REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	**Development of GT-Power Model of a Gasoline Engine with Low Pressure EGR Suitable for Model-Based Predictive Control of an Air Path**
Author's name:	**Bc. Jakub Jaroš**
Type of thesis :	master
Faculty/Institute:	Faculty of Mechanical Engineering (FME)
Department:	Department of automotive, combustion engine and railway engineering
Thesis reviewer:	Ing. Vít Doleček, Ph.D.
Reviewer's department:	CTU in Prague – FME, Department of Automotive, Combustion Engines and Railway Engineering

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **challenging**

Evaluation of thesis difficulty of assignment.

The thesis is focused on development of fast model suitable for MPC, which require very fast models capturing dynamic behavior of simulated plant. MPC should be used for more accurate EGR flow rate control and engine power output control by setting of EGR valve and intake throttle valve. GT-Power allows gradual simplification of detailed engine model up to mean value model, which can be used for linear models generation. Linear models for many engine operating points is the basis of MPC.
Beforehand, I would like to point out, that diploma work assignment lacks any specific, measurable task definition and is very vague.

Satisfaction of assignment **fulfilled with minor objections**

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

Diploma thesis is divided into several parts. The first one deals with research from available sources and very detailed introduction into the field of emission and fuel consumption testing. It continues with description of possible solutions of emission production improvement and EGR technology. Successful implementation of EGR demands fast and reliable controller, which will be Model-based Predictive Control. Diploma thesis is focused on building of engine models suitable usage in MPC.
The second part of diploma thesis deals with description of 1-D model calibration with help of measured data. EGR line connected to prescribed boundary conditions was calibrated. It was not necessary because it was recalibrated once more after implementation into full engine model.
The third part deals with mean value model calibration. When standard mean value model calibration procedure is used, look-up maps are derived from calibrated detailed 1-D engine model together with simplified model. Simplified model structure is also derived from detailed 1-D model. It is not very clear why standard approach was not used because previous chapters deal with calibration of detailed 1-D model and this model could be used. Instead of standard approach, alternative MVEM calibration was done using test bench measured data. The procedure of MVEV calibration requires many operating points but the measurement was done only for 69 points. The regression of measured points was used for interpolation between them. This created sufficient number of operating points for subsequent MVEM calibration. This approach is not very physical and not very accurate. The question remains - why detailed 1-D model was not used for calculation of demanded number of operating points? At the end MVEM validation was checked in two steps - with and without turbocharger. Model error was worse for model with turbocharger, which is not surprise. It could be caused by uncertainty in turbocharger definition. There are only several remarks about twin-scroll turbocharger implementation. Addition of both turbine volutes volume in form of couple fictive pipes without any connection of intersections is not physical and not accurate. There are also not discussed possible errors and uncertainties in turbocharger map.
The fourth part deals with detailed 1-D engine model calibration together with single cylinder TPA calibration of predictive turbulent flame combustion model using measured indicated pressures. The discussion of calibration quality is at the end of this part. The results shows the worst model prediction in turbine inlet temperatures, which is probably caused by bad implementation of twin-scroll turbine model. Turbocharger operation has to be also influenced by it. Predictive

combustion model could be another possible reason of exhaust temperature shift, but the comparison of peak combustion pressures was not presented.
Diploma thesis lacks any specific results or outputs. Diploma thesis deals only with calibration process of various models without any obvious context. I cannot understand why MVEV calibration process from measured data was used when 1-D detailed model with predictive combustion model was available. Lastly, I miss comparison of all engine models with linearized engine model, which should be the result according the assignment.

Method of conception **partially applicable**

Assess that student has chosen correct approach or solution methods.

Calibration process of several engine models in diploma thesis was already described in previous paragraph. I miss consistency of the work. It is unclear why so complicated process was used and why diploma work does not contain linearized engine model as it was stated in the assignment. MPC requires precision of linearized models especially in dynamic operation but dynamic capabilities of all models has not beed tested.

Technical level **D - satisfactory.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

Technical level of the work is inconsistent. On the one hand, diploma work show quite high knowledge of engine modeling techniques. On the other hand, whole calibration process is very fractionalized and confusing. The work is full of descriptions of all dead ends and failures, which makes diploma work very long. Nevertheless, not all important decisions are properly clarified. Remarks about bad results due to convergence are not necessary, when only converged results are relevant of showing in diploma thesis.

Formal and language level, scope of thesis **C - good.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

Typographical arrangement of the work is on good level. The text is supplemented by well arranged pictured, nevertheless, only few of them have reference from text. The work contains some typing errors and grammar mistakes. Some sentences are hard to understand. Language level of the work is worse close to the end of the work.

Selection of sources, citation correctness **C - good.**

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

Cited sources are properly marked and cited according to citation norm. The list of sources contains a lot of online sources, where relevance is always questionable. Evaluation of online sources combines English with Czech. Conference papers are not referred according to the citation norm and citation convention.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

The assignment of diploma work was quite challenging and it requires knowledge of modelling of all engine parts and systems. Diploma thesis contains model calibration of several models with various model depth. Inconsistent structure of the work contains many parts describing faults and dead ends. The result of diploma work is not particular linearized model capable of usage in MPC but only mean value model, which could be used as an input for building such a model. This fact reflects in diploma thesis absent of any concrete result leaving only recommendation for future work. It seems that diploma work is rather not finished.

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III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

I evaluate handed thesis with classification grade **E - sufficient.**

I would like to ask these questions during diploma work defense:

- Why detailed engine model was calibrated when it was not used for mean value model calibration?
- Why twin-scroll turbine model was implemented into model with its volume? And how it could be improved?

Date: **31.1.2019** Signature: