## ABSTRACT

The emission legislation for large medium-speed engines has become increasingly stricter in recent years. One of the more common ways of meeting these restrictions is to treat the exhaust gases with various external devices, such as catalysts and scrubbers. However, to ensure admissible air pollution levels throughout the life-time of the engine system, the long-term performance of the different engine control-loops needs also to be guaranteed. The dynamics of marine and power plant engines are usually dependent on many different factors, such as the operating point of the engine and external conditions. Aging, wear and clogging of mechanical components affects, furthermore, the dynamic behaviour of the engine. As a consequence, the optimal set of controller parameters varies over time and deteriorates the performance of the closed-loop control system. To consider the dynamic variations due to nonlinearities and changing conditions, gain scheduling control schemes are usually used, where the controller parameters are a function of a measured quantity, e.g. the engine load. To eliminate the need of additional measurements, adaptive control schemes could be considered. A typical problem with adaptive control methods is the drifting of the identified parameters during states of insufficient excitation. Multi-model adaptive control scheme has been proposed as an approach which is more robust to excitation problems.

The contribution of this paper is the development of a multi-model adaptive control method for waste-gate control of an internal combustion engine. Instead of using additional measurements, the dynamic changes in the process due to varying operating conditions are identified using process identification which are then used for adjusting the controller behaviour. The adaptive control scheme is evaluated on a 2.7 MW Wärtsilä 6L34SG natural gas engine, where the dynamics variations due to the wastegate and turbocharger are successfully identified and used for determining the correct response of the controller.


## INTRODUCTION

For large medium-speed internal combustion engines, as typically used for electricity production and for propulsion of marine vessels, environmental regulations have traditionally been somewhat more relaxed in comparison with, for example, automotive vehicles. In recent years, however, the emissions regulations have also become stricter, in particular, for marine applications where IMO (International Maritime Organization) has set new and significantly stricter emission targets for its upcoming Tier 2 and 3 standards. To comply, one of the more common strategies is to apply complex mechanical on-engine solutions for achieving optimal control of the fuel combustion or various external devices for treating the exhaust gases.

As both the emission levels and the engine performance are directly affected by the quality of the engine control, it has become important to ensure the performance of the engine control circuits, not only during commissioning, but also throughout the life-time of the engine.

The dynamics of internal combustion engine dynamic are generally influenced by several different factors, e.g. nonlinear process components, varying operating conditions and component wear. To manually determine the optimal controller parameters over time becomes hence a complex and time consuming task which has to be periodically performed. As the comprehension of modern engine systems and their dynamics has in general decreased during the last decades amongst operating personnel, ensuring optimal engine control quality has become even more difficult to achieve. As a consequence, the engine control is in practice often sub-optimally in the field, which results in deterioration of the engine performance and an increase in the emission levels.

Closed-loop control of industrial processes has traditionally been achieved by using PID controllers. This is because of their relatively low complexity and the possibility to manually and experimentally determine appropriate controller parameters. However, for process with variations in the dynamics, other process control schemes could be used for improving the control quality. For process control in general, adaptive-control schemes can be used as an alternative to the classical PID controller. The advantage of adaptive control is that the regulator is able to adjust itself according to the dynamics behaviour of the process subject to control. That is, optimal control performance can be achieved throughout the lifetime of the engine, without re-tuning of the parameters.

A suggested alternative adaptive control strategy is the multi-model adaptive control (MMAC) scheme. A finite set of concurrently updated discrete models are used for modelling the process subject to control. Each model has associated an optimal controller which parameters are determined in an off-line fashion. The actual controller output is then usually determined as e.g. the weighted sum of all