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НОВА И ИДНА ГЕНЕРАЦИЈА НА ФЛОТАЦИСКИ МАШИНИ

A NEW AND A FUTURE GENERATION OF FLOTATION MACHINES

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Introduction

The increase in the prices of base metals restored the impetus for the development and expansion of flotation, together with a deeper search for knowledge about its theoretical principles. Efforts continued towards improving both quantitative and qualitative parameters of flotation, while simultaneously reducing costs. As well as the trends toward larger cell sizes, and the floating grains at larger particle sizes, significant applications of column flotation were reported.

The flotation of both ores and industrial minerals is currently the most widely used physical treatment method. In the future, it'll encompass the treatment of more than 95% of total ore reserves.

After stagnation in the last two years, revival of the technical process proceeded in 1986. Whereas, in the last two years, advantages of previous research were applied in practice, in 1986 the first results of recent research appeared. New designs of large-volume flotation machines asserted themselves in all areas of mineral processing; only the most conservative designers still hesitate to take advantage of the energy savings of these designs. Installation of large- scale cells in flotation lines is still in the forefront of interest. It seems that the growth of the cell volume, which is today up to more than 60 m^3, will be limited only by the limit of growth of the grinding equipment able to supply one line of the large-volume cells.

The application of large-volume cells is continuing, bringing high economic benefits for both flotation plants and mining companies. In addition, the separate treatment of coarse-grained fractions in the flotation pulp will become much more common throughout the world, bringing both qualitative and quantitative improvements, while the replacement of toxic reagents will be essential for environmental protection. The large flotation cells application has had an enormous economic effect, with the principal manufactures being companies such as Minpro, Denver, Dorr-Oliver, Outokumpu, Sala and Wemco.

Essentially, the concept is simple: large flotation cells are more efficient at recovering valuable mineral, and are more economical in doing it, than small cells. There has been a noticeable trend in recent years for the installation of high-capacity cells into both new concentrators, and also as retrofit equipment during concentrator modernization programs. Most of the world's principal flotation equipment manufactures have been involved in the development of this technology, and it has been installed, or is in the process of installation, in many of the industry's major sulphide recovery circuits.

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Column flotation cells have received world-wide attention from designers, engineers, investors and technologists. These cells, have large volumes, so enabling the whole operation to be undertaken in one unit, giving significant reductions in the required floor space and energy usage. Column cells offer fewer flotation stages and circuit simplification. Research teams and manufacturers are working towards improvements in column flotation machines from two directions: improvements to column design, and the development of better aeration nozzles.

Development work on flotation had shown that the performance of conventional, mechanically-agitated flotation machines is limited by the depth of froth that can be produced. More efficient flotation cleaning can be achieved by using a deeper column of froth, which promotes a longer retention time. These flotation machines, the column cells, besides being much taller than conventional units, use compressed air, introduced near the bottom of the column, to provide the agitation normally produced by mechanical means. The fineness of the particles makes this possible, because these units are used in the cleaner circuit. In addition to cells with propellers, column flotation cells asserted themselves. Research on these units is still in progress. The column cell consists of a mineralization zone where pulp mixing and formation of bubbles occur, and a cleaning zone. Another new feature was been the theoretical elaboration and practical realization of the conditions for flotation acceleration and intensification. The performance of impeller-type cells is limited by the low rate of mineralised bubble formation, the slow rise of the bubbles to the froth layer, and insufficient energy of the mineral particle to penetrate the water film of the bubble. Improvements to the design of aerators, using perforated hose systems to optimize bubble size, and aerating chambers based on the principal of air suction have been introduced in an effort to reduce flotation energy consumption.

Column vs. Mechanical Flotation

The choice between column and mechanical cell is in fact becoming fundamental in the design of new circuits. Increased gas rates, froth thickness and the use of wash water for increased cleaning point to column flotation. Evidence also suggests that effective selectivity requires very thick froths, up to 2 m high, such as in column. Thus it's unsurprising that when selectivity, rather than cleaning, is the objective, many stages of mechanical cells can be effectively replaced by a single column. Which are the guide- lines?

The traditional view is that columns will out perform cells for difficult separations, when selectivity is more important than cleaning. This view is in excellent agreement with results presented in this chapter, but it can be refined. For example, columns are usually not thought to be good scavangers. This may need to be re-examined. Scavenging normally requires thin froths, because the low concentration of hydrophobic particles yields weak froths. The column, with its low surface area to slurry volume ratio, concentrates these particles; water addition further stabilizes the froth. Thus thicker froths can be used, with better separation and decreased circulating loads. There is at least one such application of columns for scavenging, for gold-bearing sulphides.

Columns are increasingly used not only as cleaners, but also as roughers and scavangers. This begs the question: are mechanical cells doomed? To answer the question, it may be useful to consider applications where the cell outperforms the column. Applications of coarse flotation, such as potash, phosphates, or flash cells in grinding circuits, are unlikely to become column applications, because of the low residence times of coarse particles. Another

limitation of columns is their carrying capacity, low because of the low froth surface to slurry volume ratio. Columns can be used in parallel to solve this problem, but the water balance can be a problem. A better approach may be a first recovery step by mechanical flotation, followed by a scavenging column. This would be applicable where feed material contains a large fraction of coarse well liberated hydrophobic particles, such as for coal.

Advanced, Developing and New Flotation Technologies

The recent years have seen the re-evaluation of earlier novel flotation machines and new innovative designs. Their introduction was led to improvements in process economics, through savings in both capital and operating costs, as well as improved performance and grade and/or recovery. In general, as process tonnage has increased, the potential benefits of the larger machines have become even more evident, greater use of floor space, cheaper installation costs, more efficient power utilization, and lower operational/maintenance manpower requirements.

Conventional Cells

Flotation has for many years been conducted in banks of stirred tanks. The use of a number of tanks in series helps to overcome problems of short-circuiting that would occur in one larger tank. The major development in the evolution of the conventional flotation machine has been the steady increase in the size of individual units. Among the factors having an influence on flotation circuit design are the following:

- ◊ the need of effective volume is as necessary in a large as in a large as in a small cell;
- ◊ the selectivity of large cells is often better than that of small cells, because of the thick froth layer;
- ◊ the possibilities for controlling product quality by adjusting air and/or pulp level are better with large cells, because there are fewer control points.

The above mentioned companies have manufactured a range of flotation cells. Bateman Equipment Ltd manufactures cells from special features which include U-shaped tank, internal launders and specially designed rotors and stators, which are claimed to give enhanced metallurgical performance and reduced power consumption, cell sizes ranging from 38 m^3. Denver Equipment Company manufactures two basis flotation machine designs: Cell-to-Cell and DR (openflow) types. Developments in the mining industry have led Denver to develop open flow (DR) machines for high-capacity roughing, cleaning and scavenging flotation applications. These cells utilizes vertical circulation of pulp, drawing the pulp through a recirculation well above and through the reversible, rotating impeller, mixing the slurry with low- pressure air. The first installation from 28 m^3 volume are renewed in 43 m^3 volume. The future of flotation development at Denver will be guided by economic considerations for larger volume flotation machines exceeding 85 m^3. The Dorr- Oliver Company Ltd. manufactures flotation cells in a wide range of sizes, from the DO-1 to DO-1550 (44 m^3). Amongst factors giving low power consumption is the company's design of stator, which is of a new overhung configuration with legs that hold the stator clear off the bottom of the cell tank: hence there is no restrictive baffling effect in the lowest circulation zone. The Outomec Oy, part of the Outokumpu group of companies, is a leading supplier of flotation machines and equipment with cell sizes ranging from 0,05 m^3 to 100 m^3. The patented OK mechanism ensures excellent air dispersion and the impeller keeps solids in suspension throughout the

cell volume. The smaller impeller diameter allows easy start-up in fully sanded conditions and its low peripheral speed reduces wear. The U-shaped tank ensures minimum sanding and reduces short-circuiting. Contemporary, the Outomec introduced the Flash Flotation Method, which eliminates overgrinding by recovering coarse, liberated valuable minerals from the grinding circuit, processed in a special coarse flotation cell (Skim-Air). The Wemco has long been a leading manufacturer of large flotation equipment. After the first introduced installation from 28,3 m^3, Wemco produced cells in ranging from 45 m^3 to 85 m^3. In the development of larger flotation units, Wemco realized that flotation machine size scale-up must satisfy the following hydrodynamic functions simultaneously: provide good air-pulp contact and mixing; maintain a stable pulp-froth interface; adequately suspend the solids in the cell; and provide sufficient froth removal capacity.

Column Cells

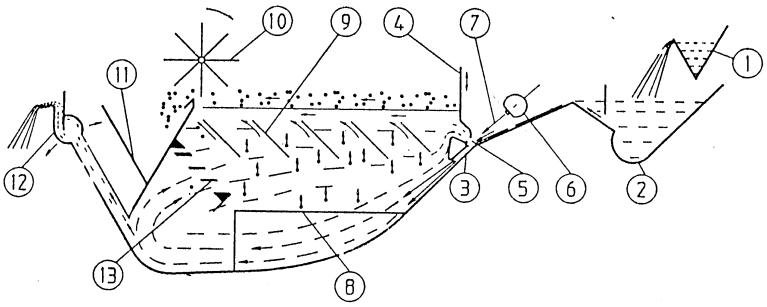
Column flotation has experienced a recent revival of interest which has been fueled by a better understanding of column fundamentals and the many benefits it offers when incorporated into processing flowsheets. These included the following benefits: better processing performance; reductions in capital and operating costs; suited to simple automatic control; ability to efficiently treat very fine mineral particles. Flotation column are now well established in the processing of base metal ores and being considered and adopted for precious metal, industrial minerals and coal processing. The elimination of entrainment can bring the separation achieved near to the "ideal separation". Various designs of flotation column are being promoted, including microbubble column flotation, packed bed columns and stirred columns. These cells do have disadvantages, the major problem being their height requirement. It has also been found that where rapid oxidation of mineral surfaces is a problem the relatively long residence time of fine particles in a column can cause the column's performance to be worse than that of conventional cells.

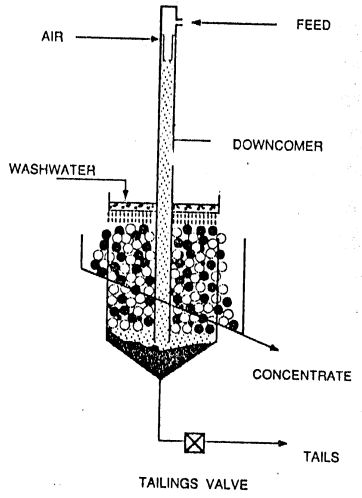
The Canadian "conventional" column operates without the use of a stirrer or impeller. The feed slurry after appropriate "chemical" treatment is fed into a tall vessel, up to 12 m in height, where it contacts a rising stream of air bubbles introduced at the bottom of the column. The Cominco Engineering Services Ltd. is one of the world's largest suppliers of column flotation equipment worldwide with diameter sizes from 152 mm to 4,6 m. All characteristics including grade improvements, lower operating cost, lower capital cost, and superior control are present in these cells. CESL's cells have been applied to date on such metals as zinc, lead, copper, iron ore, and gold, as well as a range of non-metallics such as coal, talc, graphite and phosphates, successfully operating in Australia, Canada, Chile, the U.S., Peru, the R.S.A. etc. The main features of CESL's technology is the patented Cominco air sparging system used to generate the fine air bubbles necessary for flotation. Bubble generators are no longer required and have been replaced by pre-mixing air and water.

The Deister Concentrator Company has manufactured and is one of the most advanced column flotation cells on the world market. The Deister Flotaire Bubble Generator System generates the fine bubbles external from the column flotation cell and introduces the microsized bubbles into the column cell through open-ended, flexible plastic tubes. There are many developing news also. With over 170 column flotation cells in commercial operation world-wide, Deister is one of the world leader in column flotation cell manufacture and operation.

A Future Generation of Flotation Machines

Flotation has received much research and development over the last decade, primarily due to the popularity of column flotation and the quest to understand its operation, resulting some new forms of flotation cells. Some of them are the Wemco/Leeds column, the Air sparged hydrocyclone, the Jameson cell, the Contact cell, the Fastfloat cell, the Packed column, the new versions of pneumetic machines such as the EKOF cell, the Large-diameter column flotation cells etc. The most important of these new developments is the Jameson Cell which is based on premixed air/slurry and has received widespread commercial application. This cell draws ambient air into a few downcomers by a venturi effect and is capable of injecting approximately one volume of air per volume of slurry (a holdup rate of 50%). The Jameson cell has successfully applied in five different plants in Australia, such as in three distinct processes (Pb-Zn ores) at Mount Isa Mines; at the Newlands coal mine; and at Peko Mines - copper concentrator.





The principle of the Jameson cell.

Fig. 1

The second one very important innovative and a new development is the FASTFLOAT cell developed by the Flotation Group of M.D. Research Co. specially to process complex, finely mineralized ores requiring a five grind to liberate wanted mineral. The future processing of above mentioned ores before any benefaction process may be commenced. While current flotation technologies can handle the flotation of moderately fine (10 microns) to medium fractions (100 microns) reasonably well, they are ill equipped to yield reasonable flotation rates and hence reasonable concentrate grades and recoveries for very fine particles in the 1-10 microns range. This problem is fundamentally linked to the mechanism of mineral particle collection on the bubbles surface. Chudacek has explained three accepted mechanism. The Fastfloat cell maximizes use of hydraulic energy through its unusual shape: when the pulp reaches the point of discharge there is virtually no energy left in the stream, all having been utilized to perform useful tasks. The process claims much higher flotation rates than mechanical flotation cells and typically requires only 25% to 33% of the residence time of a

conventional circuit. The process is suitable for cleaning and recleaning duties when treating hard-to-float ores, as well as for processing finely ground ores. It can also be used as a pre-float stage when circuit residence time is inadequate for high recovery.

The third very important and a future generation of flotation machine is the CONTACT CELL which consists of two parts: the Contactor, where the mixing of air and slurry takes places, and the Separation Vessel, where the mixture is allowed to disengage into concentrate and tailings. The latter functions are column flotation units ones. The "Contact Cell" can achieve very high degrees of controlled air holdup and contains:

◊ Air sparging within the contractor with a USBM-type sparger to provide bubble size control;

◊ A pressurized contactor for further air holdup control; -A separation vessel with the washing features of column flotation.

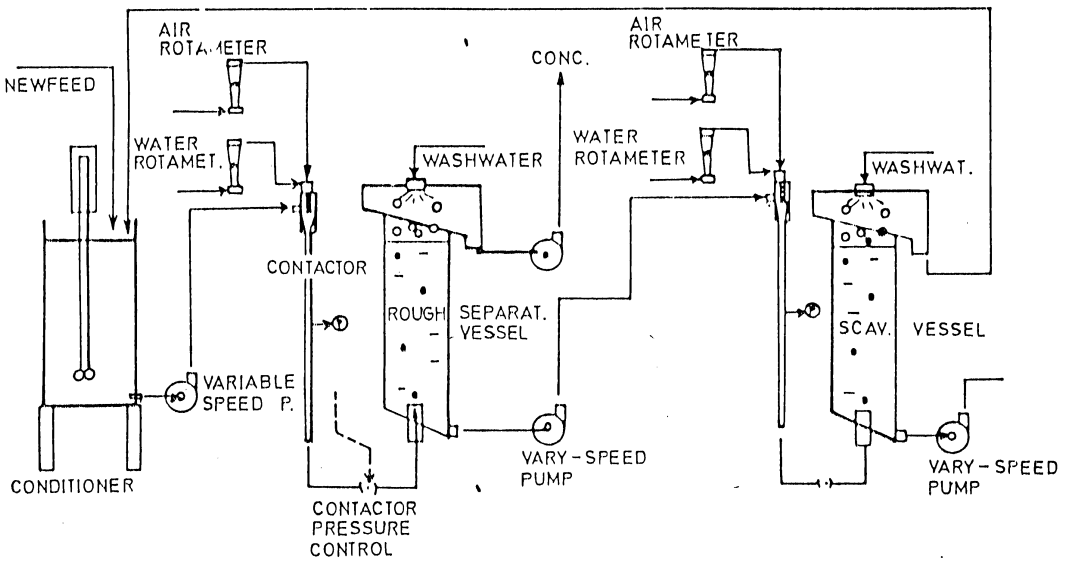


Fig. 2

The variables affecting kinetics are air rate, air holdup (i.e. bubble size), contactor pressure, contactor residence time, and slurry characteristics (i.e. percent solids, particle sizing etc.). Affecting the performance of the Separation Vessel are the bias rate, froth depth, and to some degree, dispersion characteristics. The overall test results gave grade/recovery curves that were generally improved over those obtained by the plant using conventional cells. The Contact Cell's fast kinetics, froth washing characteristics, and compactness are likely to encourage the development of a new generation cells for processing plants.

The other developments have had a significant role in the future processing practice. The Air-Sparged Hydrocyclone (ASH) is an exciting new technique of mineral recovery suggested in a contribution by authors from South Africa. The technology combines froth flotation principles together with the flow characteristics of a hydrocyclone such that the air-sparged hydrocyclone system can perform flotation separations in a matter of seconds or even less. The most important feature of the ASH is its high specific capacity which corresponds to significant savings in capital cost (i.e. equipment and floor space). The system is essentially a cross between the traditional hydrocyclone and flotation, for its principal difference is that air

is injected through the wall of the cyclone. Air bubbles are formed which, as in flotation, attach to non-wettable mineral particles. These then are floated out of the pulp in the cyclone and report to the overflow, while the wettable particles, to which the air bubbles do not attach, form the underflow. The use of cyclones instead of flotation cells about coal cleaning, the volcanic sulfur ore flotation, and the low grade sulphide or gold-bearing sulphide minerals recovery offers the potential for much higher throughput rates per unit volume than are achieveable today with flotation. However, the consumption of the flotation reagents, such as collectors, is bigger than in conventional cell. Obviously, more work is still required, but with interest growing in the process in various centres around the world, there is clearly good potential for this system to be developed into a satisfactory, economic method of minerals recovery.

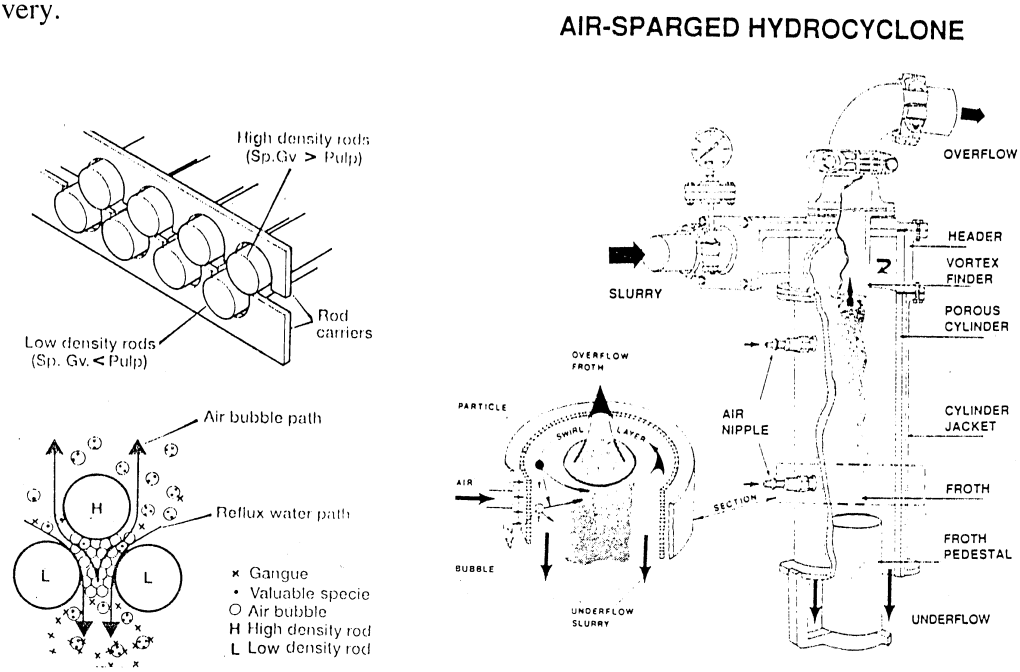


Fig. 3

In addition to conventional mechanical and pneumomechanical flotation cells, the innovative and new flotation column of various types and designs are used more and more. An intermediate type is the WEMCO/LEEDS cell which has a bottom- driven impeller and a totally unimpeded open top with a batch column with its stages of teetering barriers sitting upon the flotation cell. There are a number of horizontal barriers which are arranged vertically, one above the other, separating the pulp in the column into a series of vertical compartments. The results show (Cyprus Bagdad copper concentrator) significant improvement over conventional flotation.

The example-form of pneumatic flotation is the EKOF-system. This one has enabled the suspending of particles, transporting pulp and producing small air bubbles by means of several units connected in line, each optimizing its specific task. The reagentized pulp is distributed to a number of aerators surrounding a separation vessel. In comparison to conventional flotation methods, equipment and machinery costs are reported to decrease by 30-60% depending on the number of stages. EKOF system have been installed in USA for coal slurry treatment obtaining concentrates with 8-9% ash from a feed containing in excess of 50% ash.

The next interesting possibility is the LARGE-DIAMETER COLUMN FLOTATION CELLS. The level of reliability of these larger units has reached a point where the equipment can be selected with confidence. These ones have been found to have a number of cost advantages over smaller units that merit their consideration. Looking to the future, it'll be interesting to see over the coming years what the upper limit for cell size will ultimately become. The lower capital costs, the confidence air-sparging system, the carrying capacity limits are advantages which have to show to Research & Skill Groups of the appropriate teams to make up their mind - to choice or not Large-diameter flotation column, the round vs. square cross-section etc.

Conclusion

Until recently flotation was almost completely dominated by the conventional-mechanical agitation type units, in the recent years are appeared the re-evaluation of earlier novel flotation machines and new innovative design. All of them are characterized with their improvements in process economics, savings in both capital and operating costs, improvements in both performance and grade/recovery. Which are guidelines and the next directions? The choice between traditionally conventional methods or a new innovative-future generation flotation cells. The decision is being a question of time.

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