EVALUATION OF HEAT TRANSFER PERFORMANCE BY USING NON-CONVENTIONAL SHAPES OF RIBS

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Abstract : This paper presents an experimental investigation carried out for heat transfer enhancement with the help of two shapes of ribs for heat exchanger application. The aim of project is to examine effect of rib & groove arrangement on forced convection setup. The experiment is performed on flat plate fitted with reverse boot shaped rib and funnel shaped rib with rectangular grooves, having width 'w', pitch 'p' and rib height 'e'. Numerically by taking pitch ratios of 6,8, and 10 simulation was done, but it was found that pitch ratio of 6 gives the best performance. The pitch ratio of 6 was kept same for funnel shape as well as for reverse boot shaped rib. Also, pressure drop was measured. A uniform heat flux of 800W /m^2 using a flat type heater. With the help of 6 thermocouples temperature was measured at 6 different places on ribs. The Reynolds no. is varied in range of 20000 to 30000 at constant heat flux. Numerically, Nusselt no. was enhanced by 16% for funnel shaped rib and by 6% for reverse boot shaped rib when compared to flat plate. Also, in case of friction factor it was enhanced by 49% for funnel shaped rib and by 9% for reverse shaped rib when compared to flat plate. By experiment, it was found that Nusselt No. was enhanced by 11.8% for funnel shaped rib and by 5% for reverse boot shaped rib when compared to flat plate. Also, in case of friction factor it was enhanced 35.7% for funnel shaped rib and by 7% for reverse boot shaped rib when compared to flat plate. Thus, the results show that the funnel shaped rib with rectangular groove gives best performance and has significant enhancement as compared with flat plate.

***IndexTerms* - Rib Shape, Rectangular Grooves, Heat Transfer Enhancement**

I. INTRODUCTION

The study of improved heat transfer performance is referred to as heat transfer augmentation, enhancement. The common thermo hydraulic goals are to reduce the size of a heat exchanger required for a specified heat duty and to upgrade the capacity of an existing heat exchanger, also to reduce the pumping power. Heat transfer enhancement techniques are commonly used in areas such as process industries heating and cooling in evaporators, thermal power plants, air conditioning equipment, refrigerators and radiators for space vehicles, automobiles etc. Ribs are generally installed on cooling channel for internal cooling of gas turbine blades. The heat transfer from surface may in general be enhanced increasing the heat transfer coefficient between a surface and its surrounding or by increasing heat transfer area of the surface or by both. This heat transfer augmentation technique is applied to many industrial applications such as shell and tube type heat exchanger, electronic cooling devices, thermal regenerators, and internal cooling system of gas turbine. The flow disturbance caused by the rib arrays greatly increases the production of turbulent kinetic energy, which enhances turbulent heat transfer in the channel. Among the many geometric parameters related to the rib arrangement and configuration, the shape of the rib cross section affects the formation of a separation bubble behind the rib and the amount of turbulent kinetic energy production; thus, the rib shape is a major factor that determines the heat transfer performance of the rib. The heat transfer rate is increased by using different shape of ribs. The rib geometry, pitch ratio, rib arrangement, spacing angle of attack, rib size, rib groove arrangement have significant impact on the performance of heat exchanger. This paper deals with non-conventional shape of ribs which are funnel shape and reverse boot shape rib with rectangular grooves.

Fig. 1 Reverse Boot Shaped Rib

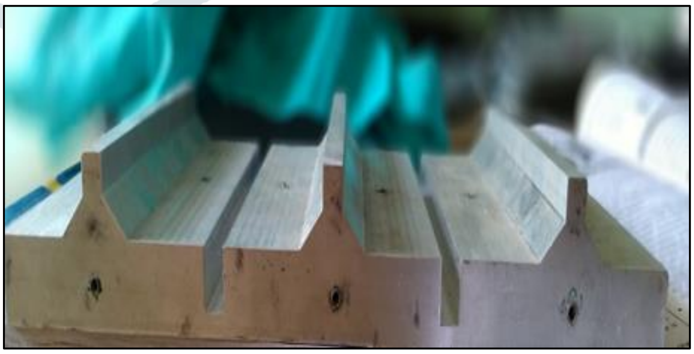

Fig. 2 Funnel Shaped Rib

II. CFD SIMULATION:

. Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to solve and analyse problems that involve fluid flows. In our simulation we have used the ANSYS WORKBENCH 19 as our software for simulation. We have studied this software with the help of YOUTUBE and we have done the simulation by taking proper dimensions and measurement as per our model. CFD is used for getting results before the experiment in order to save the cost and time. With the help of CFD we get accurate results and so it becomes easy for further work in that setup or process.

We have designed new shapes of non-conventional ribs. By studying various shapes of ribs, we have designed 2 new shapes which are reverse boot shaped and funnel shaped rib and to that we have added a rectangular groove for more enhancement of heat transfer. By considering the rib pitch ratio, aspect ratio, rib height, groove height and measurement of duct we have designed our ribs.

The geometrical parameters of our ribs are as follows:

1) Duct Length= 45.4cm
2) Duct Height= 21cm
3) Rib Length= 21.4cm
4) Rib Height= 1.57cm
5) Groove Height= 1.25cm
6) Groove Width= 0.75cm

With the help of these above dimensions we have designed 2 ribs of different shapes and also a flat plate is designed. Following will show the geometries of funnel shaped rib, reverse shaped rib and flat plate in ANSYS WORKBENCH.

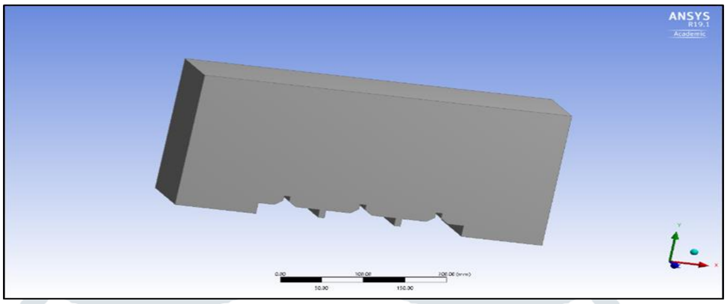

Fig.3.: Funnel Shaped Rib with Rectangular Groove

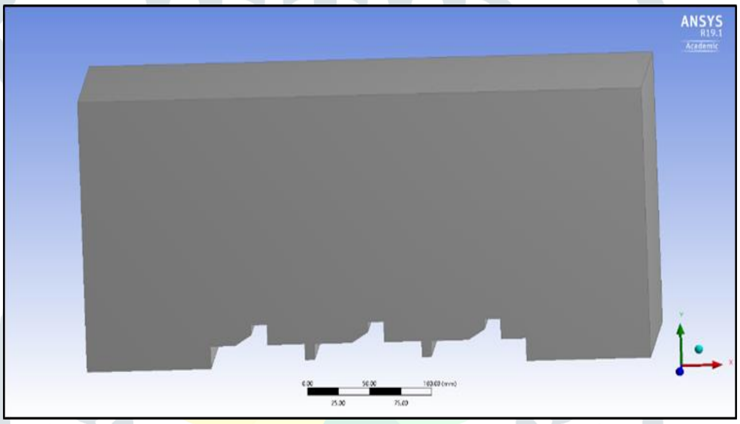

Fig. 4: Reverse Boot Shaped Rib with Rectangular groove

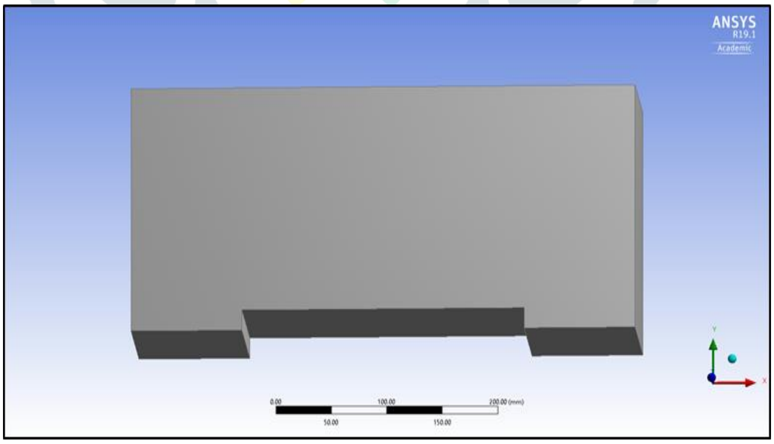

Fig. 5: Geometry of Flat Plate

The first step of analysis is meshing of the parts. Meshing of our geometry is done by tetrahedron cells. We made the geometry more accurate with the help of meshing for further solution. In our next step we selected energy equation and because the flow is turbulent, we used the best model i.e. k-epsilon standard model. K-epsilon model is a turbulent model, it is used over laminar as it gives the best results possible. After that in boundary conditions for the heater plate the heat flux, we gave was 800W/m^2.

Inlet velocities were varied from 2.5m/s to 1.8m/s. We obtained solution graphs for all 4 velocities in simulation. The results we obtained were positive and as expected the heat transfer coefficient for flat plate was less that the reverse boot shaped rib and funnel shaped rib.

III. EXPERIMENTAL SETUP:

The setup for our project is "Forced convection setup with rectangular duct", which is available in lab in our college. The components of the setup are motor, blower, dimmerstat, ammeter, voltmeter, speed controller. The following will show the experimental setup:

Fig. 6 Actual Experimental Setup

The above fig. shows the actual experimental setup of forced convection. The experiment was conducted with variable flow rate of air at constant power supply to the heater. The thermocouple readings and velocity of air flow have been taken at steady state, and the heat transfer coefficient was calculated both theoretically and experimentally.

The ribs are first connected to the heater plate and then this assembly is placed in the duct and the heater plate is connected to the electric supply. Then the blower is turned on and the desired velocity is obtained in the duct with the help of a flow control valve. The temperature of the ribs is measured by using temperature indicator and the temperature is measured at 6 different points by using the J type thermocouple. The heat generated by the rib is about 300W.

Fig. 7. Rib Arrangement inside channel

IV. RESULTS AND DISCUSSIONS

The present work carried out is for enhancement of heat transfer coefficient. In this we have experimentally and numerically validated the results and we have got satisfactory results. The analysis was carried out on reverse boot shaped rib with rectangular grooves and funnel shaped rib with rectangular grooves. Reynolds No. was varied between 20,000 and 30,000. First, we did simulation and then experiment was carried out. Numerically by taking pitch ratios of 6,8, and 10 simulation was done, but it was found that pitch ratio of 6 gives the best performance. The pitch ratio of 6 was kept same for funnel shape as well as for reverse boot shaped rib. Also, pressure drop was measured**.** Thermal enhancement factor was also obtained with the help of Nusselt No. and friction factor.

Friction factor is evaluated by: **$2\Delta P d_h / \rho l v^2$**

Following graphs are of funnel shaped rib with rectangular grooves representing their comparison between experimental and numerical simulation:

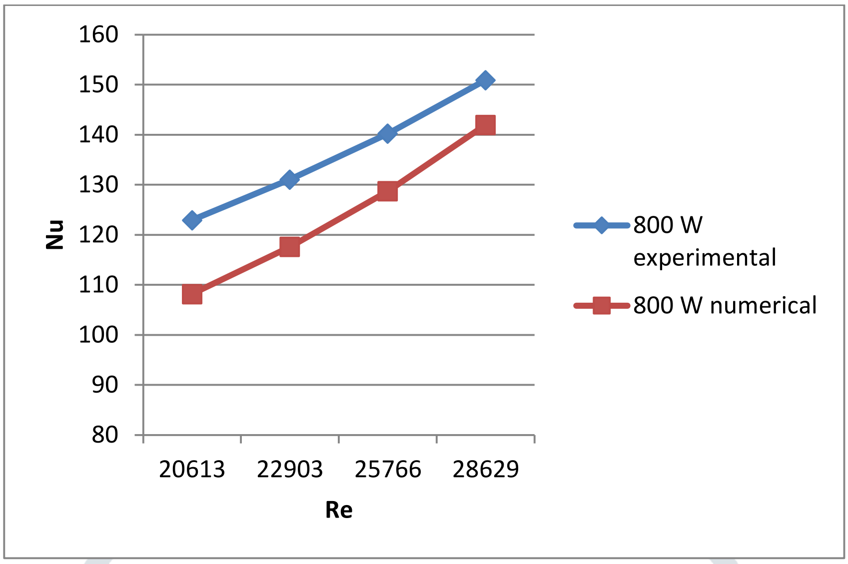

Fig 8: Nu Vs Re (Comparison)

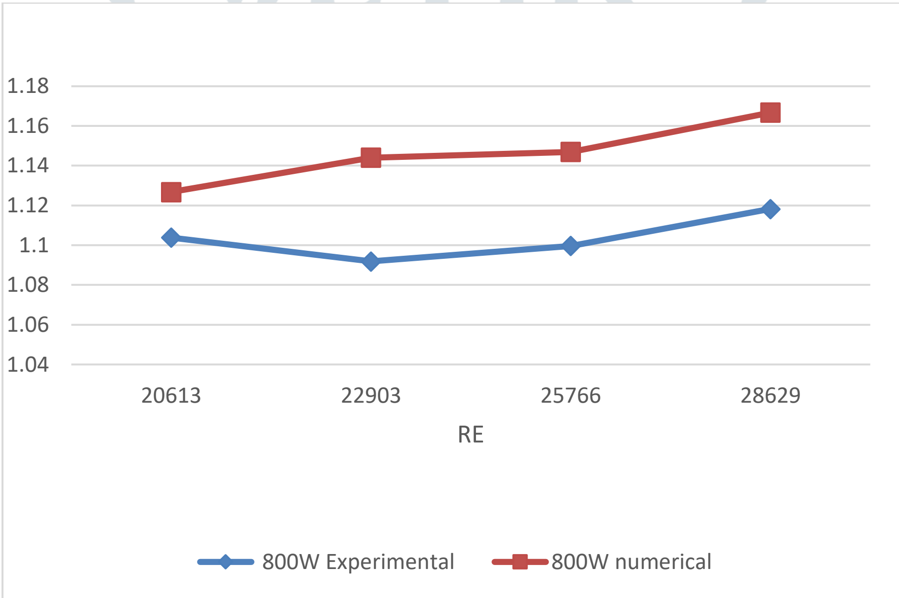

Fig. 9 Nu/Nuo Vs Re (comparison)

Now, for Reverse boot shaped rib with rectangular grooves, following graphs will represent their comparison between experimental and numerical simulation:

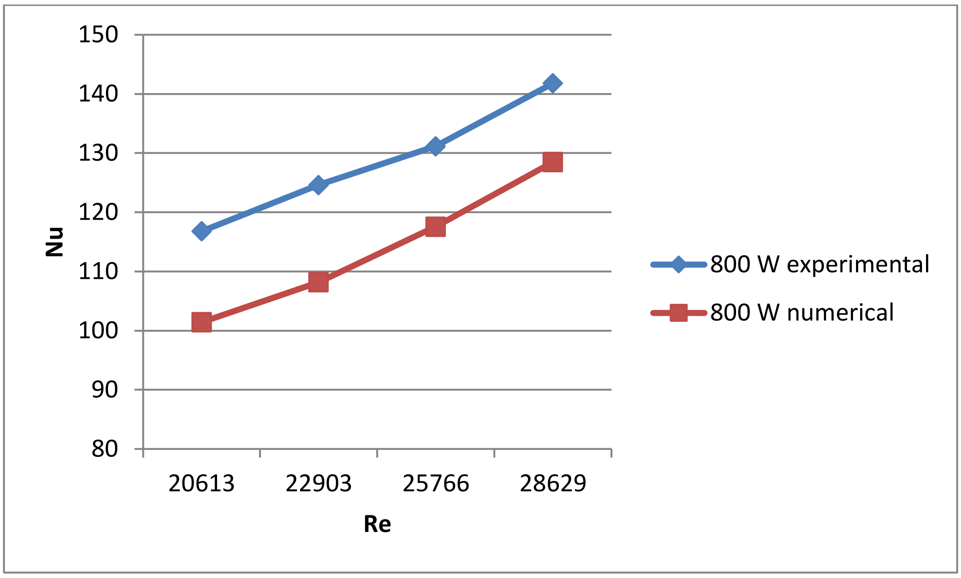

Fig. 10 Nu Vs Re (comparison)

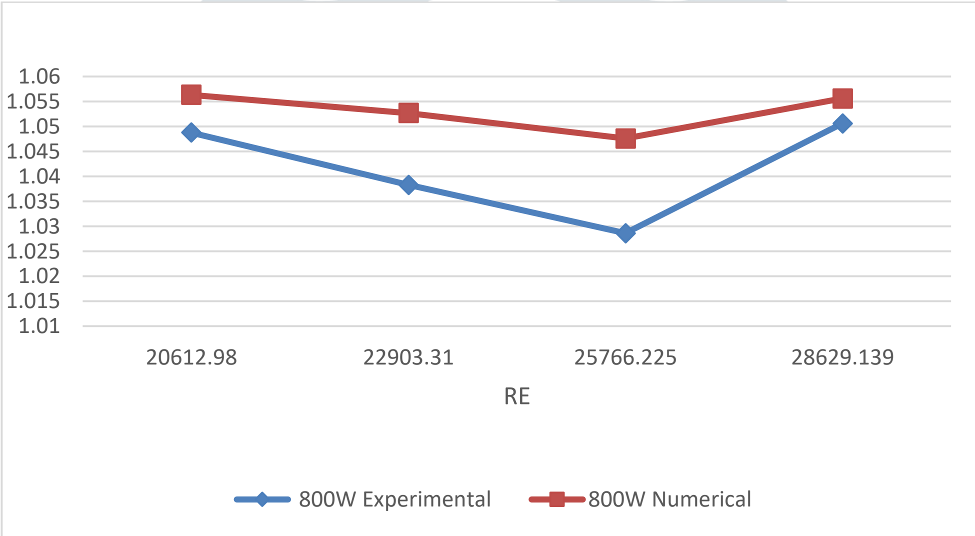

Fig. 11 Nu/Nuo Vs Re (comparison)

Following graphs will show comparison between all three shapes i.e. flat plate, funnel shape rib, reverse boot shaped rib. These graphs will show for Nu Vs Re and Nu/Nuo Vs Re.

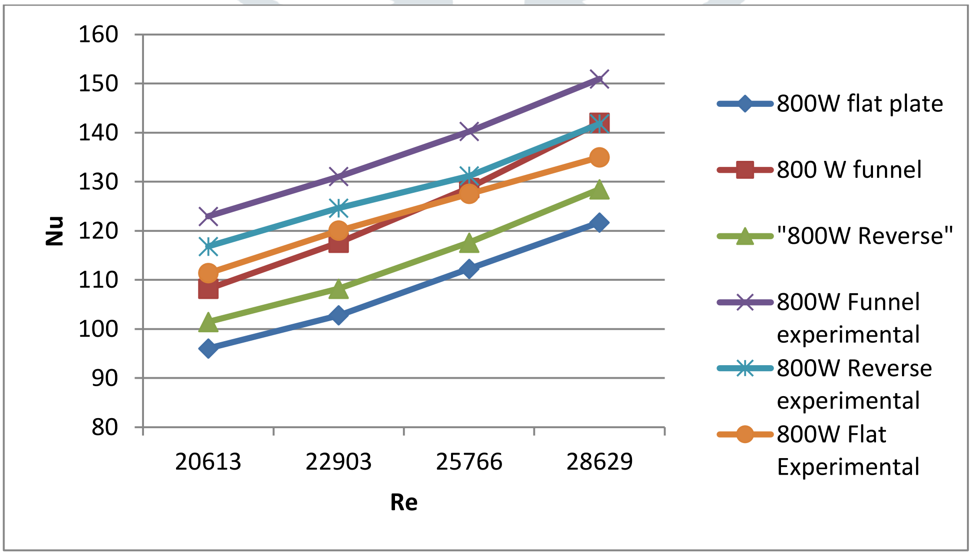

Fig. 12 Nu Vs Re(comparison)

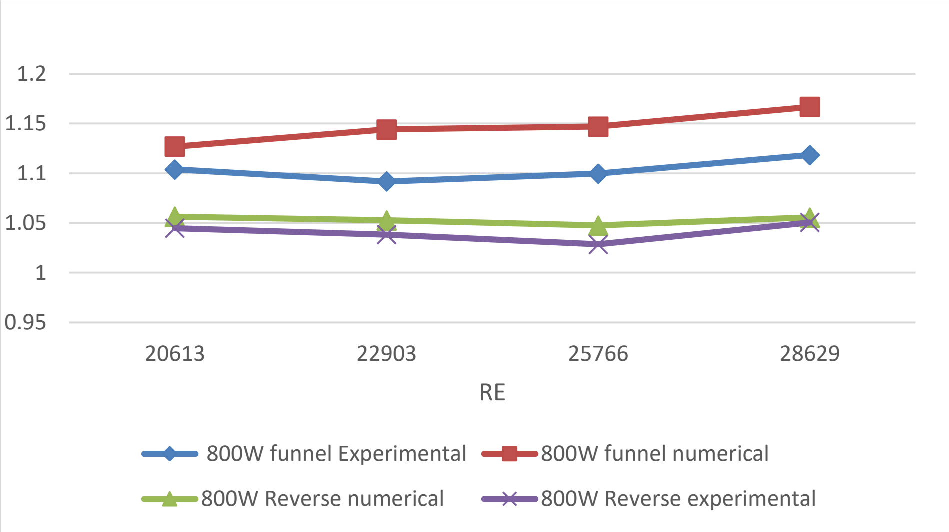

Fig. 13 Nu/Nuo Vs Re (comparison)

Also, thermal enhancement factor is calculated and below the graphs are plotted for same:

TEF: **$(Nu/Nu_{flat})/F/F_{Flat})^{0.33333}$**

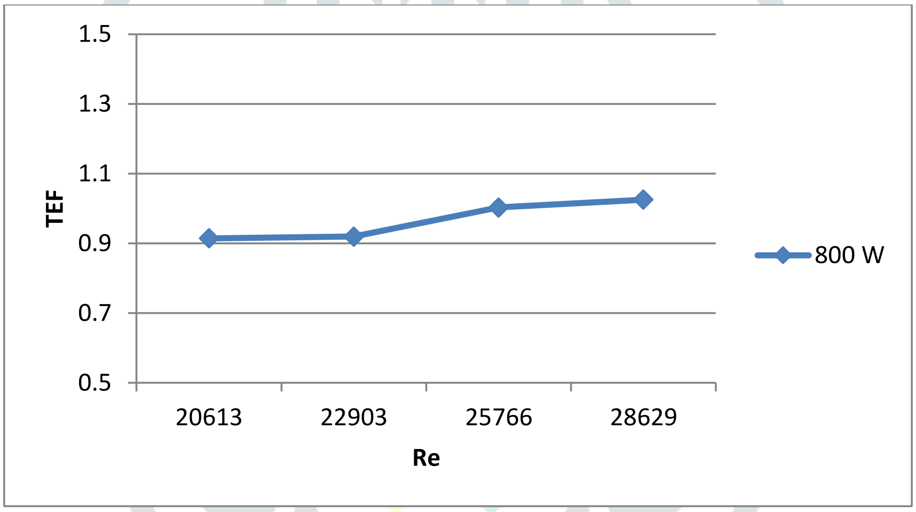

Fig. 14 TEF Vs Re (Reverse Boot Shaped Rib with rectangular grooves)

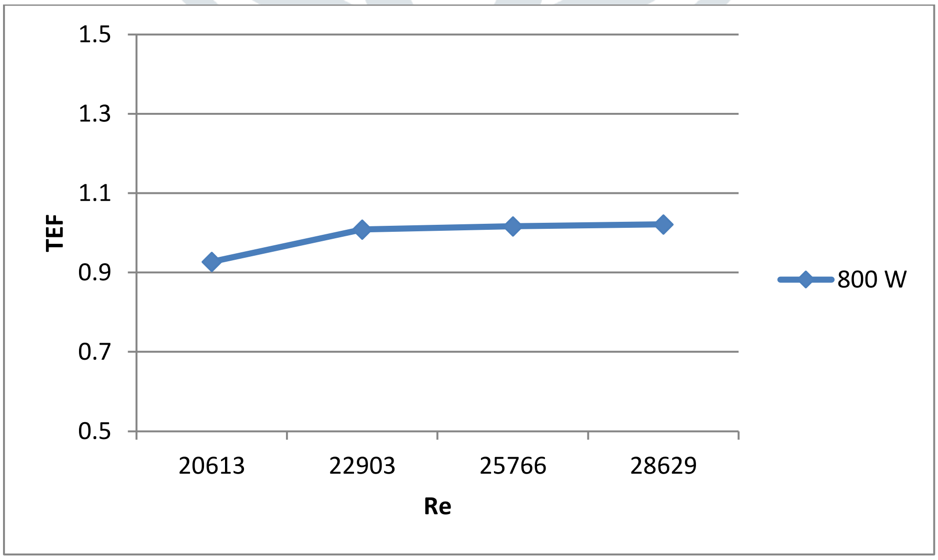

Fig. 15 TEF Vs Re (Funnel Shaped Rib with rectangular grooves)

Numerically, Nusselt no. was enhanced by 16% for funnel shaped rib and by 6% for reverse boot shaped rib when compared to flat plate. Also, in case of friction factor it was enhanced by 49% for funnel shaped rib and by 9% for reverse shaped rib when compared to flat plate. By experiment, it was found that Nusselt No. was enhanced by 11.8% for funnel shaped rib and by 5% for reverse boot shaped rib when compared to flat plate. Also, in case of friction factor it was enhanced 35.7% for funnel shaped rib and by 7% for reverse boot shaped rib when compared to flat plate. For numerical analysis, for highest Reynolds No. i.e. 28,629 the heat transfer coefficient obtained was 21W/m^2K for funnel shaped rib while for reverse shaped rib it was 19 W/m^2K. While for flat plate it was 17.7W/m^2K. Therefore, the heat transfer coefficient was enhanced by 18.8% in case of funnel shaped rib with rectangular grooves, while in case of reverse boot shaped rib with rectangular grooves it was only enhanced by 7.08% when compared to flat plate. Thus, it proved that funnel shaped rib with rectangular grooves gives best performance and has significant enhancement as compared with flat plate.

V. CONCLUSION:

Experimental and numerical study has been carried out to investigate airflow friction and heat transfer characteristics in a channel fitted with two types of ribs. Reynolds No was varied between 20000 and 30000. The pressure drop was seen in funnel shaped rib than the reverse boot shaped rib. The pitch ratio of 6 shows considerable heat transfer augmentations. Grooves also play major role in heat transfer enhancement. As the thermal enhancement factor was greater than 1 for funnel shaped rib it proved that it was effective than the reverse boot shaped rib with rectangular grooves. For reverse boot shaped rib with rectangular grooves, it was observed that it counted the least friction factor.

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