CO₂/SO₂ emission reduction in CO₂ shipping infrastructure

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Abstract

There is an increased focus on the reduction of anthropogenic emissions of CO₂, and this has resulted in CO₂ capture processes for storage in geological formations or enhanced oil recovery. The necessary link between the capture and storage process is the transport system. Ship-based transport of CO₂ is a better option when the distance exceeds 350 km compared to an offshore pipeline and offers more flexibility for transportation, unlike pipelines which require a continuous flow of compressed gas. Liquefied CO₂ ship transportation is mainly used in food industries with capacities ranging from 800-1000 m³. For carbon capture and storage (CCS) purposes, a more significant size is needed. Several feasibility studies have been undertaken to ascertain the viability of large-scale transportation of CO₂ by shipping regarding the liquefaction process, gas conditioning, but limited work exists on emission reduction from the ship’s engine fuel combustion.

Figure 1: Capture process for both CO₂ and SO₂

CO₂ and SO₂ emissions are a significant concern in combustion processes. Emissions from shipping currently represent about 3 % and 13 % of the world’s total CO₂ and SO₂ emissions, and the industry’s share is increasing. The international body responsible for regulating shipping, the International Maritime Organization (IMO), has placed a world cap limit on sulfuric emissions. From 2020, ships operating in all areas will be required to use fuels with 0.5 % or less sulfur content (versus 3.5 % now) or adopt adequate measures to reduce these emissions. This study aims to explore the use of solvent-based post-combustion carbon capture process to reduce these emissions from a typical CO₂ carrier through process simulation from different sources to sinks and its economic implications. The
solvent used for this capture process is also used for re-liquefaction to capture boil-off gas from the tanks.

The selected reference ship is a two four-stroke engine with propulsion power of 17 MW running on heavy fuel oil with a 3.29 % sulfur content. The first step this study addresses is to quantify the emissions by developing a model for the ship energy system. This model is validated by comparing performance data at different loads with a 9L46 marine diesel engine from Wartsila. The ship energy system consists of electric generators to provide electricity onboard, and a WHR system for each engine to increase the thermal efficiency. Further on, this paper integrates the ship energy system with an onboard capture system for emission reduction. Aqueous ammonia is used as the solvent for CO$_2$ and SO$_2$ capture in this study. It is validated with experimental data from Munmorah pilot plant which consists of a pre-treatment column for SO$_2$ removal, NH$_3$ wash columns and a typical CO$_2$ capture process as shown in Figure 1. In addition, the limitations of integrating a capture system onboard would be considered. The re-liquefaction process involves a combined refrigeration of both the captured CO$_2$ and the boil-off gas using the same solvent to reduce extra space requirements on the ship. This work is one of the first few studies in applying solvent-based carbon capture on vessels for emission reduction.

Keywords: CCS, post-combustion carbon capture, chemical absorption, on-board carbon capture, marine propulsion engine, marine propulsion engine, emission control

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