

A Risk Assessment Study on Fluid Dynamics of Single CO₂ Droplet Released into the Turbulent Seawater

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ABSTRACT

This study deals with fluid dynamics of single liquefied CO₂ droplet released into the seawater to carry out the fundamental design for our new concept, NEW COSMOS, which is proposed to contribute to sequestration and storage of CO₂ in the deep part of the ocean. A risk management study is carried out in this study to assess feasibility of this new technology, based on fluid dynamics of single CO₂ droplet released into turbulent seawater.

KEY WORDS: Risk Assessment; CO₂ Sequestration; Seawater; Computational Fluid Dynamics; CO₂ Droplet; Turbulence

INTRODUCTION

This study deals with a risk management analysis of our new concept, NEW COSMOS, for sequestration of CO₂ into the deep part of the ocean. The NEW COSMOS project is lead by National Marine Research Institute (NMRI), in cooperation with National Institute of Advanced Industrial Science and Technology (AIST), and IHI Marine United Inc (IHI-MU). In the proposed technology, CO₂ will be injected in the seawater as a liquefied CO₂ droplet from an offshore floating system structure toward the seafloor. The released droplet will sink toward the seafloor because of density difference between the droplets and the seawater. A quick outlook into the NEW COSMOS is shown in Fig. 1, and available from June 2007 issue of the *Chemical Engineering* (www.che.com). The details of the proposed technology are also given in several references by Aya and his colleagues (e.g., Aya, Yamane, & Shiozaki, 1998; Aya, Yamane, & Kojima, 2000). These CO₂ droplets are made by a mixture of liquefied CO₂ and dry ice at the CO₂ triple point (0.52 MPa and 216.6 K), whose density is typically larger than that of the seawater. The liquefied CO₂ droplets are therefore expected to sink toward the sea bottom through the turbulent seawater. The droplet will be trapped on a hollow place at the seafloor if topography there is caved in, as illustrated schematically in Fig. 1. Sending the droplets into such hollow places on the seafloor without breakup in the seawater will be one of the important factors to be realized in the proposed technology.

The chemical engineering processes required in the new technology involve several unit operations to be designed carefully for efficient sequestration of CO₂. One is a process system design for production of CO₂ slurry efficiently to avoid excess input of energy for separation and liquefaction. A liquefaction of CO₂, which is typically carried out at its triple point, also requires considerable amount of energy for realizing low-temperature and high-pressure environment. Another problem is a

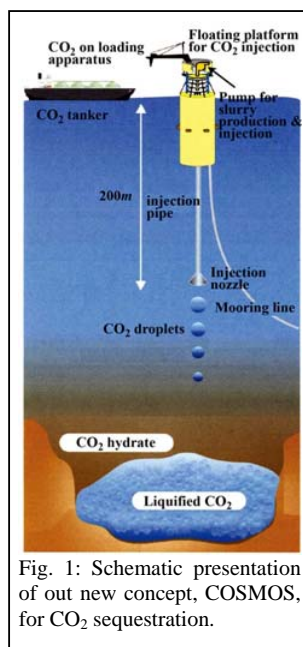


Fig. 1: Schematic presentation of our new concept, COSMOS, for CO₂ sequestration.

prediction of behavior of CO₂ droplets in the turbulent seawater. Fluid dynamics of the released CO₂ into the turbulent seawater is necessary to assess impact of the released CO₂ to the deep part of the ocean and ecosystem there. The investigation on fluid dynamics of CO₂ droplets in the turbulent seawater will also be applied to find out the optimum settling locations for the offshore floating system structure. This paper deals with fluid dynamics of sequestered CO₂ into the seawater, as a fundamental study on environmental impact of the released CO₂ droplet. The research and development on the process system for CO₂-slurry production will be discussed elsewhere in the near future.

Sequestration of the CO₂ using droplets from an offshore floating station requires specially designed devices, such as an injection nozzle to avoid collapses of the droplets in

the seawater. The injection nozzle applied to this technology should be designed for production of the CO₂ droplet without unnecessary disturbances at the nozzle outlet. Initially disturbed droplets are expected to collapse easily in the turbulent seawater. Collapse of the released droplets in the seawater should be avoided because CO₂ will be transported and diffused widely in the seawater, leading an uncontrollable circumstance with an environmental risk (Alendal and Drange, 2001; Drange et al. 2001). A study on fluid dynamics of the CO₂ droplets in the seawater will also help to design the nozzle for release of the droplets without adding unnecessary disturbances, which could be one of the reasons of their breakup. Furthermore, this study provides precious information on required physical properties of the CO₂ droplets, e.g., the density, surface tension between the droplet and the seawater, and viscosity, to sequester the CO₂ droplets on the sea bottom through the turbulent seawater without their breakup and rising toward the atmosphere-ocean interface.

A drastic simplification for assessing hydrodynamics of the CO₂ droplets in the turbulent seawater is compulsory for several reasons. One