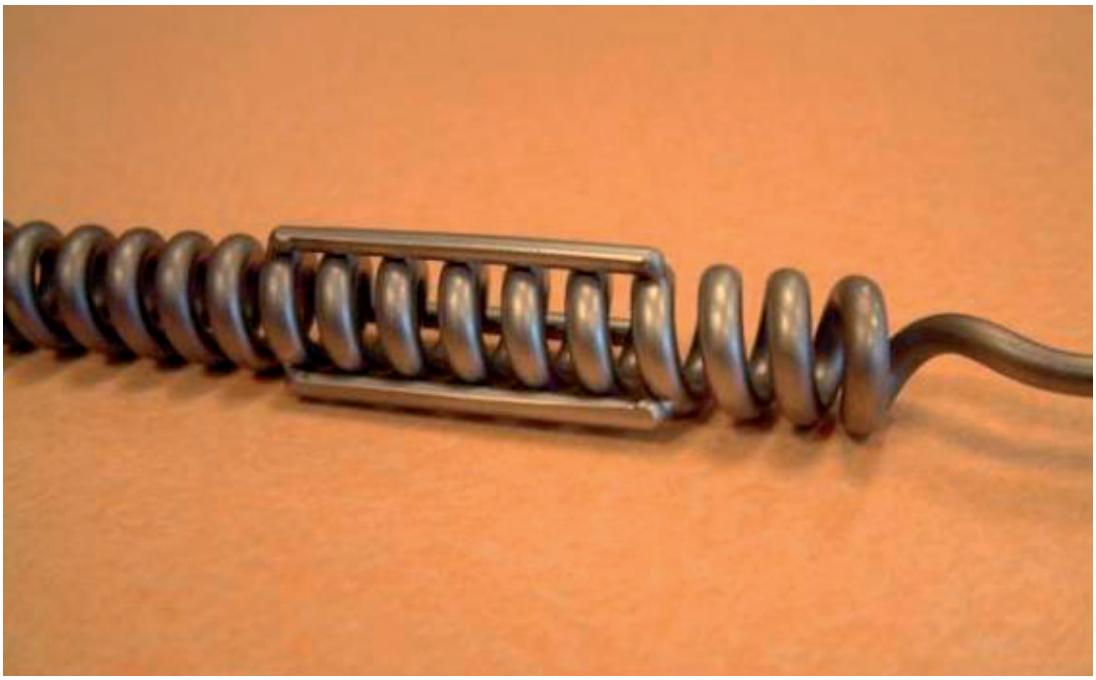
# CONTINUOUS HELIX MINI-REACTOR



*Continuous TNO Helix® reactor.*

TNO innovation for life

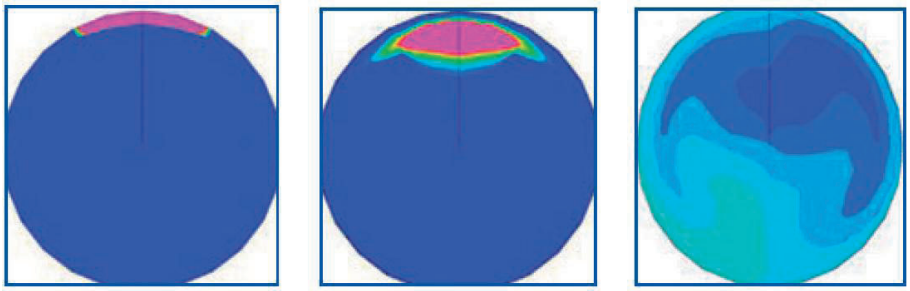
Current chemical production processes are pushed to their limits with regards to efficiency, emission control and energy consumption. In order to progress any further, a novel approach is needed. TNO developed the TNO Helix® reactor, which allows a transition from batch to continuous processes and additionally has clear advantages over a straight tube reactor. The Helix reactor is a form of mild process intensification, which is especially suited for exothermic liquid-phase reactions and for two-phase reactions like precipitation and polymerization.

## CONTINUOUS REACTOR TECHNOLOGY

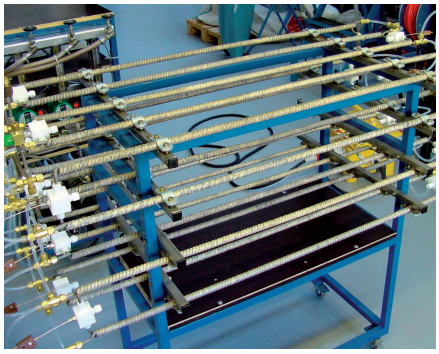
In the fine chemicals industry, the batch reactor has been the established workhorse for carrying out reactions. Its main advantage here is being multi-purpose. The chemistry that fits with this kind of equipment is, however, limited to relatively slow and mild reactions because of the limited wall surface area available for cooling. This limitation hinders the implementation of more demanding exothermic and hazardous reactions in the industry, creating a need to intensify the existing processes. Continuous reactors have the advantage that a relatively large surface area is available for cooling, allowing better control over temperature and hence the reaction conditions, while also suppressing undesired side reactions and ultimately resulting in a higher selectivity. This translates to a potentially higher yield

## TNO HELIX® CHARACTERISTICS AND ADVANTAGES

TNO developed the continuous Helix mini-reactor to combine the advantages of continuous flow reactors with the need for multi-purpose reactors which can handle multiple phases. The Helix is a continuous tubular reactor with very good heat transfer characteristics compared to straight tubular reactors. In the helix reactor secondary vortices exist that stabilize the flow of a liquid. This improves radial mixing and inhibits turbulence. The result is a near plug flow characteristic which is very well mixed compared to a straight tube while retaining a small pressure drop.



*Comparison of the TNO Helix® against a straight tube.*



*Small pilot unit for industrial testing.*

## THIS REACTOR POSSESSES:

- excellent heat transfer properties
- avoids hot-spot formation
- narrow residence time distribution
- forms a uniform product

The reactor is a multi purpose tool that can be easily customized to fit specific process requirements.

## EXAMPLES OF PROVEN PROCESSES

*Liquid phase reactions*

A solvent free alkylation of methylimidazol using ethylbromide was performed at 93°C and 6 bars to realize a single phase in the Helix reactor. After the reaction parameters were adjusted to fit the process, the desired white crystalline product was obtained after cooling.

*Two phase reactions - Polymerization*

A mini emulsion of methaxymethylacrylate was polymerized in the Helix reactor. Its gentle mixing prevented coagulation and the desired polymeric spheres were obtained.

*Two phase reactions - Precipitation*

Calcium Carbonate was precipitated in two continuous flow reactors from concentrated solutions (1M). The results show a decrease of the particle size of the precipitate in the helix compared to a conventional straight tube reactor.

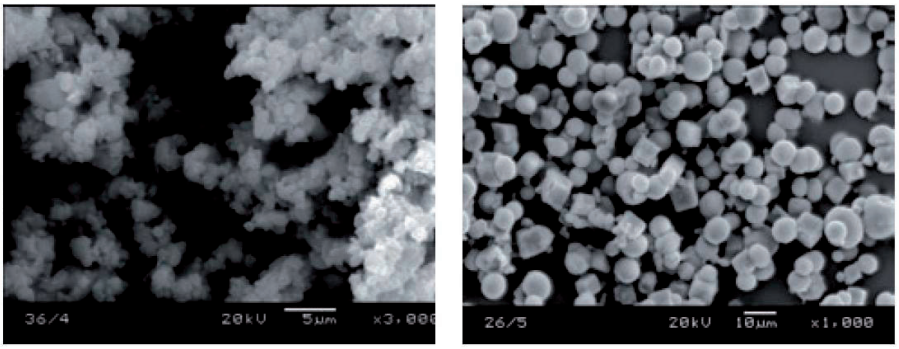
## SCALE-UP OF THE HELIX

The Helix reactor can be scaled up in different ways depending on the process at hand. The diameter can be changed to increase the throughput. This can be done up to a certain point where the Dean-vortices disappear and is dependent on e.g. viscosity. When the diameter cannot be increased, parallellization is an option. This obviously has effects on the final costs of the system.

## PROJECT APPROACH

A typical Helix reactor project involves the following steps. TNO obtains the process characteristics from the customer. With these characteristics, a feasibility study is done to determine the applicability of the Helix-reactor to the specific process and its specifications (length, diameter, parallel units, pumps, etc.). This involves theoretical work, laboratory work and economical evaluation against the competing technology. When feasibility is shown a scale-up study is done, where a larger industrially relevant pilot unit is designed together with an equipment supplier and tested at TNO or at the customer's site. Again both technical and economical evaluation is done. If this is succesfull,

TNO can design the final unit and involve the equipment supplier for implementation at the customer's site. Also, operator training can be provided.




*$CaCO_3$ precipitation in a straight tube (left) and a TNO Helix® (right).*

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