Enhancement of steam methane reforming (SMR) reactor with static mixer elements

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by

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Abstract

Steam methane reforming (SMR) converts natural gas (methane) and steam into syngas, a mixture of hydrogen ($H_2$) and carbon monoxide ($CO$). Syngas can be used for synthesis of alternative liquid fuels and many other chemicals, and is a leading source of hydrogen in the industry. The SMR reaction takes place in a reactor that is usually a set of externally heated pipes filled with a packed bed (PB) of small catalyst pellets. These pipes suffer from large radial gradients of temperature and concentration, leading to low reaction rates, possible overheating and failure of the reactor walls, and the need for very long reactors.

The current research investigates the addition of static mixer elements inside the pipes, integrated with the porous catalyst medium. Creating this geometry is possible by three dimensional printing. The purpose is to improve the radial mixing and heat transfer and reduce the radial gradients between the reactor wall and the center of the reactor.

We use the COMSOL Multiphysics® software to simulate the reactor, where we analyze the momentum, mass, chemical, and species equations, and energy balance equation with the assumption of a non-equilibrium heat transfer. The simulation working conditions are similar to those used in the SMR industry. We have considered two geometries of static mixers that are commonly used in the industry for mixing in open pipes (without the catalyst porous medium), the High Efficiency Vortex (HEV) static mixer, and the helical static mixer. This research includes various combinations of these static mixer elements.

Both of the static mixers showed improvement in the reactor performance, leading to higher conversion rate of methane and hydrogen production. The predicted increase of hydrogen concentration produced in the reaction was up to 27 percent compared to the same reactor without static mixer. The static mixer elements addition creates radial mixing that cause reduction in the radial gradients of concentration and temperature between the reactor wall and its center. We have seen that the use of a static mixer in a porous media region is indeed effective, with the mixers producing vortices and radial mixing despite the flow resistance caused by the porous media.

Such improvements can make the SMR process in the industry more efficient and economical. In the conditions investigated here, the length of the reactor can be shortened by almost 1 meter. These improvements can contribute to a variety of very endothermic or exothermic chemical reactions, in addition to the SMR reaction. This approach has great room for future optimization of the elements number, positions, angles, and size, that might present better results.