Comparison of the Thermohydraulic Efficiency of a Rectangular Fin Tube Heat Exchanger with or without Modified Rectangular Winglet Vortex Generator

Sumit Khatri[1], Naveen Hooda[1], Narinder Kaushik[2], Ravinder Kundu[1]

[1] Mechanical Engineering, UIET, MDU Rohtak, Haryana, India
[2]Department of Mechanical and Automation Engineering, MAIT, Delhi, India
Email id: sumitkhatri007@gmail.com

Abstract: Performance Evaluation Criteria (PEC)/ Thermo hydraulic efficiency of a Heat Exchanger may be increased using a Modified Rectangular Winglet Vortex Generator (MRWVG). This Modified rectangular Winglet Vortex Generator is fixed on a rectangular type fin plate and this plate is used to find the Performance Evaluation Criteria with the help of a wind tunnel. The wind tunnel test rig is used for calculating the experimental data with and without a rectangular winglet vortex generator. In this test section first, take a reading on the rectangular plate without the modified rectangular winglet Vortex Generator, and then after fixing the modified rectangular winglet and all experimental repeats same with the modified rectangular winglet Vortex Generator to find PEC. The maximum PEC is calculated experimentally for both with or without using the modified rectangular winglet and after that, a comparison should be done and find the maximum Performance Evaluation Criteria.
Keywords - Heat transfer performance, Modified rectangular winglet, Wind tunnel, Heat Exchanger, Performance Evaluation Criteria.

1.INTRODUCTION

The augmentation of the heat transfer performance of a fin tube heat exchanger depends on various factors. One of the passive methods for increasing the heat transfer performance is using the winglet. Although the rectangular type winglet gives the maximum output. Further, the rectangular winglet is also modified with a hole so this type of modified rectangular winglet is used in this research for augmentation of heat transfer performance. In this research paper, the rate of heat transfer is enhanced by using the modified rectangular winglet. A rectangular plate is considered for calculating the heat transfer performance with the help of a modified winglet while the heat transfer performance is compared without the modified winglet vortex generator. As mathematical calculations, the Colburn factor, Friction Factor, and Performance Evaluation Criterion (PEC) were found out with respect to the Reynolds number. The experiment was performed first without a winglet and then performed with a winglet to find the appropriate PEC. A comparison of heat transfer performance is to be done with or without the winglet to find appropriate results. Modi et al. [1] conducted the experimental research which effected of a rectangular type winglet and redesigned the also a heat exchanger. Min, C, et al. [2] produced the cutting corners of a rectangular-type winglet with Experimental studies and comparisons with the original rectangular LVG. Sinha, A, et al. [3] examined the Air flows via vortex generators of fin-tube heat exchangers. Naik, et al. [4] find the performance of curving winglets installed on a rectangular type channel. Tang, L. H., et al. [5] increased the heat transmission in a rectangular channel, and a new winglet longitudinal vortex generator (LVG) structure was proposed. Liu, Liu, et al. [6] examined the heat transfer characteristics flow of a circular-type tube equipped with a rectangular-type winglet.

Modi, A.J., et al. [7] calculate the rate of the thermo-hydraulic with rectangular type winglet. Modi et al. [8] investigate a thermo-fluid and analysis of the fin tube compact type heat exchangers. Gholami et al. [9] observed a new type Wavy-up as well as wavy-down rectangular winglets. Gupta, S., et al. [10] worked on the longitudinal vortex generators and improved the heat transmission performance. Li, Y., Qian, Z., & Wang, Q. [11] enhanced the performance of a heat transfer by expanding the turbulent region and generating multiple vortices from the inserted tube. Qian, Z., Wang, Q., & Cheng, J. [12] showed that the resistance qualities and thermal performance of the rectangle-winglet vortex generator had improved, while the weak zone had been strengthened. Using a different k-ε-enhance mathematics calculation model, they investigated how different Re numbers affect the thermal performance of rectangle-winglet. Syarifudin et al. [13] investigate the use of a concave rectangular winglet vortex generator to improve the efficiency of a heat exchanger. He, Y. L., et al. [14] examined the efficiency of various types of heat exchangers and gave optimum heat exchangers. Kashyap et al. [15] improved the heat transmission use of the wetted surface area. Ali, R. K. [16] guides the flow toward the center of the stagnation zone and rectangular winglets
with a common inflow orientation. Habchi, C., et al. [17] employed to increase the coefficients of heat transfer in heat exchangers. Varun Kumar et al. [18,19] also researched a modified/ designed delta winglet on a rectangular-type fin tube and measured PEC with the help of a wind tunnel test apparatus. So here also in this research, a modified rectangular type winglet is used to find more efficient.

2.RESEARCH GAPS

The topic is significant for the future scope as it can make drastic changes in this area of heat transmission. Based on the literature discussed the main focus of this research will be on finding the PEC of a rectangular-type plate with or without using a Modified rectangular Winglet. As the past study shows the Performance Evaluation Criteria (PEC) are calculated by various researchers with or without various types of winglets on a rectangular plate. However, in this research paper, the Performance Evaluation Criteria (PEC) are calculated with a modified rectangular winglet vortex generator. A hole is to be made on the rectangular winglet for modifying the winglet. So after this modification, the new winglet is also known as a Modified rectangular Winglet Vortex Generator (MRWVG). So this research is based on this Modified rectangular Winglet Vortex Generator (MRWVG).

3. EXPERIMENTAL PROCEDURES

The current studies were conducted to increase the overall performance of the fin tube heat exchanger, with or without a modified rectangular winglet vortex. To do this, winglets as vortex generators have been placed and pierced from the rectangular fin plate surface. The wind tunnel test gear is utilized to do the experimental work. The goal of this study is to use a modified rectangular winglet to maximize thermo hydraulic efficiency/performance evaluation criteria (PEC) in a fin-tube heat exchanger. The investigations are carried out on the wind tunnel test rig's rectangular flat fin plate. PEC is calculated before and after fitted with the modified rectangular winglet to the rectangular type flat fin plate and the results are compared. The apparatus utilized in this study is known as the instrument Wind Tunnel which is mostly used to measure air effects on any object as shown in figure 3.1.

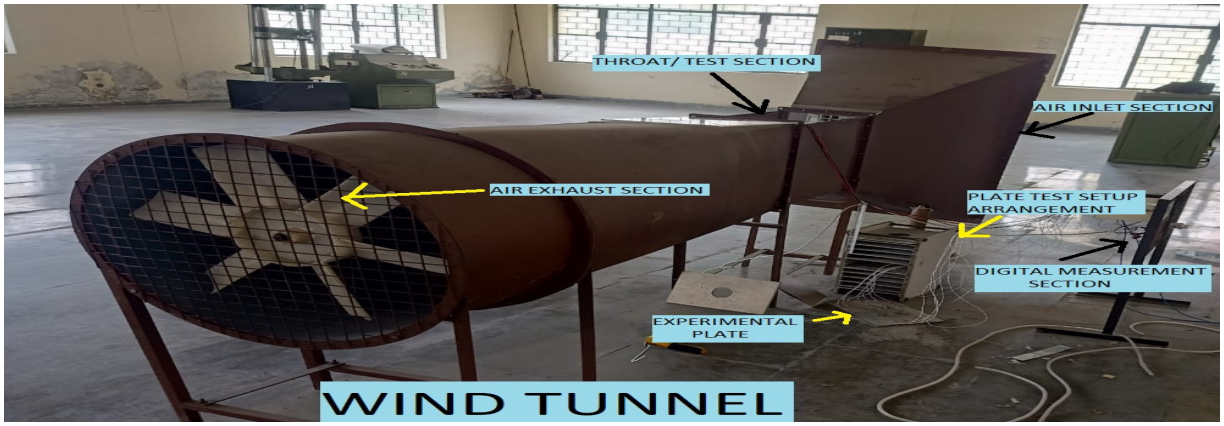

Figure 3.1: Wind Tunnel Experiment

The experiment setup possesses three types.

1. Air inlet section
2. Throat
3. Air outlet section

All the experiments are carried out on the experimental plate. We are made up of rectangular type plates. The plate's dimensions are 300mm by 200mm by 4mm. Here 13 plates are used for performing the above research work. 12 plates are supporting plate that gives the smooth airflow to the experiment plate. The experiment plate is fitted at mid section of all plates.

3.1 Plate Test Setup

The arrangement of the plate is to be done so that the experiment plate is fitted in mid of all the plates. For the plate setup arrangement total of 13 plates are taken in which at midsection experiment plate is fitted. The other plates are used for making the smooth flow of air in wind tunnel. Whereas the size of the plate is taken as 43 cm * 22.4 cm * 30.2 cm. Figure 3.2 shows the plate set up arrangement.

Figure 3.2 Experimental Plate Test Set Up

3.2 Modified Rectangular Winglet Vortex Generator Dimensions

For this experiment, we use the Modified Rectangular-type winglet. The Modified rectangular winglet consists of a rectangular shape with a hole. It consists of 18 mm length and 12 mm breadth and is also modified with a 4mm diameter circle in the mid portion of this rectangular

fin. This Modified Rectangular-type winglet is modified based on various experimental setup readings after calculating the results and compared with other types of winglets. So the best results output is selected for this research work. Figure 3.3 shows the modified rectangular-type winglet vortex generator with dimensions.

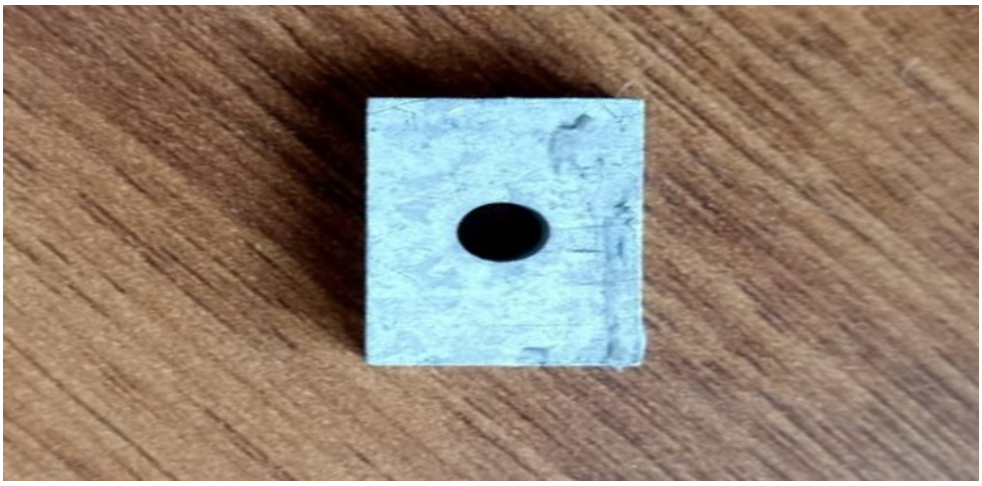

Figure 3.3: Modified Rectangular Winglet

3.3 Experimental Work

A simple rectangular-type fin plate without any winglet is used for optimizing the effects of the rate of heat transfer. The rate of heat transfer depends on the performance evaluation criteria also known as PEC. For finding the PEC, first we required the colburn's factor and friction factor; because the PEC is the ratio of the colburn's factor and friction factor. Before finding Colburn's factor and friction factor the temperature difference and pressure were found with the help of experimental work on the instrument's wind tunnel. Further, the mathematical calculation used for calculating the colburn's factor and friction factor. So in this way after finding the PEC without the winglet, we fit the modified/ designed winglet vortex generator fix it on the experimental plate repeat the same experiment procedure, and calculate again the value of PEC.

4. EXPERIMENTAL RESULTS

4.1 Experimental Results Without Winglet

Heat transfer characteristic is measured using Colburn's factor. The figures below demonstrate the findings without the use of winglets. The Colburn factor is displayed alongside the Reynolds number in Figure 4.1. The Colburn factor's value ranges from 0.000779 to 0.004146. The friction factor is displayed beside the Reynolds number in Figure 4.2. The friction factor has a value between 0.010501 and 0.507666. The pressure decrease is shown by the friction factor. The Reynolds number is displayed with the Performance Evaluation Criteria (PEC) in Figure 4.3. The PEC's value falls between 0.008167 and 0.074202. The thermal-hydraulic efficiency is shown by the PEC. A comparison between the Friction factor, the Colburn factor, and the Performance evaluation criteria are all displayed in a single graphic with Reynolds number in

Figure 4.4. In contrast, the Reynolds Number ranges from 2950.27 to 23602.16. From 4.1 to 4.4, all of the readings displayed in the figure are computed without the use of a winglet. To calculate the final findings, take ten readings at each air velocity without using an MDWVG then, find the average of these readings and calculate to get error-free results.

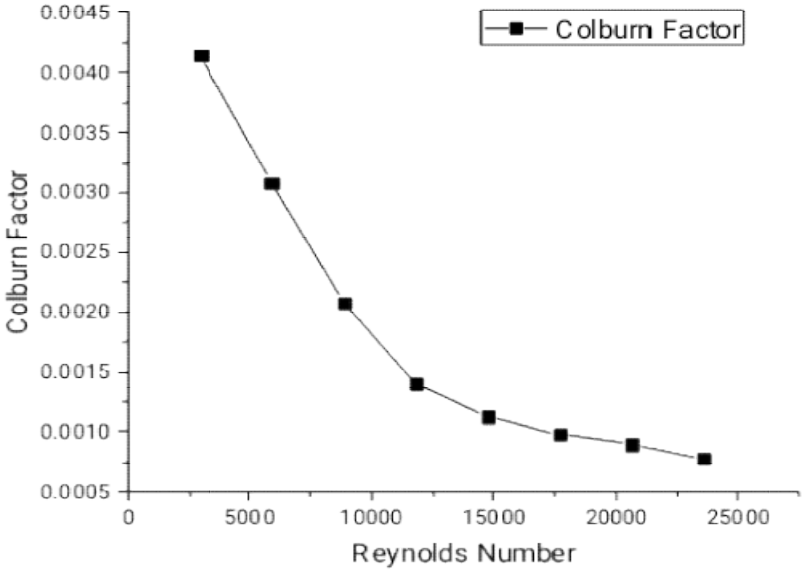

Figure 4.1: Colburn's Factor With Reynolds Number

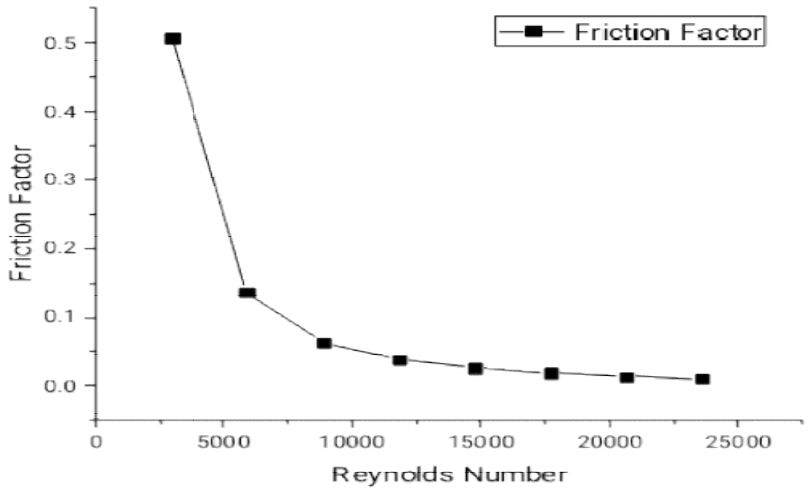

Figure 4.2: Friction's Factors With Reynolds Number

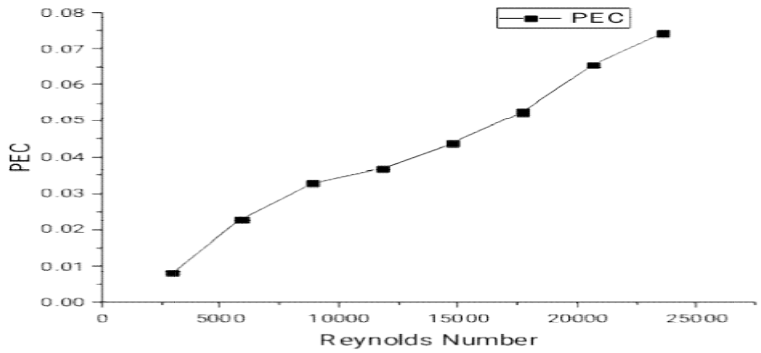

Figure 4.3: Performance Evaluation Criteria (PEC) With Reynolds Number

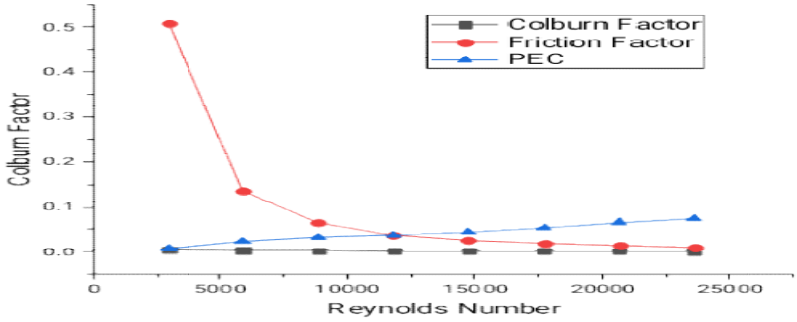

Figure 4.4: Comparison With Reynolds Number

4.2 Experimental Results With Winglet

Figures below with winglets applied display the results. The Colburn factor is displayed alongside the Reynold number in Figure 4.5. The value of the Colburn factor ranges from 0.000639 to 0.001733. The friction factor is displayed with the Reynolds number in Figure 4.6. The friction factor has a value between 0.005139 and 0.021003. The pressure decrease is shown by the friction factor. The Reynolds number is displayed alongside the Performance Evaluation Criteria (PEC) in Figure 4.7. The PEC's value falls between 0.06138 to 0.166764. The thermal-hydraulic efficiency is shown by the PEC. A comparison also with Colburn's factor, friction's factor, and performance evaluation criteria are all displayed in a single graphic with Reynolds number in Figure 4.8. In contrast, the Reynolds Number ranges from 2950.27 to 23602.16. The readings in the figure ranging from 4.5 to 4.8 are all computed with the use of a winglet. To determine the final findings, obtain ten readings at each air velocity using a modified delta winglet vortex generator (winglet); then, find the average of these readings to get error-free results. This computation must also be completed using the MS Excel program Design.

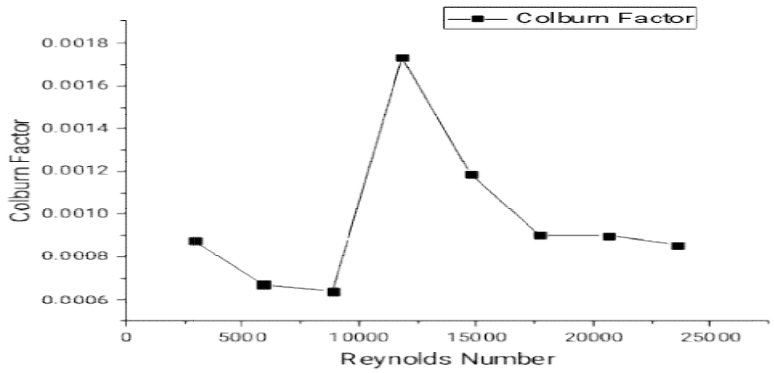

Figure 4.5: Colburn's Factor With Reynolds Number

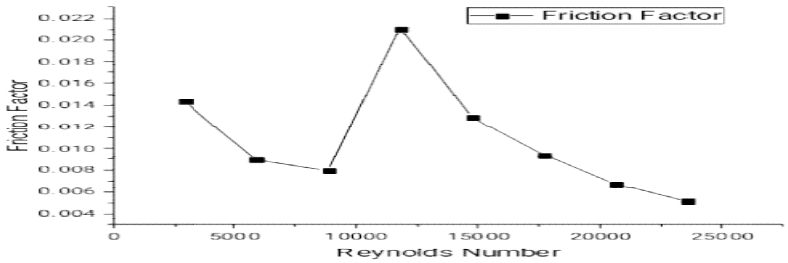

Figure 4.6: Friction's Factor With Reynolds Number

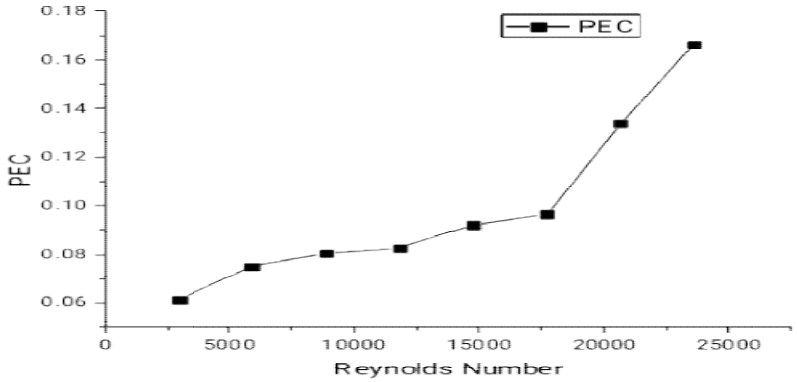

Figure 4.7: PEC With Reynolds Number

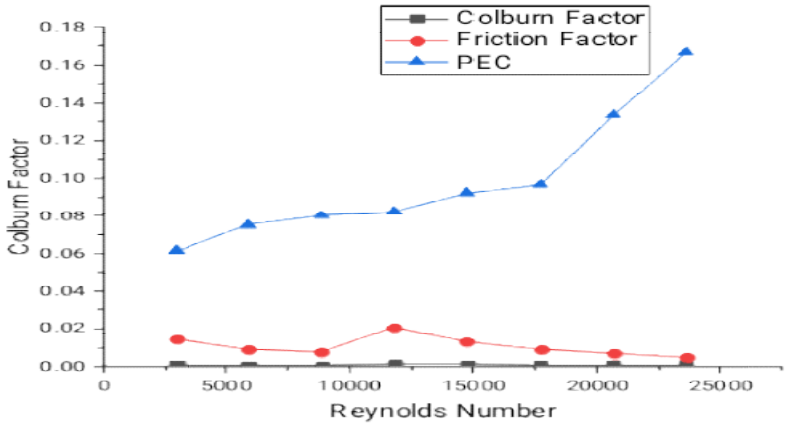

Figure 4.8: Comparison With Reynolds Number

4.3 Comparison Between With And Without Winglet

A comparison of the rectangular-type fin plate with and without using the modified rectangular winglet vortex generator (winglet) can be made using the above table. The results are compared with and without winglets in the figures below. The Colburn factor is displayed beside the Reynolds number in Figure 4.9. The friction factor is displayed beside Reynold's number in Figure 4.10. The Reynold's number is displayed alongside the Performance Evaluation Criteria (PEC) in Figure 4.11. Winglet is used to calculate all of the readings from 4.5 to 4.8 that are displayed in the figure. Figures 4.1 to 4.4 show the reading on the surface plate without a winglet. Further, a comparison is also shown in Figures 4.9 to 4.12 with or without using the winglet.

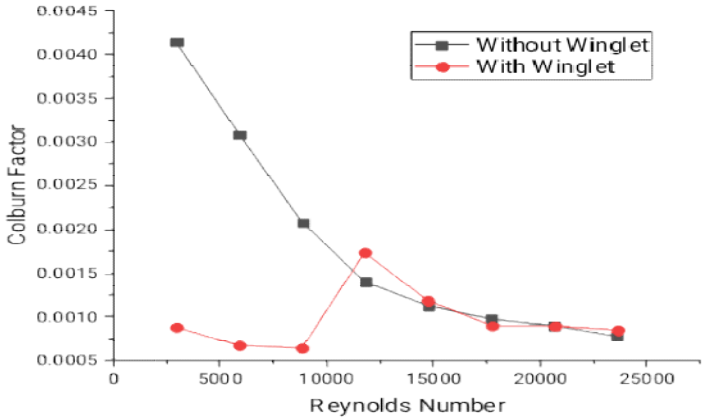

Figure 4.9: Colburn's Factor With Reynolds Number

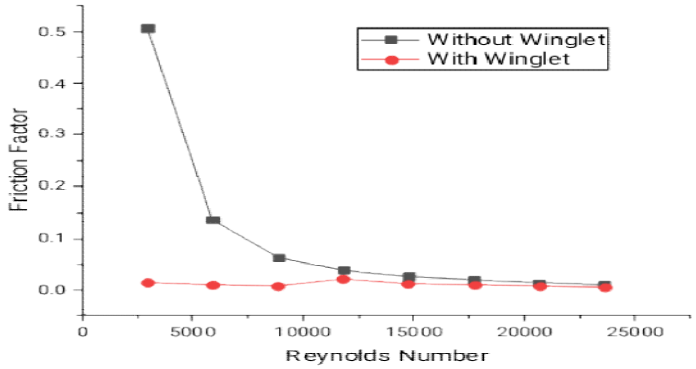

Figure 4.10: Friction's Factor With Reynolds Number

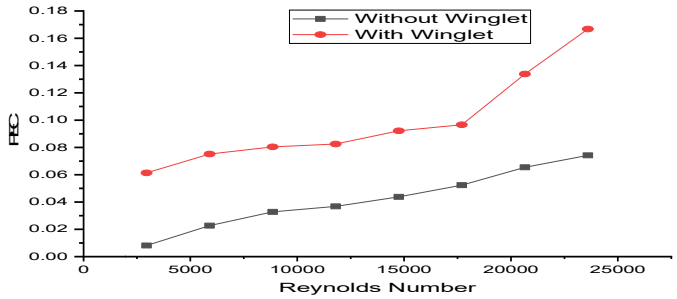

Figure 4.11: PEC With Reynolds Number

5.ERROR PERCENTAGE

When the experiment is performed again on a wind tunnel with and without the modified rectangular winglet type vortex generator then after find the final PEC increment with given formulae. As we know with PEC graph reading the PEC is obtain with winglet is 16.67 and PEC is without winglet is obtained 7.42. So further the increment of PEC is calculated in percentage for percentage.

We know that the PEC Increament (%) $=\frac{(PEC\ with\ winglet - PE\quad without\ \boldsymbol{winglet})\times 100}{PEC\ with\ winglet}$

$$\text{PEC Increament (\%)} = \frac{(16.67-7.42)\times 100}{16.67}$$

$$\text{PEC Increament (\%)} = 55.48\%$$

6.CONCLUSION

The Thermo hydraulic performance for a modified rectangular fin plate for a channel flow is increased with a modified rectangular winglet-type vortex generator. When the experiment is performed again on a wind tunnel with and without the modified rectangular winglet type vortex generator then find the final PEC increment with given formulae. As we know from the PEC graph reading the PEC obtained with a winglet is 16.67 and the PEC without a winglet is obtained 7.42. So the PEC increase is 55.48%.

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