HEAT RECOVERY FROM HYROGEN PRODUCTION WITH A PMR

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ABSTRACT

Developing new and improved ways of producing hydrogen is important to increase its use. The Protonic Membrane Reformer (PMR) combines steam-methane reforming (SMR), water-gas shift (WGS), gas separation and electrochemical compression [1] and produces compressed hydrogen and concentrated CO_2, reducing energy penalties for including CO_2 capture [2]. Based on the PMR technology, we designed a hybrid concept including both hydrogen production from the PMR as well as CO_2 capture by CO_2 liquefaction [3]. It was shown that the energy cost of the process is the most important factor determining the cost of producing hydrogen, and thus maintaining a low energy consumption is important for the competitiveness of the concept.

To maximize the hydrogen production rate per membrane area, the PMR can be operated to produce a larger amount of heat from ohmic heating and electrochemical compression of hydrogen than what is needed for the endothermic SMR reaction. Such surplus heat can be conveniently used to meet the process heat demands, maximizing the energy efficiency of the system. Thus, we designed a heat exchanger network to optimize the heat integration, which ended up reducing the energy consumption by 2%p. However, this assumed that all the surplus heat could be recovered from the PMR. To ensure that this is feasible, we here investigate this heat recovery.

To study the heat extraction from the PMR we utilized a flexible in-house modelling framework developed by SINTEF Energy Research [4]. First, a model of the membrane tubes was developed, giving information about the amount of heat generated along the PMR, the amount of hydrogen transferred through the membrane, as well as the chemical composition. This was then used to model the streams in the system as a heat exchanger, including the feed flow inside the membrane tubes and surplus heat generated, the hydrogen transfer from the feed stream to the sweep stream and the heat recovery stream(s) to collect the surplus heat. Two different heat recovery configurations were considered. First, the single jacket design shown in Figure 1 was investigated, in which a single stream flows in a jacket surrounding the PMR to collect all the surplus heat, and then afterwards flows through heat exchangers to transfer this heat to the correct streams. Second, the triple jacket design shown in Figure 2 was investigated, where three jackets are placed surrounding the PMR and heat is directly transferred to the three streams identified in the HEN optimization. The streams were placed such that their target temperatures were decreasing as one moves further out from the PMR.

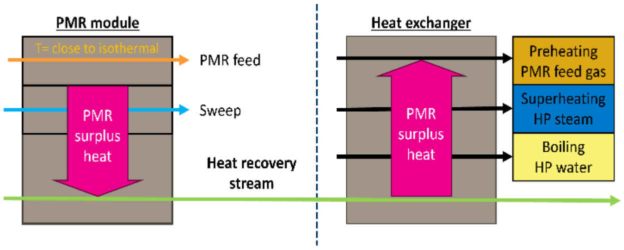

Figure 1. Schematic of the single jacket concept with indirect heat recovery.

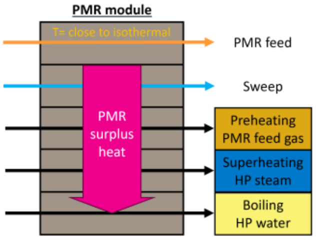

Figure 2. Schematic of the triple jacket concept with direct heat recovery.

Overall, both the single jacket and triple jacket designs were able to extract all the extra heat produced by the PMR and deliver it to the heat requiring streams. However, for the triple jacket each stream had a target temperature set by the HEN optimization and reaching this for all streams at the same time turned out to be challenging. Too much heat was transferred to the outer colder streams, such that not enough was left for the feed preheating. Increasing the diameters of the tubes would reduce the velocity of the streams and the heat transfer coefficient, thus reducing the amount of heat transferred to the outer tubes. However, the triple jacket design was already quite large, and thus increasing the size even further was deemed not attractive.
Therefore, the single jacket design was considered as a better design, allowing for all the extra heat to be transferred to the heat recovery stream and for it to be heated close to the target temperature of 800°C. However, due to the heat recovery stream starting off with quite a low temperature, this led to one end of the PMR becoming quite cold, which would lead to an impact on the core hydrogen producing process inside the membrane tubes. Reducing the heat transfer coefficient by increasing the diameter of the shell reduces this drop in temperature, but also leads to other parts of the PMR becoming hotter. Thus, the heat recovery of heat from the PMR becomes a tradeoff between the peaks and the drops in the temperature of the PMR.

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