

Experimental setup to find heat transfer coefficient in boiling process of water – Design and fabrication

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Abstract— The purpose of following project is to find out coefficient of heat transfer for boiling water inside a tube in dynamic condition. Heat transfer coefficient plays a crucial role in almost all the application of boiling water. So it is important to have a practical setup in colleges for deep understanding of students. The problem here stands that whatever setup available are costly, so most of the colleges do not prefer to have this setup in laboratories. Our sole objective is to prepare an experimental setup which is less costly yet sufficient for experiment and simpler in operation. The major components used in this setup are Heater, Pump, Copper tube, condenser and some sensors. Our aim is to design the setup for efficient performance. The copper tube used has inside diameter of 8 mm and outside diameter of 10 mm. We start the flow of water from a container by heating the water to 50°C. The copper tube is wound by heating coil for further heating of the water is taken place. The thermocouple fitted on the copper tube shows the reading of the temperature of the water through which we can find coefficient of heat transfer for water by the formula of heat transfer coefficient used in convection process. After that the boiling water is passed through the condenser for cooling and after that the cooled water is again passed into the container for the preheating.

Keywords—Heat Transfer coefficient, water, experimental setup, two-phase boiling, design.

I. INTRODUCTION

Water is the most important part of any industries like power plant, food processing, etc. In these industries we require to transfer the heat through a medium which is water.

In power plants the boiling of water is most important phenomena without which it is impossible to run a power plant. Hence we need to study about coefficient of heat transfer for water. The boiling water which is flowing inside a tube has a varying heat transfer coefficient which depends upon the factors such as heat flux, mass flux, etc. In this project we are going to study the variation in coefficient of heat transfer for water. The saturation temperature of water at atmospheric pressure is 100°C. Our aim in the project is to work at this saturation temperature only. The boiling process is categorized in two types pool boiling and flow boiling. Pool boiling process is easy to understand but our aim in this project to study the flow boiling. Flow boiling includes mass liquid in motion, buoyancy effect, hence generalized theories are unavailable for flow boiling because of the various flow complexities. Analysis of earlier work shows that the major parameter affecting heat transfer coefficient under flow boiling is heat flux, saturation pressure and thermo physical properties of working fluid.

Hambarde and Kadam[1]] investigated study on the variation of coefficient of heat transfer for water inside tube because of the effect of heat and mass flux. As many applications are involved the heat transfer coefficient inside the small diameter tube like heat exchangers, refrigerants, boilers and food industries. Chen(1996) was the first to investigate the heat transfer in tube, placed vertically for flow boiling and still we can find series of works that have been pursued at boiling and two phase laboratory in Purdue university. N.T. Ravikumar, L. Syam Sunder and P. Bhramara[2] studied the variation in overall heat transfer coefficient due to different concentrations of Fe₃O₄ in water. The study showed that the Fe₃O₄ particles increased the heat transfer. G.P. Williams[3] studied heat transfer coefficients for water surfaces. Experiments conducted to determine coefficient of heat transfer for various water surfaces and relationship between the heat transfer and temperature difference. Jordan Pollack

and Matthew McCarthy[4] studied the rising boiling heat transfer via low conductivity materials. They used methods such as bi-conductive surface fabrication and pool boiling characterization. Jan Havlik and Thomas Dlouhy [5] dealt with experimental determination in coefficient of heat transfer. The calculation of coefficient of heat transfer plays crucial issue in designing and sizing of the heat exchangers. S. Ramachandran [6] conducted experimental heat transfer correlations in two phase system in compact heat exchangers. The ratio of heat transfer coefficient of two phase fluid and that of single phase fluid was correlated. It enables calculations of two phase coefficient of heat transfer. W.H. Azmi, N.A. Usri [7] analysed convective coefficient of heat transfer of water ethylene glycol based nanofluids. It was found that coefficient of heat transfer for nanofluids enhanced with greater concentration. M. Kumar, V. Bhutani and P. Khatak[8] reviewed the previous work on heating of various liquids in pool boiling. Nucleate pool boiling, an effective and efficient method of boiling water since high heat flux are possible. Jong wook CHOI and Jin Won CHOI[9] experimented for finding convective coefficient of heat transfer of high pressure water jet. Heat transfer coefficient was measured by Numerical analysis and from experimental values by hydraulic descaling system. Piasecka and Maciejewska[10] presented the results for boiling heat transfer coefficient during laminar flow in minichannel of 1mm depth, situated vertically and horizontally. Calculations were targeted at evaluation of heat transfer approaches to determine local heat transfer coefficient.

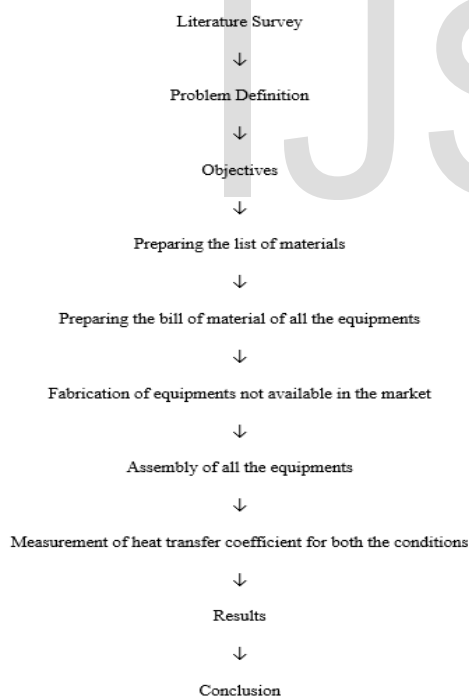


Fig.1 Overall Methodology

We are going to design and then fabricate experimental setup for boiling water in a tube to calculate coefficient of heat transfer. The process of finding heat transfer coefficient in flow boiling is costly and complicated. Whatever setup available are costly and complicated. Our main aim is to reduce the size of the setup and to decrease the cost of the setup.

II. DESIGN DETAILS AND CALCULATIONS

The fundamental equations for heat transfer coefficient are

$$Q = U \times A \times \text{LMTD} = \dot{m} \times C_p \times (t_2 - t_1) = h \times A \times dT$$

$$dT = (T_s - T_{\text{sat}})$$

Where,

T_s = Surface Temperature of tube (inside)

T_{sat} = Saturation temperature of water

Q = heat transferred per unit time (kJ/s)

A = heat-transfer area(m²)

LMTD = Log mean temperature difference

C_p = Specific heat of fluid (KJ/kg K)

\dot{m} = mass flow rate of fluid (kg/s)

Tube Diameter :

The most common sizes used are 6,7,8,9 mm inner diameter and 12,14,16,18 mm outer diameter. (As per reference paper)

We selected smaller diameter for greater heat transfer area with a normal minimum of 12 mm outer tube diameter due to cleaning considerations and vibration. 6 mm tubes can be used on shorter tube lengths say < 0.5m.

Tube length : 1.5-2 metre

Heat Transfer Area :

It is longitudinal area (i.e Surface area) not cross sectional area from where heat transfer takes place inside the tube.

$$\text{Area} = \pi d l$$

d = inside diameter of tube

l = length of tube

Flow meter :

Copper material, Waterproof, Heat resistance, pressure resistance. Built-in with integrated magnetic hall sensor. The output of sensor is an electrical pulse with every revolution. To keep the sensor safe and dry, the hall sensor is sealed from water pipe.

Working range:2-50L/min

Sensor: Hall effect.

Heating Element :

Nichrome is an alloy produced by mixing nickel and chromium. Sometimes iron is also added in this alloy. It is known for its heat resistance, as well as its resistance to both corrosion and oxidation.

III. FABRICATION

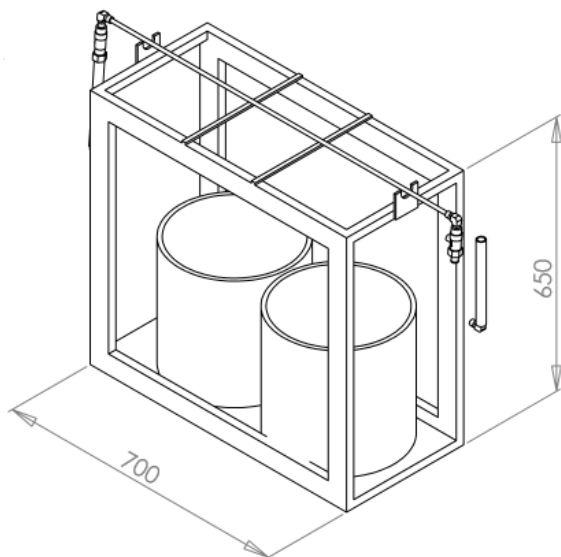


Fig.2 Model for the fabrication

The design was prepared according to the calculations and further fabrication process was carried out.

All the necessary equipments were incurred and fabrication was done accordingly. The copper tube was first covered with a mica sheet to prevent short circuiting and then wound around by the nichrome coil. The nichrome coil is further covered with keapton tape to prevent the heat loss to the surrounding. One end of the copper is attached with a pump, which supplies the flow of water into the tube from the pre-heater container. The other end of the copper tube is connected to the outlet chamber where the heated water is released.

IV. RESULT AND CONCLUSION

The fabrication was cost effective as that of the other equipments available in the market. The fabricated setup is able to give the required outputs. The heat transfer values are greatly affected by the heat flux, temperature of the fluid flowing inside the tube and mass flow rate.

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