Review of Doctoral Thesis

Author: **Ing. Filip Černík**
Title: **Phenomenological Combustion Modeling for Optimization of Large 2-stroke Marine Engines under both Diesel and Dual Fuel Operating Conditions**
Reviewer: **Jiří Navratil, Ph.D.**

Ph.D. candidate describes the development and validation of a unique combustion model designed specifically for large two-stroke engines running at both steady-state and slow transient regimes. The combustion model is applicable for both single and dual fuel operations. The developed 1-D engine model has been linked with detailed hydraulic injection and dynamic exhaust valve model.

The basic difference between available combustion modeling approaches is described in the first chapter followed by the single and dual fuel combustion theory touching the NO_x and soot formation simulation possibility. The next chapter focuses on a detailed diesel model formulation - walking reader step by step through the modelling process parts (spray, premixed and diffusion model) where the injection profile presents the boundary condition. Similarly, the dual fuel combustion model is described in detail. I appreciate demonstrative and clear description of every sub-model part and sensitivity studies performed for every parameter or tuning coefficient, helping to understand the model response and its validation approach. The last chapter present validation results from both diesel and gas dual fuel models compared to the test data. An integration of chosen 1-D engine model together with hydraulic injection system and dynamic exhaust valve model demonstrates state of art virtual powertrain model capable running in slow engine load and speed transient sea conditions.

The main contribution of this doctoral thesis stays in the unique combustion model designed especially for uniflow 2-stroke combustion engines and its implementation to a commercial 1-D gas thermodynamic code as a user combustion sub-model. I find the explanation of both single and dual combustion models clear and straightforward, confirming that the doctoral candidate understands chosen modeling techniques and moreover being able to code them to the Fortran programming code. I am not entirely happy with the resulting tuning constants, their values and trends, whose would be hopefully the same for all engine models - admitting this really ambitious. It is really nice to see the approach showing speeding virtual engine co-simulation of the three model pieces, since the current engine simulation development is heading towards using real-time 1-D simulation approach allowing marine and genset engines on-line engine diagnostic, emission prediction and sensors count reduction.

The thesis is well structured with few minor grammar mistakes and typos. I appreciate, that it is written in English and performed in cooperation with well-known heavy duty engine company. In my opinion, this thesis fulfills all conditions for gaining the Ph.D. degree, therefore it is **recommended**.

Prague, 21st March 2018 Jiří Navrátil