PRE-CONTACT COLUMN FLOTATION MACHINES – DESIGN FEATURES AND PRINCIPLES OF OPERATION

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ABSTRACT. Over the past few decades, flotation has been one of the fastest developing and commonly applied processes in the mineral processing industry. Along with that, the flotation machines are constantly developed, modified and improved. The pneumatic pre-contact flotation machines are representatives of a new generation of flotation machines with a number of design features that improve the flotation process. This article discusses several types of pneumatic pre-contact flotation machines e.g., PNEUFLOT, SFR (Staged Flotation Reactor), IMHOFLOT, and SIMINE Hybrid Flot.

Keywords: column flotation machines, pre-contact flotation

КОНСТРУКТИВНИ ОСОБЕНОСТИ НА ФЛОТАЦИОННИТЕ КОЛОННИ МАШИНИ С ПРЕДВАРИТЕЛЕН КОНТАКТ

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РЕЗЮМЕ. През последните няколко десетилетия флотацията е един от най-бързо развиващите се и прилагани процеси при преработката на полезни изкопаеми. Паралелно с това се развиват, модифицират и усъвършенстват флотационните машини. Представители на едно ново поколение флотационни машини са флотационните машини от колонен тип с предварителен контакт. Те притежават редица конструктивни особености, които подобряват флотационния процес. В настоящата статия разглеждаме няколко типа колонни флотационни машини с предварителен контакт, а именно PNEUFLOT, SFR (Staged Flotation Reactor – Стъпков флотационен реактор), IMHOFLOT и SIMINE Hybrid Flot.

Ключови думи: колонни флотационни машини, флотация с предварителен контакт

Introduction

Contemporary requirements in the field of pulp aeration theory and air bubble mineralisation require the creation of pneumatic pre-contact flotation machines. Those are representatives of a new generation of floating machines which are used in the flotation of ores of ferrous and non-ferrous metals, precious metals, coal, and other minerals.

The pneumatic pre-contact flotation machines are representatives of a new generation of flotation machines with a number of design features that improve the flotation process. The mixing of the solid and gas phases in an aqueous medium is carried out in advance, outside the volume of the flotation cell, in heterogeneous devices designated by the various manufacturers, such as aeration devices, mixing chambers, and others. The elementary flotation act (attachment of hydrophilic solid particles to air bubbles) occurs in these devices. Pre-contact flotation machines do not have an impeller system which means there is no wear and tear in the stator-rotor system. Another important feature is the ability to create finer air bubbles and lower air consumption than conventional pneumo-mechanical machines, resulting in flotation of fine products and production of high-quality concentrates.

This paper explores some of the most widely used column pneumatic flotation machines operating under the flotation method with pre-contact, in the process of studying the efficiency of the processing of a variety of raw materials (the feeding of the flotation cell, the pulp aeration, the residence time, and others). They are as follows: PNEUFLOT (MBE Coal & MINERALS TECHNOLOGY), SFR (Woodgrove Technologies), IMHOFLOT G-Cell (Maelgwyn Mineral Services Ltd.), and SIMINE Hybrid Flot (SIEMENS).

IMHOFLOT

Pneumatic flotation, as developed by Dr Rainer Imhof, has been applied in commercial beneficiation operations since 1987. Over 85 flotation cells have been installed in more than 30 operations successfully treating a wide range of minerals. Flotation machines with a pre-contact collar type column include: power supply, air bubble generation, bubble/particle contact, and phase separation of the froth from the tailings. The Imhoflot V-Cell design is presented in Figure 1. The suspension is pumped with sufficient fluid to obtain intense aeration of the air and rapid dispersion for efficient air bubble/particle contact (Imhof et al., 2005).

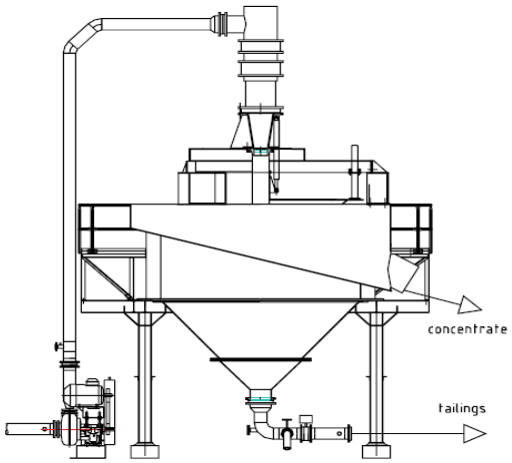

Fig. 1. Imhoflot V-Cell (Imhof, et al., 2005)

The aeration unit, or bubble generator, is a fundamental component of the process and is constructed of fused silicon carbide components to protect it from wear. Bubble sizes generated by the aerator have been measured in the range of 10 μm to 1500 μm, with the statistical average being around 300 μm (Brown, 2001). Figure 2 shows an Imhoflot aerator in assembly. The Imhoflot V-Cell incorporates froth level control and variable cross sectional area for froth removal; both can be used to control mineral enrichment and mass pull (Imhof, 2000).

Fig. 2. Imhoflot – aerator in assembly (Imhof, et al., 2005)

Pneumatic flotation technology of Imhoflot has been developing over a period of over 25 years. This has led to the development and patenting of G-Cell Imhoflot, where the application of centrifugal forces to accelerate the elemental flotation act results in a significant reduction in the amount of space required for the flotation equipment (Imhof, et al., 2005). Figure 3 shows the Imhoflot G-cell flotation machine.

The Imhoflot flotation machines are characterised by high selectivity and a number of advantages such as: efficiency in the extraction of fine (<20 μm) and large (> 350 μm) particles; absence of moving parts; low power consumption because no rotor/stator is needed to stir the flotation pulp.

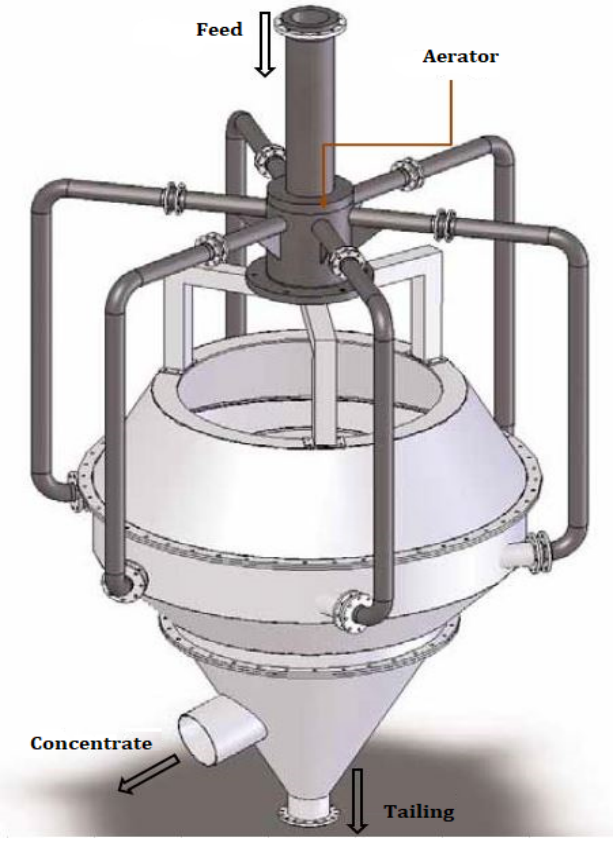

Fig. 3. Imhoflot G-Cell (https://www.maelgwyn.com, 2018)

The elemental flotation act in the Imhoflot flotation machine takes place outside the cell where pre-contact is taking place. The separation and recovery of the valuable component is performed in the cell without requiring mechanical dispersion of the air phase. The flotation process takes place at a high speed. The pulp is discharged through the aeration facility by means of a centrifugal pump which provides the necessary energy for complete aeration of the pulp. The aeration system has a self-priming aeration device. With the Imhoflot pre-contact flotation machines, a higher recovery is achieved, with a very short retention time of the flotation pulp in the cell. It is also possible to make large variations in the feed rate and the grain size of mineral particles. The design of the distribution pipes, the aeration unit, and the flotation cell allow easy assembly and replacement of the parts (repairs). The main parts are made of ceramics and wear-resistant materials. The flotation line is fully automated and operated using a PLC. The process is suitable for recovery hard-to-float minerals, resulting in reduced initial investment and subsequent operating costs (Imhof, 2000).

PNEUFLOT

The first PNEUFLOT pneumatic flotation plant was put into operation in Pennsylvania in 1987. The installation, owned by Pittstone Coal Co., is for coal flotation, and since then PNEUFLOT has been widely applied in the processing of coal and coal slimes, industrial minerals, iron minerals, and non-ferrous metals such as copper, lead, nickel, and zinc and precious metals - platinum, gold, silver and etc.

The PNEUFLOT pneumatic flotation machine with a pre-contact collar type column is based on the principle of mixing the air and solid phases in a continuous flow. The preliminary contact between hydrophobic mineral particles and fine air bubbles takes place in special aeration devices. The introduction of the aerated pulp into the flotation cell ensures the formation of air bubbles with a size appropriate for the respective flotation cycle. The flotation pulp is fed forward to the aerator located in a vertical tube above the flotation cell. After aeration, the pulp stream is introduced through the central tube into the distribution nozzles located at the bottom of the cell. Air bubbles covered with hydrophobic particles rise to the top of the cell and form a froth layer on the surface that separates around the cell. The particles that remain unattached to the air bubbles are detached at the bottom of the cell. The pulp level is kept constant by means of a gooseneck that actuates a control valve. The kinetic energy required for bubble/particle adhesion is generated by the turbulent flow of pulp in the aerator. The required flow and pressure are achieved by a feed pump for the suspension. The slurry is pressed through small wear-proof ceramic nozzles distributed in circles pointing to a large Venturi, thus creating a vacuum when the pulp is pumped through it. This effect pulls air into the pulp. The circular arrangement of the nozzles distributes the pulp flow creating the necessary turbulence for intensive air bubble/mineral particle contact. The air supplied serves both to aerate the slurry and to stabilise it. Furthermore, all parts exposed to friction are made of special rubber and ceramic materials that ensure their wear resistance. These aerators are offered in various sizes to suit different pulp flow rates and different mineral throughputs. Therefore, only one aerator unit per flotation cell is needed to achieve high performance. Another advantage of PNEUFLOT is the ability to obtain bubbles with a very wide range of sizes (0.00-1000 μm), with the same equipment being used in all stages of flotation - from rougher to scavenger and cleaner flotation (MBE Coal & Minerals Technology GMBH – Pneuflot, www.mbe-cmt.de, 2018).

Figure 4 shows industrial installations of the PNEUFLOT flotation machine (left) and the PNEUFLOT laboratory flotation machine (right) used for the laboratory flotation experiments.

Fig. 4. Industrial installation (left) and PNEUFLOT laboratory flotation machine (right)

SFR - Staged Flotation Reactor

The Staged Flotation Reactor has been developed thanks to the efforts of a team of specialists who have explored the shortcomings of both conventional flotation machines and those of a new generation, trying to improve the major stages of the flotation process. In this way, the team has created a flotation machine with a pre-contact column type which separates the three stages of the flotation process into three different reaction zones represented in Fig. 5: zone 1- particle collection unit (PCU); zone 2 - bubble disengagement unit (BDU); and zone 3 - froth recovery unit (FRU).

SFR is a technical and technological innovation in the flotation practice. It has several advantages: flotation conditions with pre-contact between the solid and air phases; reduced electricity consumption; less equipment area; significantly lower air consumption; a smaller number of cells; lower maintenance costs; better control scheme and easier automated control. The rate of the flotation process and the content of the valuable component in the concentrate is higher (www.woodgrovetech.com/SFR.html, 2018).

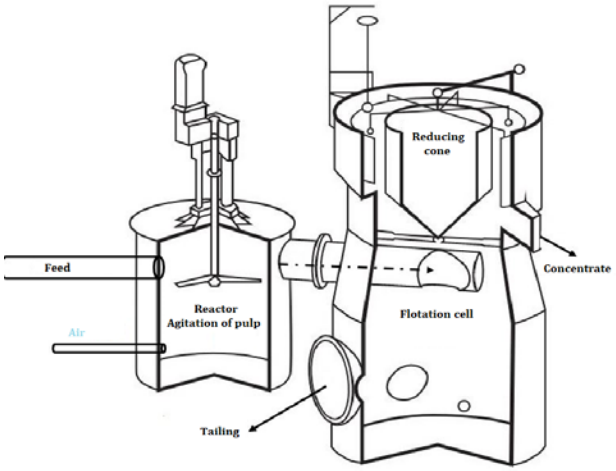

Fig. 5. Staged Flotation Reactor Flotation Machine (www.woodgrovetech.com/SFR.html, 2018)

Staged Flotation Reactor - Woodgrove Technologies Inc. is applied for a second time in the world and for the first time in Bulgaria, at Chelopech Mining EAD. Its implementation is planned by Dundee Precious Metals Inc. for the processing of the ore from the "Khan Krum" deposit, "Ada Tepe" section, until a gold-silver concentrate is obtained.

Figure 6 presents the industrial pneumatic flotation machines (SFR), put into operation at the Dundee Precious Metals processing plant in Chelopech, Bulgaria.

Fig. 6. SFR Flotation Machines at „Dundee Precious Metals Chelopech“, Chelopech, Bulgaria

Pneumatic flotation machine SIMINE Hybrid Flot

The SIMINE Hybrid Flot pre-contact flotation machine effectively combines the operation of pneumatic and column flotation machines. In the design of the cell, two basic construction stages are identified: upper and lower. The upper section works pneumatically with a three-phase injector - a solid/liquid phase (flotation pulp) and a gas phase through which the feed pulp passes where it is saturated with air. As a result of saturation, pre-contact occurs. In the froth product, the floating fractions of the recovery raw material are most easily extracted, the concentrate being drawn to launders circumferentially spaced around the flotation cell. The circular movement in the pneumatic section, along with the conical intersection between the upper and lower section, lead to a centrifugal effect while the turbulent flow is destroyed to enable a laminar flow in the second stage (column section). At the bottom of the column, the bigger gas bubbles catch coarse particles that have not attached in the first stage at lower enrichment factors. This significantly increases the total recovery while providing a high selectivity. Froth washing is possible to lower entrainment into the froth product. The concentrate from the second (lower) section is directed to a separate collection chute located at the top of the flotation cell. The regulation of the aeration device located at the bottom of the flotation cell provides a good opportunity to optimise the contact between the mineral particles and the air bubbles.

As with other pre-contact flotation machines, the SIMINE Hybrid Flot does not have a flotation pulp stirring device which contributes to the lower electricity costs and the insignificant wear on work surfaces. Figure 7 presents a general view of the SIMINE Hybrid Flot Flotation Machine (Primetals Technologies Hybrid Flotation FTC LAB, https://www.primetals.com, 2018).

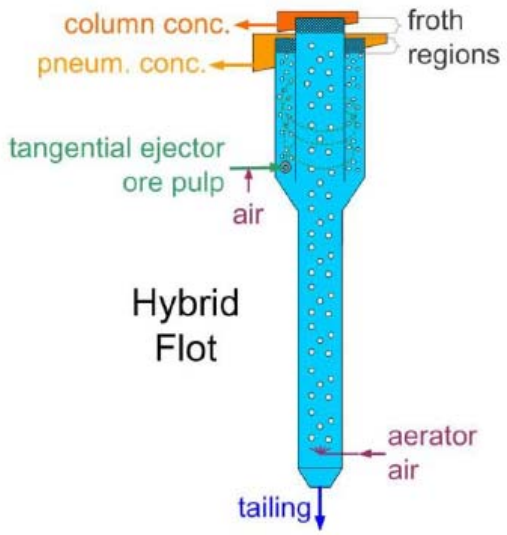

Fig. 7: Principle of the Hybrid Flotation Cell (https://www.primetals.com, 2018)

Conclusion

In the course of the past few years, constant attempts to improve the design and optimise the operation of the flotation machines have led to the development of a new generation of pneumatic flotation machines with a pre-contact column type. The established long-term trend towards decreasing the content of valuable components, especially for ore minerals, is one of the reasons for exploring the possibilities to optimise and improve the efficiency of both flotation machines and overall technological operations. One of the most important tasks that the mineral-raw material industry faces is the development of innovative engineering solutions aimed at improving the efficiency of the flotation process and leading to the full utilisation of increasingly used raw materials. The implementation of pre-contact flotation machines in the process of the concentrator plants and the hydrometallurgy plant is one of the most reliable solutions for the optimisation of the production process.

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