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# Integration of a novel Ammonia synthesis process with ORC cycle as a waste heat recovery unit: Energy and Exergy Analysis

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**Abstract**

This study aims to design and introduce a novel ammonia synthesis process that uses an organic Rankine cycle as a waste heat recovery system. Two methods of the first and second law of the thermodynamic are used to investigate the proposed system. In this novel system, liquid ammonia is produced at three plug flow reactors, and waste heat of the process is rejected to the evaporator of the ORC cycle. The net-work production and the proposed system's exergy efficiency are obtained at 2735 KW and 41%, respectively. Also, the results show that this system can produce 4038 kgmole/h liquid helium.

**Keywords: Ammonia Synthesis, Organic Rankine Cycle, Waste Heat Recovery, Exergy Analysis**

## 1. Introduction

The industrial flue gas emitted to the atmosphere is considered harmful to the environment and a waste of plentiful resources of thermal energy. The thermal energy extracted from the industrial flue gas can be employed for multiple purposes [1]. This study proposes a new configuration to use flue gas to produce ammonia. Waste heat recovery is an effective way to reuse waste energy to produce useful energy products. This technique aids in the reduction of CO2 emissions and to create sustainable and efficient systems. The Organic Rankine Cycle (ORC) is a usual choice in waste heat recovery technologies because this cycle can operate with low, medium, and high-temperature heat sources. So this cycle presents high flexibility and compatibility with waste heat [2]. In this research, R-134a is used as the working fluid of the ORC cycle. Ammonia is one of the most highly produced inorganic chemicals. There are numerous large-scale ammonia production plants worldwide, producing 144 million tonnes of nitrogen (equivalent to 175 million tonnes of ammonia) in 2016. China produced 31.9% of the worldwide production, followed by Russia with 8.7%, India with 7.5%, and the United States with 7.1%. 80% or more of the ammonia produced is used for fertilizing crops. Ammonia is also used to produce plastics, fibers, explosives, nitric acid (via the Ostwald process), and intermediates for dyes and pharmaceuticals. Today, most ammonia is produced on a large scale by the Haber process with capacities of up to 3,300 tonnes per day. In this process, N2 and H2 gases are allowed to react at pressures of 200 bar. A new configuration of biomass gasification based cascaded ammonia synthesis proposes two different configurations of ammonia synthesis system using the Stoichiometric and Gibbs reactors investigated in the Aspen Plus V11. A new heat recovery technique from biomass gasification using syngas cooling is also proposed in this study. The designed system produces 21.9 kmol/h of ammonia and 3405 kW electrical power [3]. A model is presented that enlarges the well known linear optimization models for joint production planning problems that are typical for the process industries by integrating by-products and residues and emission taxes. The model is implemented with the help of the process simulation system ASPEN PLUS and applied as an example to a real-world ammonia synthesis plant [4]. A study proposes a new configuration for synthesizing clean ammonia using clean hydrogen produced by renewables. The proposed system mainly consists of a proton exchange membrane electrolyzer, pressure swing adsorption unit, compressor, ammonia synthesis reactors, and condenser. The designed configuration uses a cascaded approach for ammonia synthesis by employing two reactors to achieve high conversion ratios and reduce the recycling loops [5]. The economies of scale are analyzed in ammonia synthesis loops embedded with iron-based catalysts (Fe) and ruthenium-