Experimental setup to find heat transfer coefficient in boiling process of water – Fabrication and analysis

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Abstract— **The purpose of this project is to fabricate an experimental setup to find out the boiling water heat transfer coefficient inside a tube in dynamic condition. Heat transfer coefficient plays 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 setups 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 objective is to fabricate the setup for proper working and analyze the flow inside tube. Before fabrication, a 3-D model is prepared for analysis and then the fabrication procedure was accomplished. 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 the heat transfer coefficient for the 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. The readings taken are further analyzed and time required for heating water up to certain degrees is predicted by this analysis.**

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

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 heat transfer coefficient of 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 heat transfer coefficient of water. The saturation temperature of water at atmospheric pressure is 100°c. Our aim in this 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 coefficient of heat transfer under flow boiling is heat flux, saturation pressure and thermo physical properties of working fluid. The analysis of experimental setup is further followed by fabrication.

Hao Wang, Xiande Fang Ce[1] presented complete study of applicability of available correlation in flow boiling heat transfer coefficients to ammonia. The correlations that have better performances for predicting heat transfer coefficient in flow boiling are identified. Heat transfer coefficient of boiling water varies with the vapor quality. Chen-Ching Ting, Chien-Chih Chen[2] used experimental methods to analyze heat transfer behavior of water flowing inside heat pipe. It illustrated that the performance inside heat pipe is changed as same as to the copper pipe by reason of integration with the

cooling plates. Hambarde and Kadam[3] investigated study on the variation of coefficient of heat transfer for water inside tube because of the effect of heat and mass flux. Many applications are involved with heat transfer coefficient within small diameter tube such as 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. Ali Akbar Jafari[4] made analysis on silica nanofluid's heat transfer coefficient with water as base fluid under transitional flow. The main key of this research is to see how the properties will vary while heating and cooling.

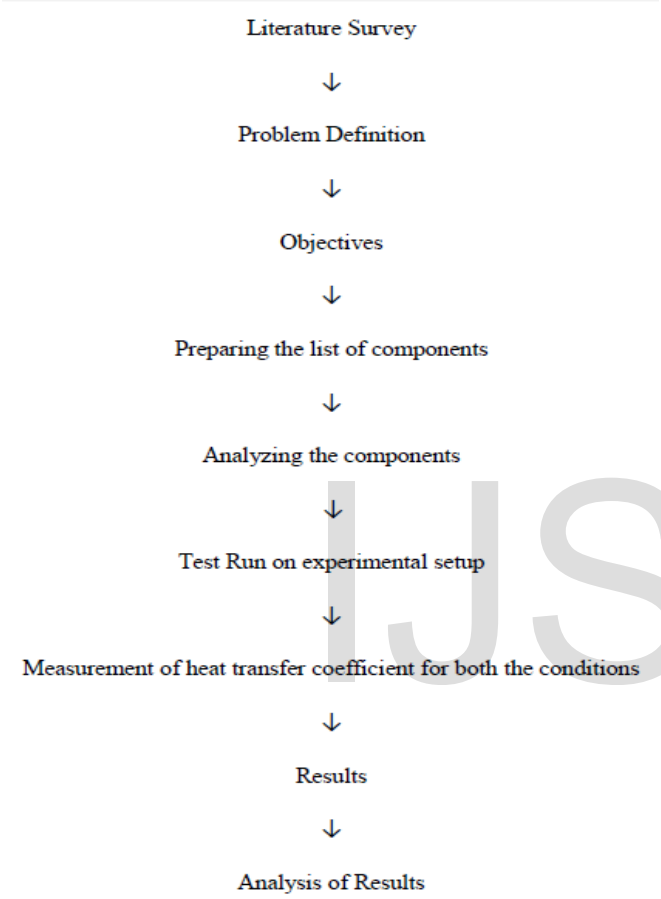

Fig. 1. Overall methodology for fabrication and analysis

Kong and Deethayat[5] conducted experiment on transfer of heat phenomena on waste heat improvement in combustion stag gas with deionized water. These results concluded that deionized water has better capacity of heat transfer than normal water. The study was helpful in utilizing the maximum waste heat of gases. Jong wook CHOI and Jin Won CHOI[6] 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 hyadraulic descaling system. Li Hua Yu, Guo-Yuan and Jun Wang[7] the experimental research on heat transfer of boiling water on horizontal copper rod is presented. The equations of regression of the boiling water heat transfer coefficient are obtained lying on the data obtained from experiments which is convenient for practical applications. S. Ramachandran [8] conducted experiments to get heat transfer correlations for two phase system in a 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 [9] 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.

We are going to do analysis and fabricate the experimental setup to find out coefficient of heat transfer for water in flow boiling. Our goal is to fabricate a less costly setup with proper working for experimentation. The result of the experiments will be analysed further.

II. EXPERIMENTAL DESIGN

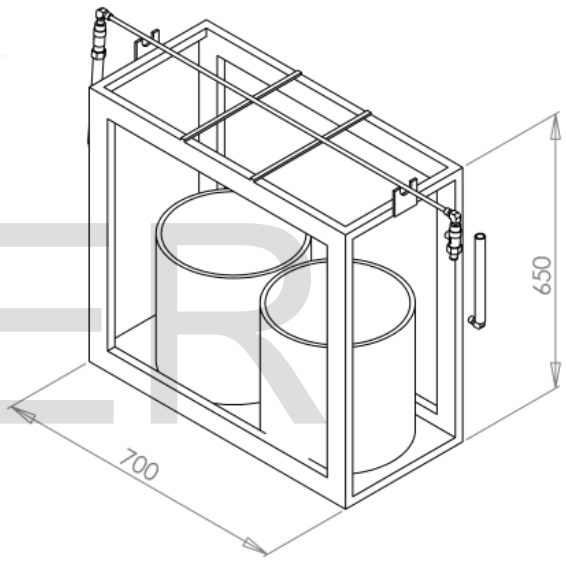

Fig. 2. 3-D model of setup

The basic idea for the setup was to fabricate a model which will accommodate less space in the labs. The design is simple and it can be fabricated easily.

The key concept in setup is to provide heat to the water through the copper tube. As it is impossible for heating the water inside a tube from room temperature to the saturation point, we are going to heat the water in a preheated container. The pre-heating takes place up to 50^{O} C and the further increment in the temperature takes place in the copper tube. The thermocouples installed on the copper tube measures the temperature of copper tube as well as water. For a closed cycle, condenser can be installed at the end of copper tube to liquefied any steam that is present system. And for the open cycle, the heated water can be taken out of the system.

The thermocouple installed on the tube for the readings of water temperature shows variation as shown in the below graph.

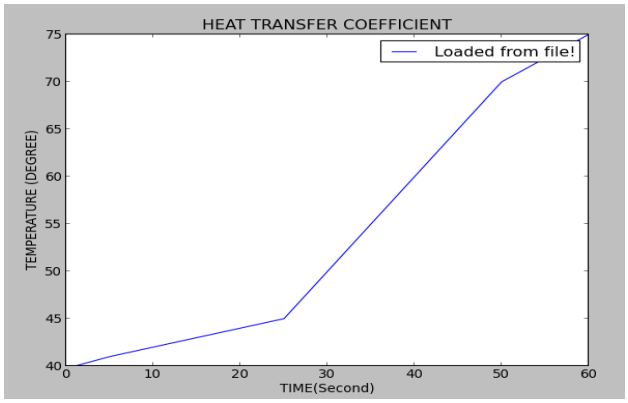

FIG.3 – TEMPERATURE VS TIME GRAPH

The above graph shows that the time required for the heating of water from 40 to 45^{O} C was more compared to 45 to 70. Again it takes more time for further heating from 70^{O} C.

III. RESULT & CONCLUSION

The results indicated that increasing temperature takes more time to get heated than the water at room temperature.

Coefficient of heat transfer depends upon the factors such as temperature of water, mass flow rate of water flowing through tube.

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