Development and Implementation of an Automatic Continuous Online Monitoring and Control Platform for Polymerization Reactions

Academic researchers will develop basic control and automation technology using the laboratory scale Automatic Continuous Online Monitoring of Polymerization reactions/ Control Interface (ACOMP/CI) system (left). The technology will be validated using the pilot scale ACOMP/CI (right). *Photos courtesy of Tulane.*

Enabling energy and resource efficiency in polymer manufacturing

Polymers, such as plastics, are an important class of chemical compounds composed of many repeated sub-units of monomers. The ability to engineer them to yield a desired set of properties (strength, stiffness, density, heat resistance, electrical conductivity) has greatly expanded the many roles they play in the modern industrial economy. Market applications of polymers include composite building materials, paints, adhesives, coatings, personal care products, biomedical components, and 'intelligent' new materials.

Despite the important role of polymers, due to the complexity of characterizing polymers, the design and implementation of polymer reactors is still an art rather than a science relying on operator judgment and reaction 'recipes.' Most polymer processes utilize time-consuming and labor-intensive offline analyses to validate, perform quality control, and provide some level of process control. Major problems can also occur during reactions, for example, runaway and dangerously exothermic reactions, failed reactions, production of unwanted side products, and reactor fouling. As a result, polymer production is highly inefficient with high levels of product waste and lost production time.

This project aims to target inefficiencies and enhance sustainability of polymer production by seeking to create a paradigm shift in the way polymers are manufactured. Researchers will use an existing platform called the Automatic Continuous Online Monitoring of Polymerization reactions (ACOMP) developed and patented at Tulane University. This system relies on continuous sample withdrawal, dilution, conditioning, and measurement to provide data on multiple critical polymer properties, and has already validated reaction monitoring at lab, pilot, and industrial scales. Researchers will develop predictive models driven by this data and integrate modeling and automated feedback control to create the ACOMP/Control Interface (or ACOMP/CI).

Benefits for Our Industry and Our Nation

The ACOMP/CI platform is fully compatible with current polymer manufacturing infrastructure and will enable:

- Increased production efficiency due to a reduction in grade changeover time, off-spec production, and unexpected production events.
- Increased efficiency by following optimized reaction trajectories during manufacture.
- Reduced energy and material feedstock consumption per pound of polymer produced.

Applications in Our Nation's Industry

While the ACOMP/CI platform is being developed specifically for polymerization reactions, the impact could be significant since the market applications of polymers are extremely broad. The polymer industry provides materials for sectors such as automotive, aerospace, agriculture, paints, resins, adhesives, optics, electronics, lightweight building materials, and many more. The ACOMP/CI system should also enable more efficient development of new and better polymers for 'intelligent' new materials.

Project Description

This project will use Automatic Continuous Online Monitoring of Polymerization reactions (ACOMP), integrated for the first time with modeling and feedback control to create the innovative ACOMP/Control Interface (ACOMP/CI). At the completion of this project, ACOMP/CI will be a self-contained intelligent system for advanced operation and control of polymerization processes throughout the polymer industry.

Barriers

- Establishing polymerization reaction process characteristics that are broadly applicable across the polymer industry to enable feedback control.
- Designing and implementing a reliable ACOMP/CI prototype for the industrial environment.

Pathways

Conceptual feasibility will be demonstrated by reaction control on simple free radical polymerization reactions. This early phase data will be used to design and build an ACOMP/CI system comprised of a pilot reactor, the ACOMP system and the control interface. Initially the ACOMP/CI system will be challenged to follow specified, well understood reaction trajectories using manual active control. Manual active control will allow an operator to 'drive' the monitored reaction as close to an ideal polymerization reaction trajectory as possible.

A matrix of industrially relevant reactions will be developed and the reaction characteristics within ACOMP/CI control capabilities will be established. Advanced model-based control and monitoring algorithms will be developed based on these reactions. Automatic feedback control will be tested and validated by achieving desired reaction trajectories and final polymeric products. Software modules will be developed and finalized into reliable, automated, working code for a commercial prototype to ensure accelerated commercialization and industrial implementation.

Milestones

This two year project started in December 2014.

- Design and build of a high performance, versatile pilot reactor outfitted with ACOMP and CI, and parallel design and build of an industrial prototype at the IIP facility (Completed).
- Demonstrate manual active control of the ACOMP/CI at full pilot scale by steering an acrylamide homopolymerization reaction along a pre-determined trajectory (Completed).
- Demonstrate ACOMP/CI control at pilot scale of a selected matrix of industrially relevant polymerization reactions (2016).
- Develop advanced model-based control and data-driven non-linear monitoring algorithms and deploy for reaction control on the ACOMP/CI (2016).

Commercialization

A high priority is placed on transfer of the ACOMP/CI technology to the polymer manufacturing sector. As such, a tandem approach is being taken whereby two complete ACOMP/CI systems are designed and built; an R&D ACOMP/CI on which the academic project partners will develop the basic control and automation technology to be used on both units, and the industrial instrumentation partner will build an industrial grade prototype in addition to providing engineering and prototyping support to Tulane. This will involve collecting data on operational reliability, live reaction kinetics, and other criteria in order to verify the physical prototype's effectiveness for the target application of manufacturing reaction monitoring and control.

Project Partners

Tulane University
New Orleans, LA
Principal Investigator: Wayne Reed
Email: wreed@tulane.edu

Advanced Polymer Monitoring Technologies, LLC
New Orleans, LA

Louisiana State University
Baton Rouge, LA

For additional information, please contact

Dickson Ozokwelu
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-2561
Email: Dickson.Ozokwelu@ee.doe.gov ■

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