Investigations on power requirements for industrial compression strategies for Carbon Capture and Sequestration

N.K. Daud [a]*, N. Nasuha [b], S. Martynov [c] and H. Mahgerefteh [d]

a Faculty of Chemical Engineering & Natural Resources, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Pahang, Malaysia
b Faculty of Chemical Engineering, Universiti Teknologi MARA, Cawangan Pulau Pinang, Kampus Permatang Pauh, 13500 Permatang Pauh, Pulau Pinang.
c,d Department of Chemical Engineering, University College London, London WC1E7JE
*Corresponding author email: khonisah@ump.edu.my

Abstract:
The efficacy of Carbon Capture and Sequestration (CCS) as a means to mitigate the CO2 gas emissions from industrial sectors, including fossil fuel operated power stations, requires the minimisation of the costs associated with compression and transportation of the captured CO2. CO2 compression shares a large portion of the costs and energy penalties induced by CCS. The main purpose of this study is to identify the optimum multistage compression strategies for minimising the compression and intercooler power requirements for pure CO2 feed stream. An analytical model based on thermodynamics principles is developed employing Plato Silverfrost FTN95 software and applied to determine the power requirements for various compression strategies and inter-stage cooling duties for CO2 stream compressed from a gaseous state at 1.5 bar and 38 oC to the dense-phase fluid at 151 bar. Compression options examined include conventional multistage integrally geared centrifugal compressors (option A), advanced supersonic shockwave compressors (option B) and multistage compression combined with subcritical (option C) and supercritical liquefaction (option D) and pumping. In each case, the compression power requirement is calculated numerically using a 15-point Gauss-Kronrod quadrature rule in QUADPACK library, and employing the Peng-Robinson Equation of State (PR EOS) implemented in REFPROP v.9.1 to predict the pertinent thermodynamic properties of the CO2. In the case of determining the power demand for inter-stage cooling and liquefaction, a thermodynamic model based on Carnot refrigeration cycle is applied. From the previous study by Witkowski et al., (2013), the power demand for inter-stage cooling duty was assumed neglected. However, based on the present study, the inter-stage cooling duty is predicted to be significantly higher and contributes approximately 30 % from the total power requirement for compression options A, C and D, while reaches 58 % when applied to option B. It is also found that multistage compression combined with subcritical liquefaction using utility streams and subsequent pumping can offer higher efficiency than other compression strategies, while supercritical liquefaction efficiency is only marginally higher than that in the conventional integrally geared centrifugal compression.

Keywords : Compression Options; Peng-Robinson Equation of State; Compression Power; Inter-stage Cooling Duty

Acknowledgment

First author (N.K. Daud) acknowledges the funding received from the Research University Grant under agreement number RDU1803177 from Universiti Malaysia Pahang (UMP).