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Effect of Variables on Water Split Behavior in Hydrocyclone

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Chandranath Banerjee	Department of Mining Engineering, Indian Institute of Technology, Kharagpur
Suresh	Department of Mechanical Engineering, University Institute of Technology, Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal - 462036, India
Prof. Arun Kumar Majumder	Department of Mining Engineering, Indian Institute of Technology, Kharagpur
Prof. S N Verma	Department of Mechanical Engineering, University Institute of Technology, Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal - 462036, India

ABSTRACT

Understanding of water split behavior in any centrifugal separator at different operating conditions is essential to understand particle separation mechanism. In this paper an attempt has been made to quantify the effects of four major variables- spigot diameter, vortex finder diameter, feed inlet pressure and vortex finder length on water partitioning in hydrocyclone. For this purpose systematic experiment was carried out with a 76 mm hydrocyclone at various operating conditions. The study reveals that out of these four variables only spigot diameter and vortex finder diameter play a significant role in water partitioning behavior but feed pressure and vortex finder length has marginal effect on water split. Therefore, an attempt has been made to develop a correlation to predict the water partitioning behavior in the cylindro-conical cyclones using spigot diameter and vortex finder diameter as individual variables based on regression analyses of systematic experimental data generated. From the developed correlation it is found that these two variables almost have equal impact on the water split in hydrocyclone.

Introduction

Hydrocyclones are used as a classifier in mineral processing industries. The hydrocyclone consists of a conical shaped vessel, joined to a cylindrical section, which has a tangential feed inlet. There are two axial product outlets, the spigot is situated at the apex of the conical part and the vortex finder is located at the upper end of the cylindrical section and contains a tube extending into the hydrocyclone, known as vortex finder length. This is a dynamic particle separation unit, which utilizes centrifugal force to enhance the relative settling velocity differentials between the particles.

Despite of several advantages associated with hydrocyclones, the inability to classify particles at a givencut size consistently is the major disadvantage with them. The inefficiency is mainly due to the misplacement of significant amount of fine particles through underflow. Lynch and Rao (1975) have concluded that the recovery of relatively finer particles in the cyclone underflow is directly proportional to the water recovery through underflow. This suggests that water split behavior in a hydrocyclone influences its classification efficiency.

Therefore, many correlations (Abbot, 1962; Lindner, 1956; Moder and Dahlstrom, 1952; Plitt, 1976; Stass, 1957; Yoshioka and Hotta, 1955) have been developed to predict the water split in hydrocyclone. All these models are empirical in nature and therefore, the actual mechanism of water partitioning behavior in a hydrocyclone is yet to be understood properly. It may also be observed that majority of the models developed so far use cone ratio (ratio of spigot diameter and vortex finder diameter) as one of the model parameters. Use of cone ratio as a variable may be misleading (Shah et al, 2006) because the ratio may be kept constant by changing appropriate dimensions of spigot and vortex finder diameter but their effects are bound to be different.

Castro (1990) found that the water split is mainly controlled by the air core size and, therefore, the water split is governed by those operating conditions and variables which affect the air core. In literature, it is found that the vortex finder diameter (VFD), spigot diameter (SPD) and feed inlet pressure (P) are the three major variables, which affect the water split behaviour in cyclones (Verghese et al, 1994; Banerjee et al, 2003; Shah et al, 2006). As the effect of vortex finder length (VFL) has not yet been studied extensively on the water split behavior, an attempt has been made to do so.

Experimentation

Experiments were carried out in a laboratory scale 76 mm diameter hydrocyclone fitted in a closed circuit test rig consisting of conventional sump and pump assembly. A series of tests were conducted to study the effects of spigot diameter, vortex finder diameter, vortex finder length and feed pressure on water split. One variable at a time methodology was used during experimentation. A product splitting arrangement fitted on the top of the feed tank enabled the collection of overflow and underflow water simultaneously. The range of variables use in the experiment are shown in table bellow

Table 1. Ranges of variables used for experiments with water

Sl. No.	Variables	Levels	Range of variables
1	VFD (mm)	4	16, 19, 22, 25
2	SPD (mm)	5	9, 11, 13, 15, 17
3	P (psi)	4	10, 20, 30, 40
4	VFL (mm)	4	40, 42, 44, 46
Total Number of Experiments = 4 x 5 x 4 x 4 = 320			

RESULTS AND DISCUSSION

It is well known that the size and the stability of an air core created inside a hydrocyclone depend on the intensity of pressure drop in between the conical and the cylindrical portion (Nowakowski et al., 2004). This is because the centrifugal force generated inside a hydrocyclone due to the tangential entry increases with decreasing cyclone diameter. The performance of an industrial hydrocyclone is generally controlled by using suitable spigot diameters keeping other variables unchanged. Any change in spigot diameter will, therefore, change the pressure drop. Again any change in spigot diameter also changes the inlet velocity of fluid as the nature of restriction at the hydrocyclone outlet changes automatically.

Similarly, any change in the vortex finder diameter and the feed inlet pressure also change the inlet velocity of fluid and as a result the pressure drop in between the conical section and the cylindrical section inside a hydrocyclone also changes. Any change in vortex finder length also changes the distance between the two discharge ends i.e. the distance between the vortex finder and the spigot.

It is imperative from the above discussions that water split behavior in a hydrocyclone is strongly influenced by the feed inlet pressure (P), spigot diameter (Du), vortex finder diameter (Do) and the vortex finder length (VFL). To calculate the water partitioning at each operating condition the following equation has been used:

% Overflow = (flow rate through vortex finder (/Total flow rate) x100

Effect of Spigot Diameter (Du)
The effect of vortex finder diameter on water split is shown in Fig. 1. It may be observed that with increase in vortex finder diameter, water split decreases exponentially. The experimental data may, therefore, be expressed in an exponential form as

$R_{of}=K_1 (D_u)^{n1}$ (1)

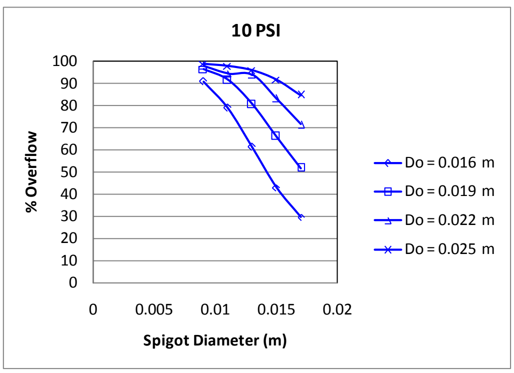

Figure 1: Effect of Spigot Diameter

The exponent value ranges from -0.10 to a value of -1.75.The negative sign represents the negative effect of Du on the % Overflow. Taking average for all the values of we get a value of -0.70. Incorporating this value in Eq. (1) we may write

$R_{of}=K_1 (D_u)^{-0.70}$ (1a)

Effect of vortex finder diameter (Do)
The variations of % overflow with vortex finder diameter at different spigot diameter at a given pressure shown in figure bellow. At different operating pressure the nature of the curve remains identical

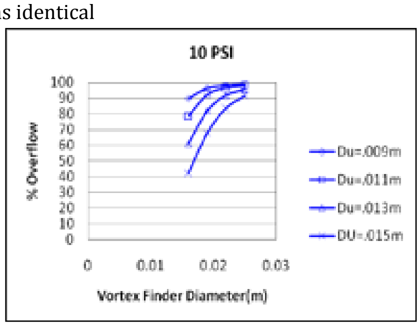

Figure 2: Effect of Vortex finder Diameter

The effect of vortex finder diameter on percentage overflow is shown in Fig. 2. To quantify the effect of vortex finder diameter on experimental data may, therefore, be expressed in an exponential form as

$R_{of}=K_2 (D_o)^{n2}$ (2)

The exponent value ranges from a minimum of 0.109 to a maximum value of 1.442. This huge variation in the exponent value establishes as well the strong influence of Do on the % Overflow. Taking average for all the values of we get a value of 0.645.Incorporating this value in Eq. (2) we may write

$R_{of}=k_2 (D_o)^{0.645}$ (2a)

Figure 1: Effect of feed inlet pressure
The variations of % overflow with feed pressure at different spigot diameter at a given vortex finder diameter is shown in figure bellow.

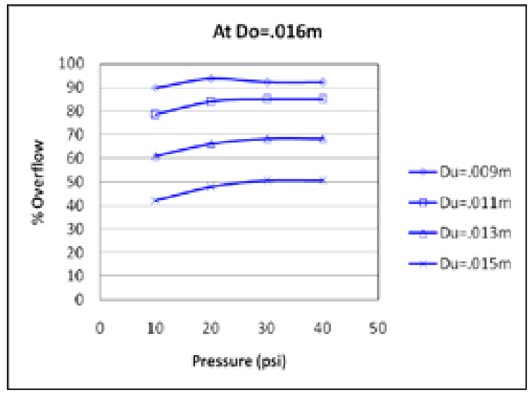

Figure 3: Effect of feed inlet pressure

From figure 3 it is observed that the % Overflow increases marginally with increasing feed inlet pressure at a constant Du and Do. As the variation in data is marginal, no attempt has been made to quantify the trends of the data observed.

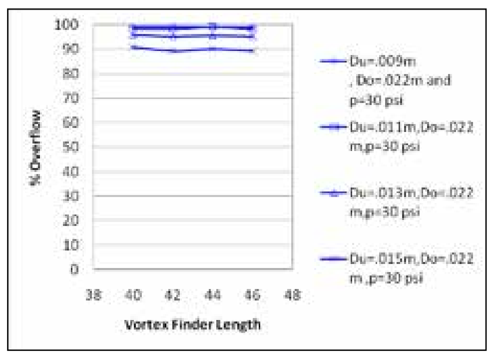

Figure 4: Effect of Vortex Finder Length

It is also observed from the Figure 4 that the % Overflow increases marginally with increasing vortex finder length at a constant Du and Do and feed inlet pressure, P. As the variation in data is marginal, no attempt has been made to quantify the trends of the data observed.

From the above discussion it is interesting to note that amongst the four variables studied only Du and Do are the most sensitive variables causing water split in a classifying cyclone.

Conclusions
1. Water flow rate in overflow directly depends on spigot opening and vortex finder diameter.
2. Instead of using cone ratio as a model parameter, spigot and vortex finder diameters should be used as independent variables for water split modeling in hydrocyclones.
3. Inlet pressure has little role to play in water split behavior, this is opposed to the conventional understanding of the water split mechanism as explained in the literature. Actually, feed inlet pressure controls the inlet water velocity which is dependent on the effective cross-sectional areas of the spigot and the vortex finder when the hydrocyclone is in

operation. Therefore, the increase in feed inlet pressure beyond a critical limit will not increase the inlet water velocity further as the increase in inlet pressure beyond a certain limit will be due to back pressure only which will have no impact on inlet water velocity.

4. Vortex finder length also does not affect much on the water split behavior.
5. The values of the exponents of Du and Do are almost identical which establishes the equal impacts of these two variables on the water split behavior in a hydrocyclone.

Nomenclature

- Du Spigot diameter in meter
- Do Vortex finder diameter in meter
- Di fee inlet diameter in meter
- Dc cyclone cylindrical diameter in meter
- k_1 k_2 and K Constants
- R_{of} percentage recovery in overflow
- Q_O water flow rate in overflow, kg/s
- Q_u water flow rate in underflow, kg/s

REFERENCE

1. Abbot, J., Trans. Inst. Min. & Metall., 71, 531 (1962). 2. Banerjee P. K., Rao T. C., Govindarajan B., Bapat J. P.,Chatterjee, S. Barnwal, J. P. and Rao, P. V. T. A Plant Comparison of the Vorsyl Separator and Dense Medium Cyclone in the Treatment of Indian Coals. International Journal of Mineral Processing, Vol. 69, 101-114, 2003. 3. Bradley, D., The Hydrocyclone, 1st edition, Pergamon Press, New York, 1965. 4. Castro, O., Pulp Rheology effects for hydrocyclone models, M.Sc. Thesis, University of Queensland, 1990. 5. D.J. Kelsall and J.A. Holmes, Hydrocyclones, U.S. Patent No. 3,130,157, 1964. 6. Govindarajan, B., Modeling Studies on Vorsyl Separator and Heavy Medium Cyclone, PhD Tesis, Indian School Of Mines, Dhanbad, 1991. 7. Lindner, E., Maschinenbautechnic, 5, 455 (1956). 8. Lynch, A.J., Rao, T.C., Modelling and scale up of hydrocyclone classifiers. Paper Presented at 11th Int. Min. Process. Cong., Cagliari, Italy, (1975). 9. Moder, J.J., and Dahlstrom, D.A., Chem.Engg. Progr., 48,75(1952). 10. Nowakowski, A.F., Cullivan, J.C., Williams, R.A., Dyakowski, T., 2004. Application of CFD to modeling the flow in hydrocyclones. Is this a realizable option or still a research challenge? Minerals Engineering 5, pp. 661–669 (2004). 11. Plitt, L.R., A mathematical model of the hydrocyclone classifier, CIM Bull., 69(776), pp. 114-123(1976). 12. Shah, H, Majumder A.K., and Barnwal J.P., Development of water split model for a 76 mm hydrocyclone, Minerals Egineering, 19, pp.102-104(2006). 13. Stass, M., Int. Min. Dress. Cong., Stockholm (1957). 14. Wills, B.A., Mineral Processing Technology, 5th edition, Pergamon Press.New York, 1992. 15. Yoshioka, N. and Hotta, Y., Liquid cyclone as a classifier, Cehm. Engf. Japan, 19, pp 632-640(1955).