Pure Hydrogen Production from Natural Gas via Fuel Processor based on Steam Reforming with WGS and PSA units

Giuliana Ercolino[a*], M. Arsalan Ashraf[b], Stefania Specchia[a]
[a]*Politecnico di Torino, Department of Applied Science and Technology, Torino, 10129, Italy*
[b] *University of Bath, Department of Chemical Engineering, Bath, BA27AY, United Kindom*
**Corresponding author: +39.011.0904699, giuliana.ercolino@polito.it*

Abstract: H_2 is produced mostly from reforming of fossil fuel followed by a series of purification steps. This work is a sensitivity analysis of H_2 production plant from natural gas. The plant consists of steam reforming, a water gas shift, and a pressure swing adsorption units to produce high-purity H_2. The sensitivity analysis was carried our varying the percentage of H_2 recovery from the PSA (70-75%) and the operating pressure (5-30 bar,g), in order to identify the best operative conditions that provide the best equilibrium between H_2 production and the overall efficiency of the system.
Keywords: water gas shift, pressure swing adsorption, sensitivity analysis.

1. Introduction

The vision of "hydrogen (H_2) economy" and utilization of H_2 as an energy carrier will require increasing H_2 production by more than an order of magnitude of the current production levels [1].

H_2 can be produced from a variety of sources. Fossil fuels may be used to produce H_2 by first converting their fuel value to gas phase by reaction with steam, oxygen or air (gasification/reforming) followed by H_2 enrichment and separation. The choice of H_2 separation technology often depends on the hydrocarbon feedstock used and the resulting synthesis gas composition. PSA (pressure swing adsorption) has been the most commonly used technology for producing high-purity H_2 as product by steam reforming. PSA is based on an adsorbent bed that captures impurities in the syngas stream at high pressure and then releases them at low pressure. For this purpose, multiple beds are used simultaneously, so that a continuous stream of H_2 at purities up to 99.9% may be produced recovering up to the 76% H_2 present in the reformate syngas [2].

2. Experimental

The work focus on a simulation study for H_2 production in a refilling station starting from natural gas (NG). The overall process consists in H_2 production (steam reforming, SR, and water gas shift, WGS, stages), purification (PSA stage), compression, and refrigeration, with the recirculation of PSA exhaust in the burner. In our previous work [3], a comparison between two clean-up methods (CO preferential oxidation, CO-PROX, and CO selective methanation, CO-SMET) for a refilling station (not integrated system) and for an auxiliary power unit (APU, integrated system) was investigated. Now, the final purpose of this work is to replace CO-PROX or CO-SMET with a PSA, to obtain pure H_2 ready for use. Besides, the thermal conditions of the system varying the PSA H_2 recovery (from 70% to 95%) at different reforming pressure (5-30 bar) were investigated. The PSA exhaust contains a noticeable part of the produced H_2, which can be sent to the integrated burner (I-BR) to sustain the reforming reaction. Moving from 70% to 95%, there is a thermal neutral point (TNP) above that that the system is not anymore self-sustained. In these configurations, part of the total NG feed to the reforming is shifted to the I-BR to supply the reforming reaction. Whereas below the TNP, not all the recirculated fuel is required from the I-BR. Therefore, the remaining part of the fuel is sent to another burner (BR) that produces waste gases to preheat the air required to the I-BR. The TNP moves in the range of H_2 recovery when the reforming pressure changes.

Moreover, we completed the simulations with a H_2 compression and refrigeration (NH_3 plant) stage, in order to provide a full view of a refilling station plan from the production to the storage of pure H_2.

Thus, this work consists in a sensitivity analysis of the reforming pressure coupled with an economic analysis of the different plant configurations, in order to establish the best one in terms of reforming pressure and H_2 recovery.

3. Results and discussion

A series of simulations were carried out at different H_2 recovery level (70-95%) and different operating pressure (5-30 bar). The NG conversion in the reforming decreases with the increasing of the operating pressure. The specific H_2 production of the overall system decreases with the operating pressure but increases the H_2 recovery. H_2 production is not influenced by the operating pressure. The TNP moves towards higher H_2 recovery increasing the operating pressure. Based on this, the highest value of net efficiency of the system was obtained at 90% of H_2 recovery (**Fig. 1**).

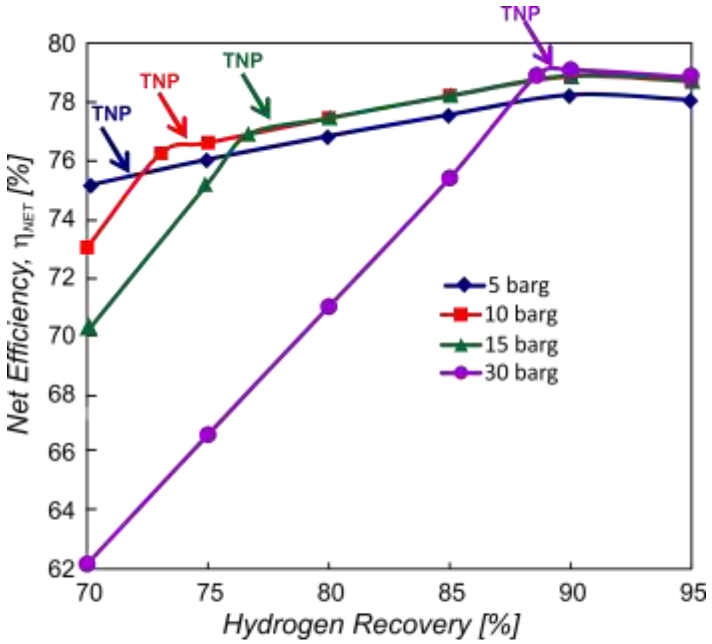

Figure 1. Net efficiency of the system at different operating pressures.

4. Conclusions

A series of simulations of an H_2 refueling station were carried out by Aspen Plus. The H_2 refueling station was based on SR of NG plus WGS and PSA units, included various compression stages to compress pure H_2 up to 700 bar,g. The simulation were carried out varying the H_2 recovery (70-95%) and the operating pressure of the system (5-30 bar,g). After the calculations, the best operating conditions were found at 90% of H_2 recovering and at 30 bar,g.

References

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