Application Note

Fiber Optic Temperature Sensing of Exothermic Reactions in Packed Bed Column Reactors

The Challenge

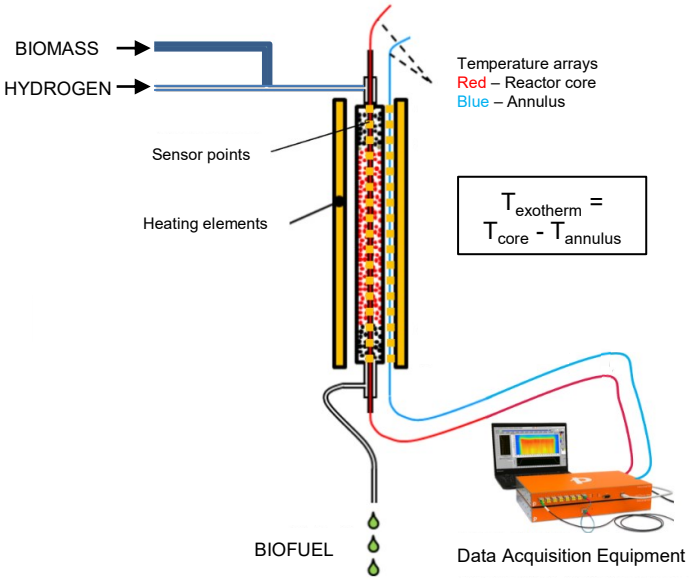
One of the most common chemical reactor designs is the packed bed reactor. These are often of tubular design, with a combination of fluids flowing through a packed column of ceramic pellets coated with a catalyst. The catalysts are designed to perform various chemical transformations such as deoxygenation, desulfurization and hydrocracking.

Often, these reactions are exothermic, i.e., lead to the release of heat. The amount of generated heat depends on different key parameters that vary with, e.g., mass transfer and kinetics. However, it is very challenging to monitor these reactors accurately and almost impossible to establish the amount and location of the exothermic heat being released. The long length of the reactors, and unintentional wear of the catalyst that may move the reaction zone, increase the measurement difficulties.

The Solution

Fiber Bragg gratings (FBGs) are high-resolution temperature sensors inscribed within a miniature (125µm) optical fiber. FBG array sensors have a very small form-factor, support many measurement points with a single probe, are zero power and so intrinsically safe, and provide very high-resolution measurements over an extraordinarily large temperature range. So, they are ideally suited to meet this chemical reactor measurement challenge.

In a ground-breaking partnership, Proximion and the Research Institute of Sweden (RISE) built an experimental packed bed reactor with FBG array temperature array sensors to demonstrate the new measurement capability. The sensing system demonstrated its capability to measure the relatively minor exothermic reactions that occurred along the complete length of the column.



The experimental packed bed reactor for conversion of forest product to biofuels (the Research Institute of Sweden, Södertälje).

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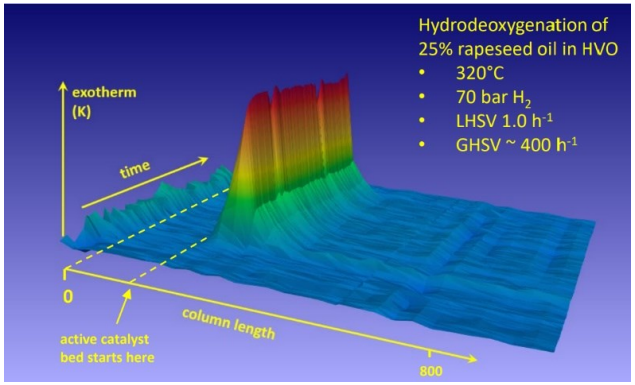
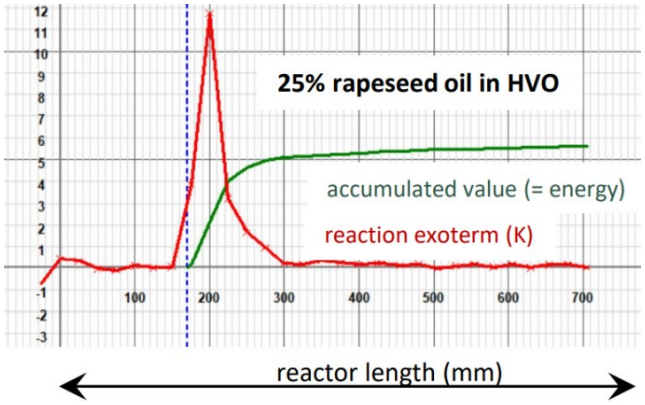
Following the success of the RISE experiment, Proximion has supplied the system to industrial customers wishing to monitor and optimise their chemical manufacturing processes.
Instrumenting reactors with this significantly improved exothermic temperature sensing has unlocked the following improvements:

- Increased conversion rate, capacity and product quality
- Optimized process control to maintain steady state production
- Monitoring of the bed (packing) and catalyst (activity, poisoning and coking) over time and location
- Improved control algorithms and reaction models
  via modelling from high quality kinetic data
- Real-time knowledge of the location of the reaction in the column

The RISE experimental reactor is used in research about the production of biofuels from forest products. The model system selected for the evaluation of the FBG measurements technology was hydrodeoxygenation of rapeseed oil with the exothermic measurement over time vs. column length as shown in the below figure.



Measurement of exothermic release in a packed bed column reactor using two Proximion array sensing probes, one within the reaction zone and one as reference outside the reaction zone (analysis by the Research Institute of Sweden, Södertälje).



The extracted exothermic temperature heat measurement (red line) and the integrated temperature curve / accumulated energy (green line). Analysis by the Research Institute of Sweden, Södertälje. See a video summary of the results at: youtube.com/watch?v=5UY2QO1_0zM

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