**TECHNOLOGY BRIEF:**

Efficient mixing of gases and liquids is a critical step in many chemical and biological process technologies. Static mixers and inline rotor/stator mixers are typically used in gas-liquid applications where high intensity mixing, short contact time and/or continuous processing are required.

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**Inline mixing of gases and liquids**

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**Mixing gases into liquids**

Gas-liquid mixtures are standard in chemical and biological process technologies. A typical purpose is to produce a chemical reaction or provide mass transfer between the two phases.

Several types of gas-liquid contactors are available but mechanically agitated reactors or stirred vessels are the most commonly used batch systems. Low-viscosity liquid is stirred and gas is normally injected below the impeller. The rotation of the stirrer breaks-up the entering gas stream into bubbles which are directed outward by the impeller action.

For applications that require high intensity gas-liquid mixing, short contact time and/or continuous processing, static mixers and inline high shear rotor/stator mixers are chosen.

**Static mixers**

A static mixer is a unique device in that it has no moving parts and it relies on external pumps to move fluids through it. An array of static mixer elements is placed inside a pipe and the conduits, plates or baffles within the device manipulate the fluids to divide, recombine, spread, rotate, eddy or swirl.

Process factors considered in static mixer design selection include allowable pressure drop, heating/cooling requirements, residence time or flow rates, length of piping, and liquid viscosity.

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When the amount of gas exceeds its solubility in a formulation or the gas is immiscible with the liquid phase, it is necessary to form a stable and uniform emulsion. In these cases, proper gas dispersion requires high shear conditions. Turbulent flow in a static mixer achieves this task but may require high operating pressures and/or multiple elements.

**Inline high shear mixers**

An inline high shear mixer consists of a rotor/stator assembly installed in a housing with inlet and outlet connections. The rotor is connected to a shaft that is directly driven or belt driven by the motor. A mechanical seal is utilized on the rotating shaft to isolate the mix chamber from the environment. Interchangeable stators provide flexibility to adapt to a variety of mixing needs for different product recipes.

In gas-liquid mixing processes, the liquid flows by gravity or positive pressure into the mix chamber (the mixer acts like a centrifugal pump) while the gas is injected through a dedicated port directly into the rotor/stator assembly. Here the product is subjected to high shear as the rotor turns at tip speeds ranging from 3,000 to 4,000 ft/min and expels the mixture out of the chamber through the holes of the stationary stator. Ultra-high shear mixer designs with rotors that run up to 11,000 ft/min or higher are available for products requiring more intense shear levels.

Depending on the rotor/stator geometry, an inline mixer can handle viscosities up to 10,000-20,000 cP without external pumping assistance. With an auxiliary pump, it can process products up to 200,000 cP.

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**Sample Application: Polyurethane Foam**

Working to provide environment-friendly materials for the plastics industry, the Formacel Group of DuPont developed a family of hydrofluorocarbon (HFC)-based blowing agents used in the manufacture of polyurethane foams. Unlike their chlorofluorocarbon (CFC) predecessors, HFC’s are not chlorinated and have zero ozone depleting potential.

Despite their environmental appeal, HFC’s bring with them a new set of processing challenges to the polyurethane foam molder. The main difference stems from the fact that CFC’s are liquids at the processing temperature and easily soluble in polyol. HFC’s, on the other hand, are gases at ambient conditions with limited solubility in polyol. The necessary quantity of HFC’s required for use as a blowing agent often exceeds its solubility. A stable polyol liquid/HFC gas emulsion is therefore needed to provide a homogenous feed to the polyurethane foam machine.

To accomplish this requirement, DuPont uses a Ross inline high shear rotor/stator mixer piped to a polyol pressure tank for recirculation. As the polyol enters the mixer inlet, the Formacel blowing agent, which is stored under pressure in a gas cylinder, is injected directly into the mix chamber. The minimal clearance between the rotor and stator combined with the high velocity of the rotor creates intense shear required for efficient dispersion and emulsification. After mixing, a valving arrangement diverts the stable polyol/Formacel emulsion to a reaction injection molding machine where it meets isocyanate to produce polyurethane foam.

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