Accepted Manuscript

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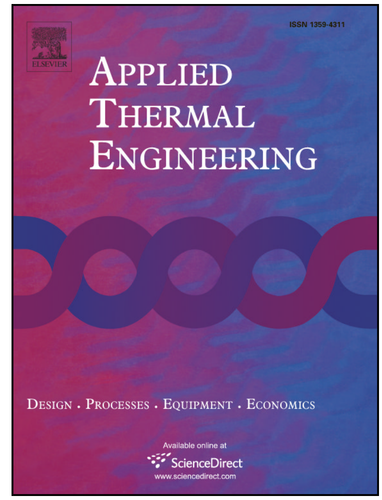

PII: S1359-4311(17)31168-7
DOI: http://dx.doi.org/10.1016/j.applthermaleng.2017.06.147
Reference: ATE 10719

To appear in: *Applied Thermal Engineering*

Received Date: 27 February 2017
Revised Date: 26 June 2017
Accepted Date: 29 June 2017

Please cite this article as: D. Ybyraiymkul, K. Choon Ng, A. Kaltayev, Experimental and Numerical Study of Effect of Thermal Management on Storage Capacity of the Adsorbed Natural Gas Vessel, *Applied Thermal Engineering* (2017), doi: http://dx.doi.org/10.1016/j.applthermaleng.2017.06.147

Experimental and Numerical Study of Effect of Thermal Management on Storage Capacity of the Adsorbed Natural Gas Vessel

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Abstract: One of the main challenges in the adsorbed natural gas (ANG) storage system is the thermal effect of adsorption, which significantly lowers storage capacity. These challenges can be solved by efficient thermal management system. In this paper, influence of thermal management on storage capacity of the ANG vessel was studied experimentally and numerically. 3D numerical model was considered in order to understand heat transfer phenomena and analyze influence of thermal control comprehensively. In addition, a detailed 2D axisymmetric unit cell model of adsorbent layer with heat exchanger was developed, followed by optimization of heat exchanging device design to minimize volume occupied by fins and tubes. Heat transfer, mass transfer and adsorption kinetics, which occur in ANG vessel during charging process, are accounted for in models. Nelder-Mead method is implemented to obtain the geometrical parameters, which lead to the optimal characteristics of heat exchange. A new optimized configuration of ANG vessel was developed with compact heat exchanger. Results show that storage capacity of the ANG vessel increased significantly due to lowering of heat exchanger volume for 3 times from 13.5% to 4.3% and effective temperature control.

Keywords: adsorption; adsorbed natural gas; optimization; heat exchanger; thermal management.

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1. Introduction

The application of natural gas (NG) as a fuel for motor vehicles will lead to reduction of air pollution caused by the particulate matter (PM). For example, according to California Air Resources Board, PM produced by diesel engines was responsible for as much as 75% of all cancer cases attributed to air toxics in 2003 [1]. Additionally, application of NG would lead to reduction of contaminant emissions, such as sulphur dioxide (SO2) by 83%, carbon dioxide (CO2) by 25%, carbon monoxide (CO) by 40% and smog-forming compounds by 92% [2]. Furthermore, NG could be produced in abundant amounts from associated petroleum gas or from coal seams. NG is mostly composed of methane (95%) which is in supercritical state at the standard conditions. Conventionally, methane could be stored as a compressed gas at high pressure (20-25 MPa) or a liquid at cryogenic temperature 110.15 °K (-163 °C). Compressed natural gas (CNG) is used worldwide. However, CNG storage tanks are also rather heavy, while achieving 20.7 MPa (3000 psi) pressure requires costly multi-stage compression. On the other hand, liquefied natural gas (LNG) method is generally used for transportation purposes. Required specialized container design and refueling procedures are undesirable for vehicular fuel application [2]. Another way of storing methane is using adsorbent materials inside storage tanks. In these tanks, during charging process, methane molecules can be attracted onto surface of pores of adsorbents by the means of Van der