Transient Simulation of a Large Two-Stroke Marine Diesel Powerplant Operation with a High Pressure SCR Aftertreatment System

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Summary

The IMO Tier III legislation concerning nitrogen oxide (NO_X) emissions from marine engines has compelled engine designers to apply new technologies for NO_X abatement. Selective Catalytic Reduction (SCR) is a promising aftertreatment technology that enables compliance with the new rules. However, due to the large size of these engines the size of the SCR reactor is quite considerable (comparable to the size of the engine). As a result, the large thermal inertia of the SCR system has a detrimental effect on the transient and low load operation of the engine. Since the current number of SCR vessels is low and engine testing is expensive, having a fast and reliable model would be useful in order to study the SCR transient behaviour. In this paper, the transient response of a two-stroke marine diesel engine equipped with a High Pressure SCR system is studied. Each part of the propulsion system is modelled, namely, the main engine, the SCR unit, the propeller and the hull of the ship. The prediction capability of the entire model is validated by comparing model predicted results against on-board measured data available from a sailing vessel. The complete propulsion system model makes it possible to study the performance of the SCR system under various transient loading conditions.

1. Introduction

Emissions produced by large two-stroke marine diesel engines have recently gained attention due to their detrimental environmental effect. The International Maritime Organization (IMO) recently introduced stricter legislation on NO_X emissions, produced by marine diesel engines, also known as the IMO Tier III standard. The IMO Tier III legislation, is applicable to vessels with a keel laying date on or after January 1st 2016, when operating inside Nitrogen Emission Controlled Areas (NECAs) [1]. The North American coast, parts of Canada and the Caribbean Sea are currently designated as NECAs. As of January 1st, 2021 the North Sea and the Baltic Sea will also be designated as NO_X ECA [2]. The reduction in NO_X emissions required by the Tier III legislation, cannot be met only by in-engine modifications, such as combustion improvement or slide fuel valves. The most prominent technologies for Tier III compliance is Exhaust Gas Recirculation (EGR) and Selective Catalytic Reduction (SCR), both long used in the automotive and truck industry. EGR is a method that reduces the formation of NO_X during the combustion, by recirculating a fraction of exhaust gas back to the scavenge receiver. The heat capacity of the gas entering the engine cylinders increase, due to the large heat capacity of CO_2 contained in the recirculated exhaust gas. Consequently, the maximum temperatures in the cylinder