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ScienceDirect

Energy Procedia 101 (2016) 368 – 375

Energy Procedia

71st Conference of the Italian Thermal Machines Engineering Association, ATI2016, 14-16 September 2016, Turin, Italy

Marine engines emission and dispersion in fuel switching operation: a case study for the port of Naples

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Abstract

This study analyses the production and the dispersion of air pollutants produced by ship engines of great displacement during the approaching phase to the seaports. In agreement with the present environmental rules, several scenarios were examined, considering the possibility of fuel switch, from heavy fuel oil to marine gasoil. After characterizing the emissions during this fuel change-over, and taking into account the most frequent routes, we analyzed the specific case of the port of Naples. For this case-study we evaluated different scenarios of pollutants dispersion from ships arriving and departing, by using the Gaussian model ISC and considering in particular the effect on the coastal zone adjacent to the port. The results are represented graphically and provide valuable insights about the impact of marine traffic on air quality. Such information may be seen as useful tools for the improvement of maritime legislation on emissions, since emission of air pollutants from ships of large size is a key factor in air quality state in the surrounding areas to ports.

Peer-review under responsibility of the Scientific Committee of ATI 2016.

Keywords: Marine diesel engines; pollutant emission and dispersion; fuel change-over.

1. Introduction

Marine transport is a vital sector for the global economy since over 80% of freight is transported by ships [1]. That is also the most energy efficient and sustainable mode of transportation of goods from an environmental perspective, whereas CO_2 emissions required to carry a ton of freight per kilometer by sea are just 25% of those on

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Peer-review under responsibility of the Scientific Committee of ATI 2016.
doi:10.1016/j.egypro.2016.11.047

road transport for the same distance, and only 1% of those provided by the air transport. Ports represents certainly a concentrated area of marine transport, so they are a major and growing source of pollution, and can impose significant health risks on nearby communities [2].

Emissions by ship traffic are becoming a significant source of air pollution in cities near major ports, also considering widespread actions world-wide to reduce emissions deriving from road transport sector during the last years [3]-[5]. Recent evaluations of global sulfur and nitrogen oxide emissions from international shipping report 6.49 Tg S and 6.87 Tg N, respectively [6]. Although ship emissions nowadays constitute only a small fraction of total global emissions, they could have relevant environmental influence on coastal areas near ports with heavy ship traffic as highlighted in studies for regions in Europe, Asia and North America [7]-[12].

However, today ships represent a major unregulated source category. Furthermore, emissions from shipping activities are growing. Ship emissions will increase significantly in next 10–40 years owing to expanding international commerce [13]. As a result, it is necessary to understand atmospheric impacts of these emissions, especially on regional air quality.

This study evaluates the environmental impact of ship emissions on the coastal zone nearby the port of Naples (South Italy) which is one of the busiest Italian port. In particular, the study covers emissions from large size two-stroke diesel engines, taking into account the fuel change-over from heavy fuel oil (HFO) to marine gasoil (MGO) and vice-versa, moving toward and away from the port. In order to calculate the polluting concentrations from ships and to assess the resulting air quality state in the area surrounding the port of Naples, this analysis was carried out by using the Gaussian model ISC. The modelling approach presented in this study can be considered as an important assessment tool for the local environmental authorities [14], since it can be applied in order to evaluate both the compliance of air quality with the limit values established by current legislation, and the influence of various scenarios of pollutant emission from arriving and sailing ships on the local air quality state.

2. Ship emission and fuel change-over

As widely known, the air emissions from marine traffic are regulated by Annex VI of MARPOL 73/78 (Marine Pollution), promulgated by the IMO in 1997 and subsequently amended. This regulation has been transposed in Europe by Directive 2005/33/ EC and in Italy by DM. 205 of 6 November 2007. In particular, these regulations govern SOx and NOx emissions which are present in the exhaust gases of internal combustion engines for ships of large size.

The limits on the emission of SOx are two, one more compelling relative to ports and SECA areas and one less compelling relative to all other areas. Ships that do not have systems to reduce SOx emissions, such as sea water scrubbers, must therefore be prepared using two different types of fuel, HFO and MDO (or MGO), the first for areas not subjected to emission control, the second for emission control areas and ports.

When a ship is going to pass through an emission control area, it has to start a fuel change over procedure, in time and in such a way that the engine will be burning MGO at the inlet of the area.

Fuel change-over must be performed carefully in order to avoid engine failure [15],[16]. There is not a universal procedure to do it but some items must be monitored:

- Fuel viscosity must be kept within the range 2-20 cSt;
- Fuel temperature variation rate at fuel pump inlet, should not exceed 2°C/minute.

A low value of viscosity can cause:

- reduced lubricant effectiveness, resulting in excessive wear and possible failure of the injection pump;
- fuel leaks from pumps, valves and piston rings, preventing the ship to reach the maximum power.

About the temperature of the fuel, typically, HFO is heated to about 150 °C and has to be changed to MGO, used at about 40 °C, so the temperature gap is about 110 °C. Considering the allowed rate of change of 2 °C/minute, the process of replacing the fuel should last a minimum 55 minutes to carry out safely.

A quick change from HFO to MGO can cause overheating of MGO which causes a rapid loss of viscosity and gassing in the fuel system. Likewise, a too rapid a change from unheated MGO to HFO can lead to excessive cooling of HFO and therefore excessive viscosity to the injectors resulting in possible loss of power or shutdown.