

The Development and Application of the Hybrid Centrifugal – Dissolved Air Flotation System for Wastewater Treatment

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ABSTRACT

Solid/liquid separations are commonly the first (primary treatment) step in any wastewater treatment. Such technologies are mature and new developments are rare. However, in the last decade some significant improvements in separation techniques for industrial wastewater pretreatment have been implemented. Advances in the technology include more efficient, faster centrifugal mixing of treatment chemicals and wastewater contaminants, “in situ” continuous flow coagulation and flocculation, implementation of very high molecular weight flocculants and development of more efficient flotation technologies.

Flotation is one of the most effective removal systems for suspensions that contain fats, oil and grease mixed with low density organic suspended solids and colloids. Flotation is a process in which one or more specific particulate (particular) constituents of a slurry or suspension of finely dispersed particles or droplets become attached to gas bubbles so that they can be separated from water and/or other constituents. Gas/particle aggregates float to the top of the flotation vessel where they are separated from water and other non-floatable constituents.

Flotation processes in water and wastewater treatment are designed to remove all suspended particles, colloids, emulsions, and even some ions or soluble organics that can be precipitated or adsorbed on suspended solids. In this case, the process is optimized by the maximum recovery of cleaned water with the lowest concentration of contaminants. It is also often desired that the recovered sludge contain a high percentage of solids. Such solids can sometimes be recycled and reused. The design features and operating conditions of flotation equipment used for this purpose must be modified accordingly. It is evident that the processes causing water loss to the froth phase or migration of solids to the water phase must be minimized and appropriate conditions established for complete particle recovery.

Dissolved-air flotation (DAF) is the most common system in the treatment of oily wastewater. In DAF, a stream of wastewater is saturated with air at elevated pressures up to 5 atm (40-70 psig). Bubbles are formed by a reduction in pressure as the pre-saturated water is forced to flow through needle valves or specific orifices. Small bubbles are formed, and continuously flowing particles are brought into contact with bubbles. There is a price to pay for having such small bubbles (up to 20 microns): Such bubbles rise very slowly to the surface of the tank. This is the main driver of the large

dimensions for DAF tanks. Final solubility of gas in water, even at high pressures, also results in fairly low air-to-water ratios. Air-to-water ratios of 0.15:1 by volume are common in DAF systems, and it is very difficult to achieve higher ratios. Therefore, classical DAF systems are not efficient in treating wastewater with more than 1% of suspended solids.

In dissolved-air flotation, bubbles are formed by a reduction in pressure of water pre-saturated with air at pressures higher than atmospheric and up to 120 psi. The supersaturated water is forced through needle valves or special orifices, and clouds of bubbles 20 to 100 microns in diameter are produced. Yet, to avoid clogging of such orifices with particles, only 20% of already cleaned water is pressurized and recycled to the wastewater stream. This results in a low-energy mixing of the main wastewater stream and the bubble stream. Treatment chemicals, coagulants and flocculants have to be added in mixing tanks upstream. As already described earlier, floc separation happens in this tank, which requires quiescent conditions and a large footprint.

One of the recent developments in flotation technology circumvented some of these problems. In particular, the air-sparged hydrocyclone (ASH) couples a porous cylindrical membrane with design features of a centrifugal liquid hydrocyclone. Gas is introduced through the porous membrane while wastewater is pumped through the hydrocyclone. Such a device is not dependent on the gas solubility and can introduce air-to-water ratios as high as 100:1. Because the bubbles are sheared off the wall of the porous membrane due to the high velocity and centrifugal forces inside the hydrocyclone, they are broken up into very small sizes comparable to those observed in the DAF. Thus, even though the ASH is essentially a mechanically sparged device similar to the early flotation devices, it does not suffer from similar problems (large bubbles). The ASH is one of the first centrifugal flotation techniques that was developed and applied in the treatment of wastewater. However, dissolved air still produces the smallest bubbles.

We proposed that a more efficient flotation system could be developed by combining high-energy centrifugal mixing of a liquid cyclone system (we termed it the liquid cyclone particle positioner, LCPP) with dissolved air as a source of flotation bubbles. Coagulants and flocculants can be delivered *in situ* directly into the flotation hydrocyclone unit. Pressurized air can be delivered to LCPP heads at the same time as flocculants. Such a procedure results in flocs, which are very porous and loaded with entrained and entrapped air

As shown in Figure 1 the LCPP also acts as a liquid-solid-gas mixer (LSGM). Replacing the classical hydrocyclone head with the LCPP provides extremely energetic mixing by sequentially transporting liquid and entrained particles and gas bubbles throughout a centrifugally rotating liquid layer. Microturbulence in such vortices results in all particles and bubbles down to colloidal and molecular size acting as little mixers. Axial and radial forces inside the LCPP help mix coagulants and flocculants with the particles. Uncoiling of polymer and better mixing of ultrahigh-molecular-weight polymers (and more concentrated emulsions) is achieved in the LCPP. Such efficient mixing is important for

proper flocculation of suspended particles. Centrifugal mixing also results in less floc breakage than with commonly used impeller or floc tube mixers..

Further modification of LCPP heads, as opposed to hydrocyclone heads, introduced multiple holes with plugs inside the LSGM heads, as shown in Figure 2. By changing the number of plugs, we can modify the mixing energy and head pressure from very low to very high. In this way, we can mix low-molecular-weight coagulant at relatively high energy and high-molecular-weight flocculants at relatively medium and low mixing energy to promote final large floc formation.

Hybrid centrifugal – dissolved air flotation technology (The GEM System developed at CWT [see Figure 3]) provides the best of both centrifugal and dissolved air systems: efficient continuous flow mixing and in line flocculation with the nucleation and entrainment of fine dissolved air bubbles. This development has resulted in systems with very efficient removal of particulate contaminants, a small footprint, drier sludge, durable long lasting flocs, fast response and treatment of the total wastewater stream (no recycling characteristic for DAFs). The design of on-line turbidity or fluorescence driven sensors for automatic control of coagulant and flocculant dosage is also underway. Computational fluid dynamics (CFD) has been used to design better flotation tanks with a vortical flow pattern that results in the formation of a dense air bed inside the tank. Such fine bubble layers prevent sedimentation of already floated heavier particulates, which results in significantly higher flotation rates.

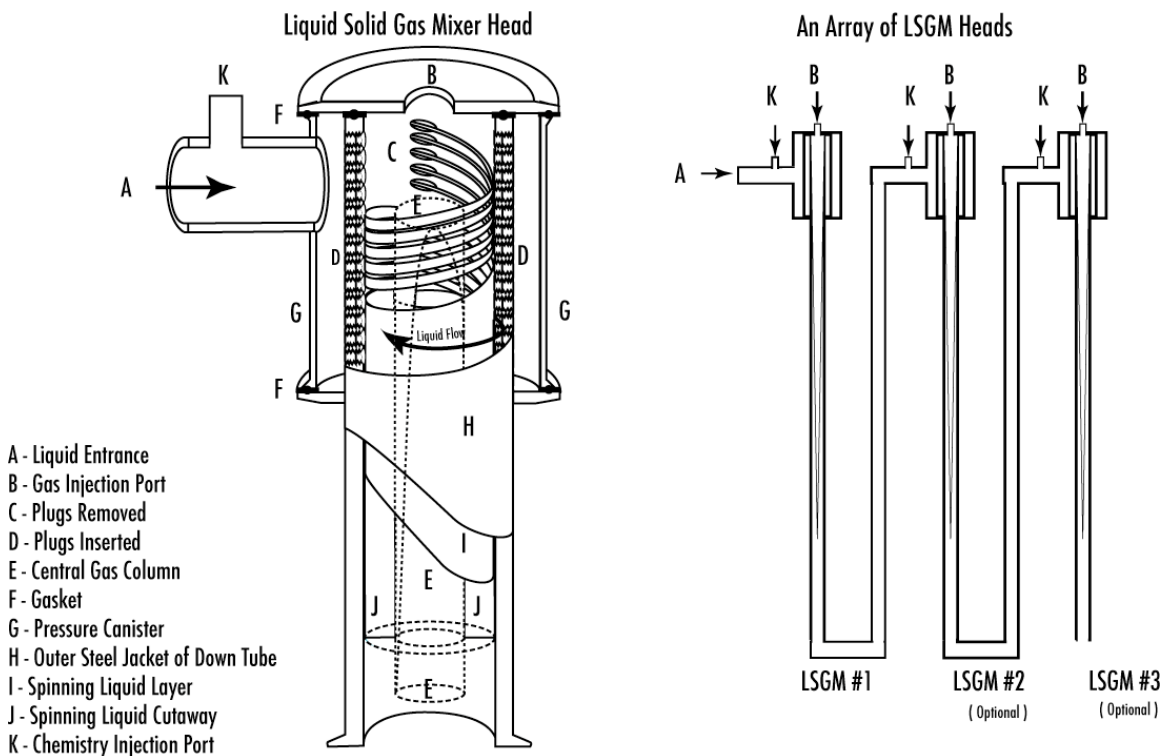


Figure 3. Schematic Presentation of the Hybrid Centrifugal – Dissolved Air Flotation (the GEM System)

