

Field integration of benchtop NMR instruments for online monitoring and process control of a modular industrial reaction step

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Motivation

- New "plug and produce" concept
- Modular and standardized chemical production elements
- Novel online sensors
- Closed-loop control methods

More efficient and flexible low to medium scale production for specialty chemicals.

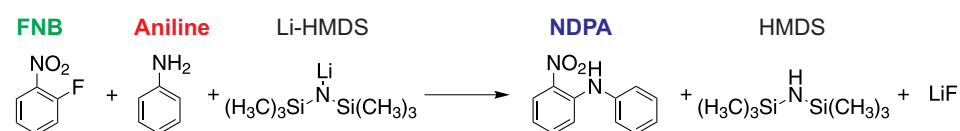


Fig. 1: Containerized modular plant from F³ Factory project (www.f3factory.com)

Online NMR spectroscopy has an enormous potential to become an important analytical tool for reaction monitoring, when flow probes are directly coupled to reactors.

Model Reaction and Specific Challenge

In case study 1, two aromatic substances (Eq. 1) are coupled by a lithiation reaction [1]:



Eq. 1: Reaction scheme, FNB: 1-Fluoro-2-nitrobenzene, Li-HMDS: Lithium bis(trimethylsilyl)amide, NDPA: 2-Nitrodiphenylamine

The two aromatic reactants are mixed with the lithium-base in a helical reactor. After some time, a fouling layer grows and leads to clogging of the reactor. Hence the production has to be interrupted for cleaning the reactor.

Concept

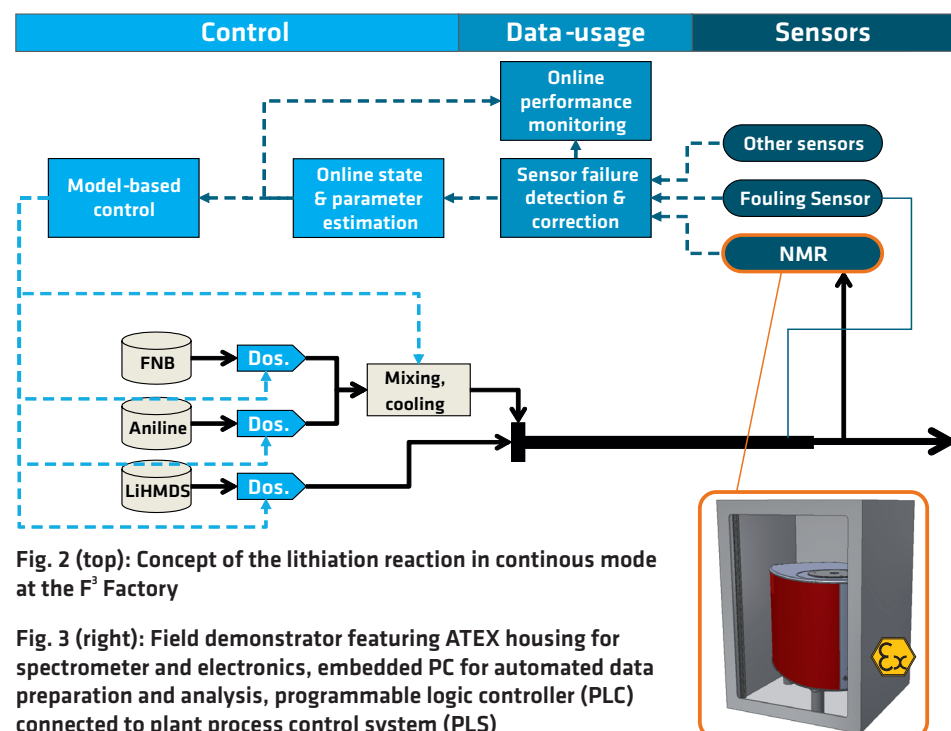


Fig. 2 (top): Concept of the lithiation reaction in continuous mode at the F³ Factory

Fig. 3 (right): Field demonstrator featuring ATEX housing for spectrometer and electronics, embedded PC for automated data preparation and analysis, programmable logic controller (PLC) connected to plant process control system (PLS)

Online Spectra of Lab Experiments

The reaction was performed in batch mode using a 25 mL glass reactor. The Li-HMDS was dosed stepwise. Spectra were acquired with a high field and a benchtop instrument (Fig. 4).

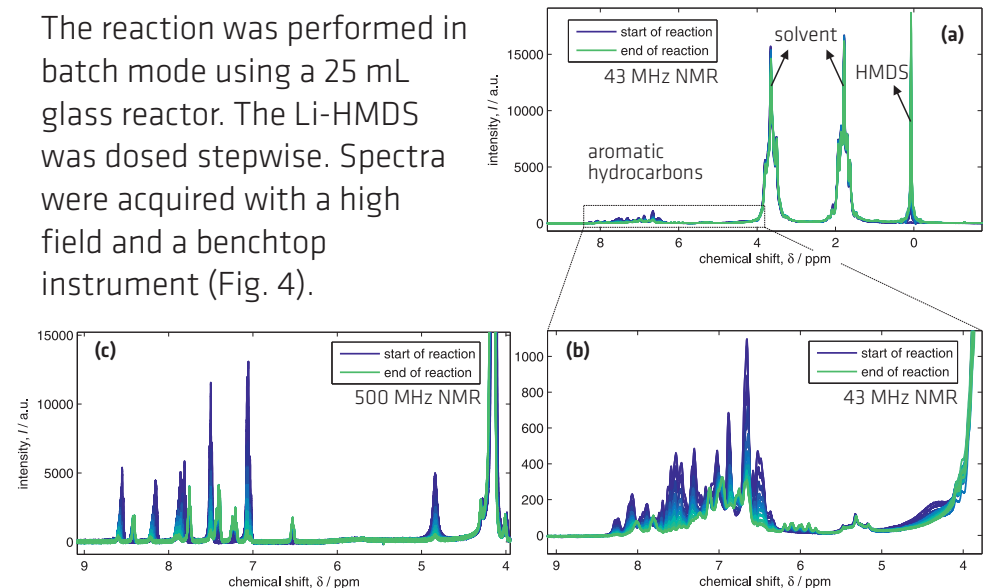


Fig. 4: (a) Complete spectrum (43 MHz) and aromatic region of shift corrected ¹H spectra at (b) 500 MHz and (c) 43 MHz for the lithiation reaction

Spectra for two different batches vary due to the quality of the respective shim (Fig. 5). A robust data pretreatment and evaluation strategy with potential for automation is fundamental.

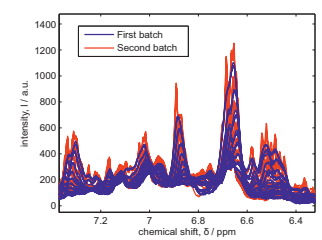


Fig. 5: Shift corrected ¹H spectra at 43 MHz for two batches of the lithiation reaction

Data Evaluation by IHM and PLS-R

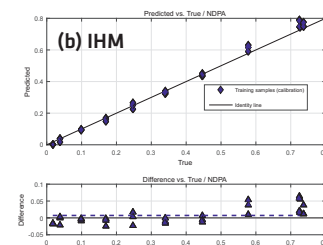
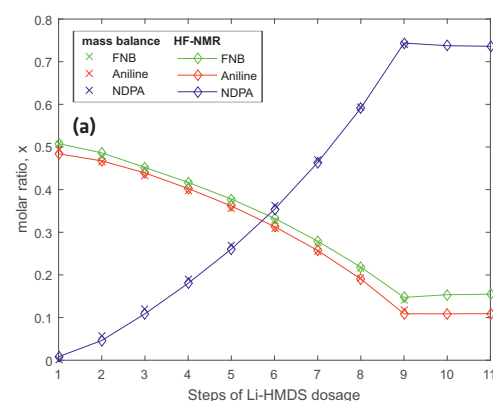


Fig. 6: Comparison of molar ratios generated by 43 MHz low field NMR spectra using (IHM (b) and PLS-R (c)), 500 MHz high field NMR data (direct integration) and by mass balance (a)

References and Acknowledgements

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