Review of Doctoral Thesis

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Title: **Physical Modelling of Combustion Engine Process and Gas Exchange for Real-Time Applications**

Recapitulation
The dissertation investigates computational models of ICEs of the various levels being focused on the relationship between model accuracy and its real-time usability. Various approaches to simplifying the model structure are described and analyzed in order to find an optimum trade-off between model complexity and its correct interpretation of the physical reality. The goal is to create a physically reasoned model that will be usable as a part of SW equipment of engine ECU dedicated for mass-produced vehicles. Finally, the author compiled a version of the model which is able to reach an acceptable deviation of the relevant physical quantities (according to the limits declared by the author) and shows a real-time factor below 1 (according to the "off-line test").
In my opinion, the declared objectives are fulfilled.

Remarks
P16 It is cited from the well-known textbook: The indicated power of an internal combustion engine at a given speed is proportional to the mass flow rate of air. Of course, this is valid for constant mixture composition (OK for $\lambda = 1$ / TWC) and constant indicated efficiency (?).

P19, 21 A new physical quantity "richness factor (l_i)" is introduced. According to the definition in 3.27, it is in fact well know equivalence ratio. In Nomenclature, l_i is not listed, whereas λ is described as: Air-fuel equivalence ratio. It is a bit confusing.

P18 The author states: It is assumed that all gas fractions are distributed homogenously and have therefore an equal temperature [33]. If it means, that temperature of the burned and unburned mass fraction is the same, then the declared implementation of the two-zone model (on the previous page) is disputable.
Also, the description of cylinder charge as a "gas mixture composed by three specie" is not compatible with the two-zone model.

One may assume, that the reader may have a problem understanding the philosophy of the use of "burned fuel", even if I understand the implementation of one state variable (sometimes called "reaction coordinate"). Maybe more instructive would be

$$M = M_{Airb}+M_{Fb}+M_{Airu}+M_{Fu} \qquad \text{(3.18 modified)}$$

While $M_{Airu}+M_{Fu}$ is a fresh mixture and $M_{Airb}+M_{Fb}$ are combustion products (or exhaust gas).

P64 Author mentioned: This constructive measure leads to reduction of the fuel consumption. It is worth adding: …and especially to minimize the emission of the products of incomplete oxidization. On the other hand the exhaust manifold cooling decrease enthalpy of driving gas for the turbine (but with the gasoline-fueled engine with a relatively low compression ratio it is no problem as can be seen in Fig. 77).

P17 It is mentioned that: the stochiometric (maybe STOICHIOMETRIC would be better) air-fuel ratio c_S = 14 obtained from fuel measurements. On P54 (Equation 4.70) (probably more precise) figure is introduced, namely, 14.2 based on fuel analysis. I assume that the fuel is a blend of gasoline with certain so-called biofuel. Specification of fuel composition and its properties (e.g. LCV) would be useful.

Equation 4.69 ignores both the residual gas and the short-circuit scavenging.

P67 It is stated that: temperature after intercooler being regulated to 30°C by the thermo-management system…Such data may be used for calibration of the model but in real life engine ECU must be able to cope with low as well as extremely high ambient temperatures.

P122, FIG. 90 The exhaust gas temperature as a result of the model is averaged over the engine cycle according to a user-defined algorithm. The value measured by a thermocouple exposed to a rapidly changing temperature and flow rate is also averaged, but the algorithm is usually unknown. Therefore, the exhaust gas temperature is the last suitable physical quantity to verify the model results. The same goes for the next image/page

P110, Fig57. It is occasionally mentioned in the literature, that at least 160 cycles have to be used for the calculation of standard deviation (and subsequently COV). According to our laboratory experience, the standard deviation after 100 cycles still does not show a stable value.

P64 Fig33 The turbine does not have an outlet.
Fig. 46 in the Appendix cross-referenced on P23 does not exist.
P29 The title of Fig 10 does not correspond to the figure content
P110 Description of color scale in Fig. 59 should be probably nTC [10^4 rpm]
P41 Cross-reference to Fig. 3 probably should aim at Fig. 18.

Unfortunately it have to be stated, that occurrence of miswriting is too frequent:
P3 bride solutions; P7 discretization shames; P38 Propsed method; Fig. 40 and many subsequent scaveing area; Fig. 46 freh air; P69 opiating range.

The above remarks are not intended to call into question the quality of the dissertation. In my best opinion, the comments should make the dissertation more complete by archiving them together.

Questions
The pressure p22 is declared as angle-resolved on P52, while p21 is (as I understand it) sampled with a sampling frequency of 10 Hz. How was Equation 4.80 calculated? Among other things, one can fear the effect of aliasing at a sampling frequency of 10Hz.

I do not understand what has to be changed in Equation 4.72 when applied to a diesel engine.

Conclusion
The defined goals of the thesis were achieved.
The candidate has analyzed a wide range of publicly accessible documents related to the topic.
The main theoretical asset of the thesis is probably the identification of the relationship between model complexity and the quality of its result.
The main practical output is a proposal of a physically reasoned model able to be operated on mass-produced engine ECUs.
The candidate used appropriate methods in an appropriate manner.

The candidate sufficiently demonstrated his ability to perform scientific work. I support his admission to defend his thesis and in case of success, I recommend that Mr. Fortl will be awarded the doctoral degree.

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