Performance Analysis of an Ammonia Synthesis Reactor

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ABSTRACT

Ammonia is the raw material for several products, such as fertilizers, household cleaners, dyes, nylon, explosives, and other chemical compounds (Erisman *et al.*, 2008). To achieve the increasing demand for ammonia-based products and, at the same time, reduce production costs, plant designers have been looking for more efficient industrial processes (Mesquita *et al.*, 2025). The efficiency of the ammonia process is related to the performance of the ammonia reactor, the main equipment into the ammonia synthesis loop. Despite the well-known ammonia production process, many factories are still operating with old reactors and seek more profitable operational and/or design practices. The most used process for ammonia synthesis is based on the reaction of nitrogen and hydrogen over an iron catalyst, at high pressure and high temperature. The control of the synthesis reactor conditions is crucial for ammonia production (Johnson, 2022). However, several factors may influence these conditions and, consequently, the ammonia production. In this work, a performance analysis study is presented for an ammonia converter with two catalyst beds, two heat exchangers and internal radial flow. The focus of this analysis is the effect of process input variables, such as pressure, temperature, flow rate and composition of the feed stream, on the ammonia yield. Therefore, a steady-state pseudo-homogeneous model was developed and validated with industrial data. This model assumes that mass and energy vary radially and considers the mass and heat integration system present inside the reactor. The developed model can predict industrial data with a relative deviation of 17%. Performance analyses of the ammonia synthesis reactor were able to show the influence of several variables on the reactor under study. It was observed that the higher the reactor inlet pressure, the lower the conversion to ammonia and the higher the energy consumption of the compressors in the ammonia synthesis loop stage. Increasing the reactor inlet temperature also reduces the conversion of NH_3. The reactor, which typically operates with an inlet temperature of about 120°C and an inlet pressure of 140 kgf/cm^2, could achieve better production values if these values were lower, 112°C and 139 kgf/cm^2, respectively. The developed and validated model can be used in further optimization and control studies.

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