Pump Cavitation Demonstration Device

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Abstract

Cavitation is a physical phenomenon in which fluid, typically entering a pump, forms vapor bubbles due to the lowering of pressure, on the suction side, to below the saturation pressure for the fluid's temperature. As these vapor bubbles proceed to higher pressure regions of the pump, they collapse or implode which creates pressure waves in the fluid. These pressure waves can cause noise, vibration and physical damage to the pump's impeller surfaces and causes the pump to operate less efficiently. Cavitation is typically discussed in fluid mechanics courses but students often have a hard time visualizing the concept. In order to provide a ready, visible demonstration of this phenomenon, a project was undertaken to design and construct an experimental device which can be used to demonstrate the phenomenon of cavitation using a pump, piping, control valve, and a heating element. It is anticipated that this device can be used in fluids labs/classes to demonstrate cavitation and its results.

Technical Accomplishments

The design and completion of the pump cavitation demonstration device accomplished the task the group set out to do. Cavitation can be a vague concept, but the department will now be able to demonstrate the phenomenon by observation to future students. The clear acrylic facing allows a small group to clearly view the pump impeller. The device also gives a true representation of cavitation with cavitation noticeable by hearing as well as seeing. This will allow students to recognize the sound when cavitation cannot be seen, which could be valuable in their future endeavors. With cavitation being a problem encountered in many engineering workplaces, this project will give students the knowledge necessary to understand, recognize, and correct the problem before it becomes a major problem.

Lessons Learned

While the design and implementation of our team's pump cavitation demonstration device was accomplished mostly according to plan, some valuable lessons were learned by the team members. The team especially struggled with the realities of following a budget, a compact timeline in which to perform the work, and the unanticipated events that always occur in such a project. Looking back at the experience, our project could certainly have been completed more efficiently.

A pump was decided on and ordered before returning from Christmas break. The pump arrived on schedule; however, getting the clear acrylic pump volute machined properly soon proved to be more time consuming than predicted. This was the result of scheduling conflicts with a faculty member that was to direct our use of the equipment and the time required for operating the equipment.

Arkansas Tech allows each group a budget of $250 for design projects. However, since this project was to be property of the university and a tool for student instruction, the budget was allowed to be expanded. The initial budget calculation for the project was $790.48 for full completion of the project. This price included all material for the project and included a cart to mount the device on. A used slide project cart, however, was furnished by the university. This eliminated that expense from our budget (which was quoted at $128.25). By the end of the project the group was still under the $790.48 proposed, but would not have been if the cart had not been free. This miscalculation in budget resulted from several factors. The cost was calculated with estimates found on manufacturers' and vendors' websites, but the parts were purchased at a local hardware store. Also, during construction parts had to be replaced. The initial pressure gauges were replaced with fluid filled gauges in order to reduce reading variations due to pump vibrations and to also allow for reading a vacuum pressure (which was likely to be achieved at times). Pipe sections and fittings also had to be replaced due to errors in cutting, gluing, etc. This resulted in more money spent on parts than expected (with the exception of projected spending for the donated cart).

Because of this, the group learned to keep an open mind when planning a project. There are many things that can change the time allocated, budget, and the scope of work of a project. Luckily, few difficulties were encountered, and those few that were encountered did not result in major delays or other detrimental effects. However, had this project been on a much larger scale in terms of budget, scope, and time, mistakes could have been disastrous to the project. This taught the group to spend more time on the risk assessment portion of the design. A detailed plan in advance can save much time and other resources in the future. In addition, the group learned not to be too conservative with the prediction of the budget, and to add a contingency cost to the final calculation. In a competitive market, a higher priced proposal may seem bad, but there will surely be no complaints if a project is completed under the budget (quite the contrary with completion over the budget).

In conclusion, the stated goal of the project was met and the department now has a device with which to demonstrate the phenomenon of pump cavitation to students. The authors feel very fortunate to have had the opportunity to complete this project. It has been a tremendous learning experience with smaller risks than what is expected to come.

Acknowledgments

The authors wish to acknowledge the assistance of the Mechanical Engineering Department at Arkansas Tech University for the financial means for completing the physical implementation of this project and for our faculty mentors and other faculty guidance and advice.

The project manager wishes to acknowledge Dr. Ed Clausen of the Department of Chemical Engineering, University of Arkansas for the inspiration for this project through the description of a similar experiment presented at the 2010 ASEE Midwest Conference.

Biographical Information

Jake Brighter graduated from Arkansas Tech University in May, 2012 with a Bachelor of Science in Mechanical Engineering. He is currently employed by Entergy Corporation.

William Childs graduated from Arkansas Tech University in May, 2012 with a Bachelor of Science in Mechanical Engineering. He is currently employed as an engineer by Cloyes Gears in Subiaco, Arkansas.

Derek Mobbs graduated from Arkansas Tech University in May, 2012 with a Bachelor of Science in Mechanical Engineering. He is currently employed as an engineer by Albermarle Corporation in Magnolia, Arkansas.

Zach Ross is a senior Mechanical Engineering student at Arkansas Tech University. He is scheduled to graduate in December, 2012.

Dr. John Krohn is a Professor with the Mechanical Engineering department at Arkansas Tech University. Dr. Krohn is in his 22nd year at ATU and has been an author on two previous ASEE Midwest Conference papers.

Cavitation Demonstration Device

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What is Cavitation?

Cavitation is a phenomenon where the localized pressure inside of a liquid is dropped below the saturation pressure for the fluid. This drop in pressure causes the liquid at the low pressure regions to vaporize or "boil". When the vapor bubbles reach the volute, the pressure is rapidly increased and the bubbles implode resulting in a

Scope of Work

The team developed an affordable system with a centrifugal pump that is able to create the necessary conditions for cavitation. The pump volute was designed in such a way that the phenomenon of cavitation and the effects it has on the impeller are visible.

Effects of Cavitation

Cavitation can be detrimental to the system in which it occurs. In pumping systems, the shockwave developed due to cavitation can cause pitting on the impeller, volute, piping, and can wreak havoc on the pump's seals. This leads to premature failure, increased power consumption, and decreased flow rates. Cavitation can be characterized by increased vibration as well as increased noise.

Cost Comparison

Our device came to a final cost of $657 whereas; the commercially available device from Turbine Technologies costs $26,000 without shipping.

Table 1: Budget data.

Component	Cost	Component	Cost
PVC Fittings	$ 38.00	Bulkhead Fitting	$ 20.00
PVC Pipe	$ 10.00	Acrylic	$ 22.00
PVC Valves	$ 12.00	Clear PVC Pipe	$ 15.00
Brass Fittings	$ 28.00	Misc. Hardware	$ 20.00
Brass Valves	$ 21.00	Heating Element	$ 7.00
Vacuum Gauge	$ 40.00	Galvanized Plumbing	$ 25.00
Pressure Gauge	$ 20.00	Temperature Controller	$ 76.00
Pump	$ 223.00	Misc. Electronics	$ 30.00
Tank	$ 45.00	Thermocouple	$ 5.00
		Total	$ 657.00

Figure 2: PumpLab commercially available device. http://www.turbinetechnologies.com/centrifugal.html

Statement of Problem

Many engineering students graduate without a clear understanding of what cavitation is. If the students were able to view cavitation, their understanding of what it is and how to avoid it will be increased. There are few devices on the market for demonstrating cavitation and the devices that are available are not affordable.

Process Flow Diagram

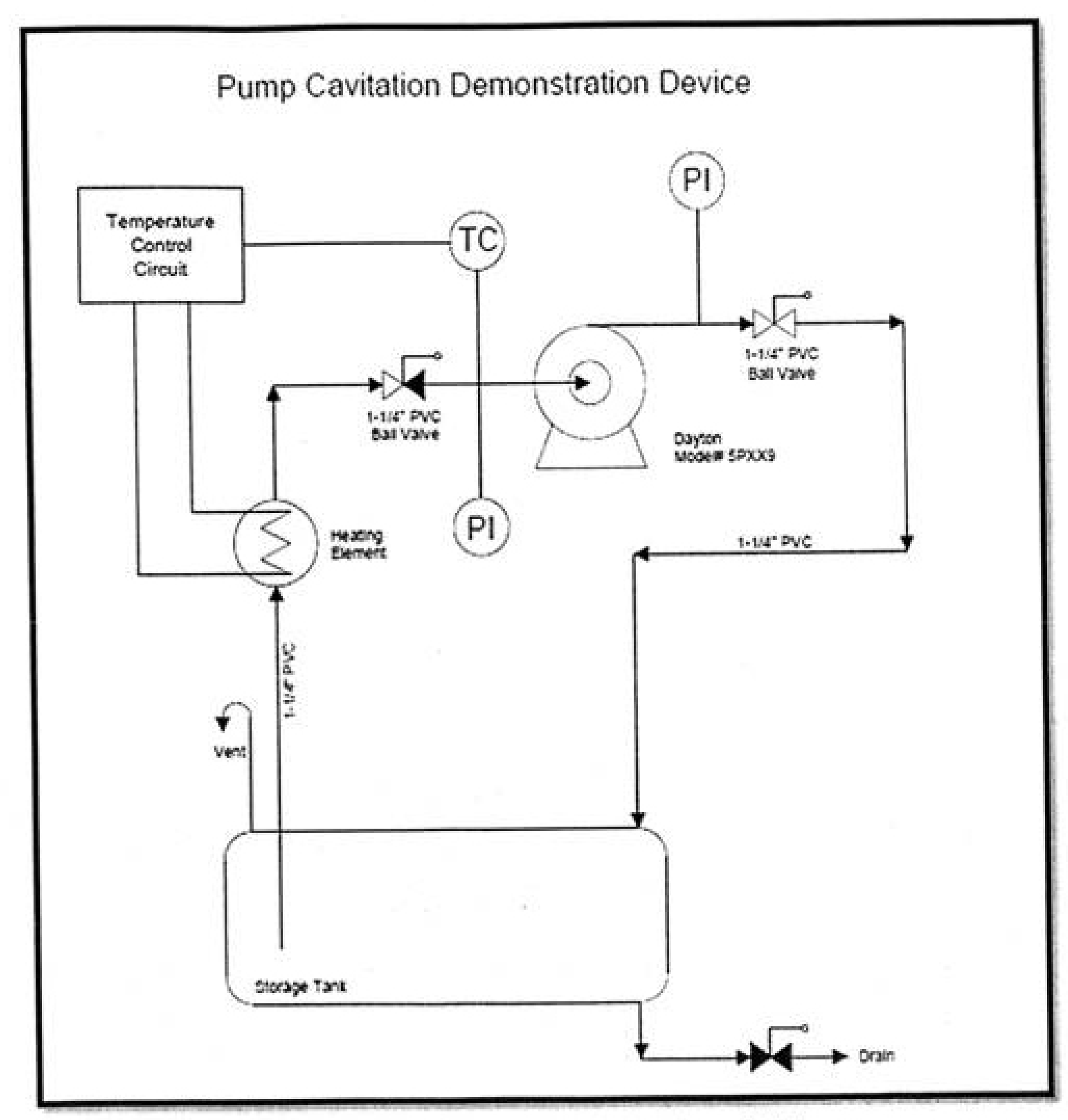

Figure 1: Process flow diagram drawn by Derek Mobbs in Microsoft Vizio.