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Optimal control maps for fuel efficiency and emissions reduction in maritime diesel engines

Abstract: The paper introduces an advanced modelling method and optimisation algorithm, by which ship diesel engines control parameters can be effectively designed. The fuel consumtion is minimised while at the same time fulfilling the NO_x emission constraints. The problem is non-trivial: the methodology introduced proves efficient, is fair and fulfils the regulations set by the International Maritime Organisation.

Keywords: diesel engine, NOx emissions, fuel efficiency, control map, optimisation, optimal design

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Extended abstract. Oceangoing ships are the largest single cause of nitrogen oxides (NOx) emissions globally, and NOx is generally a major air pollutant in the atmosphere. Most of these emissions are released near the land, which causes a ma-jor pollutation problem and health risk to the people. It has been reported that outdoor air pollutation caused about three million premature deaths globally in 2010. Since ship transportation is constantly increasing, it is easy to understand that the International Maritime Organization (IMO) is setting more and more stringent restrictions to ship emissions. Large tankers are major pollutants driven by diesel engines. Even if the number of diesel engines in automobile industry is foreseen to decrease fast in the future, such a trend cannot be foreseen for maritime engines, because replacement of large diesel engines as power source in maritime applications seems to be a hopeless task for several decennia to come.

The engine manufacturers are interested in developing more and more efficient engines with increasing efficiency, reduced fuel consumption and redured emissions. Unfortunately, considerable efficiency increase is already hard to establish, and reducing fuel consumption generally implies higher NOx emissions and vice versa. Because of this, IMO has set regulations (Tier II and Tier III) that set limits to NOx emissions in some operation points (speed and load) of the ship. However, only a few operation points have been set, which means that it is unclear how the ship emissions should be controlled over the whole operation range. Even worse, the current regulations give a possibility to “cheat” by setting the emissions low at the given operation points (high fuel consumption) but use all effort to save fuel in other operation points (high NOx emissions). The paper presents a method, where the Design of Experiments (DOE) method is used to model the fuel consumption and NOx emission at any given operation point. It then becomes possible to construct smooth functions to cover all operation points of the ship engine. At any operation point an optimization problem can be set and solved, where the fuel consumption is minimized under a given constraint of maximum NOx emission. The solution gives certain control parameters of the ship (common rail pressure, charge air pressure, start of ignition timing), which are to be used in the operation point in question for optimal performance. It now becomes possible to compare the fuel consumption and emission level under standard routes travelled by the ship. In addition to that it becomes possible to construct optimal operation parameters and allowed NOx levels under a large number of operation points, thus giving advice to IMO how te future regulations could be stated, in order to cover all operational areas and to avoid all possibility to cheat. The results of the paper have been obtained and confirmed using real diesel engine data from large engine manufacturers.

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