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Influence of Solid Particles on Centrifugal Pump Characteristics

A. Benretem, A. Haddouche, H. Cheghib and S. Saad
Departement of Electromecanique, Faculte sciences de l'Ingenieur,
Laboratoire des systemes Electromecaniques, Universite BadjiMokhtar, Annaba, Algerie

Abstract: In this work the influence of solid particles on centrifugal pump is presented. The solid used is slurry of washed phosphate having a density of 2800 kg m^{-3} and a maximum solid particles diameter of 3 mm. The tests are carried out with a metal impeller pump having 6 blades.The obtained results are compared with those available in the literature and recommendations are proposed to recalculate centrifugal characteristics of pumps functioning in mixture.

Key words: Centrifugal pump, mixture, characteristics

INTRODUCTION

Because of their inherent advantages such as consistent flow rate, maintainability and excellent stability, the centrifugal pumps are largely used in hydraulic transport systems of solid particles. The pumps selection in transport depends mainly on the results of the tests already made on the characteristics of pumps with clear water[1]. When solid particles are introduced into the liquid, the physical and mechanical properties change and the liquid cannot be regarded as homogeneous. Generally when solid particles speed is lower than 1mm/s, the liquid is regarded as homogeneous. Several studies[2] were carried out giving results for real conditions because of the absence of a universal method expressing the influence of solid particles on the perfermances of centrifugal pumps. In this work the real conditions of centrifugal pumps operating in a processing phosphate plant (Djebel-onk Algeria) were taken into considerations

Fairbank[3] presents a complete theoretical method which expresses the pump characteristics change according to the mixture parameters.The speeds of the water particles and solid at the exit of the impeller are calculated and used to calculate the height developed in mixture.

$$H_m = \frac{\omega}{g.S_m}\begin{bmatrix} S_s.C\left(R_2.Cu_{2.s} - R_1.Cu_{1.s}\right) + \\ \left(1-C\right)\left(R_2Cu_{2.0} - R_1Cu_{1.0}\right) \end{bmatrix}$$

Or Sm and Ss are repectively the densities of the mixture and the solid.
And

$$Sm = Ss.C + (1- C)$$

Frasier[4] presents a simple expression of pump efficiency reduction factor determination but it does not include solid paryicle sizes.

Vocaldo and Sagoo[5] suggerst simply that pump head of discharge in mixture decreases by 10 to 20% compared to that obtained from clear water.

Burgess and Reizes[6] give an estimation method of pump characteristic in mixture by knowing that of clear water and propose an empirical relation between water head and mixture:

$$K_H = (1-C_P)^N$$

K_H - head reduction factor
C_P - Concentration in weight

The value of parameter N for each solid used is given according to Table 1

Smolderev[7] shows that the pump head with concentrations lower than those criticized can be expressed at follows:

$$H_m = 1+K_1(\rho m/\rho o -1)^m$$

with

$$K_1 = 0.5\text{-}0.6$$
$$m = 0.85$$

Table N°1: Value of parameter N

	Type of solid	N
01	Sand beach	0.333
02	Stream sand	0.589
03	Ilmenite	0.450
04	Heavy ore	0.561

Corresponding Author: A. Benretem, Departement of Electromecanique, Faculte sciences de l'Ingenieur, Laboratoire des systemes Electromecaniques, Universite BadjiMokhtar, Annaba, Algerie

Mogilevski[8] proposes that the head in mixture created by the pump in the zone of ±20% of the nominal state isexpressed as follows:

$$H_m = H_0\, \rho m/\rho o$$

The Institute of Search for Hydraulics of Ukraine[9] gives the head relation according to mixture density and solid particle diameter.

$$H_m = H_0(1 + \frac{0,5}{\psi^{0,5} + 0,5})(\frac{\rho_m}{\rho_0} - 1)$$

ψ-coefficient which takes into account solid particle shapes.

These relations do not take account in consideration geometrical and kinematical parameters of the pumps, they are valid only for tested pumps.

Gahlot V[10] proposes a recalculation of the pump characteristic factor by using the influence of bulk density, particle sizes and concentration.

$$K = 0.00056\,(S\text{-}1)^{0.72}\,(1+3/S)\;C_P \lg\,(50d)$$

D-solid particles diameter.

This equation is similar to that proposed by Cave[11], the difference results in the term (S-1) which take into consideration the solid bulk density.

MATERIALS AND METHODS

The pump used in the test rig is a single stage centrifugal pump of the K-20-30 type driven by an electric motor with a rated speed of 2900 rpm. To keep the same transport conditions during the tests, a closed circuit was used. The pump position facilitates the regulation of the flow and the mixture concentration without cavitations mode. The reception tank is provided with a special measuring cap, a filter and a sensor to indicate yhe liquid level. The flow is measured by a with diaphragm flowmeter. The discharge pressures and of suction are given by the vacuumeter and the pressure gauge. The mixture density is measured by a hydrostatic densimeter. The pump characteristics and solid particles are given in Table 2 and 3.

Table 2: Pump characteristics

Designations	Value
Suction pipe (mm)	0.062
Control of repression (mm)	0.062
Diameter of the wheel (mm)	162
Type of wheel	Closed
A number of blade	6
Specific speed	70
Number of revolutions rpm	2900
Head of discharge (m)	30
Flow (l/s)	5.5

Table 3: Solid particle properties

Proprieties	Larry of washed phosphate
Density kg m^{-3}	2800
Maximum diameter of the particles (mm)	0.2
Concentration %	30

RESULTS AND DISCUSION

The effect of solid particles density and their equivalent sizes are very important for the determination of head reduction factor and efficiency. The influence of the solid particles was studied by many authors. For example, the data of Burgess and Riezes[12] were obtained with an ore product having a relative density of 4.35 and particles of diameter D = 290 micron, the reduction factor is similar to that of pumps operating with a sand having a relative density of 26.50. The reduction factor value is the same for the tow densities and is equal to 0.10. Sellgren and Addie[13] have found that the granulometric distribution is very important for reduction factors determination, thus a great fraction of fine particles has an effect on these factors. Considering the studied impeller has an external diameter of 162 mm and a width of 8 mm which leads us to use particles of diameter lower than 0.3 mm.

For concentrations in volume lower than 15% the head and the efficiency of reduction factors varies linearly. For significant concentration values, factor variation is very large. Tests were carried out using centrifugal pump with impeller diameter of D = 0.81 m and a solid particle diameter of d = 1.50 mm[14]. Since the maximum concentration in volume is 15% thus, the head factor and efficiency varies linearly with mixture concentration.

By using the factors with undefined sizes of the head **δ** which is defined by: **δ** = $g.H/(\omega^2.D^2)$ and of the flow **σ** defined by: **σ** = $Q/(U.D^3)$ or g is the acceleration of gravity in m/s^2, H is the head developed by the pump is expressed in meters of water column or in meters of column of mixture, Q the flow in m^3/s, U the driven speed in m/s, ω the angular velocity in rad/s and D the diameter of the pump impeller in meters. Fig. 1 a, b, c shows clearly that the concentration or the mixture density has a significant effect on the centrifugal pump performances. The decrease of head and efficiency increases with concentration in volume increasing. This reduction is more significant for higher concentrations.

The obtained curves reveal that the absolute decrease of the head H_o-H_m or efficiency η_o-η_m for the same concentration is constant independently of the flow.

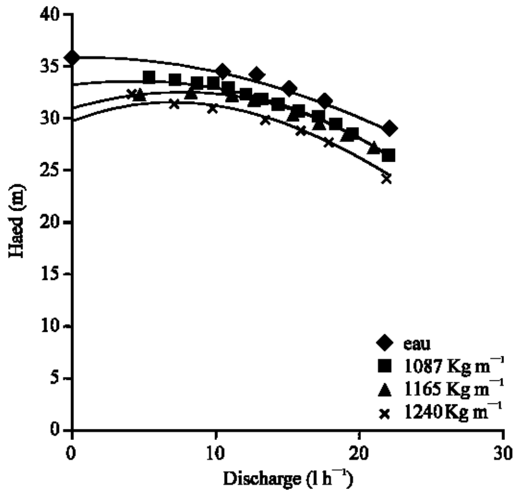

Fig. 1a: Characteristic head virsus discharge for different mixture densities

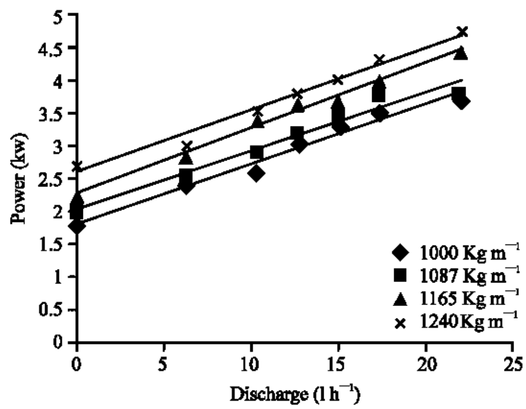

Fig. 1b: Characteristic of power versus discharge for different mixture densities

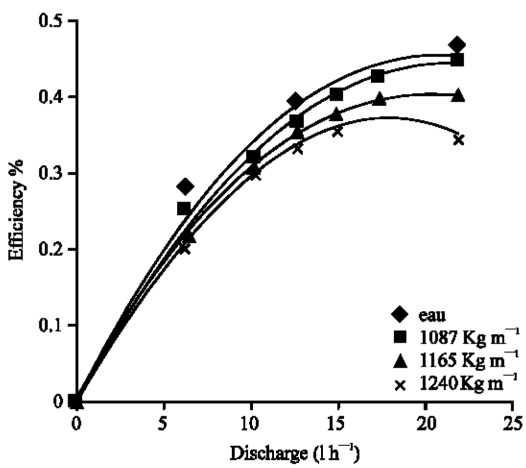

Fig. 1c: Characteristic efficieny virsus discharge for different mixture densities

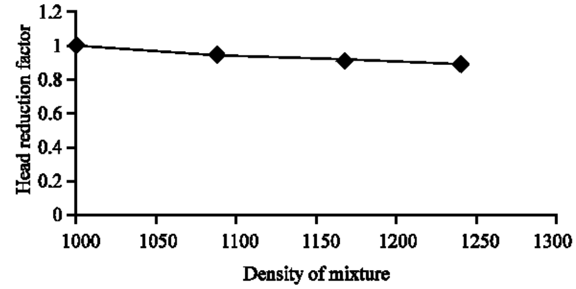

Fig. 2a: Variation of the head factor according to mixture density

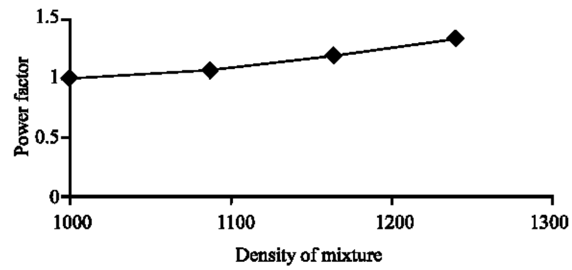

Fig. 2b: Variation of the power factor according to mixture density

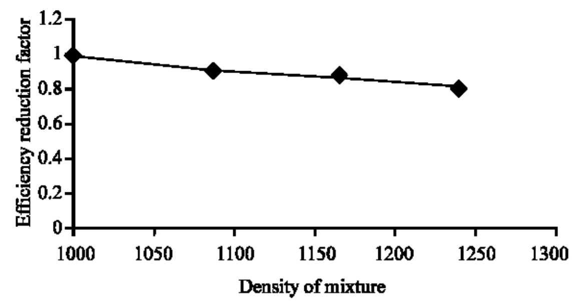

Fig. 2c: Variation of the efficiency factor according to mixture density

A quantitative analysis can be obtained by comparing the results of the K-20-30 pump with those obtained by F.NI, W.J.Vlasblom, A.Zwartbol[15] who have used a centrifugal pump driven by diesel engine of 164 KW with impeller diameter of D = 400 mm and 3 blades. The head reduction factor is KH = H_o-H_m/H_o and of the efficiency is $K\eta$ = η_o-η_m/η_o, for a concentration lower than 35% and a diameter of solid particles lower than 0.372 mm, the two factors are identical Fig. 2 a, b, c.

CONCLUSION

The study of the literature and the obtained experimental results enable us to make the following conclusions:

The correction methods of centrifugal pump characteristics are given for well defined conditions, i.e. absence of a universal adequate method.

The correction factors vary with mixture mechanical and physical parameters: concentration, particle sizes, solid particle shape and mixture density

The mixture concentration has a considerable effect on the centrifugal pump characteristics. For concentrations lower than 15% the head reduction factor and efficiency are almost equal.

The granulometric distribution is very significant for the determination of pump performances working in mixture in particular the wear and the choice of parts material.

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