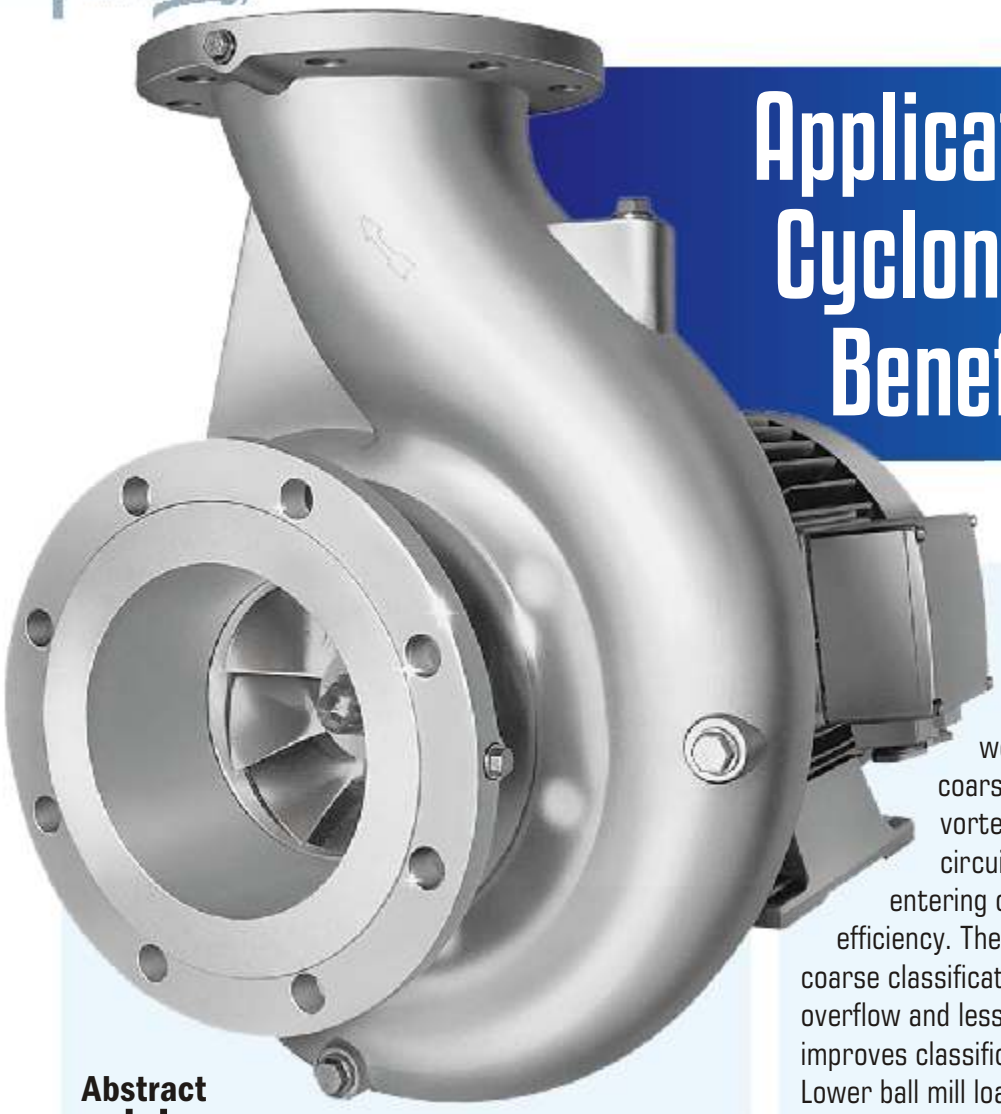


Application of Hydro-Cyclones in Iron Ore Beneficiation Plant

- Xueqi Cui [1]*, N. S. Rathor[2], Shuli Wang[3] & Lei Wang[4]

Abstract

Hydro-cyclone is widely used in closed-circuit grinding process. However, in the first classification operation of coarse particles with high pulp density, the shortcomings of traditional cyclone are that the grinding cycle load is much high and classification efficiency is less. Specifically, the problems of traditional cyclone used in grinding process are as follows. Mill utilization factor is low and its handling capacity is small. Coarse particles mixing in cyclone overflow affects the following separation process and fine particles mixing in underflow causes over-grinding, which affects the total recovery rate of valuable minerals. High grinding cycle load leads to large amount of high-density slurry pumping, which causes high energy consumption and severe wear of cyclones, pipelines and pumps. The applications of new pre-classification hydro-cyclone with centrifugal volute in the first classification process of Iron Mine Mill are introduced in the paper. Particles fed in the centrifugal volute were arranged in advance, so that coarse particles can be far away from the vortex finder, which can reduce the short circuit current to avoid coarse particles entering overflow and improve classification efficiency. The strong points of new cyclone in the coarse classification operation are as follows. Finer overflow and less fine particles mixing in underflow improves classification efficiency more than 10%. Lower ball mill load cycle improves ball capacity more than 10%. In short, new pre-classification cyclone with centrifugal volute solves the problems of fine particles mixing in underflow, high grinding cycle load and less classification efficiency in the coarse classification operation. Therefore, it has broad application prospects in ferrous metal and non-ferrous metal ore dressing plant.

Introduction

The common range of classification for hydro-cyclones is 40 microns to 400 microns, with some remote applications as fine as 2 microns or as coarse as 1000 microns. It is widely used in closed-circuit grinding operations but has found many other uses, such as de-sliming, de-gritting, and thickening. Hydro-cyclone has replaced mechanical classifiers in many applications, its advantages being simplicity and high capacity relative to its size. Screen is extensively used for size separations from 300 mm down to around 75μm, and the efficiency decreases rapidly with fineness. While it comes to de-sliming of 30μm, 25μm, 19μm, 10μm and 5μm, only cyclones do work while capacity of screens in this case will quite be disappointing, not to mention that corresponding industrail aperture sizes haven't been developed yet.

Although there are screen types that are capable of efficient size separations down to 75µm, sizing below 250µm is also undertaken by classification. Selection between screening and classification is influenced by the fact that finer separations demand large areas of screening surface and therefore can be expensive compared with classification for high-throughput applications. The area of the inlet determines the entrance velocity and an increase in area increases the flow rate. Also important is the geometry of the feed inlet. In most cyclones the shape of the entry is developed from circular cross-section to rectangular cross-section at the entrance to the cylindrical section of the cyclone. This helps to spread the flow along the wall of the chamber. The inlet is normally tangential, but involuted and centrifugal voluted feed entries are also common. Centrifugal voluted entry, also called spiral inlet, are more and more popular in practice. The characteristic of centrifugal voluted entry cyclone will be discussed in detail in following paper.

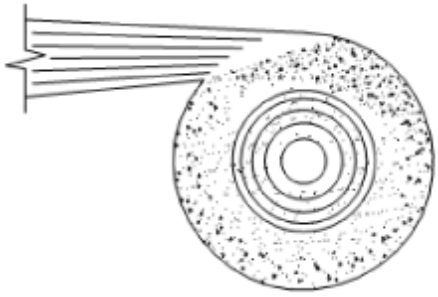
Grinding and classification operation is a process of the maximum operating power consumption in ore dressing plants. Therefore, the work state of grinding and classification is directly related to the mine's economic benefits. Meanwhile, the grinding and classification operation is the key technical process, which determines the monomer dissociation degree of valuable minerals in ore and directly affects follow-up separation index. However, in the first classification operation of coarse particles with high pulp density, the shortcomings of traditional cyclone are that the grinding cycle load is much high, the apex of cyclone is easily to be blocked and classification efficiency is less. Specifically, the problems of traditional cyclone used in grinding process are as follows.

Mill utilization factor is low and its handling capacity is small. Coarse particles mixing in cyclone overflow affects the following separation process and fine particles mixing in underflow causes over-grinding, which affects the total recovery rate of valuable minerals. High grinding cycle load leads to large amount of high-density slurry pumping, which causes high energy consumption and severe wear of cyclones, pipelines and pumps. To solve the problems of conventional cyclone mentioned above, Haiwang Cyclone successfully develops a new centrifugal volute cyclone. At present, the conventional cyclone feeding methods include tangent type, involute type, spiral type, arc-type and so on. So far, almost all forms of physical design of the cyclone feed did not consider the pre-classification of particles before entering the chamber, that is, particles in the feed section is essentially a uniform distribution. The new centrifugal volute cyclone developed by Haiwang pre-arranges the particles in the feed volute, which is helpful to improve the classification efficiency and accuracy. In the process of coarse particles classification with high pulp density, the new cyclone avoids the coarse and heavy material accumulating in the underflow, which reduces the cycle load and improves the mill's capacity.

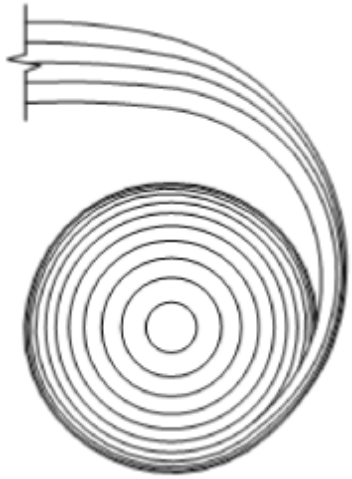
Results & Discussion

Compared to the involute cyclone, the centrifugal volute cyclone has a newly developed feed chamber, which is shown in Figure1 and the cylinder length, inlet diameter, vortex finder, apex and other structural parameters are the same with the involute cyclone. The numerical simulation of continuous phase in cyclone flow field is firstly studied in the paper using water under normal temperature as the continuous phase, the density of the water is 998.2 kg/m3, and the dynamic viscosity is 0.001003 kg/m•s. Shear Stress Transport k–ω is used as a numerical calculation model and SIMPLE-Consistent is used as numerical calculation method. The simulation results of the average pressures in inlet, overflow and underflow of the two cyclones with different feed chambers are shown in Table 1. And the inlet pressure contour diagrams are shown in Figure2 and Figure3. It is showed in Table1 that the inlet pressure of the cyclone with involute feeding chamber is 1.30atm, while the inlet pressure of centrifugal volute feeding chamber is 1.14atm. Therefore, centrifugal volute feeding cyclone has lower energy consumption. It is clearly showed in Figure2 and Figure3 that the inlet pressure of centrifugal volute feeding chamber is lower than the inlet pressure of involute feeding chamber, which lead to less abrasion to the new feeding chamber. It is clearly showed in Figure4 and Figure5 that the inlet velocity distribution of new centrifugal volute feeding chamber is more uniform than traditional involute feeding chamber, which reduces the partial wear of feeding liner and vortex finder. Moreover, slurry is feeding more smoothly and progressively and turbulence in cyclone is greatly reduced. So classification efficiency of centrifugal volute cyclone is much higher than traditional cyclones.

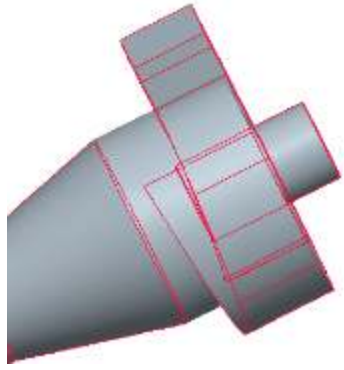
FIG. 1 : TANGENTIAL, INVOLUTED AND CENTRIFUGAL VOLUTED ENTRIES



TANGENTIAL ENTRY



INVOLUTED ENTRY



CENTRIFUGAL VOLUTED ENTRY

TABLE-1 : AVERAGE PRESSURE COMPARATIVE ANALYSIS OF TWO CYCLONE WITH DIFFERENT FEED CHAMBER

NEW CENTRIFUGAL VOLUTE FEEDING CHAMBER	
Average of Facet Values Total Pressure	(atm)
Inlet	1.141569
Outlet - 1	0.18567861
Outlet - 2	0.034756141
Net	0.50308066

TRADITIONAL INVOLUTE FEEDING CHAMBER	
Average of Facet Values Total Pressure	(atm)
Inlet	1.3026161
Outlet - 1	0.17995557
Outlet - 2	0.020363077
Net	0.54919816

Note : *Outlet-1 is Overflow, Outlet-2 is Underflow*

FIG. 2 : THE INLET PRESSURE CONTOUR DIAGRAM OF NEW CENTRIFUGAL VOLUTE FEEDING CHAMBER

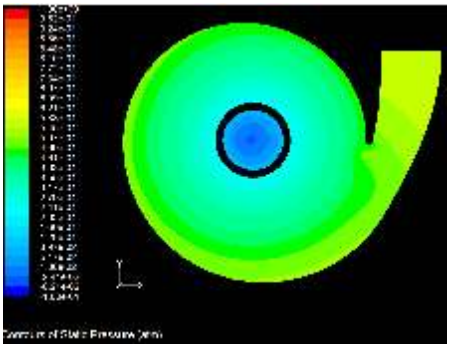
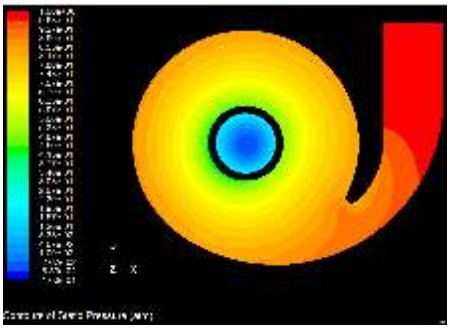


FIG. 3 : THE INLET PRESSURE CONTOUR DIAGRAM OF TRADITIONAL INVOLUTE FEEDING CHAMBER



The centrifugal volute cyclone has been used successfully in many magnetite and hematite ore-dressing plant. Practice has proved that the new cyclone has the strong points of higher classification efficiency, larger capacity and lower energy consumption.

FIG 4 : THE INLET VELOCITY DIAGRAM OF NEW CENTRIFUGAL VOLUTE FEEDING CHAMBER

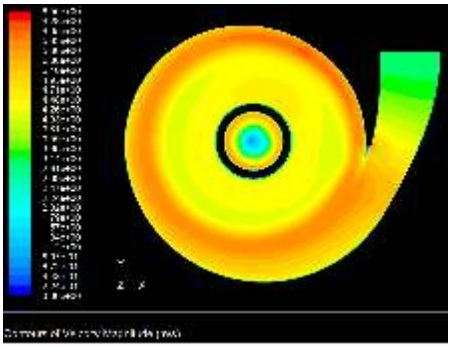
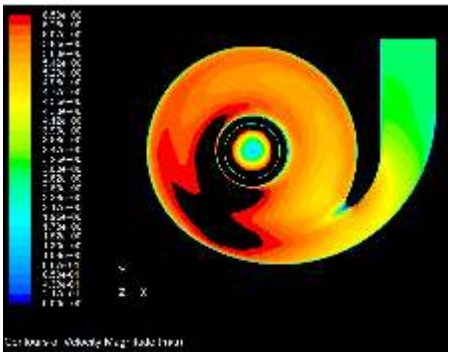


FIG. 5 : THE INLET VELOCITY DIAGRAM OF TRADITIONAL INVOLUTE FEEDING CHAMBER



Application in Magnetite Ore Dressing Plant of an Iron & Steel Group

The centrifugal volute cyclone used in the first closed circuit grinding process of magnetite concentrator achieves good technical indicators. Table 2 is the technical indexes comparison results between the new cyclone and conventional one.

It is showed in Table 1 that centrifugal volute cyclone compared with conventional cyclone has obvious advantages as follows.

The fineness of overflow improves 3.02%, fine particles mixing in underflow reduces 6.14%, grading quality efficiency and quantity efficiency increases 13.24% and 15.78% respectively.

The lower feed pressure (0.06 MPa) reduces energy consumption and improves cyclone's service life.

Ball mill productivity improves 28t/h, mill utilization coefficient increases 0.51 t/m3•h, grinding power consumption reduces 2.86 kw.h/t-200, the grinding efficiency improves 0.36t-200/(m3.h).

Application in Hematite Ore Dressing Plant of an Iron & Steel Group

Classification indicator also made significant improvement by using centrifugal volute cyclone in the first closed circuit grinding process of hematite concentrator. Table 3 is the technical indexes comparison results between the new cyclone and conventional one.

TABLE - 2 : TECHNICAL INDEXES COMPARISON BETWEEN NEW CYCLONE AND CONVENTIONAL ONE IN MAGNETITE DRESSING PLANT

Comparison Parameters	Centrifugal Volute Cyclone	Conventional Cyclone	Differential
-200 Mesh Content in Overflow (%)	55.21	52.19	+3.02
-200 Mesh Content in Underflow (%)	7.47	13.61	-6.14
Quality Efficiency η (%)	58.26	42.48	+15.78
Quantity Efficiency E-200 (%)	73.93	60.69	+13.24
Feed Pressure (MPa)	0.04	0.10	-0.06
Ball Mill Productivity (t/h)	213	185	+28
Mill Utilization Coefficient (t/m3.h)	3.94	3.43	+0.51
Grinding Efficiency q-200(t/m3.h)	1.98	1.62	+0.36
Grinding Power e-200(kw.h/t)	12.72	15.58	-2.86

It is showed in Table 2 that the new cyclone compared with conventional cyclone has obvious advantages as follows.

Content less than 200 mesh in overflow improves 8.01%, -200 mesh content in underflow reduces 3.46%, grading quality efficiency and quantity efficiency increases 12.76% and 18.41% respectively. Grade of ball mill discharge and cyclone underflow reduces 1.89% and 1.23% respectively, grade of cyclone overflow increases 0.66%. The derichment problem of the cyclone underflow is released preferably. The centrifugal volute cyclone has lower feed pressure, so energy consumption of pump reduces by more than 12%.

TABLE - 3 : TECHNICAL INDEXES COMPARISON BETWEEN THE NEW CYCLONE AND CONVENTIONAL ONE IN HEMATITE DRESSING PLANT

Comparison Parameters	Centrifugal Volute	Conventional	Differential
-200 Mesh Content of Ball Mill Discharge (%)	32.19	27.34	+4.85
-200 Mesh Content in Overflow (%)	54.53	46.52	+8.01
-200 Mesh Content in Underflow (%)	13.56	17.02	-3.46
Quality Efficiency η (%)	46.54	33.78	+12.76
Quantity Efficiency E-200 (%)	77.93	59.52	+18.41
Grade of Ball Mill Discharge (%)	31.98	33.87	-1.89
Grade of Cyclone Overflow (%)	28.48	27.82	+0.66
Grade of Cyclone Underflow (%)	35.82	37.05	-1.23

Conclusions

The applications of new centrifugal volute hydro-cyclone in iron ore dressing plants prove that it has obvious advantages as follows.

Finer overflow and less fine particles mixing in underflow improves classification efficiency more than 10%. Lower ball mill load cycle improves mill capacity more than 10%. The derichment problem of underflow is released preferably in the iron ore grinding and classification operation.

In short, new pre-classification cyclone with centrifugal volute solves the problems of fine particles mixing in underflow, less classification efficiency and high grinding cycle load in the coarse classification operation with high pulp density. And it can improve the capacity and grinding efficiency under the condition of meeting the fineness requirement. Therefore, it has broad application prospects and significant economic benefits in ferrous metal and non-ferrous metal ore dressing plants.

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Acknowledgements

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