Parameterizing compact and extensible compressor models using orthogonal distance minimization

Xavier Llamas*
Vehicular Systems,
Department of Electrical Engineering,
Linköping University,
Linköping SE-581 83, Sweden
e-mail: xavier.llamas.comellas@liu.se

Lars Eriksson
Vehicular Systems,
Department of Electrical Engineering,
Linköping University,
Linköping SE-581 83, Sweden
e-mail: lars.eriksson@liu.se

A complete and compact control oriented compressor model consisting of a mass flow submodel and an efficiency submodel is described. The final application of the model is a complete two-stroke mean value engine model which requires to simulate the compressor operating at the low flow and low pressure ratio area. The model is based on previous research done for automotive-size compressors and it is shown to be general enough to adapt well to the characteristics of the marine-size compressors. A physics based efficiency model allows, together with the mass flow model, to extrapolate to low pressure ratios. The complexity of the model makes its parameterization a difficult task, hence a method to efficiently estimate the nineteen model parameters is proposed. The method computes analytic model gradients and uses them to minimize the orthogonal distances between the modeled speed lines and the measured points. The results of the parameter estimation are tested against nine different standard marine-size maps showing good agreement with the measured data. Furthermore, the results also show the importance of estimating the parameters of the mass flow and efficiency submodels at the same time to obtain an accurate model. The extrapolation capabilities to low load regions are also tested using low load measurements from an automotive-size compressor. It is shown that the model follows the measured efficiency trend down to low loads.

1 Introduction

The marine propulsion industry is facing new and more strict regulations on the engine exhaust emissions. For example, the Tier III regulations [1] have to be fulfilled for new vessels built from January 2016 on certain emission control areas. For the case of the low speed two-stroke marine engines, industry is developing and testing technologies that have potential in achieving such emission limits. One of these technologies is the Exhaust Gas Recirculation (EGR) that has been widely used in the automotive industry to reduce NO_x formation during combustion and thus exhaust emissions.

Testing is required for the development of the EGR technology. However, performing tests on such big engines is limited mainly due to two reasons. First, there is a lack of available engines to perform such tests, the production numbers are much lower than the automotive case. The second issue is the very high economic cost required to perform tests in those large engines, mainly associated to fuel consumption. Due to these limitations, a reliable and fast dynamic engine model would be a valuable tool for the development of EGR systems and control strategies. A common approach for control oriented engine models is the Mean Value Engine Model (MVEM), which has the particularity that the model is based on average values of the engine cycle. For more information see e.g. [2–4]. Furthermore, [5] contains an overview of the targeted type of two-stroke engine as well as the current modeling status. Such engines contain several components that need to be modeled, and obtaining a reliable control oriented compressor model is one of the first challenges.

A compressor model consists of a mass flow model and an efficiency model, normally more emphasis is found for the mass flow-pressure ratio model in literature. Many different compressor models can be found in literature, in particular many different modeling approaches are investigated for automotive compressors, see e.g. [6,7]. For the much bigger compressors used for turbocharging the low speed two-stroke engines there is less research done. Nevertheless some different models can be found in the literature. In [8] the compressor model is based on the fact that marine engines are loaded following the propeller law, and thus the compressor model has to be accurate only on the projected propeller

*Address all correspondence related to ASME style format and figures to this author.