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A Review Paper on CFD Analysis on Heat Transfer Enhancement Using Twisted Tube Inserts in A Tube Heat Exchanger

*Mr. Prakhar Dubey [*1], Kunal Dilip Sonar [*2], Mr.Sachin Baraskar[*3]*

[*1] *Guide, ME Department, SSSUTMS, Sehore, M.P., India*
[*2] *Research scholar, ME Department, SSSUTMS, Sehore, M.P., India*
[*3]*HOD, ME Department, SSSUTMS, Sehore, M.P., India*

A B S T R A C T

Wavy surfaces and channel have been employed in many environmental and industrial applications. The key factor for adopting such shaped (wavy) instead of using flat surface is due to improving the mass and heat transfer mechanisms, associated with large pressure variations. In the proposed work a CFD analysis will be carried out in order to analysis the turbulent flow through wavy channel. The influence of various parameters such as number of waves, pitch, amplitude, length, width of a wavy channel will be investigated and exclusive comparison will be made between smooth channel and a wavy channel. The computational analysis will be carried out using ANSYS 14.5 and all the flow governing equations are solved through FLUENT solver. The obtained results will be validated with experimental and computation work of available literature. And the significance of wavy surface or channel will be explored.

1. INTRODUCTION

Turbulent flow over a rough surface is a significant crisis in fluids engineering and occurs in diverse situations. Many systems of engineering interest, such as re-entry vehicles, missiles, aircraft, ships, turbines, heat exchangers, piping networks, and atmospheric flows, have surfaces that are often rough in the hydrodynamic or aerodynamic sense. Therefore, there is a great deal of interest in accurate predictive models for turbulent flow over rough surfaces. Surface roughness affects, additionally to the flow itself and the transportation of heat and mass in the flow.

1.2 Significance of Wavy surface/channel

Literature reveals that the hydrodynamic performance characteristics of pipe, channel, ducts, and enclosure are mainly depends on the fluid flow region or surface through which fluid is flowing. The nature of fluid flow examined on the on the bases of Reynolds number .The turbulent flow over the wavy surface has been widely experienced in the environmental and industry fields. For example, the coupling fluxes between the atmosphere and ocean occur through a wavy surface that changes spatially and temporally. If Reynolds is less than 2300 it is said to be laminar and more than 4000 it is said to be turbulent. In laminar flow where viscous forces are dominant, and is characterized by smooth, constant fluid motion where as in turbulent flow occurs at high Reynolds numbers viscous forces are dominated by inertial forces, which tend to produce chaotic vortices ,eddies, and other flow instabilities. Therefore in turbulent flow turbulence is largely responsible for mixing, dispersion, frictional losses, vibrations and noise.

1.3 Research objective

Extensive literature review has been carried out in the field of fluid flow and heat transfer through wavy surface/channel. In this work the hydrodynamic performance characterizes of wavy channel has been examined in comparison with the smooth channel (straight). The analysis has been carried out by using Finite element tool (CFD) ANSYS Fluent is employed for solving governing equation. However, to verify the obtained result exclusive comparison has been done with the available literature of computational as well as experimental work and it has been found the results are showing good agreement and are within acceptable limit.

2. LITERATURE REVIEW

W Li et.al. 2022 investigated the occurrence and structural behavior of vortices induced in 2D wavy channel for steady condition. They conclude that longitudinal vortices are appeared in a channel with a narrow spacing and vortex destruction leads to increase in turbulence.

Samutpraphut et al. 2023 A numerical method for the solution of the Reynolds-averaged Navier- Stokes equations, together with a two-layer turbulence model, has been used to describe steady flow in a two-dimensional channel with a wavy wall. Comparisons of calculations with experiments demonstrate the effects of alternating pressure gradients induced by alternating surface curvatures, and multiple separations and reattachments. The numerical method and the turbulence model are shown to capture the overall features of such a flow, including the breakdown of the logarithmic law of the wall in strong pressure gradients and in separated flow.

Khafaji et al. 2022 A numerical procedures are developed for the analysis of flow in a channel whose walls describe a travelling wave motion. Following a perturbation method, the primitive variables are expanded in a series with the wall amplitude as the perturbation parameter. The boundary conditions are applied at the mean surface of the channel and the first-order perturbation quantities are calculated using the pseudo spectral collocation method. Although limited by the linear analysis, the present approach is not restricted by the Reynolds number of the flow and the wave number and frequency of the wavy-walled channel. Using the computed wall shear stresses, the positions of flow separation and reattachment are determined. The variations in velocity and pressure with frequency of excitation are also presented

J Chen et al. 2022 scrutinized the Stability characteristics of wavy walled channel flows. The governing equation are solved by using floquet theory and spectral collocation method.

PB Dehankar · 2022 Developing flow and heat transfer in a wavy passage are studied using a numerical scheme that solves the two-dimensional unsteady flow and energy equations. Calculations are presented for a wavy channel consisting of 14 waves. Time-dependent .simulations have been performed for several Reynolds numbers. At low Reynolds numbers, the flow is .steady in the complete channel. As the Reynolds number is progressively increa.sed, the flow becomes unsteady. As a result of the unsteadiness, there is increased mixing between the core and the wall fluids, thereby increasing the heat transfer rate. With further increase in Reynolds number, the flow becomes unsteady at a much earlier spatial location.

Dellil et al.2004 This paper reports the numerical modeling of turbulent flow and convective heat transfer over a wavy wall using a two equations eddy viscosity turbulence model. The wall boundary conditions were applied by using a new zonal modeling strategy based on DNS data and combining he standard k–e turbulence model in the outer core flow with a one equation model to resolve the near-wall region. It was found that the two-layer model is successful in capturing most of the important physical features of a turbulent flow over a wavy wall with reasonable amount of memory storage and computer time. The predicted results show the shortcomings of the standard law of the wall for predicting such type off lows and consequently suggest that direct integrations to the wall must be used instead. Moreover, Comparison of the predicted results of a wavy wall with that of a straight channel, indicates that the averaged Nusselt number increases until a critical value is reached where the amplitude wave is increased. However, this heat transfer enhancement is accompanied by an increase in the pressure drop.

Hang et al. 2005 Large eddy simulation (LES) has been applied to turbulent thermal fields in a channel having one wavy wall for Prandtl number = 0.7. Wall wave amplitude is changed in three steps. Increasing the wall wave amplitude, a flow separation bubble comes to appear and a separated turbulent shear layer develops above the separation bubble. Additionally, in the up- slope region of the bottom wavy wall, near-wall stream wise vortices are generated with larger population. These two turbulence features, i.e., the separated shear layer and the near-wall stream wise vortex, play an important role for the heat and momentum transfer near the wavy wall.

3. MODELING AND ANALYSIS

This leads to the governing equations of fluid flow and a discussion of the necessary auxiliary conditions – initial and boundary conditions. The main issues covered in this context are:

1. **Derivation of the system of partial differential equations (PDEs) that govern flows in Cartesian (x, y, z) co-ordinates**
2. **Thermodynamic equations of state**
3. **Newtonian model of viscous stresses leading to the Navier–Stokes equations**
4. **Commonalities between the governing PDEs and the definition of the transport equation**
5. **Integrated forms of the transport equation over a finite time interval and a finite control volume**
6. **Classification of physical behaviours into three categories: elliptic, parabolic and hyperbolic**
7. **Appropriate boundary conditions for each category**
8. **Classification of fluid flows**
9. **Auxiliary conditions for viscous fluid flows**
10. **Problems with boundary condition specification in high Reynolds number and high Mach number flows.**

3.1 Governing Equations Of Fluid Flow And Heat Transfer

The governing equations of fluid flow represent mathematical statements of the conservation laws of physics:

• The mass of a fluid is conserved

• The rate of change of momentum equals the sum of the forces on a fluid particle (Newton's second law)

• The rate of change of energy is equal to the sum of the rate of heat addition to and the rate of work done on a fluid particle (first law of thermodynamics)

4. CONCLUSION

• The pressure drop considerably increases in wavy channel/surface as compared to straight channel.

• On increasing Reynolds number dynamic pressure increases significantly. However, straight channel has comparatively low dynamic pressure as compared to wavy channel.

• Coefficient of skin friction increases as Reynolds number increases. In wavy channel Coefficient of friction is significantly more due to have more surface area than straight channel.

• On realizing wavy 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 turbulence promotes the friction factor as Reynolds number increases.

• The thermal performance of any heat exchanger can effectively been increases by employing wavy surface/channel.

• Shear stress at the wall increases as the fluid flow rate increases.

• The heat transfer characterizes in pipe and ducts are enhanced by using extended surface in form of Wavy surface, Fin, baffles, artificial roughness which ultimately, increases the friction factor. Therefore it is extensively been employed in heat exchanger design

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