CAVITATION EROSIVE WEAR IN CENTRIFUGAL PUMP

by

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ABSTRACT

The aim of this work is to present experimental results concerning erosion in centrifugal pumps due to cavitation. In addition, cavitation induced vibration is also studied. The test loop is equipped with a centrifugal pump having five blades aluminium impeller. The results show that the cumulative weight loss-time curve confirms the conventional"S" shape, and the weight loss rate increases rapidly with impeller speed. It is found that increasing cavitation intensity is associated with increasing vibration level. The data obtained show that it might be possible to correlate the weight loss rate as a function of the nominal incubation period.

INTRODUCTION

Erosin is one of the major concequences of cavitation. Cavitation erosive wear is generally encountered in the operation of fluid flow devices such as pumping machinery, water turbines and hydraulic structures. A vast amount of literature has been published dealing with cavitation erosion phenomenon. A review of the fluid induced erosion phenomenon is presented by Hammitt[1]. Most of the existing research work has been carried out using laboratory cavitation test devices such as vibratory horn, etc....
The experimental results from hydraulic machinery prototype cavitation experiments are rare[2]. At the present time, the major problem is the relative inability to predict the erosion rate in fluid machinery from available laboratory tests or theoretical models[1]. One of the major difficulties of the prediction of erosion rate from available laboratory results is the corrosion. The damage in the test devices is the result of the combined effect of erosion and corrosion, the laboratory test devices will emphasize the mechanical erosion.

Generally, it is now supposed that cavitation erosive wear is a result of liquid impingement. A liquid microjet is generated from bubbles collapse. Since the erosion is connected to the jet impingement, the density and frequency of the impingement are the most important variables. This leads to the consideration of vibration and noise emission in the study of cavitation erosion phenomenon. The experimental results presented in references[3,4] show that a correlation existes between noise intensity and erosive wear.
There are some parameters may be considered in the evaluation of wear such as time, size scale effect, and suppression pressure NPSH. The experimental results and field measurements show that increasing NPSH reduces cavitation damage [1]. A survey of cavitation effects in hydraulic turbines shows that the size scale exponent has not appear to be a reliable predicator of increasing erosion rate with increasing size[5]. The time scale effect is strongly connected to the erosion

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mechanism. The cumulative weight loss versus time curve is characterized by an incubation period followed by a period of increasing erosion rate, up to a maximum and finally a period of decreasing erosion rate. A correlation between the parameters involved in the study of the time scale effect is presented in reference [6] . The results show that the wear loss rate may be predicted from the incubation period and more precisely the nominal incubation period as defined in [3] .

The objective of this investigation is to present experintal results concerning the vibration level, cavitation factor, running speed and erosion rate in view of possible correlation between these factors.

EXPERIMENTAL SET'UP AND TEST PROCEDURE

A test rig has been designed and constructed to investigate the cavitation phenomenon in centrifugal pumps. The test rig is shown schemattically in fig.1. The loop is equipped with a centrifugal pump having five blades impeller. The impeller is made from aluminium. The pump is driven at different speeds by two motors through a system of pulleys. Suction and discharge pipes are made from glass. The cavitating flow condition is reached with decreasing NPSH by the two following methods:

1- partial closing of the suction valve.
2- increasing the impeller velocity.

Vibration analysis was performed in three selected points each in three directions. Points 1 and 2 are on the bearing of the low speed motor and point 3 is on the pump casing. Vibration analyzer is used. It is connected to an accelerometer sensor of the type pizoelectric. The vibration analyzer has a built-in tunable filter with range 60 to 600000 cpm. Weight loss of the impeller is measured by digital scale self calibrated with accuracy of 0.1 mg. U-tube manometers were used to measure pressures with accuracy of 1 mm . The discharge was measured by a calibtrated tank.

RESULTS AND DISCUSSIONS

Thoma cavitation factor (σ)does not include the impeller speed. Therefore, its ratio to the suction specific speed (ξ, σ/s) will be considered as one of the dominating parameters.

A- Cavitation erosion

1. Time scale effect

In order to study the time effect several runs were carried out for three different Thoma factor. The parameters as running speed and temperature were kept constant. Fig 2 illustrates the cumulative weight loss (CWL)against the operating time for three different . It is clear that the CWL decreases with increasing Toma cavitation factor. The CWL versus time relation confirms the conventional"S"shape of the curve as presented in litratures[1,2]. According to Fig.3, the weight loss rate (WLR)increases with time upto a maximum and then decreases again for a specified . Since the relation between WLR and time is of cyclic nature, thus combined exponential and sine curve function may exhibit the characteristics of the relation. The relation may be written in the following form :

$$WLR = \beta \cdot e^{\alpha t} + (WLR)_m \cdot \sin\left(\psi_0 - \frac{2\pi t}{\tau}\right)$$

where β, α and γ are constants determined experimentally, the above correlation indicates that the erosion is a result of fatigue type failure.

2. Suppression Head "NPSH"Effect

Fig.4 shows the effect of impeller speed and NPSH on the WLR for the first six hours of operation. Generally, the WLR decreases as NPSH decreased, which is acceptable as presented in [1]. On the other hand the WLR increases sharply as the impeller speed increases. The relation between the WLR and impeller speed at constant NPSH is an exponential relation of the form

$$WLR \propto (speed)^{\alpha}$$

According to the obtained results (Fig.4) the exponent α equals 1.8,approximately. In fact the exponential relation between the WLR and speed is acceptable as presented in [1,3].

B- Cavitation induced vibration

The vibration level was measured at normal and cavitating conditions. Analysis of vibration was performed in the frequency rang 600-600000 cpm. According to Fig. 5 it can be deduced that the amplitude and velocity of the vibration increase as NPSH decreased. The measurements inducate that the amplitude, velocity and acceleration of cavitation vibration occured at blade running frequency(B.R.F) and its multiplications.

Fig. 6 presents the relation between the flow discharge Q and vibration measured in terms of spike energy. The cavitation inception points are shown on Fig.6 by the dotted line. The cavitation inception is manifested by the appearance of the bubbles in the discharge line accompanied with approximately 4% reduction in the manometric head. The advantage of using spike energy term instead of velocity term is that; the spike energy detects the pulse amplitude, rate of occurance of the pulses and the amplitude of the high frequency broad band vibratory energy associated with bubbles collapse[7]. In fact, the spike energy measures the ultrasonic microsecond range pulses caused by microjet impengement due to bubble collapse[7].Fig.6 illustrates that increasing cavitation intensity is associated with increasing vibration level

C- WLR and Nominal Incubation Period

Fig.7 shows the relation between Thoma cavitation factor and the maximum weight loss rate period(MWLRP). On the same figure the variation of nominal incupation period(NIP) is also presented.It is clear that NIP and MWLRP increase with increasing Thoma cavitation factor which is physically acceptable.

The relation between the MWLRP and its corresponding maximum weight loss rate is shown on Fig.8 for constant impeller speed and constant temperature.THE figure indicates that as the maximum weight loss rate period increases the lower is the wear rate. The same trend was obtained by Selim[6]. From figures 7 and 8 the WLR may be predicted knowing either the NIP or MWLRP.

CONCLUSIONS

Based on theobtained results and discusion the following conclusions are drawn:

1. The experiment conferms the"S"type shape of the cumulative weight loss curve, this cycle may be repeatable with different amplitude.
2. Increasing the net positive suction head reduces the rate of cavitation erosion.
3. For fixed net positive suction head the relation between the erosion rate and impeller speed is exponential form. The numerical value of the exponent as obtained equals 1.8.
4. Increasing cavitation intensity increases the vibration level.The vibration frequencies equal the blade running frequency and its multiplication.
5. A relation exists between the weight loss rate and the nominal incubation period.

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NOMENCLATURE

CWL	Cumulative weight loss
BRF	Blade running frequency (Nxnxγ)
g	Gravitational acceleration
g.S.E.	Acceleration unit of spike energy
n	Number of blades
N	Impeller speed,r.p.m.
NPSH	Net positive suction head
NIP	Nominal incubation period,hr
WLR	Weight loss rate mg/hr
$\mathrm{WLR)}_m$	Maximum weight loss rate
W	Angular velocity
Q	Discharge
S	Suction specific speed $W\sqrt{Q} / (NPSH.g)^{3/4}$
τ	Erosion period
σ	Thoma cavitation factor NPSH/Hm
γ	Multiplication factor
ξ	Thoma cavitation factor to suction specific speed ratio

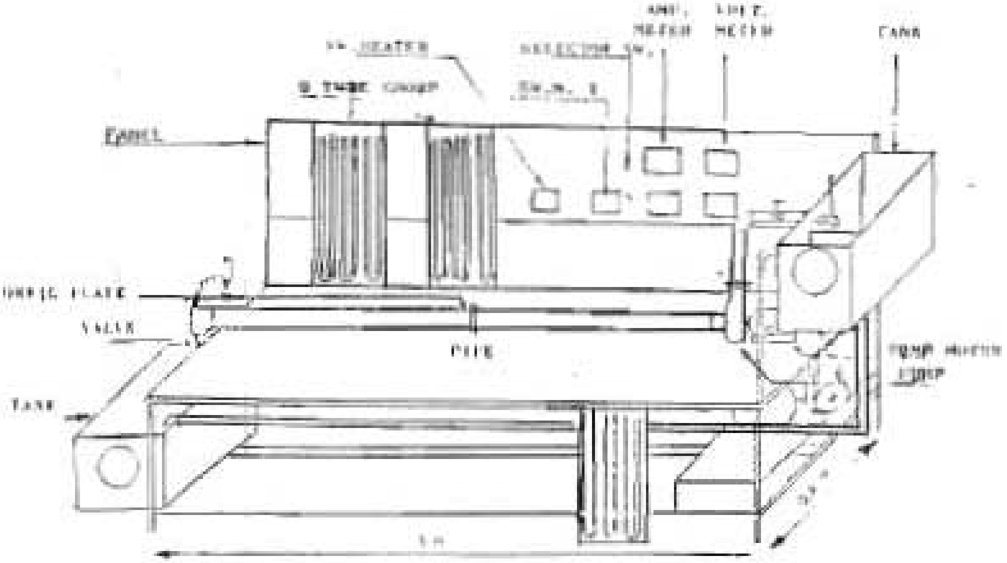
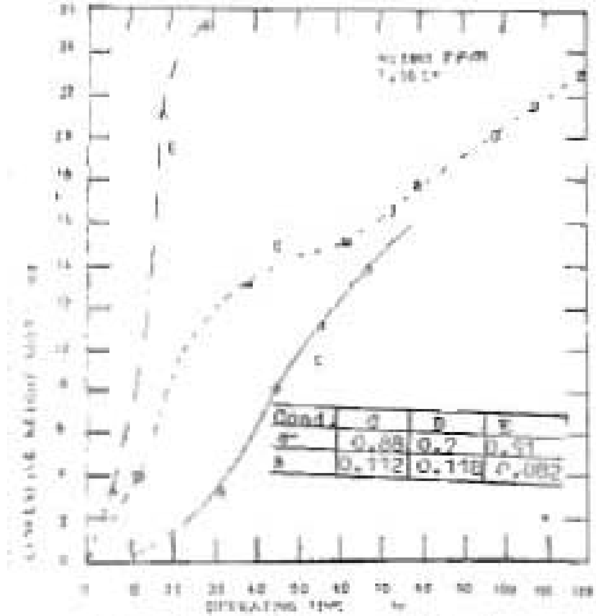
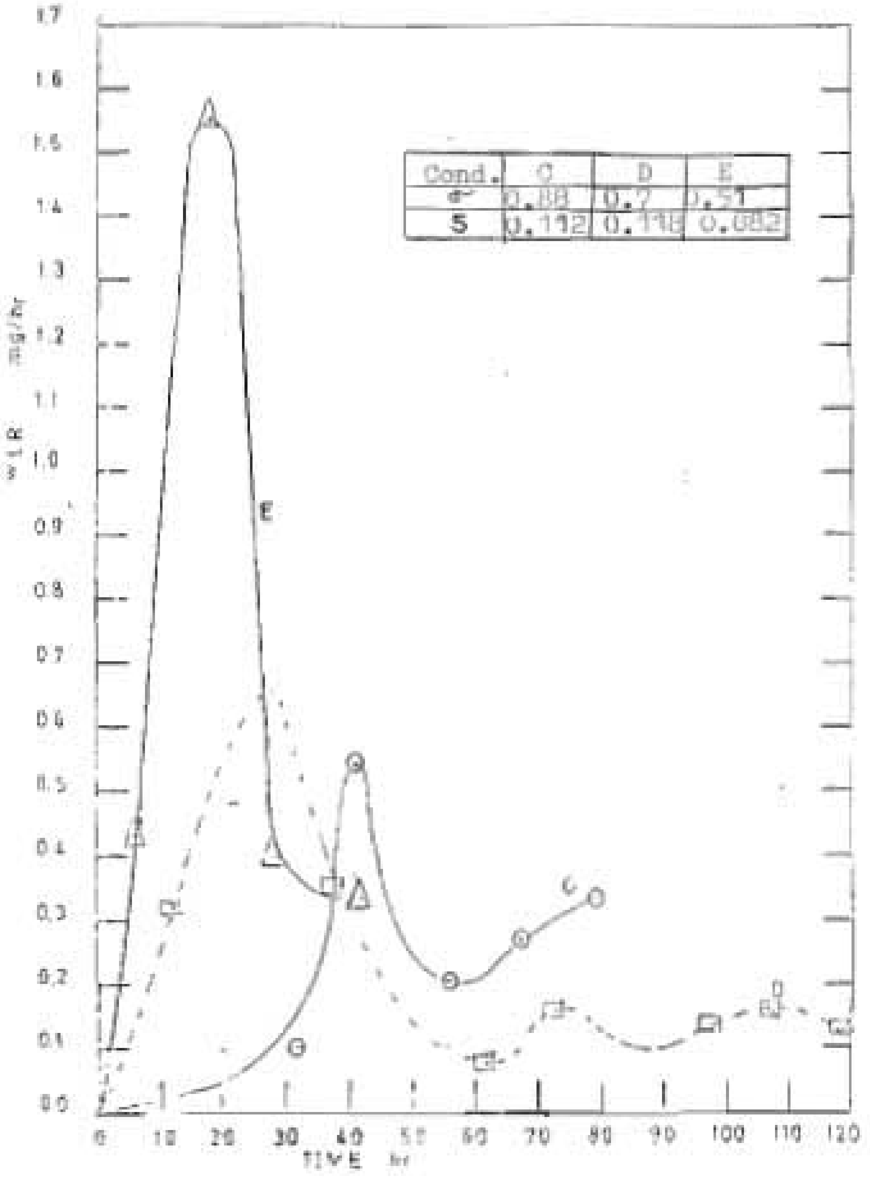


Fig.1 Test Rig



Cond.	C	D	E
α	0.88	0.7	0.51
a	0.112	0.118	0.082

Fig.2 Cumulative weight loss



Cond.	C	D	E
σ	0.88	0.7	0.51
S	0.112	0.118	0.082

Fig.3 Weight loss rate as a function of time at different covitating conditions

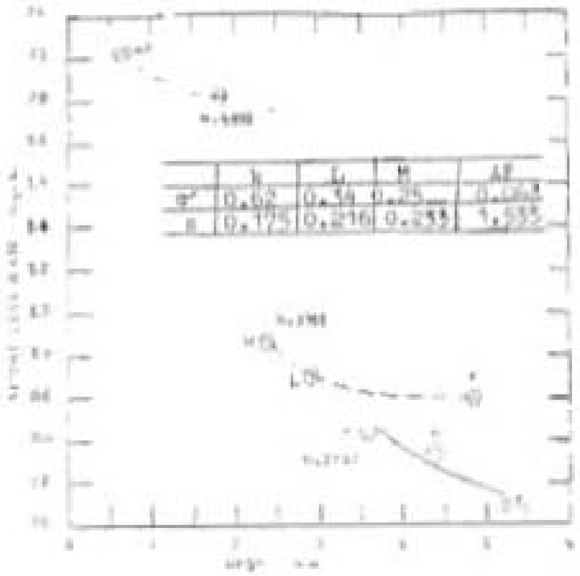


Fig.4 The relation between NPSH and the rate of weight loss in the first 6 hr of operation

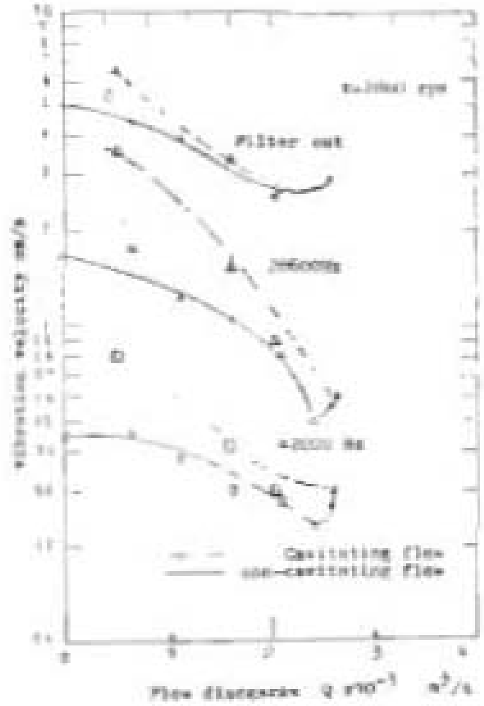


Fig.5 Vibration velocity againest flow discharge

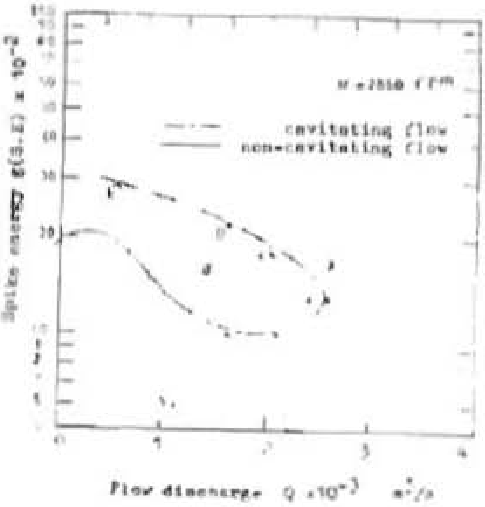


Fig.(6) Spike energy againest flow discharge

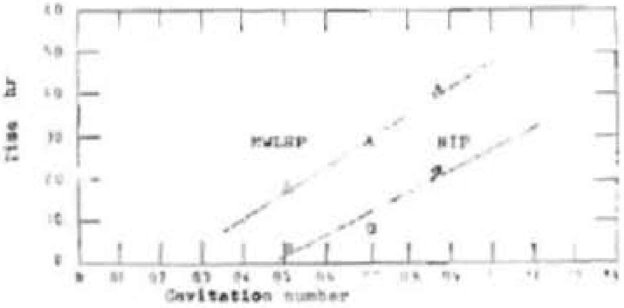


Fig.(7) Maximum weight loss rate period(MWLRP) and nominal incubation period

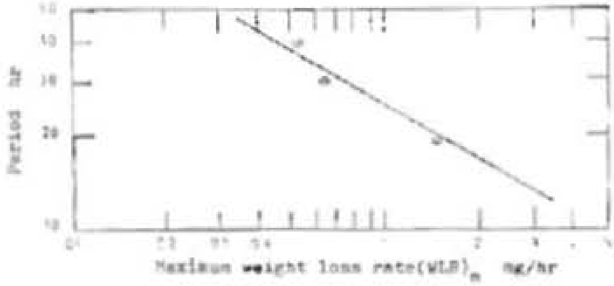


Fig.(8) Period of maximum weight loss rate againest maximum weight loss rate