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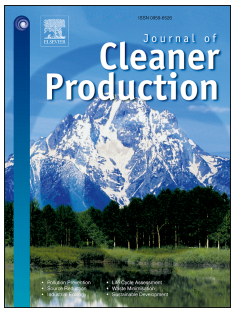

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Antonio Sánchez, Mariano Martín

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Optimal renewable production of ammonia from water and air

Antonio Sánchez, Mariano Martín[1]

Department of Chemical Engineering. University of Salamanca, Pza. Caídos 1-5, 37008 Salamanca (Spain)

Abstract

In this work a production facility of ammonia has been evaluated using air and water as raw materials. Nitrogen is obtained from air separation using a Linde's double column. Hydrogen is produced from water splitting. Next, hydrogen and oxygen are purified to remove water and traces of chemicals. Finally, ammonia is synthesized in a three bed packed reactor. Two cooling designs were considered, indirect and direct cooling. The ammonia is recovered by condensation using the cold air. Power for compression and electrolysis is obtained from renewable sources either solar, photovoltaic, or wind energy. The process is simulated developing surrogate models for each of the units involved with special attention to the electrolyzer, Linde's column, synthesis reactor and ammonia recovery. In particular, the multibed reactor is modeled rigorously off line to validate the conversions and its operation. The full process is formulated as an MINLP problem. Solar energy and indirect cooling are selected for the production of ammonia. However, the high cost of panels results in high investment capital, over 1500M€, but promising production cost of ammonia, 1.35€/kg.

Keywords: ammonia; hydrogen; process optimization; solar energy; water; wind energy

[1] Corresponding author. Tel.: +34 923294479
Email address: mariano.m3@usal.es