

Ultrasonic fouling sensor for curved tubular reactors

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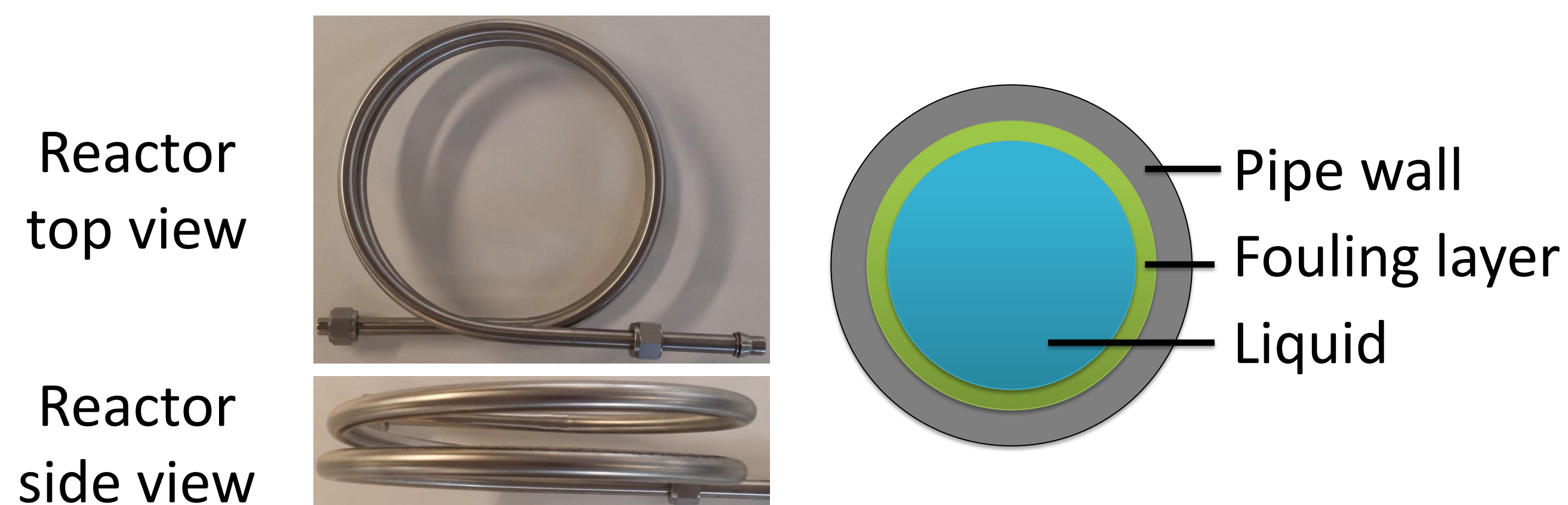
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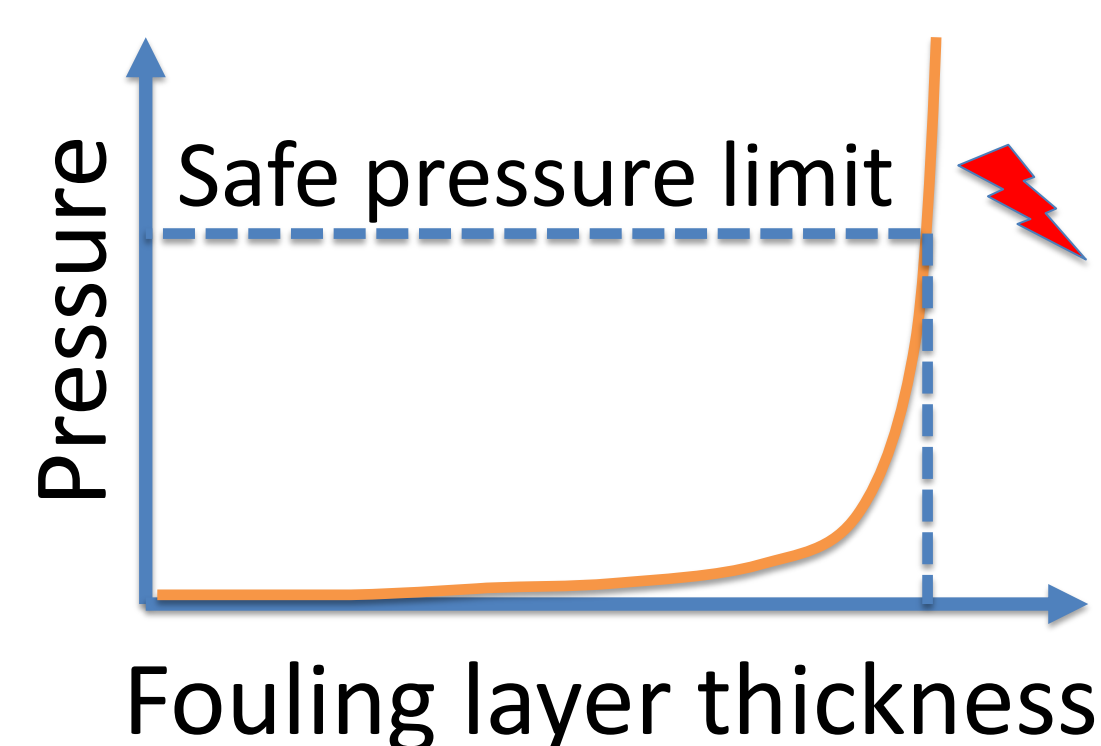
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Introduction

Fouling is a commonly occurring problem in a diverse set of chemical production processes. Here, a fouling sensor is developed for a strongly exothermic synthesis process in a continuous reactor. The reaction by-products accumulate on the reactor wall over a period of hours and increasingly block the flow and the transfer of heat.



Thus the temperature increases as well as the pressure drop over the reactor. Consequently, the end-product quality suffers and eventually the process is shut down by a safety valve. The common method of detecting fouling, a pressure sensor, only detects a significant pressure increase if the reactor is almost blocked. Cleaning the reactor causes a significant downtime, production loss and waste. A fouling sensor allows for the monitoring of the build-up of the fouling layer, and for appropriate intervention using a control loop – eg. by changing the product formulation or by rinsing the reactor.



Sensor principle

The fouling sensor is based on the propagation of guided waves through the pipe wall and the fouling layer. These waves typically have an amplitude of 1 nm.

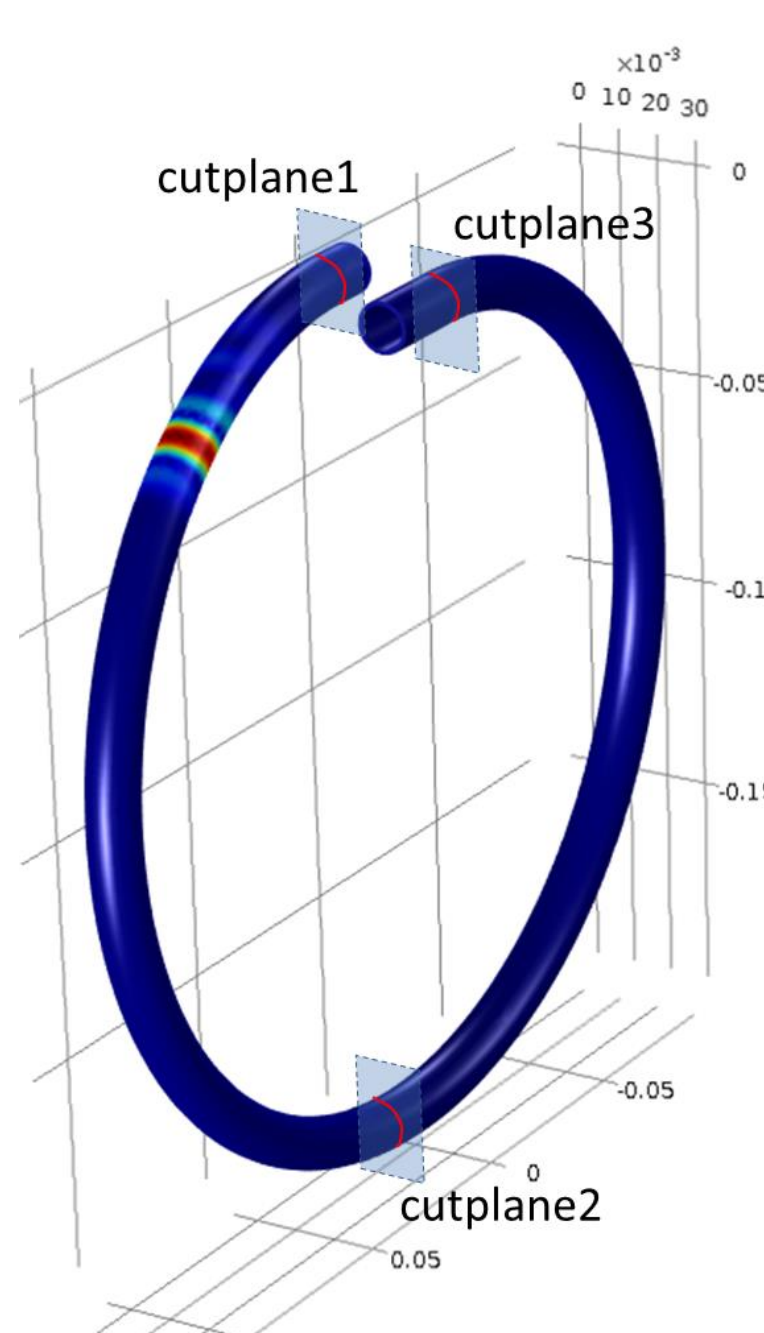
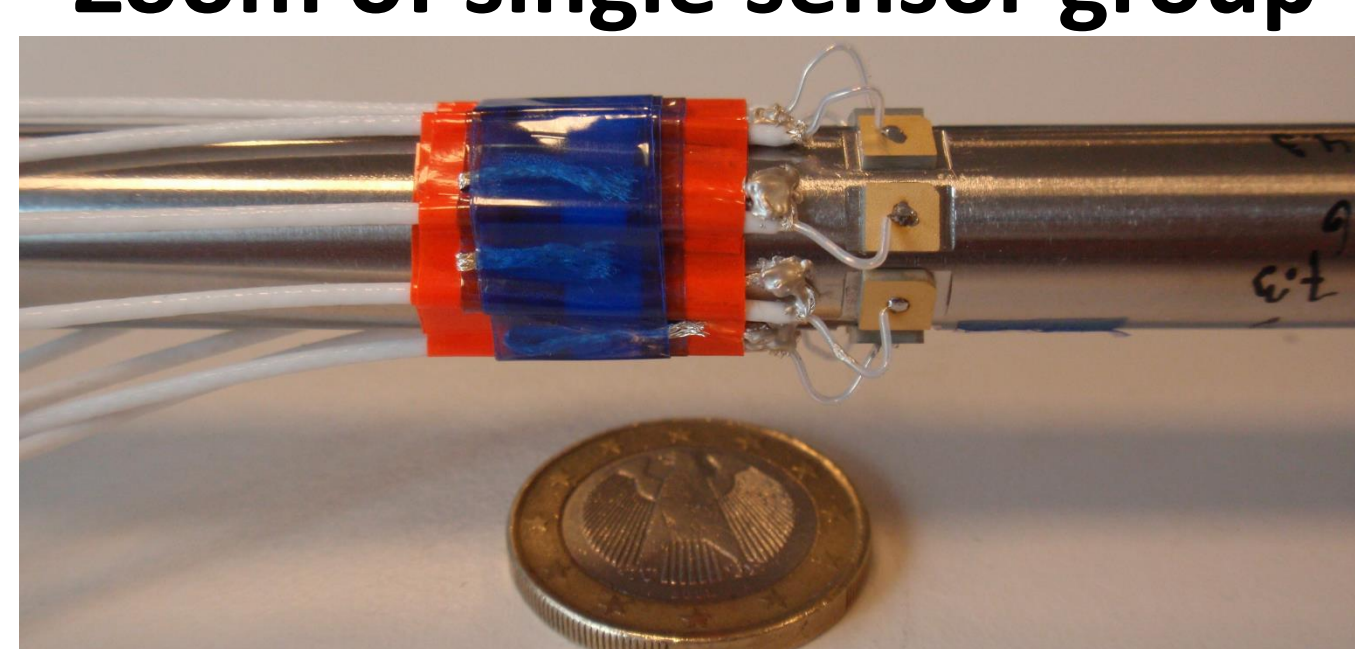
If fouling is present, the waves interact with the fouling layer:

- the velocity of the guided wave is altered,
- the attenuation of the guided wave is increased,
- part of the wave energy refracts into the fouling layer leading to a distortion of the measured time signals.

By analyzing these effects in real-time the thickness of the fouling layer can be estimated.



Zoom of single sensor group



Sensor features

The sensor:

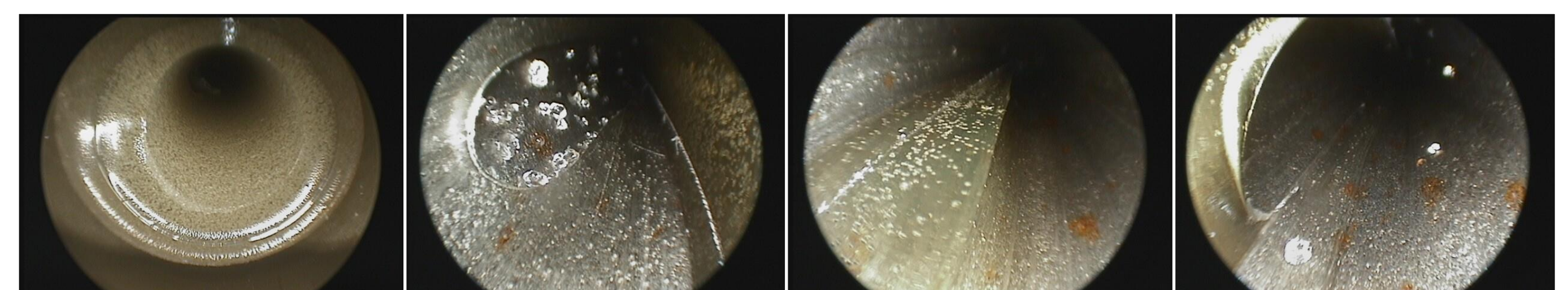
- is non-intrusive,
- measures over longer distances
- works with a metal (steel) reactor walls
- Works with curved tubular reactors

Results

Initial experiments have been performed using fouling layers consisting of polyurethane D60 with a variety of thicknesses and a number of shapes.

Fouling layer material: polyurethane D60	Theoretical resonance dip location [kHz]	Measured resonance dip location [kHz]
Fouling thickness [mm]		
1 mm	179	178
2 mm, fouling half-way	90, 270	98, 273
2 mm, fouling in middle	90, 270	112, 293
3 mm	60, 180, 299	83, 197, 313

The uniformity of the fouling layer was the main determining factor in the accuracy of the results.



Conclusion

- A fouling sensor for straight reactors has been designed.
- A series of fouling sensor prototypes for straight pipes has been realized.
- Initial experimental results based on polymerization fouling are promising.
- Accuracy limited uniformity fouling layer
- The effect of curved piping on the wave propagation has been investigated.
- A design for curved tubular reactors has been created.

References and Acknowledgements

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