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Date: **29 November 2018**

SUBJECT: Review of the dissertation thesis "Model Identification for Advanced Tunnel Ventilation Control", written by Mr. Jan Šulc for achieving a PhD degree.

Dear Mrs Duchoslavová,

Please find below the review of the dissertation thesis of Mr Jan Šulc, as requested in your letter from Oct. 31st 2018.

1. General remarks

The review follows the structure given by the Faculty of Electrical Engineering of the Czech Technical, University in Prague. The thesis contains an introduction section followed by a replication of journal papers. According to the footnote 1 given in section 4, such a format is approved at the Czech Technical University, Praha by a Directive of the dean from Dec. 13th 2017.

Although the journal papers were reviewed in the framework of their own reviewing process, they had to be evaluated once again in the context of this reviewing process. The integration of the individual papers resulted of course in a duplication of many parts, so that at the end only few parts of each individual journal paper contain "new" material for evaluating the author's qualification. Nevertheless, the thesis contains sufficient new scientific information to perform the review.

There is another peculiarity, which had to be considered in this reviewing process: the topic of the thesis is strongly related to Control Engineering. However, within the control process the calculation of air movement in a tunnel is necessary. Although this is done using a simple method, a solid understanding of aerodynamics is required – especially in the sections where the basics for this topic are described. This interdisciplinarity has to be seen in a very positive context as Mr. Šulc had to deal not only with complex control processes (which is his main field of expertise), but also with transport processes (natural science).

2. The Thesis

The thesis deals with controlling ventilation systems in complex road tunnels. The complexity is defined by the consideration of tunnels with multiple accesses to surface roads (i.e. slip roads). This results in a complex behaviour of the air movement inside the tunnel, i.e. the aerodynamics. As the movement of air in normal operation mode and smoke in incident operation mode of the tunnel has to follow detailed requirements, a control system has to be applied.

Mr. Šulc structures his thesis logically by following the path from describing the tunnels, the aerodynamics, ventilation control targets and finally the control system how to achieve these targets. At the end he describes the system application for the Blanka tunnel complex in Prague.

The first section deals with the general description of tunnel ventilation and control systems. Although not decisive for the work, a more thorough description of the systems could be expected in a PhD thesis. System types and their usage are partly not correct defined. Especially when it concerns transverse ventilation. E.g. fig. 3.3 does not describe a transverse ventilation system (as stated), this is a simple (longitudinal) ventilation system with massive point extraction, etc.

It gets more critical in section 3.4, where the mathematical models are dealt with. The author claims to apply a one-dimensional model. However, this is not the correct description. A Bernoulli based model is not a 1D model in aerodynamics. The model is only applied stepwise to various parts of the tunnel system, thus giving it a dimension in one direction. But this is not the 1D solution of the aerodynamics, described by Euler (without friction) and Navier Stokes with friction for Stokes' fluids (the description given in section 3.4.3 is misleading). Statements like "Euler equations can be derived from Navier-Stokes equations" is correct in a mathematical sense, but not in the scientific one. The NS equations are based on the Euler approach and not the other way round. A more careful handling of physics could be expected (even with a background in electrotechnics), as it is part of the thesis. The same statement could be made for the section describing the pressure losses. The exit loss is simply the kinetic energy loss of the tunnel air at the exit – which very often is (but only for numerical simplification) given as a resistance factor (value =1), etc.

The strength of the work is definitely to be seen in the development of the control system and its application and validation. In this section a very sound description of the state of the art is given, novel approaches are developed and applied. This concerns the feedback and feed-forward controllers. The feedback approach for incident ventilation was successfully developed and the parameters derived for the Blanka tunnel system, the feed-forward approach was developed and successfully applied for so-called normal operation of the tunnel ventilation system.

Mr. Šulc developed step by step new approaches in the field of ventilation control. He developed the methods, implemented them, derived the relevant parameters on an experimental basis and finally implemented the full system. This approach needs a quite solid understanding of the problem, the physics of the airflow and the theory of control schemes.

3. Conclusion

The objectives stated in the thesis are fulfilled. All necessary parts of the chain tunnel, model, control system and application is covered to a sufficient extent.

When focusing on the part relevant for Control Engineering it can be stated, that the content of this thesis is relevant for the scientific community. New ideas were brought forward and successfully integrated. The method described makes it possible to control ventilation in complex tunnels in an efficient way and in a secure way in case of incidents with fire and smoke production. Of course, as the Blanka tunnel is not the only one complex tunnel in the world which is in operation, effective system control mechanism for those tunnels have been developed too. Nevertheless, the work of Mr. Šulc contributes to the state of the art and brings some novel ideas to the scientific community. The successful application to the Blanka tunnel makes it even more valuable. It has to be mentioned that the application of the developed model helps engineers to proper design ventilation systems for complex tunnels and to develop the correct control strategies.

The work can be taken as basis for further development of science, especially when it comes to application of RAMS methods to road tunnels in order to increase the resilience of important traffic infrastructure and to define minimum operation conditions. Another important aspect is to be seen in investigations concerning system optimisation and energy reduction capabilities.

The review can be summarised with the following statement:

The author of the thesis proved to have an ability to perform research and to achieve scientific results. I do recommend the thesis for presentation with the aim of receiving a PhD degree

It is really a pity, that the flaws in the parts describing physics are reducing the quality of the thesis. Without these nasty flaws, the written thesis would have been even much more valuable.

Sincerely,

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