Continuous Processing

From process development to customized production, continuous separation and work-up

Evonik has more than 50 years of experience in developing and applying continuous processes:

- Established processes with micro reactors, tube reactors, loop reactors, trickle-bed reactors, and many more.
- In-house reactor optimization / development.
- Continuous separation and work-up technologies: Distillation, extraction, crystallization, membranes.
- Simulation and design capabilities at our Hanau, Germany site.

Pilot plant

A flexible modular continuous processing pilot plant at our site in Hanau, Germany.

- Main reaction types: Hydrogenation, high and low T, hazardous gases
- Upgrade to cGMP possible
- OEB 3

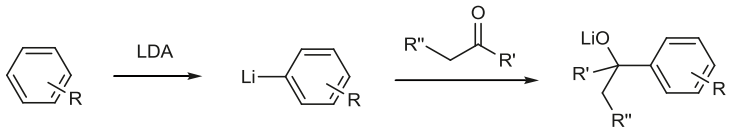
Large-scale production

- More than 60 % of Evonik's products are produced using continuous processes.
- In-house process technology and engineering unit (> 500 engineers and chemists) for complex projects.
- Track record of complex and large investment projects (also in exclusive customer projects).

Big engineering network

- Experienced engineering capabilities for special topics
- Cooperation with experts:
  - Process Analytic Technology (PAT) group
  - Simulation and additive manufacturing (3D-printed reactors)

Example 1: Continuous hydroxyalkylation in a tube reactor



Significant improvements byswitching from batch reaction to tube reactor:

- Yield of batch process was improved by 50 %
- Consistently higher quality of final product, fewer impurities
- More than 10 campaigns have been run so far at Evonik

Process development capabilities

Modular Small-Scale Flow System:

- Different mixers/reactors (tube, micro mixer, static mixer, T-mixer, dynamic magnetic driven mixer)
- –70 to +200 °C
- Residence times from 3 seconds to 30 minutes
- Flow rate: 6 to 1200 ml/h
- Two consecutive reaction units with independent temperature control

Loop/Tube Reactor:

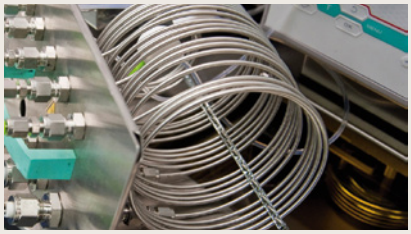
- –40 to +170 °C
- Residence times from 3 to 30 minutes
- Flow rate: 50 to 500 ml/h
- Two consecutive reaction units with independent temperature control

Continuously Stirred Reactor Cascades:

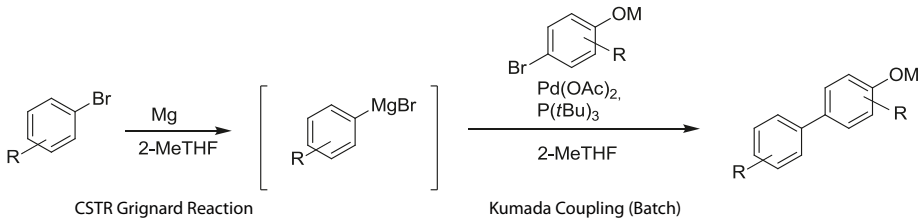
- Automated parallel equipment: 30 – 100 ml
- 1 – 2 l double jacketed vessels
- Cascades of up to 8 reactors
- –10 to +140 °C
- Residence time: 10 – 120 min/stage

Process analytical technologies:

- Collaboration with Process Analytical Technology (PAT) group
- PAT technology
  - FTIR
  - RAMAN
  - Automated sampling



Example 2: Continuously stirred tank reaction to produce an API intermediate (600 kg scale)



CSTR Grignard Reaction

Kumada Coupling (Batch)

- Grignard run as a continuously stirred tank reaction in 100 l reactor
- Manufactured several tons of Grignard solution

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