Power-2-Olefins: supersonic olefin production

Mike Bonheure, Rejish L. Johnson, Tom Verstraete, Georgios D. Stefanidis, Kevin M. Van Geem

Our world is facing huge challenges. Climate change, a problem created by people that goes far beyond national borders, requires a coordinated solution with drastic mindset changes at all levels of our current society. It is, therefore, undebatable that the current worldwide society requires an economic vision wherein renewable energy and circularity thrive. In this respect, an essential and crucial role is reserved for the chemical industry provided that it becomes CO_2-neutral. Electrification of the (chemical) process industry offers a solution if combined with the usage of renewable and/or recycled raw materials and carbon capture utilization and/or storage. This transition would, however, require massive quantities of cheap net zero-carbon electricity. Nevertheless, this prerequisite alone is not sufficient to shift from conventional to electrified processes. Current chemical plants are not designed for swift integration of electricity. Yet electrification does offer an opportunity to completely reinvent -often outdated- production processes to enhance energy efficiency and product yield and thus profit margins [1].

In this respect, a turbomachine-like reactor design -originally developed by Vladimir Andreevich Bushuev in 1998 [2]- has been computationally assessed focusing on the production of light olefins. In this design, the inlet and outlet are connected with a vaneless spaced duct in which multiple stages are positioned. A stage comprises a stator followed by a rotor and a diffuser. By utilizing high-speed rotation, the reactor provides the required kinetic energy -reaching supersonic levels- to the fluid, which is subsequently transformed into heat upon the reduction of flow velocity (i.e. subsonic velocities in the vaneless space) in the diffuser cascade. Specifically, this movement generates stationary shockwaves across which the flow decelerates from supersonic to subsonic velocities over a very small length (a few micrometers). Hence, velocity is being traded for enthalpy, resulting in heating times for shock-heated gases in the order of nanoseconds. Behind the diffuser cascade, a vaneless space is situated where residence time, turbulence, and temperature are sufficiently large for the chemical reactions to take place. After this vaneless space, another stage is implemented and the process repeats itself until the desired conversion is reached within a continuous process.

As a proof of concept, 0D/1D reactor models have been developed to assess the potential of turbomachine-like reactors and to compare it to the potential of conventional Millisecond furnaces. Additionally, 3D non-reactive steady-state simulations were performed to provide the established 0D/1D reactor models with more accurate temperature, pressure, and residence time distribution profiles for improved yield predictions. The results have shown that this turbomachine-like reactor design, compared to a conventional Millisecond furnace, could enhance the propylene and ethylene yields by up to 4 wt%.

References

[1] K. M. Van Geem and B. M. Weckhuysen, "Toward an e-chemistree: Materials for electrification of the chemical industry," (in En), *MRS Bulletin,* pp. 1-10, 2022-01-01 2022, doi: doi:10.1557/s43577-021-00247-5.

[2] V. A. Bushuev, "Method for producing lower olefins, reactor for the pyrolysis of hydrocarbons and device for quenching pyrolysis gases," Russia, 2000. [Online]. Available: https://patents.google.com/patent/RU2124039C1/en?oq=inassignee:%22Vladimir+Andreevich+Bushuev%22