EINDHOVEN UNIVERSITY OF TECHNOLOGY

Further Development of a Control-Oriented Air-Path Model of a Heavy-Duty Engine

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I. Introduction

In recent years, due to heightened environmental awareness and stricter legal regulations related to emission standards, manufacturers of heavy-duty (HD) trucks have invested significant effort in extensive research aimed at reducing pollution emissions from diesel engines, especially for Nitrogen Oxides (NO_x). In order to reduce the engine-generated NO_x emissions, the development of a precise engine air-path system is crucial. DAF, as one of the leaders in this field, actively participates in a long-term project aimed at achieving optimal control of the engine air-path.

As a part of the long term project, in the past year, a collaborative effort between DAF and an EngD colleague from TU/e resulted in the development of the initial version of Engine Modeling Toolbox (EMT), which is a MATLAB-based software tool designed for the development and parameterization of control-oriented air system models for heavy-duty engines. The toolbox is designed to be deployed on the engine control unit (ECU). However, there is still room for improvement in the system identification capabilities of the toolbox [1].

Building upon the achievements of the previous trainee, DAF is extending its collaboration with the university into the current year with the aim of reducing the steady-state modeling errors within the toolbox. Additionally, the focus is on enhancing the toolbox's ability to track dynamic measurement values more effectively and preparing it for the incorporation of advanced controller design functions.

II. Design Approach

In the toolbox, the engine air-path model is broken down into components for identification. Each component is modeled using gray box modeling, black box modeling or a combination of the both methodologies. In gray box modeling, the physical characteristics of the component are considered, and the least square approach is employed to identify unknown parameters within the model equation.

$$\begin{aligned} \underset{\theta}{\text{minimize}} \quad & \mathcal{J}(\theta) = \sum_{n=1}^{N} e(n)^2 \\ \text{s.t.} \quad & g(\theta) \leq 0, \end{aligned}$$

For certain components, neural networks are incorporated, either wholly or partially, during the modeling process to enhance model accuracy. Careful consideration is given to hyperparameters and training datasets to ensure a highly effective model.

After identifying the components, the engine air-path model is constructed by integrating them in accordance with the actual sequence of the air-path system within the engine.

III. Toolbox Evaluation

The new version of the toolbox is evaluated based on the DAF engine model MX-11. Four types of evaluations are conducted, namely component-level steady-state evaluation, engine-level steady-state evaluation, component-level dynamic evaluation, and engine-level dynamic evaluation. When compared to the previous version of the toolbox, the evaluation results demonstrate an improvement in the accuracy of component models, particularly for critical components like Exhaust Gas Recirculation (EGR) and Variable Geometry Turbine (VGT). Furthermore, the dynamic simulation results can effectively track the trends observed in the measured values. These evaluations collectively validate the fulfillment of the project requirements.

References

[1] G.H.H. Linskens. *Towards Model Based Control of a HD-Diesel Engine Air Path with the Engine Modeling Toolbox*. EngD thesis, Technische Universiteit Eindhoven, October 2022. 1

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