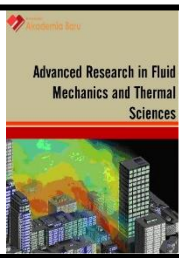
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



The Effect of Varying Tube Diameters on Enhancement Heat Transfer by Forced Convection Through a Horizontal Tube

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ARTICLE INFO

Article history:
Received 14 December 2019
Received in revised form 14 January 2020
Accepted 20 January 2020
Available online 26 February 2020

ABSTRACT

Forced convection (FC) is one of the important topics in engineering applications. Therefore, the process of improving the convection heat transfer coefficient (CHC) and determining the factors causing it has become a subject of interest to researchers. One enhancement approach is the varying dimension of the flow conduit. The present work involved the experimental study of forced convection inside copper cylinder fixed horizontally with varying heat flux and diameter (D = 0.02, 0.035, and 0.045) m, to investigate CHC, in this study assuming the flow is hydrodynamically fully developed. The work covers all the values of the imposed heat flux (HF) under investigation of ($7.33 \le q \le 107.424$ W/m^2) that yields Reynolds numbers range ($1252 \le Re \le 3032$) was investigated. Experimental results showed that the effect of varying the diameter was examined and results indicated that the Nusselt number (Nu) increased as the diameter increased which lead to higher surface temperature (SF) distribution along the smallest diameter tube. Results also show that the values of the local Nu (LNu) are always decreased and reached its lowest value at the tube exit section of the imposed HF. For all tubes, the result shows that an increase in the tube diameter results increasing in Nu_{av}.

Keywords:
Forced convection; constant heat flux; varying diameter; tubes

1. Introduction

Heat transfer (HT) in Forced convection (FC) is a significant application in designing. The primary determinant for improving the presentation of steam boilers, heat exchangers, and solar collectors. Likewise, the comparative issue of FC has basic applications in geothermal stores where weight slopes are produced because of withdrawal or reinjection of geothermal liquids. The laminar stream in a roundabout pipe was evaluated, Hartnett [1] and Bhatti *et al.,* [2]. Unfaltering completely created incompressible laminar move through a roundabout conduit is Study fully developed incompressible laminar flow through a circular duct is referred to as Hagen-Poiseuilli flow. Laminar convection in circular channel was deeply investigated for channel subjected to homogenous heating conditions, Shah *et al.,* [3]. HT around the heated cylinder during mixed convection FC with buoyancy effect. The

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proposed method has been done CFD simulation to investigate the problem with unconstrained surrounding Michelsen *et al.,* [4]. Researchers Explored the impact of Axial conduction in cylinder divider on HT procedure of Fully Developed Laminar Flow (FDLF) in the (cylinders under consistent divider temperature), steady HT and CHC limit conditions at the external pipe surface, Ou *et al.,* [5] and Arici [6]. Laminar Flow in cylinders exposed to pivotally fluctuated divider HT was examined [7-11]. In numerous applications, the water dividers of boilers, solar panel authorities, and the Heating surfaces are just halfway warmed along the outline of the pipe while the remainder of cylinder Circumference is thermally protected, Sparrow *et al.,* [12] and Wadhah [13]. A numerical investigation of HT in FC of FDLF in a roundabout cylinder warmed along of its boundary while the remainder of the circuit is adiabatic. The investigation and tests were done for warming conditions with uniform HF along the warmed segment of the cylinder surface. The laminar flow through Newtonian liquids should be occurred of pipe streams, Quaresma *et al.,* [14] and Barletta *et al.,* [15]. The speed profile of the completely created laminar stream inside the cylinder is outstanding, Al-Taha [16]. The impact of Re and the impact of the heat flux on the laminar stream were investigated. The outcomes demonstrated that increasing in the Nu qualities resulted inHF increments, Salman *et al.,* [17]. One of the methods used recently to improve the coefficient of HT by convection using of nanotechnology. A theoretical study was conducted to show the effect of (Ag/Heg) concentration on HTC by changing Reynolds number within the range (100,000 <Re <120,000). It was recorded that the Nessult number increased by almost 18%, Ny *et al.,* [18].

The proposed method will try to avoid the gap observed in literature and provide a better solution. This study will be different from the above literatures review by taking the mutual effect of HF and diameter on CHC at the same time. This study aims to change the diameter, fluid velocity and HF to show the effect of these three variables on the temperature distribution and the Nu of the heat transfer by forced convection.

2. Methodology

An experimental facility was constructed for laboratory experiments to study the Mixed Convection in a stuffed immersed permeable media warmed with a consistent warmth motion through the three chambers.

2.1 Test Section and Thermocouples

Three copper cylinders are used, its inside and external separations crosswise over are (0.048, 0.035, 0.02) m and (0.052, 0.038, 0.022) m independently, the length was (0.9 m). 1hp air compressor with a rotational speed of 2500 rpm was used. Thermocouples (T-type) are installed to record the required temperatures along the test section tube. The power supply is used to control the temperature of the Heater. The electrical circuit prepared for this purpose consists of (Ammeter, Voltmeter, Data Koschen, and Variable resistance) to record the required data. An opening plate is used to measure the speed of air. A 1hp air propeller was used to provide the required flow at the required speed. Figure 1 illustrates all parts of the system. Figure 2 represents the front section of the test section.

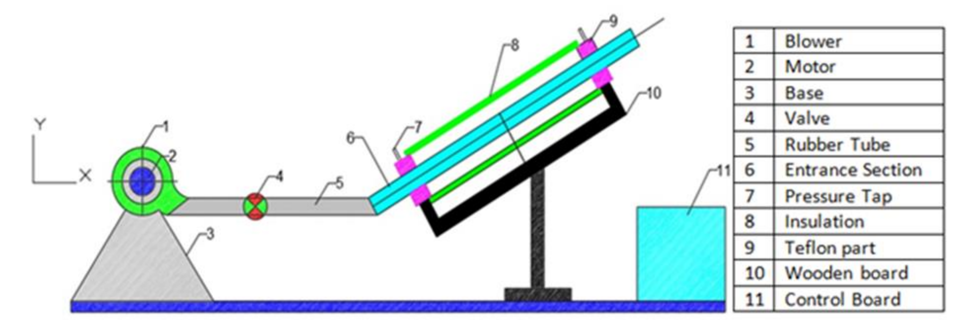

Fig. 1. Schematic of the experimental apparatus

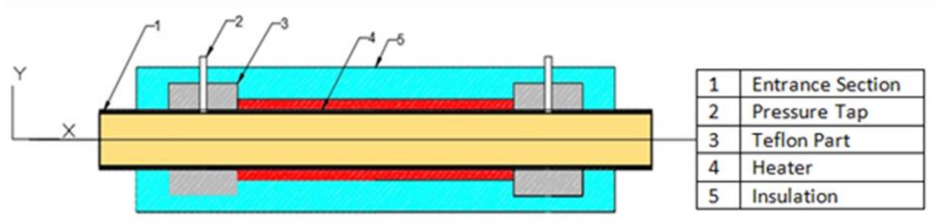

Fig. 2. Schematic of the test section

2.2 Experimental Procedures

The test method can be recorded as pursue.

i. Turn broadcasting live blower, and the wind stream is controlled.
ii. Turn on the power supply.
iii. The circuit is closed and held back for three quarters of the hour to reach a steady state condition, Ibrahim *et al.,* [19].
iv. Logging readings incorporate temperatures, mass flow rate, voltages, and current.

2.3 Data Reduction Analysis

Subsequent to logging the information there are numerous factors have been determined, for example, heat motion, Nu, Re, and Pe Then the nearby warmth move coefficient was determined, Ibrahim *et al.,* [19].

$$h_z = \frac{q}{(T_w - T_b)_z} \quad (1)$$

where (q) is calculated from

$$q = \frac{Q_i}{A} \quad (2)$$

where,

$$A = \pi D L \quad (3)$$

The bulk temperature was calculated, Holman [20].

$$T_b = \frac{(T_o - T_i)}{L} z + T_i \quad (4)$$

The characteristic of the fluid was calculated from the equations below, Al-Doori [21] and Ataalah *et al.,* [22].

$$\rho_f = 1.21003 + 7.4715 * 10^{-3} T_b - 3.8919 * 10^{-5} * {T_b}^2 + 4.54786 * 10^{-8} {T_b}^3 \tag{5}$$

$$\mu_f = 1.577 * 10^{-4} - 1.285 * 10^{-6} T_b + 3.836 * 10^{-9} {T_b}^2 - 3.662 * 10^{-12} {T_b}^3 \tag{6}$$

$$k_f = 0.155 - 1.236 * 10^{-3} T_b + 3.760 * 10^{-6} {T_b}^2 - 3.588 * 10^{-9} {T_b}^3 \tag{7}$$

$$Pr_f = 2.692 - 1.691 * 10^{-2} T_b - 4.799 * 10^{-6} {T_b}^2 - 3.588 * 10^{-9} {T_b}^3 \tag{8}$$

$$C_{pf} = 825.885 + 1.627 T_b - 4.974 * 10^{-3} {T_b}^2 + 5.205 * 10^{-6} {T_b}^3 \tag{9}$$

The amount of the heat was determined as pursue.

$$Q = \dot{m}\, C_p (T_o - T_i) \tag{10}$$

Also, the power supply.

$$P = I * V \tag{11}$$

The percentage heat loss.

$$\epsilon = \left(1 - \frac{Q}{P}\right) \tag{12}$$

Also, the LNu was calculated.

$$Nu_Z = \frac{h_Z\, D}{k} = \frac{q\, D}{k(T_W - T_b)_Z} \tag{13}$$

Re was calculated.

$$Re = \frac{\rho_f u D}{\mu_f} \tag{14}$$

And Pe was calculated as follows.

$$Pe = Re\ Pr \tag{15}$$

Pr was calculated at bulk temperature.

The Nu_{av} was calculated from

$$Nu_{av} = \frac{1}{L} \int_{Z=0}^{Z=L} Nu_Z\, dZ \tag{16}$$

Testes had been curved the following rang ($7.33 \leq q \leq 107.454$) of HF, and Re are used from (1252, 2504, and 3032). Repeat the process at each case or change the diameter of the tube (0.02, 0.035 and 0.045) m.

3. Result and Discussion

All tests were performed by changing the following variables HF from (7.33-107.56) W/m^2, Re are used from (1252, 2504 and 3032) and the diameter of the tube (0.02, 0.035 and 0.045) m.

3.1 Surface Temperature Distribution

Figure 3-5 spoke to the connection between the cylinder ST with length at deferent estimations of HF pointer as in figures.

For tube diameter of (D = 0.02m, 0.035m, 0.045m) and Reynolds numbers are used 3032. The cylinder surface temperature concerning its length proportional to tube length the maximum temperature is occurring at (z/L= 0.54, 0.6, 0.62) with temperature differences of (30.44°C and 44.5°C) correspondingly. This conduct because of that limit layer begins from zero at the passage of the chamber, and its thickness is expanded to arrive at its greatest incentive at the split.

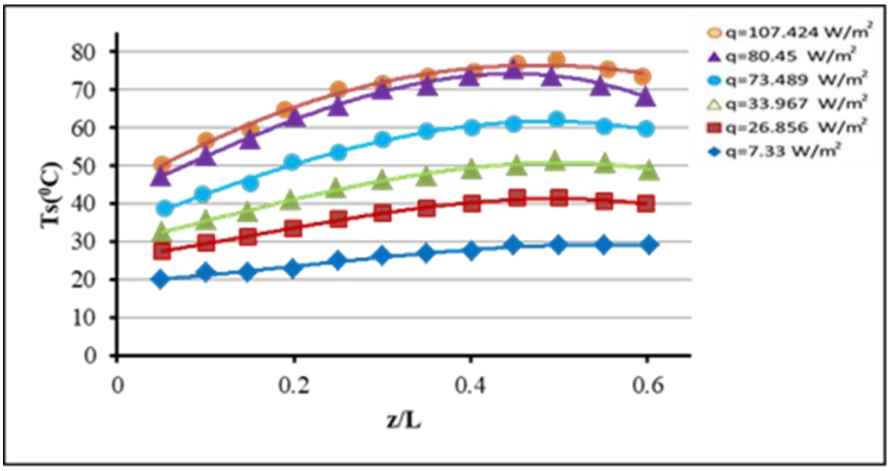

Fig. 3. The cylinder ST concerning its length for Re = 1252.3 and D = 20mm

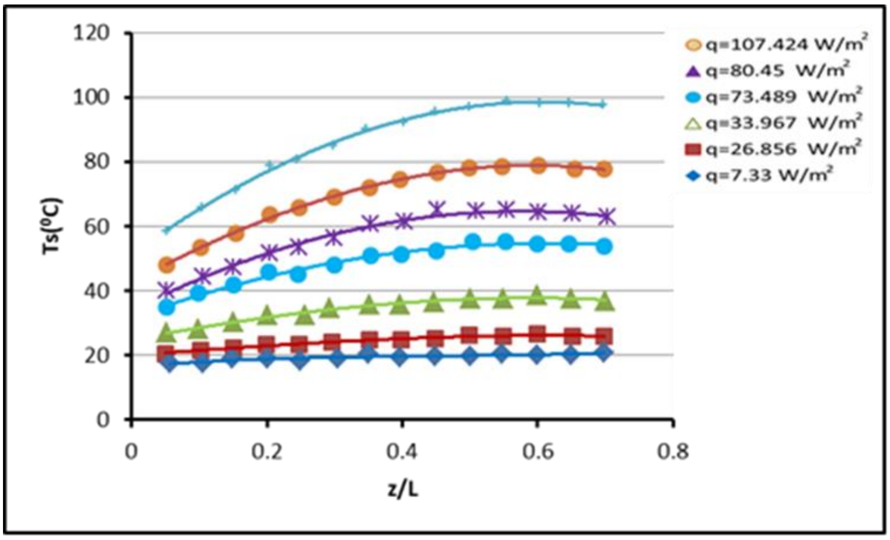

Fig. 4. The cylinder ST concerning its length for Re = 1252.3 and D = 35mm

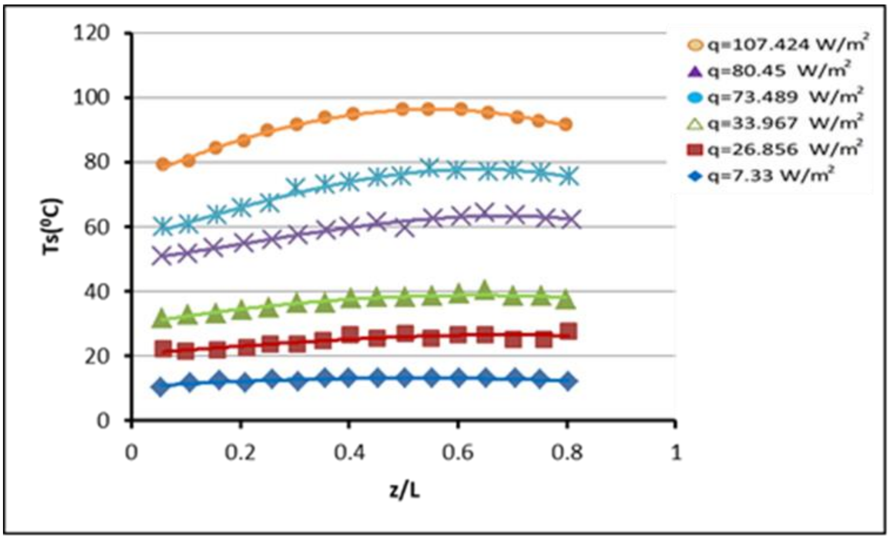

Fig. 5. The cylinder ST concerning its length for Re = 1252.3 and D = 45mm

3.2 Local Nusselt Distribution (Nu_z)

The variety of (Nu_z for the instance of cylinder distance across (D = 0.02m, 0.035m, 0.045m) and consistent Reynolds number of (Re = 1252) regarding tube length is plotted in Figure 6-8. As observed from these figures, the nearby Nusselt number abatements with the expansion in the pivotal position given the contrast between the mass air and cylinder surface temperature and the thickness of warm limit layer increment to arrive at least an incentive at (z/L = 0.4) at that point increment to arrive at beginning worth at (z/L = 0.6). The thickness of the limit layer expanding a long way from the bay area, it winds up consistent after warm entrance length. Be that as it may, close to the exit of cylinder warmed locale the Nu_zvalues are slight increments because of the cylinder end misfortunes.

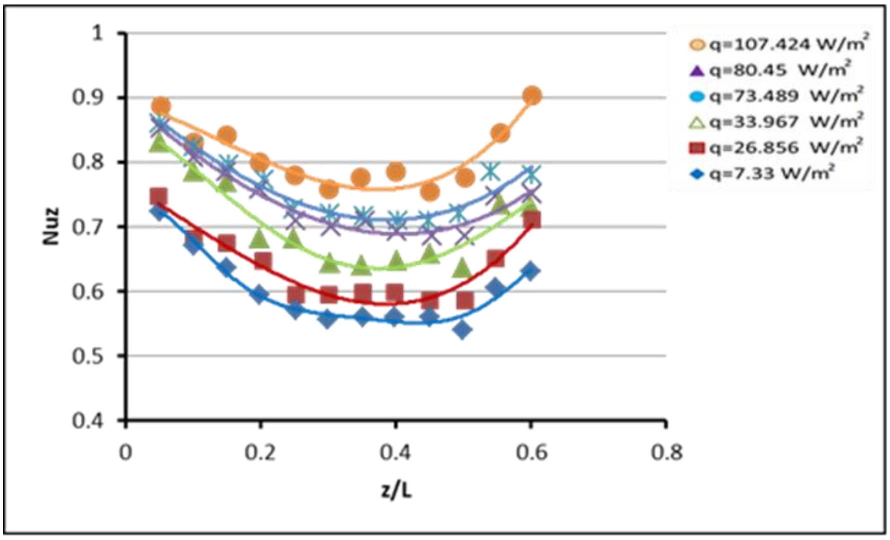

Fig. 6. Nu_z concerning tube length for Re = 1252.3 and D = 20mm

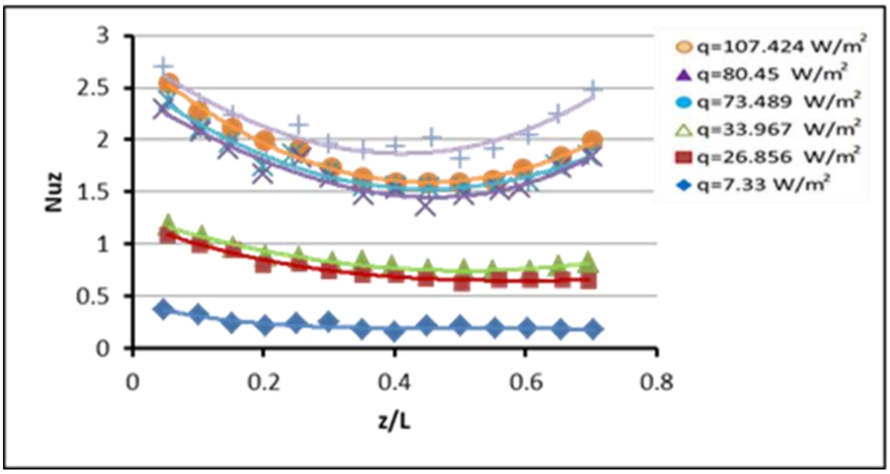

Fig. 7. Nu_z concerning tube length for Re = 1252.3 and D = 35mm

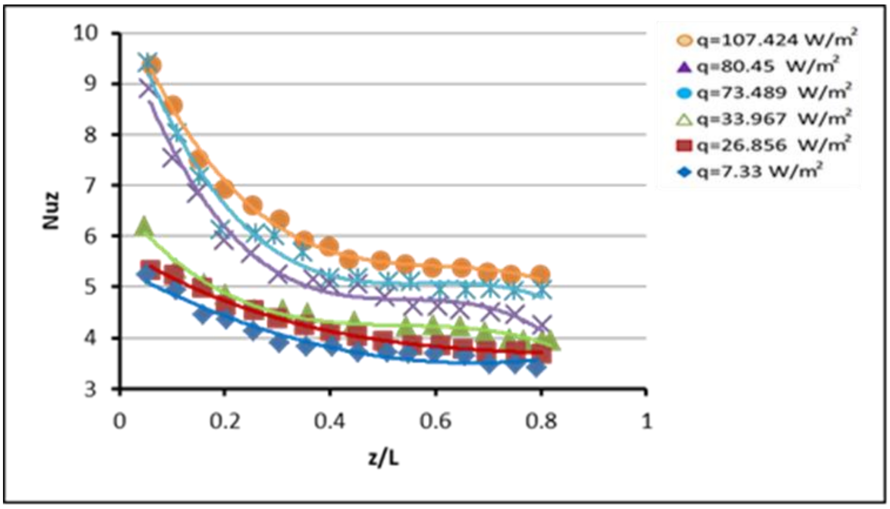

Fig. 8. Nu_z concerning tube length for Re = 1252.3 and D = 45mm

3.3 Average Nusselt Distribution (Nu_{av})

The relationship between Nu_{av} for the case of tube diameter (D = 0.020, 0.035 and 0.045) m at the heat flux $(q = 80.45\ W/m^2)$ for the tube length is plotted in Figure 9. As seen from this figure, at a given heat flux, the LNu increase with the increase in tube diameter. The value of (Nu_{av}) for tube diameter $(D = 0.045m)$ is higher than that for other tubes $(D = 0.035m\ and\ D = 0.02m)$. This is related to the variation of tube diameters. This factor becomes more effective which improves the HT results. Also with increase the tube diameter corresponding higher thermal entrance length for these cases $(at\ D = 0.045\ m, \mathrm{z/L} = 0.5, at\ D = 0.035\ m, \mathrm{z/L} = 0.3, at\ D = 0.02\ m,\ \mathrm{z/L} = 0.23)$ axial position because of the difference between the bulk air and tube ST and the thickness of thermal boundary layer increase.

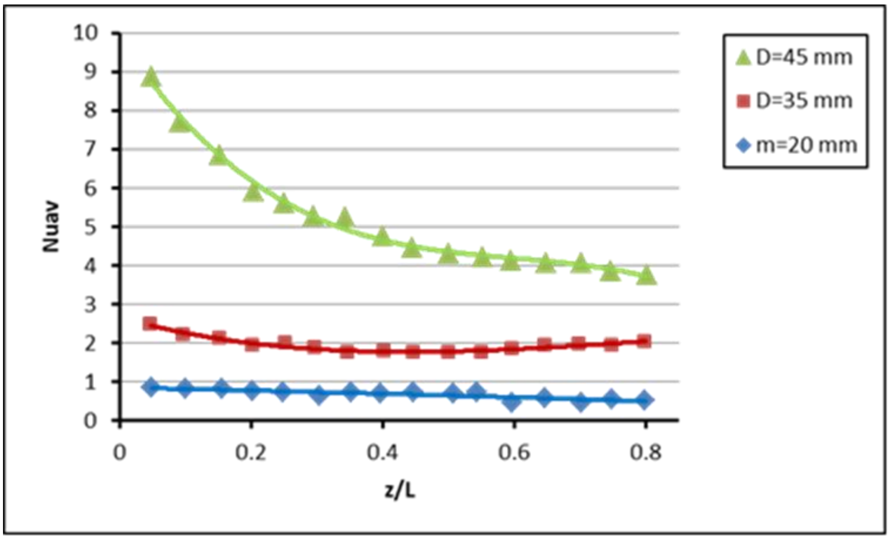

Fig. 9. Nu_{av} concerning the tube length

The variation of the average Nusselt number (Nu_{av}) with different tubes diameter for different values of heat fluxes which are ranged ($7.33 \leq q \leq 107.454$) is plotted. The effect of tube diameter on the $Nu_{av}$is illustrated in Figure 10 which indicated that the (Nu_{av}) value increase with the increase in tube diameter. As seen from this figure at tube diameter ($D = 0.02\ m$) the Nussselt has lower value and concentration about average value equal to (0.8). Also, with an increase in tube diameter ($D = 0.035\ m$) the value of Nu_{av} increasing at beginning with nonlinear and there is variation these values equal (1.3-2.3). While at ($D = 0.045\ m$) the trend of the curves is nonlinear, and the values of Nu_{av} is ranged for minimum to maximum (4-6.3). So, the Nusselt number more variation in this case.

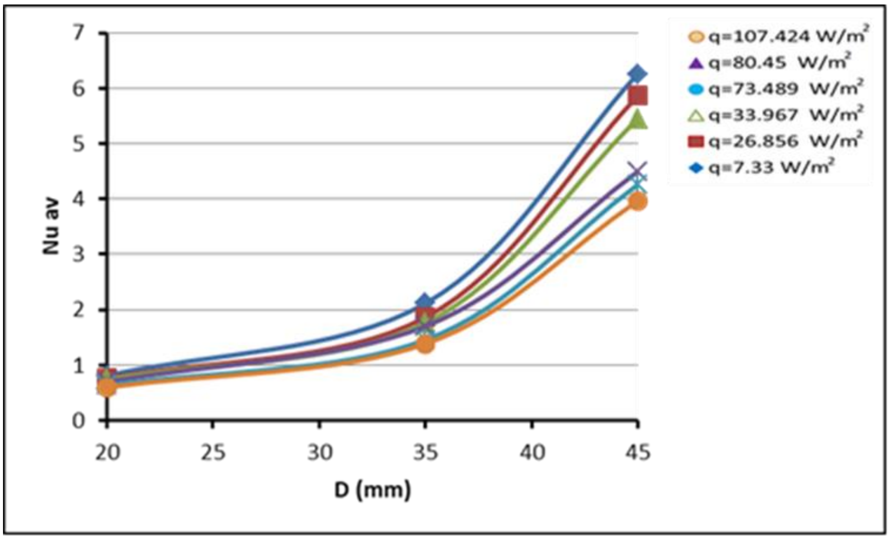

Fig. 10. Nu_{av} concerning the tube diameter

4. Conclusions

i. Both wall and fluid temperatures increased in a manner that the wall temperatures are higher than the fluid temperatures in the tube center.
ii. The surface temperatures decreased as the diameter increased for the same imposed heat flux.

iii. At the tube entrance section, the values of the LNu are almost close together, and after the tube entrance section, the values of the local Nusselt number decreased slightly and reached its minimum value at the tube exit section.
iv. The LNu increased as the Re, and HF increased for the same tube diameter.
v. The average Nu increased as the tube diameter increased and the variation between then is nonlinear.

Acknowledgement
The authors would like to thank Tikrit University and the Northern Technical University for providing laboratory facilities.

References

[1] Hartnett, J. P. *Single phase channel flow forced convection heat transfer*. No. DOE/ER/13311-T1. Univ. of Illinois, Energy Resources Center, Chicago, IL (United States), 1999.
[2] Shah, R. K_, and M. S. Bhatti. "Laminar convective heat transfer in ducts." *Handbook of single-phase convective heat transfer* 3 (1987).
[3] R. K. Shah and A. L. London. "Laminar Flow Forced Convection in Ducts." *Advances in HEAT TRANSFER* 5 (1978): 78-152.
[4] Michelsen, M. L., and John Villadsen. "The Graetz problem with axial heat conduction." *International Journal of Heat and Mass Transfer* 17, no. 11 (1974): 1391-1402.
[5] J. W. Ou and K. C. Cheng. "Viscous Dissipation Effects on Thermal Entrance HT in Laminar and Turbulent Pipe Flows with Uniform Wall Temperature." *ASME* 74 (1974): HT-50.
[6] Arici, M. E. "Analysis of the conjugate effect of wall and flow parameters on pipe flow heat transfer." *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science* 215, no. 3 (2001): 307-313.
[7] Tyagi, V. P. "Laminar forced convection of a dissipative fluid in a channel." *Journal of Heat Transfer* 88, no. 2 (1966): 161-169.
[8] L. N. Tao. "On Some Laminar Forced Convection Problems." *Journal of Heat Transfer* 83, no. 4 (1961): 466-472.
[9] Al-Doori, W. H. A. R. "Enhancement of natural convection heat transfer from the rectangular fins by circular perforations." *International journal of automotive and mechanical engineering* 4 (2011): 428-436.
[10] Reynolds, W. C. "Heat transfer to fully developed laminar flow in a circular tube with arbitrary circumferential heat flux." *Journal of Heat Transfer* 82 no. 2 (1960): 108-112.
[11] Al Doori, Wadhah H. "Numerical estimation of pressure drop and heat transfer characteristics in annular-finned channel heat exchangers with different channel configurations." *Heat Transfer—Asian Research* 48, no. 4 (2019): 1280-1291.
[12] E. M. Sparrow and S. V. Patankar. "Relationships Among Boundary Conditions and Nusselt Numbers for Thermally Developed Duct Flows." *Journal of Heat Transfer* 99, No. 3 (1977): 483-485.
[13] Al Doori, Wadhah Hussein Abdulrazzaq. "Effect of using various longitudinal fin number in annular finned channel heat exchangers on Heat flow characteristics." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 53, no. 1 (2019): 1-10.
[14] Quaresma, J. N. N., and R. M. Cotta. "Exact solutions for thermally developing tube flow with variable wall heat flux." *International communications in heat and mass transfer* 21, no. 5 (1994): 729-742.
[15] Barletta, A., and E. Zanchini. "Thermal entrance region for laminar forced convection in a circular tube with a power law wall heat flux." *International journal of heat and mass transfer* 39, no. 6 (1996): 1265-1272.
[16] Al-Taha, Wadhah Hussein Abdulrazzaq. "Effect of the circular perforations on the heat transfer enhancement by the forced convection from the rectangular fins." *DIYALA JOURNAL OF ENGINEERING SCIENCES* 11, no. 3 (2018): 62-70.
[17] Mohammed, Hussein A., and Yasin K. Salman. "Experimental investigation of mixed convection heat transfer for thermally developing flow in a horizontal circular cylinder." *Applied thermal engineering* 27, no. 8-9 (2007): 1522-1533.
[18] G. Y. Ny, N. H. Barom, S. M. Noraziman, and S.T. Yeow. "Numerical study on turbulent-forced convective heat transfer of Ag/Heg water nanofluid in pipe." *Journal of Advanced Research in Materials Science* 22, no. 1 (2016): 11-27.

[19] Ibrahim, Thamir K., Ahmed T. Al-Sammarraie, Wadhah H. Al-Taha, Mohammad Reza Salimpour, Manar Al-Jethelah, Ahmed N. Abdalla, and Hai Tao. "Experimental and numerical investigation of heat transfer augmentation in heat sinks using perforation technique." *Applied Thermal Engineering* 160 (2019): 113974.
[20] Holman, J. P. "Heat transfer, 10th editi. ed." *Mc-GrawHill Higher education* (2010).
[21] Al Taha, Wadhah Hussein Abdul Razzaq. "Analysis, Performance and Optimization of Perforated and Non-Perforated Fins under Forced Convection." PhD diss., Sudan University of Science and Technology, 2018.
[22] Abtan, Nageeb Salman, Ataalah Hussain Jassim, and Mustafa Shakir Marmoos. "Study on the Effects of Rotational and Transverse Speed on Temperature Distribution through Friction Stir Welding of AA2024-T3 Aluminium Alloy." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 53, no. 2 (2019): 234-248.