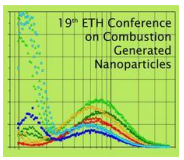

Impact of SCR on particle emissions in HFO application

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Introduction

NO_x and SO_x emissions from ship exhausts are limited by IMO (International Maritime Organization) ship pollution rules. With tightening limitations the use of emission control technologies is increasing. SCR (selective catalytic reduction) is an available technology for NO_x reduction. SOx limitations can be reached by using lower sulphur level fuels or with after-treatment systems, like scrubbers, while allowing the use of inexpensive heavy fuel oil (HFO). The PM is expected to decrease indirectly through the SO_x limitations (by reduction of sulphate particle emissions), but at the moment, no direct PM limitations exist.

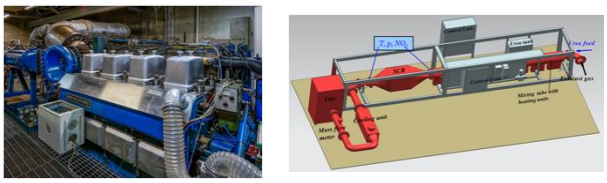

Figure 1. Test engine (Wärtsilä Vasa 4R32) and partial flow test bench.

Experimental

A partial flow test bench was used to study SCR with a proper exhaust gas from a medium speed diesel engine (1640 kW). A heavy fuel oil (2.5% S) was utilized as test fuel. Two different SCRs, having differences in structure ("SCR A "- an extruded honeycomb type and "SCR B" - a packed bed reactor, typically used for low dust and low temperature applications), were utilized using engine load of 75%. In addition, different exhaust temperatures were utilized. The effect of SCR on (particle and gaseous) emissions was studied with measurements according to the ISO 8178 method. The particle filters were further analysed for sulphates and organic and elemental carbon. In addition ELPI was employed to study the particle number size distribution.

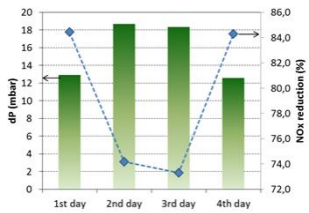

Figure 2. Pressure drop over the 'SCR B' unit and the corresponding NO_x reduction values. High temperature (450°C) test done between 3rd and 4th day.

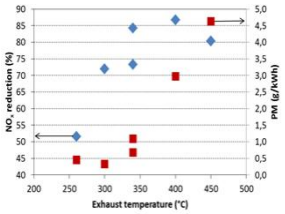

Figure 3. NO_x reduction and PM as a function of exhaust temperature ('SCR B').

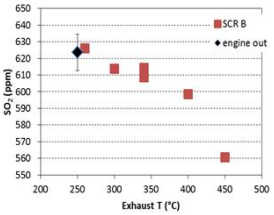

Figure 4. SO_2 measured (with FTIR) downstream of 'SCR B' and engine out (load 75%).

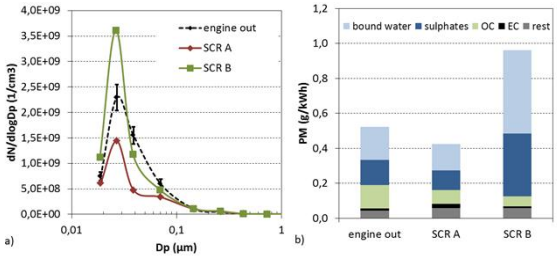

Figure 5. a) Particle number size distributions measured without any SCR and downstream of "SCR A" and "SCR B" . b) PM analyzed for sulphates and EC and OC. (75% engine load at exhaust T of 340°C).

Results and Discussion

For the SCR operation the exhaust temperature was found to be important as well as the soot accumulation in SCR. The soot accumulation in the SCR unit increased the pressure drop which seemed to rapidly affect also the NO_x efficiency. This confirms the fact that SCR in combination with poorer fuel quality requires a very good soot blowing system.

The NO_x efficiency enhanced with the increasing temperature (Fig. 3) being highest at 400°C (~85% with 'SCR B' with constant NH_3/NO_x~0,9). At the same time, the PM increased with the temperature increase and the SO_2 level decreased (Fig. 4) indicating sulphate formation is happening.

The sulphate formation is confirmed by sulphate analyze results (Fig. 5). Higher sulphate levels were measured downstream of SCR B than engine out. Sulphur is also believed to be in key role in nanoparticle formation since a clearly higher nanoparticle mode was found downstream of the SCR B. On the contrary, a decrease in nanoparticle mode was observed downstream of the SCR A (*Lehtoranta et al. 2015*) indicating sulphates are collected in the catalyst. The difference in structure between the two SCR units is not believed to be very significant (when discussing sulphate and nanoparticle formation). But higher concentrations of e.g. vanadium oxide will lead to an increased SO_3 level and with that higher sulphate concentration downstream of such catalyst. The information about the active compounds were not provided by the catalyst manufacturers, but the different nanoparticle formation is believed to be explained by the differences in active compounds and those amounts.

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