Hydrocyclone — a useful tool in comminution circuit

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Since their development at the Dutch State Mines at Limburg in 1939, hydrocyclones have gained widespread use as size separating units in the mineral processing industry. These are basically centrifugal classifiers and have been widely accepted because of their low cost, flexibility of operation, high capacity per unit floor area and amenability to computerised control through modelling and simulation.

To be able to get the maximum benefit from such a useful unit in a comminution circuit, a good understanding of the performance characteristics of hydrocyclones is necessary. Simulation model of a hydrocyclone, essentially consists of a series of a equations[1] which describe :

(a) Pressure-throughput relationship,

(b) Water flow ratio,

(c) Classification size, that is, d_{50}

(d) Reduced efficiency curve.

The details are as below :

(a) Pressure-throughput relationship :

Pressure - throughput relationship for a hydrocyclone with constant inlet dimensions is,

$$Q = K\,(VF)^{1.00}\,(P)^{0.5}\,(FPW)^{0.125} \quad \ldots \quad (1)$$

K is a constant which remains unchanged over a wide range of variations in Q, VF, P and FPW.

This equation is valuable when an existing hydrocyclone installation is being investigated upon and no change in inlet area is to be made. This equation is also necessary in the design of pumps for hydrocyclone installations.

(b) Water flow ratio :

A linear relationship exists between water in the fine product and the water in feed over a wide range of operating conditions. For a given feed slurry, the operating variable which has the greatest influence on this relationship is the spigot diameter.

A simple equation which has been found to describe with reasonable accuracy the water split for a wide range of conditions at constant size distribution of particles in the cyclone feed is :

$$WOF = 1.07\,WF - 3.94\,spig + K' \quad \ldots \quad (2)$$

K' has been found to be constant for a given installation over a wide range of variations in WOF, WF and spig and may be evaluated for that installation from one set of observations. Thus for that installation the water split may be readily calculated for changes in spigot diameter or flow rate to the cyclone.

(c) Classification size, d_{50} :

This is the cut-point or separation size of the cyclone and is defined as the point on the Tromp curve for which 50 percent of the particles in the feed of that size report to the underflow i.e., particles of this size have an equal chance of going either with the overflow or underflow. The sharpness of the curve depends on the slope of the central section of the Tromp curve, the closer to the vertical is the slope, the higher is the efficiency.

The value of $d_{50\,(c)}$ is directly proportional to vortex finder diameter and operating pressure and inversly proportional to the spigot diameter and rate of water in cyclone overflow. The regression equation relating $d_{50\,(c)}$ to these variables is,

$$\log d_{50\,(c)} = VF/2.6 - spig/3.5 + P/10.7 - WOF/52 + K'' \quad \ldots \quad (3)$$

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where K" is a constant depending on cyclone and ore type.

(d) Reduced efficiency curve :

The reduced efficiency curve is a measure of the probability of appearance of particles in the coarse product due to centrifugal action alone and is suitable for use in the assessment of the performance of a cyclone as the operating conditions are altered. It has been found that the reduced efficiency curve of a given operation is constant for wide changes in flow rates and solids content of the pulp and vortex finder and spigot diameters of the hydrocyclone. It has been observed that the reduced efficiency curve for a mineral classified in hydrocyclones remains constant for all conditions including change in hydrocyclone diameter provided that geometric similarity is maintained.

It has been observed that the shape of the reduced efficiency curve is defined by the equation

$$Y = \frac{e^{\alpha X} - 1}{e^{\alpha X} + e^{\alpha} - 2} \qquad (4)$$

where α is the variable parameter which describes completely the shape of the curve.

Application of the Model at Rakha Concentrator :

Sampling of mill discharge and cyclone products were done in the operating plants and the data thus obtained were analysed and used for development of cyclone model[1]. Lynch and Rao[2,3] modelling approach has been used.

This model was used to determine the optimum conditions of operation and it was established that the system should be operated around 22 tph for achieving best results. The circulating load at this feed rate remains about 370 percent.

To reduce circulating load and to increase the throughput rates, secondary classification system was installed in one stream. This system gave a 10 percent increase in throughput. Though the coarse fraction in the flotation feed has increased slightly it was noted that its effect on flotation was insignificant. However, continuous operation over a period and further modification had shown that an increase of 30 percent in capacity has been achieved.[4]

This has resulted in increasing the ore treatment rate from 1000 to 1300 tpd. Alternatively, one of the grinding and classification circuits and one row of flotation cells can be stopped for about 10 to 15 hours every day leading to a saving of about Rs. 1500 to 2000 per day.

Thus the concept of modelling and two stage classification is worth trying in other ore treatment plants in the country.

Hydrocyclone—A Useful Tool for Control of Comminution Circuit :

Hydrocyclone is not only useful as a classification device, but advantage can be taken of its presence as an on-stream analyser, for control of the same comminution circuit.

A system of the type shown in Fig. 1 may be considered for the present discussion, although the arrangement may readily be extended to a system of any degree of complexity. In the figure the instruments used are :

W = gamma gauge which measures the specific gravity of the pulp,

Q = magnetic flowmeter which measures the volume flowrate of the pulp, and

P = pressure gauge to measure the pressure in the feed line ahead of cyclone.

With the help of these instruments, the mass flowrate of water in the cyclone feed pulp (symbol F) may be calculated from the measured values 'W' and 'Q' and d_{50} (corrected) value may be obtained from equation (3).

If d_{50} (calculated) is greater than d_{50} (required) more water may be added to the system to bring it to within required limits. If it is less, then the water addition at the sump may be reduced. A control algorithm of the form to be used is

$$Y = K X$$

where X is the difference between the calculated and the required d_{50} (corrected) and Y is the change to be made in the water addition at the pump sump.

This concept is successfully exploited in developing on-line control strategies in many comminution circuits in Australia, Canada and U. S. A.

Symbol Nomenclature

Q = Volumetric throughput, lpm.

P = Operating pressure.

VF = Vortex finder dia, cms.

FPW = Percent water in a hydrocyclone feed slurry.

WOF = Mass flow rate of water in overflow tph

Spig = Spigot dia, cms

WF = Mass flow rate of water in feed, tph.

X = Ratio of size of particle (d) to d_{50} c.

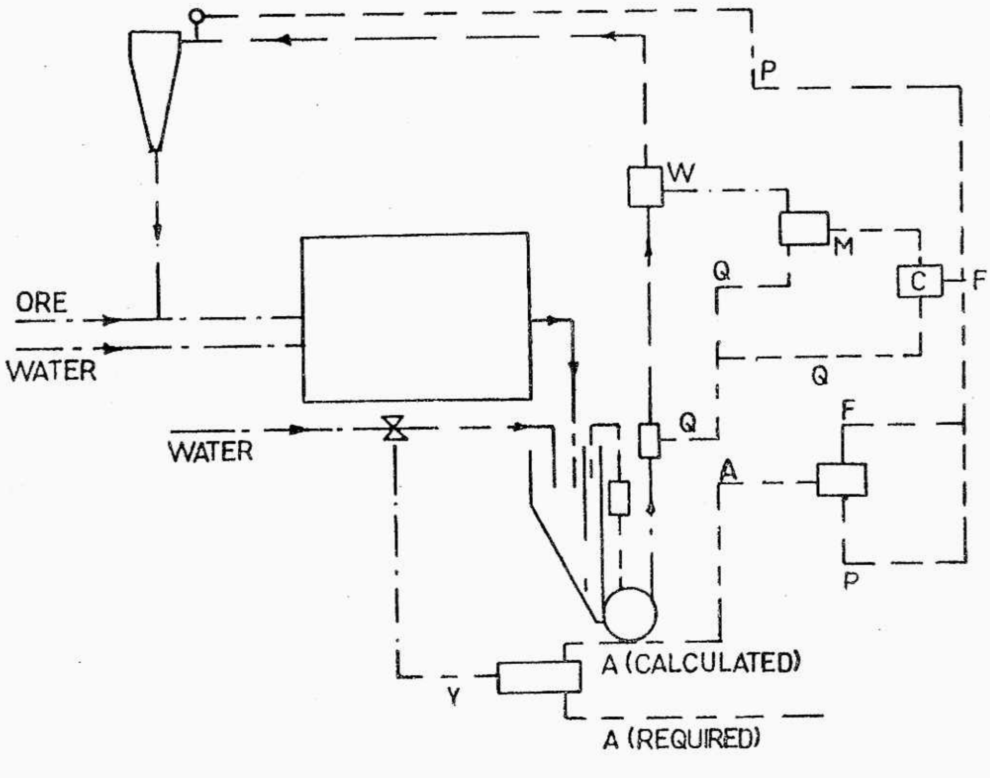

FIG. 1: CONTROL OF A COMMINUTION CIRCUIT

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