Improving polypropylene plant performance with process gas chromatographs

Process gas chromatographs have been used since the 1950s to provide real-time compositional data to process control systems. Today, there are tens of thousands of process gas chromatographs in use throughout the process industry making the gas chromatograph the analytical workhorse for online compositional measurements. One example of how process gas chromatographs are used for improving process operations can be found in the polypropylene plant in a refinery.

One of the most common polymers in the world is polypropylene. It is found in applications ranging from plastic bottles for household cleaners, parts inside automobiles and the fibers for carpet. Polypropylene is also temperature-resistant, making it an ideal material for medical equipment since it can be sterilized. It is also commonly used to make baby bottles since being heated can clean them. To meet this demand for polypropylene polymer, polypropylene plants can be found around the world.

The Polypropylene Plant

As with other polymers, polypropylene is often a mixture of propylene plus a second compound called a comonomer. The actual chemical used for the comonomer varies depending on the desired properties, but can range from a simple chemical like ethylene to more complex butenes and hexenes. Figure 1 shows a typical polypropylene plant design with the chemical reactions done in two stages. Polymer-grade propylene enters the first reactor along with the catalyst. Hydrogen is also added to control the size of the polymer molecule and sets the overall melting point of the final product. These reaction components are continuously fed into the first reactor. To keep everything as a slurry, an inert diluent compound such as hexane or butane is added. The diluent also helps absorb the heat that is generated in the reaction.

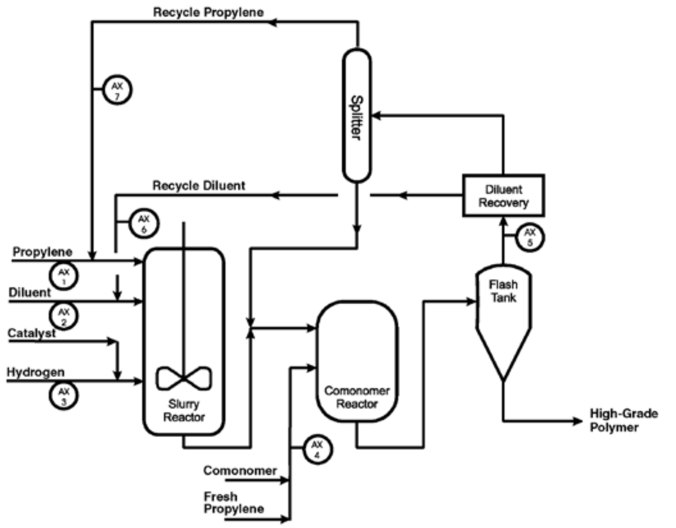

Figure 1 - Flow diagram of a typical polypropylene plant

The still chemically active mixture leaves the first reactor and enters the second reactor where fresh propylene and the comonomer are added to finish the reaction process. The finished polymer leaves the second reactor, along with the diluent and any unreacted components and enters a flash tank. Due to the flash tank's lower pressure, any unreacted monomers and diluent vaporizes and leaves the top of the vessel. The polymer settles out the bottom to be extruded into plastic sheets or pellets.

The vapors leaving the top of the flash tank enter a diluent recovery system to separate the diluent from any unreacted monomers as well as to filter out any polymer dust that might have carried over. The diluent is recycled back to the feed of the reactor. The unreacted propylene and comonomer enter a stripper where they are separated from each other. The propylene is recycled to the feed of the first reactor and the comonomer is recycled to the feed of the second reactor.

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Improving unit performance with process gas chromatographs

Due to the extremely competitive nature of a commodity like polypropylene, it is critical that the quality of the plastic be high and consistent. To insure this high quality, it is important that the ingredients fed into the polymer reactor be tightly controlled. A number of process gas chromatographs are used to provide live feedback on the quality of the feed streams.

The first three process gas chromatographs measure the quality of the feed entering the first reactor starting with the propylene feed (AX #1 in Figure 1). This gas chromatograph monitors common impurities like C_2, C_3, methyl acetylene (MA) and propadiene (PD). The diluent is monitored (AX #2 in Figure 1) for the presence of impurities; as is the hydrogen feed to the reactor (AX #3 in Figure 1). Finally, the feed to the second reactor is measured (AX #4 in Figure 1) for impurities. The actual compounds that are measured vary depending on which comonomer and diluent are used.

To provide feedback to the control system on how the reactions are progressing in the reactors, it is common to measure the flash tank off-gases (AX #5 in Figure 1). Measuring the amount of unreacted $C_3^=$ as well as the comonomer and H_2 can indicate the quality of reactions occurring. However, this can be a difficult point to sample due to the high concentration of polymer dust. Special sample probes are used to filter out the polymer and to self-clean the filters to minimize plugging.

The last two common measurement points monitor the recycle streams. The diluent recycle is monitored (AX #6 in Figure 1) for H_2, $C_3^=$ and comonomer. The propylene recycle is monitored (AX #7 in Figure 1) for H_2 and comonomer. A summary of these applications can be seen in Figure 2.

The Emerson Solution

Emerson has a long history of providing process gas chromatographs for the polypropylene industry. Emerson's process gas chromatographs are setting the standard for online process measurement by supplying analyzers that are both robust and capable of handling the analytical requirements.

Analyzer #	Stream	Components Measured	Measurement Objective
1	Propylene feed	C_2, C_3, MA, PD	Propylene feed purity
2	Diluent feed	Hydrocarbons	Diluent feed purity; exact components vary with diluent used
3	Hydrogen feed	Hydrocarbons	Hydrogen feed purity
4	Comonomer feed	Hydrocarbons	Comonomer feed purity; exact components vary with comonomer used
5	Flash tank off-gas	H_2, $C_3^=$, comonomer	Feedback to control system on reaction kinetics
6	Diluent recycle	H_2, $C_3^=$, comonomer	Monitor impurities recycled with the diluent
7	Propylene recycle	H_2, comonomer	Monitor impurities recycled with the propylene

Figure 2 - Summary of process gas chromatograph applications in a typical polypropylene plant

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