Development of Virtual lab Equipment on Cavitation of Centrifugal Pump

[1]Dipti Prakash Behera [2]Vallayil N.A Naikan
Subir Choudhury School of Quality and Reliability
Indian Institute of Technology,
Kharagpur, India
[1]diptiprakash.behera@gmail.com, [2]naikan@hijli.iitkgp.ernet.in

***Abstract*—** Web-based learning process is an essential part in the present education framework. As experimental study is important part of education in science and technology, the concept of E-labs has become part of such frame work. This paper presents the concept of an Elab for understanding the problem of cavitation and for diagnosing the same by vibration monitoring. Cavitation is a typical problem of fluid handling systems such as centrifugal pumps leading to metal erosion and associated problems. A student can do the experiment and interpret the results using the virtual lab in the web.

***Index Terms*—** web-based learning, virtual laboratory, cavitation, simulation, rotating machinery

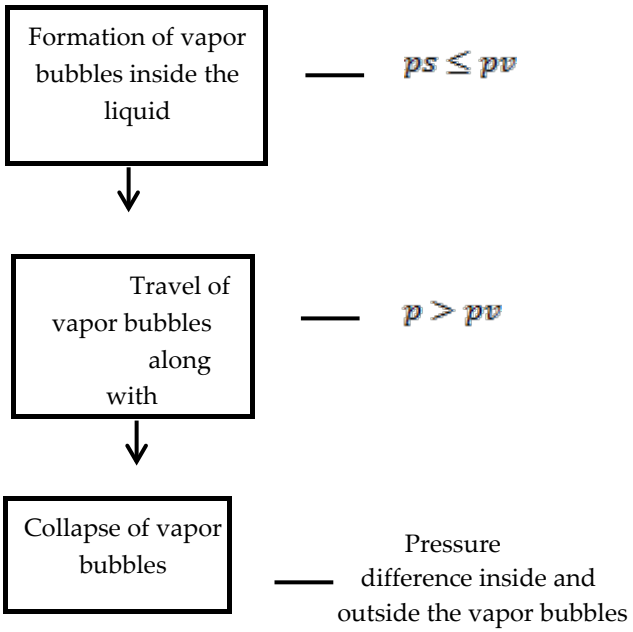
I. INTRODUCTION

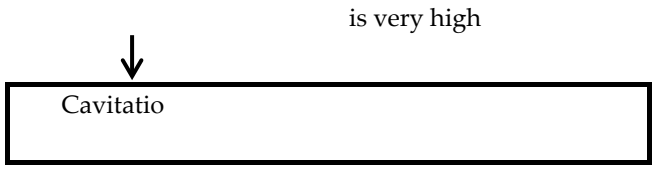
The present paper concentrates on improving the offline classification tests. The idea here is to perform the analysis in virtual mode while utilizing web access. The E-learning processes are enhanced each day by various emerging technologies that play a vital role in modern education system. Therefore, due to easy implementation and worldwide accessibility, virtual online laboratories are gaining popularity in these days. Such virtual labs are essential where the complication due to high machinery or hardware cost makes it difficult to build an actual laboratory. Cavitation of centrifugal pump test is one of the modules of rotating machinery fault diagnosis. The point of this test is to teach and prepare the students about different types of rotating machinery issues, for example, fault detection, fault diagnosis, cracked shafts, bent shaft and misalignment etc. The students can virtually analyze the modules and discover the new ways to analyze these issues by vibration analysis and build up a more profound comprehension of the design and execution issues at equipment and programming level including real time issues. Virtual lab can be categorized into two types: on-line and off-line. In on-line, real test can be achievable remotely from any place. Here the host server and PC is connected to real research centre and a remote person can help out in controlling the system through world wide web. On the other hand offline mode does not work on real time environment. Thus, a recreated research facility setup will be required where no real test will be done.

When the pressure of the flowing liquid is less than its vapor pressure, the vapor bobbles start to form automatically, which results in different types of problems e.g. vibration, severe noise, damage to mechanical parts of the hydraulic devices [1-5].

II. CAVITATION AND ITS EFFECT

Consider a flowing liquid in a system. If the pressure of the flowing liquid becomes equal or less than the vapor pressure (p_v), the vaporization of the liquid starts. The bubbles of these vapors are carried by the following liquid into the region of high pressure where they collapse giving rise to high impact pressure. The pressure developed by the collapsing bubbles is so high that the material from the adjoining boundaries gets eroded and cavities formed on them with an occurrence of high vibration. This phenomenon is known as cavitation. Cavitation is classified into five different types such as Vaporization Cavitation, Turbulence Cavitation, Vane Syndrome Cavitation, Internal Re-circulation Cavitation and Air Aspiration Cavitation.





Steps in Cavitation

Considering the nature and behavior of the cavitation, it is of two types, namely inertial and non-inertial cavitation. In some cases, there is a sudden occurrence of shock waves produced from the collapsing of the vapor bobbles in the hydraulic components like control valves, propellers, impeller etc. this type of cavitation is known to be inertial cavitation. Sometimes bobbles formed, get accumulated and form a layer on the top of the liquid. If it gains momentum from any sources of energy, it tends to oscillate. This type of oscillating movement of the bubble layer is classified as noninertial cavitation.

Causes of cavitation

The main causes of cavitation in centrifugal pump are as follows:

A liquid boils at a lower temperature at lower pressure. When there is a drop in pressure at the suction of the nozzle, it encourages the bubble formation as the Net Positive Suction Head Available (NPSHA) is low. High-velocity results in lower pressure. So when the liquid velocity increases at the suction, it leads to the reduction in pressure and cavitation may occur because of vaporization and turbulence. Cavitation may also occur as the temperature of the flowing liquid increases, as there will be less energy required to excite the liquid molecule to go to the gaseous phase. Also when the flow at the pump suction reduces, it results in cavitation. *Effects of cavitation*

The main effects of cavitation in centrifugal pump are as follows:

Due to cavitation, the metallic surface gets damaged and cavities are formed. As the vapor bubbles collapse suddenly, after coming in contact with the metallic part, a considerable amount of noise and vibration is produced, so efficiency gets reduced and the total life span of the pump components gets decreased. The cavitation cause pitting action on the surface of the impeller and it becomes rough hence the proper functioning of the mechanical parts gets hampered.

Prevention of cavitation

The following steps could be followed to circumvent cavitation

1. An optimum level of fluid pressure (> Vapor Pressure) should be maintained.
2. Care should be taken to reduce pressure variations
3. Improve material properties like hardness, surface finish and corrosion resistance.

III. DEVELOPEMENT FOR VIRTUAL LAB

Research laboratory facility is made available to the user by an invitation letter sent through the virtual lab portal. The user will be able to access the virtual laboratory when he receives the access privilege. Once the user granted the access he is able to perform the experiments on the website in step by step manner like objective, theory, procedure, simulation, quiz, feedbacks. These sorts of virtual research labs allowed from any supporting application, which is usually known as Free and Open Source Software (FOSS). Free and Open

Source Software are user licensed free, circulate and modify the source code to extemporize the design of the software. The software used for developing the virtual lab on online machinery fault diagnosis is Java, JavaScript, PHP, HTML5 and database MySQL. A client is permitted to get to the code from anyplace and can join extra components with legitimate capacities in that system. This makes it more portable and scalable. Here a simulation can run easily in nonstop manner on the client machine without any disturbance. This sort of program will be free from any web program modules or application alternately requisition server autonomous. The web application for the concepts of rotating machinery fault simulation is made available through the virtual labs website.

A. Experimental Methodology

The methodology to conduct an experiment has been explained in the website. Therefore, beginners need to go through the detailed experimental setup before starting a new experiment. In addition to this, we discuss a brief about the experimental process as follows [6].

- Step 1: Go to the website and click on “experiment”. •Step 2: Click experiment 9: Cavitation of Centrifugal pump.
- Step 3: Click “virtual lab”. The experimental setup appears. It consists of an electric motor and centrifugal pump. Accelerometer is fixed on the pump. •Step 4: Click “start” button on the control panel. The motor starts the pump. •Step 5: Click “without cavitation” on the control panel. The accelerometer output appears us vibration spectrum. An overall flat, low level acceleration can be seen, this indicate that there is no significant cavitation in the pump.
- Step 6: Now press the “stop” button and thereafter “start” button to set the experiment ready for the next stage that means the pump with cavitation. •Step7: Click the button “cavitation” on the control panel. Now the accelerometer output is visible. It can be seen that the vibration level corresponding to the frequency from 3 KHz to 5 KHz have increased. This indicates that the centrifugal pump experiences cavitation. •Step 8: Compare the vibration level in step 5 and step 7. What do you observe? •Click the button “stop” on the control panel to complete the experiment.

B. Typical Outputs of Experiments

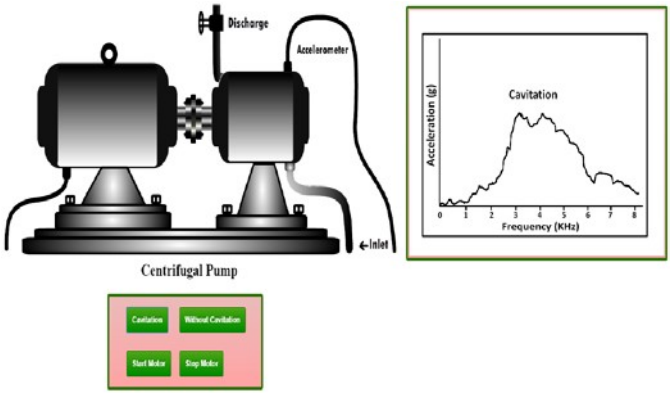


Figure 1: Cavitation

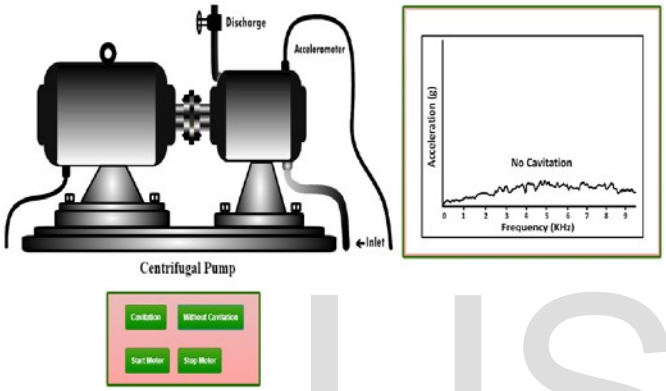


Figure 2: Without Cavitation

IV. VIRTUAL LAB ACCESSIBILITY

The virtual lab experiments can be used by the students, across the globe through the World Wide available at - http://vlabs.iitkgp.ernet.in/rmfs/. The prime objective of this website is to provide quality online education along with easy accessibility for promoting self-learning in a simple and clear manner. For both the graduate and post graduate students, the web based self-learning content and tools can be used. To perform experiments in virtual lab, each student needs to register and create a personal account. The registration for the virtual laboratory is free of cost and the material provided in the website will be accessible by the student. In order to perform the experiment by themselves, so that the advance of the students can be appraised
[6], [7].

The website utilizes free and open source software to provide the feeling of the real lab experience to the students. The students could perform the experiments on the simulator and see the outputs on a real time basis. A group of expert technical people have built up the site to avoid the incompatibilities of various web browsers. Step by step instructions on how to conduct the experiments are available on the website to guide the students in the correct way. Feedback option can be introduced to the website by which students can contribute towards improving the website.

The web server host makes the virtual lab accessible across the globe through World Wide Web. To accelerate the learning of technical concepts, the interface of the site is kept user friendly and effective. With the help of images, audios and audiovisuals the understanding about the subject has been made much easier. The genuine look and appeal of this site gives its user the experience of a real research laboratory.

CONCLUSION

A lab set up for testing cavitation of centrifugal pump has been described and discussed the implementation developing architecture in this paper. Important effect of cavitation on pumps is drop in head and efficiency. Cavitation can't be allowed to develop in pump to such a stage as to cause damage as in turbine runners. Cavitation makes issue in operation of every one of the three sorts of centrifugal pumps especially radial, mixed and axial flow pumps whenever high discharge, high rotational speed or low head is come across. Cavitations have been widely seen in hydraulic machinery such as pump and turbine in mechanical engineering. The recommended test set up might be an ideal candidate for consideration in to any undergraduate rotating machinery lab. The lab gives an opportunity for the user to perform an experiment in a virtual platform.

ACKNOWLEDGMENT

We are grateful to Ministry of Human Resource and Development, New Delhi for their financial assistance and Subir Choudhury School of Quality and Reliability, Indian Institute of Technology, Kharagpur for providing the platform carryout of this virtual laboratory.

REFERENCES

[1] Y. Utturkar, J. Wu, G. Wang, W. Shyy, "Recent Progress in Modeling of Cryogenic Cavitation for Liquid Rocket Propulsion," Progress in Aerospace Sciences, 41(7), pp. 558–608 (2005).

[2] R. T. Knapp, J. W. Daily, F. G. Hammitt, "Cavitation," McGraw-Hill, New York (1970).

[3] C. E. Brennen, "Cavitation and Bubble Dynamics," Oxford Engineering Sciences Series 44, Oxford
University Press (1995). [4]D. D. Joseph, "Cavitation in a flowing liquid," Phys. Review E, 51(3), pp. 1649–1650 (1995).

[5] D. D. Joseph, "Cavitation and the state of stress in a flowing liquid," Journal of Fluid Mechanics, 366, pp. 367–378 (1998).

[6] D. P. Behera, R. Behera and V. N. A Naikan, "Virtual Fault Simulation for Bearing Defects of Various Types of Rotating Machine," IEEE 2014 5th International Conference - Confluence The Next Generation Information Technology Summit (Confluence), pp. 726– 730 (2014).

[7] D. P. Behera, R. Behera and V. N. A Naikan, "Virtual Fault Simulation for Diagnosis of Shaft Misalignment of Rotating Machine," IEEE 2014 International Conference on Advances in

Computing, Communications and Informatics (ICACCI), pp. 2476–2480 (2014).

Dipti Prakash Behera received both Master of Technology in Computer Science and Engineering (M. Tech 2015), and Master of Computer Application (MCA 2007) from North Orissa University. Currently he is working as a Project Associate in Subir Chowdhury School of Quality and Reliability at Indian Institute of Technology Kharagpur, India.

V. N. A. Naikan is currently a joint Professor in Industrial and Systems Engineering and Professor and Head of the Subir Chowdhury School of Quality and Reliability at the Indian Institute of Technology Kharagpur, India. He also associated with Indian Space Research Organization, Chinese University of Hong Kong, Indian Institute of Management, Ahmedabad and Union Carbide India Limited. He has published more than 120 research papers in international journals and conferences, a book on Reliability Engineering and Life Testing and several book chapters. He has served as Coeditor-in-chief of the International Journal of Performability Engineering (2015-2016), advisory and editorial board member of several other journals. He also worked as a visiting professor at CALCE, University of Maryland, USA. He was awarded Emerald Literati Network Award for Excellence (2016).