# Cavitation Monitoring & Control System

**Prof. Vaibhav Kamble[1], Vishalkumar Soni[2], Prathamesh Kharat[3], Vivek Wadkar[4], Aakash Shahane[5]**

[1]*Professor, Dept. of Mechanical Engineering, Vishwaniketan iMEET, Maharashtra, India*
[2,3,4,5] *Student, Dept. of Mechanical Engineering, Vishwaniketan iMEET, Maharashtra, India*

---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract -** *This paper is about implementing the automation technology in the pump system for preventing its damage which happens due to cavitation. So, our idea is to sense the cavitation occurring in the centrifugal pump by the method of pressure & temperature monitoring and vibrations which arises when cavitation happens. The temperature & pressure are monitored with the help of temperature sensor & pressure sensor and the vibration can be sensed by using a vibration sensor. As soon as, there is a cavitation inside the pump the sensors will send the signal to the microcontroller. Then microcontroller will limit the speed of the motor with the help of motor controller, this will cause the motor to run at the speed below where the cavitation started but this may cause decrease in pressure lead on output of the pump. In some cases, so, there we can install other supporting system which will be actuated as soon as cavitation is sensed and will also help in reducing the cost of whole system.*

***Key Words***: **Microcontroller, Cavitation, Motor Controller, Centrifugal Pump, Pressure Sensor, Temperature Sensor, Vibration Sensor**

## 1. INTRODUCTION

Cavitation is the formation of vapor cavities in a liquid, small liquid-free zone ("bubbles" or "voids"), that are the consequence of forces acting upon the liquid. It usually occurs when a liquid is subjected to rapid changes of pressure that cause the formation of cavities in the liquid where the pressure is relatively low. When subjected to higher pressure, the voids implode and can generate an intense shock wave.

Cavitation is a significant cause of wear in some engineering contexts. Collapsing voids that implode near to a metal surface cause cyclic stress through repeated implosion. These results in surface fatigue of the metal causing a type of wear also called "cavitation". The most common examples of this kind of wear are to pump impellers and bends where a sudden change in the direction of liquid occurs. Cavitation is usually divided into two classes of behavior: inertial (or transient) cavitation and non-inertial cavitation.

Inertial cavitation is the process where a void or bubble in a liquid rapidly collapses, producing a shock wave. Inertial cavitation occurs in nature in the strikes of mantis shrimps and pistol shrimps, as well as in the vascular tissues of plants. In man-made objects, it can occur in control valves, pumps, propellers and impellers.

Non-inertial cavitation is the process in which a bubble in a fluid is forced to oscillate in size or shape due to some form of energy input, such as an acoustic field. Such cavitation is often employed in ultrasonic cleaning baths and can also be observed in pumps, propellers, etc.

Since the shock waves formed by collapse of the voids are strong enough to cause significant damage to moving parts, cavitation is usually an undesirable phenomenon. It is very often specifically avoided in the design of machines such as turbines or propellers, and eliminating cavitation is a major field in the study of fluid dynamics. However, it is sometimes useful and does not cause damage when the bubbles collapse away from machinery, such as in super cavitation.

### 1.1 Objective

The main objective of this paper is to help in reducing the maintenance cost of pumps suffered by industries and increase its service life of the pump, by monitoring the occurrence of cavitation and limiting it, preventing the degradation of pump.

- To design and build a system for simulating cavitation in a centrifugal pump and studying different pump parameter that may be use for cavitation detection and diagnosis.
- To identify the suitable sensor for the measurements of pump parameters.
- To model and simulate pumping system in order to define cavitation characteristics.

### 1.2 Problem Definition

Cavitation is one of the most challenging fluid abnormalities leading to detrimental effects on both the centrifugal pump flow behaviors and physical characteristics. Centrifugal pumps' most low-pressure zones are the first cavitation victims, where cavitation manifests itself in form of pitting on the pump internal solid walls, accompanied by noise and vibration, all leading to the pump hydraulic performance degradation. This causes decrease in service life and increasing the cost of maintenance.

Cavitation can be simply explained as, formation of bubbles or cavities in liquid, developed in areas of relatively low pressure around an impeller. The imploding or collapsing of these bubbles trigger intense shockwaves inside the pump, causing significant damage to the impeller and/or the pump housing.

If left untreated, pump cavitation can cause:

- Failure of pump housing
- Destruction of impeller
- Excessive vibration - leading to premature seal and bearing failure
- Higher than necessary power consumption
- Decreased flow and/or pressure

## 2. LITERATURE SURVEY

### 2.1 Salem A Alhashmi (2005): Detection And Diagnosis Of Cavitation In Centrifugal Pumps

The research work documented here concerns the monitoring of cavitation in the centrifugal pump which is considered as a fundamental machine in most domestic and industrial applications. Cavitation is a common fault in centrifugal pumps that results in deterioration of the hydraulic performance, damage to the pump components, produces high vibration and noise. To prevent cavitation and maintain pump performance, it is necessary to adopt an optimal system for the detection and diagnosis of cavitation. This thesis analyses the implementation of different methods for condition monitoring the centrifugal pump; specifically, the different methods of monitoring cavitation. These methods include the monitoring of vibration, acoustics, instantaneous angular speed and motor current signature. Analyzing and comparing the features and the capability of each method was vital for defining the optimal method for cavitation detection in centrifugal pump.

An enhanced test-rig was built and equipped with the necessary high-quality sensors and equipment in order to be able to apply and compare the efficacy of the four monitoring methods. The pumping system was customized in order to effectively monitor the occurrence and nature of cavitation within it. Signal data was processed and analyzed using MATLAB software. The interpretation of the results was based on the identification and extraction of a series of significant features of the signals that can be used for detection and diagnosis cavitation in centrifugal pump. Conventional processing of signals in time and frequency domain was found to be adequate for most features.

This research represents an accumulation and confirmation of most of the previous work on this topic, and adds some important new contributions to the field of condition monitoring in general and specifically to the field of cavitation monitoring in the centrifugal pump. These contributions include detection and diagnosis cavitation in centrifugal pump by using instantaneous angular speed and motor current signature analysis. The contributions also take account of utilizing low frequency (0-1kHz) of vibration and acoustics spectrum for cavitation monitoring in centrifugal pump

### 2.2 Maxime Binama, Alex Mukhirwa, Emmanuel Bisengimana: Cavitation Effects In Centrifugal Pumps

Cavitation is one of the most challenging fluid flow abnormalities leading to detrimental effects on both the centrifugal pump flow behaviors and physical characteristics. Centrifugal pumps' most low-pressure zones are the first cavitation victims, where cavitation manifests itself in form of pitting on the pump internal solid walls, accompanied by noise and vibration, all leading to the pump hydraulic performance degradation. In the present article, a general description of centrifugal pump performance and related parameters is presented. Based on the literature survey, some light were shed on fundamental cavitation features; where different aspects relating to cavitation in centrifugal pumps.

### 2.3 Dan Yin (2012): System And Method For Monitoring And Control Of Cavitation In Positive Displacement Pumps

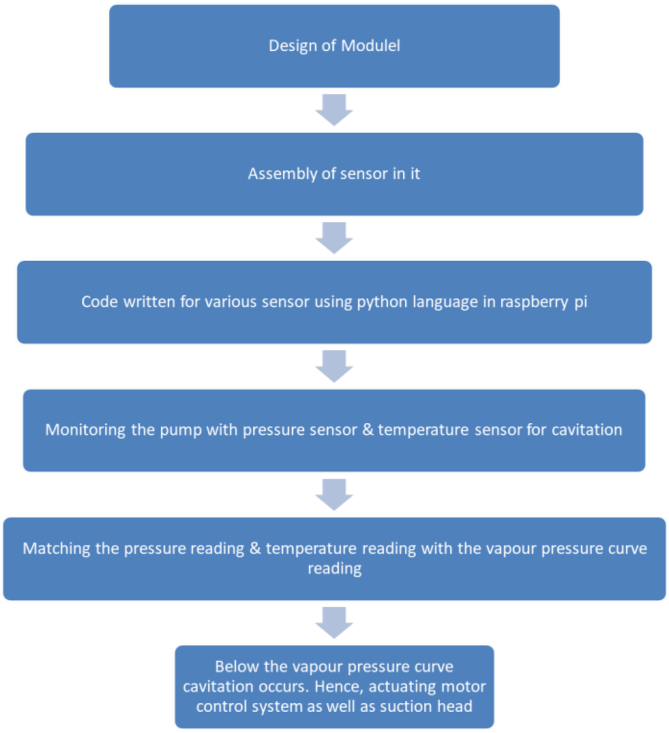
A system and method are disclosed for monitoring and controlling a positive displacement pump using readings obtained from a plurality of pressure sensors. The pressure sensors may be mounted at the suction, discharge and interstage regions of the pump. Signals from the pressure sensors are compared to obtain a ratio that is used to predict whether a cavitation condition exists within the pump. The ratio can be compared to user provided limits to change an operating characteristic of the pump to reduce predicted cavitation. The pump may be stopped, or pump speed changed, when the ratio is less than a predetermined value. In some embodiments, historical information regarding the ratio may be used to obtain standard deviation information which may then be used to predict whether gas bubbles are passing through the pump. Other embodiments are described and claimed.

### 2.4 Frederick M. Discenzo, Dukki Chung, Joseph K. Zevchek (2003): System And Method For Controlling Pump Cavitation And Blockage

A pump control system and a controller therefor are disclosed which operate a motorized pump in a controlled fashion. The controller provides a control signal to a motor drive according to a setpoint or according to a cavitation signal from a cavitation detection component in the controller. If the cavitation detection component determines that pump cavitation is likely or suspected, the controller may operate the pump motor according to the cavitation signal, in order to reduce or eliminate the cavitation condition, before resuming normal control according to the set point.

## 3. METHODOLOGY

### 3.1 Flow Chart




### 3.2 Cavitation Detection

Cavitation is a very high-speed phenomenon at a point of not being easily seen by a human eye, that's why it is hard to understand how cavitation occurs. The process of cavitation happens very fast that none of its stages (bubble formation, growth, and collapse) can be detected unless advanced devices and methods are used. Moreover, cavitation occurs in mostly hidden places where it is very difficult to find a way in, thus it's practically inaccessible unless special technics are used. As a result, most of the early cavitation studies have been focusing on its theoretical and numerical details rather than observational ones.

### 3.3 DS18B20 Temperature Sensor

### Key Features

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Reduce Component Count with Integrated Temperature Sensor and EEPROM
    - Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
    - ±0.5°C Accuracy from -10°C to +85°C
    - Programmable Resolution from 9 Bits to 12 Bits
    - No External Components Required
- Parasitic Power Mode Requires Only 2 Pins for Operation (DQ and GND)
- Simplifies Distributed Temperature-Sensing Applications with Multidrop Capability
    - Each Device Has a Unique 64-Bit Serial Code Stored in On-Board ROM
- Flexible User-Definable Nonvolatile (NV) Alarm Settings with Alarm Search Command Identifies Devices with Temperatures Outside Programmed Limits
- Available in 8-Pin SO (150 mils), 8-Pin µSOP, and 3-Pin TO-92 Packages.

### Temperature Sensor Code:

```
// First we include the libraries
#include <OneWire.h>
#include <DallasTemperature.h>

// Data wire is plugged into pin 2 on the Arduino
#define ONE_WIRE_BUS 2

// Setup a oneWire instance to communicate with
any OneWire devices
// (not just Maxim/Dallas temperature ICs)
OneWire oneWire(ONE_WIRE_BUS);

// Pass our oneWire reference to Dallas
Temperature.
DallasTemperature sensors(&oneWire);

void setup(void)
{
 // start serial port
 Serial.begin(9600);
 Serial.println("Dallas Temperature IC Control
Library Demo");
 // Start up the library
 sensors.begin();
}
void loop(void)
{
```

```
 // call sensors.requestTemperatures() to issue a
global temperature
 // request to all devices on the bus

 Serial.print(" Requesting temperatures...");
 sensors.requestTemperatures(); // Send the
command to get temperature readings
 Serial.println("DONE");

 Serial.print("Temperature is: ");
 Serial.print(sensors.getTempCByIndex(0)); //
Why "byIndex"?
  // You can have more than one DS18B20 on the
same bus.
  // 0 refers to the first IC on the wire
  delay(500);
}
```

### 3.4 SKU237545 Pressure Sensor

**Specification**

- Working Voltage: 5VDC
- Output Voltage: 0.5-4.5 VDC
- Sensor material: Carbon steel alloy
- Working Current: ≤10 mA
- Working Pressure Range: 0-1.2 MPa
- The Biggest Pressure: 2.4 MPa
- Cable length: 19cm
- Destroy Pressure: 3.0 MPa
- Working TEMP. Range: 0-85°C
- Storage Temperature Range: 0-100°C
- Measuring Error: ±1.5 %FSO
- Temperature Range Error: ±3.5 %FSO
- Response Time: ≤2.0 ms
- Cycle Life: 500,000 pcs
- Application: non-corrosive gas liquid measurement

**Pressure Sensors Code**

```
void setup() {
  Serial.begin(9600);
}
void loop(){
int sensorVal=analogRead(A1);
Serial.print("Sensor Value: ");
Serial.print(sensorVal);

float voltage = (sensorVal*5.0)/1024.0;
  Serial.print("Volts: ");
  Serial.print(voltage);

 float pressure_pascal = (3.0*((float)voltage-
0.47))*1000000.0;
 float pressure_bar = pressure_pascal/10e5;
  Serial.print("Pressure = ");
  Serial.print(pressure_bar);
  Serial.println(" bars");
  Serial.print("Pressure = ");

  delay(100);
}
#include <DallasTemperature.h>
#include <OneWire.h>

int greenLedPin = 2;
int yellowLedPin = 3;
int redLedPin = 4;

int temp_sensor = 5;

float temperature = 0;
int lowerLimit = 15;
int higherLimit = 35;

OneWire oneWirePin(temp_sensor);
DallasTemperature sensors(&oneWirePin);

void setup(void){
 Serial.begin(9600);

 //Setup the LEDS to act as outputs
 pinMode(redLedPin,OUTPUT);
 pinMode(greenLedPin,OUTPUT);
 pinMode(yellowLedPin,OUTPUT);

 sensors.begin();
}
```

### 3.5 Vibration Sensor

### Vibration Sensor Code

```
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
}
// the loop routine runs over and over again forever:
void loop() {
  // read the input on analog pin 0:
  int sensorValue = analogRead(A0);
  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
  float voltage = sensorValue * (5.0 / 1023.0);
  // print out the value you read:
  Serial.println(voltage);
}
```

## 3.6 Vapor Pressure of Water

The vapor pressure of water is the pressure at which water vapor is in thermodynamic equilibrium with its condensed state. At higher pressures water would condense. The water vapor pressure is the partial pressure of water vapor in any gas mixture in equilibrium with solid or liquid water. As for other substances, water vapor pressure is a function of temperature and can be determined with the Clausius–Clapeyron relation.

But Clausius–Clapeyron relation requires two pressures & two temperatures in its equation and gives exact reading for the vapor pressure curve reading. Using Clausius–Clapeyron relation we will be able to know the inlet pressure of the pump and control cavitation with help of it. But it is bit complex and requires two temperature sensors, one for ambient or room temperature and another for inlet temperature, for it, hence increasing the cost of system and decreasing the efficiency of the control system.

We can optimize this by using Buck's equation and know whether the pressure lies on vapor pressure curve with single temperature and pressure sensor.

## 3.7 Bucks Equation

$$P = 0.61121 \exp\left(\left(18.678 - \frac{T}{234.5}\right)\left(\frac{T}{257.14 + T}\right)\right),$$

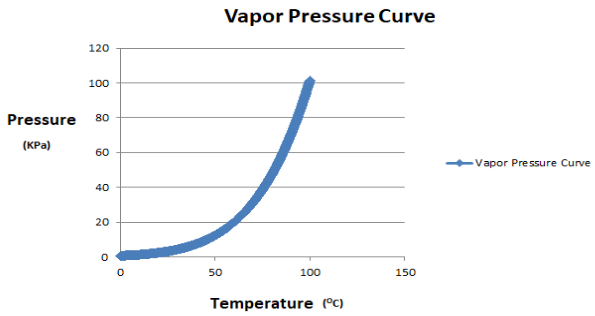
Where $T$ temperature where cavitation occurs is in °C and $P$ is vapor pressure in kPa

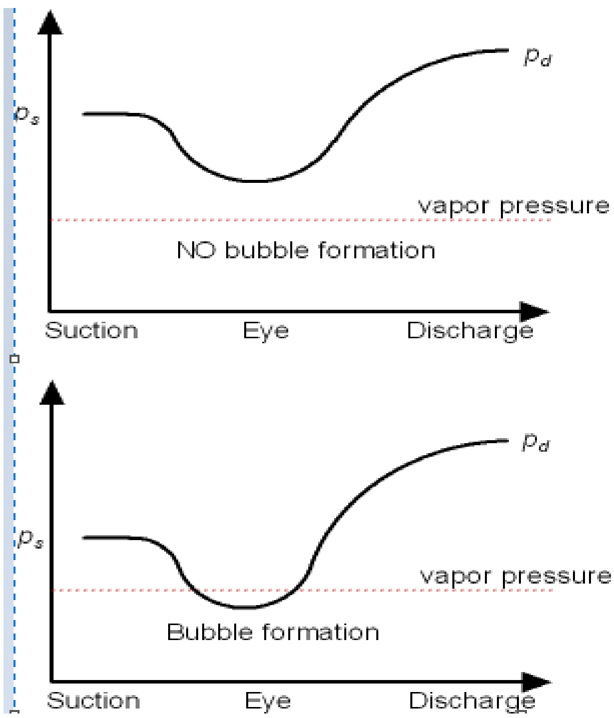
| Temperature (°C) | Clausius-Clapeyron Vapour Pressure(kPa) | Bucks Equation Vapour Pressure (kPa) |
|---|---|---|
| 0 | 0.6113 | 0.6112 (-0.01%) |
| 20 | 2.3388 | 2.3383 (-0.02%) |
| 35 | 5.6267 | 5.6268 (+0.00%) |
| 50 | 12.344 | 12.349 (+0.04%) |
| 75 | 38.563 | 38.595 (+0.08%) |
| 100 | 101.32 | 101.31 (-0.01%) |

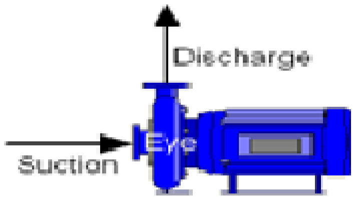
Figure No.: Table of comparison of exact vapor pressure to the Buck's vapor pressure at respective temperature

Clausius-Clapeyron relation uses exact method for calculating vapor pressure whereas Bucks equation uses approximation method for calculating vapor pressure which can be seen in above table.

As the deflection of bucks equation is not more than the exact solution of Clausius-Clapeyron. Therefore it is convenient to use bucks equation for our work.






- The above graph represents the occurrence of cavitation in the centrifugal pump.
- At inlet condition, the suction head or pressure head is likely to be constant over time. But at the region of impeller, sudden pressure drop due to vacuum create in this region.
- If this pressure falls below the vapor pressure then cavitation occurs in the pump.
- Then Motor controller will limit the current to the pump which results in reducing pump RPM & give signal to operator or a system to increase the water level in the sink.

### 3.8 Final Output

```
#include <OneWire.h>
#include <DallasTemperature.h>

#define ONE_WIRE_BUS 2

OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

void setup(void)
{
 Serial.begin(9600);
}

void loop(void)
{
 //TEMPERATURE CODE
 Serial.print(" \n Requesting temperatures...");
 sensors.requestTemperatures();
 Serial.println("DONE");

 Serial.print("Temperature : ");
 Serial.print(sensors.getTempCByIndex(0));
 float T=(sensors.getTempCByIndex(0))+273.15;

 //PRESSURE CODE
 int sensorVal=analogRead(A1);
 float voltage = (sensorVal*5.0)/1024.0;
 float pressure_bar =(3.0*((float)voltage-0.49));

 Serial.print("  Pressure : ");
 Serial.print(pressure_bar);
 Serial.println(" bars");

 //VIBRATION CODE
 int sensorValue = analogRead(A0);
 float voltage1 = sensorValue * (5.0 / 1023.0);
 Serial.print("  vibration volts:");
 Serial.print(voltage1);

 //CALCULATION
 float P1= pressure_bar*100;
 float P2=0.61121*exp((18.678-
(T/234.5))*(T/(257.14+T)));
 if(P1 <= P2){
 Serial.print("  CAVITATION IS OCCURRING.");
 }
 else {
 Serial.print("  NO CAVITATION");
 }

 delay(500);

}
```

## 4. RESULT & DISCUSSION

- As the pressure & temperature of the inlet water is equal the point on the vapour pressure curve, the microcontroller sends signal to the motor controller to limit the speed of the pump hence, controlling the cavitation
- Microcontroller also gives signal by the means of LED to the operator that cavitation is happening and he need to rise the water level.
- This project also helps in maintaining the efficiency of the pump, which decreases with regularly occurring cavitation. Since here our system prevents the cavitation from happening hence maintaining its efficiency.

## 5. CONCLUSIONS

- This project helps in monitoring the inlet pressure and temperature of the water on centrifugal pump.

- This project also helps to detect when the cavitation occurs and take necessary action to control it.

- It is capable of initiating others measure to control cavitation or else signal it, if it occurs.

- It also helps the pump in mentioning its efficiency and reducing its maintenance cost and increasing its life.

## ACKNOWLEDGEMENT

Apart from personal efforts to work, constant inspiration and encouragement given by a number of individuals served as the driving force that enabled me to submit this dissertation in the present form. Inspiration, guidance, co-operation, all came in abundance.

We wish to express our deep sense of gratitude to Prof. Vaibhav Kamble, for his constant support, excellent guidance and inspiring suggestions that has encouraged us to come up with this paper. His willingness to motivate us, contributed tremendously to our paper.

**REFERENCES:**

**JOURNAL PAPER**

1. Binama Maxime.Int. Journal of Engineering Research and Applications, www.ijera.com ISSN: 2248-9622, Vol. 6, Issue 5, (Part - 1) May 2016, pp.52-63

THESIS

1. Salem A Alhashmi (2005): Detection and Diagnosis Of Cavitation In Centrifugal Pumps

PATENTS

1. Maxime Binama, Alex Mukhirwa, Emmanuel Bisengimana: Cavitation Effects in Centrifugal Pumps

2. Dan Yin (2012): System And Method For Monitoring And Control Of Cavitation In Positive Displacement Pumps US 9546652 B2

3. Frederick M. Discenzo, Dukki Chung, Joseph K. Zevchek (2003): System and Method for Controlling Pump Cavitation And Blockage US 6663349 B1