Flotation of A Sulphide Ore Using High Velocity Water Jets

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ABSTRACT: A jet of water issued at high velocity from a calibrated nozzle can be used in a variety ot application owing to its unique capability of carrying a high power concentrated in a vary small space. Although this technology is still applied in many fields of rock and stone engineering (excavation, slotting, cutting, drilling, surface finishing) no commercial instances can be found in the area of mineral separation. The paper highlights a new approach followed in the design and the development of a flotation cell in which conventional impeller is replaced by high velocity water jets generated through a suitable nozzle configuration. The features of the prototype installed at the DIGITA Department of the University of Cagliari are illustrates and the results obtained in the flotation with such technology of a sulphide ore are reported. In particular the influence on metallurgical results of various operation variables like water pressure and flow rate, air flow rate, collector and frother dosage and residence time, is illustrated and discussed in comparison with a similar cell equipped with conventional impeller. Experimental results show that specific energy consumption of the waterjet cell is noticeably lower than that of the conventionally agitated cell.

1 INTRODUCTION

A jet of water issued at high velocity from a calibrated nozzle can be used in a variety of applications owing to its unique capability of carrying a high power concentrated in a very small space. Although this technology is still used in many fields of rock and stone engineering (excavation, slotting, cutting, drilling, surface finishing) no instances of commercial application can be found in the area of mineral separation.

However waterjet can offer new opportunities for designing new machines or improving the performance of conventional equipment (Chudachek etal. 1997).

For proving the concept a prototype of a waterjet-agitated cell (Hydrojet) has been designed and built at the DIGITA Laboratories of the University of Cagliari (Carbini el al. 1998).

2 FEATURES OF THE HYDROJET CONCEPT

2. / *Apparatus*

The prototype of the Hydrojet cell consists of a cylindrical vessel, 200 mm in diameter and 400 mm high (total free volume 10.2 litres), provided with a hemispherical bottom screen for the discharge of the reject through a central outlet. Froths are skimmed out through a chute in the upper section of the cylindrical body.

2.2 Plant

The laboratory plant is composed by an agitated conditioning tank, a feeding system via a peristaltic pump, the Hydrojet cell itself, a high pressure plunger pump connected to the waterjet lance for the generation of high velocity jets which produce the agitation and bubble dispersion into the vessel, two peristaltic pumps for collector and Irother addition, a pulp aeration system. The liquid level is controlled by acting on the tailings discharge pump speed.

A schematic view of the experimental setup is given in Figure I.

2.3 Past experience

In the past the Hydrojet cell has been tested successfully on coal and on a barite ore.

Regarding coal, the following aspects are worth underlining (Agus et al. 1998):

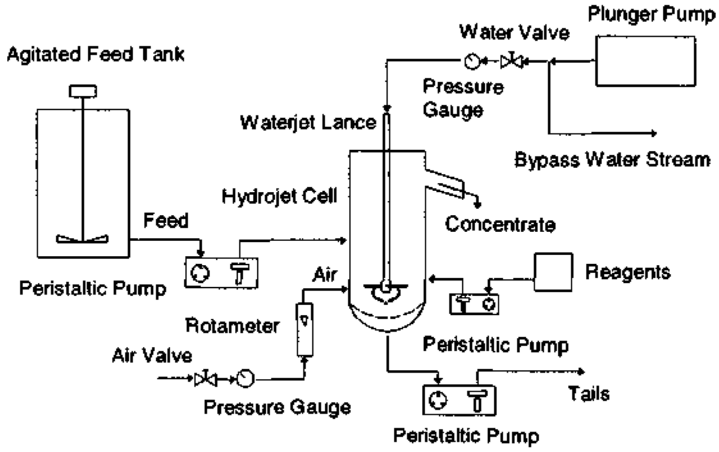

Figure I - Laboratory plan! used in flotation tests it *ilh the Hydrojet cell.*

- In all experimental conditions fuel recovery increased gradually with residence time, accompanied by a parallel increase in ash content for both the product and the reject;
- recovery with waterjet was considerably higher than that achieved with mechanical agitation;
- results were better using only two jets since both recovery and ash in the reject were higher than with four jets, although the quality of the product was slightly worse;
- an increase in pressure from 9 to 15.5 MPa at equal hydraulic power using two 0.2 mm nozzles (resulting water tlowrate: 0.48 I/min) did not bring any improvement.

A further advantage offered by the waterjet cell was a considerable reduction in energy consumption. In fact, specific energy with two 0.3 mm jets was less than half compared with conventional cell of equal size and shape.

Concerning the barite ore, results were substantially similar (Carbini et al., 1998). In fact:
- BaSQj recovery with waterjet was somewhat higher than that achieved with mechanical agitation at any dosage of collector, although with lesser evidence than for coal (Carbini et al. 1998; Agus et al. 1998);
- BaSOj content in the concentrate was slightly higher with waterjet in spite of using half the power;
- again results did not improve by doubling the jet flow rate using four 0.3 mm nozzles instead of two at equal pressure.

The above findings are of great interest for the future development of the concept and the improvement in the design and operation of a waterjet cell.

3 FLOTATION TESTS

3.1 Characteristics of the ore sample

The zinc sulphide ore used for the new series of experiments originates from the Sos Enattos mine (Lula, Italy), and averages about 9.5 % Zn. The orebody consists of a number of veins with different economic interest but in recent times only the "Tupeddu" vein was kept in production. The valuable mineral is sphalerite with minor presence of galena and iron sulphides. The main gangue mineral is quartz and the embedding rocks are medium-grained shales.

A sample of the ore was dry ground to below 0.2 mm and the top size was controlled by sieving. The resulting particle size distribution is represented in the following Table 1.

Table I - Sus Eitattm zmc »re. Sue analysis <>/flotation feed

Size Class (nun)	*We i KÌıt 1%)*	*Cum. Weight (%)*
-0.200 + 0.150	*19.01*	*19.01*
-0.150+0.075	*31.04*	*50.05*
-0 075+0.0.175	*IS.45*	*6H.50*
-0.0375	*31.50*	
Feed	*100.00*	

Preliminary batch tests have been carried out using a 2 litre Minemet laboratory cell aiming at identifying the optimum dosage of modulating agent, collector and frother.

In order to put into a better evidence the expected advantages achievable by using water jets, two parallel series of flotation tests have been carried out using the same cylindrical vessel, hosting the waterjet nozzle head (Hydrojet cell) or the conventional impeller (Minemet), respectively.

Common experimental conditions were:

- Volume of the vessel: 10.2 I
- Mass concentration of solids: 25 % by weight
- Modulating agent ($CuS0_4$): 200 g/t
- Collector dosage (Sodium Isopropyl Xanthate): 15 g/t
- Frother (Dowfroth 1012): 30 g/t
- Conditioning time: 5 min
- Solids feed rate: 0.9 kg/min
- Residence time: 3.5 min
- Air flow rate : variable from 2.55 to 10.2 Nl/min.

Rotation velocity of the impeller in the mechanical cell was 2,000 rpm, waterjet nozzle diameter was 0.3 mm.

Further separation tests were carried out with the Hydrojet cell in order to put into evidence the influence on metallurgical results of various operational variables like water pressure, air How rate, residence time and collector dosage.

The experimental conditions were similar to those reported in the above except for :

Collector dosage (Sodium Isopropyl Xanthate): variable from 15 g/t to

- 30 g/t;
- Solids feed rate: variable from 0.7 to 1.5 kg/min (Residence time: from 2 to 4.5 min);
- Pressure at the pump: variable from 5 to 14 MPa (flow rate: variable from 0.615 to 0.825 1/min);
- Air rate: variable from 2.55 to 10.2 Nl/min.

3.2 Experimental procedure

Under the above setting conditions flotation tests were carried out according to the following standard procedure:

- the pulp was fed at constant rate and the froth/slurry interface in the cell (about 5 cm below the discarding edge corresponding to the thickness of the froth layer) was maintained steady by adjusting the speed of the bottom discharge peristaltic pump;
- after a waiting time necessary for the achievement of a steady state (at least twice the residence time), two samples of the froths and of the discharge slurry were drawn in sequence.

The above sampling procedure resulted to be accurate enough and the differences between samples were within tolerable limits. Excluding the rare anomalous results data were averaged.

4 RESULTS

4.1 Waterjet versus impeller

Results of the comparative tests between Minemet and Hydrojet cell carried out according to the above described procedure are summarised in Figure 2, where Zn recovery and Zn grade of the rougher concentrated are plotted against air rate.

It is worth underlining that both Zn recovery and Zn concentrate grade with the Hydrojet cell are well higher (by more than 10 percent points, and by about 2-3 points, respectively) than those achieved with mechanical agitation at any pulp aeration conditions, while the metal loss in the tailings is significantly lower (by at least 2 points).

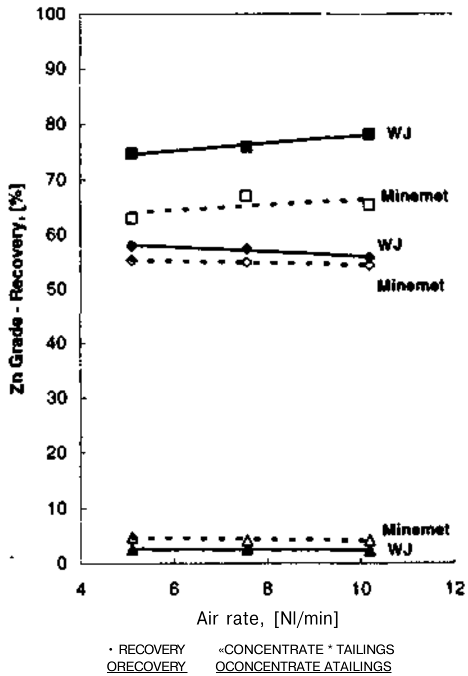

Figure 2 - Influent e ut tur rale tm floiatıtm remits.

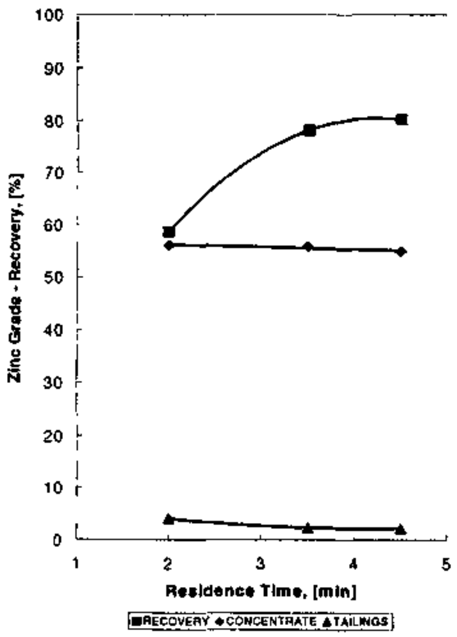

Figure . 1 - Hvilro/et Cell - Influent e of résilient e lime on flotation results.

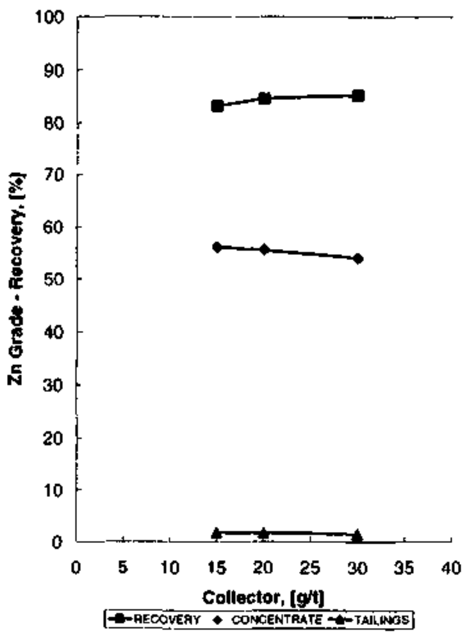

Figure 5- Hvtlroıet Cell - Influence of collet lor on flotation results

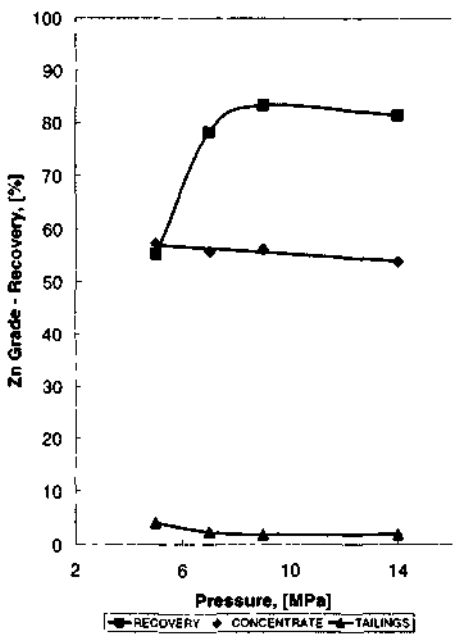

Figure 4- Hytlıojet Cell • Influente of pleasure on flotation results.

Regarding the air rate Figure 2 shows that in the range examined this variable has only a slight influence on separation results producing, as expected, a worsening of concentrate grade at increasing aeration of the pulp.

As represented in Figure 3 residence time has an important influence on the tailings grade while leaving almost unchanged the concentrate grade, thus producing a rapid increase in recovery when passing from 2 to 4.5 min.

Concerning the watcrjet features, tests have been carried out with a collector addition of 15 g/t aiming at singling out the optimum value of pressure. Results are represented by the curves of Figure 4 where Zn recovery and grade of the concentrate and Zn grade of the reject are shown as a function of pressure at the plunger pump. Mass flowrate of solids was 0.9 kg/min (residence time 3.5 min) and solids concentration in the pulp 25% by mass.

It is worth noting that:

- Zn grade of the froth product decreases almost linearly with pressure;
- Zn recovery increases considerably if pressure is raised from 5 to 9 MPa; a further increase in pressure beyond 9 MPa does not bring any improvement whereas flotation tends to deteriorate meaning that optimum pressure is around 9 MPa;

- Zn grade of tails decreases noticeably when pressure increases from 5 to 9 MPa then diminishes less markedly.

As shown in Figure 5, the metal grade and recovery follow the general trend of typical flotation tests. In tact at increasing collector dosage both concentrate and reject grade decrease while recovery increases.

5 DISCUSSION

The standpoint underlying the new concept based on the use of water jets in flotation appears corroborated by the experimental tests also in the case of sulphide ores, in addition to coal and industrial minerals. This represents a clear confirmation of the theoretical predictions based on the effect of high shear velocity on the process of bubble formation into the pulp (Klassen & Mokrousov 1963).

It is worth underlining that an intense shear action is necessary only at the bottom section of the cell where bubbles arc generated and dispersed into the pulp, whereas in the upper region only a moderate agitation is advisable in order to avoid the disruption of the collection froths.

In fact, results with only two water jets bearing half power, aimed right at the outlet points of air-nozzles, are much better that those with four jets since the two additional jets having no influence in the process of bubble generation produce an unfavourable stirring, eventually leading to a loss in recovery and a decrease in selectivity. Moreover this would be a great advantage from the economic point of view since energy represents an important cost item in flotation.

It seems that optimum operating pressure is around 8-10 MPa, giving a jet velocity at the nozzle of about 100 m/s. An increase in pressure beyond that level at equal hydraulic power using smaller nozzles does not appear very profitable. However it is likely that higher pressure will be needed in the scale-up of the system.

6 CONCLUSIONS

The use of water jets generated at moderate pressure can be considered as a suitable way for improving the required conditions for the full development of flotation mechanisms, especially in the case *of* very line fractions of the ore.

Separation results are always considerably better than those achieved with conventional mechanically agitated cells at equal conditions.

The following advantages can be predicted with the further improvement and the industrial scale-up of the technology, compared to conventional methods:

- more favourable bubble features;
- efficient control of the agitation pattern by optimising the nozzle arrangement and using fan jets;
- higher recovery and better separation selectivity;
- increased energy efficiency.

ACKNOWLEDGEMENTS

Work carried out in the frame of the research projects supported by MURST and CNR.

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