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ABSTRACT:

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The corresponding dimensionless groups obtained from a dimensional analysis of centrifugal and jet pump performance are compared in this paper. A new characteristic parameter for the correlation of jet pump cavitation performance is derived from the comparison, the new parameter being the analog of suction specific speed for a centrifugal pump. Data are presented to illustrate the correlating ability of the parameter.

It is the object of this paper to exploit the basic similarities between centrifugal and jet pumps to construct, for the jet pump, a set of dimensionless parameters completely analogous to those employed for the presentation of centrifugal pump performance. In particular, the jet pump analog of centrifugal pump suction specific speed will be derived for correlation of jet pump cavitation performance.

Basically, the centrifugal and jet pumps differ only in the method employed to transfer energy to the pumped fluid. The centrifugal pump utilizes rotation of an impeller disc; the jet pump employs injection of a high-velocity jet.

Let us begin with a hasty review of the performance analysis for a series of geometrically similar centrifugal pumps. We shall be concerned first with pump head-rise H , and its dependence on the density ρ and viscosity μ of the pumped fluid, the volume flow-rate Q , impeller size D , and rotational speed n . The treatment of gravitational acceleration g as a separate variable is avoided by taking the product gH as the dependent variable. We therefore assume⁽¹⁾

$$gH = f_1(\rho, \mu, Q, D, n)$$

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(1) "An introduction to Fluid Mechanics and Heat Transfer", J. M. Kay, University Press, Cambridge, 1957, pp. 88-92.

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Dimensional analysis then reduces this function to the simpler dimensionless relationship

$$\frac{gH}{n^2 D^2} = f_2\left(\frac{Q}{nD^3}, \frac{\rho n D^2}{\mu}\right)$$

-2-

where the three dimensionless groups are a head coefficient, a flow coefficient, and a Reynolds number, respectively. A parameter involving only pump operating conditions may be constructed by elimination of impeller diameter between the head^{and}/flow coefficients. With the proviso that ^t rotational speed appear linearly, this yields the dimensionless specific speed,

$$n_s = \frac{n \sqrt{Q}}{(gH)^{3/4}}$$

-3-

Turning our attention now to cavitation performance, it has been shown⁽²⁾ that similarity of cavitation conditions is attained if the Thoma parameter σ , i.e., the ratio of net suction head H_{sv} to pump head H , is held constant for similar flow conditions, the latter implying constancy of specific speed. Eliminating H between σ and n_s then yields a parameter involving only inlet conditions. This parameter is, of course, the suction specific speed. In dimensionless form,

$$S = \frac{n \sqrt{Q}}{(gH_{sv})^{3/4}}$$

-4-

It is this last quantity whose jet pump analog is sought.

Nozzle head-difference H_N and nozzle flow Q_N yield a measure of the energy input to the jet pump; impeller size and rotative speed serve the

(2) "Cavitation Characteristics of Centrifugal Pumps Described by Similarity Considerations", G. F. Wislicenus, R. M. Watson, and I. J. Karassik, Trans ASME, Vol. , 1939, pp. 17-24.

same function for the centrifugal pump. Let us therefore begin the analysis by replacing n and D by gH_N and Q_N . We then have

$$gH = f_3(\rho, \mu, Q, Q_N, gH_N) \quad -5-$$

Equation -5- may be reduced to

$$\frac{gH}{gH_N} = f_4\left(\frac{Q}{Q_N}, \frac{\rho Q_N^{\frac{1}{2}} (gH_N)^{\frac{1}{4}}}{\mu}\right) \quad -6-$$

where the three dimensionless groups have the same physical interpretation as in equation -2-.

Comparing corresponding groups in equations -2- and -6-, we obtain Table 1, which shows equivalent quantities for the two pumps. The first three lines of Table 1 were obtained directly from equations -2- and -6-; only two of these equivalence-pairs are independent, of course, any one being derivable from the other two. The remaining two equivalence-pairs result from eliminating n and D , respectively, in the first three lines.

The jet pump analog of specific speed is then obtained from equation -3- and Table 1.

$$n_{sj} = \left(\frac{H_N}{H}\right)^{\frac{3}{4}} \left(\frac{Q}{Q_N}\right)^{\frac{1}{2}} \quad -7-$$

Finally, we obtain the jet pump analog of suction specific speed from equation -4- and Table 1 as

$$S_j = \left(\frac{H_N}{H_{sw}}\right)^{\frac{3}{4}} \left(\frac{Q}{Q_N}\right)^{\frac{1}{2}} \quad -8-$$

The right-hand side of equation -8- is the new cavitation correlation parameter.

Figure 1 shows ORNL data plotted on the usual head coefficient versus flow coefficient coordinates for both non-cavitating and cavitating operation of a jet pump. The non-cavitating data were taken with a large submergence on the pump. The cavitating data were taken by reducing the net suction head to the values shown on the figure and forcing the pump into cavitation by increasing nozzle flow. The hook shape of the curves is characteristic.

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The cavitation data of Fig. 1 are correlated in Fig. 2 in terms of a cavitation coefficient and the cavitation parameter S_j . The cavitation coefficient is defined as the ratio of the cavitating to the non-cavitating head ratio. On the basis of the limited data presented, the correlation seems quite good.

In summary, then, dimensional analyses were made of centrifugal and jet pump performance. Equivalence-pairs were determined from a comparison of corresponding dimensionless groups. From these equivalence-pairs and definitions for the centrifugal pump were obtained the jet pump analogs of specific speed and suction specific speed, n_{sj} and S_j , respectively. S_j was applied to the correlation of a limited amount of jet pump cavitation data with promising results.

Table 1 Centrifugal and jet pump equivalents derived from a dimensional analysis.

Centrifugal Pump	Jet Pump
$n^2 D^2$	$g H_N$
$n D^3$	Q_N
$n D^2$	$Q_N^{1/2} (g H_N)^{1/4}$
D	$(g H_N)^{-1/4} Q_N^{1/2}$
n	$(g H_N)^{3/4} Q_N^{-1/2}$

LEGEND

- Non-cavitating
- △ Cavitating, 3.0 in H_2O suppression head
- + Cavitating, 4.5 in H_2O suppression head

Fig. 1. Performance of a Jet Pump under Noncavitating and Cavitating Conditions. Nozzle-to-Throat Area-Ratio = 0.107.

Fig. 2. Cavitation Performance of a Jet Pump as a Function of the Cavitation Parameter S_j . Nozzle-to-Throat Area-Ratio = 0.107.