, used abbreviations for physical quantities and values. Subsequently in text are this symbols used without

unit. I would welcome these units in the list of symbols. This thesis contains many references to scientific literature and sources.

The final conclusion

This Dissertation thesis is of a very good standard and deals with current technical issues – anti slip control method for wheel rail vehicle. The doctoral student reached important knowledge by numerous simulations verified by experimental measurements on special stand. The content of the dissertation thesis and submitted results document that the objectives of the thesis were satisfied and are complete from my point of view. At the same time I am not aware of any other errors or uncertainties in this issue. In view of the submitted documents**, I recommend the dissertation thesis for the defence**.

Questions for discussion:

1. Chapter 2.3 describes the standard topologies and regulation principles that are used in anti-slip or slip controllers. Please clarify and describe of way or using method for select of subsequently used 5 control schemas.
2. You have in Table 1 values of inertial moments and diameters which you used. How different values of these values (e.g. different inertial moments) would have affect the results and slip regulator settings.
3. In several chapters of your work you mentions information about sampling rate during experiments (200Hz), speed of control action of the slip algorithm (25Hz), etc.. Which values of sampling rate and regulator speed is optimal for test stand system from your point of view? How will the PWM modulation frequency or the control scheme of a controlled motor affect this setting value?
4. How do you see the future of these types of slip regulators in terms of neural networks or machine learning or deep learning? As you can see the future of the current methods in terms of optimizing the setting of PI control constants characterizing the currently active adhesion curve.

In Batňovice
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Doc. Ing. Ondřej Černý, Ph.D.

reviewer