CO₂ Injection System with CO₂ Cold Energy Recovery

Hwalong You¹, Youngkyun Seo¹, Cheol Huh², Daejun Chang¹

¹Division of Ocean System Engineering, Korea Advanced Institute of Science and Technology
Daejeon, Korea

²Technology Center for Offshore Plant Industries, Offshore CCS Research Unit, Korea Research Institute of Ships & Ocean Engineering,
Daejeon, Korea

ABSTRACT

This study proposed a new CO₂ injection system that recovers cold energy in ship-based carbon capture and storage (CCS) chain. The new system used Rankine cycle to recover CO₂ cold energy wasted by heating process of CO₂ in conventional systems. The study compared the conventional system to the new CO₂ injection system in terms of power efficiency. Proper operating conditions including pressure and temperature were defined in accordance with the environmental conditions of the target region. Process simulation was conducted for the comparison of the efficiency of the processes.

KEY WORDS: Carbon Capture and Storage; CO₂ injection; Cold energy recovery; Rankine cycle; Power generation;

INTRODUCTION

Global warming caused by greenhouse gases is a significant issue in the world. The many possible solutions to minimizing the effects of global warming include using renewable energy, saving energy and improving system efficiency in industry. Carbon capture and storage technology (CCS) has been received attention as one of the most practical ways of reducing CO₂ emissions.

CCS is a means of mitigating the CO₂ produced by large-emission sources by capturing and isolating it. Generally, the CCS technology comprises three segments: capture, transport, and storage. Figure 1 shows the system block diagram of a ship-based CCS chain. First, the CO₂ is captured at the CO₂ emission source, whether it is a fossil-fueled power plant or steel plant. Next, the captured CO₂ is transported to an offshore-storage site by ship. Although CO₂ can be transported by either pipeline or ship, this study focuses on ship transportation. To transport CO₂ by ship economically, it must be liquefied. The liquefied CO₂ is stored in intermediate storage tanks on a barge, and it is transported to the offshore-storage site. Finally, the CO₂ is injected into geological formation which has suitable conditions to store the CO₂. To inject the CO₂ into the storage site where it is injected into geological formations which are suitable for storing the CO₂.

A conventional CO₂ injection system generally consists of two processes: pressurizing process and heating process. The pressurizing process increases the pressure of the liquefied CO₂ and the heating process raises its temperature to avoid several operational problems such as back flow, hydrate formation, icing, and two phase flow.

Since CO₂ is liquefied near the triple point (5.2 bar, -56.4 °C), its temperature is low. The energy induced by the difference between the temperature of the freezing source and the environmental temperature is called the cold energy. Heating CO₂ for injection wastes this cold energy.

The liquefied natural gas (LNG) industry has some practical applications for using cold energy. The LNG cold energy is utilized during the regasification, which changes the phase of the natural gas from liquid to vapor. There are two ways to take advantage of the LNG cold energy: direct and indirect. The direct uses include liquefaction of oxygen and nitrogen, production of dry ice, and in industrial frozen food complexes. Indirect use creates the electrical power from the LNG cold energy.

There are three types of power cycles typically: The direct-expansion cycle, the Rankine cycle, and a combined cycle. The power-generation cycle with cold-energy recovery is usually installed in LNG receiving terminals. In-hwan Choi et al. proposed a new concept called cascade-Rankine cycle, which recovers LNG cold energy for use in power generation. Xiaojun Shi et al. proposed a combined-power system using cold energy. Huan Wang et al. examined optimization of a combined-