INVESTIGATION OF THERMAL PERFORMANCE SINOSOIDAL AND CORRUGATED CHANNEL USING FINITE VOLUME

[1]Animesh Goswami, [2]Prof. Ashish Muchrikar

[1]M-Tech Scholar, [2]Professor & HOD
Department of Mechanical Engineering,
Corporate Institute of Science & Technology Bhopal, (M.P) - 462021

***Abstract*: In this paper, an exclusive comprehensive report has been presented for the heat transfer and fluid flow across the corrugated and sinusoidal channels or pipes. Various researchers have been carried out experimentally, numerically and computationally to examine the heat transfer and flow characteristics of these channels and pipe. The pipes and channels are conventionally used in various thermal systems where mutual heat transfer takes place from one medium to other medium. Due to have different shape characteristics the heat transfer and flow separation in not same, therefore the each shape have their own importance as per the flow regime i.e. laminar to turbulent. Effects of aspect ratio, cross-section shapes emphasize that the pipes/channel along with offset enhance the heat transfer compared to the conventional heat exchanger. In this article we discussed and made a comparative evaluation among various characteristics of geometrical parameters of sinusoidal and corrugated channel are technique to enhance the thermal performance heat transfer.**

Keywords: Corrugated, heat transfer, Mass transfer, Reynolds Number.

I. INTRODUCTION

Introduction of corrugated and wavy texture is regarded to be an most effectual passive technique for heat transfer enhancement. These are extensively practiced in compact plate heat exchangers to enhance heat transfer area and generate turbulence even at low flow rates. In channel confined flows, wall sinusoidal and corrugations produce longitudinal and transverse vortices that results in destabilization of thermal boundary layer and enhance mixing of the fluid. These texture act as promoters of unsteadiness and may form turbulence in the flow [1]. For low Reynolds number (Re) flows, separated flows in the form of trapped vortices remain confined within the grooves of the corrugations having almost no interaction with the core fluid [2]. With rise in Re, the increased inertia of core flow leads to evolution of instability in the trapped vortices due to tearing effect of the shear layers.

II. MATHEMATICAL MODELLING

For the fluid flow through pipe, duct and channel the conventional governing equations are the **Navier–Stokes equations** can be written in the most useful form for the development of the finite volume method:

$$\rho\frac{Du}{Dt} = -\frac{\partial p}{\partial x} + div(\mu grad u) + S_{Mx} \quad (1)$$

$$\rho\frac{Dv}{Dt} = -\frac{\partial p}{\partial y} + div(\mu grad v) + S_{My} \quad (2)$$

$$\rho\frac{Dw}{Dt} = -\frac{\partial p}{\partial z} + div(\mu grad w) + S_{Mz} \quad (3)$$

Governing equations of the flow of a compressible Newtonian fluid

Continuity

$$\frac{\partial \rho}{\partial x} + div(\rho u) = 0$$

x-momentum $$\frac{\partial(\rho u)}{\partial x} + div(\rho u u) = -\frac{\partial p}{\partial x} + div(\mu grad u) + S_{Mx} \quad (4)$$

y-momentum

$$\frac{\partial(\rho v)}{\partial y} + div(\rho v u) = -\frac{\partial p}{\partial y} + div(\mu grad v) + S_{My} \quad (5)$$

z-momentum

$$\frac{\partial(\rho w)}{\partial z} + div(\rho w u) = -\frac{\partial p}{\partial z} + div(\mu grad w) + S_{Mz} \quad (6)$$

Energy

$$\frac{\partial(\rho i)}{\partial t} + div(\rho i u) = -p\,div u + div(k\,grad T) + \Phi + S_i \qquad (7)$$

Using various correlation FEV results are been compared analytically

$$h_f = f\frac{LV^2}{D_h 2g}$$

Where,

f is the friction factor for fully developed laminar flow

L: length of the channel, duct, pipe

V: mean velocity of the flow

d: diameter of the pipe

f is the friction factor for fully developed laminar flow:

$f = \frac{64}{Re}$ (For Re<2000) $Re = \frac{\rho u_{avg} d}{\mu}$

C_f is the skin friction coefficient or Fanning's friction factor.

For Hagen-Poiseuille flow: $C_f = \tau_{wall}\, l\, \frac{1}{2}\rho u_{avg}^2 = \frac{16}{Re}$

For turbulent flow: $\frac{1}{\sqrt{f}} = 1.74 - 2.0\log_{10}\left[\frac{\varepsilon_p}{R} + \frac{18.7}{Re\sqrt{f}}\right]$ Moody's Chart

R: radius of the channel, duct, pipe

ε_p: degree of roughness (for smooth channel, duct, pipe, $\varepsilon_{p=0}$)

$Re \to \infty$: Completely rough channel, duct, pipe.

III. Literature Review

K.Rahmani 2017 A great deal of relevant research work consists of numerical simulations of forced convection mechanisms with turbulent flows in corrugated channel. We are interested in determining the flow for various amplitudes and periods. The influence of geometry on several factors such as: temperature, the local Nusselt number, friction number, turbulent kinetic energy k and its dissipation are considered. Based on the Navier-Stokes equations, these equations were solved by a CFD technique using the Finite Volume Method. The results show that when we gradually increase the amplitudes of the protuberance part (say a=0.03, a=0.06,) the maximal temperature increases with the increase of amplitude. This is due to the rise of the heat transfer surface of the modified wall..

Hamed et al. 2017 Corrugated shell and corrugated tube were employed instead of smooth shell and smooth tube through a shell and tube heat exchanger in this paper. Distinct arrangements of concave and convex type of corrugated tubes were investigated. In the present work exergetic parameters were experimentally studied for a shell and tube heat exchanger made of corrugated shell and corrugated tube.

Lihong et al. 2017 Three-dimensional numerical computations are conducted to investigate the effects of the blowing ratio and corrugation geometry on the adiabatic film cooling effectiveness as well as the heat transfer coefficient over a transverse corrugated surface. It is noticeable that the adiabatic wall temperature on the wavy valley of the transverse corrugated surface is relatively lower than that on the wavy peak.

Valinataj et al. 2015 use artificial be colony approach in a sinusoidal wavy channel in order to optimize the heat transfer of twp phase modeling of a nano fluid. The effect of using nano-particles on thermal-hydraulic performance factor (j/f) has been examined which considers both heat transfer and hydrodynamics aspects.

Jam adam et al. 2014 applied of fundamental solutions and the radial basis functions to examine the viscous laminar flow in a wavy channel and conclude that the main advantage of the proposed procedure is its simplicity and analytical form of the approximate solution. Such mesh less approach was never applied previously for the problem of viscous laminar flow in the wavy channel.

IV. Methodology

For simulated the corrugated and Sinusoidal channel the adopted methodology for performing CFD (Computational Fluid Dynamics) analysis has been discussed herein. A two dimensional model of corrugated and Sinusoidal channel have been developed by using ANSYS geometrical module where the geometrical detail has been adopted from the Rahmani et al. [26-27]. The details for performing forced convective heat transfer through corrugated and Sinusoidal channel have been detailed in table 1. After modeling the two dimensional model has been discretized in 10^5 orders of nodes and elements. The mesh here is taken a face sizing with Mapped meshing. The Corrugated and Sinusoidal channel have been discretized into 24954 nodes and 24284 elements Different names are should be assigned to the two dimensional models for apply boundary condition. So as to simulation boundary conditions can be given such as Inlet, Outlet, Topwall, Buttomwall, corrugated/Sinusoidal top, Corrugated/Sinusoidal bottom. The thermal performances of corrugated and Sinusoidal channel have been examined by solving the governing equations i.e. Navier–Stokes equations by ANSYS Fluent module. As the details of Navier-stokes continuity equations have been detailed in chapter 4.

While performing analysis two Sinusoidal channel are molded with different amplitude and compared with smooth channel

Following steps show the guidelines for carrying out CFD (Fluent) Analysis.

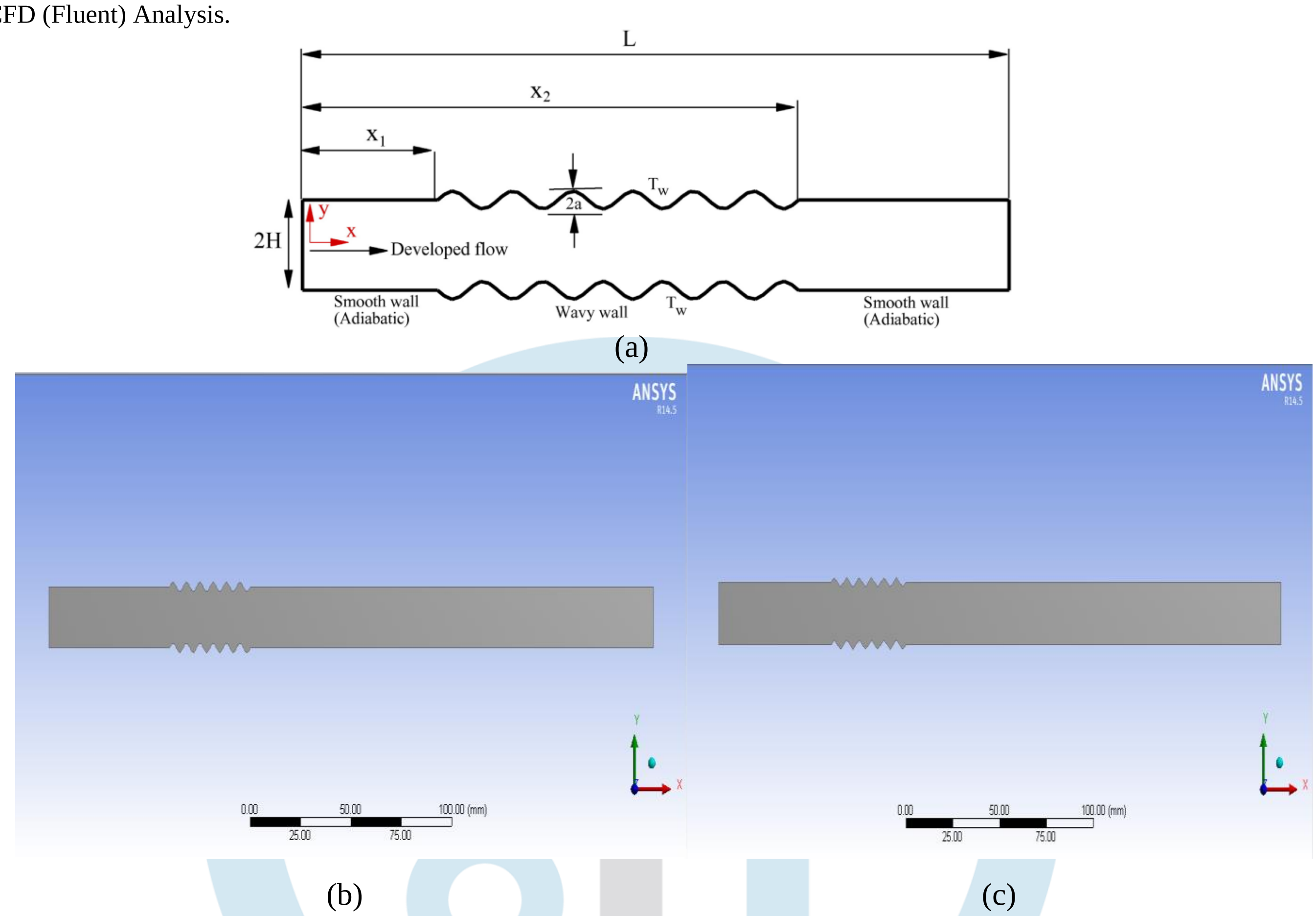

Figure 1. Model Geometry

1. Set preferences. (Fluid Flow (Fluent)
2. Model the Geometry
3. Follow bottom up modeling and create the geometry
4. Generate the mesh
5. Setup, here the simulation process is begins with the giving initial condition of fluid properties and simulation starting zone.
6. Result

V. Results and Discussion

Using Ansys fluent the heat transfer governing equation for corrugated and Sinusoidal channel and smooth channel i.e. The Navier stokes continuity equation has been solved. On the basis of this FEV work the thermal performance characteristic of the smooth channel and channel with corrugated and Sinusoidal surface has been evaluated with a grid size of 10^6 shows good convergence during the grid dependence test. Moreover, the comparative performance between various channel i.e. smooth vs Sinusoidal vs corrugated channel are illustrated in the corresponding results.

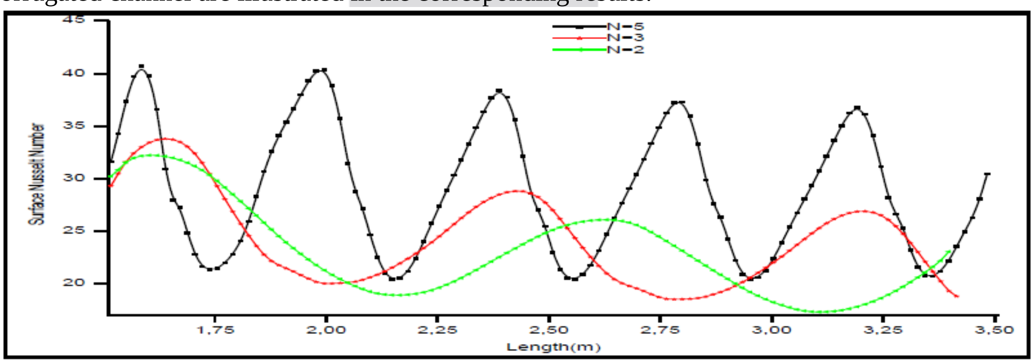

Figure 2.Evolution of Nusselt number within Sinusoidal channel

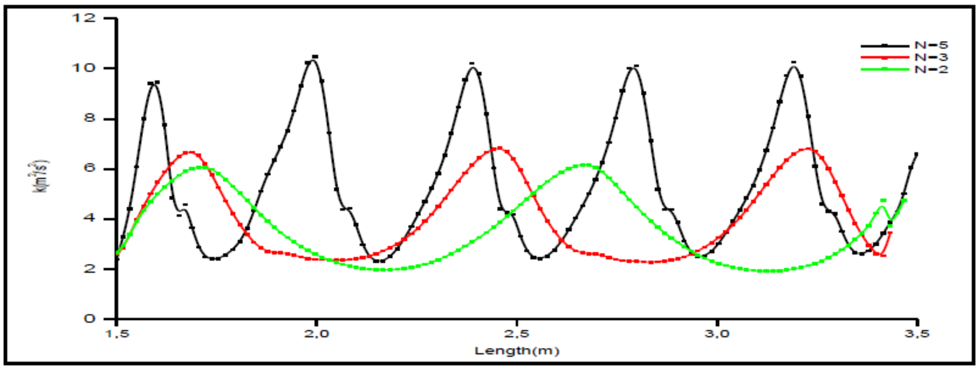

Figure 3.Evolution of the turbulent kinetic energies within Sinusoidal channel

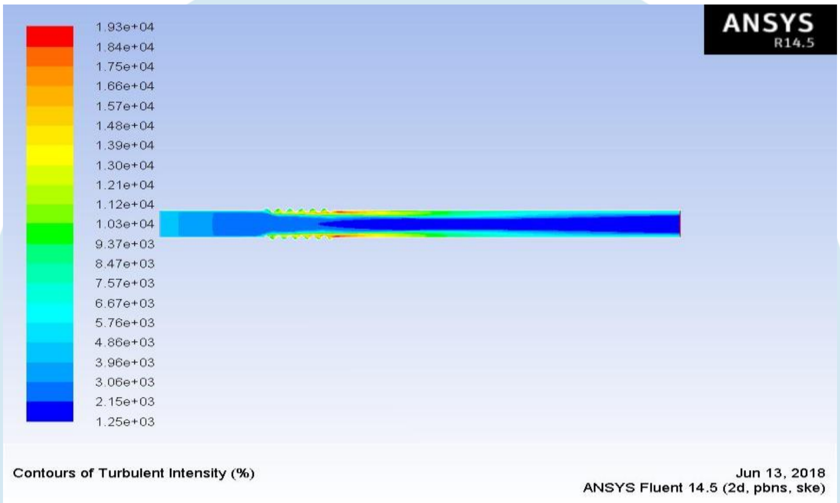

Figure 4.Contour plot of turbulent intensity across Sinusoidal channel

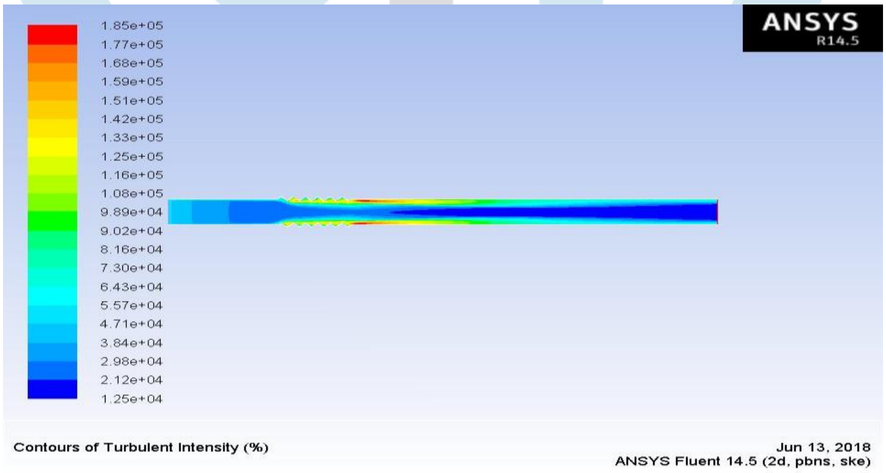

Figure 5.Contour plot of turbulent intensity across corrugated channel

It has been seen that the presence of Sinusoidal/corrugated texture significantly increases the rate of turbulent intensity. This is because of boundary layer separation and reattachment leads to increases in dispersion of boundary layer in higher Reynolds number. In addition to this the effect of amplitude has also been observed that remarkably affects the thermo hydrodynamic performance characteristics such as pressure drop, dynamic pressure, pressure coefficient, skin friction, heat transfer coefficient and Nusselt number .

Table 1. Effect of Reynolds number of pressure coefficient

		Pressure Coefficient		
Reynolds Number, Re	**Velocity, m/s**	**Smooth**	**Sinusoidal**	**Corrugated**
3.42293506	0.0025	5.33E-07	0.008362846	78.736099
34.2293506	0.025	5.52E-06	7.40E+00	6.76E-06
342.293506	0.25	6.50E-05	9.43E+01	8.65E-05
3422.93506	2.5	0.002840457	2846.6404	0.002838097
34229.3506	25	0.088415779	51212.742	0.045268033

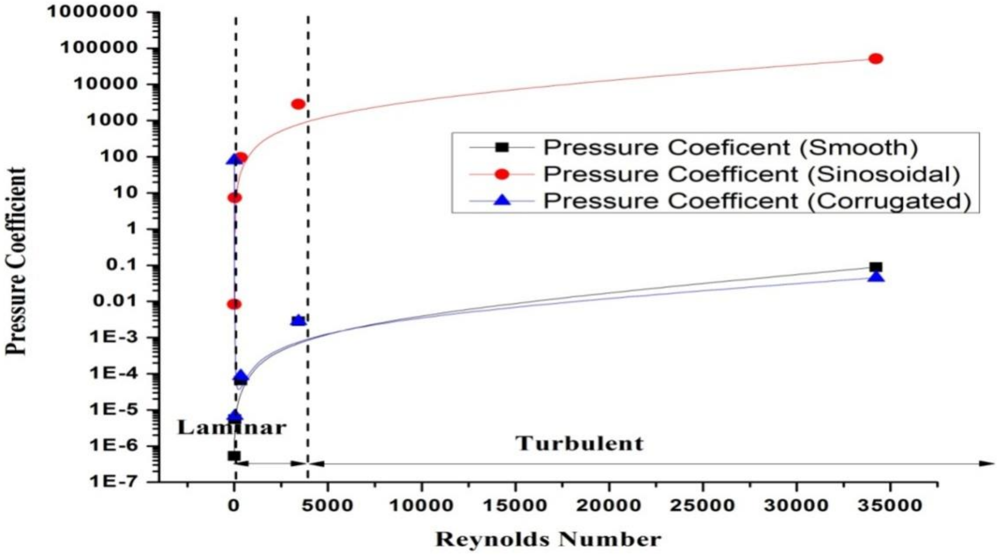

Figure 6. Effect of Reynolds number on pressure coefficient

Effect of Reynolds number on pressure coefficient. It has been observed that pressure coefficient considerably increases linearly as Reynolds number increases. From the figure it can be more evident that the pressure coefficient for Sinusoidal channel is more remarkable as compared to corrugated and smooth channel.

VI. Conclusion

- The pressure drop considerably increases in corrugated and Sinusoidal channel compared to smooth channel.
- On increasing Reynolds number dynamic pressure increases significantly. However, smooth channel has comparatively low dynamic pressure as compared to corrugated channel.
- Coefficient of skin friction increases as Reynolds number increases. In Sinusoidal channel Coefficient of friction is significantly more due to have more surface area than straight channel.
- On realizing Sinusoidal surface in laminar regime turbulence can be created.
- Turbulent intensity is direct function of Reynolds number. In other words, as Reynolds number increases turbulent intensity correspondingly increases.
- Increasing in turbulency promotes the friction factor as Reynolds number increases.
- The thermal performance of any heat exchanger can effectively been increases by employing corrugated and Sinusoidal channel.
- Shear stress at the wall increases as the fluid flow rate increases.

VII. Future Scope

- 2nd law analysis can be perfumed
- Optimization of the proposed can be done by using any optimization technique.
- Thermo-economic analysis can be perfumed.
- Exergy destruction can be calculated.
- This Sinusoidal configuration can be adopted in analyzing solar air heater.

REFERENCES

[1] HamedSadighiDizaji, SamadJafarmadar, SoheilAsaadi, Experimental exergy analysis for shell and tube heat exchanger made of corrugated shell and corrugated tube, Experimental Thermal and Fluid Science, Volume 81, February 2017, Pages 475-481

[2] Alsanossi M. Aboghrara, B.T.H.T. Baharudin, M.A. Alghoul, Nor Mariah Adam, Husam A. Hasan, Performance analysis of solar air heater with jet impingement on corrugated absorber plate, Case Studies in Thermal Engineering, Volume 10, September 2017, Pages 111-120

[3] LihongQu, Jingzhou Zhang, Xiaoming Tan, Minmin Wang, Numerical investigation on adiabatic film cooling effectiveness and heat transfer coefficient for effusion cooling over a transverse corrugated surface, Chinese Journal of Aeronautics, Volume 30, Issue 2, April 2017, Pages 677-684

[4] Zhenping Wan, Qinghong Lin, Xiaowu Wang, Yong Tang, Flow characteristics and heat transfer performance of half-corrugated microchannels, Applied Thermal Engineering, Volume 123, August 2017, Pages 1140-1151

[5] Kuldeep Singh, B. Premachandran, M.R. Ravi, Experimental and numerical studies on film cooling of a corrugated surface, Applied Thermal Engineering, Volume 108, 5 September 2016, Pages 312-329

[6] M. Khoshvaght-Aliabadi, S.E. Hosseini Rad, F. Hormozi , Al2O3–water nanofluid inside wavy mini-channel with different cross-sections Journal of the Taiwan Institute of Chemical Engineers, Volume 58, January 2016, Pages 8-18

[7] Naznil Singh, Rajneel Sivan, Manuialouolaga Sotoa, Mohammed Faizal, M.R. Ahmed, Experimental studies on parallel wavy channel heat exchangers with varying channel inclination angles, Experimental Thermal and Fluid Science, Volume 75, July 2016, Pages 173-182

[8] Gun Woo Kim, Hyun Muk Lim, Gwang Hoon Rhee, Numerical studies of heat transfer enhancement by cross-cut flow control in wavy fin heat exchangers, International Journal of Heat and Mass Transfer, Volume 96, May 2016, Pages 110-117

[9] M. Akbarzadeh, S. Rashidi, M. Bovand, R. Ellahi, A sensitivity analysis on thermal and pumping power for the flow of nanofluid inside a wavy channel Journal of Molecular Liquids, Volume 220, August 2016, Pages 1-13

[10] Assel Sakanova, Chan Chun Keian, Jiyun Zhao, Performance improvements of microchannel heat sink using wavy channel and nanofluids , International Journal of Heat and Mass Transfer, Volume 89, October 2015, Pages 59-74