RECENT EXPERIENCES WITH LARGE OUTOKUMPU FLOTATION CELLS

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1. Introduction

The worldwide trend in the mineral industry has recently been towards using bigger units of process equipment. The reasons for this are:

- lower grade orebodies require larger scale operations to be profitable
- lower energy consumption, compensates against rising energy price
- simpler instrumentation and operation through large unit sizes
- simplified circuit design enables effective use of automation
- lower capital investment through savings in equipment and building costs

When designing larger flotation machines the following requirements are of essential importance:

- even dispersion of large amounts of air
- good capability of keeping solids in suspension
- lower power requirement
- low wear rate
- easy start-up on full load
- low short circuiting
- low sanding
- high selectivity
- easy installation and maintenance

Outokumpu has developed a flotation machine mechanism which is especially designed with large flotation machines in mind. The test work was done at the Company's own concentrators before releasing the machine for world wide marketing.

The first large flotation machines were running in 1973. The cell size at that time was 16 m$^3$. The first units of the next size, 38 m$^3$, were started in 1979 in South Africa. Now over two hundred of these 38 m$^3$ cells are operating all over the world.

1.1. Mechanism Design for Large Flotation Machines

The flotation cell mechanism has two main tasks: disperse air and at the same time keep solids in suspension.

This problem is solved by pumping effectively slurry.
through the mechanism. Some manufacturers have boosted their mechanisms by additional pumping parts, others have installed vanes, false floors, tubular elements, etc. around the mechanism in order to improve pulp circulation in large flotation machines. The Outokumpu mechanism has been designed especially for large volume machines and does not need any additional elements. The design is based on a physical theory (Fallenius, 1976) and a mathematical model has been developed for scaling the different flotation machine sizes. (Fallenius, 1979)

1.2. Air Dispersion

The air is fed into the OK rotor through a hollow shaft and it is discharged through the vertical air slots. The downward tapering form, which enables the compensation of hydrostatic pressure, is determined mathematically. This so called constant pressure principle makes it possible to use practically the whole rotor height for air dispersion.

It can be noted in Table 1 that the amount of air used per volume unit cell (m³/m³) is decreasing with increasing cell volume, but is about constant per cell area unit (m²/m²). This means that the density of rising bubble cloud is constant in all cell sizes.

<table>
<thead>
<tr>
<th>Cell size (m³)</th>
<th>Air Consumption (m³/min)</th>
<th>m³/m³</th>
<th>m³/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>10-25</td>
<td>0.5</td>
<td>1.4</td>
</tr>
<tr>
<td>16</td>
<td>6-15</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>8</td>
<td>4-10</td>
<td>0.8</td>
<td>1.3</td>
</tr>
<tr>
<td>3</td>
<td>2-4</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>1.5</td>
<td>1-2</td>
<td>1.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 1- Air consumption in different cell sizes

1.3. Slurry Suspension

A good slurry suspension is essential for the operation of the flotation machine. Only in suspension can the mineral fasten to the air bubbles and get flotated.

The OK rotor has separate slots for air and slurry. The rotor acts like a slurry pump sucking from the lower section of the rotor and discharging from the upper section (Figure 1). The slurry and air flows are brought into contact with each other in the rotor-stator clearance and strong aerated slurry flow leaves the mechanism to the surrounding cell volume.
2. Energy

It is known fact that power consumption of the flotation machines per unit volume of the cell, decreases when the cell volume is increased. Table 2, based on material collected by Mr. Young, shows the trend.

<table>
<thead>
<tr>
<th>Cell Size Av. m$^3$</th>
<th>Power Consumption KW/m$^3$ (mechanism + blower)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>main brands</td>
</tr>
<tr>
<td>28-40</td>
<td>1.4</td>
</tr>
<tr>
<td>14-16</td>
<td>1.8</td>
</tr>
<tr>
<td>6.5-8.5</td>
<td>2.1</td>
</tr>
<tr>
<td>2.8-5.1</td>
<td>2.8</td>
</tr>
<tr>
<td>1.2-1.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Table 2 - Power consumption versus cell size

Although figures in Table 2 are very general and factors such as pulp density, air amount and speed effect them somewhat two general conclusions are clear: 1) in large sizes especially the power consumption of self-aerated machines is not lower than that of machines using super charged air; 2) the power of consumption of OK impeller is some 20% less than corresponding other mechanism. This is because in Outokumpu impeller the air is discharged through separate air slots, thus the air does not disturb the efficiency of mixing.

Figure 2 illustrates a practical example of the power consumption of the OK -16 and the OK -38 mechanism as a
function of air feed. It can be noted that by using large amounts of air the decrease in power consumption is considerably more than the increase in the air blower power consumption.

Figure 2- Power consumption as a function of air feed.

3. Mechanical Wear

3.1. Mechanism

It is a relatively common belief that the wear in large flotation machines is stronger than that in the small cells. In actual fact, the situation is quite contrary. Because of the efficiency of the OK mechanism the tip speed of the rotor is practically the same throughout all cell volumes. The construction of the large mechanism is stronger and it means that the life time is longer than that of small mechanisms. Hammaslahti and Pyhäsalmi copper pyrite concentrators used their original OK-16 m³ mechanisms for more than seven years.

3.2. Tank

Because of the constant tip speed of the rotor, the velocity of the slurry flow leaving the mechanism is practically the same in all cell sizes. In a large cell the distance to the cell wall is bigger and the velocity of the slurry at the wall is lower causing less wear. In many cases only a good coat of paint is required to protect the cell walls, unless the lining is necessary for other reasons such as chemical corrosion.

4. Start-up of Flotation Machine

It is imperative for the operation of the flotation circuit, that the flotation machine can be shut down and
started up on full load. This is especially true with large flotation machines. This is possible with the OK mechanism because the solids settle on the rotor cover plate and the downward tapering form of the rotor prevents the blocking of the clearance between the rotor and the stator.

Figure 3 illustrates some practical measurements of the power consumption of the OK-38 mechanism after full load shut down of five minutes and two hours with pump flow still going to the cell. To get the power back to operating level, i.e., to get the slurry back to suspension took 0.5 min. and 2 minutes, respectively. Start-up after shut down is recommended to be done with the air valve open.

Figure 3—Power consumption as a function of time from re-start

5. Tank Design for Big Flotation Machines

In large cells the tank design becomes very important because of mechanical stresses caused by hydrostatic pressure, elimination of sanding, prevention of short circuiting and wear, too.

Practically all manufacturers have tried to solve the problems by cutting the lower corners.

In sizes from 8 m³ up Outokumpu uses U-shape tank which is mechanically strong and allows very little sanding.

The amount of settled solids on the bottom has been measured to be only 1.5% of the live volume of the cell. With the rectangular tank design the corresponding figure is normally 10% to 15%. The U-shaped cell is also lighter because of the self supporting structure. This means easier
and cheaper installation.

The role of the U-shaped tank is essential in preventing short circuiting. The gravity on the inclined cell wall/bottom, together with the centre directed pulp streams on the bottom, move the coarse particles again and again towards the centre of the cell where the mechanism forces them back into circulation. In some other big cells the flow close to the bottom is outward, pushing coarse particles away from the mechanism.

5.1. Selectivity

A deep tank design is beneficial for selectivity and needs less floor space for installation. The selectivity is improved because the mechanism is further away from the froth and thus turbulence causes less disturbance. It is also possible to use thick froth without losing too much pulp volume.

As an example of improved selectivity at Pyhäselmi mine they can produce pyrite concentrate containing 52% S with 38 m$^3$ roughers only. This is not possible in parallel installation with 3 m$^3$ cells, one or two cleaning steps are then needed.

Figure 4 illustrates the four different regions affecting flotation.

![Figure 4 - The different regions in deep flotation cell](image)

1. The lowerest region is a strongly turbulent mixing zone where even the coarsest mineral particles are well in
suspension and have a high probability of coming into contact with air bubbles.

2. The tranquil zone where the air bubbles rise upwards collecting more mineral particles on the surface, fine particles in particular get flotated in this region because now the velocity difference between the growing air bubbles and slurry is big. The flotation carried out in this region is especially selective because there is no strong turbulence.

3. "Semifroth" or autogeneous cleaning region is formed under the thick froth layer. In this region the air bubbles get tightly pressed against each other and partly join causing a liquid phase to start flowing downward between the bubbles, releasing mechanically bonded impurities. The chemical bond between mineral particles and air bubbles still remains.

4. The fourth region is the conventional froth bed which only transports the concentrate out of the cell.

In small and shallow flotation machines, regions 2 and 3 are almost completely non-existent, meaning that the shallow froth layer is almost immediately on top of the strong turbulent slurry.

5.2. Short Circuiting

The problem of short circuiting becomes very important with large cells, because the number of cells needed is reduced. The short circuiting can be decreased by strong inside circulation of slurry so that even the minerals descending to the bottom of the cell repeatedly are picked up by the mechanism in order to increase the possibility of bubble contact. Separating walls with small openings also clearly prevent short circuiting.

![Figure 5](image.png)

Figure 5-
The copper content in tails as a function of flotation time
Experience has shown that the U-shaped cell has a surprisingly low short circuiting. Figure 5 illustrates an application where two 38 m³ cells installed parallel to two rows of 3 m³ cells, 14 cells in each row in copper scavenger flotation. In this application with two large U-shaped cells the same copper content in the tailings was achieved in eight minutes, as in twenty-two minutes with the small cells.

6. Review of some Large Cell Installations

(1) Keretti concentrator, Outokumpu Oy, Finland
The ore contains 3.2% Cu and 0.3% Co. The production rate is 1,700 tpd. The mill was modernized 1976-7 and the earlier five parallel lines of 2.4 m³ cells (total volume 140 m³) in copper circuit were changed to eight 16 m³ cells (128 m³) in one line only. A similar change was made in cobalt flotation too. As a result the circulating load of pyrrhotite dropped from 100-200 % to 50-100 % because of better selectivity, consumption of reagents decreased 12-30 %, power consumption in flotation dropped from 935 KW to 432 KW. The copper recovery was improved from 94.4 % to 94.7 % and at the same time the concentrate grade went up 0.4 % Cu.

(2) Pine Point Mines Ltda., Pine Point, N.W.T., Canada
The Pine Point Mine is a lead and zinc operation on the south shore of the Great Slave Lake in the Northwest Territories. The concentrator started production in 1965. The flotation circuit consolidation was carried out in 1980. The new flotation circuit consists of the following cells:
- Pb rougher and scavenger flotation cells; 9 x16 m³ cells in combination 2 + 3 + 4.
- Zn rougher and scavenger flotation cells; 10 x 38 m³ cells in combination 2 + 4 + 4

The throughput of the mill is 11,000 tpd. The first nine months of the large flotation machine installation, compared to the previous five years period, indicated the following results:
- lead concentrate is up 1.2 units in lead content,
- lead metal recovery in lead concentrate is up 2.9%,
- overall lead recovery is up 2.4%,
- zinc concentrate grade is up 0.6 units in zinc content,
- zinc metal recovery in zinc concentrate is up 0.2 % and overall zinc recovery is up 0.2%.

These results are indicative of vastly improved circuit performance when one considers that feed grades are down. Reduction on reagents consumption:
- xantate - same
- cyanide - same
- MIBC - 45.5%
- Cu SO4 - 33.0%
These results have been attributed to the improved selectivity of the cells due to improved mixing characteristics.

Power savings:
- overall - 2,250 Kw
- only pumps - 685 Kw

(3) Cyprus Anvil Mining Corporation, Faro, Yukon Territory, Canada.
The Cyprus Anvil Mine is a Canadian lead and zinc operation which installed large flotation machines in three stages during 1981, without any lengthy disruptions in the mine's production. The present flotation circuit is as follows: includes 38 OK machines distributed in lead and zinc roughers and scavengers as well as for first lead cleaners. The earlier roughers were connected to lead and zinc 2nd and 3rd cleaners. The throughput of the mill is 11,000 tpd. At that time of writing the main benefits of the new installation came from considerable saving in power consumption. The average power consumption of the OK-38 shaft is 40 Kw. Due to the short time that the new flotation circuit has been in use, no accurate metallurgical data is available and was noticed improvement in metallurgy. The use of OK-38 cells also as first cleaner cells has been successful.

(4) Siilinjärvi Concentrator, Kemira Oy, Finland.
Kemira Oy's apatite concentrator in Finland is another example of new trend flotation circuit design where large cells are used throughout the whole flotation plant. Even the last cleaning is an OK-38 cell. From the very beginning the results of the full size installation exceeded those of the pilot plant circuit. The plant is presently expanding from 6,000 to 15,000 tonnes per day and as a result of the good experience with the original design the same flotation circuit design is being used for the expansion.

7. Overall Economy
Based on the 16 m³ and 38 m³ flotation machine installation, the following benefits can be obtained over the installation of small, about 3 m³, flotation machines:
- energy consumption over 50% lower
- reagent consumption 10-15% lower
- savings in floor space over 50% especially if cell covers are used as walkways
- price of equipment about 40% lower per unit volume

Additionally, the pumping costs are lower due to the reduced circulating loads. The instrumentation and electrification costs are lower because less equipment is needed and for the same reason control of the circuit is easier.
There is a considerable reduction in maintenance costs. For example, at Keretti Mill (Kallioinen) have been estimated savings of 85% or USD 63,200 in maintenance costs when 108 small cells were replaced by 14 16 m³ cells.

8. Conclusion

The advantages of the large flotation machines are most obvious with high feed rates. Low energy and other operating costs, good controllability and lower investment costs are the main benefits of the large cells.

The OK mechanism developed for large cells is capable of working effectively in even bigger units.

In future, cell sizes of even up to 100 m³, can prove to be economical in large concentrators. Cells of this size could be built of concrete and they could be located outside the main concentrator building and thus change the whole concept of concentrator engineering.

References