Represented by
M. A. Olson Co., Inc.
414 Old Boston Road
Topsfield, MA 01983
Phone: [978] 887-2384
Fax: [978] 887-3234
: Lightnin@maolson.com

Up-pumping mixing technology

Breaking the mold of traditional systems

Multiphase processes, like hydrogenation, fermentation, wastewater aeration and solids make-down, represent some of the most complex mixing processes. In those applications, intimate contact between gas, liquid and solid phases is required to achieve the desired process results. Depending on the specific application, various combinations of impellers are employed. Regardless of the specific process or impeller configuration, multiphase mixing is prefaced by combinations of radial and/or down-pumping impellers. The impellers pump the contents of the tank with the goal of holding the air or gas down in the tank as long as possible, suspending solids and blending the liquid components. Using impellers that pump upwardly, rather than radially or downwardly, can provide a superior solution.

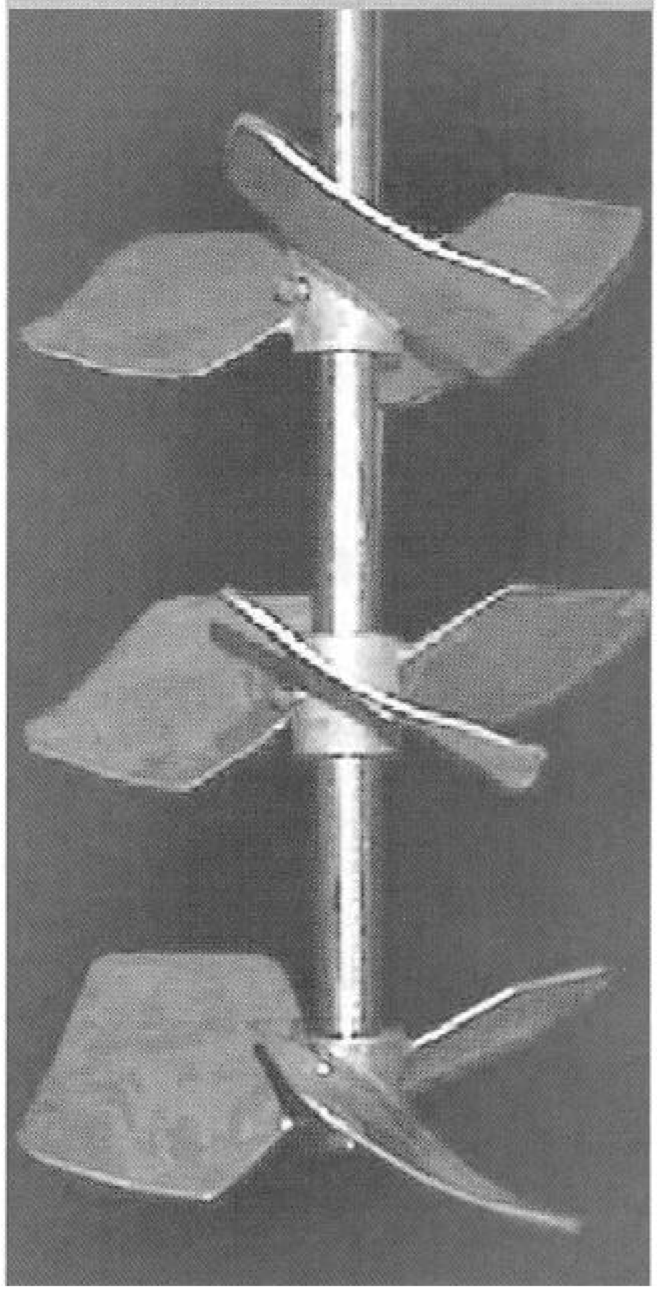


Fig. 1. Typical up-pumping mixing system

Up-pumping technology

Up-pumping mixing technology uses multiple hydrofoil impellers in multiphase mixing applications (see Fig. 1). Up-pumping impeller technology achieves reduced reaction times, increased yield, improved purity, enhanced uniformity and lowered catalyst costs.

Moreover, considerable mechanical advantages exist. Because fluid forces and torque fluctuations are reduced there is less vibration. This improves seal and bearing life as an added benefit.

Empirical experience, as well as the results of formal tests, demonstrates that up-pumping technology offers advantages. Even so, most process engineers find the technology counterintuitive. Multiple up-pumping impellers circulate the contents of the tank up through the impellers. If the goal is to hold the gas or air in the tank as long as possible, then why pump it up and out of the tank?

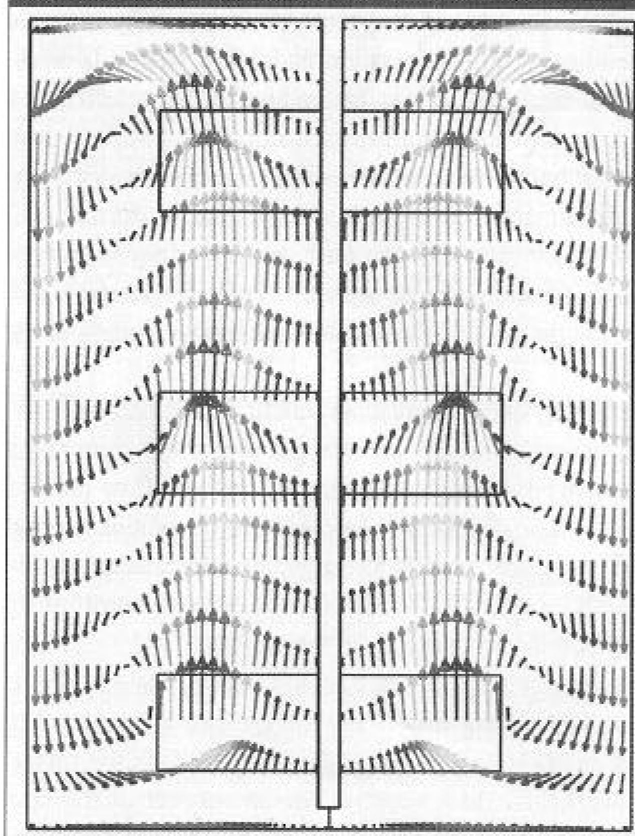
Up-pumping benefits and fluid dynamics

To understand why up-pumping works, look at some fundamental mixing concepts as they pertain to multiphase mixing. Often in multiphase mixing applications, the multiple mixing objectives include blending, suspension of solids, gas dispersion, mass transfer, gas induction and heat exchange. Hydrogenation, for instance, requires proper hydrogen dispersion, good catalyst distribution, correct heat removal and good reactant blending. Likewise, the uniform distribution of air and nutrients is essential to fermentation of biological media.

Although many observers regard mass transfer as the most important step in multiphase applications, the optimization of any multiphase process must satisfy all of the concurrent process goals. For instance, improvements in blending or heat transfer can increase the process reaction rate while not directly influencing mass transfer.

Traditional multiphase systems with combinations of radial and down-pumping axial flow impellers often create flow patterns within the tank that lead to staging between the impellers. In other words, several individual flow patterns are created and there are dead (no mixing) zones between impellers. That results in suboptimal blending, dispersion and solids suspension as well as a decrease in the resulting mass transfer.

Fig. 2. Velocity profiles in an up-pumping system as determined by computational fluid dynamics



Multiple up-pumping impellers, on the other hand, create a single-loop flow pattern similar to that of a draft tube. Computational Fluid Dynamic (CFD) modeling techniques and laser velocimetry analysis have both predicted and confirmed the single-loop flow pattern (see Fig. 2). In up-pumping systems, the rising gas is driven up through the impellers to the uppermost impeller, which produces a strong recirculating flow. The velocity of the recirculating flow pattern is so great that the system's contents (including entrained gas bubbles) actually accelerate back down the sidewall to the bottom of the tank. The lower impeller reverses the flow and pumps the tank contents upward-thus, the single-loop flow pattern.

Enhanced mass transfer and gas holdup

That flow pattern affects all the mixing objectives mentioned earlier. As in traditional systems, the bottommost impeller disperses gas as it is sparged into the tank. The goal of dispersion is to increase the gas-liquid interfacial area for greater mass transfer. In up-pumping systems, the gas is further dispersed as it rises through each impeller, increasing the area available for mass transfer. It is especially important in coalescing systems like fermentation because air bubbles tend to increase in size as they rise to the surface. Up-pumping systems maintain constant gas dispersion throughout the system and thereby enhance the gas-liquid mass transfer.

As a further benefit, even without sparged air (or other gas), the recirculating velocities of the upper impeller induce surface gases into the fluid. That results in higher gas holdup. Gas holdup has always been related closely to mass transfer performance. Nowhere is that improvement in gas induction more evident than in hydrogenation. Actual process results have confirmed that significantly less hydrogen sparging is required. In fact, some customers have eliminated hydrogen sparging (and the associated costly capital equipment) in favor of 100% surface induction.

Better blending, suspension and heat transfer

The strong velocities down the sides of the tank wall and the single-loop flow pattern dramatically improve blending, solids suspension and heat transfer. In traditional multiphase mixing systems (characterized by tall, narrow tanks and distant impeller spacing), dead zones often develop between impellers. With up- pumping impeller systems, solids are uniformly distributed throughout the tank and blending is significantly faster and more uniform. In hydrogenation, that means the catalyst is distributed evenly throughout the tank and is more fully utilized. Likewise, pH-sensitive processes like fermentation benefit. Better blending performance maintains process pH uniformly throughout the tank. Because of the strong, uniform flow pattern, heat transfer improves. Temperature fluctuations within full-scale tank installations have been measured at only $\pm 0.29\ ^{0}$C variance. Those improvements combine to increase the productivity of the system.

Another great advantage of up-pumping systems is that they cannot flood, regardless of the power level or gas rate. Flooding occurs when the gas (not the mixer) controls the flow pattern. The movement of the tank contents is chaotic, and, if solids are present, they remain on the bottom of the tank. In large tanks, the only means of determining whether a tank is flooded is to see if there is geysering (see Fig. 3) on the surface. If a tank is intermittently flooded, however, the surface is smooth- even though no distinct flow pattern exists below the impellers, and solids still remain on the bottom.

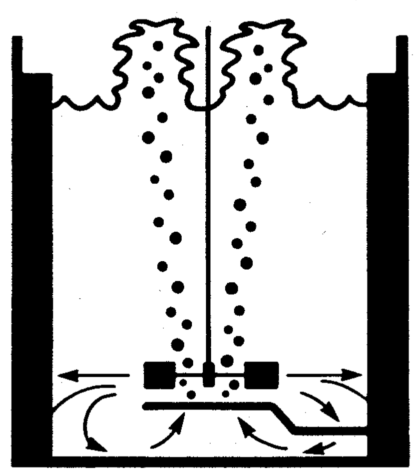


Fig.3 - Illustration of Gysering

Finally, increases in power are directly associated with improvements in process operation. In all systems, the power imparted by the impeller system decreases upon

aeration and must be accounted for in the design. The power drop is defined as the ratio of gassed horsepower to ungassed horsepower and is known as the K-factor. The lower the K-factor, the more the power drops off upon aeration. The K-factor of the up-pumping system has a much flatter response to
gas rate increases than the K-factors of traditional systems. That allows greater operational flexibility and less dependence on costly gas-interlock and/or speed control systems needed to prevent overloading of traditional systems upon gas failure.

Up-pumping applications

Most multiphase systems are idiosyncratic and must be engineered to optimize results. That is true regardless of whether a system employs traditional technology or up- pumping technology. Usually, up-pumping systems begin as retrofits of older systems. Increasingly, however, end users are installing new systems. The number of installations is increasing in the United States and Europe, and a number of companies are running side-by-side comparisons to quantify the production improvements of the technology.
Some installations include several 50-hp to 300-hp hydrogenation reactors. When those reactors were retro- fitted with up-pumping technology, catalyst life increased fivefold and fouling of the heating coils was eliminated- significantly reducing downtime. A sparger was no longer required because sufficient gas was drawn in from the headspace, and batch time was reduced by 50%.
In a polymer oxidation plant using a 50-hp mixer, batch time was reduced from 12 hr to 1.5 hr; and product purity improved so much that earlier batches were recalled.
In one 750-hp fermenter that contained viscous coalescing media, gas bubbles the size of trucks were significantly reduced in volume, and blending and temperature uniformity dramatically improved. As a result, a 30% improvement in yield occurred with a 50% power reduction.
So long as a multiphase system is mass-transfer limited, up-pumping impeller technology offers potential improvements in blending, heat transfer, solids suspension, gas induction and dispersion. Flooding, coalescence and shear also can improve. That explains why the mass transfer coefficients of up-pumping systems are generally twofold greater than in traditional systems. That, in turn, translates into significant improvements in system productivity, yield and profitability.

This article was reprinted form the October 1998 addition of Chemical Processing and is available on line at http://www.maolson.com along with complete product line brochures and other reference materials.