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Influence of the Backpressure on Urea Sprays Generated by an Air-Blast Atomizer for Large-Scale SCR-Applications

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Abstract

In 2016, the latest step of emission standards for marine ships came into operation. As the emission limit for nitric oxides has decreased to approximately 25% of the former values, selective catalytic reduction (SCR) will play an important role to fulfil those limits. SCR is an established method in the field of trucks and heavy diesel cars, but applying it to ships requires further research and development. The demands on ship engines are different, not only due to the large scales but also because the engineering process is strongly based on numerical simulations. To allow the validation of simulations at well-defined conditions and to investigate the fundamental processes, e.g. of the injection of urea solution for marine applications, a high pressure hot gas test rig was built up at the ITV. The current work focuses on the injection of urea solution by an air-blast atomizer. The spray breakup is the initial part of the urea decomposition, which is why reliable validation data is needed for modelling and simulating the respective spray and chemical processes. Therefore, the role of the atomization air flow rate in combination with different hot gas pressures was studied. The pressure influence is of particular interest, due to the possibility to install an SCR-system upstream the turbocharger of a marine engine. High speed shadowgraphy was applied to investigate the primary breakup of the urea spray. The breakup phenomena are discussed and combined with droplet spectra, which were measured by phase-Doppler anemometry (PDA). Apart from obtaining validation data, the study gives answers to the guiding question how to obtain acceptably fine sprays by using minimal atomization air under various circumstances.

Introduction

Selective catalytic reduction (SCR) is a widely-used technology to reduce nitric oxides (NO_x) in exhaust gases. Originally, SCR was developed for industrial furnaces [1], but nowadays it is one of the standard solutions for the exhaust gas aftertreatment of trucks and heavy diesel cars [2]. Concerning marine shipping, the latest stage of emission standards came into operation in January 2016 [3]. The limits for NO_x have decreased to approximately 25% of the former values [3]. Currently, they have to be fulfilled in northern American emission control areas (ECA's) (figure 1). Therefore, SCR is considered to be a preferred technology also in the field of marine ship engines.

The SCR aftertreatment is based on a catalyst that converts NO_x into nitrogen (N_2) by means of a reducing agent, typically ammonia (NH_3). This reaction is selective, which is the precondition for SCR to work with exhaust gases with excess oxygen. The ammonia is provided from aqueous urea solution, which is sprayed into the hot exhaust gas path. After the water has evaporated from the droplets, the remaining urea is decomposed thermally into ammonia and isocyanic acid (HNCO). The isocyanic acid reacts with water to ammonia and carbon dioxide (CO_2).

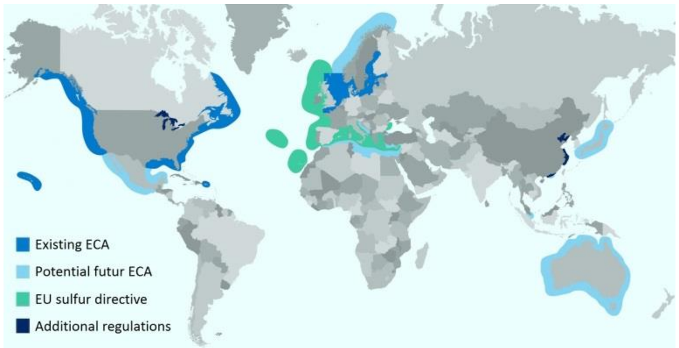

Figure 1. Map of emission control areas [4]

As initial part of the urea decomposition, the spray process plays an essential role. Extensive work has been done concerning the spray processes of automotive SCR systems, especially focused on the spray-wall interaction, e.g. in [5], [6], [7]. Applying the SCR technology for large scale ship engines requires further research and development. First the present large scales require different technological approaches compared to car and truck systems, for example the use of air-blast atomizers. A major aspect is the possibility to install the SCR-system upstream the turbocharger [8]. Secondly the large amount of variant types of ship engines requires respective adaptions of the SCR-systems. To cover these variant types, the engineering process is strongly based on numerical simulations. A hot gas test rig was built up at the ITV with the main objective of providing validation data for numerical simulations. The test rig allows the investigation under realistic temperature and high pressure conditions for large scales.

Experimental investigations of air-blast atomizers for SCR-applications can be found in [9] and [10].In the present study, the test rig is used for studying the spray processes and properties, considering both, understanding morphology of the breakup as well as quantitative measurement of droplet spectra. Special attention is