Fluence Analytics

OPTIMIZING POLYMER MANUFACTURING AND R&D PROCESS EXCELLENCE

Leveraging Continuous Real-time Monitoring For Improved Product Quality, Faster Cycle Times, And Rapid Research & Development

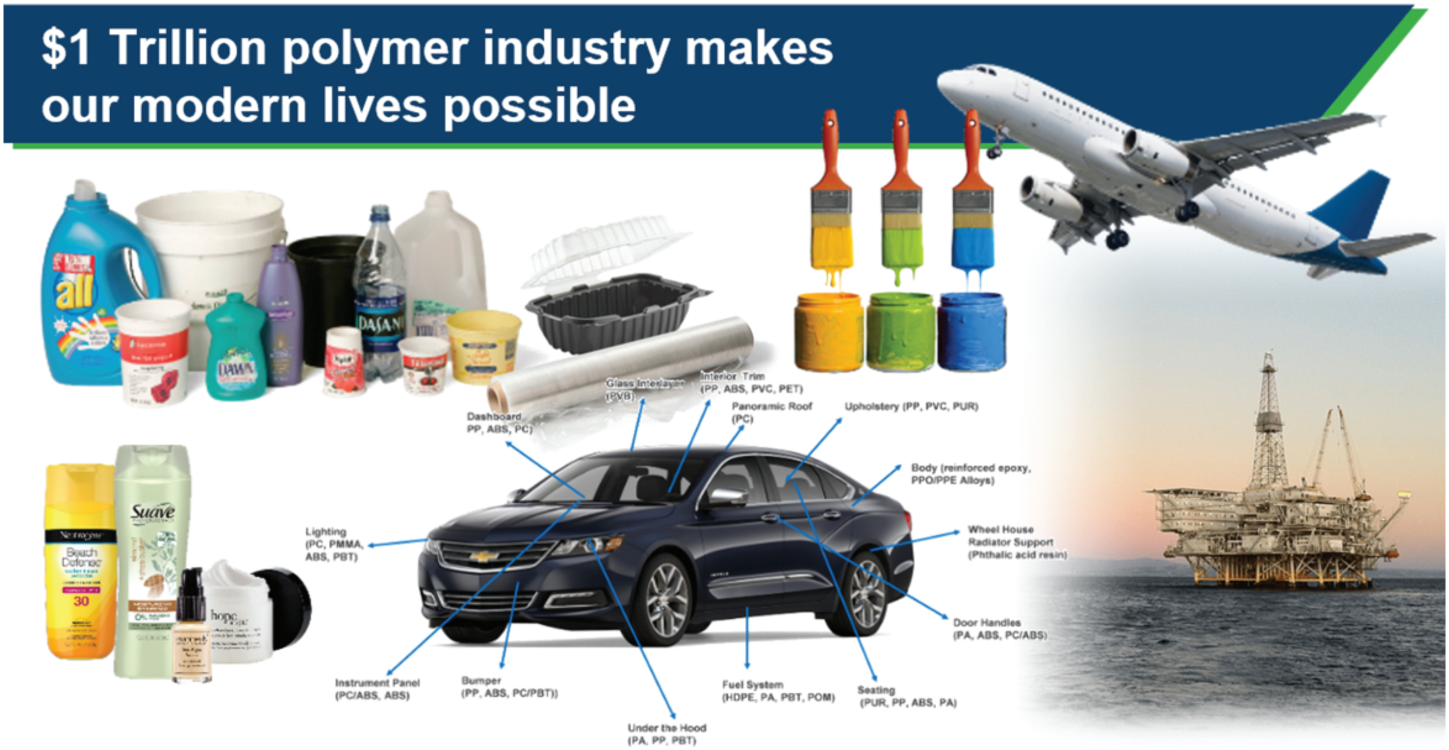
CONTENTS

CHAPTER ONE

EXISTING AND EMERGING CHALLENGES IN POLYMER MANUFACTURING

The global polymer industry is one of the critical foundations of the modern human economy, producing approximately USD $1 Trillion per year in essential materials. Roughly ⅔ by value consists of commodity materials for applications in packaging, construction and transportation, including polyolefins, polystyrene, ABS, PET, PVC, polyurethanes and some elastomers.

Mostly, these are produced in high-volume, continuous processes though there are exceptions such as solution SSBR produced in batch reactions. In contrast, speciality polymers are high value and are typically, though again not always, produced in batch reactions, sometimes at quite low volumes. These include materials for electronics, personal care, life science applications, adhesives, paints and coatings, polymers used in extraction of natural gas and polymers with high-temperature performance for engineering applications . It is truly an industry that makes our modern lives possible.



Manufacturing these products comes with existing and emerging challenges, including operational optimization, managing dynamic business environments, dealing with rapid changes in the workforce, gaining greater visibility in supply chain transparency, environmental sustainability, new laws and regulations, and major macroeconomic factors which have a global reach. Polymer manufacturers need to leverage every technical advantage possible to survive within a globalized economy in a constant state of flux and focus on what they can actually control internally as an organization.

One such area is process control optimization, which over the past few decades has stagnated in some aspects of the manufacturing process. When it comes to optimizing process control, traditional polymer monitoring and quality control processes still reign supreme. However, advances in disruptive polymer manufacturing technologies are creating new opportunities to consistently produce high quality materials at a lower cost. These disruptive technologies can dramatically improve the bottom line from polymer manufacturing by maximizing the value from existing assets, or even delivering more with less. In this eBook, we will introduce a new innovative approach to accelerate the quality control processes during polymer production, one that is just beginning to transform the industry.

1.1 The Current State of Polymer Manufacturing

The polymer manufacturing industry still heavily relies upon manual sampling and testing methods. This presents a vast opportunity for companies seeking to implement new sophisticated process control technologies and break away from traditional practices in polymer production and research & development.

Despite continual technology advancements, many polymer plants and facilities still use outdated equipment and rely on legacy processes and recipes. Thus, many, if not most, polymer manufacturing plants and production processes are not optimized for maximum efficiency. This is due to a combination of issues, including a lack of standardization, the usage of older monitoring and control methods, and a reliance upon time consuming manual sampling during the manufacturing process to ensure quality control.

Although in recent years the chemical manufacturing industry has attempted to standardize processes across multiple plant sites, many facilities are acquired through mergers and acquisitions and others are built as stand-alone facilities with completely different processes to other plants in the network. Therefore, it is quite common for different plants to have different operating procedures, oftentimes with different product qualities, which can be a challenge in establishing uniform, global quality standards. Furthermore, when new plants are built, their construction is often constrained by their immediate need and available budget. Sometimes manufacturers will rely on local technologies and methods when building these new sites (as an example, in China new construction is generally reviewed by local design institutes which impose technical requirements). This results in manufacturing plants that can vary widely based on their geographical location or when they were built.

Because of these variations in design and construction from plant to plant and company to company, many manufacturers tend to be quite conservative in their production processes, relying on their "tried and true" manufacturing methodologies which have worked in the past. Many production processes are designed to consistently achieve a satisfactory level of production yields and product quality. While this may suffice for high-volume, low-dollar commodity polymers, there is a growing need for more specialty chemicals with higher standards of performance. In order to meet production goals, manufacturers must produce these specialty polymers in greater quantities, and the "tried and true" manufacturing processes may prove inefficient and not deliver the desired optimal product quality consistently.

However, it is not only the process configuration and control systems used by a manufacturing plant that can have issues – much of the knowledge and information used in individual plants often reside in the minds of long-term employees. This legacy knowledge is generally passed from employee to employee, creating an institutional knowledge base specific to that plant. If this knowledge needs to be shared with another plant, those employees with the knowledge must pass it on to others, either through teaching or experience. As seen through demographic shifts at many mature organizations, knowledge loss is a growing issue across the industry. If no one else in the plant or company possesses the same knowledge, it may be lost and result in production delays and other issues, including painful repetitive learning. Knowledge capture and quantification are major areas of emphasis across the industry.

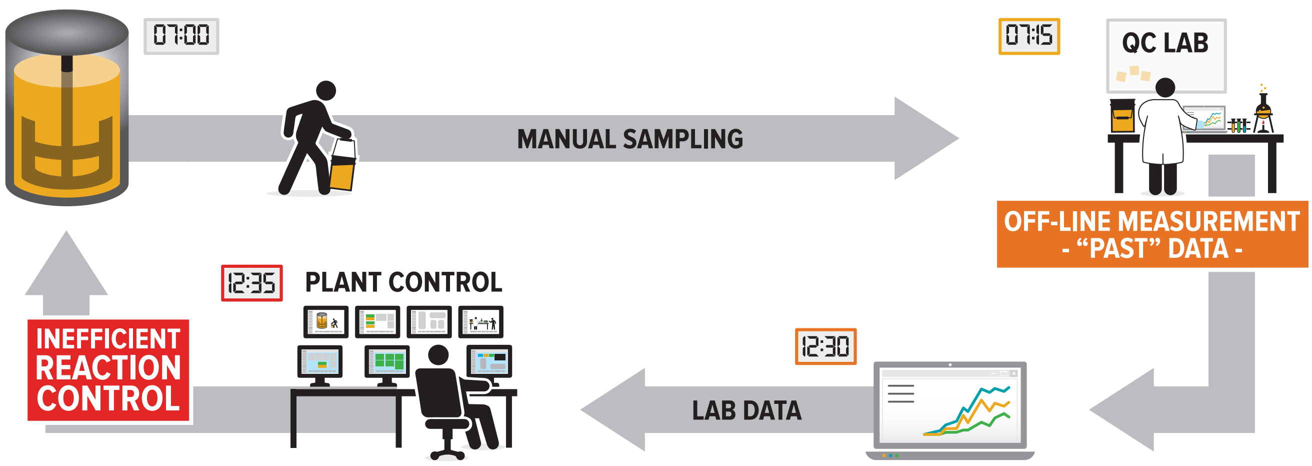
All the aforementioned factors lead to processes that have improved over time and have become safe enough, while also enabling the best chance of creating adequate products with low amounts of off-specification materials. While not necessarily inefficient, they are certainly not optimized to their full potential.

1.2 The Current QC Process

Product quality is key during polymer production. In fact, the properties of these polymers are the very thing that manufacturers sell to their customers to guarantee performance in the target application. If the quality of the end product does not meet the customer's required specifications, that product becomes a liability since it may not perform as expected in its final application. While some off-specification product is salvageable through rework or selling to customers with applications that have lower performance requirements, in other cases, the off-specification product must be disposed of, incurring additional costs.

Quality control is a process that ensures that defects in products are inspected and subsequently verified to be within specification before they are shipped to customers. To ensure that the product remains within specification during manufacturing, Quality Control (QC) testing is performed at regular intervals during the production process. These tests are typically done by operators who extract manual samples from, in this case, a chemical reactor, and transport the samples to a QC lab where they are tested using a series of experiments with different instruments.

Once the manual testing is complete, the resulting data is sent to the plant operator controlling the manufacturing process. At this step the QC lab data is used to adjust reactor parameters to ensure the reactor contents are within specification. This is similar to how a chef samples food during the cooking process to ensure what is being cooked will turn out as intended. Below is a diagram on the traditional and inefficient process for measurements and quality control adjustments:



This entire process of transmitting data from sampled reactor contents back to the plant control room may take anywhere from thirty minutes to several hours, depending on the type(s) of test(s) being performed. Moreover, if the QC data comes back with an undesirable result, more testing must occur to verify that there is indeed a problem. This problem is intensified if a deviation occurs within the reactor during the polymerization. This can lead to further product degradation, resulting in an additional loss of time and increased energy and material consumption. Even when following the same recipe, in the same reactor, using the same materials, in the same plant, deviations can occur due to polymer reaction kinetics. These deviations can become even more costly and compounded when dealing with continuous processes at a larger scale. Imagine the force multiplication of such process inefficiencies across 10 or 20 plants and the ensuing financial implications to the business. The ramifications can be devastating.

For example, in rubber manufacturing, Mooney Viscosity is a test that is frequently performed during the manufacturing process. Plants that produce rubber use both continuous and batch processes. A common complexity in rubber manufacturing is that while different grades of rubber have different characteristics, many grades end up having similar Mooney viscosity values. This means that in order to ensure the end-product conforms to specification, not only does the Mooney viscosity have to be measured, but it is beneficial to monitor other properties, such as molecular weight or composition, to triangulate a more granular measurement of product performance.

1.3 Inefficiencies in the Process

Polymer production facilities use various instruments and techniques to generate measurements on polymer properties like viscosity and molecular weight. Currently, the most common and standard method of measurement for polymer molecular weight is Gel Permeation Chromatography (GPC). This technique includes various multi-detector schemes, 2D separations, and combinations of interactive chromatography, which must be supervised by skilled professional technicians. Even in the most basic form, GPC tests are tedious and labor-intensive, and the equipment is sensitive, requiring periodic calibration to maintain the accuracy of its measurements. Additionally, due to the different types of detection approaches, column selection, and the range of procedures, it can be challenging to replicate accurate and absolute molecular weight values with GPC.

Within a polymer production plant, reactor and operator time are valuable resources and production downtimes and inefficiencies detract from the bottom line. As previously mentioned, manual sampling and lab testing and analysis are rife with inefficiencies. Moreover, when a polymer sample is manually extracted, transported to the lab, and then analyzed, the generated data is already obsolete, since the product is still inside of the reactor "cooking."

In order to determine what is "really going on" inside a reactor, multiple tests have to be done, and the corresponding data may also need to be compared with a model. By the time a conclusion is reached, it can be up to several hours from the sampling point where the material started to deviate away from the required specification. This scenario can have heavy implications in wasted resources, energy and raw material consumption, and lower profit margins overall.

Testing methodology and consistency can also cause problems during the QC process. Different lab practices can affect the outcome of test results. Even equipment used during the QC process can cause data fluctuations and inaccuracies due to general wear and tear, lack of calibration, and disturbances in the environment, such as temperature and humidity. In addition, varying experiences and skill-sets among lab technicians may produce inconsistent results, even when using the same equipment and processes. While the data from different experimentation processes may be precise, it may not be accurate, and accuracy is key in producing high quality polymer end-products.

Operational costs can also be an issue of contention. Depending on the product and its production budget, performing regular QC testing can not only be unaffordable, but it involves safety risks. Personnel manually collecting samples from a reactor are dealing with hazardous materials, and because of this, manufacturers generally try to reduce the number of manual samples extracted. Of course, this increases the chance of product deviations and off-specification polymer products. The traditional QC process during polymer production, from the manual sampling to the array of lab measurements performed on out-of-date samples, is filled with inefficiencies.

CHAPTER TWO

THE CASE FOR REAL-TIME DATA

As discussed above, the status quo in polymer manufacturing relies extensively on analytical measurements from the lab which are always delayed, often by hours. In this section, we will illustrate the advantages of real-time data in order to fundamentally revamp and optimize polymer production processes, with positive benefits to the business' bottom line.

2.1 Industry 4.0 and the Need to Stay Competitive

Staying competitive in a global marketplace requires a focus on continuous improvements as a core goal of a company's business strategy. This is especially true in manufacturing, where domestic companies must compete with those in other countries to operate and produce the same or similar products at a comparable price. Companies in other countries often have an advantage due to less government restrictions, regulations, and lower valued currencies.

Polymer manufacturers seek to produce quality products at the lowest cost to maximize profits. This is a fine line that businesses must balance, but achieving this harmony requires a deep focus on process optimization to extract as much value from existing assets as possible. Today, companies are also looking for ways not only to reduce waste, but to also lower their overall environmental footprint.

When competing globally, companies cannot just be innovative. They must also operate efficiently. Applying new, innovative technologies is a great start, but such improvements will have little impact if they are applied to an inefficient process. New methods and technologies must also be leveraged to drive process optimization. Breakthrough technologies and new manufacturing methods helped drive advancements during the Industrial Revolution; however, a focus on production efficiency is absolutely essential to remain relevant and thrive in today's global marketplace.

When computers were introduced and integrated into manufacturing in the 1970s, they ushered in the Third Industrial Revolution. Not only did computers provide new ways of controlling and managing manufacturing, but they delivered more efficient methods to automate processes through the application of electrical engineering and information technology. As time went on, the Internet, and in particular, the Industrial Internet of Things (IIoT), also helped improve upon automated assets, systems, and processes.

Currently, roughly 80% of polymer manufacturers use some combination of manual, semi-automated, and automated processes and assets for their day-to-day operations. While one might initially assume the remaining 20% are further behind than the 80%, it is actually the opposite. While most manufacturers are deriving some benefits from industrial automation, only about 20% of the current polymer manufacturing industry has begun to actively explore and implement the next level of industry autonomy.

Where Industry 3.0 introduced computers to manufacturing, Industry 4.0 seeks to optimize their use by merging Information Technology (IT) with Operational and Engineering Technology (OT and ET, respectively). This fusion of technologies and methodologies facilitates a new frontier of smart manufacturing capabilities with data and processes that can elevate manufacturing execution to entirely new levels.

Industry 4.0 is also enabling digital transformation to occur in manufacturing. Here, workplace knowledge and information is not only being digitized, but it is also streamlined and retooled in a bid to help create more efficient processes, while at the same time making the data available to the right people, at the right time, to make the best strategic decisions.

This is done by leveraging advanced technology such as Artificial Intelligence (AI), neural networks, machine learning, and cloud computing, and in tandem deploying assets equipped with remote sensors and advanced functions that provide real-time telemetry to create maximum visibility into the processes. What gets measured, gets managed and improved.

However, ascending to Industry 4.0 does not end with smart manufacturing. By further leveraging new technology and real-time data, these same smart assets can be further enhanced to become semi or even fully autonomous. While Industry 4.0 is not yet focused on an autonomous industry, it is only a matter of time before industry autonomy becomes a necessity and the normal modus operandi. In the case of the 80% of manufacturers firmly stuck in the category of traditional industrial automation, it is believed that they will need to reach some level of industrial autonomy within the next decade to remain competitive in the global marketplace.

2.2 The Benefits of Smart Monitoring in the Polymer Industry

Applying smart manufacturing processes and assets to polymer production can have a huge impact on productivity and efficiency. In particular, the ability to monitor polymerization reactions in real time can lead to several key benefits:

- Reduction in product cycle times: Real-time monitoring of the polymerization process can be used to predict the trajectory of a reaction and signal when that process is complete. This is achieved by using predetermined criteria such as a target molecular weight, intrinsic viscosity, or residual PPM (parts per million) of a monomer. Because most legacy processes are not optimized, they tend to run longer than necessary. Actively monitoring a process in real time, and ending it once the desired target specifications are met, can improve efficiency and production capacity.

- Improve quality and consistency: Smart monitoring of a reactor does not just improve cycle time. Knowing when a targeted property is achieved in real time can also improve product quality and consistency. If the production process of a material ends too early, it could lead to an inferior or off-specification product. Furthermore, if the process runs longer than required, it could stress the product and lead to degradation. Ending the production process once the desired product specifications are met is crucial to consistently generating quality materials.

- Real-time corrections: As explained in the previous chapter, the current QC process in polymer manufacturing is very labor intensive and inefficient. Conversely, real-time monitoring of polymerization reactions can not only show when the product is starting to deviate from its desired specification, but it can also be used to detect kinetic anomalies, such as the onset of micro-gelation. Through the use of real-time data, such process anomalies can be mitigated or corrected before they intensify and lead to the waste of time, materials, and other resources.

- Optimization through real-time data: The real-time monitoring of a reaction provides a never-before-seen veritable treasure trove of data. This data can not only help ensure that the polymerization reaction finishes successfully, but it can also be used to optimize the production process. Since most legacy processes and recipes are not fully optimized, using real-time data can further improve the process, potentially increasing yields or reducing the consumption of raw materials.

- Improved safety: Current analytical QC methods mostly require manual sampling, where operators draw samples directly from the reactor. Real-time monitoring makes the sampling process autonomous, eliminating the need for operator intervention. Limiting the amount of direct interactions between operators and the reactor can help prevent potential mishaps, thus improving safety at the plant level.

2.3 The Need for Real-Time Data

Real-time data is key to enabling not just autonomous manufacturing, but also smart manufacturing. The more data a control system's operator has available, the more likely the operator will make more accurate decisions faster. Real-time data can also help prevent problems from occurring by correcting or stopping them as soon as anomalies are detected. Even when a plant is manually operated, real-time data can still help to make more accurate decisions and prevent problems, thus ensuring an optimal product is manufactured.

Real-time data can also be used in the development of new products. The ability to observe a reaction from start to finish can accelerate product development by reducing the number of experiments necessary to create the product.

With all the benefits associated with real-time data, the question remains: How does one get that real-time data?

The application of smart manufacturing technologies and processes to polymer production has not been lagging behind because of a lack of desire to innovate. Rather, the polymer industry faces unique difficulties and challenges not present in the production of small molecules. Aside from the inherent difficulties of polymer characterization, many materials are optically turbid as they are processed. This turbidity means that many process streams require special attention to perform effective analyses and testing. Moreover, the environment within a reactor is harsh and can damage optical probes and sensors, and the fouling of these sensors can cause serious data deviations.

Despite these challenges, there has been a push to develop and use in-situ sensors in polymer manufacturing. Among these, Raman, infrared spectroscopy, and rheological technique-based probes have had limited success in acquiring real-time data measurements. More often, data provided by temperature and pressure sensors is interpreted through the use of modeling. While modeling will continue to have an important role in polymer manufacturing, it does not equate to the kind of real-time monitoring that is necessary to drive smart manufacturing.

Previously, the missing piece was a unique and innovative method of generating and collecting real-time data from a reactor. There was a need to provide accurate and quality measurements in real time, while also analyzing key characteristics of a material or a reaction directly. That missing link was ACOMP, a smart manufacturing system for the continuous online monitoring of polymerization reactions.

CHAPTER THREE

ABOUT FLUENCE ANALYTICS

Fluence Analytics, formerly known as Advanced Polymer Monitoring Technologies (APMT), was founded in 2012 to commercialize technologies invented at Tulane University's PolyRMC, an R&D center active in fundamental and applied synthetic and biological polymer research. Fluence Analytics is a venture backed startup, and current investors include Energy Innovation Capital, Diamond Edge Ventures (a subsidiary of Mitsubishi Chemical Holdings), JSR Corporation, and Yokogawa Electric Corporation. The company's goal is to provide IIoT hardware, software, and data products for the chemical and biopharma industries.

3.1: Company History

The history of Fluence Analytics dates back to the 1980s, when Wayne Reed, a Professor of Physics at Tulane University and Co-founder of Fluence Analytics, began using light scattering to characterize macromolecules. In 1997 he filed his first patent application for a novel light scattering device, followed in 1999 by an application for the automatic monitoring of polymerization reactions.

After decades of research, Professor Reed founded the Tulane Center for Polymer Reaction Monitoring and Characterization (PolyRMC) in 2007 to advance research and development in polymerization reaction monitoring. Five years later, Professor Reed, Alex Reed, and Michael Drenski began exploring the idea of commercializing PolyRMC's patented technologies. Alex (founding CEO) and Michael (founding CTO) worked at PolyRMC and eventually became Professor Reed's (founding CSO) co-founders at APMT. The final co-founder was Dr. Bill Bottoms (founding Executive Chairman), a PolyRMC advisory board member and a seasoned technology executive and investor based in Silicon Valley.

Shortly after APMT's creation, the company began working on a joint development project with Nalco and launched the first-generation ACOMP in 2014. In parallel, APMT secured SBIR funding to develop the ARGEN product line, a laboratory instrument that accelerates the development of biopharmaceuticals and other biomolecules. During 2016 the company released a second-generation ACOMP, and it delivered an ARGEN instrument to Professor Christopher Roberts, a leading expert in biopharmaceutical characterization, of the University of Delaware.

In 2017 the Company rebranded to Fluence Analytics, announced a Series A funding round, officially launched ARGEN, and released a third-generation ACOMP. In the following years, the company has added more institutional investors; launched a low temperature ARGEN system; announced Jay Manouchehri, an experienced digital transformation executive, as the new CEO; and delivered multiple ACOMP and ARGEN systems to customers throughout the world. In 2021 Fluence Analytics moved its headquarters from New Orleans to Houston, TX.

3.2: The Mission of Fluence Analytics

The mission of Fluence Analytics is to transform the polymer and biopharmaceutical materials industries by producing patented measurement and analytics technologies delivering novel data sets to manufacturers and researchers worldwide.

3.3: Company Values

INNOVATION — Pushing the boundaries of what's possible, one dataset at a time.

QUALITY — Striving to deliver the best quality of products and data to customers.

RELIABILITY — Providing customers with reliable systems that generate accurate data.

INSIGHT — Delivering realtime, novel insights that transform customer processes.

INTEGRITY — Committed to honesty and empiricism in our customer relationships.

CHAPTER FOUR

THE ACOMP PLATFORM

Automatic Continuous Online Monitoring of Polymerizations (ACOMP) by Fluence Analytics is designed to optimize polymer manufacturing by enabling the use of smart manufacturing technology in the polymer industry. It does this by providing a steady stream of real-time data via a continuous sampling and measurement process of the reactor contents, yielding never-before-seen process insights that enhance efficiency. Since ACOMP is a connected smart system, it is easily integrated into a plant's distributed control system (DCS). This integration allows engineers and other plant personnel to access data on the polymer's properties and the production process throughout the entire reaction.

4.1: How It Works

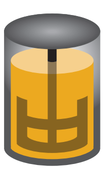
ACOMP is a real-time measurement tool for polymer reactors that helps chemical companies increase profits and quality while reducing costs and waste. Unlike the industry standard of manual QC and lab testing of a single datapoint, ACOMP can standardize and optimize chemical reactions with new data sets.

ACOMP continuously extracts material from polymer reactors via a tie-in point in a continuous flow or from a fast loop. Once the polymer is inside the ACOMP, the material continuously flows through the system and undergoes a series of dilutions and possible conditioning steps. The dilutions are performed with a liquid solvent in which the analyzed polymer is soluble, typically an aqueous or organic solvent readily found at the industrial site. The dilution rates are typically 10-100x at each dilution stage, and this depends on the reactor concentration, size of the polymer, and other factors required to achieve an appropriate measurement in the detectors. The subsequent conditioning steps can include filtration, volatilization of monomers, inversion of emulsion phases by surfactants, and other changes of solution conditions. Once the polymer sample stream is diluted, it flows through ACOMP's detector train.

ACOMP is controlled by a programmable logic controller (PLC) via a series of operating modes, typically automated based on condition alerts from the customer's process. In addition to the main data collection, analysis, and control mode, other modes include clean cycles, solvent baseline, monomer baseline, and end reaction cycles for batch processes. Additionally, the PLC is the primary driver for data acquisition from all of the detectors, as well as a number of smart sensors placed throughout the system to assess performance and health. Finally, ACOMP has analysis software that processes all data and performs proprietary calculations to output measurement values from ACOMP. These measurement values are the core outputs to customers.

SAMPLING TECH

Continuously extracts, dilutes and conditions a viscous liquid stream from the reactor



DETECTORS

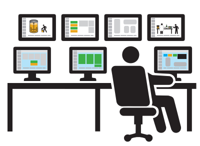
Conditioned stream passes through the detectors

ANALYSIS SOFTWARE

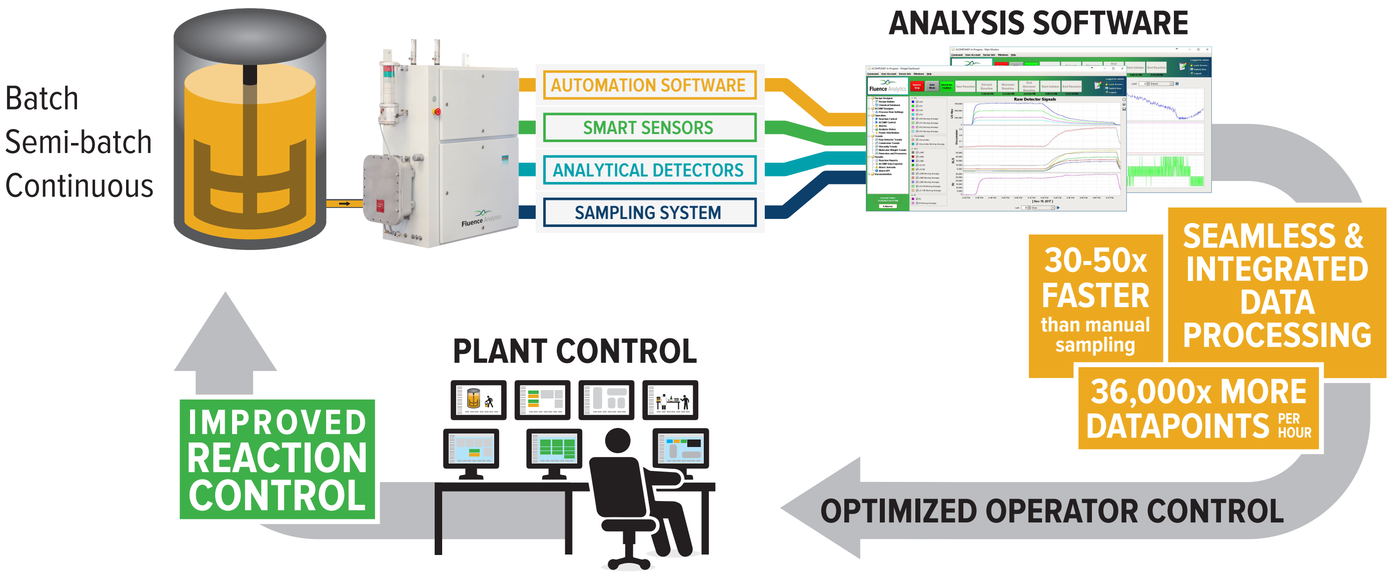
Proprietary analysis algorithms output key parameters for optimization

CONTROL

Operator is enabled to optimize process control, reduce cycle times, improve yield and consistency with the data provided by ACOMP



Overview of the ACOMP Process



4.1.1: The ACOMP Front End

ACOMP extracts, dilutes and measures a very small, representative sample stream of reactor contents at an approximate rate of roughly 0.1 to 2 ml/min, depending on the size of the reactor. The time between the drawing of the sample and the completion of the analysis typically ranges from 30-500 seconds. Once a sample stream is withdrawn from the reactor, the analysis process begins in ACOMP's front end, which consists of a set of pumps, mixing chambers, and conditioning elements that are used to dilute the polymer sample for analysis through the detector train. This is designed to work with virtually any type of liquid phase polymerization, making it highly versatile.

Depending on the type of material, the sample stream can go through a single or multiple mixing stages. The solvent used is specific to the reaction being monitored and ideally is a solvent used in the actual process, such as THF (tetrahydrofuran) or styrene. The sample stream is also subject to filtration, degassing, phase inversion, or stripping to make sure a conditioned sample passes through the detector train. This ensures that accurate measurements are produced.

Since ACOMP's front-end uses an automatic liquid-to-liquid preparation method, the dilution of the sample stream occurs quickly. The front end uses multiple identical flow and filtration paths, each regulated by one or more pressure transducers to help minimize clogging. Moreover, because ACOMP is intended to run 24/7, the system is engineered to perform self-cleaning and only requires periodic preventative maintenance to ensure consistent operations.

4.1.2: The Detector Train

Once the sample stream is diluted and conditioned, it flows through ACOMP's detector train. The standard ACOMP detectors include a Multi-angle Static Light Scattering (MALS) detector, low shear viscometer, high shear viscometer, UV and visible absorption detector (UV/Vis), and Differential Refractive Index detector (DRI). Combined, these detectors can monitor the following characteristics:

- Molecular Weight
- Intrinsic Viscosity
- Composition
- Monomer Conversion
- Residual Monomer PPM
- Polymer Concentration
- Process Anomaly Detection

The detector train for a particular ACOMP system is customized and built based on customer requirements and the characteristics ACOMP will monitor. Research is currently underway to test, evaluate, and ultimately add new detectors to ACOMP that will enhance functionality and the range of measurements generated by the smart system. Some of these include dynamic light scattering and mid and near-infrared spectroscopy. Please see section 4.2.5 for a full list of these detectors.

Although ACOMP does not inherently use chromatographic methods to analyze polymer samples, the sample stream that enters the detector train has roughly the same dilution levels as those used by GPC. Thus, it is possible to attach a GPC system with an automatic injector valve to the ACOMP platform, and use the ACOMP outlet stream to directly run GPC measurements. This enables the combined use of continuous detection and intermittent, chromatographic detection.

4.1.3: Data Analysis

Once the raw data signals are relayed by the detector train, proprietary algorithms enable ACOMP's software to analyze the data and generate the desired reaction parameters. These outputs can then be sent to the plant's control room and other systems via an OPC.

By providing real-time data on important polymer properties, ACOMP can also detect process anomalies as they occur. This provides plant operators and personeel in the control room with unprecedented insights to make adjustments to process parameters, ensuring the process is optimized while also eliminating the production of off-specification materials and gelation. Furthermore, ACOMP's predictive data analytics can also look at historical datasets and predict the time to completion for a polymer reaction if this is required.

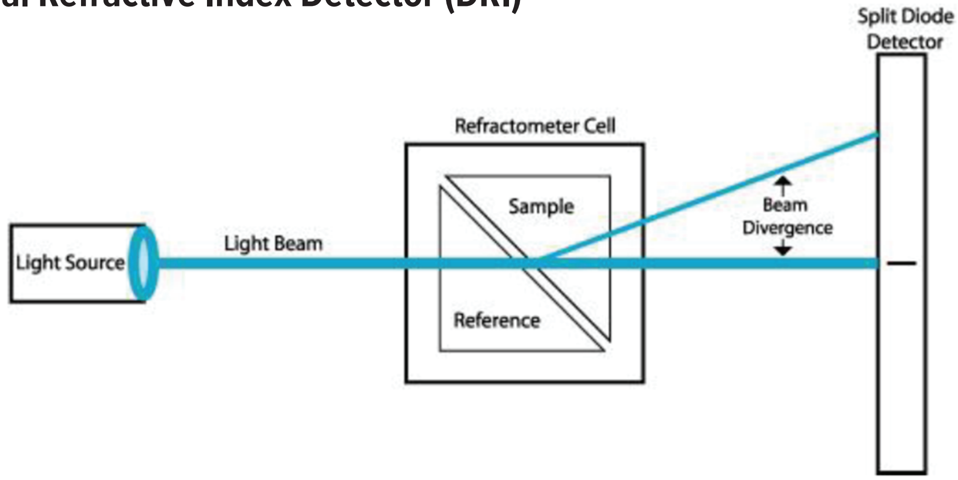
ACOMP's software automatically generates reports, including data analytics, historical trends, and correlations with other process data. Additionally, the software can create customized business and technical reports and distribute them via email or any other method a customer already has in place.

4.2: Detectors

ACOMP's customizable detector train consists of four standard modules – a Differential Refractive Index (DRI) detector, an Ultraviolet Absorption (UV) detector, a Dilute Solution Viscometer (Visc), and a Multi Angle Light Scattering (MALS) detector. These core detectors are constantly upgraded, in tandem with R&D activity to incorporate new detectors into future ACOMP versions. The new detectors will augment ACOMP's real-time monitoring and detection capabilities across a growing spectrum of polymer chemistries.

This section details a list of ACOMP's standard and optional detectors, as well as a brief description for each.

4.2.1: Differential Refractive Index Detector (DRI)

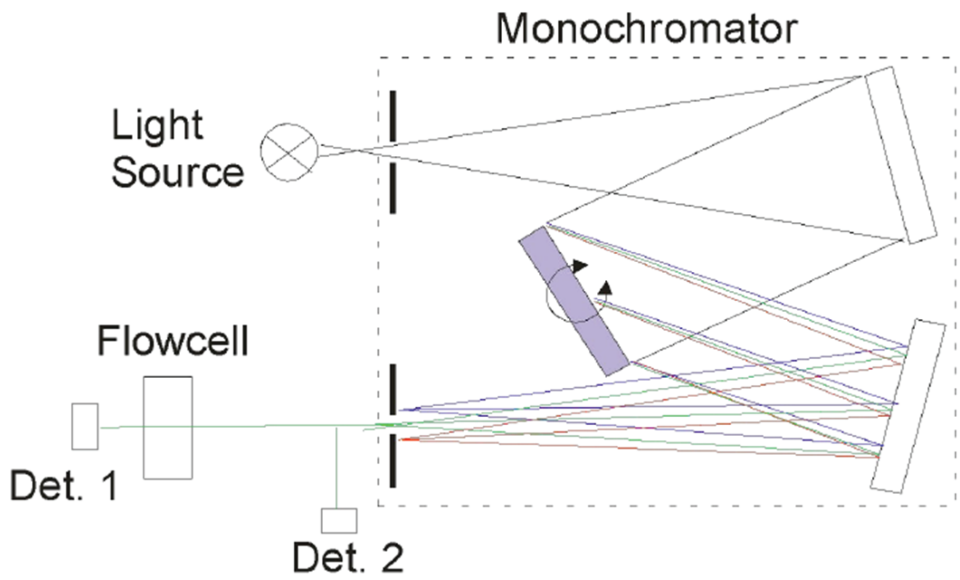


The DRI is a concentration detector that measures the differential change of the material's index of refraction with the concentration of polymer. As the polymer is formed, the detector tracks its concentration change by shining a light on the sample, and measuring the resulting refractive index signal. This value, along with the base values of the solvent and monomer, the dilution factors, and the differential refractive index (dn/dc of the monomer and polymer), is used to calculate the polymer concentration in real time. The polymer concentration can also be calculated via mass balance from the monomer concentration, typically obtained from the UV detector as described below. From either the monomer concentration or the polymer concentration, the monomer conversion can be determined.

Refractive index monitoring is highly sensitive to the polymerization process. In particular, it can deliver measurements during the early stages of a polymerization, whereas other variables such as reduced viscosity only start to significantly change at higher polymer concentrations.

4.2.2: Ultraviolet Absorption Detector (UV)

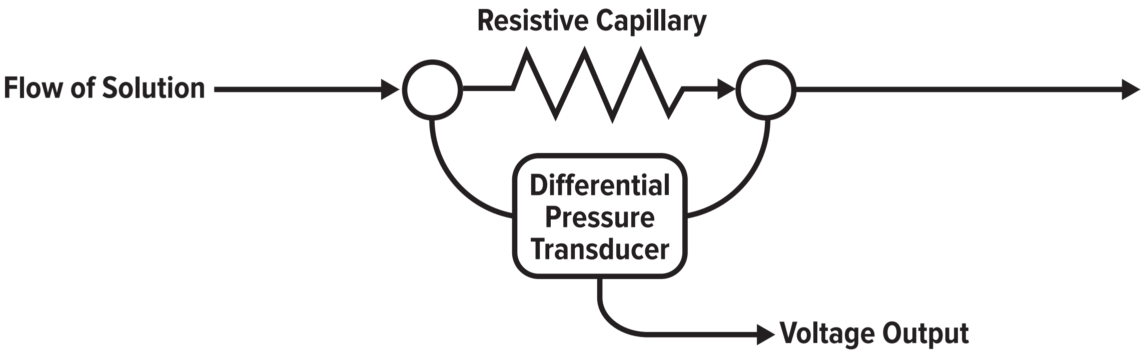
The UV detector uses ultraviolet light to measure monomer concentration. Monomers with an unsaturated double-bond often have a measurable UV absorption spectrum in the 200-300 nm range. The amount of light absorbed by a given monomer can be characterized by its extinction coefficient. Because UV absorbance declines significantly when the monomer converts into a polymer, its disappearance is often a robust means of detecting conversion.



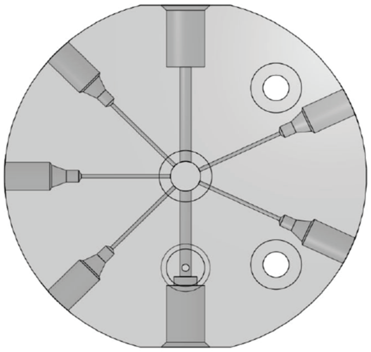
The UV detector works by passing a polychromatic light source through a diffraction grating, which splits the light into different wavelengths. These individual wavelengths are then directed through a flow cell that contains the diluted stream of polymeric material, where the light passing through the detector is translated to a difference between the sample absorption versus the baseline absorption. This data is used to determine the extinction coefficient of the passing material, which is then used to calculate the prevailing monomer concentration in the polymerization process at that time. If there are multiple monomers, it is generally necessary to quantify each monomer separately using different absorption peaks.

4.2.3: Dilute Solution Viscometer (Visc)

The Visc detector is a single capillary viscometer with a differential pressure transducer installed across a capillary cell. It measures the pressure drop across the capillary as the flow is held constant. This data can be used to calculate the viscosity via the well-known Poiseuille's Law. At the sufficiently low concentrations that are used in ACOMP detection, the equation yields the viscosity of the diluted polymer molecules in solution, which is very different from the bulk viscosity of the product in the reactor. This intrinsic viscosity is a property of the specific polymer freed from intermolecular interaction effects.



4.2.4: Multi Angle Light Scattering Detector (MALS)



The MALS detector uses a 5-angle static light scattering flow cell. A vertically polarized laser beam is directed down the path of the flow cell in which the electromagnetic radiation induces the scattered light that is detected. The detector records the intensity of the scattered light from each angle which is then interpreted as the Rayleigh Scattering intensity and used according to the Zimm equation to generate a Zimm plot. The extrapolation of the Zimm plot to zero concentration and zero angle allows the ACOMP to determine the absolute weight-average molecular weight (Mw) and also the radius of gyration (Rg), which is often correlated with the polymer's hydrodynamic volume.

The Fluence Analytics MALS detector was developed specifically for the ACOMP platform, but it works similarly to light scattering sensors in GPC systems. However, Fluence's proprietary detector is designed to operate at higher flow rates and pressures, thus it is more durable and less likely to foul.

4.2.5: Non-Standard Detectors

The following is a shortlist of detectors that are currently in the development phase. Unlike ACOMP's standard detectors these are case specific, applicable to certain polymer chemistries and processes. Internal R&D and customer collaborations have resulted in further development of the detectors listed below for the purpose of incorporating them into future ACOMP versions. The addition of these new detectors will broaden the range of polymer chemistries and processes that are compatible with ACOMP.

- **pH:** This detector makes real-time measurements of reaction parameters that are sensitive to pH and can also show how pH correlates with molecular weight, reaction ratios, viscosity, and conversion.

- **Conductivity:** The conductivity detector provides real-time monitoring of polymer charge density in polyelectrolytes.

- **Polarimetry:** This detector can help determine the amount of a product that goes to waste by monitoring carbohydrates and polysaccharide concentrations as a byproduct or production waste.

- **Particle Size (Mie Scattering):** This detector determines the size of a droplet or the particle size in emulsion and inverse emulsion polymerizations either in real-time or through discrete auto sampling.

- **Fourier Transform Infrared (FTIR) and Near Infrared Spectroscopy (NIR):** In addition to RI and UV detection, Fluence Analytics is also working to incorporate infrared detectors that can monitor reactivity, composition, distribution, branching, and physical and chemical parameters.

CHAPTER FIVE

THE VALUE OF ACOMP

ACOMP's real-time data can lead to numerous benefits in polymer manufacturing, including reduced product cycle times, operational costs, and energy and raw material consumption, improved quality and consistency, and increased safety and risk mitigation. ACOMP helps deliver maximum optimization in manufacturing processes, and customers have even derived a full return on their investment within the first year of using the smart system.

5.1: How ACOMP Can Benefit Polymer Manufacturing and the Bottom Line

As described in previous chapters, ACOMP's real-time data not only provides telemetry during polymerization reactions for molecular weight, viscosity, composition, and monomer conversion, but the analysis software can also detect anomalies during the polymerization process. Since the real-time data and its output are tailored to meet a customer's preferences and requirements, one does not need a PhD in to read and interpret the data. ACOMP not only helps to mitigate process upsets but can also be used to free up capacity by reducing batch cycle time.

The standard operating procedure for many polymer recipes takes a conservative approach to the "cook time" to ensure the resulting polymer batch is within specification. This means that polymer batches often cook longer than necessary. ACOMP's real-time data enables the determination of the optimal product manufacturing time so the polymer product can be moved from the reactor with greater precision, leading to consistent product quality. This is one way that ACOMP can help reduce the cycle time and increase the production capacity of a polymer reactor. Furthermore, ACOMP can decrease the level of stress applied to a product during the polymerization, mitigating or eliminating product degradation, off-specification materials, and ultimately lost revenue.

In summary, active, real-time monitoring of a polymer reactor can help improve product quality and consistency. These new insights allow reactor operators to adjust process parameters with much more granularity, helping to ensure the end-product is within specification. Making decisions based on real-time data also mitigates the chances of anomalies occurring which can lead to gelation or the creation of dead stock material.

While ACOMP's data can be analyzed post-production to help optimize recipes and improve process control, its benefits are not isolated to production efforts. The smart system can also help in the development of new products by increasing efficiency and providing real-time insights that can also be used in data modeling.

5.1.1: ACOMP With Batch and Semi-Batch Processing

As highlighted throughout this eBook, ACOMP's ability to monitor polymer reactions as they occur allows for the reduction of cycle times by providing real-time insights that help determine the optimal endpoint for a process. Some ACOMP customers have used the system's real-time analytics to predict the endpoint of a batch either from achieving a target viscosity, a residual monomer specification, or a molecular weight specification in a step growth (polycondensation) reaction. Others have used ACOMP in multi-step reactions to determine when to initiate the optimal next phase of the reaction, such as a coupling step or adding a secondary catalyst, initiator feed, or a monomer feed. Using ACOMP to optimize monomer feeds can also yield an ideal trajectory for composition and Mw in semi-batch processes.

For example, a 15kt plant with an average annual sales volume of $40 million could potentially see an increase of up to $1 million in revenue from the reduction of product cycle times and increased production capacity. The real-time data from ACOMP can also help improve the quality control aspects of a batch or semi-batch process by identifying abnormalities as they occur. This not only saves time and rework, but also helps to maintain superior product quality. Moreover, by using ACOMP to optimize process control in batch and semi-batch processing, the quantity of material used can be reduced, potentially resulting in less wasted materials per batch.

5.1.2: ACOMP with Continuous Processing

In addition to batch and semi-batch production, many of the same optimization benefits provided by ACOMP can be applied to continuous production efforts as well. For continuous processes, ACOMP is particularly useful in minimizing off-specification materials during grade changes and steady state operations. Many of the steps taken during continuous processes are directly tied to knowledge that customers have of their chemistry, and with ACOMP's real-time data, customers can continue to learn and optimize production efforts.

To illustrate an example during a continuous process, a 60kt plant averaging a $150 million in annual sales could see savings up to $1m or more just by reducing the amount of off-specification material produced by only a few percent. This reduction in off-specification material can also lead to further savings in energy and material consumption used to repurpose the bad material.

5.1.3: ACOMP in a Laboratory Environment

While the Industrial ACOMP can provide numerous benefits in a production setting, its benefits can also translate into R&D labs. Lab ACOMP by Fluence Analytics can improve scale-up efforts, help create next-generation smart materials, and optimize existing processes at the bench and pilot plant scale.

Lab ACOMP is small enough to fit inside a typical laboratory hood and can be coupled with a reactor and even a control system to enhance functionality. Since Lab ACOMP is intended for polymer monitoring at the bench and pilot scale, the platform can be set up to run multiple chemistries and applications. This allows a single lab technician to monitor multiple reactors and polymer processes with little modification. Lab ACOMP can also be integrated with most standard laboratory control interfaces and other instruments like GPC and pilot reactors.

In addition to the typical benefits resulting from real-time monitoring capabilities, Lab ACOMP provides a number of other advantages. These include helping to build target molecules through the sequential addition of monomers and catalysts and helping to synthesize complex molecules. Lab ACOMP can also be used to stop polymerization reactions once targets are achieved, such as specific conversion points or residual monomer levels.

Many Lab ACOMP customers use the system's real-time kinetic insights for data modeling purposes to better control process parameters. Unlike Industrial ACOMP, Lab ACOMP is specifically designed for R&D scientists and can be customized to specific applications. This combination of control and real-time data can greatly improve laboratory efficiency by reducing the number of experiments needed to attain desired results.

Since Lab ACOMP samples directly from the reactor, worker safety is significantly improved and is considered by most customers as an added benefit. Furthermore, Lab ACOMP's control system can terminate dangerous and potentially toxic reactions remotely, while even automatically stopping runaway reactions if they exceed safety thresholds.

Lab ACOMP system

CHAPTER SIX

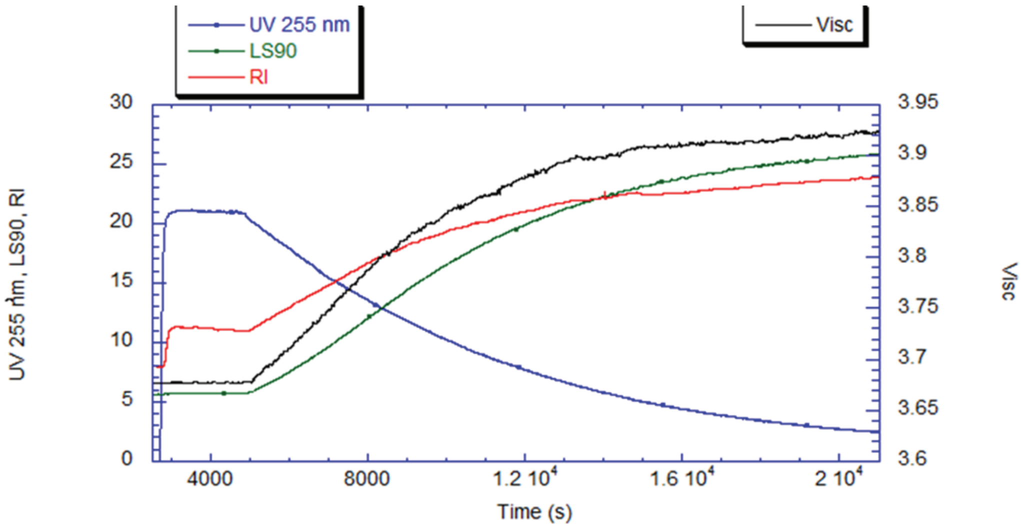
CASE STUDIES

As demonstrated thus far, ACOMP's capabilities are extensive, and its potential to change the way polymers are manufactured is profound. The following is a series of abbreviated technical notes that show ACOMP's true capacity to transform polymer development and production. At the end of each technical note is a link to access the full article.

6.1: Monitoring the Polymerization of Polymethylmethacrylate (PMMA) in the Presence and Absence of a Crosslinking Agent

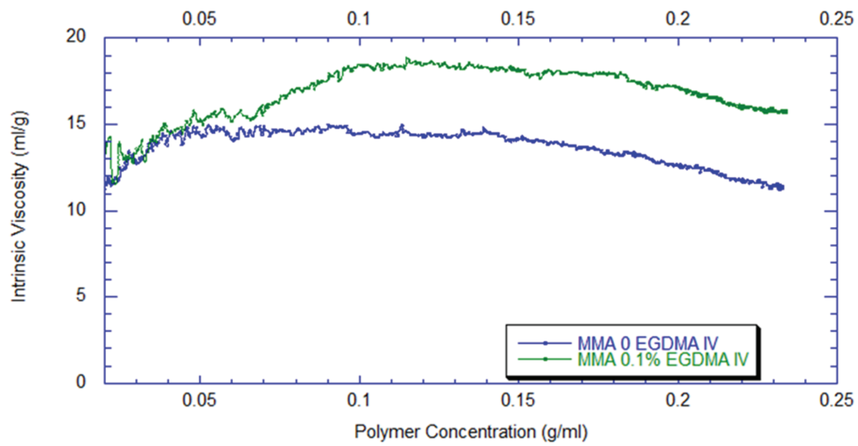
A highly transparent and durable polymer, Polymethylmethacrylate (PMMA), is used as a lighter and more impact resistant alternative to glass. PMMA is used in various applications, including shatter-resistant panels for windows, bathtubs, LCD screens, coatings, and various medical and dental applications. Crosslinking PMMA with other compounds (ethylene glycol dimethacrylate in this example) can create a more ductile polymer with a higher glass transition temperature, which is a desirable trait for certain applications.

In this application, ACOMP was used to monitor the polymerization of methyl methacrylate (MMA), both with and without a crosslinker added to the reactor. The ACOMP detectors used to monitor this reaction were multi angle light scattering (MALS), UV, differential refractive index (DRI), and a viscometer.

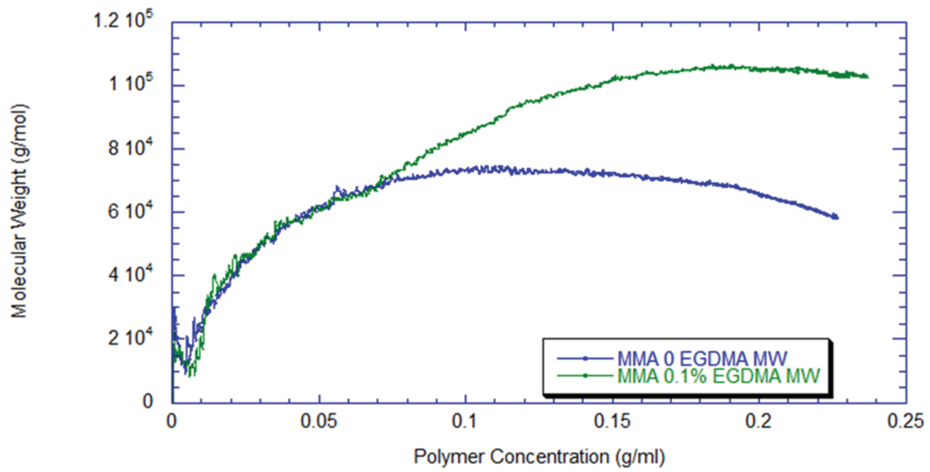


The image above shows raw ACOMP data that was generated during the polymerization. As the reaction progresses, the UV, highlighted in blue, decreases as the monomers polymerize, while the light scattering and viscosity values (green and black respectively) increase due to increases in molecular weight and polymer concentration. Meanwhile, as the polymer count increases and monomer levels decrease, the refractive index (red) increases.

The next image shows the intrinsic viscosity versus the polymer concentration of both experiments. This first batch (Blue) is a 30% Methyl Methacrylate by mass of total monomer and 70% butyl acetate. The second batch (green) held the same amount of butyl acetate, but it had 29.9% methyl methacrylate and 0.1% of the crosslinker Ethylene Glycol Dimethacrylate. Somewhat counterintuitively, for both reactions the intrinsic viscosity goes through a broad plateau and starts to decrease as higher values of polymer concentration are reached (in terms of time, this occurs roughly three hours into the polymerization).



This final graph shows that in the absence of crosslinker, Mw also plateaus and turns down at the same time as the viscosity. However, with the crosslinker present, the Mw continues to increase over the next few hours before plateauing at a higher level. At the end of the experiment, batch one has a final molecular weight of 62,300 g/mol, while batch two has a molecular weight of 102,400 g/mol.



This summation clearly shows that ACOMP can easily monitor the free radical solution polymerization of methyl methacrylate, yielding quantitative results for conversion and other polymer properties. In particular, intrinsic viscosity and molecular weight, important fundamental polymer properties that determine final end-use characteristics, are measured in real time.

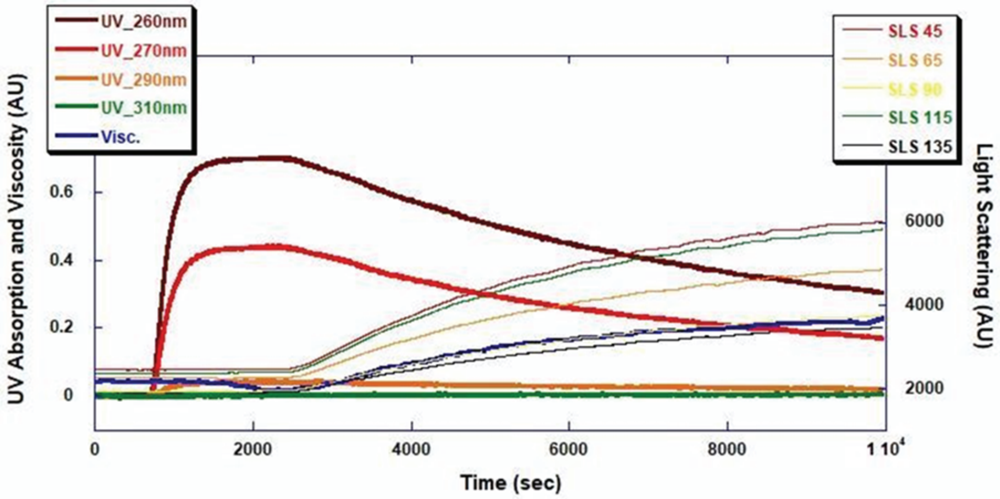
Please click on **this link** to view the full version of the PMMA technical note.

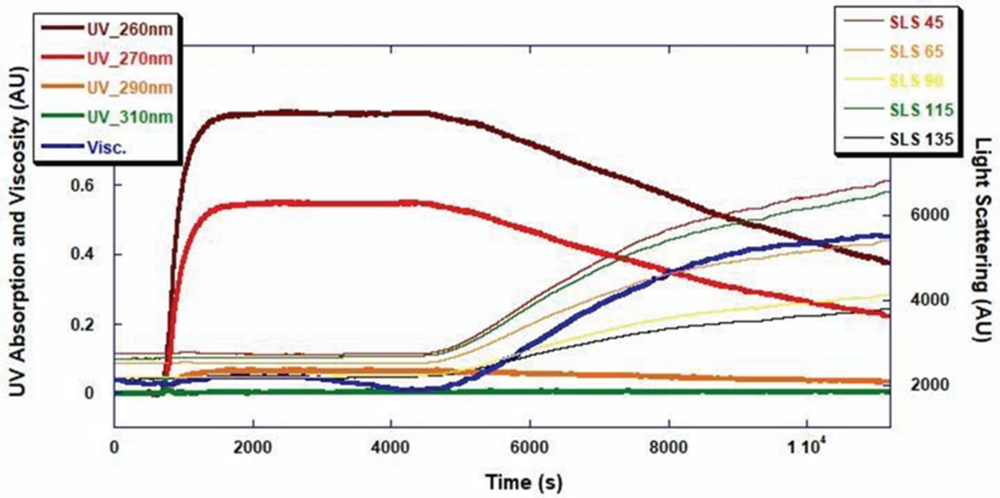
6.2: Using ACOMP to Monitor Acrylate-based Polymerizations in Pressure-sensitive Adhesive Formulations

Pressure-sensitive adhesives (PSAs) are critical in the construction, food packaging, electronics and medical industries, and the segment is expected to grow by 6% by 2030. PSA manufacturers continue efforts to commercialize materials that meet stringent customer requirements in existing and new applications.

The key use properties of a PSA are tack (stickiness), peel strength (adhesion), and shear strength (cohesion). These properties are strongly influenced by fundamental polymer properties like molecular weight (Mw) and intrinsic viscosity (IV). In order to tailor the physical properties of a PSA, various blends of reactant monomers such as acrylic acid (AA) and 2-ethylhexyl acrylate (2EHA) are used.

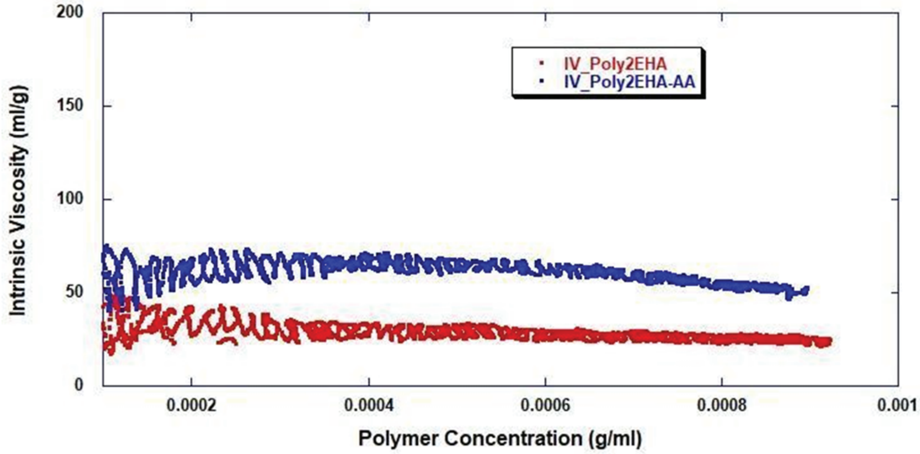
This technical note describes how ACOMP was used to monitor the synthesis of Poly2EHA and Poly2EHA-AA. Batch one, Poly2EHA, contained ethyl acetate as the solvent (277.6 ml) and 2-ethylhexyl acrylate (83.21 ml). Batch two, the Poly2EHA-AA, contained the same amount of solvent but had 76.88 ml of 2-Ethylhexyl Acrylate and 5.6 ml of Acrylic Acid. The reactor contents were purged with nitrogen for one hour prior to the start of the polymerization.



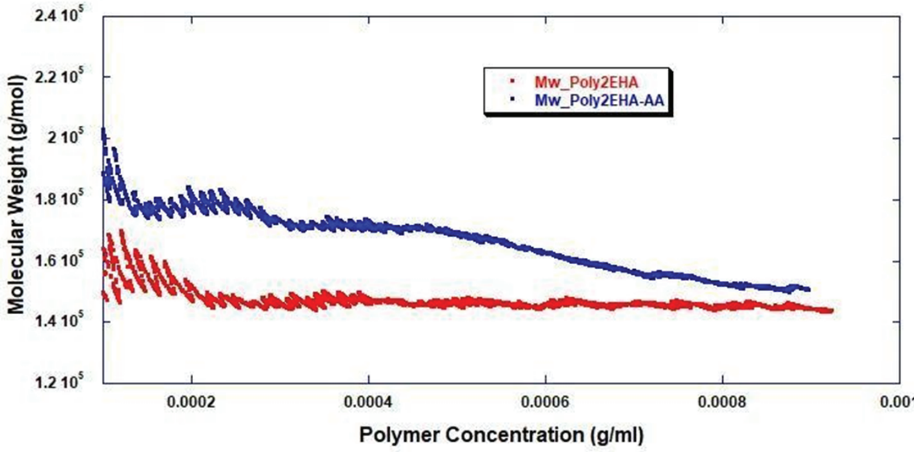


The previous two graphs show ACOMP's raw data from monitoring both batches. The first graph exhibits the 2EHA batch polymerization, and the second is the copolymerization of 2EHA and AA. They show the UV absorption at 260, 270, 290, and 310 nm, as well as the intrinsic viscosity in the thicker colored lines. The thinner colored lines show the data from each of the five angles used by the MALS detector, specifically at 45, 65, 90, 115, and 135 degrees. The difference between the Poly2EHA and Poly2EHA-AA is captured right away.

The graph below shows the intrinsic viscosity versus polymer concentration during both polymerizations. The Poly2EHA (Red) had a final IV of 24 ml/g, while the Poly2EHA-AA (Blue) had a final IV of 51 ml/g.



The graph highlighting the molecular weight versus polymer concentration shows the Mw trajectory from the start to the end of both reactions. The Poly2EHA had a final molecular weight of 146,000 g/mol, and the Poly2EHA-AA had a final molecular weight of 151,200 g/mol. This shows that while the addition of AA to Poly2EHA does not drastically affect molecular weight, it does have a significant impact on intrinsic viscosity, which rose by 112% due to an increase in hydrodynamic volume.



Beyond using ACOMP to monitor these polymerizations in real time, a GPC system was also used to measure the characteristics of both end products in this application.

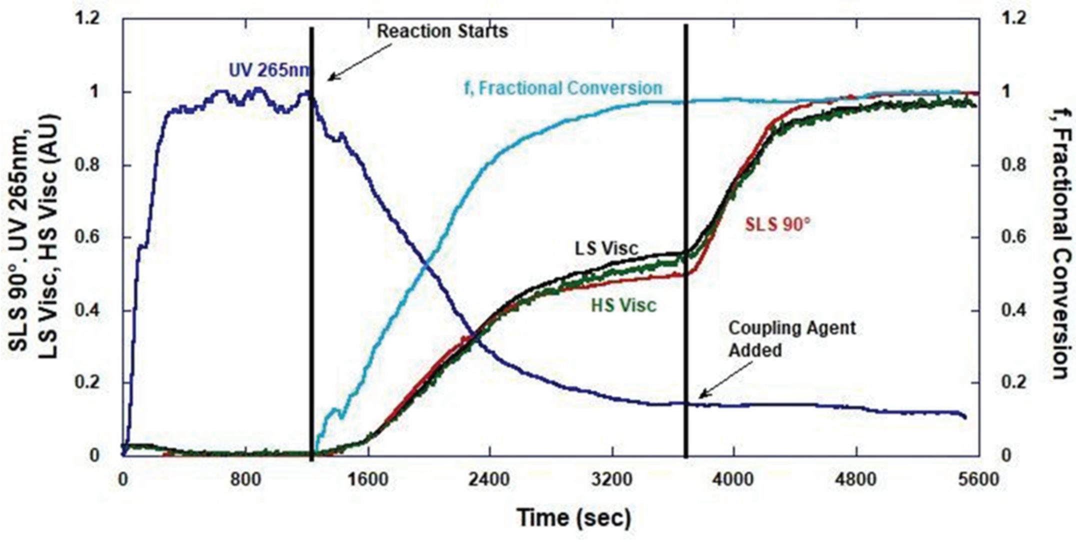
The results of the GPC analysis for the Poly2EHA reaction was very close to the ACOMP measurement, showing a molecular weight of 153,474 g/mol. The Poly2EHA-AA however, had a molecular weight of 259,081 g/mol, a significant increase compared to ACOMP's results. This is due to the early incorporation of AA to the Poly2EHA which increased the hydrodynamic volume of the molecules in a dilute state, causing a higher Mw result from GPC. It should be noted that ACOMP's measurement is an absolute molecular weight based on physical theory, whereas GPC's molecular weight measurement is inherently based on the calibration standard of a sample's elution through a gel column. The higher polydispersity of the Poly2EHA-AA copolymer product as measured by GPC also reflects the exhaustion of AA in the polymerization, resulting in an abundance of small chain 2EHA homopolymers that formed at the end.

Please click on **this link** to view the full version of the PSA technical note.

6.3: Monitoring Styrene Butadiene Rubber

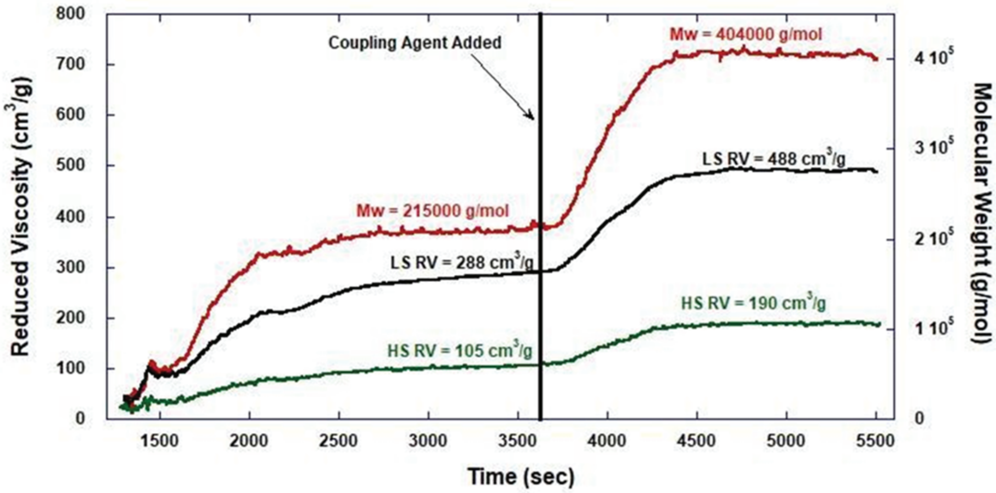
Styrene-butadiene rubber (SBR) was originally developed in the 1930s and commercialized during World War II as a replacement for natural rubber in vehicle tires. In the 21st Century, because of the increased interest in improving fuel efficiency, Solution SBR (SSBR) began to replace traditional SBR that is produced in an emulsion process. This was done to enhance the rolling resistance properties in car tires. Today, the global demand for SSBR is huge, and it continues to increase every year.

In this application, ACOMP was used to continuously measure the anionic polymerization of SSBR. Here, ACOMP successfully tracked conversion, along with weight-average molecular weight (Mw), and low and high shear reduced viscosities (RV), including during a coupling reaction. The effect of the coupling agent was directly monitored and showed approximately a doubling in Mw over time, as well as increases in RV.



This graph shows raw detector signals for UV Absorption (UV), Static Light Scattering (SLS), and high and low shear viscometers on the left axis. The UV signal in dark blue does not return to its solvent value, due to scattering and absorption by the polymer that has formed. The fractional conversion on the right axis is determined by a procedure for dynamically removing the polymer scattering and absorption, thus yielding the true polymer concentration and conversion. This feature was developed by Fluence Analytics and is included in the ACOMP software package. These signals are normalized to a scale of 1.

The decay of the UV signal at 265 nm shows the conversion of the styrene into polymer. The light scattering at 90° increases with respect to increasing polymer mass, and it reaches a plateau during the first phase. When the reaction begins, both viscosity signals increase until a plateau is reached. The addition of the coupling agent causes strong increases in both viscometers.



This graph shows weight-average molecular weight and low and high shear reduced viscosity versus time, including the coupling reaction. When using ACOMP, Mw is derived from rigorous physical theory applicable at very low concentrations. In this case, both Mw and low and high shear RV increase monotonically in the first phase of this anionic polymerization (in contrast, in free radical reactions, chains are initiated, propagate, and terminate quickly, so Mw decreases versus time). Examining the first and second plateau values shows that Mw,2 is roughly double Mw,1, indicative of a robust coupling reaction. Similarly, high and low shear RV increase in the first phase, again exhibiting 'living' type behavior of the reaction, and increase after coupling.

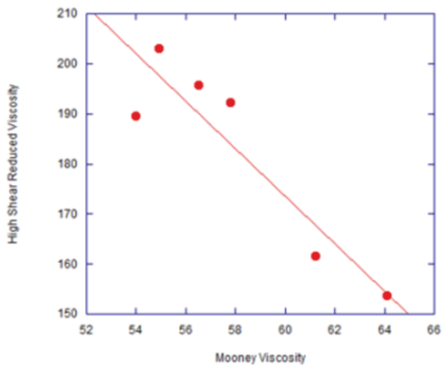
This information provides useful insights into production rates and efficiencies, enabling improved cycle times and yields while achieving product consistency from batch to batch. These parameters can be correlated with important rheological properties of polymer end products such as Mooney Viscosity.

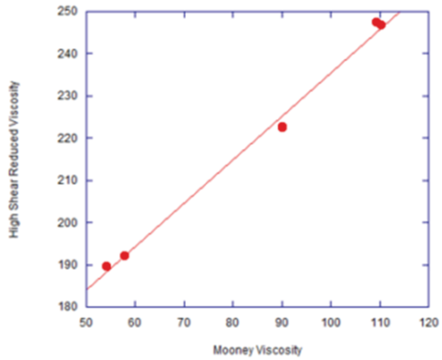
Please click on **this link** to view the full version of the SSBR technical note.

6.4: Determining Industrially Useful Correlations in EPDM Rubber between Rheological and Application Properties using ACOMP

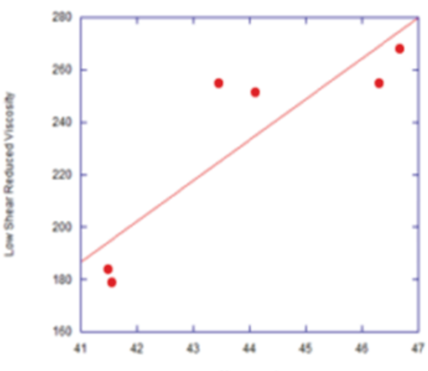
Ethylene Propylene Diene Monomer (EPDM) rubber is a type of synthetic rubber that is used in a wide variety of applications. It is used to create weather-stripping, seals, tubing, washers, insulation, and can even be found in cars as wiper blades. In this application ACOMP was successfully used to measure low and high shear reduced viscosity (RV) in EPDM rubbers.

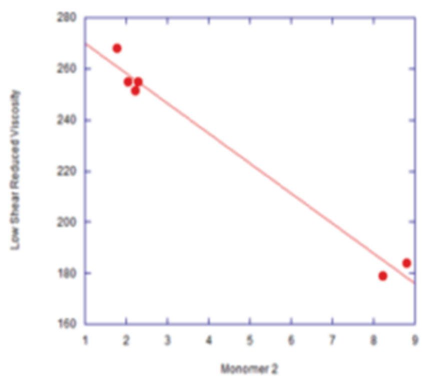
The analyzed EPDM samples were taken from a production line at Lion Elastomers (Geismar, LA) and were measured in hexane solution to simulate online conditions. The ACOMP data was used to build correlations between the RV and the compositional and physical properties of the EPDM rubber. The correlations showed a linear relationship between the RV measured by ACOMP and Mooney viscosity that was grade-specific.

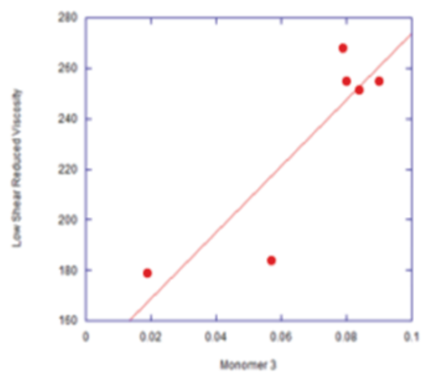




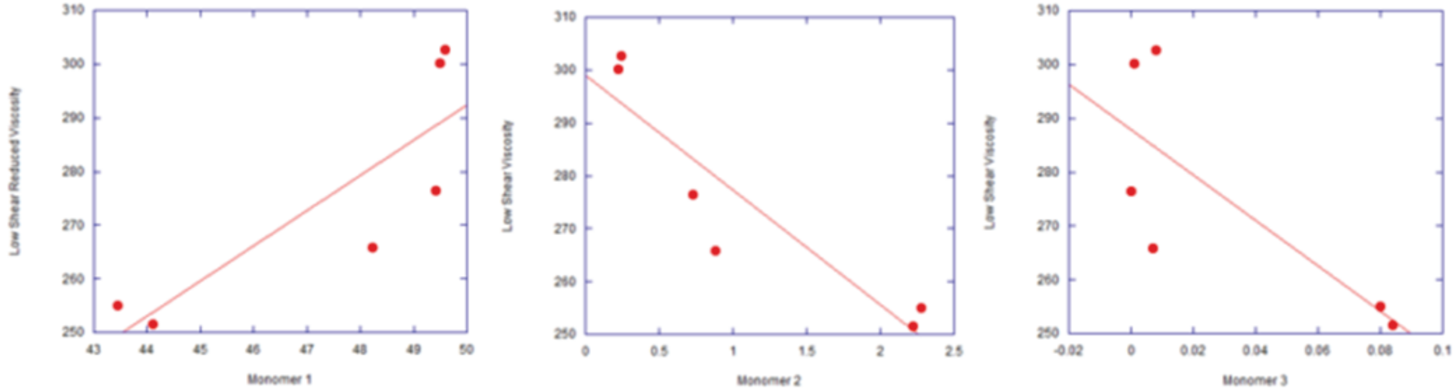
These graphs show the correlation between reduced high-shear viscosity and the Mooney viscosity among different grades of EPDM rubber from discrete samples collected during the process of grade changeovers. Clearly, these types of correlations show the potential for ACOMP to track the progress of grade changes, using real-time monitoring of the reduced viscosity as a proxy.







This set of graphs shows good, albeit scattered, correlations between reduced viscosity from ACOMP's low shear viscometer and concentrations of monomers for two different grade transitions, again based on discrete samples. It is expected that the quality of these correlations could be greatly improved if the samples were directly captured from the industrial reactor.



The additional insights derived from the correlations of RV to the chemical composition can likely be utilized to further optimize EPDM production to achieve a target Mooney viscosity at a target composition. It is expected that correlations between RV and Mooney will be grade dependent, probably due to differences in the molecular weight distribution among grades. For a given set of grades that are manufactured in a product cycle, correlations using low-shear RV or high shear RV can be developed to target specific end performance properties.

Please click on **this link** to view the full version of the EPDM technical note.

CHAPTER SEVEN

ACOMP ROADMAP

ACOMP is split into two systems, an extraction box and the primary ACOMP enclosure. The extraction box contains all of the components for the sampling interface, dilution and conditioning steps. The ACOMP enclosure contains all of the power, electronics, PLC, PC and detectors. Overall, ACOMP is a critical missing link for polymer companies seeking a complete digital transformation and to achieve Industry 4.0.

As a platform technology, ACOMP is continuously undergoing iterations to deliver higher levels of value to customers. This includes enhancements to the suite of onboard detectors, sampling system hardware, and analytics software.

A non-exhaustive list that Fluence Analytics is actively working on with select customers can be found below.

- Expanding the range of target applications to include higher pressure and temperature processes
- New detectors and measurements
- User interface software enhancements
- Reporting and visualization upgrades
- Standardized integration solutions
- Enhanced cleaning hardware and automation
- Process control software
- Analytics software algorithm expansion

As the technology is developed and tested with new chemistries and feedback is received from customers, Fluence Analytics will adjust priorities to meet customer needs.

CHAPTER EIGHT

CUSTOMER JOURNEY TO ACQUIRING ACOMP

Fluence Analytics has different options for customers interested in exploring initial feasibility and ultimately implementing ACOMP in polymerization processes. However, the first step is typically an application assessment to determine if ACOMP is compatible with the intended application and its process conditions. Once stakeholders conclude that the application is viable with ACOMP, customers can take one of three steps:

1. Paid Proof of Performance trial - only for new applications
2. Process Analytics Services (platform as a service)
3. ACOMP purchase

8.1: Application Assessment

The application assessment is an evaluation of customer requirements, current processes, products, and other variables to make an informed decision as to whether ACOMP is compatible with a customer's polymer chemistry, process parameters, and overall plant environment. During this process, a Non-Disclosure Agreement may be required to ensure the privacy of any sensitive or confidential information belonging to either party that is revealed during the application assessment. This is evaluated on a case-by-case-basis and is typically put in place prior to the exchange of detailed chemistry or process information.

8.2: Site Visit

Once the application assessment is complete, the next step may require individuals from the Fluence Analytics engineering team to visit the intended laboratory, pilot plant, or production site. The site visit helps ensure that the necessary spatial requirements for ACOMP and the reactor interface are available. If the required interface is not present, Fluence Analytics will work with the customer to determine the best pathway for ACOMP to interface with the polymer reactor. The site visit also includes a safety review for ACOMP's implementation.

8.3: Proof of Performance and PAS Services

After feasibility is determined and the site visit occurs, Fluence Analytics will continue to work with the customer on the appropriate next step for an ACOMP acquisition. This includes three options: a Proof of Performance trial (only for new applications), a Process Analytics Services agreement, or an ACOMP purchase.

8.3.1: Proof of Performance

The Proof of Performance (PoP) offering is a paid trial where a customer can experience ACOMP's power and insights on its own materials at its own facility only to be used for new applications. A Fluence Analytics team member is available on-site during a portion of the PoP trial, if not for the entire duration. The value of a PoP is that it allows a customer to validate that

ACOMP works with the new targeted polymer chemistry and polymerization process firsthand, while also enabling the collection of weeks' worth of real-time polymer data. This data collection is sometimes used to build a value case to secure the final sign offs for an ACOMP purchase and other times simply for analysis and verification purposes. Most times some of the cost of a PoP trial is credited towards the purchase of an ACOMP system or a PAS agreement, if the decision is made within a certain timeframe.

8.3.2: Process Analytics Services (PAS)

The PAS option is a bundled offering from Fluence Analytics that includes hardware, software, services and support for an annual subscription and a one-time installation cost. The PAS offering also includes ongoing maintenance, software and automation upgrades.

8.3.3: ACOMP Purchase

Fluence Analytics customers who make an outright purchase of ACOMP also have the option to buy annual service agreements, which include customized reports, data analytics tools, and expert consulting services.

8.4: Site Preparation and the ACOMP Build

Once the purchase agreement is complete, the build of the ACOMP unit begins. Each ACOMP system is configured specifically to meet a customer's specifications utilizing a menu of options. Simultaneously, as the new ACOMP system is built, Fluence Analytics will work with the customer's team to prepare the customer's site for the ACOMP installation, which requires a collaborative project to achieve complete integration of a unit into the process. This includes implementing necessary reactor modifications to ensure that it can interface with ACOMP. Since ACOMP can directly tie into most polymer reactors, this phase usually requires minor engineering and integration work.

8.5: Installation, Training, and Handoff

Once the ACOMP platform is built and the site is ready, a team of Fluence Analytics engineers will finish the implementation process. This includes ACOMP training sessions that are typically completed within a week. Following the training, Fluence Analytics will formally hand off the ACOMP system to the customer.

8.6: Getting the Maximum from your ACOMP

Having completed the above steps, a customer is now ready to deploy ACOMP into a production process and save on operational expenses while also accelerating R&D efforts to more rapidly and efficiently develop new products.

Fluence Analytics stands behind its customers by providing service and support including new improvements, such as detectors with additional monitoring capabilities, as well as system and software upgrades as they become available.

Fluence Analytics confidently expects that ACOMP will become an integral part of any team's production and R&D processes, a part that can be expanded as applications for ACOMP in new polymer systems and enhanced control strategies continue to develop.

Feedback on this eBook and overall ACOMP experience is greatly appreciated.

Email: info@fluenceanalytics.com

References

Marr, B. (2018, September 2). What is Industry 4.0? Here's a Super Easy Explanation For Anyone. Forbes. https://www.forbes.com/sites/bernardmar/2018/09/02/what-is-idu try-4-0-heres-a-super-easy-explanation-for-any-one/?sh=2bfb66709788

Soroush, M., Baldea, M., & Edgar, T. F. (2020). Smart Manufacturing Applications and Case Studies. Elsevier publications.

The Industrial Revolution—From Industry 1.0 to Industry 4.0. (n.d.). DiConnex. https://diconnex.com/en/blog/2020/06/23/the-industrial-revolution/

Images sourced from inhouse documentation and https://www.fluenceanalytics.com/