Flotation Machines

Flotation is a physiochemical separation process that utilizes the difference in surface properties of the valuable minerals and the gangue minerals. The process of separation of mineral includes 3 important mechanisms:

1. True Flotation –selective attachment to air bubbles
2. Entrainment – in the water which passes through the froth
3. Aggregation – physical entrapment between the particles in froth

True flotation dominates the recovery of the valuable minerals and the other two decide the separation efficiency between the valuable and the gangue.

There are two ways of flotation:

1. Direct Flotation: In which the mineral is attached to the froth and the gangue remains in the tailing.
2. Reverse Flotation: In which the gangue is attached to the froth and minerals remain in tailing. (eg- phosphates, silica from magnetite, lithium)

Mechanics of flotation

The basis of froth flotation is the difference in wettability of the mineral and gangue particles. On the basis of wettability, particles are classified as Hydrophobic and Hydrophilic. The valuable minerals can attach to the air bubbles, only if they are hydrophobic. Once they reach the surface, due to the buoyancy of the air bubbles, the particle bubble contact can sustain only if they form a stable froth. The stability of the froth depends on the strength of the attachment of the bubble to the mineral surface.

Separation of the valuable is achieved by rendering the surface of the mineral particle hydrophobic, usually with a collector, so that it preferentially attaches to a bubble, which then rises to the surface of the cell where it collects as froth.

<u>A flotation machine must ensure</u>:

- Good mixing of pulp

To be effective, a flotation machine should maintain all particles uniformly in suspension within the pulp, including those of relatively high density anchor size. Good mixing of pulp is required for maximizing bubble-particle frequency.

- Appropriate aeration and dispersion of fine gas bubbles

An important requirement of any flotation machine is the ability to provide uniform aeration throughout as large a volume of the machine as is possible.

- Sufficient control of pulp agitation in the froth zone

As mentioned earlier, good mixing in the machine is important. However, equally important is that near and in actual froth bed at the top of the machine, sufficiently smooth or quiescent pulp conditions must be maintained to ensure suspension of collector-coated particles.

- Efficient mass flow mechanisms

It is also necessary with any flotation machine that appropriate provisions are made for feeding pulp into the machine and also for the efficient transport of froth concentrate and tailing slurry away from the machine.

Flotation Machine

Various types of flotation machine designs can be classified into different categories on the methods used for generation and introduction of air bubbles into the equipment. Each of the techniques has its own advantages and disadvantages. Therefore careful selection of these equipments is necessary:

Factors affecting machine selection:

1. Metallurgical performance, as represented by a grade and recovery curve.
2. Capacity (tons per hour per unit volume).
3. Operating cost per ton of feed, power consumption, maintenance, direct labor, etc.
4. Ease of operation.

Types of Flotation Machines

Electro-flotation Units

Electro-flotation is the electrochemical version of traditional dissolved air flotation. It is characterized by its mechanism of oxygen and hydrogen bubble formation due to water electrolysis.

Electro-flotation presents several advantages:

1. Silent process which does not require large amount of energy
2. High removal efficiency of suspended solids
3. High COD abatement rate by native oxygen bubbles formed at the anode
4. Possible control of mass and size of bubble produced by simple adjustment of current density and possible use of solar energy as a power source

Dissolved Air flotation Units

Dissolved air flotation works by attaching small bubbles of air to suspended solids. The bubbles are generated by saturating a recycled stream of water with air under pressure, then releasing the pressure rapidly to produce clouds of microbubbles. Attaching the bubbles to the solids requires a reduction in charge of the particles and the production of hydrophobic spots on the surface of the solids via chemical/physical pre- treatment. Dissolved air is the most common type of flotation gas used in potable water treatment. The dissolved air flotation (DAF) process mixes a clarified stream from the outlet of the unit with air at 3–9 bar, to produce a supersaturated (compared with saturation at atmospheric pressure) solution of air in water. This is rapidly depressurized at the inlet of the unit to produce a mass of microbubbles which attach to the solids present, floating them to the surface.

Eg: The dissolved air flotation process is more commonly used for sewage and potable water treatment. It is gaining popularity for the treatment of slaughter house, poultry processing, sea food processing and food processing in wastes.

DAF can further be classified into Vacuum flotation and Pressure flotation.

a) Pressure Flotation

Pressurization could be carried on the entire feed stream or a fraction of the feed stream while the remainder is introduced directly without aeration into the flotation tank. This is the more widely used process. In contrast to vacuum flotation, dissolved air flotation unit can be operated on continued basis by the application of pressure. This consists of pressurizing and aerating process stream and introducing it into the flotation vessel that is maintained at low atmospheric pressure. The reduction in pressure results in the formation of fine air bubbles and the collection of fine particulates to be floated and removed as sludge.

The split flotation system offers a cost saving over the full flow units. In both cases however, the solid particles in the feed stream are flocculated before introducing top the flotation tank, the high shear during pressurization, aeration and pressure release can destroy flocs.

b) Vacuum Flotation

In vacuum flotation, the process stream is saturated with air at atmospheric pressure and introduced to the flotation tank on which a vacuum is applied giving rise to the generation of the air bubbles. The process can be run only as a batch process and requires sophisticated equipment to produce and maintain the vacuum. By and large, the amount of air released during flotation is limited by the vacuum achievable.

Dispersed Air Flotation Units:

Dispersed air flotation involves the generation of air bubbles either pneumatically or by mechanical means. In both cases, relatively large air bubbles are generated. In order to control the size and stability of air bubbles froth are added to the flotation devices.

a) Mechanical Cells

In a typical installation, a number of flotation cells are connected in series such that each cell outputs froth into a launder. And the overflow from one cell goes to another.

The cell design must be such that the flow of slurry from one cell to another can neither be restricted by weirs nor unrestricted. These machines provide mechanical agitation and aeration by means of a rotation impeller on an upright shaft.

b) Pneumatic Machines

Pneumatic machines are those which either use the air entrained during pulp addition or the air blown in or induced. Generally, give a low- grade concentrate and little operating trouble. Examples are the Davcra Cell, Flotation Columns and the Jameson Cell.

Flotation Columns work on the principle of countercurrent flow of air bubbles and solid particles, which is accentuated by the adding of wash- water at the top.

Flotation Columns

Flotation columns belong to the class of pneumatic devices in that air bubble generation is accomplished by a gas sparging system and no mechanical agitation is employed. Inputs to the column include pre- conditioned slurry feed and air and wash water spray which is introduced at about 2/3rd of height from the bottom, in the bottom region and at the top of the column respectively. The outputs are froth overflow consisting of hydrophobic particles from the top and underflow from the bottom of the tank, carrying the non-floatable hydrophilic particles.

Typical industrial Column Cell comprises a steel tank equipped with a feed inlet pipe near the top of the column, a system of internal and external launders to collect and remove froth and a slurry outlet near the bottom of the tank to remove non- floating material. Drain nozzle and a series of re- pulping nozzles are also located at the bottom. Depending on the tank geometry, it may contain several internal baffles to control the mixing characteristics within the tank. A gas sparging system used to generate the bubbles required for the flotation process is located at the bottom of the vessel. A froth washing system, used to cleanse the froth of entrained impurities, is installed at the top of the tank.

Commonly used Industrial Flotation Machines

Outokumpu Cell

The OK impeller mechanism is designed with a hemispherical-shaped impeller consisting of a horizontal disc on the top which is attached to a number of narrow vertical slots tapered downwards. The impeller has separate slots for air and slurry movement. The mechanism has a forced air type entry mode in which air is brought into the impeller through a hollow shaft. The stator in the OK mechanism is mounted on the bottom of the tank. There are two stator designs used in an Outokumpu cell: one is known as the multi-mix or conventional stator and the other is known as free-flow. The multi-mix stator is typically used for fine particle flotation, whereas the free flow stator is typically used for coarse particle flotation.

Wemcro-Fagregren Cell

The feed enters the cell through a circular port in the bottom, and is drawn up into the rotor by the action of the lower impeller; the suction exerted by the upper impeller draws air down into the pulp at the same time. The combined effect is to force the aerated pulp through the rotor and stator into the outer zone. The rapid compression and expansion of the mixture as it passes through the spacing bars produces intense agitation and very thorough aeration. The outer zone of the cell is more quiescent than is common in mechanically agitated machines, due to the fact that the stream of pulp moves outwards in a horizontal direction; the absence of surging on the surface is one of the characteristics of the Fagergren Machine. The mineral-loaded bubbles rise and collect on the surface of the pulp as a froth which is often voluminous enough to flow over the lip into the concentrate launder surrounding it without the use of a paddle, in which case a circular cell can be used. The tailing passes into a discharge compartment at the side of the cell, the heavier portion flowing out through a sand gate, while the fines overflow an adjustable weir which serves also as a means of regulating the level of the pulp in the machine.

The bottom of the cell is pierced with 12 small holes for the circulation of the pulp. They are equally spaced along two lines at right angles and deliver into transfer passages underneath through which the pulp passes to the port under the rotor, where it mixes with the feed and is drawn up with it into the cell. The horizontal direction of the stream of pulp issuing from the rotor combined with its very thorough aeration makes it possible to maintain a shallow pulp column in a wide cell, resulting in lower power consumption than is normally obtainable in a machine of the mechanically agitated type.

Denver D-R Cell

In the Denver DR Flotation machine, the pulp is introduced through a feed box and is distributed over the entire width of the first cell. Circulation of the pulp through each cell is such that, as the pulp comes into contact with the impeller, it is subjected to intense agitation and aeration. Low pressure air for this purpose is introduced down the standpipe surrounding the shaft and is thoroughly disseminated throughout the pulp in the form of minute bubbles, when it leaves the impeller/diffuser zone, thus assuring maximum contact with the solids.

Each unit is suspended in an essentially open trough and generates a “ring doughnut” circulation pattern, with the liquid being discharged radially from the impeller, through the diffuser, across the base of the tank, and then rising vertically as it returns to the eye of the impeller through the recirculation well. This design gives strong vertical flows in the base zone of the tank in order to suspend coarse solids and, by recirculation through the well, isolates the upper zone which remains relatively quiescent. Froth baffles are placed between each unit mechanism to prevent migration of froth as the liquid flows along the tank. The liquor level is controlled at the end of each bank section by a combination of weir overflows and dart valves which can be automated. These units operate with a fully flooded impeller, and a low pressure air supply is required to deliver air into the eye of the impeller where it is mixed with the recirculating liquor at

the tip of the air bell. Butterfly valves are used to adjust and control the quantity of air delivered into each unit.
The liquid flows along the cell bank and passes over a weir, and directly enters the unit via a feed pipe and feed hood. Liquor is discharged radially from the impeller, through the diffuser, and is directed along the cell base and recirculated through ports in the feed hood. The zone of maximum turbulence is confined to the base of the tank; a quiescent zone exists in the upper part of the cell. These units induce sufficient air to ensure effective flotation without the need for an external air blower.

Jameson Cell

A Jameson cell consists of 3 main zones: the downcomer, the tank pulp zone and the tank froth zone.

The Downcomer is the heart of the Jameson cell where intense contact of air bubbles and particles occur. Feed is pumped into the downcomer through the slurry lens orifice, creating a high pressure jet. The jet of liquid shears and entrains air from the atmosphere. Removal of air inside the downcomer creates a vacuum, causing a liquid to be drawn up inside the downcomer. The jet plunges into the liquid column where the kinetic energy of impact breaks the air into fine bubbles which collide with the particles. The very high interfacial bubble area and intense mixing, results in rapid particle attachment to the air bubbles and high cell carrying capacities.

The Tank Pulp zone is where mineral laden bubbles disengage from the pulp. The design velocities and operating density in this zone keep particles in suspension without the need for mechanical agitation. Due to the rapid kinetics and separate contact zone in the downcomer, the tank is not sized for residence time, so tank volumes are much smaller than equivalent mechanical and column cells.

In the Tank Froth zone, the grade of the concentrate is controlled by froth drainage and froth washing. Cells are designed to ensure an efficient, quiescent zone that maximises froth recovery. Froth travel distance and concentrate lip loadings are integral to the tank design.

References:

https://www.longdom.org/proceedings/electroflotation-process-for-the-wastewater-recycling-32649.html

https://www.911metallurgist.com/blog/jameson-flotation-cell

https://www.sciencedirect.com/