ГОДИШНИК НА МИННО-ГЕОЛОЖКИЯ УНИВЕРСИТЕТ "СВ. ИВАН РИЛСКИ", Том 50, Св. II, Добив и преработка на минерални суровини, 2007
ANNUAL OF THE UNIVERSITY OF MINING AND GEOLOGY "ST. IVAN RILSKI", Vol. 50, Part II, Mining and Mineral processing, 2007

# DESIGN OF CENTRIFUGAL HYDRAULIC CLASSIFIERS BASED ON HYDRODYNAMIC SIMILITUDE

***Romulas Sârbu****

*University of Petrosani, Romania*

**ABSTRACT.** Today, the hydrocyclon design starts from some technological parameters and empirical calculus relations. The present paper offers a few mathematical models by hydrodynamic similitude, based on experimental research (at laboratory scale) of quartziferous sands. Based on laboratory results, on the correlations between the hydrodynamic and construction parameters, it was carried out a hydrocyclon to the industrial scale. This new type of hydrocyclon was tested to the quartziferous ores from the Faget-Timisoara processing plant.
Hydrocyclon design, mathematical models by hydrodynamic similitude.

**ПРОЕКТИРАНЕ НА ЦЕНТРОБЕЖНИ ХИДРАВЛИЧНИ КЛАСИФИКАТОРИ НА БАЗАТА НА ХИДРОДИНАМИЧНА СИМУЛАЦИЯ**

***Ромулус Сърбу***

*Петрошански университет, Румъния*

**РЕЗЮМЕ.** В съвременни условия проектирането на хидроциклони се осъществява при наличието на няколко технологични параметри и емпирично изчислени зависимости. Представения доклад предлага няколко математически модели на хидродинамична симулация, базирайки се на експериментални изследвания (за лабораторен модел), на кварцови пясъци, съдържащи желязо. На базата на лабораторните резултати и установени корелации между хидродинамичните и конструктивни параметри, бе създаден хидроциклон до индустриални размери. Този нов тип хидроциклон беше тестван в обогатителната фабрика на Тимишоара при обогатяването на кварц-желязо съдържащи руди.

## 1. MANUFACTURE AND HYDRODYNAMICS OF ADDITIONAL WATER FLOW HYDROCYCLON

The special role the hydrocyclon plays in the field of useful mineral substances processing and within the related industries arises from its multilateral usage. This equipment can be used either for classification, thickening, slime pulp de-sliming and finally as concentration equipment.

The additional water flow hydrocyclon (see fig. no 1) consists of one relatively high cylindrical part (1) where the raw slime pulp is fed in by means of a feeding pipe (2) placed tangent to the cylindrical part.

At the bottom of cylindrical part certain concentric cones (3) are placed, which are tangentially fed with an additional water flow by means of the inlet pipe connections (4) placed at the same level with the free spaces between the above mentioned cones.

At the moment when the rotary downward slime pulp flow gets into the concentric cones area, named **washing area**, the rotary additional water flow interferes with this one involving the following:

- an increase of particles' tangential motion velocity; this fact brings about an increase of the centrifugal force;
- an increase of dilution which involves a better washing of the fines in the centrifuged material layer and a better aerated re-stratification depending on the sizes;
- driving of slime pulp containing small size particles - onto the hydrocyclon axis, this phenomenon being also favoured by the conic shape of the elements within the washing area.

The slime pulp containing mainly large size particles continues its downward motion, arriving into the lower cylindrical part (5) having larger diameter but lower height which is followed by a conical part (6); these elements can be easily assimilated both in manufacture and operation process with a classical hydrocyclon.

The *radius fracture* involved by the lower cylindrical part leads to a new re - stratification and re-arrangement of the material on size basis, having as final effect a reduction of under-size grains quantity, and implicitly an increase of classification efficiency.

Close to the cone point, a part of downward slime pulp flow changes its motion direction and it is forming an upward helical flow current which is overlapping over the existing upward flow current within the washing area.

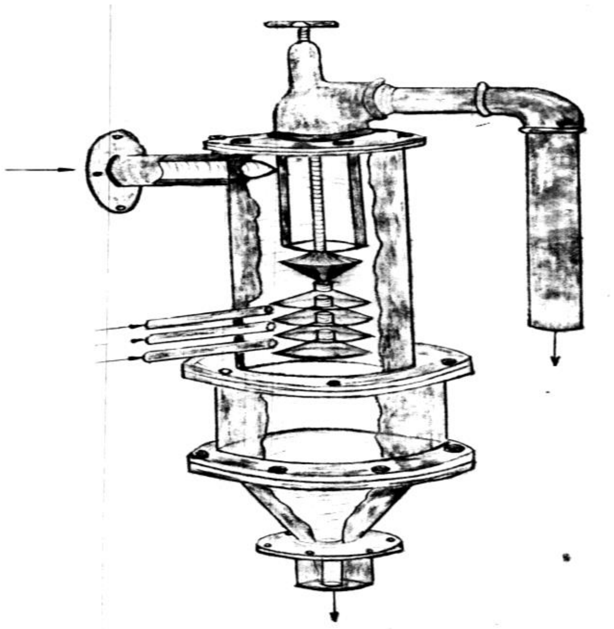

**Figure no.1. - Additional water flow hydrocyclon**

The slime pulp flow, containing mainly fines, in its upward motion meets a deflecting cone (7), which can be adjusted upon its vertical axis by means of the threaded rod (9) in the view of adjusting the overflowing and, implicitly, the separation size.

The upward pulp slime flow is forced to wrap up onto the lateral face of this cone, and interferes with the central part of the main pulp slime flow, where a relative stratification has already occurred, and takes over a large part of the fines and drives them to the siphon tube (9).

More over, in comparison with the conventional hydrocyclon, the new additional water flow hydrocyclon allows utilisation of certain simple and flexible methods for controlling the sizing process, it can be easily automatized and makes the sizing process be more accurate in accordance with the requirements of modern engineering concerning the processing of mineral resources.

The disadvantages consisting of more complicated construction and additional water consumption are compensated by the special results obtained with this equipment.

With the aim of improving the sizing efficiencies, and, especially, the uniformity rate of the products obtained at Faget – Timis siliceous sand processing plant on one hand and with the aim of establishing the interdependences between the sizing results and the hydrocyclon constructive and hydrodynamic characteristics – on the other hand - a set of 14 sizing tests on raw sand (grit) have been performed with an additional water flow hydrocyclon having the following characteristics:
- diameter of upper cylindrical part $d_2$ = 90 mm
- diameter of feeding inlet pipe $d_a$ = 25.4 mm
- diameter of overflowing outlet pipe $d_s$ = 25.4 mm, whose values depend on the deflecting cone position. For this reason the equivalent diameter ($d_s$) is considered for calculations.
- diameter of coarse product discharging outlet pipe, $d_e$ = 5 – 10 mm

With the aim of transposition the laboratory research results onto industrial scale, the first step consisted in appraising the influence of the constructive characteristics ($d_e$ and $d_s$) and of the technological characteristics (dilution "n", and additional water flow rate "$q_a$" expressed in percentages of feeding flow rate) upon the sizing result expressed by the separation size.

For this purpose the correlation and regression method was used, which, as it is very well known, not only allows determining the linear dependence (with good approximation) but also provides information regarding the intensity with which a variable influences the response. /1/

For a better evaluation of all these dependences, and due to the fact that the dependent variable is the same for all correlations, we proceed to the overlapping of all dependences onto the same diagram, (see figure no. 2).

Analyzing the figure no.2, it can be noticed the variation law of separation size depending on the constructive and technological parameters, as well as their antagonism.

While the separation size increases at the same time with the increase of overflow outlet pipe's equivalent diameter, of feeding dilution and of additional water flow rate, it was registered the decreasing of the under granulation into the thickened product, which leads to the improvement of sizing efficiency. At the same time, an increasing of fines content in overflow is obtained; all these together lead to the increase of the sizing accuracy.

## 2. TRANSPOSITION OF LABORATORY RESEARCH RESULTS ONTO INDUSTRIAL SCALE

For the design of the hydrocyclon main industrial subassemblies based on hydrodynamic similitude, it was used the mathematical model called **"Criterion M"** within the specialized reference material, which establishes the relationship between hydrocyclon constructive parameters and processing flow rate.

It will be considered that two models of different dimensions will behave identically from hydrodynamic point of view only if the criterion M has the same value. /2/

$$M=(d_2' - d_1') \times \left[ (d_2^2 - d_1^2)/Q' \right]^3 \quad (1)$$

Where:
$d_2'$ – diameter of laboratory hydrocyclon's cylindrical part
$d_1'$ – diameter of laboratory hydrocyclon's siphon pipe
$Q'$ – feeding flow rate in laboratory conditions

At the same time it was taken into account the specialized reference material recommendation regarding the ratio between the feeding pipe diameter "$d_a$", the siphon pipe diameter "$d_s$", the discharging pipe diameter "$d_e$", as well as the cylindrical part diameter at the level of feeding pipe "$d_2$", namely:

$$d_a=(0.4 - 1)\, d_s \; ; \quad d_s=(0.2 - 0.4)\, d_2 \quad (2)$$

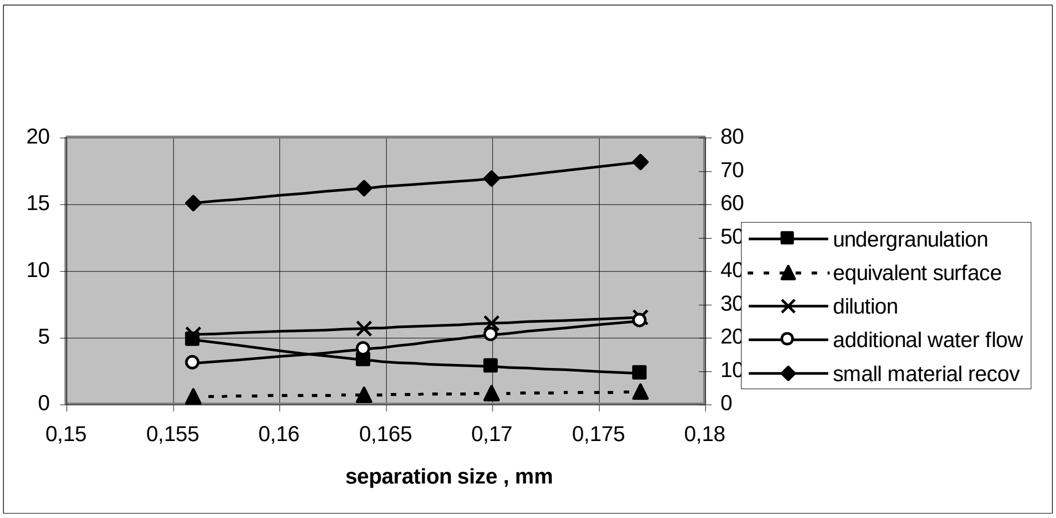


**Fig. no. 2 – Variation of separation size with technological parameters**

Under the conditions of HCCAD (additional water flow hydrocyclon) - laboratory model the value M = 26.763 was obtained.

For example: under the condition of a flow rate established by the beneficiary of Q=100 m$^3$/h, for the same M value, the following constructive dimensions have resulted : $d_2$ = 0.400 m, $d_s$ = 0.160 m, and da = 0.128 m.

The slime pulp ingoing velocity at the level of the feeding inlet pipe results from the law of continuity:

$$Q = u_{t2}.S_a \, , \tag{3}$$

from where:
$u_{t2}$ = 2.16 m/sec.

In order to calculate the tangential velocity at the level of siphon pipe, it was used the relationship of Kellsal /2/:

$$u_{ti} = \frac{u_{t2} r_2}{r_i} \frac{1+\ln\left(\frac{r_i}{r_1}\right)}{1+\ln\left(\frac{r_2}{r_1}\right)} \tag{4}$$

This way it was found: $u_{t1}$= 2,81 m/sec, and $u_{t2}/u_{t1}$ = 1,30.

Dynamic pressure at the siphon pipe level is:

$$P_{di} = \frac{u_{ti}^{\;2} \Delta_T}{2} \tag{5}$$

Where:
$\Delta_T$ – slime pulp density

Dynamic pressure considered for 250 gr/l concentration of solid phase in feed is of 4540 N/m$^2$.

The separation size achieved by the industrial hydrocyclon results from the condition of equilibrium of centrifugal forces and of forces of resistance to motion into the separation area, resulting from following relationship:/2/

$$d_p = \frac{3}{u_{ti}} \sqrt{\frac{Q\eta_{st}}{\pi h_i (\delta - \Delta_t)}} \tag{6}$$

Where:
$\eta_{st}$= dynamic viscosity of slime pulp,

$$\eta_{st} = \eta \frac{1}{(1-c_v)^{25}} \tag{7}$$

where:
η = water viscosity, 10$^{-3}$ [Ns/m$^2$]
$c_v$ = volumetric concentration in parts of unit
$h_i$ = height of rotating fluid coaxial area at the siphon pipe area's level
δ = solid phase density

In order to calculate the siphon pipe immersion depth, it is imposed the sizing dimension obtained for laboratory conditions, 0,2 x 10$^{-3}$ m.

Under these conditions, from relationship (8), the siphon pipe immersion depth against the upper level of feeding pipe will be of 0,22 m. Once this height value is known and using its calculus relation /2/, the apical angle of hydrocyclon conical part will be obtained:

$$h_i = \frac{r_2 - r_1}{tg\frac{\alpha}{2}} + d_a \tag{8}$$

The resulted apical angle is α = 105$^0$, which represent another characteristic of this type of hydrocyclon; this type of angles are met only at the thickening equipment.

Calculation of additional water inlet pipes' diameter and of water penetration tangent speed into the washing area cones' free spaces results from the condition that the additional water rotaries flow rate dynamic pressure of should be greater than the main slime pulp flow rate. Following the above-presented algorithm it results a diameter of 30 mm for the inlet pipes and an additional water flow velocity of minimum 2,79 m/sec, to which corresponds a dynamic pressure of 3917 N/m$^2$.

Based on the above-presented theoretical principles, as well as on the similitude mathematical models and on specialized reference material recommendations was designed the additional water flow hydrocyclon HCCAD 400 presented in figure no.3.

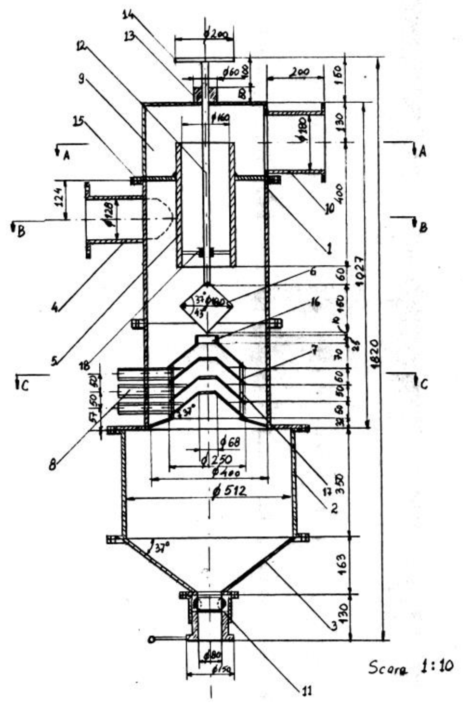


**Figure no.3 Additional water flow hydrocyclon – HCCAD 400**

1. Upper cylindrical body
2. Lower cylindrical body
3. Conical body
4. Feeding pipe
5. Siphon pipe
6. Deflecting cone
7. Overlapped cones (hoppers)
8. Injection inlets
9. Collecting room
10. Overflow discharging pipe
11. Adjustable discharging device
12. Throated rod

## Conclusion

Nowadays, for the design of sizing equipment, in general, and of hydrocyclons, especially, it is proceeded from a few technological pre – established parameters and by means of calculus relationships – which generally are of empiric type – the equipment main constructive elements are dimensioned.

In the present paper, based on a correlation and regression study it is established the influence of constructive and process parameters onto the sizing results, and further on, based on the results obtained and using for this purpose the hydrodynamic similitude mathematical models it is designed an industrial hydrocyclon type HCCAD 400 with nominal processing flow rate of 100 m$^3$/h.

The truthfulness of this dimensioning calculation method was verified in practice at Faget – EXTRACERAM – TIMIS Quartziferous Sand Processing Plant.

## Bibliography


1. **Simionescu A.,Nagy B**. – *Preparation processes' optimisation ,Technical Publishing House, Bucharest 1979.*
2. **Sarbu R.** – *Gravitational Preparation, Vol. I, Petrosani University Lithography, 1993.*
3. **Sarbu R.** – *Additional Water Flow Hydrocyclon, Application for invention patent, Brevet OSIM, no.119930 / 30. 08. 2006.*


Recommended for publication by the Editorial board