# EXPERIMENTAL PROCEDURES ON AN APPROACH TO THE AIR HEAT TRANSFER PROCESS THROUGH THE TUBE

[1] Khashayar Teimoori and [2] Ali Sahebi and [3] Shahram Shahroodi
[1]Young Researchers and Elites Club, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2]Department of Applied Arts, Peachtree Rd NE, Atlanta, Georgia 30326, U.S.A
[3]Faculty Member, Department of Mechanical and Aerospace Engineering, Science and Research Branch, Islamic Azad University, Tehran Iran
[1] Head of Nonlinear Sciences Department, Backstretch™ *Academy of Sciences*, P.O Box 14185- 488 Tehran IR
[2] Backstretch™ President *Academy of Sciences*, P.O Box 14185- 488 Tehran IR

***ABSTRACT***

*The results of analytical perceiving as well as calculations, while heat is transferred through the tube, were researched. Since the entrance heat as well as the outlet heat at the end of the tube is not steady, the resulted $NU$ numbers therefore, out of both the former heat transfer and the latter at the tube outlet way are inaccurate. In order to attain the accurate $NU$ numbers, the average four temperatures in a row of one to ten are taken granted. According to the data dissipation, the ever-changing heat temperatures at both ends are not technically a concern. Analytically responding to this research, there are resulted line diagrams so as to specifically illustrate the situated process.*

***KEYWORDS:*** *Force Convection, Error Analysis, Heat Transfer Coefficient, Conduction*

## I. INTRODUCTION

Suppose that there is a plate on which a fluid is moving. Being conducted this heat is entered into the fluid on the plate providing it is heated from bellow. This heat is transferred by fluid molecules, because the fluid is running. As a result this kind of heating transfer is called convection. It is noticeable in order to have the fluid moved, at the beginning a fan blows or a piston moves a force to the fluid which is running. Consequently an external force causes the fluid to move which is called Force Convection. The mentioned fluid in the experiment is the air. The major problem in heat transfer is how to find the coefficient of heat transfer (h). As an example the force convection is the function as the following $h = f(\rho, C_p, u_\infty, L, \mu)$. As it is perceived the co efficiency of heat convection is pertinent to the slope of temperature distribution in fluid on the wall. As a consequence, the temperature distribution is obtained from the energy equation. There is the term speed in energy equation which therefore the continuity equation as well as the measurement of motion must be always solved to obtain the speed distribution. With respect to the alternative heat temperature through the specific tube the $NU$ numbers are unachievable unless considering averagely the middle part of the tube there are four resulted heat temperature which permit to assumingly calculate the resulted $NU$ numbers. There is a pipe where the electric circuit is connected at seven thermocouples which are installed on the inner wall of the pipe. Also there is a pump at the beginning of the tube to pump the environment air of the laboratory into the tube. The laboratory cold air is pumped from the environment-air into the tube which is passed through the heater taps at both ends of the tube. This experimentation is called the FORCE CONVECTION. The $NUs$ actually and technically are resulted through two methods; such as formulation and the experiment. By accelerating the speed of the air flow in accord with increasing the REYNOLDS numbers (Re), the $NU$ number**s** are also increased. Finally, through the $NU$ increase, the co-efficiency of heat convection is therefore increased. FC occurs at the tube inside area which is primarily and significantly a concern at the tube inside area. It is expectable that the thermocouples are to be installed on the pipe inner-side to measure the temperatures at instant time of experiment. There is a conduction heat transfer on the tube thickness. Therefore the tube inside area temperature is resulted from conduction phenomenon thus here is a way with reference to $h_i$ related to the thermocouples which installed on the tube inner-side. Each thermocouple has different unique temperature with respect to the heat transfer through the air flow. Hence, the occurred FC, which caused by the air flow conductively led into the tube from the pumped air to the outlet end of the tube. Here, the air of the environment of the laboratory pumped by the installed pump which is purveyed at the tube inlet. There, the resulted $NU$ numbers, which are calculated from the four average thermocouples, obtained in two ways that are importantly significant in order to reach the existing errors due to the experimental obtained parameters with the ratio of theoretical calculations. It is noticeably remarkable that the applied data in calculation is quite as same as both in experimental parameters of equations as well as formerly obtained existing theoretic formulas in heat transfer.

## 1.1. Geometry of the work

The geometry used in this study contains a tube which is supported by the pump installed right before at the tube inlet to blow the room-air into the tube. Thermocouples are installed in the tube inner-side because of the FC. Moreover, the temperatures through the tube which are sensed and measured by the installed thermocouples understood that there is a parabolic cycloid diagram with respect to the length of the tube which is shown on Figure 1.

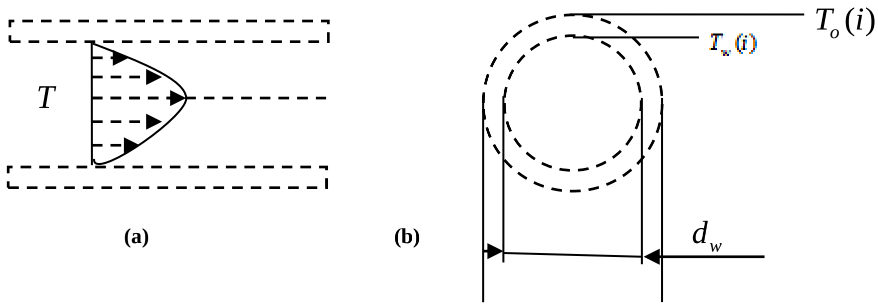



**Fig.1 a)** Temperature Profile with respect to the length of the tube **b)** Area and wall-thickness of the tube

According as shown on Figure 2, the studied construction of the air flow tube including the details shown in 2D.

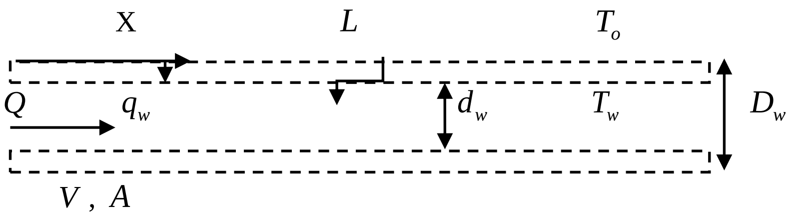
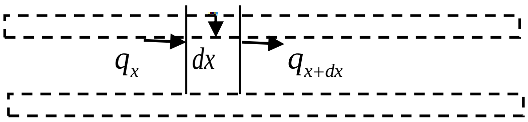



**Fig.2** Geometry of the tube and its information

$T_w$ (k), the wall inner-side temperature. $T_o$ (k), the wall temperature outlet. L (m), the tube length. $D_w$ (m), the tube outer diameter and $d_w$ (m), the tube inner diameter. Besides, $V$ and $A$ are also sequentially the speed and area of the tube. Showing the main process in using experimental equations and calculations, there is a well-defined illustration on Figure 3. Moreover, here $T_b$ is the bulk temperature through the air flow in the direction of $X$ axis.




**(a)**

**(b)**

| OHMIC HEATED TUBE | |
|---|---|
| Material | Ni-Cr Steel |
| Out Dia | $D_w = 6\times10^{-3}(m)$ |
| Ins Dia | $d_w = 5\times10^{-3}(m)$ |
| Length | $X = 8.5\times10^{-1}(m)$ |
| Thickness | $L = 5\times10^{-4}(m)$ |
| Th.Conduction | $K = 14\ Kcal/hm^2\deg$ |

**Fig.3 a)** Element theory is offered to analyze the air flow **b)** The tube properties used in experiment process

Which, $q_w$ is the mass flow rate with respect to the inner-diameter-thickness and can be determined by $q_w = h_i(T_w - T_b)$, where $q_w$ is in terms of ($Kcal/h.m^2$). [1] Other parameters are equated as bellow;

$$T_b = \frac{\int_A \rho u c_p t dA}{\int_A \rho u c_p dA} = \frac{\int_A u t dA}{\int_A u dA} \tag{1}$$

$$\int_A \rho u c_p t dA - \left[\int_A \rho u c_p t dA + \frac{\partial}{\partial x}\int_A \rho u c_p t dA \times dx\right] + q_w \pi d_w dx = 0 \tag{2}$$

$$\frac{\partial}{\partial x} T_b \int_A \rho u dA = q_w \pi d_w / c_p \tag{3}$$

It is remarkably noticeable that the actual instant laboratory pressure and temperature is to be taken granted so as to obtain its impact on the experimental conditions. Accordingly, the measurement of the temperature, pressure and the coefficient of the pressure are obtained as; $P_s = 1.333$ ($Kgf/cm^2$), $T_s = 293K$ and $C_p = 0.24(Kcal/Kg\ ^{\circ}C)$. Circumstances which considered in the laboratory environment are summarized on Table 1.

**Table.1** Properties of Air at $0^{\circ}C$ and the pressure of $10^5\ pa$ in the laboratory actual instant conditions

| UNIT \ TEMP $^{\circ}C$ | 0 | 20 | 40 | 60 | 80 | 100 | 120 |
|---|---|---|---|---|---|---|---|
| $\gamma(Kg/m^3)$ | 1.293 | 1.205 | 1.127 | 1.060 | 1.000 | 0.446 | 0.898 |
| $\nu(m^2/h)$ | $4.96\times10^{-2}$ | $5.62\times10^{-2}$ | $6.3\times10^{-2}$ | $7.06\times10^{-2}$ | $7.81\times10^{-2}$ | $8.6\times10^{-2}$ | $9.43\times10^{-2}$ |
| $P_r(-)$ | 0.72 | 0.71 | 0.71 | 0.71 | 0.70 | 0.70 | 0.70 |
| $k_s(Kcal/hm^2\deg)$ | 0.0207 | 0.0221 | 0.0234 | 0.0247 | 0.0260 | 0.0272 | 0.0285 |

Which, here *2 is the coefficient of air kinematic viscosity at $T_{bo}$ (the air bulk temperature) for calculation of $h_o$ (the outer heat transfer coefficient) which is remarkable that both $T_{bo}$ and $h_o$ have an average value in this study through the air flow in the tube.

### 1.2. Isothermal Parallel Horizontal Sensors Location

Horizontal thermocouples are geometrically typical for heat transfer experiments. It is considered that it is tried to have each thermocouple shown their targets as thermal differences at the tube inner-length. The certain spacing channel is considered on each installed thermocouple shown on Figure 4.

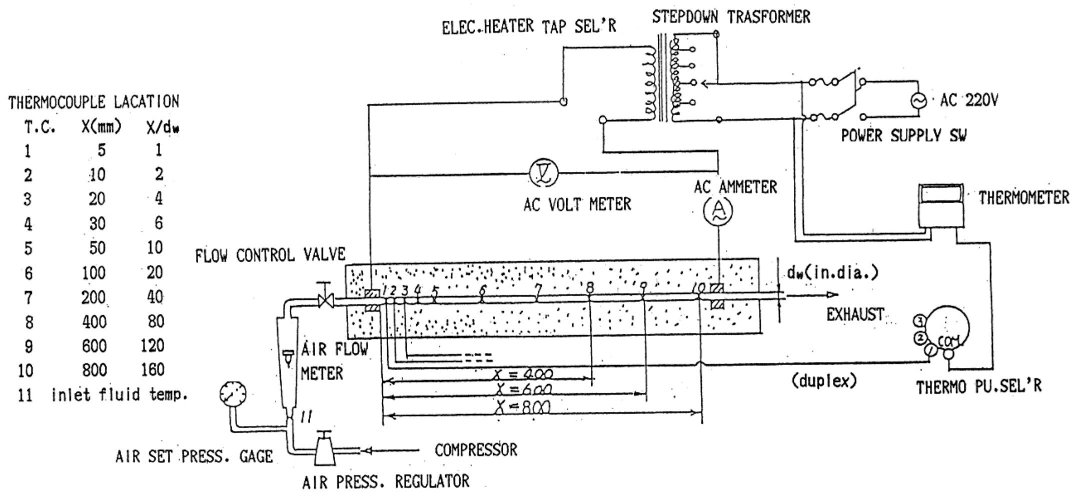



**Fig.4** Circuit diagram of apparatus

Reciprocally, the installed thermocouples can be followed by the next figure which is illustrated to show the measurement of the localized distances with the ratio of origin among each thermocouple installed on the tube inner side wall.

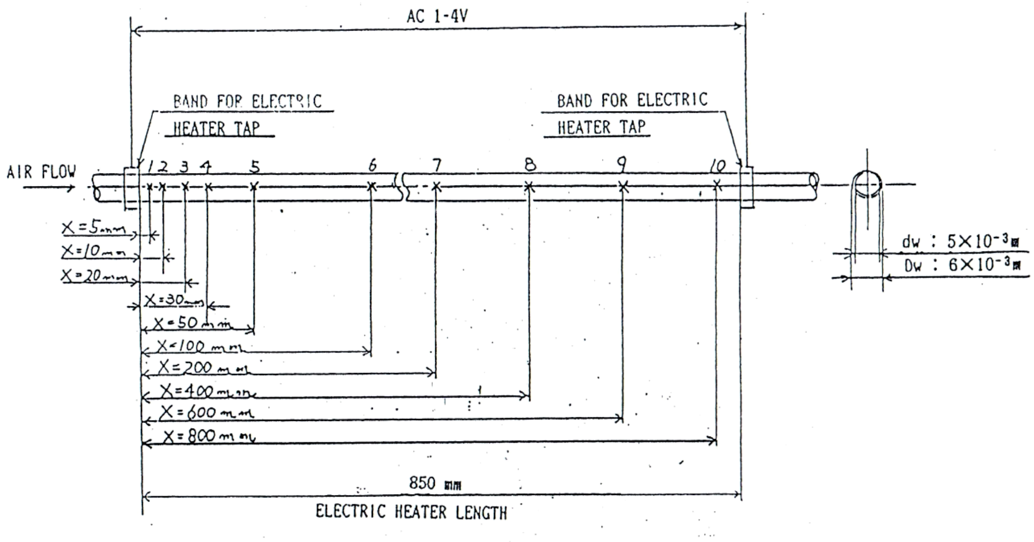



**Fig.5** Thermocouples location

The ten installed thermocouples with certain spacing channel beginning at the inlet air flow to the outlet air flow applied at different spacing length to technically result in the best temperature assumption sensed by thermocouples. It is significant that the sensed temperature is aimed to result as the average temperature among the certain spacing thermocouples as shown on Figure 5.

## II. CALCULATIONS AND FORMULAS

The applied calculations so as to achieve the $h_i(i)$ parameters (Local Heat Transfer Coefficient) are as the following:

$$\int_A \rho u dA = G' \Rightarrow \frac{\partial}{\partial x} T_b = \frac{q_w \pi d_w}{C_p G'} \tag{4}$$

$$\frac{\partial}{\partial x} T_b = cte \Leftrightarrow \frac{\partial}{\partial x} T_b = \frac{\partial}{\partial x} T_w = cte \tag{5}$$

$$T_b = \frac{q_w \pi d_w}{c_p G'} X + T_a \tag{6}$$

$$T_w = T_o - \frac{q_v L^2}{K} \tag{7}$$

After all calculations done by the equations 4 to 6, the resulted temperatures with respect to the length of the tube are shown on Table 2. [2]

**Table.2** Resulted temperatures of the tube inner side

| X (mm) | Tw1 | Tw2 | Tw3 | Tw4 |
|---|---|---|---|---|
| 5 | 26.55 | 20.75 | 24.14 | 12.6 |
| 10 | 29.85 | 28.15 | 26.11 | 12.607 |
| 20 | 33.25 | 30.55 | 28.14 | 12.61 |
| 30 | 33.45 | 30.85 | 28.54 | 12.63 |
| 50 | 38.55 | 34.75 | 31.64 | 12.645 |
| 100 | 38.45 | 35.95 | 33.54 | 12.675 |
| 200 | 48.05 | 43.25 | 44.24 | 12.71 |
| 400 | 58.05 | 52.25 | 47.44 | 12.903 |
| 600 | 57.35 | 54.75 | 51.24 | 13.206 |
| 800 | 67.75 | 65.25 | 60.94 | 13.5 |

Consequently, due to the obtained statistics from the experiment are necessarily considered to be applied in both experimental and theoretical $NUs$. An experimentally achieved $NUs$ can be determined then, by $Nu = 0.023 \mathrm{Re}^{0.8} \mathrm{Pr}^{0.4}$ applied for calculation purposes so as to use for turbulent flow in a smooth tube. Also the theoretical $NUs$ could therefore be determined by $Nu_o = \frac{h_o d_w}{K}$.

The calculated $NUs$ were selectively appointed from four temperatures taken from the four centered installed thermocouples which technically are because of the existence of unbalanced temperature profile at the tube both ends which meant to be undisputedly unstable.

**Table.3** Resulted and obtained parameters of the experiment

| Tb2 | Tb3 | Tb4 | hi1 | hi2 | hi3 | hi4 | Re | Nu e | Nu f | $m$ | $m$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13.4 | 13.6 | 14.3 | 219.33 | 416.77 | 290.27 | 354.109 | 5041.14 | 27.23 | 18.42 | 1000 | 10 |
| 13.419 | 13.601 | 14.207 | 177.43 | 207.69 | 243.99 | 304.94 | 7666.26 | 32.28 | 25.75 | 10000 | 100 |
| 13.42 | 13.61 | 14.21 | 148.26 | 178.6 | 210.56 | 269.53 | 10219.4 | 36.11 | 32.14 | 100000 | 1000 |
| 13.44 | 13.622 | 14.22 | 146.95 | 175.73 | 205.85 | 218.38 | 12571.68 | 46.87 | 38.23 | 1000000 | |
| 13.498 | 13.637 | 14.23 | 114.7 | 143.96 | 170.038 | 191.57 | | | | | |
| 13.597 | 13.674 | 14.27 | 118.35 | 136.87 | 154.007 | 152.97 | | | | | |
| 13.795 | 13.74 | 14.34 | 86.67 | 79.96 | 100.311 | 116.11 | | | | | |
| 13.99 | 13.89 | 14.49 | 67.83 | 45.43 | 91.19 | 99.33 | | | | | |
| 14.19 | 14.04 | 14.64 | 69.3 | 59.94 | 82.24 | 79.57 | | | | | |
| 14.21 | 14.19 | 14.79 | 56.406 | 59.96 | 65.44 | 77.41 | | | | | |

The parameters obtained out of the calculations above were both categorized and summarized on Table 2 as the result of Nu number and Re number for manually setting four mass flow rates as shown on contrasting Figures 6 to 8 are perceivable. As the consequence of resulted diagrams from the calculated parameters are to certify to indicate the least tolerance between the experimental as well as theoretic calculations. [3] The resulted diagrams are verified in both theoretic and final experimental parameters to emphasize the correction and the least errors among $Nus$ in the results.

## III. THE VERIFICATIONS OF THE EXPERIMENT AT THE FINAL STAGE

It is divided into three phases; **a)** The resulted Nu numbers out of the theoretic calculations **b)** The resulted Nu numbers out of the experimental calculations and finally c. [4] The resulted errors calculated between phases a and b.

**a)** The Theoretical Calculations and Results

$$1 \rightarrow Nu = 0.023\,\mathrm{Re}^{0.8}\ pr^{0.4} = 0.023 \times 5041.14^{0.8} \times 0.7148^{0.4} = 18.42$$

$$2 \rightarrow Nu = 0.023\,\mathrm{Re}^{0.8}\ pr^{0.4} = 0.023 \times 7666.26^{0.8} \times 0.7141^{0.4} = 25.75$$

$$3 \rightarrow Nu = 0.023\,\mathrm{Re}^{0.8}\ pr^{0.4} = 0.023 \times 10219.40^{0.8} \times 0.7139^{0.4} = 32.41$$

$$4 \rightarrow Nu = 0.023\,\mathrm{Re}^{0.8}\ pr^{0.4} = 0.023 \times 12571.68^{0.8} \times 0.7130^{0.4} = 38.23$$

**b)** The experimental Calculations and Results

$$1' \rightarrow Nu_o = 20.23$$

$$2' \rightarrow Nu_o = 27.23$$

$$3' \rightarrow Nu_o = 34.11$$

$$4' \rightarrow Nu_o = 40.87$$

Finally, the errors between four results are obtained as bellow;

$$1'' \rightarrow \xi_1 = \frac{20.23 - 18.42}{27.23} \times 100 = 6.64\%$$

$$2'' \rightarrow \xi_2 = \frac{27.23 - 25.75}{27.23} \times 100 = 5.43\%$$

$$3'' \rightarrow \xi_3 = \frac{34.11 - 32.41}{34.11} \times 100 = 4.98\%$$

$$4'' \rightarrow \xi_4 = \frac{40.87 - 38.23}{40.87} \times 100 = 6.45\%$$

The general notion applied in force convection analysis is on one hand, the predominance of a heat-transfer mode governed by the fluid velocity of $30\,{}^{m}\!/_{s}$ considering an example, is expectedly to overshadow most free-convection effects encountered in ordinary gravitational fields because the velocities of the free-convection currents are small in comparison with $30\,{}^{m}\!/_{s}$ . [5, 6] On the other hand, a forced-flow situation at very low velocities ($\square\ 0.3\,{}^{m}\!/_{s}$) is influenced expectedly and appreciably by free-convection currents.

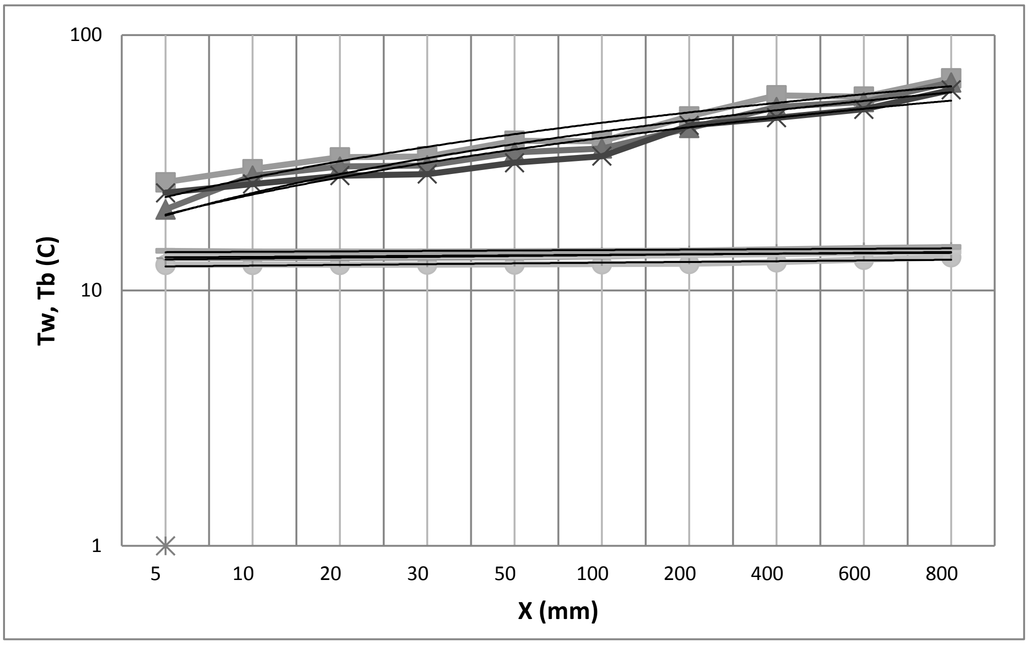



**Fig.6** Resulted changes of bulk and wall temperatures of the tube with respect to the length

As illustrated on Figure 6, the linear diagrams through the bulk and wall temperatures are approximately as similar as their slope which caused by the sensed temps of the thermocouples.

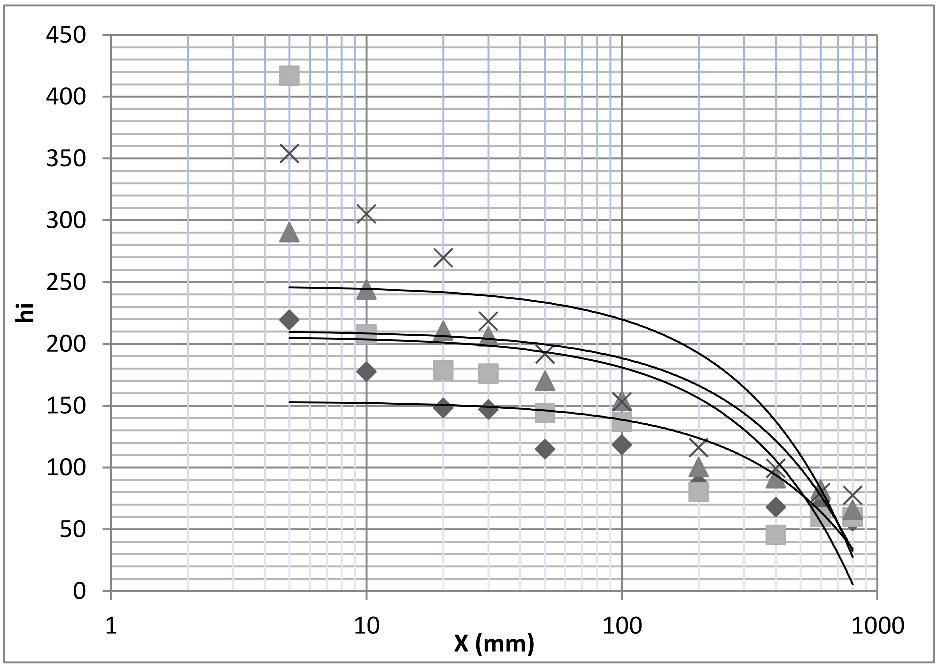



**Fig.7** Obtained coefficients of the heat transfer through the installed thermocouples into the tube wall

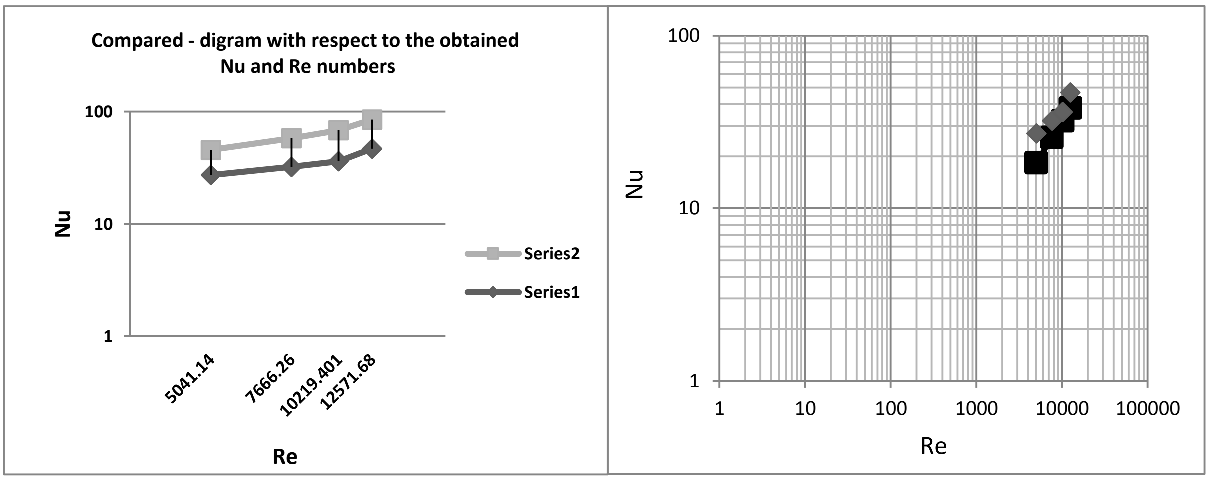



**Fig.8** Analysis in the comparison of the obtained Re and $NU$ numbers from the attained data's due to finding the errors between the theoretical and experimental calculated $NU$ numbers

## IV. CONCLUSIONS AND FUTURE SCOPES

In order to have this laboratory be more effective, it is to be localized in a controlled environment. The air conditioning unit is to be located in a room with a temperature like the rated temperature and as close to ideal air conditions as possible. Additionally, limiting the uncertainty in the measurement, the difference in the known values and the found values for the unit is decreased by the devices. The measurements were taken in the positions relied on the right amount of heat load for each state where the flow is conducted through. As the consequence of the discussed data above, it is assumingly believed that the attained $NU$ numbers in the experiment have the least tolerance between both the theoretic as well as experimental calculations with regards to minimize the final errors up to 5% which technically means that the errors as much closer to zero, more accessible to the actual circumstances so as to use more calibrated instruments as well as devices. As it is technologically inferred, the application of more accurate and precise devices in future would enable to decrease the upcoming errors up to the most appropriate and actual circumstances.

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## AUTHORS

***Khashayar Teimoori*** was born in Tehran, Iran in 1992. He is now pursuing B.S. at Mechanical Engineering in Azad University, Science and Research Branch of Tehran, Iran. He is simultaneously pursuing B.S. at Applied Mathematics in PN University, Tehran branch. He is a member of the technical societies as ASME, AMS, APS, ACM, ISME and IMS. He is also the originator of Backstretch™. He is at present the team vice-president. His special interests are Computational Mathematics, Dynamical Structures, Analyzing the complicated structures in mechanical systems and fluid behaviors.

***Ali Sahebi*** was born in 1966. He was admitted to Oxford House College in September 1988. At the same year in August, he was admitted to American Applied Arts in London branch at designing major. He started to have cooperated with Backstretch™ as the Head of International Affairs in 2010. He is now the pres dent of Backstretch™. He is now a faculty member of PN University, Tehran, Iran as Visiting Professor. He was also a Professor in Art Department at Atlanta.

***Shahram Shahroodi*** was born in 1964. Now he is an assistant Professor at Department of Mechanical and Aerospace Engineering in Science and Research Branch, Islamic Azad University of Tehran. Now he is the Heat and Mass Transfer Laboratory Head in Science and Research Branch, Tehran University. His special interests are Numerical Methods in Mechanics, Technical Programming with C++, Numerical and Experimental Heat Transfer.