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Heat transfer improvement of metallic foam catalyst for Steam-CO_2 reforming reaction

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ABSTRACT

Metallic foam catalyst was utilized to improve the heat transfer of Steam-CO_2 reforming (SCR) reactor. Nusselt number was used to evaluate the improvement of heat transfer between the wash-coated metallic foam and γ-Al_2O_3 pellet. The wash-coated metallic foam and γ-Al_2O_3 pellet with the same volume were packed in the reactor for comparison. As a result, the Nusselt number of the wash-coated metallic foam was higher than that of the γ-Al_2O_3 pellets at the entire range of the flow rate. The improvement of the heat exchange rate of the metallic foam, which means the difference of Nusselt number between metallic foam and pellets, increased with increasing the flow rate.

1. INTRODUCTION

Gas To Liquid (GTL) technology attracts significant research interest due to the exploitation of small-scale undeveloped gas resources and alternative to oil depletion. For this reason, GTL technology was main business item by major oil companies. GTL synthetic fuels prepared by Fischer-Tropsch (FT) synthesis contain extremely low sulfur and aromatic compounds. In addition, it has a low emission of carbon monoxide (CO), nitrogen oxide (NO_x) and hydrocarbons. Therefore, GTL synthetic fuels were regarded as a clean fuel (Park 2013).

The GTL process consists of three parts: reforming, FT synthesis and upgrading process. The reforming process involves the conversion of CH_4 to a syngas composed of H_2 and CO. The FT reaction is a synthesis reaction to obtain a high hydrocarbon containing wax as the main species. Finally, a clean synthesis fuel, such as a diesel, kerosene, jet fuel, gasoline and naphtha, can be produced through an upgrading process. The reforming process includes steam reforming (Aasberg-Petersen 2001), dry reforming (Antonio 2009), partial oxidation (Requies 2006), and auto-thermal reforming (Jens 2002). In particular, steam-CO_2 reforming (SCR) of methane is an attractive process for getting a H_2/CO ratio of 2 which is desirable for GTL and methanol (MeOH) synthesis processes. The SCR process is mainly considered by following three reactions as shown in Eq. (1)-(3).

$$CH_4 + H_2O \leftrightarrow 3H_2 + CO, \qquad \Delta H^0{}_{298} = 206 kJ/mol \tag{1}$$

$$CO_2 + H_2O \leftrightarrow CO_2 + H_2, \qquad \Delta H^0{}_{298} = -41 kJ/mol \tag{2}$$

$$CH_4 + CO_2 \leftrightarrow 2H_2 + 2CO, \qquad \Delta H^0{}_{298} = 247 kJ/mol \tag{3}$$

The catalyst performance on the reforming reaction has a strong dependency on the reaction temperature. The pellet supports that have been widely used show the low thermal dispersion due to its low thermal conductivity. Therefore, hot spots are formed on the catalyst surface, which can damage the catalyst during the SCR reaction. A uniform temperature distribution through the SCR reaction is a very important factor for the SCR reactor design. Recently, metallic foam catalysts having a high thermal conductivity have been widely studied. Many properties make the metallic foam attractive for use as catalyst supports, because their low density and high mechanical strength permit the design of light and stiff components. When loading a fixed-bed reactor with a foam cartridge rather than with packed particles, the high porosity would result in much lower pressure drops.

In the present study, metallic foam was selected as a substrate of the catalyst support because of its high thermal conductivity. The catalyst support was coated as a thin layer on the metallic foam substrate. The catalytic mass and heat transfer of the metallic foam support was compared with the existing Al_2O_3-pellet and wash-coated metallic foam support.

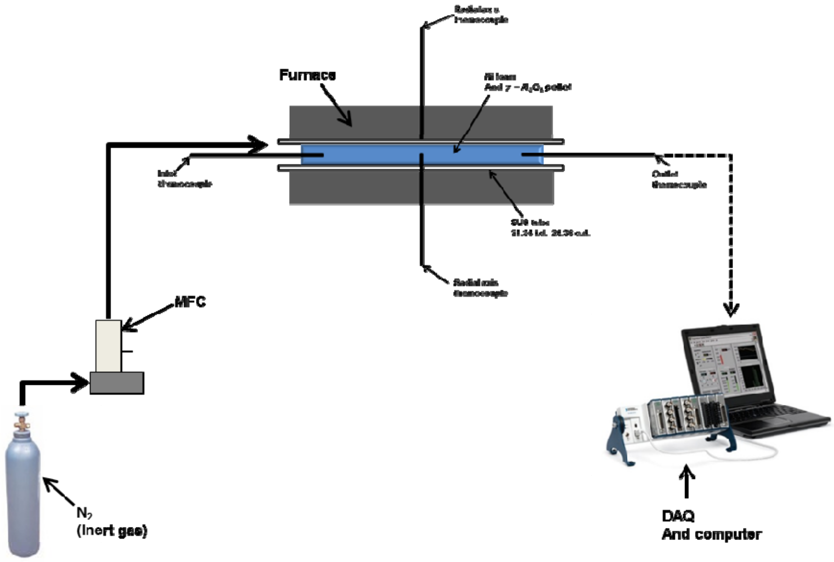

Fig.1 Experimental setup for mass and heat transfer

2. EXPERIMENTS

2.1 Preparation of the wash-coated metallic foam

AIP and PVA were dissolved in heated to 65^{o}C distilled water to wash-coating on metallic foam substrate. The PH of the aqueous solution was controlled by add on HNO_3 and the PH was adjusted to uniform. After drying for few hours at room temperature, transparent sol was obtained. Al_2O_3 powder was added to the transparent sol. After aging for few hours, the Al_2O_3 sol for wash-coating was prepared. The Al_2O_3 sol was wash-coated on the metallic foam using a dip coating method for few minutes.

2.2 Experimental setup

Fig. 1 shows the experimental setup for the heat and mass transfer on the wash-coated metallic foam and Al_2O_3 pellet supports. The SUS tubular reactor with 1 inch in diameter was used and thermocouples were located at the inlet, middle, outlet and wall. The γ-Al_2O_3 pellet and wash-coated metallic foam supports with the same volume were packed for comparison. Inert gas (N_2) was used as a feed gas. The wall temperature was fixed to 200°C in the present study (Twigg 2002).

3. RESULTS AND DISSCUSION

Fig. 2 shows the Nusselt numbers of the reactor packed with the γ-Al_2O_3 pellet and the wash-coated metallic foam. The Nusselt number of the wash-coated metallic foam was higher than γ-Al_2O_3 pellet at the entire range of the Reynolds number. The improvement of the heat exchange rate of the metallic foam, which means the difference of Nusselt number between metallic foam and γ-Al_2O_3 pellet, increased with increasing the reynolds number.

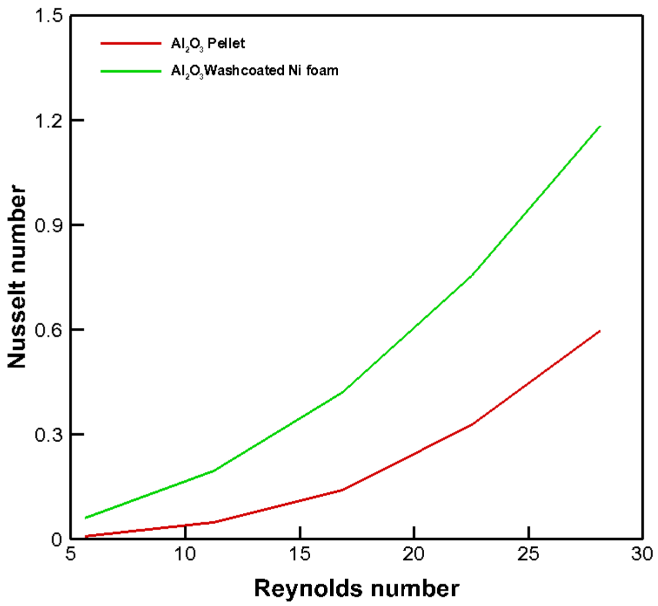

Fig.2 Nusselt number of the catalyst supports as a function of the Reynolds number

4. CONCLUSION

The catalyst support prepared by applying wash-coated Ni foam was developed to improve the mass and heat transfer through the steam-CO_2 reforming of methane reactor for GTL process. In this research has demonstrated that Nusselt number for wash-coated metallic foam is similar to correlations for γ-Al_2O_3 pellet. As a result, The Nusselt number of the wash-coated metallic foam was higher than γ-Al_2O_3 pellet at the Reynolds number

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