Design and Fabrication of Externally Driven Liquid Cavitation Heating System

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Abstract - *Domestic hot water has always been of great concern to people in the cold winter. Fossil fuel and wood fire heating has been the main form of heating. These fossil fuel based heating system brings heat to households; it also produces great pollution to the environment and in the same time continuous use will lead to extinction of natural fossil fuels. To overcome this problem the prototype of liquid cavitation heating system is designed, fabricated and the experimental performance is tested using water source to rise its temperature by introducing homogeneous cavitation process. It is based on the principle of hydrodynamics and liquid nucleation. It can apply direct heat to liquids without the use of a heat transfer surface. Also there is no scale build up in liquids. Using the same setup the super-heated steam can also be produced. Further this can produce results far exceed those of conventional technology. Comparatively due to its high thermal conversion and environmental benefits it can be used in domestic and industrial applications.*

Key Words: *liquid cavitation, homogeneous, nucleation, hydrodynamics, stretched liquid, meta-stable state.*

1. INTRODUCTION

Domestic water heating is a major load in a today's homes contributing nearly 30-50% of total electric load consumption [1]. At present primarily water is heated by means of readily available electricity. Often these devices have low conversion efficiency due to power transfer from one form to another. The water is also heated by wood, liquid fuels and petroleum gas etc. These sources also have their limitation like transport, storage, handling, cost and safety. Also these sources heat liquid depending upon size and property of heat transfer medium and storage. For a large quantity of liquid these are not economical. To address this issue the electrically operated liquid cavitation heating system can be used to heat the water which has high thermal conversion efficiency [2]. Also continuous and large quantity of water can be heated. The cavitation or homogeneous nucleation in a liquid is well known hydrodynamics phenomena. It creates cavity in the volume of water. If any liquid is brought beyond the liquid vapor equilibrium line or stretched liquid to a meta-stable state, the cavitation occurs. A portable liquid cavitation heating system can be designed and fabricated for household water heating applications to reach temperature by continual research and development of system design and heat demand characteristics [3]. The main advantage of this kind of heater is high efficiency, instantaneous, direct heat to liquids and homogenous heating.

1.1 Objective

I. To design the cavitation heater unit, driving motor setup and mounting base.
II. Assembly of heater units and hardware's like insulated storage tanks, hose, pipes, valves etc.
III. To obtain heat characteristics of the designed heater with respect to water intake and speed
IV. To determine the efficiency of the heater and to correlate the test results with the convention heater and determine the cost analysis.

2. HEATER SYSTEM DESIGN AND DEVELOPMENT

In general any of the heater system will have these basic components like heating source, heat transfer surface, heating medium and storage. In the designed heater setup the heating source is by rotation of cavitation rotor by an electrical motor. Heat is transferred directly to the water thus eliminating heat transfer medium. The heating medium used is water to rise it temperature to desired set point. It has an insulated storage tank of 10L for heat water storage and outlet. The circulation pump can be used to circuit the water in and out of cavitation unit. The metal which will be using for the cavitation rotor, housing and end plates shall have to withstand high temperature and pressure at the same time it must be easy for machining. Thus high grade aluminum is selected due to its ease in machining and economy aspects [4].

2.1 Block diagram

The block diagram of cavitation heater set up is shown in figure - 1
below.

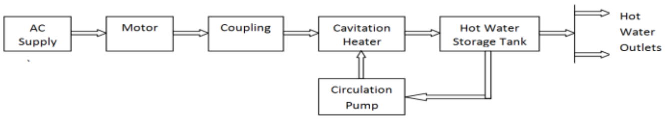


Fig-1: Cavitation heater system block diagram.

2.2 Cavitation heater

The cavitation heater first designed and then the device is fabricated from aluminum. It is designed so as to heat water up to temperature of 25°C - 60°C. As shown in figure - 2 it consists of aluminum rotor in which holes are drilled radically throughout the axis and solid aluminum cylindrical rotor housing with bearing integrated end plates and oil seals. In the end plates the provision are made for inlet/outlet to the insulated hot water storage tank.

Fig-2: Cavitation heater assembly parts.

The cavitation rotor contains of 10mm diameter & 15mm deep. These holes are drilled at an angle of 45 degrees. This hole angle will help in creating bubbles and has natural pumping action is created by the rotation of rotor inside the closed housing. The each end plate has 25mm diameter inner threaded holes to connect the plumbing adaptor. In this plate the provision is made for fixing oil seal and ball bearing assembly.

3. WORKING PRINCIPLE

The cavitation or homogeneous nucleation in a liquid is well known hydrodynamics phenomena. It creates cavity in the volume of water. According to "Classical Nucleation Theory" if any liquid is brought beyond liquid vapor equilibrium line to metastable state also called stretched liquid the cavitation occurs [5].

The main technology used here is a specialized rotor with holes. As shown in figure - 3 and 4 the spinning action generates hydrodynamic cavitation within the holes away from the metal surfaces. This cavitation pump directly converts electrical energy into thermal energy through cavitation induced by the rotation of the working fluid.

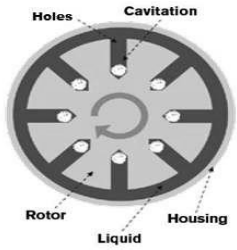
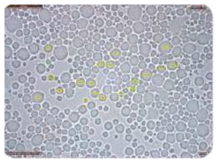


Fig-3: Cavitation heater rotor side view.

Fig-4: Cavitation heater rotor side view after machining.

Before Cavitation



After Cavitation

Fig-5: Liquid before cavitation and after cavitation.

The figure - 5 shows the liquid before cavitation and after cavitation. Energy is released in the form of heat when the bubbles collapse, causes the water temperature to rise. The bubbles also produce steam. The cavitation heat pump decreases the pressure of the working fluid, in this case water, to a point below its saturation pressure, which consequently induces cavitation. Also the low pressure created by the fast rotation of rotor helps the water to boil quickly. The powerful forces of cavitation produce heat that is far exceed those of conventional technology. By controlling the speed of rotor and the rate of flow of water the cavitation can be controlled. We can produce hot water instantaneous since the heat is directly applied to water not by other medium. Also the heating will be even or homogeneous.

4. PRACTICAL SETUP AND METHODOLOGY

Fig-6: Cavitation heater assembly experimental setup.

The practical setup consists of following components are they are listed accordingly below:

1) Cavitation Heater. 2) 0.5HP Induction Motor.
3) Claw Type Coupling. 4) Metallic Mounting Frame.
5) Hot Water Outlet Pipe. 6) Cold Water Inlet Pipe.
7) Insulated Storage Tank. 8) Tank Support.

a) The experimental setup is conducted by controlling the speed of the cavitation heater to attain desired temperature and parameters like temperature rise, time, cumulative time, ampere, wattage, pressure, power and volume of water.
b) Similarly experiment is conducted to attain desired temperature by change in rate of flow of water. Also all parameter recorded.
c) The core, body temperature of cavitation heater is also taken into account.
d) The test data's correlated and the thermal conversion efficiency is calculated.
e) The heating cost per liters of water is measured and compared with other conventional heating

5. RESULTS AND DISCUSSIONS

From the experimental results following correlated average readings are tabulated and given in below table – 1.

Table -1: Measured parameters at every 5℃ increase of water temperature.

Temperature Readings (℃)	Time Elapsed (S)	Cumulative Time (S)	Ampere (A)	Power (W)
25	0	0	3.3	390.6
30	250	250	3.15	388
35	150	400	3.05	375.9
40	170	570	2.9	373.2
45	190	760	2.7	370.6
50	200	960	2.3	369.8
55	240	1040	2.01	369.1
60	300	1250	2	369

From the correlated results the cost analysis of water heating compared to convectional electric heating is compared and given in below table -2.

Table -2: Cost analysis of water heating

Average Power (kW)	375.775
Voltage (V)	229
Total Time (h)	0.330
Electricity Rate (Rs./kWh)	0.025
Total Cost (Rs.)	3.100

As given in above tables the cost of heating water is less than the other form of heating which makes this heater highly economical & efficiency. On every test run the input and output power calculated. The theoretical efficiency of designed cavitation heater is around 83- 87%.
The detailed heating load characteristic of cavitation heater is given in below 2D graphs.

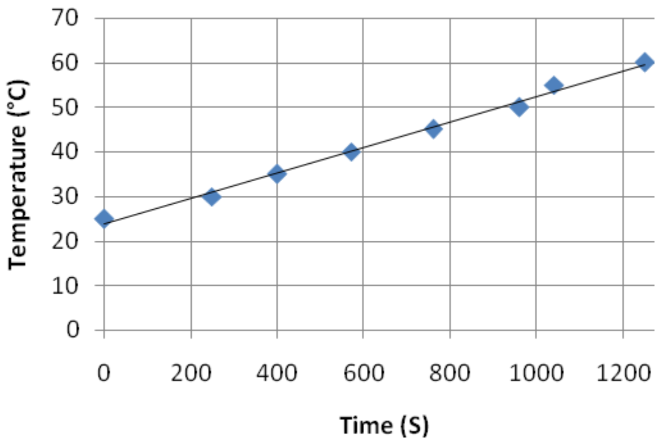


Fig-6: Temperature Vs Time

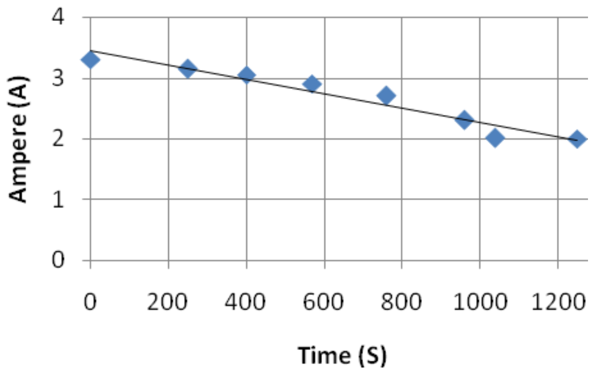


Fig-7: Ampere Vs Time

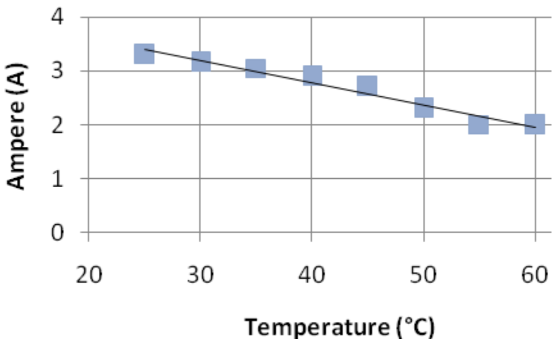


Fig-8: Ampere Vs Temperature

From the above figure – 6, 7 & 8 it is clear that the time taken to raise the temperature from 25°C to 30°C is more. Once water attains temperature greater than 30°C the heating process is almost linear. Also at the temperatures near to 60°C the heating seems to be slow this is because in the time water is transforms to stream.

The ampere also increases at beginning due to starting load of rotor and water. After few minute the ampere decreases gradually. Similarly the input power increases at starting and decreases gradually. The distilled pure water will heat quickly than the normal water.

In this designed cavitation heater the test results are expected to be in the range of designed values. But due to ambient pressure and temperature the accurate results are hard to obtain. The heat is lost through the heater outer cover, storage tank and circulation pipes. So it should be well insulated. Also the flow of water to the cavitation heater is by gravity. Due to high speed rotation of rotor the water hammering effect will be observed. To over-come this problem the circulation pump will be needed to circulate the water in and out.

From its practical design and usability, and considering its simplicity, efficiency and economy the cavitation heater should deliver high performance compared to conventional ones.

APPLICATION

The some of the application of these kinds of heaters other than household applications are in following industries like food & beverage, dairy, mixing, dispersion & homogenization, emulsification, hydration and aeration.

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BIOGRAPHIES

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