Imhoflot – Imhoflot – Evolution of pneumatic flotation. Major Trends in Development of Sulfide Ores

R.M. Imhof, J.V. Brown

General

In an historical perspective there is little difference in age between the two flotation techniques; mechanical and pneumatic flotation. But during the last century, from the onset of industrialised mining, mechanical flotation was predominant. This was probably due to the status of technology and greater reliability of mechanical devices, such as rotors and stator assemblies, compared with devices for producing fine air bubbles, such as porous media. In the 1960s the principles of column flotation were adopted, but as computers and PLC control technology were still in developmental stages, the column technique was perhaps not as successful as hoped. In the 1970s the trend for larger capacity process throughputs intensified. Large flotation tanks of up to 1000 cubic feet and more became widespread and in the 1980s it was also quite usual to replace cleaner banks with columns to improve concentrate qualities.

Pneumatic flotation, like the Bahr-cell and, some years later, the Jameson-cell, were a quite separate and different development. Process kinetics of pneumatic flotation should not be compared directly with column flotation. Whereas the separation process in a column is counter-current, the Bahr or the Jameson cell operates with a co-current feed and product configuration.

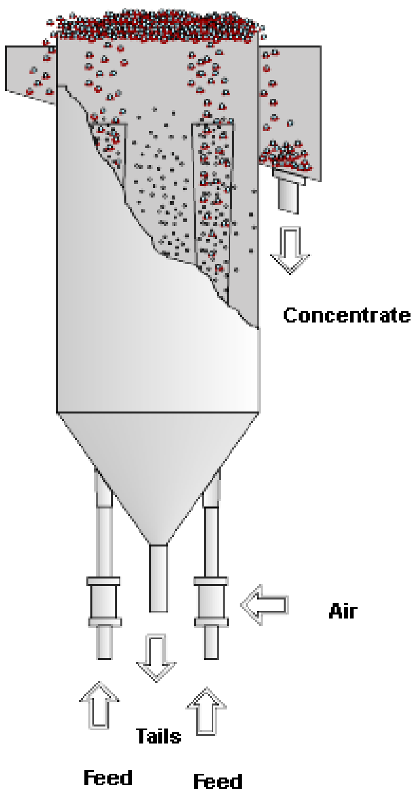

Fig 1. Bahr Cell Principles

Therefore the mineral process engineer should distinguish between mechanical (agitated) flotation, columns and pneumatic flotation. Future trends are likely to retain columns for cleaning operations, but an overlap is developing between applications for large mechanical tanks and the new pneumatic flotation systems.

The pneumatic flotation technology of today has its origins in the Bahr-cell of the late 1970s (Fig 1). At that time the first plant operations were commissioned on a coal mine in Germany. Smaller equipment suppliers manufactured the Bahr-cell under license, but little effort was contributed over the years in developing a competitive technology. In Germany, only two companies invested in research and development, and inadequate marketing resulted in a modest impact in the minerals and coal industries. In the last 15 years not more than 30 plants were sold under different trade names. In recent years, however, greater attention has been paid in development of new designs in pneumatic flotation, now called IMHOFLOT technology. These principles have been applied to commercial scale equipment designs as manufactured by Maelgwyn Mineral Services of Wales, UK.

Description of the Imhoflot Cell and the Process

Fig 2 illustrates the cell configuration. Aeration of the pulp takes place in the IMHOFLOT aerator, a patented device in which most of the applied energy is directed to the production of micro-turbulence for dispersing air and maximizing the collision events between bubbles and particles. To create this energy in the aeration unit, the pulp is fed with a centrifugal pump. The aerator device provides the essence of the flotation reaction – contact and adhesion of the valuable hydrophobic particles to the bubbles. The subsequent separation tank provides a means of recovery for the mineral loaded air bubbles. The aerator is self-aspirating, hence no compressed air is needed, and when fitted with a throttle valve the airflow into the aerator can be adjusted.

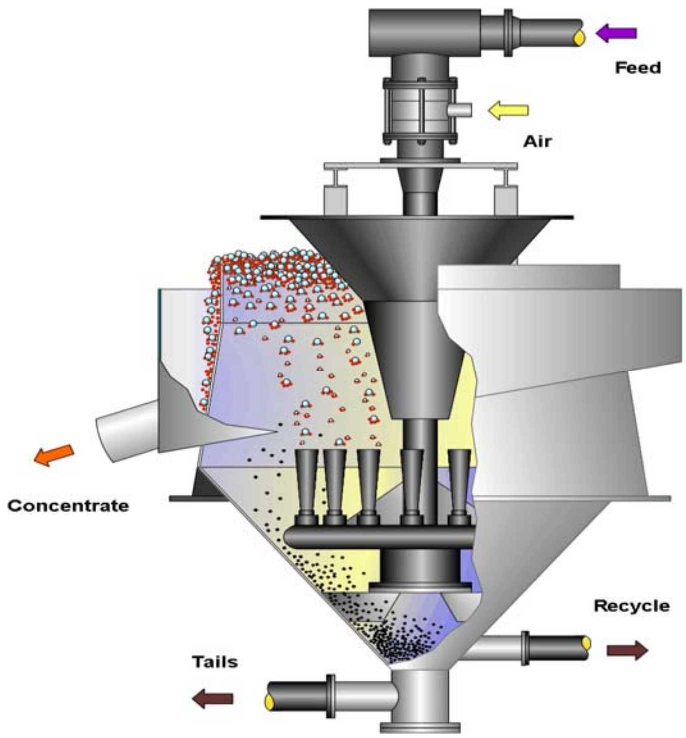

Fig 2
Imhoflot Principles

The aerated pulp flows downwards through a pipe into the separating tank, where it is distributed internally by means of specially designed nozzles fitted to a radial sparge assembly. The large number of nozzles serves to provide a symmetric and uniform supply in the separating tank, and ensure a calm froth build-up with minimal entrainment of gangue material. By this means the necessity for wash-water is avoided. The froth flows without any mechanical device into the peripheral launder. An inverted conical and concentric froth crowder, adjustable with a hydraulic drive, allows the operator to vary the cross-sectional froth area and thereby adapt the froth flow to specific process requirements.

The retention time in the separating tank is normally about 2,5 min. One pass through a cell generally provides a similar recovery to that produced by treatment in conventional mechanical cells for 8 to 10 min. For example, if the layout for conventional cells for a roughing flotation process were designed for 20 min, then three pneumatic cells in series would obtain a comparable recovery. But the quality of the froth achieved in the pneumatic cell would be significantly better. The recovery of a single pneumatic cell cannot be improved by prolonging the retention time in the separation tank, since the essential flotation reaction has already taken place, as mentioned above, in the aeration system and in the distribution assembly. Additional collecting of valuable mineral in the tank itself is insignificant. Longer retention times would not improve recovery, and shorter times run the risk of loosing fine mineralized bubbles with higher velocity down-flow near the bottom outlet of the tank.

An additional feature of IMHOFLOT design technology (Fig 2) is the recycle of a portion of the tailings flow. A dedicated pump and bleed stream to the main feed pump of the same cell usually provides this. This means that the recycle portion has a second pass through the aeration system and hydrophobic particles not recovered in the first pass have a new chance to be collected. As this recycle pump feeds into the surge pipe of the main pump, the energy consumption for this recycle is very low.

Construction of the aeration unit uses ceramic components, which are highly wear resistant. Flow velocities in the aerator are designed to be almost 20 m/s, which is intended to achieve a wide range of bubble sizes in order to float fine particles as well as coarse ones. Pressure loss requirements for the aerator are between 2 and 2,5 bar.

The pulp distributor in the separating tank is constructed with wear resistant high-density polyethylene, and nozzles are made of polyurethane and ceramics as required.

Sizing and Plant Layout

While demonstration units and bench top units have been tested in the past, reproduction of the high performance of full-scale units can be difficult to achieve. Smallest pilot cells should therefore have an internal tank diameter of 1m, while the standard pilot size is 1,4 m for a throughput rate of 25 to 30 m^3 pulp per hour. Their results provide reliable data for scale-up. Full scale sizes for plant operations start with 2 m diameter for 100 m^3/h, and a 3,5 m size can process about 450 m^3/h. The biggest cell in operation so far is 5m wide and can treat more than 1000 m^3/h.

Plant flow sheets (Fig 3) are simpler than those of conventional layouts, where, due to the higher selectivity, less cleaning circuits are needed. For easily floating copper ores in Chile only one cleaner stage is needed to obtain a saleable concentrate after rougher flotation. There are plants operating adequately in Chile with two cells in series for roughing, followed by two smaller cells for cleaning.

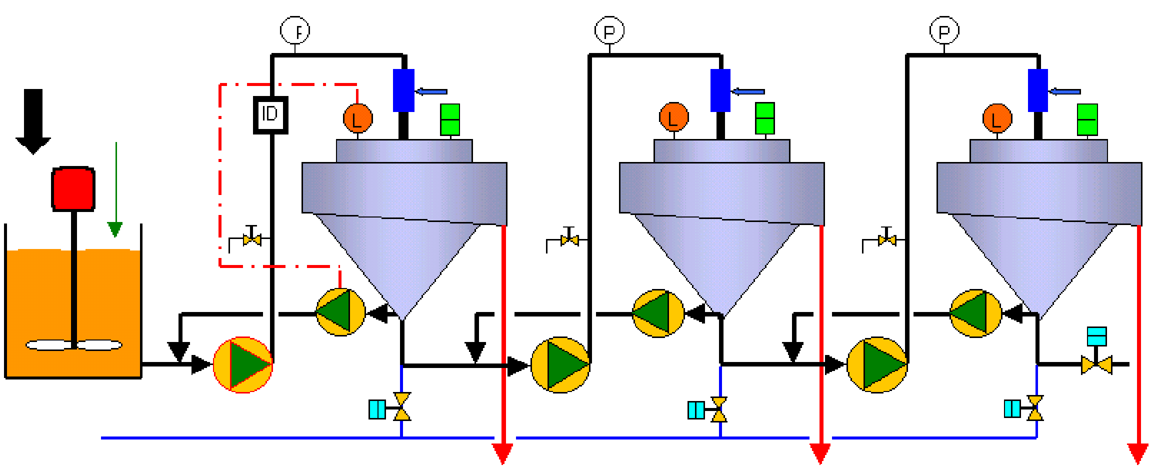

Fig 3
Imhoflot Process Flow Diagram

For an estimate of the number of cells required for economic recovery in the rougher-scavenger circuit, batch flotation tests in a conventional laboratory cell provide sufficient information. It is generally preferable, however, to operate a pilot plant to treat a bypass from an existing plant. This is possible, if this plant is to be retrofit or expanded. The test rig should consist of three cells in series to produce full recovery data. The pilot rig can be used at different points of the existing process circuit e.g. on the tailings, to test potential improvements in performance. The feed to the cleaners in particular should be tested, to prove the benefits of the technology, in terms of cost savings for replacement, and furthermore to prove by how much the current concentrate quality could be improved. The payback for the investment of one or two cells can generally be accommodated within one year.

An ideal application in existing base metal plants is the installation of an IMHOFLOT cell in the underflow stream of the mill circuit hydro cyclone. Because of high specific gravities of base metal minerals many particles which are sufficiently liberated may be returned to the mill via the cyclone underflow. These often-brittle particles become over ground in the mill, and when they eventually reach flotation, are rendered less floatable, due to their fineness. This problem can be solved by installation of a pneumatic cell to treat the underflow of the mill cyclone. Yield of froth at this point will mostly be of final concentrate quality.

Plant Results

Base Metals

The first pneumatic flotation cell in Chile was commissioned in 1995 in the rougher circuit of Compania Minera Michilla, North of Antofagasta. The ore mineralogy consists of chalcocite, covellite and oxidized Cu-minerals. The cell demonstrated significant performance benefit and two larger cells were ordered to expand the plant production. The first pneumatic flotation cell was moved into the cleaner circuit in order to produce the final concentrate. Existing mechanical cleaners were re-utilised as cleaner-scavengers. Due to the increased capacity of the two pneumatic cells, each of 3m diameter, the production rate was increased, but also the enhanced performance improved the overall recovery. In 1994, prior to installation of pneumatic flotation, the recovery for the sulfide copper had an average of below 90%. Subsequently the capacity of the plant was increased by 30% and the recovery reached 95%. The mechanical cells that were previously used for rougher flotation of the sulfides, now increased the capacity of the oxides. Two years later a further pneumatic cell was installed to improve the capacity of the oxide flotation circuit.
Compania Minera Tamaya, near Ovalle in Chile, operated a small mill for recovering copper and gold in 1997. The entire flotation circuit was replaced with pneumatic flotation cells. Two pneumatic cells were installed for rougher flotation and two cells for cleaning. Some of the conventional cells remained in the process as scavengers.

Coal

Pneumatic flotation was initially developed with the coal industry in mind. Mechanisation of German underground mines and hence increased fines production, necessitated low cost, high capacity flotation systems to be adopted in coal preparation plants. By way of example the Lohberg mine in the Ruhr district chose pneumatic flotation after initial pilot scale tests with the following considerations:

- 50% savings for civils and infrastructure costs, compared with conventional flotation.
- 25% savings for equipment and instrumentation.
- 50% savings in energy and maintenance operating costs.

The guaranteed performance at Lohberg provided a 7% w/w ash content coal from a 20% w/w feed of <0.5mm, and a recovery of 90% (for <1.5 t/m^3 coal). This was achieved using two 5.0 m nominal diameter cells in series with a throughput capacity of 750 m^3/h.

Industrial Minerals

Pneumatic flotation has been applied in the successful beneficiation of apatite, fluorspar, magnesite, potash and fly ash (PFA) materials. For example, pneumatic flotation for magnesite scavenging from conventional flotation tailings was adopted at Hochfilzen (Radex AG) in Austria. The blended tailings and crusher fines containing up to 16% CaO were treated using a five stage plant consisting of 1.8m diameter cells with a capacity of 17t/h (dry solids). Recoveries in excess of 70% were achieved, with product grades less than 3% CaO requiring no further cleaning. As an example of cleaning capability, installation of two stage pneumatic flotation in a potash beneficiation plant for Hartsalz ore produced a KCl rich concentrate of up to 62% K_2O quality.

Environmental Applications

Oil-water separation, soil washing and remediation, vegetable oil effluent treatment, and landfill leachate treatment are examples of potential applications. A difficult case was presented during remediation work at the Berlin Congress Hall. Accidental loss of fuel oil and kitchen effluents had started contaminating groundwater after soaking into the underlying soil strata. As conventional removal and soil washing was not possible, specially cultivated water-borne microorganisms were pumped into the ground and extracted from a wide spread system of wells. Discharge water contained organic hydrocarbons to a level of 500mg/l, and regulated surface water limits were 10mg/l. Organic recovery was achieved by using inorganic emulsion separators, flocculants and pneumatic flotation of the subsequent product. A single stage flotation plant achieved the effluent discharge limit, and it was also demonstrated that a second stage could reduce the effluent level to less than 1mg/l.

In an East German oil refinery, two 3.6m nominal diameter pneumatic flotation cells have been used to treat contaminated water at the rate of 260 m3/h.

Since 1998 Eberhard Recycling of Switzerland have used two 2,3 m diameter cells in series to treat up to 30 t/h sand, with a size distribution of 95% between 2mm and 63µm. The process removes contaminations of polyaromatic hydrocarbons. The aerator and cell designs tolerate these coarse abrasive sands with virtually no wear, whereas effects can be seen even in heavy-duty pumps.

References

- Imhof R M, (1988) Aufbereitungstechnik (29). "Pneumatic flotation – a modern alternative."
- Imhof R M, (1993) Aufbereitungstechnik (34). "Five years of Ekoflot: Pneumatic Flotation on the March."
- Imhof R M, et al (1993) XVIII International Mineral Processing Congress Sydney. "Pneumatic Flotation: a Reliable Procedure for a Correct Plant Layout"
- Imhof R M, et al (1994) Sixth Australian Coal Preparation Conference, Mudgee NSW "Developments in EKOF Pneumatic Flotation Technology"
- Imhof R M, (1999) Freiberger Forschungshefte 1999 Berg und Hüttenmännischer Tag."Pneumatic flotation in general and as example an application in a soil remediation plant."
- Imhof R M, (1999) Sortieren, Innovationen und Anwendungen, TU Berlin 1999. "Agitair cells, columns and pneumatic flotations – their characteristics in the techniques, their applications for raw and waste materials."

Authors

- Dr R. M. Imhof - Director

Maelgwyn Mineral Services,
Leharweg 23, 46282 Dorsten, Germany

- J. V. Brown – Process Engineer

Maelgwyn Mineral Services,
4a Mostyn Street, Llandudno, N. Wales UK