Numerical Simulation on Different Wavy Grooves Solar Absorber Plate for Enhancement of Heat Transfer

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Abstract

An enhancement in Nusselt number and friction factor is presented and discussed with reference to base paper results. The effect of different types of grooves and Reynolds number on enhancement of Nusselt number and friction factor is also presented.
When the desired heat transfer was carried with smooth and rough ribs with different grooves absorber plates, it was found that the maximum increment in the value of Nusselt number has been observed at sinusoidal wavy grooves absorber plate, however the lowest observed value of friction factor corresponding to sinusoidal wavy grooves absorber plate. Providing the sinusoidal wavy grooves, V shaped, U shaped and Transverse shaped grooves results in considerable enhancement in Nusselt number. Average enhancement in Nusselt number for sinusoidal wavy grooves absorber plate is found to be 471% higher over smooth absorber plate while friction factor of sinusoidal grooves gets decreased by 54.6% of the value as found in smooth plate.

Keywords*-CFD, artificial roughness, Nusselt number, Friction factor, Sinusoidal shaped.*

I INTRODUCTION

Ducts are used in HVAC system and ventilation process in industries ,offices ,houses they consists of a plate assembled in circular rib with different relative gap width or rectangular form with roughness for better conductivity to increase heat transfer rate during operation. Most appropriate way to analyze the solar heater air duct with different geometry is to analyze each of the geometry on CFD and compare the results obtained with the results of experimental investigation. Rajesh Maithani and J.S. Saini find out the best geometry to increase heat transfer of solar air heater duct. Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 100°C.
The absorber plate used to absorb solar radiations, normally made of metal with a black surface. A wide variety of other materials can be used with air heaters. It is usually one plate or an assembly of metal sheets or plates forming a nearly continuous surface coated with radiation absorbing black paint, black porcelain enamel or a metallic oxide.
The transparent cover which may be one or more sheets of glasses or radiations transmitting plastic film or sheet. As the number of covers increases, the loss of heat from top of collector decreases while intensity of radiation incident on absorber plate also decreases.
Tubes, passages or channels are integral with the collector absorber plate or connected to it, which carry the water, air or other fluid to transfer energy from absorber plate to the fluid.
Insulation, provided at the back and sides to minimize heat losses.
The concept of artificial roughness was given by researchers to boost heat transfer and various investigations had conducted for roughness geometry with different shape and size ribs and grooves. Sahu and Bhagoriya [1] investigates by using 90° broken transverse ribs on solar air heater absorber plate with one wall roughened and rest three insulated of rectangular duct. Roughness pitch of 20mm provides greater nusselt number enhancement. Arvind kumar and Bhagoriya et al. [2] used discrete W shaped rib with one side wall roughened and remaining three insulated of rectangular duct. Nusselt number and friction factor for W shaped rib plate are 2.16 and 2.75 times of smooth plate for 60° attack angle. A. Lanjewar et al. [3] used W rib downwards and upwards to boost warmth transfer. Heat transfer and frictional correlation are also employed. Parkpoom et al. [4] perform experimental and numerical exploration for in-phase 45° Z baffles that results good effect in heat transfer. Tabish Alam et al. [5] the effect of non circular perforation holes in V shaped blockages on rectangular solar air heater duct gives higher nusselt number and friction factor as compare to circular perforation holes with same open area ratio.K.R. Aharwala et al. [6] provide inclined regular ribs in rectangular dust on solar air heater duct to conduct experiment for warmth transfer enhancement. Nusselt number enhancement is higher at relative gap width of 1.0 for entire range of Reynolds number (3000-18000) and at relative gap position 0.25**.** Anil P. Singh et al. [7] used multiple arc shaped roughness to know the effect on warmness transfer and flow analysis on absorber plate

for relative roughness height (e/D = 0.018-0.045) Relative roughness width (1-7), relative roughness pitch (4-16) and arc angle (30°-75°) at Reynolds range (2200-22000).

S.V. Karmare and A.N. Tikekar [8] provide metal grit ribs as artificial roughness to boost thermal and frictional characteristics. R. Karwa et al. [9] performs experiment to enrich nusselt number at chamfer angle 15°. Anil Kumar et al. [10] stated synthetic roughness within the shape of repeated ribs is one of the powerful way of enhancing the performance of a sun air heater ducts. It has been done to determine the effect of various synthetic roughness geometries on heat transfer and friction characteristics in sun air heater ducts.

Kumar and Saini [11] achieved CFD primarily based analysis to fluid drift and heat transfer traits of a sun air heaters having roughened duct furnished with synthetic roughness in arc formed geometry. The warmness transfer and flow analysis of the chosen roughness detail have been executed the usage of three-D models. Sompol Skullong et al. [12] the investigation shows that the TW (Trapezoidal winglet) together with the groove affords the significant boom in warmness transfer over the smooth channel. The TW offers higher heat switch but the groove yields notably lower strain drop. The combined groove and TW gadgets at a given BR (blockage ratio) carry out the best warmness switch and friction element at smaller PR (relative pitch) and also offers extensively better thermal performance. At PR = 1, the compound tool with BR = 0.28 offers the best warmness switch and friction element at the same time as the one with BR = 0.24 gives the maximum thermal overall performance.

II MODELING AND ANALYSIS

Design procedure of absorber plate

The procedure for solving the problem is

- Modeling of the geometry.
- Meshing of the domain.
- Defining the input parameters.
- Simulation of domain.

Finite volume analysis of Absorber plate

Analysis Type - Fluent

Preprocessing

Preprocessing include CAD model, meshing and defining boundary conditions.

Table No.2.1 Ranges of geometrical and operational parameter for CFD analysis.

	Roughness and flow parameter	**Range of parameters**
1	Inlet Section	2000 mm
2	Test Section	800 mm
3	Outlet Section	500mm
4	Thickness	25 mm

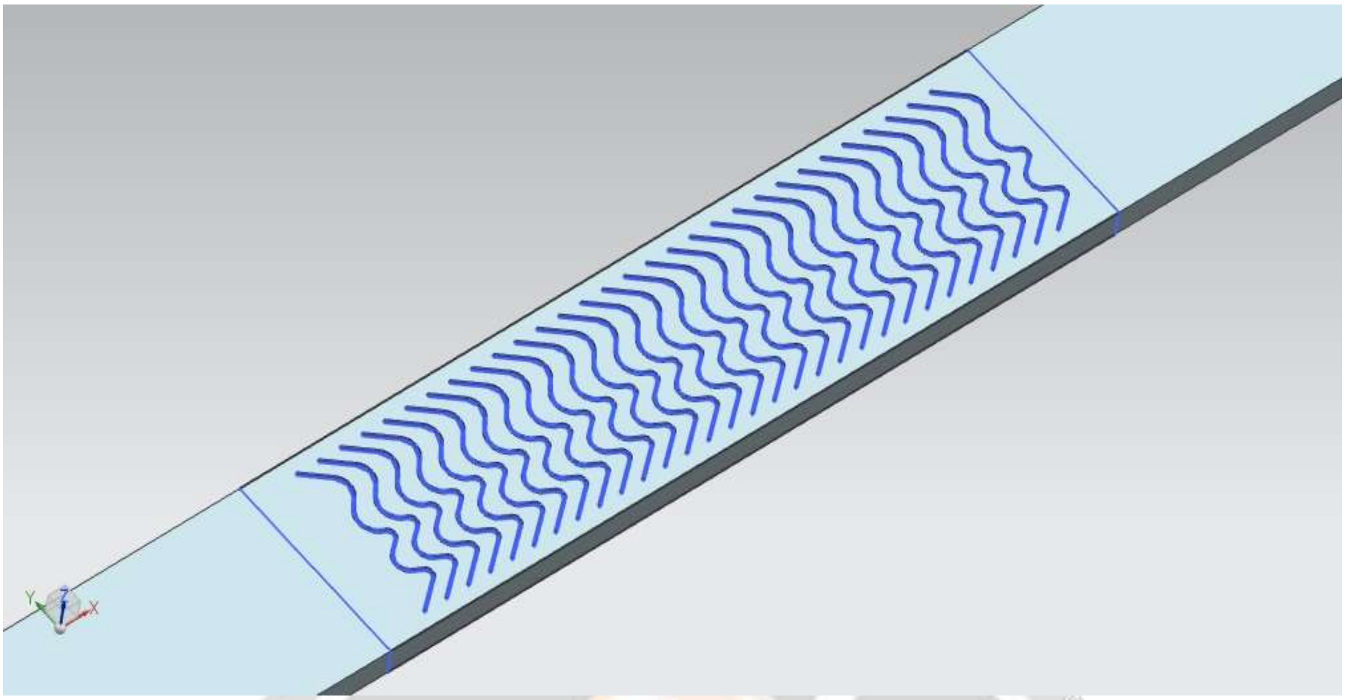


Figure: 2.1 Sinusoidal grooves absorber plate.

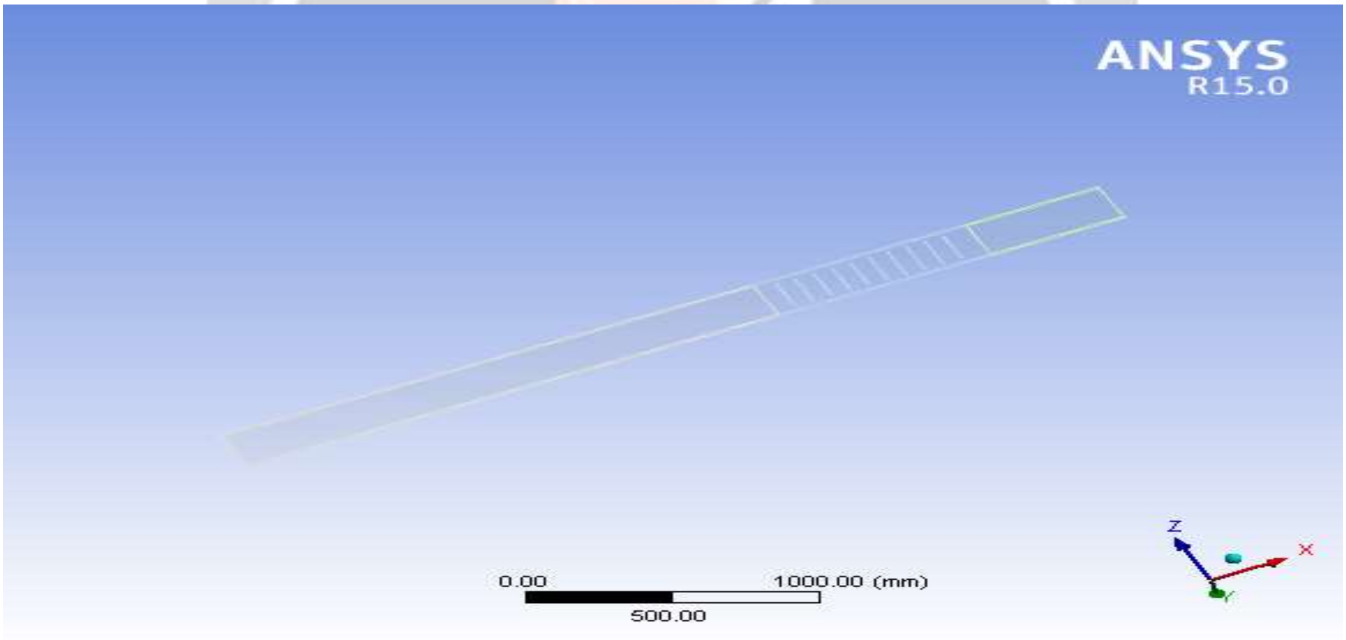


Figure 2.2 Transverse shaped grooves absorber plate.

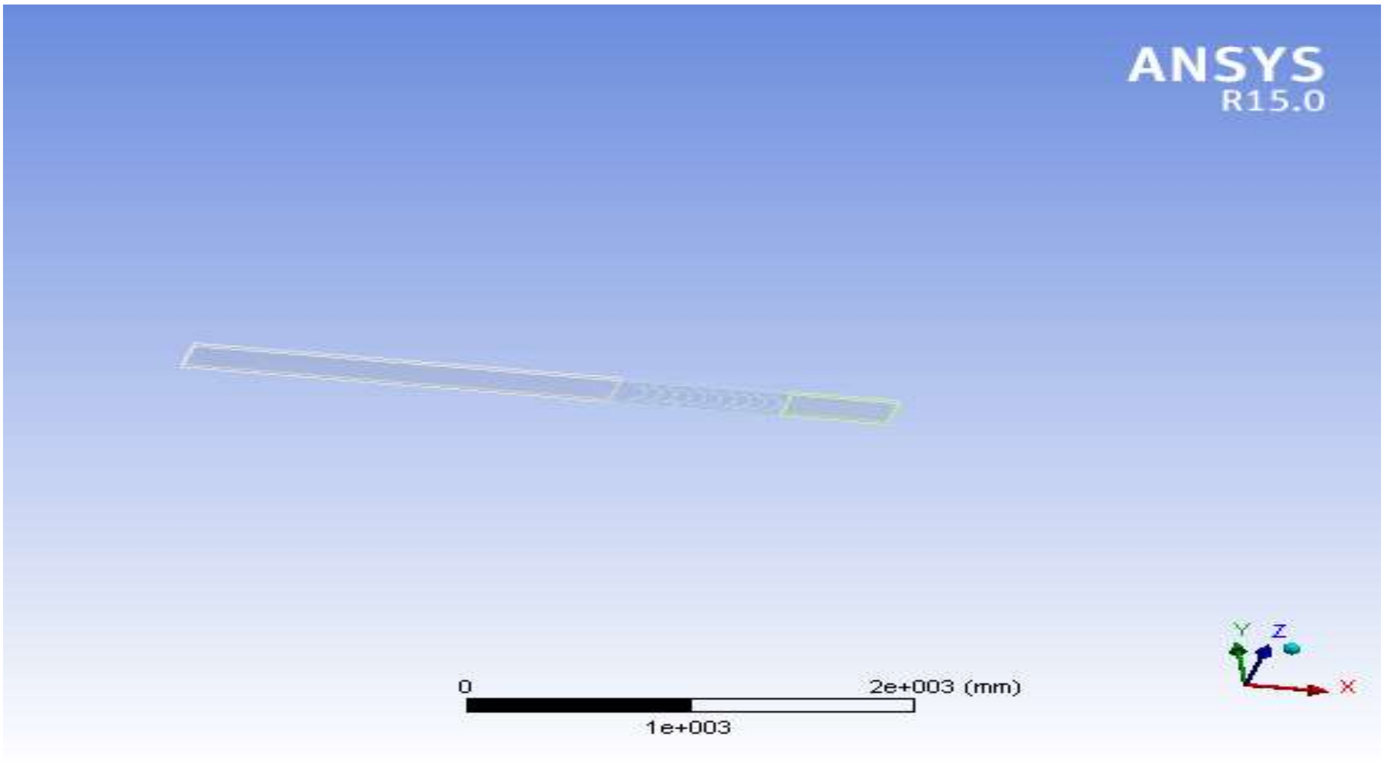


Figure 2.3 U shaped grooves absorber plate.

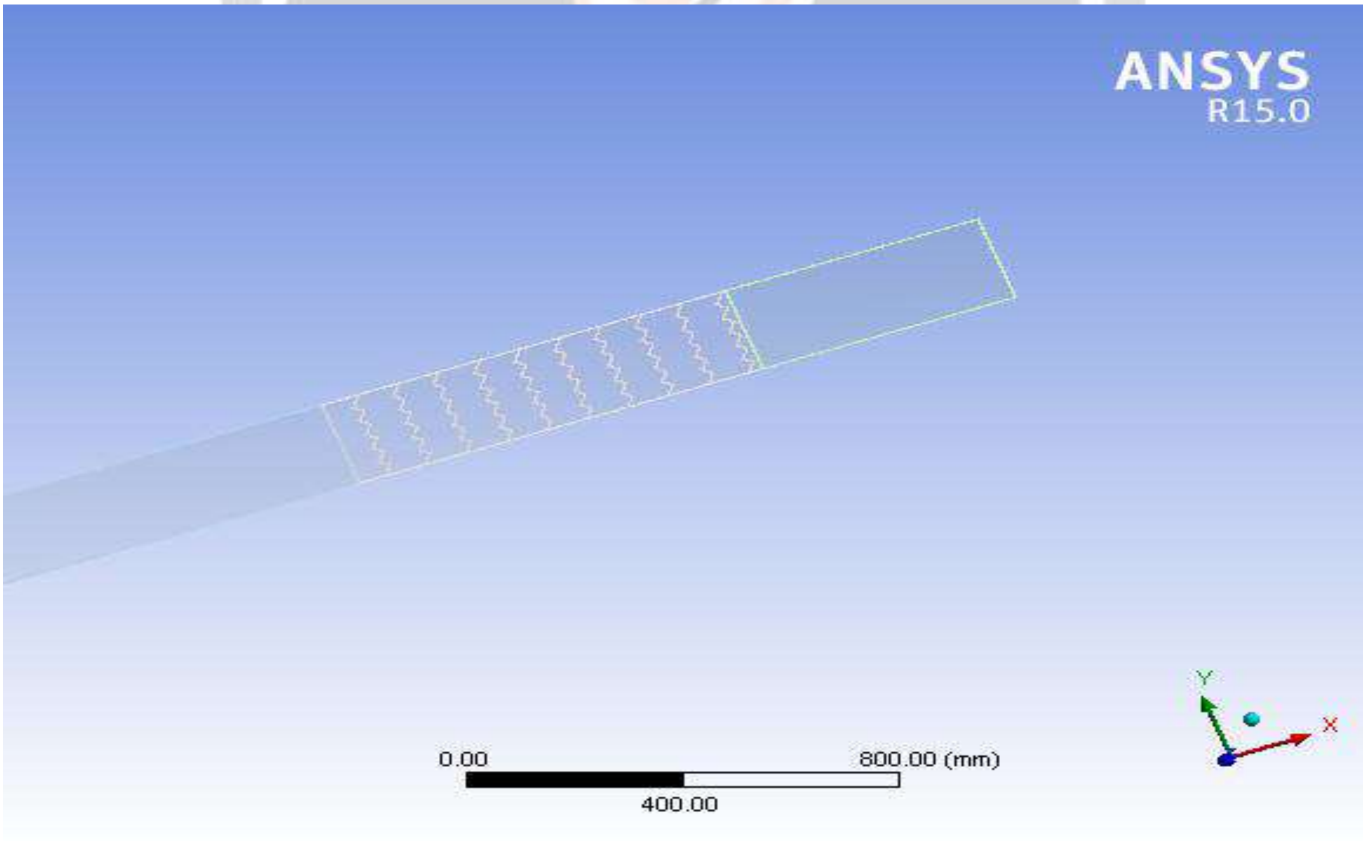


Figure 2.4 Rectangular winglets absorber plate.

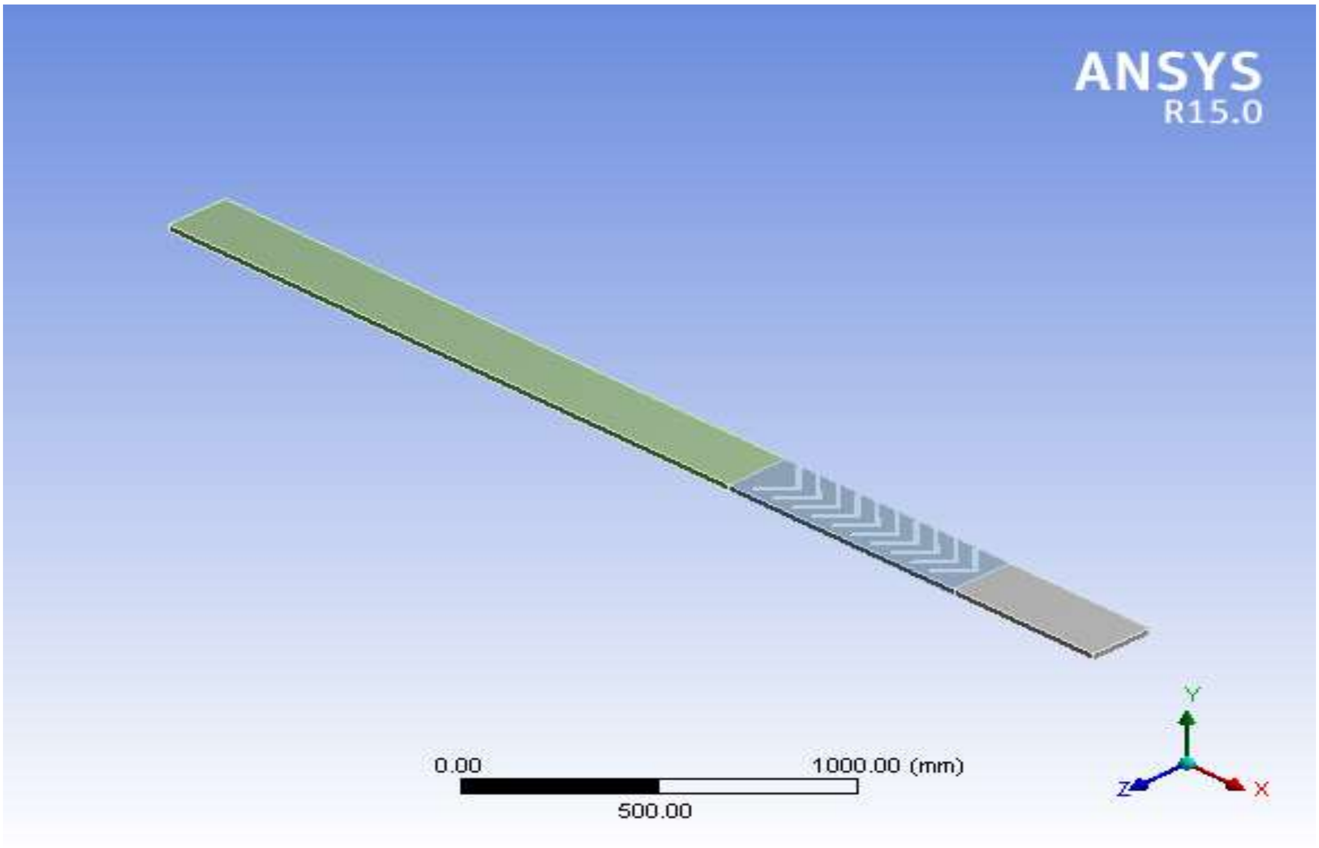


Figure 2.5 V Shaped grooves absorber plate.

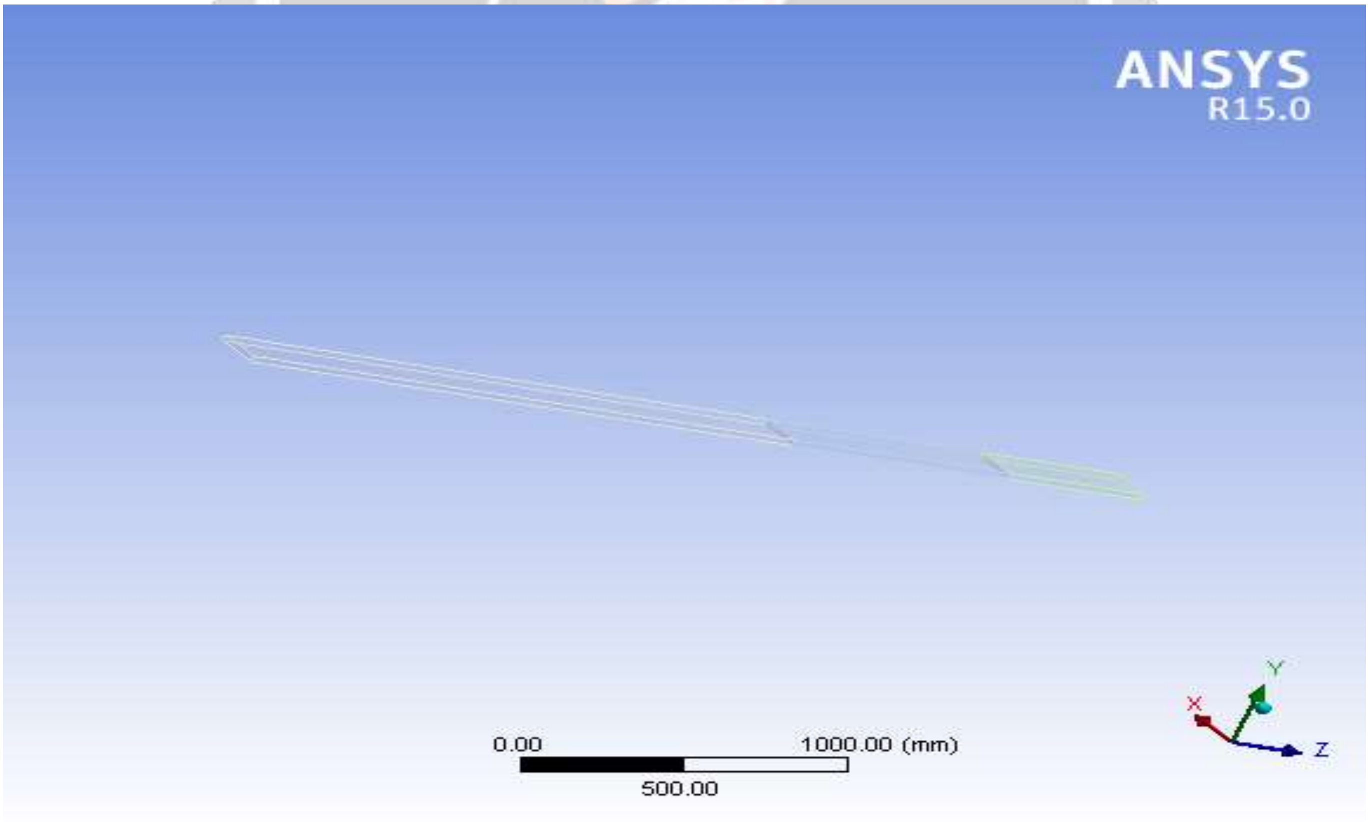


Figure 2.6 Smooth absorber plate.

Table 2.2 Properties of the working fluid (air) and absorber plate.

Properties	Working fluid (Air)	Absorber plate (Aluminum)
Density, ‘ρ’ (kgm^{-3})	1.225	2719
Specific heat, ‘C_p’ ($Jkg^{-1}K^{-1}$)	1006.43	871
Viscosity, ‘μ’ (Nsm^{-2})	1.7894e-05	-
Thermal conductivity, ‘k’($Wm^{-1}K^{-1}$)	0.0242	202.4

III RESULT AND DISCUSSION

The effects of V, U and Transverse Shaped grooves with Reynolds number (Re) on the heat transfer and friction characteristics for flow of air in a roughened rectangular duct are presented below fig. The results have been compared with experimental value of same parameter and also compare with smooth ducts operating under similar operating conditions to discuss the enhancement in heat transfer and friction factor on account of artificial roughness.

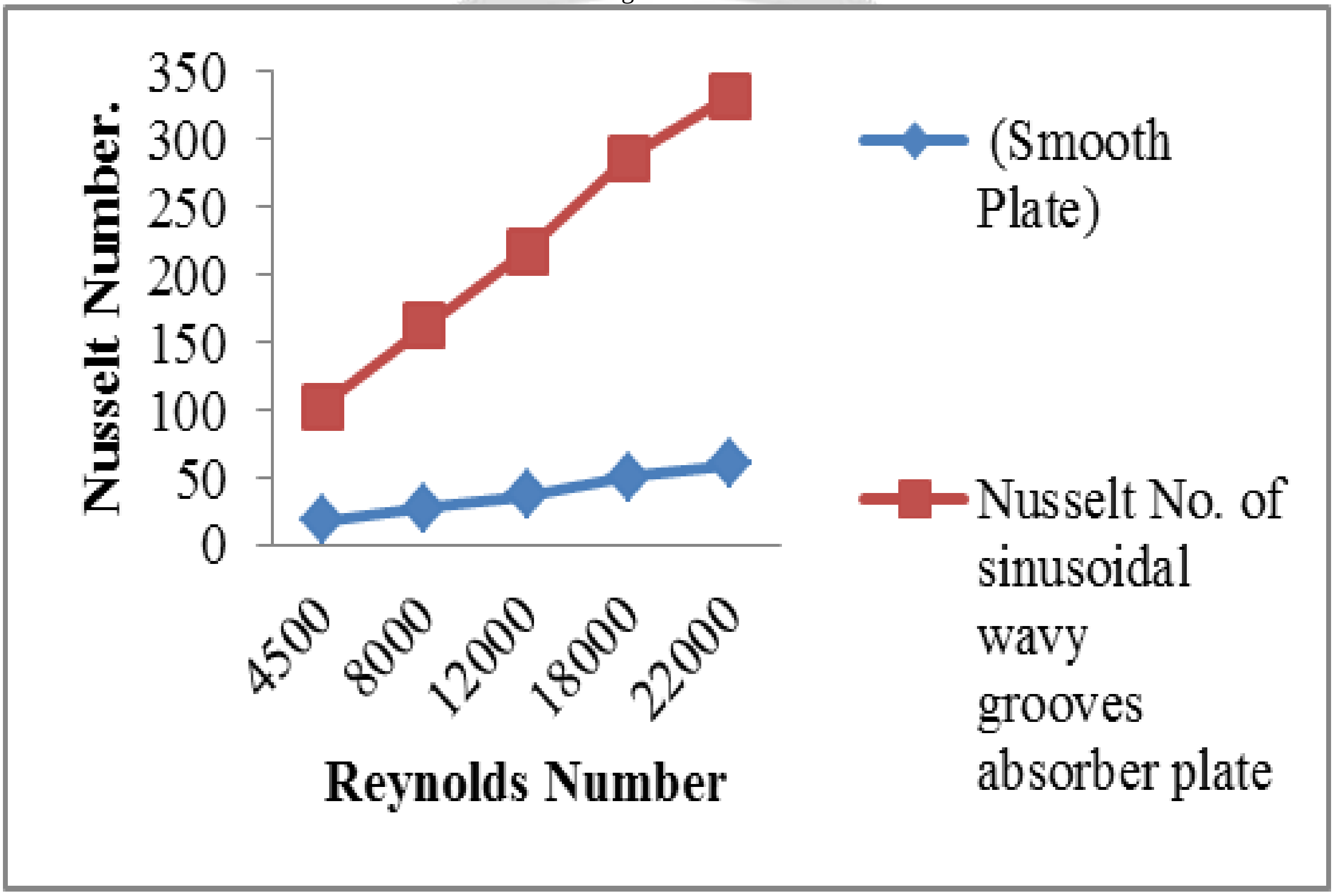


Figure: 3.1 Nusselt Number of sinusoidal wavy grooves absorber plate

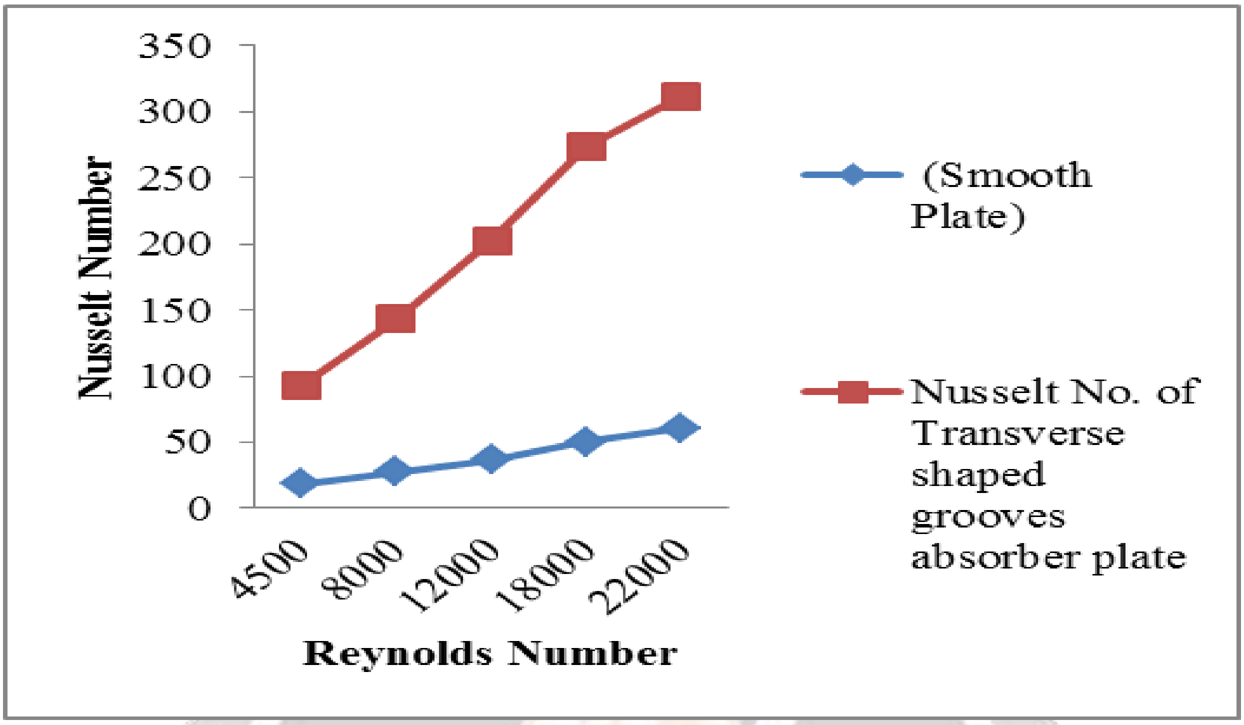


Figure 3.2 Nusselt Number of Transverse shaped grooves absorber plate

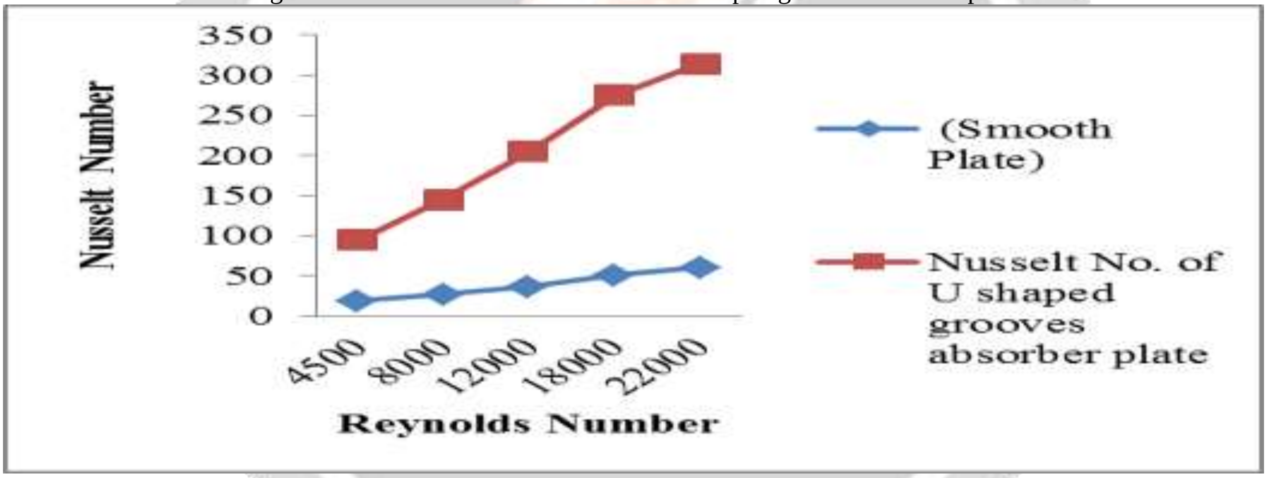


Figure 3.3 Nusselt Number of U shaped grooves absorber plate.

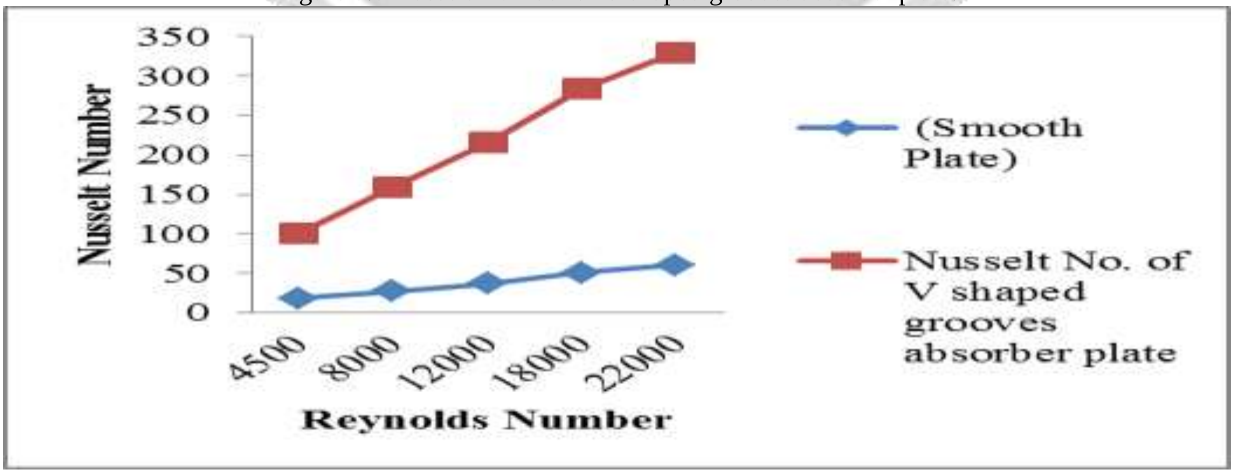


Figure 3.4 Nusselt Number of V shaped grooves absorber plate

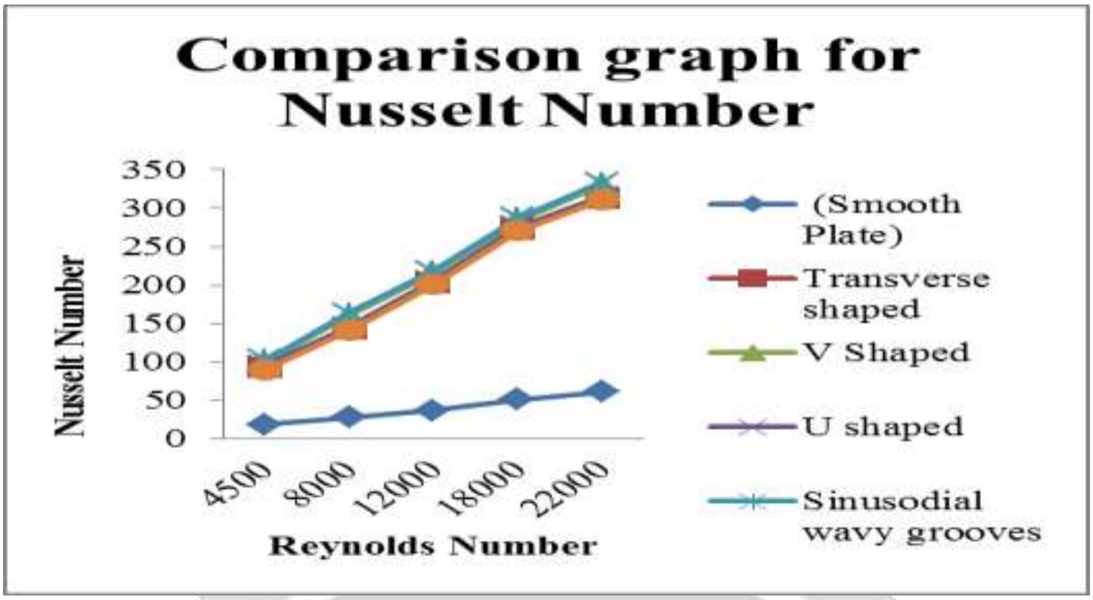


Figure 3.5 Comparison of Nusselt Number of V, U and Transverse shaped grooves absorber plate

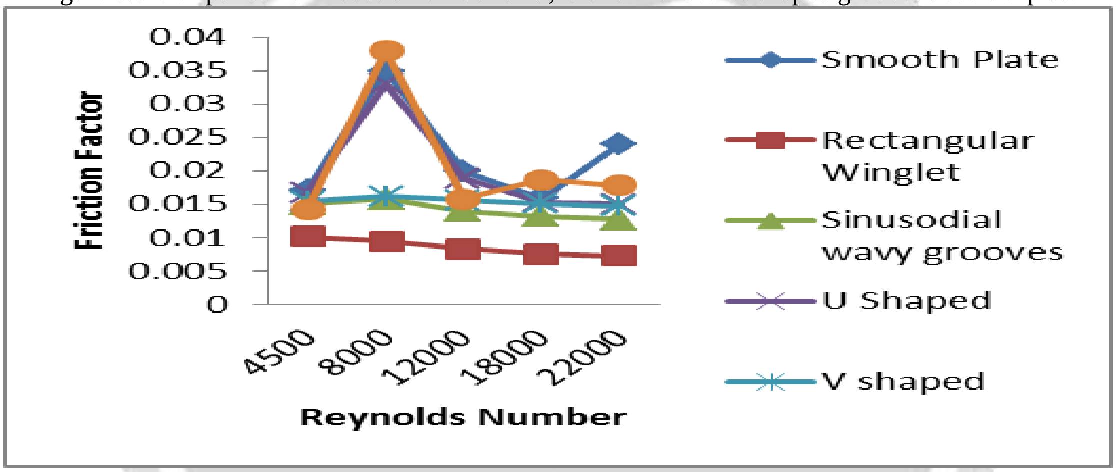
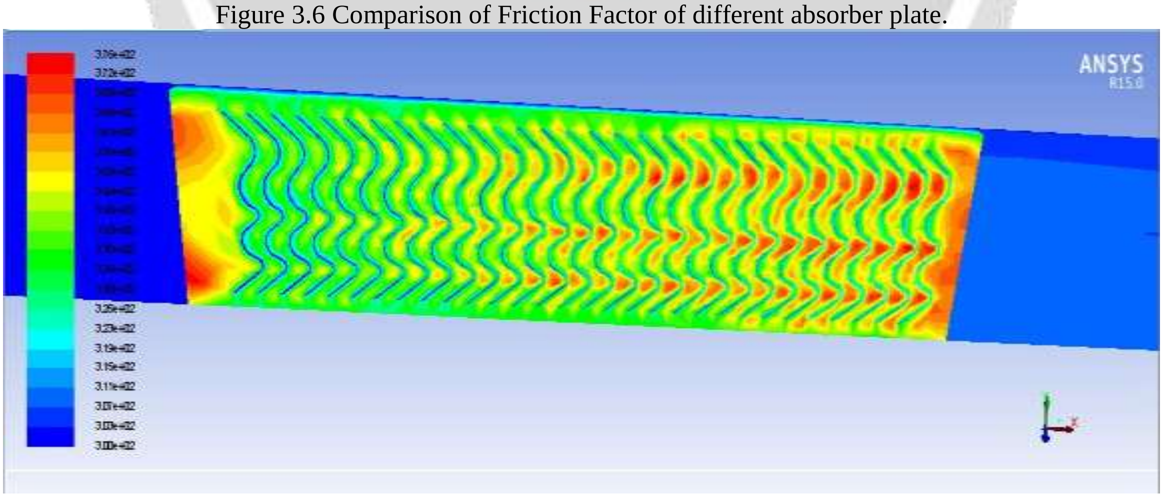


Figure 3.6 Comparison of Friction Factor of different absorber plate.



. Figure 3.7 Temperature colored contour plots of sinusoidal groove absorber plate at Reynolds number 12000.

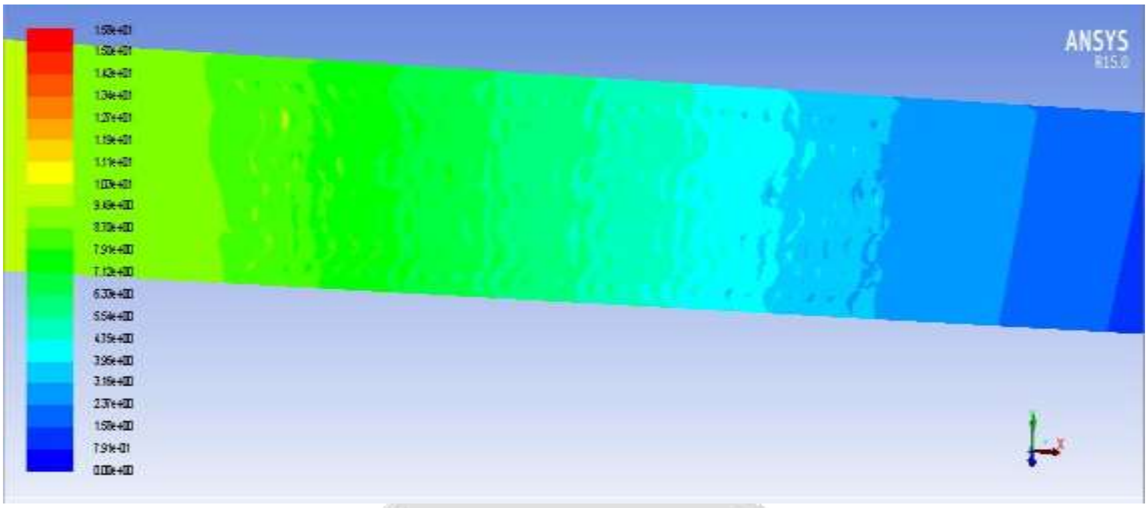


Figure 3.8 Pressure colored contour plots of sinusoidal groove absorber plate at Reynolds number 12000.

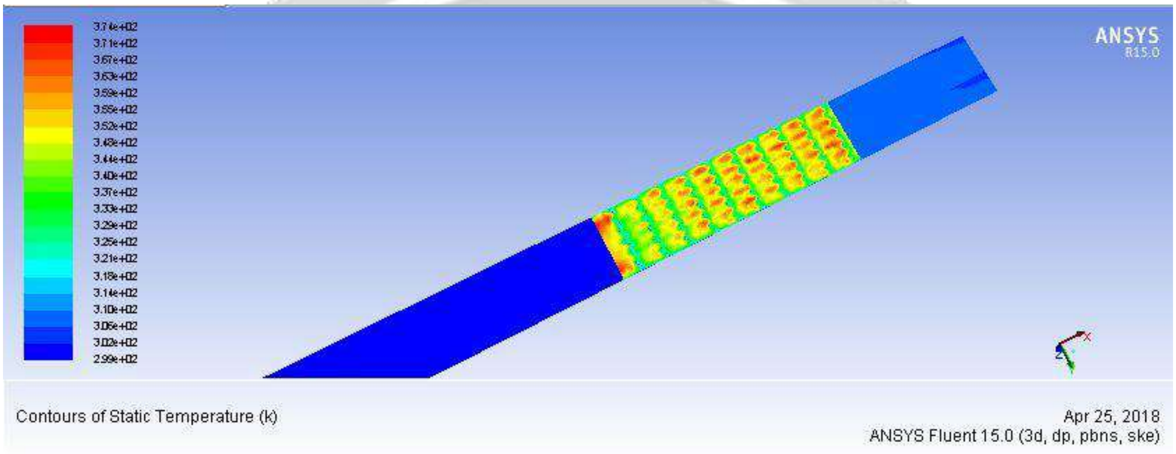


Figure 3.9 Temperature colored contour plots of Rectangular winglet absorber plate at Reynolds number 12000.

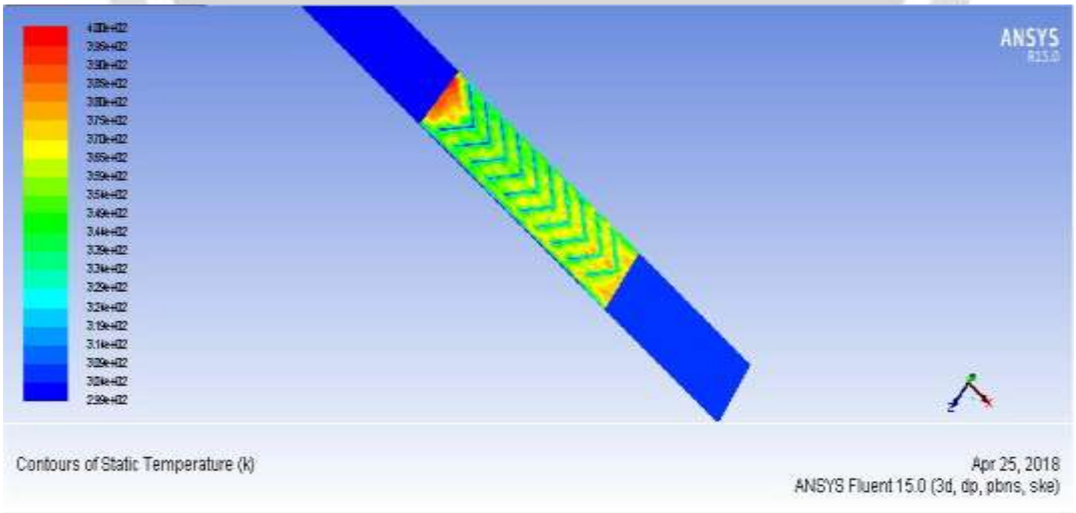


Figure 3.11 Temperature Colored contour plots of V shape groove absorber plate at Reynolds number 12000.

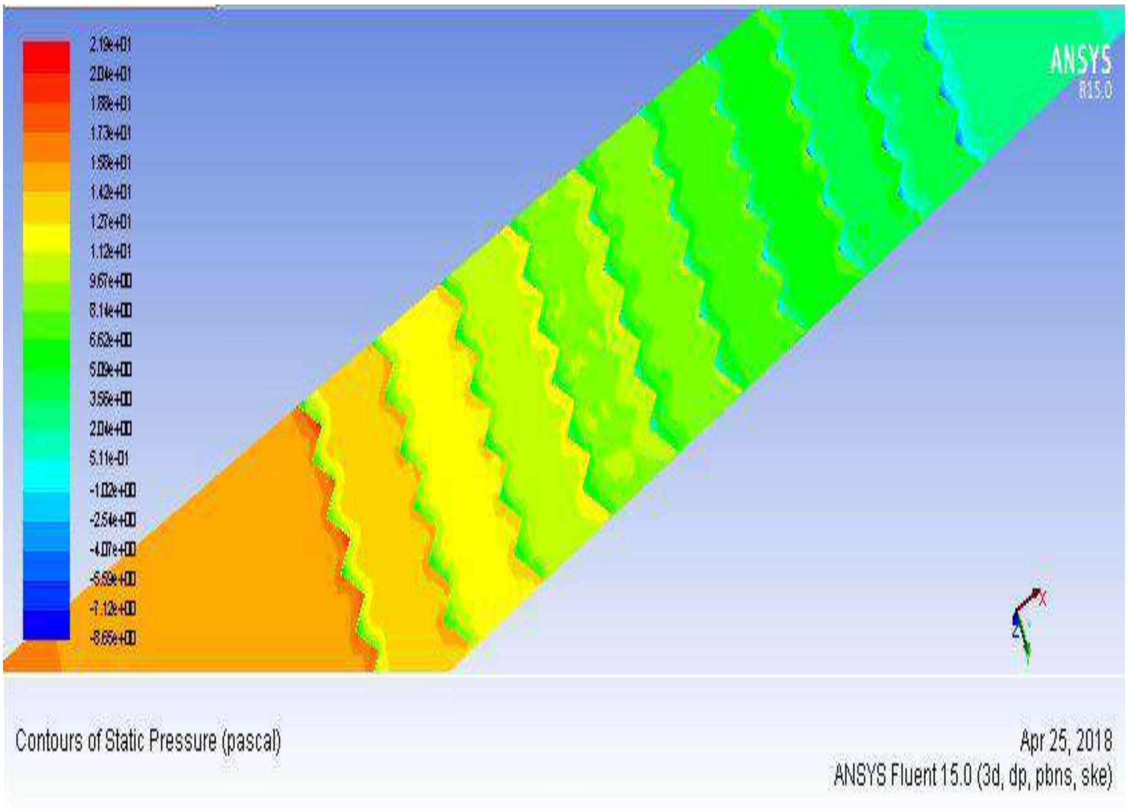


Figure 3.10 Pressure colored contour plots of Rectangular winglet absorber plate at Reynolds number 12000.

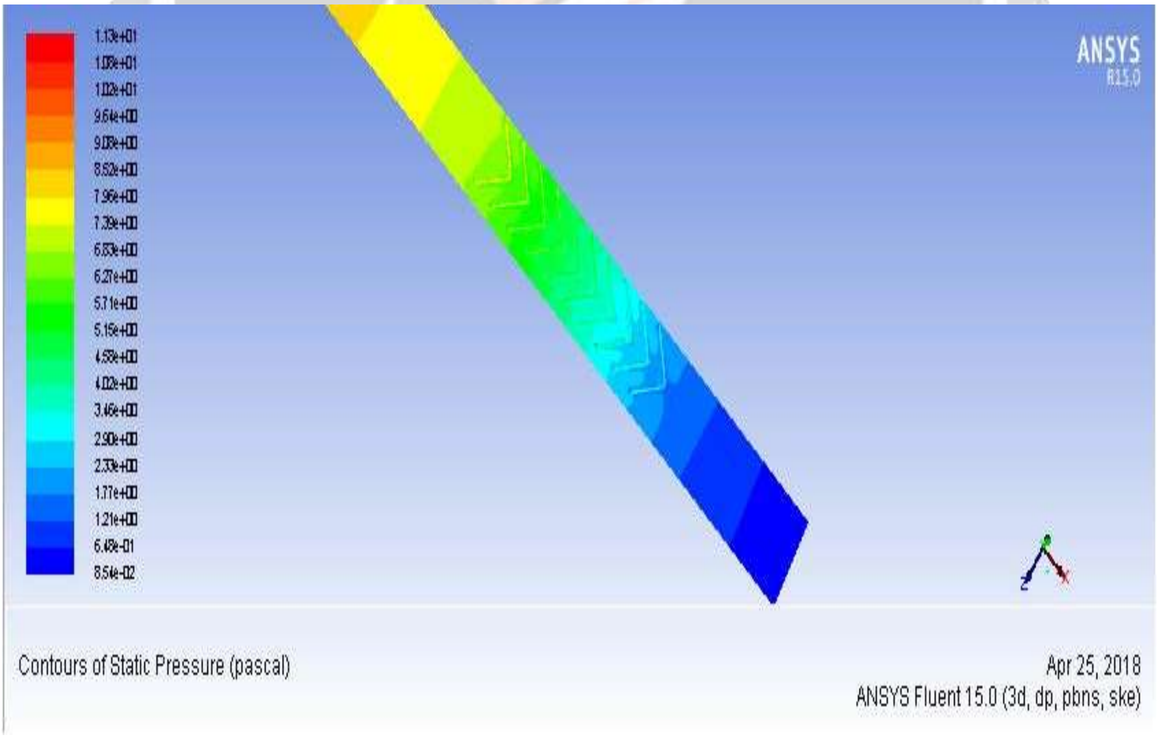


Figure 3.12 Pressure colored contour plots of V shape groove absorber plate at Reynolds number 12000.

Table No. 3.1 Comparison of Nusselt Number of different shaped grooves absorber plate with different Reynolds Number.

Transverse Shaped	V Shaped	U Shaped	Sinusoidal Wavy Grooves	Rectangular Winglets	Smooth Plate	Reynolds Number
92.4	100.2	94.8	102.4	90.2	18.6	4500
143.1	159.5	144.9	162.7	140.3	27.2	8000
202.6	214.4	204.6	218.1	200.5	36.8	12000
273.2	283.7	274.1	286.8	270.3	50.5	18000
311.9	329.9	314.2	332.5	310.2	60.4	22000

Table No. 3.2 Comparison of Friction Factor of different shaped grooves absorber plate with different Reynolds Number.

Transverse Shaped	V Shaped	U Shaped	Sinusoidal Wavy Grooves	Rectangular Winglets	Smooth Plate	Reynolds Number
0.0142	0.0154	0.0167	0.0150	0.0101	.04	4500
0.038	0.0162	0.033	0.0158	0.0094	.035	8000
0.0158	0.0156	0.0189	0.0140	0.0083	.03	12000
0.0187	0.0151	0.0153	0.0132	0.00752	.027	18000
0.0178	0.0147	0.0150	0.0127	0.0072	.024	22000

Comparative graphs of Nusselt number and friction factor for different types of grooves absorber plate is presented in figure 4.5 and figure 4.6 respectively. V shape, U shape, transverse shape and sinusoidal shape grooves showing considerable increment in Nusselt number over smooth absorber plate.

Maximum increment in Nusselt number is found in sinusoidal groove absorber plate. Average enhancement in Nusselt number for sinusoidal grooves absorber plate is found to be 471% higher over smooth absorber plate while friction factor of sinusoidal grooves gets decreased by 54.6% of value as found in smooth absorber plate.

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