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Dynamic optimization of membrane dual-type methanol reactor in the presence of catalyst deactivation using genetic algorithm

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ABSTRACT

This paper presents a study on optimization of a membrane dual-type methanol reactor in the presence of catalyst deactivation. A theoretical investigation has been performed in order to evaluate the optimal operating conditions and enhancement of methanol production in a membrane dual-type methanol reactor. A mathematical heterogeneous model has been used to simulate and compare the membrane dual-type methanol reactor with conventional methanol reactor. An auto-thermal dual-type methanol reactor is a shell and tube heat exchanger reactor which the first reactor is cooled with cooling water and the second one is cooled with synthesis gas. In a membrane dual-type reactor the wall of the tubes in the gas-cooled reactor is covered with a pd–Ag membrane, which is only hydrogen-permselective. The simulation results have been shown that there are optimum values of reacting gas and coolants temperatures to maximize the overall methanol production. Here, genetic algorithms have been used as powerful methods for optimization of complex problems. In this study, the optimization of the reactor has been investigated in two approaches. In the first approach, the optimal temperature profile along the reactor has been studied and then a stepwise approach has been followed to determine the optimal profiles for saturated water and gas temperatures in three steps during the time of operations to maximize the methanol production rate. The optimization methods have enhanced 5.14% and 5.95% additional yield throughout 4 years of catalyst lifetime for first and second optimization approaches, respectively.

1. Introduction

In the methanol synthesis process, synthesis gas (CO_2, CO and H_2) produced from natural gas in the reformer section, converts to the methanol in tubular packed bed reactor. A schematic diagram of a conventional dual-type methanol reactor has been shown in Fig. 1. This system is mainly based on the two-stage reactor system consisting of a water-cooled and a gas-cooled reactor with lengths of 8 m and 10 m, respectively. The synthesis gas is fed to the tube of the gas-cooled reactor (second reactor). The cold feed synthesis gas for the first reactor is routed through the tubes of second reactor in a counter-current flow with reacting gas and then heated by heat of reaction produced in the shell. So, the reacting gas temperature is continuously reduced over the reaction path in the second reactor. The outlet synthesis gas from the second reactor is fed into the tubes of the first reactor (water-cooled) and the chemical reaction is initiated by catalyst. The heat of reaction is transferred to the cooling water circulating on the shell side. In this stage, the synthesis gas is partly converted to methanol in a water-cooled single reactor. The methanol-containing gas leaving the first reactor is directed into the

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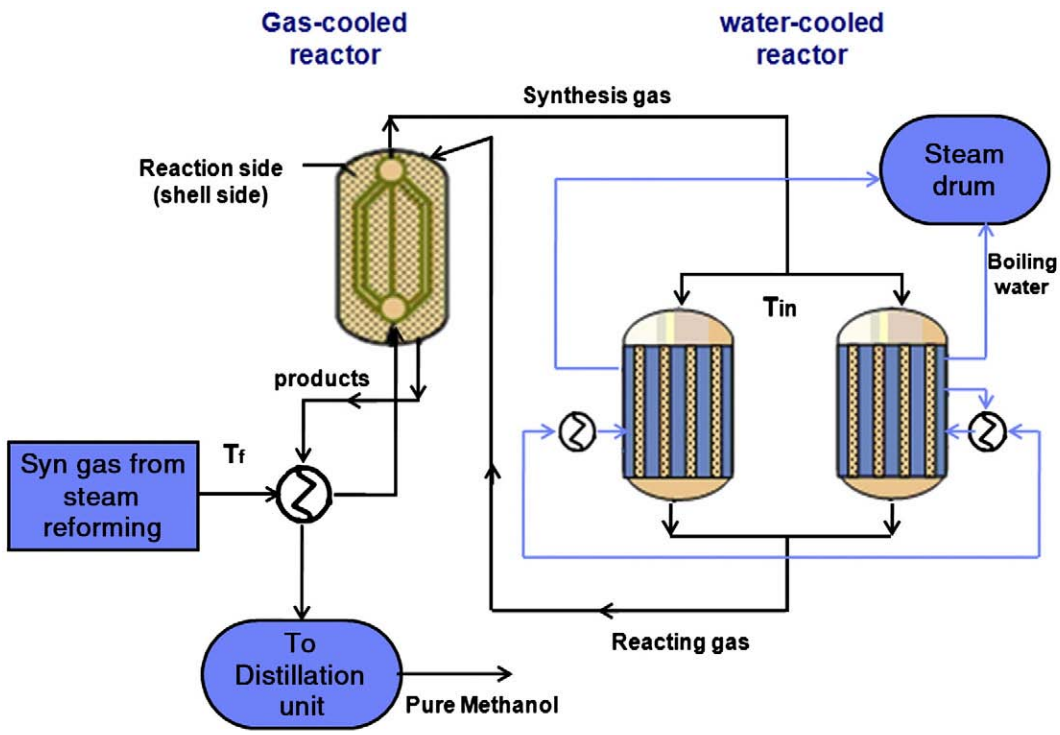

Fig. 1 – A Schematic diagram of conventional dual-type methanol reactor [2].

shell of the second reactor. Finally, the product is removed from the downstream of the second reactor. Fig. 2 shows the schematic diagram of a membrane dual-type reactor configuration for methanol synthesis. The methanol synthesis process in the membrane dual-type methanol reactor is similar to that in the conventional dual-type methanol reactor, with the exception that in membrane system the wall of tubes in the second reactor is hydrogen- permselective membrane. In the new system, the mass and heat transfer process simultaneously occurs between shell and tube, while in conventional type only heat transfer process occurs between them [1].

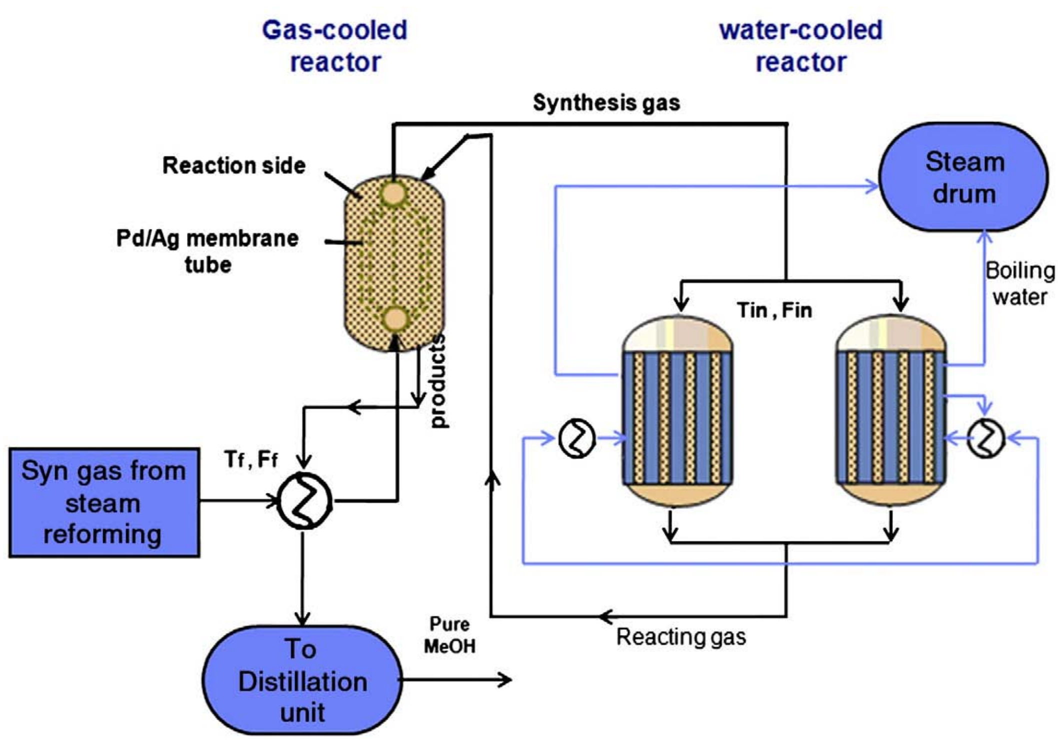

Fig. 2 – A schematic diagram of membrane dual-type methanol reactor in counter-current mode [2].