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EXPERIMENTAL INVESTIGATION OF SWIRL FLOW AND HEAT TRANSFER IN CONCENTRIC CYLINDERS

Qutaiba ADIL HASHIM AL-MAMOORI

Master's Thesis

Supervisor

Asst. Prof. Dr. Yaser ALAIWI

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The thesis titled EXPERIMENTAL INVESTIGATION OF SWIRL FLOW AND HEAT TRANSFER IN CONCENTRIC CYLINDERS prepared by QUTAIBA ADIL HASHIM AL-MAMOORI and submitted on 8/8/2023 has been **accepted unanimously** for the degree of Master of Science in Mechanical Engineering .

____

Asst. Prof. Dr. Yaser ALAIWI

the Supervisor

Thesis Defense Committee Members:

Asst. Prof. Dr. Yaser ALAIWI	Department of Mechanical Engineering, Altınbaş University	____________________
Asst. Prof. Dr. Abdullahi Abdu IBRAHIM	Department of Computer Engineering Altınbaş University	____________________
Asst. Prof. Dr. Ahmed SADIK	Department of Mechanical Engineering, Hasan Kalyoncu University	____________________

I hereby declare that this thesis meets all format and submission requirements of a Master’s thesis.

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Qutaiba Adil HASHIM AL-MAMOORI

Signature

DEDICATION

I dedication my thesis to:

Altınbaş University

My very respected supervisor

All my family members, especially my very dear mother and to my father his soul hovers around me all the time.

ABSTRACT

EXPERIMENTAL INVESTIGATION OF SWIRL FLOW AND HEAT TRANSFER IN CONCENTRIC CYLINDERS

AL-MAMOORI, Qutaiba Adil Hashim

M.Sc., Mechanical Engineering, Altınbaş University,

Supervisor: Asst. Prof. Dr. Yaser ALAIWI

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The heat transmission and flow structure of a whirling impinging jet on a flat surface with helicoid inserts are investigated both experimentally and numerically. The research focuses on flow dynamics in order to characterize the effect of swirl on impingement mechanics by modifying the number of helicoid surfaces known as single, double, and triple helicoid inserts. The goals for this project were to first simulate a viscous, low Reynolds number flow around a cylinder (Part 1) and then simulate a similar flow around an arbitrary geometry (Part 2). In Part 2, the group was interested in determining if the heat transfer increased due to the addition of a line of solid material attached to the downstream side of the cylinder at the center line. The first part of this project was used to make sure that there was a working simulation, which could test a more interesting geometry in Part 2. For this project, the hypothesis was that the heat transfer would increase due to the reduction in separation of the flow on the downstream side of the cylinder. The main assumptions and restrictions were that the flow is of a low Reynolds number and there is only two-dimensional heat transfer. The method used was a two-dimensional stream-function/vorticity finite difference model of governing equations with a Cartesian basis.

Keywords: Low Reynolds, Heat Transfer, Boundary Conditions, Nanofluids, Concentric Cylinder.

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ABBREVIATIONS

LMTD	:	Log Mean Temperature Difference
IPS	:	Indoor Positioning Systems
RFID	:	Radio Frequency Identification
DM	:	Data Mining
RSS	:	Received Signal Strengths
NTU	:	Number of Transfer Units

1. INTRODUCTION

Heat exchange between flowing fluids is one of the most important physical processes. Heat exchangers are used widely both in daily life and industrial applications such as food processing, heat recovery systems, steam generators in thermal power plants, evaporators and condensers in HVAC applications and refrigeration process, heat sinks, automobile radiators and regenerators in gas turbine engines. 90% of the heat energy utilized in energy production and management is carried through various types of heat exchangers. Due to space limits, the size of the heat exchanger is a crucial element in most applications. By improving the heat transfer properties, the size of the heat exchanger may be lowered. When compared to straight pipes, heat transfer rates in helical coil and spiral coil heat exchangers are high, especially in the laminar regime. The next section introduces heat exchangers and their categorization [1].

Numerous heat transfer augmentation techniques have been introduced by researchers considering the different issues associated with heat transfer characteristics. The benefits of the different expansion procedures incorporate lower heat obstruction [2] in a run of the mill heat exchanger by advancing better convective intensity move coefficient as surface region develops.

The persistent advancement in the area of heat transfer system is made in order to decrease the cost and size of industrial and commercial heat exchangers. Heat exchangers require further developed heat move coefficient estimation to perform successfully and productively. Smooth cylinders have unfortunate intensity move characteristics overall. Researchers are keen on the rifled cylinder due to its ability to expand the intensity move coefficient. Rifled tubes were made to further develop the intensity move viability of intensity exchangers. The exploratory assessment of intensity moves properties of water and Nanofluids streaming in a rifled cylinder at various speeds and working conditions in a rifled cylinder heat exchanger was examined.

This chapter discusses the motivation and background information regarding the research topics explored in this thesis, motivation, and significance of the work, and also the structure of the thesis.

1.1 INTRODUCTION TO HEAT TRANSFER

Heat transfer plays a major part in abundant practical situations such as automotive vehicles, electronic equipment, HVAC systems, and power plants etc. Also, many fabrication processes include transfer of heat in a variety of forms such as heat dissipation of various machining outfits, sterilization of food and the temperature tuning for activating a biochemical process. Among these applications, some heat transfer devices comprehend the heat transfer in evaporators, heat exchangers, heat sinks, and condensers [1]. Enhancing the heat transfer efficiency of these devices is necessary. Moreover, in many of the heat transfer systems, a pump is used for circulating the working fluid. It is also desirable to reduce pumping power. Therefore, the improvement in heat transfer effectiveness with least pumping power consumption is of utmost importance in present situation.

Numerous investigational and theoretical works have been conducted to augment or intensify transmission of heat in a heat exchanger. The design also involves the need for a compact structure with a least pumping power. There are certain mutual difficulties related with the application of heat exchangers in real-life conditions like surface erosion, fouling and to achieve optimum pumping power. In recent years, higher energy costs and material cost have caused an improved effort intended at making a more effective heat exchanger. The shrinking of a heat exchanger is needed for certain precise applications related to space and food processing.

An increase in effectiveness of the heat exchanger through an enhancement technique may produce a reduction in material cost. The heat transfer rate can be increased by providing a disturbance in the fluid flow. These results in increasing the pumping power. Thus, several latest methods have been suggested to accomplish a preferred heat transfer rate in a recently used heat exchangers. One among them is the addition of nanoparticles in conventional heat transfer fluids, named as Nanofluids [3] and reported they have more potential for improving convective transmission of heat in heat exchangers.

As a rule, upgraded heat move surfaces are utilized for three reasons: (1) to set aside time and cash so that heat exchangers can be made more modest, (2) to lessen how much siphoning power expected for a given intensity move interaction, and (3) to further develop the general intensity move coefficient of the intensity exchanger. The intensity move coefficient esteem is improved and might be obtained in one of two ways: (a) to find a superior intensity move rate by changing the admission liquid temperatures, or (b) to decrease the mean temperature distinction of an intensity exchanger. These enhancements result in improving the efficiency of thermodynamic processes.

When the performance of heat exchangers increases, it leads to an additional cost-effective design of heat exchanger which can aid to energy saving, reduced material and cost associated with the heat exchange process. Heat move upgrade or expansion alludes to the methodologies important to work on the warm properties of intensity exchangers, thusly saving energy, material, and cost. Because of lower warm opposition in an intensity exchanger, these procedures advance convective intensity move.

Heat transfer augmentation methods intensify the heat transfer coefficient and this results in increased pressure drop. So, a heat exchanger must be designed [4] using the available enhancement techniques in order to analyze the heat transfer rate and pressure drop. To accomplish a better heat transfer rate in a prevailing or novel heat exchanger, several innovative techniques have been suggested.

1.2 CLASSIFICATION OF ENHANCEMENT TECHNIQUES

Enhancement of heat transfer techniques provides an augmentation in thermo-hydraulic performance in the heat exchanging process. The existing augmentation techniques [5] are broadly categorized into the following different classifications. Passive Techniques, Active Techniques, Compound Techniques.

1.2.1 Passive Techniques

These methods usually use constructional or certain surface alterations to the channel of fluid flow by including inserts or extra attachments that stimulate increased heat transfer coefficients by modifying or varying the current flow performance. As a consequence of this it leads to increased pressure drop. For extended surfaces, there is an increase in effective heat transfer area across the surface side.

Passive techniques are more beneficial when compared to the active techniques since it does not entail external power supply. Heat transfer enhancement by these methods can be attained by using:

Treated Surfaces: It includes the process making modifications on the surface area of heat transfer via scratches, cavities or pits, which are used mainly for boiling and condensing duties.

Rough Surfaces: These are modifications in surface area which predominantly generate the alteration in the viscous sub-layer region, but these methods are appropriate mainly in single pass turbulent flows.

Extended Surfaces: One of the most primitive kinds of extended surfaces are plain fins, used widely in numerous heat exchangers. Finned surfaces are common nowadays because of their capability to interrupt the flow field and increase the surface area of heat transfer.

Displaced Enhancement Devices: There are different types of inserts for Confined forced convection which increases transfer of heat indirectly at the surface of heat exchanger. This is done by displacing the fluids from the hot or cold duct surface with the core fluid flow.

Swirl Flow Devices: On the axial flow of the channels these devices generates whirl or secondary circulation which is also called as swirl flow. Some of the general examples are helically twisted tape and twisted ducts which can be used together for one-pass and two-pass flows.

Rifled Tubes: Rifled tubes have internally ribbed rifles which produces centrifugal force inside the tubes. A mixture of steam and water usually flows within the tube. The centrifugal force results in heat transfer enhancement within the tubes. This process results in increased surface area with the highest heat transfer once it is compared with the performance smooth tubes.

Since it makes a twirling impact in the stream, rifled tubes capability better than smooth cylinders. Figure 1.1 (ASME, GB/T20409, Hua Xing, China) shows a rifled cylinder. The stream is constrained outwards towards the cylinder wall because of radiating power. The harshness elements of its internal math stir up the stream in the thick sub layer. Thus, a helical or twirl stream is presented close to the wall district, superimposing on the really hub stream. This whirl stream activity advances wall wetting while at the same time keeping away from significant intensity move even at high steam temperatures. The rifled cylinder development is otherwise called helically inside ribbed tube.

Figure 1.1: Rifled Tube or Helically Internally Ribbed Tube.

1.2.2 Active Techniques

This method needs some external power input to have the desired flow modification and an enhancement in the heat transfer rate. Since from the point of view of usage and design these methods are additionally complex. It has less application since it requires external power for many real time applications. When compared to passive techniques these techniques did not show much potential because of its difficulty in providing external power input in most of the cases. The different active techniques available are described below:

Mechanical Aids: These are also called as the rotating tube exchangers or scraped surface heat and mass exchangers. These aids agitate the fluid by automatic means or by revolving the surface.

Surface Vibration: This is used mainly in single pass flows. To enable the surface vibrations a low or high frequency is used which provides higher heat transfer coefficients.

Fluid Vibration: Vibrations are generated in the fluid by means of pulsations. This type of vibration augmentation procedure is done for single pass flows.

Electrostatic Fields: In order to simulate high volume mixing, magnetic or electric fields or a mixture of both from either direct or alternate sources are applied in heat exchanger systems. Moreover, electromagnetic siphoning or force convection are utilized to further develop heat transmission. This procedure can further develop the way that dielectric liquids send heat.

At the point when an equivalent or different liquid is infused into the essential mass liquid, this approach is used. The permeable intensity move interface, or its upstream part is utilized for this interaction. This strategy is utilized in the single-pass heat move technique.

Suction: This method has been used for both two pass and single pass heat transfer process. In two-pass heat transfer process, nucleate boiling is done which includes the removal of vapor through a porous heated surface, while in single pass flows, the fluid is withdrawn through a porous heated surface.

1.2.3 Compound Techniques

Compound enhancement techniques have more than one of the above stated techniques which are used in combination with the resolution to augment the thermo-hydraulic performance of a heat exchanger. This technique includes a very complex design and consequently it has very narrow applications.

1.3 PROBLEM

The heat exchangers plays a significant role in various industrial applications is in place to interchange the heat among the hot and the cold fluids. Rifled or ribbed tubes plays a vital role in many heat exchangers such as condensers, evaporators, boilers in the augmentation of the heat transfer parameters by introducing swirl effect. A survey of the published literatures depicts that not many works have been done till date to determine the heat transfer coefficient of nanofluids in rifled tubes. Heat exchangers with water based nanofluids has found application in solar based air conditioning and water heater systems, building heaters, industrial process heaters etc. The convenient and safe medium is water which is used in many industrial applications and hence considered as the base fluid in which TiO_2 nanoparticles are suspended to perform this study. Be that as it may, prior to utilizing the functioning liquid (TiO_2 - water Nanofluids) in a framework for some random application, it is basic to examine its intensity move boundaries, for example, thickness, warm conductivity, all out heat move coefficient [5], and pressure misfortunes attributable to rubbing. It ought to be noticed that while nanofluids with warm conductivity meet an essential models for their utilization, the sufficient condition is gotten from their presentation in convective circumstances. Thus, this study is significant in the ongoing setting of rifled tubes with nanofluids for heat transmission.

1.4 MOTIVATION AND OBJECTIVE

Due to the emergence of heat exchangers in various applications heat transfer enhancement plays a vital role. The rifled tube has the ability to improve the heat transfer coefficient and has been getting attention from researchers. To enhance the heat transfer efficiency of heat exchangers rifled tubes were developed. One of the latest innovations in heat transfer is the usage of nano-sized solid particles of size (1 - 100 nm) as an external agent dispersed in the base fluid. The key idea is to improve the thermal conductivity and enhance the features of convective heat transfer in conventional fluids. Recent technical advancements have made it possible to produce nano-sized particles, which when dispersed in the usual base fluids can overcome the problems caused by slurries. The term Nanofluids was given by [6] to denote a new category of heat transfer fluid that exhibits increased thermal properties than the conventional fluids.

1.5 CONTRIBUTION

Heat transfer augmentation methods could be utilized to enhance the thermal characteristics of heat transfer apparatus. Recently, numerous heat transfer augmentation methods are emerging and are used for improving heat transfer in heat exchangers such as evaporators, boilers, condensers, and other heat exchangers which is used in various enterprise applications. Rifled tube has shown tremendous enhancement in thermal energy and heat flow applications. In the present research, experimental investigations were made to evaluate the different parameters influencing the effectiveness of heat transfer and other characteristics of the internal rifled tube with internal helix angle 30o and 58o in a typical double pipe heat exchanger and those were compared with smooth tubes. The experiments illustrate that the heat transfer rate of 58o helix angle rifled tube is greater than 30o helix angle rifled tube which is better than smooth tube. Moreover, it is confirmed that for the increase in volume flow rates of both cold and hot fluids the heat transfer performance also increases. Also, it is evident that due to swirl flow in rifled tubes with higher helix angle, the Nusselt number is higher than that of smooth tubes. Many researchers proved that nanofluids have a higher heat transfer coefficient due to its thermal conductivity hence water is being replaced by nanofluids. Experimental investigations were performed with TiO2-water based nanofluids of 0.2% and 0.3% concentrations using internally ribbed tubes of 58o helix angle alone since it is found to be more effective than other test sections. The observations indicate that as the Reynolds number increases, there is a significant increase in heat transfer coefficient that causes.

1.6 THESIS OUTLINE

This thesis is divided into five chapters. In this chapter, we summarized the area that we are working on. In Chapter 2, we will go over the efforts made by academics and businesses to improve indoor localization in depth. Our project will be thoroughly examined in Chapter 3. Software requirements and architectures are displayed and discussed. In Chapter 4, we show the system evaluation and experiment results of various algorithms that we used. And in Chapter 5, we talk about our next steps forward.

2. LITERATURE REVIEW

In recent years, the world has shifted its main focus on augmenting the heat transfer equipment. The prime reason of this improvement is to preserve the energy. The tremendous rise in the researches on heat transfer enhancement techniques implies the importance of the same in improving the efficiency of a system. In case of automobiles and aircraft, the heat exchangers used are of lightweight as well as compact. These heat exchangers along with some other significant heat transfer equipment's deployed in the industries play a major role in enhancement of heat transfer. Rifled tube which is otherwise called as helically ribbed tube with a commercial name of Turbo-Chil™ tube is a passive heat transfer enhancement technique. It is an example of two dimensional rib roughness. The term 'rifled tube' is from its appearance similar to the rifled barrel in a firearm [7].

Over the decade, the heat transfer enhancement technique is mainly concentrated towards the implementation of Nano fluids as it has excellent heat transfer capability. Also nowadays, application of heat transfer augmentation technologies to heat exchanger used in refrigeration, automotive and process industries, etc. can be widely found. The performance of a heat exchanger is determined by its economical design and the working fluid used. A comprehensive literature survey was performed on various topics of the present work which includes.

i. Heat transfer characteristics in smooth and rifled tubes.

ii. Convective heat transfer characteristics of nanofluids.

iii. Heat transfer augmentation in heat exchangers with nanofluids from the investigations major conclusions are made which results in an enhanced heat transfer in rifled tubes under different operating condition.

2.1 HEAT EXCHANGERS

An intensity exchanger is a gadget that moves heat between at least two liquids of contrasting temperatures. The liquids can be single-stage or two-stage. Heat exchangers are classed in light of the intensity move process, stream course of action, and development type (figure 2.1). An immediate contact heat exchanger is one in which two liquids trade heat by coming into contact. Open feed water radiators, cooling pinnacles, desuperheaters, and fly condensers are instances of this kind. Most intensity exchangers send heat between liquids through an isolating wall, and such trades are known as immediate exchange type or recuperators. Circuitous exchange type or regenerators are heat exchangers that have discontinuous intensity trade among hot and cold liquids by nuclear power stockpiling and delivery through the exchanger surface.

The isolating mass of recuperative intensity exchangers can be an essential plain wall or a cylinder, or it very well may be a complex construction including blades, confounds, and a few entries of cylinders. Cylindrical intensity exchangers are additionally partitioned into twofold line, shell and cylinder, and winding cylinder heat exchangers. The least complex kind is the twofold line or cylinder in tube heat exchanger, which comprises of one line embedded concentrically inside one more line with a bigger width. One liquid goes through the cylinders in the shell and cylinder heat exchanger, while the other liquid streams outside the cylinders however inside the shell.

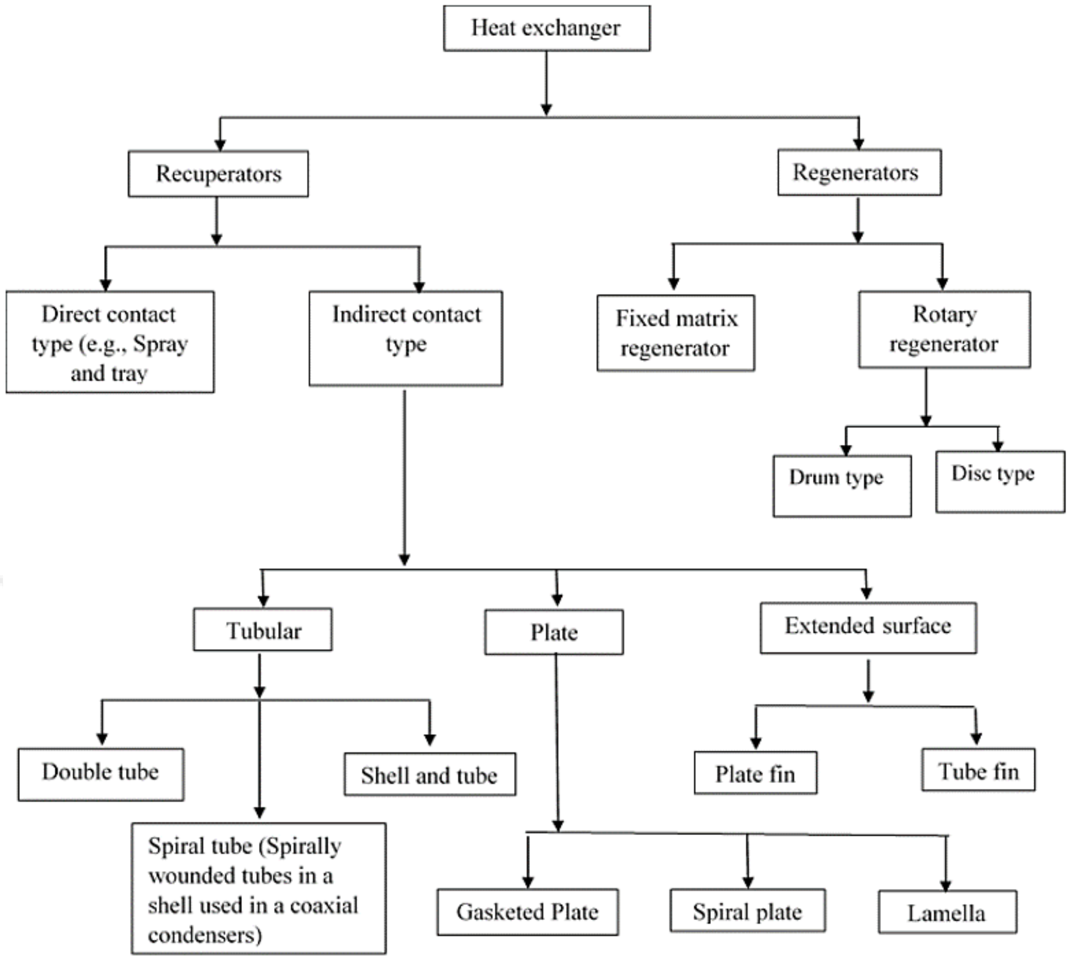

Figure 2.1: Classification of heat exchangers.

In general, regenerators are classified into the rotary type and fixed type, depending on whether the matrix material is moving or stationary. The liquid moves through the grid material at a steady speed in the turning type, and the lattice turns gradually across the two liquids. Because of going through the warm and cold liquids, the framework material is over and over warmed and cooled. The decent framework type contains two indistinguishable fixed grids, and the liquid is traded between regenerators consistently through fast working valves. Because of the inversion of the move through the grids, the lattice is consistently warmed and cooled.

Based on the direction flow of the hot and cold fluids inside the heat exchanger, they may be of parallel flow, counter flow or crossflow type. If both the fluids flow in the same direction, the arrangement is called a parallel flow type. In the counter flow type, the fluids flow in opposite directions. If the fluids flow right angles to each other, the arrangement is called a cross-flow type.

The pace of intensity move in an intensity not entirely settled by the temperature differential between the two liquids at a point that shifts with the intensity exchanger. It is regularly simpler to manage the logarithmic mean temperature contrast (LMTD) in heat exchanger examination since it is a comparable mean temperature distinction between the two liquids all through the entire intensity exchanger.

2.2 HEAT TRANSFER CHARACTERISTICS IN SMOOTH AND RIFLED TUBES

Several researchers have published articles on the implementation of rifled tubes in the heat exchange characteristics since the research on rifled tube [10] has been undergone for a long time. Over the past years, numerous flow boiling heat transfer enhancement methodologies such as, electrostatic field, rough surface, additives for fluids have been utilized. Among these, the effective flow boiling heat transfer and critical heat flux enhancement have been achieved by the spirally internally rifled tube. A practical examination of turbulent heat transfer at different temperature profiles in a rifled tube was performed by [11]. In order to do this, a spiral rib of 2.58 pitch to diameter ratio with copper bar was built by the author and was placed inside a smooth brass tube carefully. It was noted that heat transfer resistance decreased in this type of temperature profile and an enhancement in heat transfer efficiency when compared to smooth tube.

To accommodate two-stage flow patterns, the creators used internally ribbed cylinders in combination with level cylinders. They examined pitch-to-diameter ratios of 1.57 and 2.79 and compared the smooth cylinder with rifled cylinders based on single-stage friction factor. Their results showed that the friction factors for the rifled tubes were greater than that of the smooth cylinder and that there was a correlation between the friction coefficients of the two rifled tubes. The study also revealed that swirl flow could only be achieved when a critical liquid shallow velocity was reached [12].

In addition, the authors conducted a FLOW3D simulation study to investigate the flow over transverse and helically ribbed cylinders using five ribbed geometries with rib numbers ranging from 0 to 30, rib angles ranging from 0° to 59.767°, and rib widths ranging from

0.8609mm to 0.4335mm. They selected ribbed geometries with an inner diameter of 39.44mm, an outer diameter of 98.09mm, a rib height of 1.13mm, and a rib pitch of 7.29mm. The researchers compared the flow pattern and pressure drop of these ribbed geometries with that of a smooth cylinder with an inner width of 39.44mm and an outer diameter of 98.09mm. They found that apart from very small rib angles (under 19°) on the helical ribbed shape, zones of separation and recirculation did not exist in turbulent flow. The potential for a 'hotspot' or critical power flow at the wall region was very low, as the amplitude of the near-wall velocities increased significantly in the helical channel between the ribs. The authors found that the standard model was the least effective in predicting swirling flow, and there was a lack of correlation between the experimental data and simulation results [13].

Another study affirmed the neighborhood and normal vehicle coefficients for tempestuous stream in inside ribbed tubes. The examination introduced discoveries at the entry area, completely created discoveries, and nearby discoveries. The impact of rib separating and rib level in the ribbed cylinder on pressure drop was examined, and it was found that the grating element in the ribbed cylinder was less receptive to pitch and more delicate to dimensionless rib level. The creators didn't offer adequate discoveries on the siphoning ability to warm exchange proportion. The authors had both contributed to the calculation of local and average coefficient for the turbulent flow in rifled tubes. The authors concluded that the sensitivity of friction factor is high with the rib height whereas the sensitivity is zero with the pitch. Besides that, the value of Heat transfer coefficient increases with Reynolds number and vice versa. But the authors failed to arrive at the pumping power with heat transfer [14].

A research on two phase flow patterns and pressure drop in single and double helically ribs was carried out by [15]. For this, helical wire ribs with heights of 0.32, 0.64 and 1.27 cm and helical twisted ratios of 1.2, 2.1, 2.3, and 2.5 were used. These helical ribs were introduced into two tubes with variable diameters of 2.54cm and 5.10cm respectively. It was found out that the swirling occurred and critical heat flux also enhanced when a minimum flow velocity was exceeded. Relationships were proposed fully intent on being utilized in air-water frameworks that pre-owned tubes with measurements going from 1cm to 5cm, and the speed of the fluid is between 0.1m/s and 0.5m/s, while the speed of the gas differs between 0.2m/s and 25m/s.

In the same context, a recent study computes the basic intensity motion of R134a for various streams in an upward smooth and rifled tube that was similarly warmed. The basic intensity motion increase estimated here is 40-60% a bigger number of than that of the smooth cylinder. Notwithstanding mass transition and strain, exploratory information showed that the basic helical point and basic speed impacted basic intensity motion upgrade. Rifled tubing was utilized to work on the proficiency of evaporators and condensers in two-stage refrigerant stream applications. Moreover, the powerful temperature differential between the cylinder wall and the refrigerant gas-fluid point of interaction develops as film thickness diminishes, expanding heat move potential much further. Moreover, the rifled cylinder expands the size of the wetted surface region for dissipation, which is helped by supporting annular stream in the evaporator loop. Moreover, for condenser and evaporator settings, the intensity move coefficient for rifled tubing is upgraded to over two to multiple times that of smooth cylinder [16].

Further study utilized rifled vanishing tubes in steam boilers to increment steam-water combination turbulation and stay away from tube wall wear at the Nuclear energy Station Kolubara B being worked by the Electric Power Utility of Serbia [17]. [18] estimated the tension misfortune in an upward rifled tube in two stages. For tests, it utilized the Friedel model and a two-stage homogeneous model. During the analysis, the strain drop from the two indicated models was estimated. The outcomes showed that the strain misfortune brought about by contact in the rifled cylinder was more prominent than that in the smooth cylinder.

More recently, the post-dry out heat transfer was investigated in a heated smooth cylinder and rifled tubes using upward R134a upstream to examine the heat transfer characteristics in the post-dry out zone. Three types of rifled tubes with varied rib heights and widths were evaluated at a mass flow rate of 70-800 kg/m2 s and a pressure of 13-24 bar to investigate the effect of rib geometry and to compare with the smooth cylinder. The study also showed that rib height and width variations in the smooth cylinder mix influenced the heat transfer correlation for rifled tubes, and that swirl flow improved the heat transfer properties of the rifled tube. On the other hand, [20] from China investigated the heat transfer and friction characteristics of the rifled tube in water flowing in the vertical upward direction, which was designed for the wall of a 600MW supercritical CFB boiler. The experiment was conducted at pressures ranging from 12 to 30 MPa and with an inner wall heat flux varying from 130 to 720 kW/m2 [19][20].

The heat transfer properties of a low mass flux rifled tube submerged in water with upward flow were examined in a study. The investigation focused on analyzing the temperature distribution at the wall surface within the rifled tube under various operating conditions. The findings demonstrated that the rifled tube design effectively enhanced heat transfer performance, ensuring sufficient tube cooling and promoting the safe operation of the boiler water wall [21]. In another study, the influence of geometrical factors of rifled tubes on flow characteristics and heat transport in supercritical water was numerically investigated. The results revealed that an increase in mass flow or heat flux led to a decrease in pressure loss and heat transfer [22]. The heat transfer properties of a downhill tube inclined at a 45-degree angle from the horizon, featuring an inner diameter of 20 mm and operating within a pressure range of 11.5 to 28, were examined in a study. The findings indicated that the heat transfer properties of water varied along the circumference of the inclined downward tube, highlighting differences from the top surface [23].

CFD recreation was utilized to estimate the intensity move coefficient for two sorts of rifled and plain cylinders, and the connected all out heat move values were accounted for by [24]. Slawomir and Karol (2016) proposed a circulated boundary model in light of tackling balance conditions to assess heat move coefficient, liquid enthalpy conveyance, mass stream, and tension in inside ribbed tubes. The trial was completed under different working conditions, and the mathematical estimation results were contrasted with the CFD displaying discoveries. In a recent study, an investigation was proposed to assess the effect of an increment in upward flow intensity within an adjusted rifled tube. The experimentation involved conducting tests at different pressure ranges and heat flux levels. A comparison was made between the heat transfer coefficients of vertical upward and downward flows. The results demonstrated that the rifled tube design effectively prevented the occurrence of departure from nucleate boiling, in contrast to smooth tubes. Additionally, the findings concluded that heat transfer was significantly enhanced within the pseudocritical enthalpy region [25].

Many numerical and experimental investigations on different applications such as condensers, evaporators with working fluids such as R134a, water and kerosene under different conditions inferred that there was significant improvement in the vehicle of intensity. Examinations on the intensity move properties of smooth and rifled tubes under different working conditions prompted discoveries that rifled cylinders have higher generally heat move coefficients and intensity move rates than smooth cylinders.

2.3 CONVECTIVE HEAT TRANSFER CHARACTERISTICS IN NANOFLUIDS

Nanofluids are potential intensity move liquids because of their high warm conductivity increment. Prior to utilizing nanofluids in real applications, it is important to explore their convective intensity move properties [26]. A few examinations have explored the convective intensity move capacity of nanofluids [27] by considering different nanoparticle, base liquid, size, and shape factors, as well as shifted temperature conditions. This segment talks about a portion of the examination on nanofluids convective intensity move.

The heat transfer performance of carbon nanotube structures in water-based nanofluids was studied by [28] analyzed the effect of temperature and time variation. It was noted that with an increase in the number of nanotube walls, there was a reduction in the thermal conductivity. The thermal conductivity of NH_3 and water mixtures at temperatures between 293.15 K and 313.15 K was studied by [29] under experimental set up. It was found that there was an improvement in the heat transfer of NH_3-water mixture when the temperature increased, and it decreased when there was an increase in the ammonia mass fraction.

The thermal conductivity of nanoparticles such as graphene at different temperatures and different concentrations ranging from 0.01–0.2vol. % was examined by [30]. The results concluded that the thermal conductivity increased with the increase in graphite concentration and there was an enhancement of heat transfer to 27% which was achieved at 0.2% concentration. [31] developed a specific prototype to predict the effective thermal conductivity of nanofluids by taking the effect of the nano shell made of nanoparticle fluid molecules into consideration. It contrasted from the customary model in that it considered the span of the nanoparticles, warm conductivity, and thickness of the interfacial nano-shell. Also, this model anticipated expanded warm conductivity as well as the proportion of molecule and fluid warm conductivities with their relative volume portions.

In their study, proposed an innovative approach to examine the thermophysical properties of nanofluids, focusing specifically on the thermal conductivity of Al2O3-water and ethylene glycol-based coolants used in car radiators. The research findings revealed that the thermal conductivity of nanofluids increased with higher volume concentrations. Furthermore, the thermal conductivity was found to be enhanced at elevated temperatures, indicating better performance of nanofluids under such conditions [32]. Another study conducted by [33] investigated the thermal conductivity and viscosity of Al2O3 nanofluids through experimental analysis. The study considered a wide range of parameters, including particle concentrations (ranging from 0.3% to 1.5%), temperatures (20-60 °C), and various base liquids. The results demonstrated that the thermal conductivity of nanofluids increased with rising temperatures and higher volume concentrations. Notably, existing models such as the Traditional Hamilton-Crosser and Einstein models failed to accurately predict the thermophysical properties of nanofluids in the presence of temperature variations. Consequently, a correlation was proposed to estimate the properties of nanofluids.

The heat transfer coefficient was investigated by [34] for zirconia water and alumina water nanofluids at the entry region and at the fully developed region. This gave an observation that heat transfer coefficient increased up to 27% for an agreed velocity and channel geometry at 6 vol. % of alumina nanofluids. This was found to be high when compared to the water in the entry region, while the heat transfer coefficient of zirconia nanofluids exhibited enhancement at a much lower rate with regards to water. The group recommended that, just because of several combination properties of the nanofluids it behaved as homogeneous mixtures and also the coefficient of heat transfer enhancement was not irregular. [35] explored the performance of convective heat transfer with water that is suspended with alumina nanoparticles of varying sizes (such as 45 nm and 150 nm) in the pipe flow's developing region in the laminar flow regime with constant flux condition. The research resulted with observations that the nanofluids exhibited greater heat transfer coefficient with 45 nm particles than that of the 150 nm particles. Also, it was noted that at the developing region the heat transfer coefficient was high while the nearly developed region was low due to the property variation and the likelihood of superior particle migration effect with inferior particle masses.

In a study conducted by some researchers , an analysis was performed to investigate forced convection in a double-pipe heat exchanger using biological nanofluids. The base fluid used was Ethylene-glycol/water, and different volume fractions of the nanomaterial (0.1%, 0.5%, and 1%) were examined. The results confirmed that the heat transfer coefficient was significantly enhanced, with a 67% increase observed at a volume fraction of 1% [36]. In a separate study, [37] examined the use of Fe3O4/Water nanofluid with varying volume fractions of Fe3O4. The findings demonstrated an improvement in heat transfer rate at higher volume fractions, accompanied by a decrease in pressure drop. Furthermore, the authors conducted a numerical investigation to study the effects of corrugation profile and CuO-Water based nanofluids. The study revealed that increasing the volume fraction of nanoparticles and Reynolds number led to an enhancement in thermal performance [38].

In another study, a recreation was conducted to examine the behavior of nano-diamond water nanofluids and evaluate their thermophysical properties, including viscosity and thermal conductivity. The study also explored potential applications of these nanofluids in various heat transfer scenarios. The results demonstrated that at volume fractions of 12.7% and 22.8% with 1.0 vol. % concentration, there was an enhancement in thermal conductivity [39]. In a different experiment, the authors investigated the performance of heat transfer using different types of nanofluids, namely Al2O3-water, ZnO-water, and SiO2-water. The study focused on convective heat transfer characteristics in both smooth and rifled tubes under various operating conditions. The findings revealed that an increase in Reynolds number corresponded to an increase in the heat transfer coefficient [40].

The intensity transmission coefficient increments as the size of the nanoparticles diminishes. The intensity move coefficient increments as the liquid temperature increases. The intensity transmission coefficient increments as the volume grouping of nanoparticles increments. Warm conductivity is significant in further developing the convective intensity move properties of nanofluids.

2.4 HEAT TRANSFER AUGMENTATION WITH NANOFLUIDS IN HEAT EXCHANGERS

The improvement in heat transfer characteristics of multi-walled carbon nanotube were experimentally analyzed by [42] Experimentation was performed in a shell and tube heat exchanger using water based nanofluid. Utilizing base liquid that has multiwalled nanotubes expanded the presentation of the intensity move properties. [43] inspected the intensity transport of thermochromic fluid gems at different Reynolds numbers utilizing a spirally fluted tube and a smooth cylinder. The outcomes showed that at lower Reynolds quantities of 30,000 than at higher Reynolds quantities of 50,000 to 70,000, the improvement proportion of intensity move between the spirally fluted tube and the smooth cylinder is enormous.

For further experiment researchers analyzed experimentally the viscosity, turbulent heat transfer, and thermal conductivity of Magnesium Oxide–water nanofluids in a circular pipe with low concentration of nanoparticles. In the study, it was found that thermal conductivity were not successful to predict through conventional models[44] . And other performed various studies on Nanofluids in the flat, smooth, spirally corrugated tubes, and spirally coiled tubes with an emphasis on the heat transfer enhancement. The heat transfer characteristics of Al2O3-water Nanofluids in turbulent flow was studied both experimentally and numerically in a helically corrugated tube. The outcomes proved out to have better performance in terms of heat transfer when compared to a smooth tube [45].

"In a study conducted recently, different types of nanofluids were used to investigate their heat transfer properties. The study focused on Fe2O3-EG and Fe2O3-water nanofluids, which were tested in a shell and tube heat exchanger. The results showed that Fe2O3-water nanofluids performed better in terms of thermal transmission [46]. In a study conducted by [47], Cu-water nanofluids were tested to investigate their pressure drop and heat transfer properties. The study used a horizontal double-tube heat exchanger, and the results showed that the heat transfer enhancement of nanofluids increased with the nanoparticle concentration [47]. In an experiment conducted by [48], the heat transfer improvement in smooth tubes using TiO2-BioGlycol/water nanofluids was examined. A new correlation was found between the friction factor and the heat transfer enhancement. The results showed that the heat transfer performance of nanofluids had improved by approximately 28.2%, which was higher than that of the base fluid [48].

All of the above mentioned work shows that using nanofluids can increase the heat transfer rate, thermal conductivity and heat transfer characteristics. Heat transfer performance of heat exchangers can be improved using nanofluid. The performance of nanofluids also helps to reduce the cost and different heating and cooling systems. The past exploration essentially affect the stream and intensity move attributes of smooth cylinders, rifled tubes, heat exchangers, spirally folded tubes, etc. The essential commitment of this postulation is a careful assessment of the intensity transmission properties of water and TiO2-water nanofluids in rifled and smooth cylinders.

2.5 RELATED WORKS

It is for the most part realized that convective vehicle in a laminar limit layer stream on moving surfaces is more vigorous than limit layer stream on fixed limited length surfaces. Due to its natural strength and wide purposes in various designing and modern cycles, stream on moving nonstop surfaces has been seen as of gigantic importance. Hot expulsion, hot rolling, persistent projecting, wire drawing, and different cycles are models. The speed of cooling, as in the drawing of persistent fiber, affects the item's properties in numerous metallurgical cycles. The subject surface is extended with a postponed speed in different modern tasks where the end yield should be of the normal wanted thickness. The stream becomes slowed down in downstream regions because of such eased back speed. This is likewise apparent in table 4. This condition is practically identical to stream partitions as limited length surfaces. This can altogether alter the assembling system since the stream detachment peculiarities influences the wall skin-grinding and the Nusselt number in the zone of holding onto stream. Staying away from or delaying this peculiarities is consistently ideal in light of the fact that the cooling system is essentially impacted there. The gear used to fulfill modern requests, especially streamlined vehicles, has been designed to decrease energy misfortunes brought about by the event of stream detachment. In this light, it is beneficial to examine the vehicle peculiarities on a moving consistent body close to a holding onto stream zone. It is likewise deep rooted in the writing that the TVC assists with forestalling or postpone stream partition on a nonstop surface moving at a hindered speed and keeps the stream joined to the surface any more, It follows that the intensity move peculiarities close to a constant body going at a postponed speed and including surface cross over shape ought to be examined.

In their study, employed an integral approach to address the laminar flow around a circular cylinder [4]. Subsequently, several researchers investigated the flow characteristics around a translating cylinder under various flow assumptions, and some of their findings can be found in subsequent studies [6-13]. Crane [6] specifically examined the boundary layer flow induced by a cylinder moving through a quiescent fluid. He found that as one actions from the hole, the thickness of the limit layer thickens. Logical arrangement of laminar limit layer stream from a moving chamber researched by [7]. Their examination utilized an estimate approach in which the error in contact coefficient develops as the pivotal distance on a constant chamber increments. [8] inspected the consistent state temperature conveyance of a strong chamber going pivotally through a hot gas crossflow. They expressed that their discoveries may be gainful to the moving wire approach for inspecting polymer combustibility and evaluating heat from gases. In a different work, [9] researched the warm limit layer on a persistent chamber for little upsides of the surface cross over ebb and flow boundary and assessed the blunder by looking at exact and estimated arrangements delivered by the Kármán-Pohlhausen essential methodology. [10] concentrated on the limit layer stream prompted by a nonstop axisymmetric versatile surface. Their exploration was fixated on the advancement of undifferentiated from answers for the introduced issue, as well as related applications in intensity and mass exchange of flexible surfaces in the fiber fabricating process. [11] explored the intensity move of laminar limit layer stream, as well as static and persistent chambers presented to wall surface temperature and intensity motion. They utilized a neighborhood closeness arrangement and noticed that for a high standardized streamwise distance, the arrangement delivered through the nearby similitude approach is more useful than that gained with the bother system. Another examination [12] assessed the lightness consequences for a convective laminar limit layer stream incited by an in an upward direction moving chamber by thinking about the surface temperature and the wall heat transition. They utilized nearby likeness answers for represent the impact of surface cross over arch and lightness boundaries on surface erosion and intensity move rate. Wang [13] examined heat transmission in a liquid stream brought about by an extended chamber. He utilized remarkable change to get similitude arrangements and contrasted them with asymptotic arrangements. [14] inspected time-subordinate laminar stream with heat move on an extended chamber utilizing surface temperature and wall heat motion suppositions. They utilized the homotopy examination strategy (HAM) to foster a scientific answer for the endless fleeting space, and they saw that the surface cross over ebb and flow boundary essentially affects the speed and temperature limit layers.

In another study, research was conducted to investigate the effects of an intensity source or sink on laminar boundary layer flow induced by a stretched cylinder immersed in a porous medium with suction or injection [15]. Additionally, [16] examined the laminar boundary layer flow and heat transfer characteristics associated with a stretched cylinder while considering varying thermal conductivity. Several studies with different flow assumptions have been published in the literature, and additional references can be found in subsequent studies [17-25]. Various examinations have recently been directed to research heat transport investigation across axisymmetric surfaces. [26] determined the impacts of an outspread attractive field and slip on the consistent free convective limit layer stream of an electroconductive polymer across an isothermal circle. [28] approximated an unsound radiative intensity transport through an agreement chamber under the effect of magnetohydrodynamic Casson fluid. They saw that raising the worth of the flimsiness boundary essentially builds the speed of cooling. [29] examined the actual attributes of non-Newtonian (CarreauYasuda) liquid stream and intensity transport over an upper paraboloid surface of turn.

Self-comparable and non-comparative limit layer streams are frequently separated. The heft of the streams in the first examinations are all self-comparable in character. The non-comparable class is considerably greater than the class of self-comparative limit layer streams. In any case, [5] researched the principal stream made by a moving consistent chamber in 1961. Soon thereafter, Crane [6] exhibited that assuming that the chamber is extended straightly downstream, a self-comparative arrangement is conceivable. By and large, stream non-closeness can happen inferable from the idea of free-stream or reference wall speed, surface mass exchange, TVC, etc. [31] explored the intensity move peculiarities in limit layer stream close to the entry of a round and hollow line with a steady span. As indicated by the discoveries, TVC altogether increments wall shear pressure and nearby Nusselt Number. [32] researched a laminar limit layer stream on round and hollow bodies with explanatory and outstanding body shapes, showing the helpful impact of TVC on the stream. Jaffe [34] researched the laminar limit layer stream through a round chamber computationally to explore the TVC influences on the stream and tracked down great concurrence with the ebb and flow writing. Mehmood and Usman [1] researched a stream across a chamber surface with various cross segments and found that TVC assists with delaying stream partition to additional downstream places. There are different hindered reference speeds in the writing that display non-comparative way of behaving or make the stream break from the surface or get seized. Various analysts have involved different types of impeded reference speeds in their examinations [35-43] under different stream presumptions and stream boundaries, including division point computations. As of late, [2] inspected the effect of TVC on postponed limit layer stream and found that surface cross over arch serves to defer partition significantly. [3] explored a deferred wall speed of the Görtler type for moving roundabout chambers with consistent range. They determined the partition locales for various upsides of the speed example m and explored the effect of the TVC on speed profiles and wall shear pressure. It is normal to investigate the intensity peculiarities in such an isolating zone in this unique situation. It is captivating to investigate the intensity move process in the close by area of stream partition in such limit layer streams in light of the fact that the course of intensity move is anticipated to get slowed down there.

2.6 MAJOR OBSERVATIONS

From the literature survey, it is studied that most of the investigation carried out on heat transfer enhancement and the following conclusions are made which is common to all researchers,

i. The heat transfer enhancement in rifled and smooth tubes with different applications confirmed that heat transfer characteristics such as Nusselt number, overall heat transfer coefficient, heat transfer rate of rifled tubes are more than that of smooth tubes.

ii. Due to the high thermal conductivity of nanoparticles the convective heat transfer characteristics of nanofluids plays a major role in heat transfer enhancement compared to water. Many researchers have used many nanoparticles like TiO2, Al2O3, SiO2, and ZnO etc. The performance of nanofluid needs to be understood before the application of nanofluids in practical situations.

iii. When there is an increase in Reynold number there is an increase in heat transfer coefficient. When the nanoparticle size decreases there is an increase in the heat transfer coefficient. When the fluid temperature increases there is an increase in heat transfer coefficient.

iv. With the increase in nanoparticle volume concentration the heat transfer coefficient increases.

v. When the Reynolds number and particle volume concentration is higher there is a considerable penalty in pressure drop.

vi. Long standing stability of nanofluid is not clear, and

vii. Thermal conductivity plays a major role in augmenting convective heat transfer characteristics of nanofluids.

2.7 RESEARCH GAP

Based on the extensive literature review, the following research gaps have been identified for the proposed research work:

i. Few literatures have reported the effect of overall heat transfer coefficient and effectiveness of rifled tubes with different heat exchangers.

ii. Previous studies did not consider the investigations on heat transfer characteristics of both smooth and rifled tubes with their performance comparison at different flow rates.

iii. There is no study to find the effect of heat transfer in rifled tubes under different helix angles.

2.8 SUMMARY

This chapter provides a comprehensive survey of published literatures in the augmentation of heat transfer characteristics in numerous applications like boilers, heat exchangers, evaporators and condensers of refrigeration, and air conditioning systems, etc. with smooth and rifled tubes. Also, the heat transfer characteristics of Nanofluids in heat exchangers were examined and from the implication of the survey, the research gap is identified from which the objective of the research is decided.

3. PROPOSED SYSTEM

Disturbance's capacity to move and blend liquid undeniably more actually than practically identical laminar stream is a significant property. Violent liquid stream is recognized by turbulent changes in boundaries like fast changes in speed and tension in reality, as well as eccentric developments of three-layered vorticity. Disturbance is significant in deciding a few designing qualities, including frictional drag, heat move, stream partition, progress from laminar to fierce stream, limit layer thickness, and fly and wake spreading. At the point when disturbance exists, it ordinarily overshadows any remaining stream peculiarities, bringing about expanded energy scattering, dissemination, blending, heat move, and drag [49]. The present investigation pertains to analysis of turbulent fluid flow and heat transfer in cylindrical duct keeping in mind some typical applications. The study of side injection in a main turbulent flow through a circular duct is important both from a practical point of view and from a basic research point of view because a variety of fluid dynamics phenomena involved. Because of its importance in a variety of applications, several experimental, theoretical, and numerical works have been performed by many researchers. These applications include Gas Turbine Combustion Chamber, vortex burner, rotating heat exchangers and pipes, jet pump, rotating electrical machineries, mixing apparatus, drilling machineries flow of exhaust gases in chimney stakes etc [50]. In the turbulent fluid flow, the presence of turbulent fluctuations and formation of eddies of different length scales results in mixing and increment of energy dissipation. In such cases, experimental results are troublesome to evaluate and as well as it is both difficult and costly to take measurements of flow conditions under real operating conditions. This experimentation requires sophisticated instrumentations and adequate expertise, which may not be always possible and if possible, may not be satisfied up to the mark. Eventually theoretical platform become essential for the proper estimation of the turbulent flow with attainable accuracy. Results with some discrepancies may serve the purpose of getting the solution of turbulent fluid flow applicable to industrial processes. Thus numerical analysis becomes an extremely vital and significant tool to analyze, visualize and simulate such types of problems [51].

To determine optimal distance between pumping stations it is necessary to predict the energy loss as turbulence dissipates flow energy. The flow moves too slowly or even stops flowing if this distance is too large and on the other hand if the distance is too small the pumping system becomes under optimized which leads in increment of pump installation, operation, and maintenance cost. Liquid stream in roundabout and noncircular pipelines is a standard event in day to day existence. Pipes transport hot and cold water all through the house. Water is disseminated all through a city by means of huge funneling organizations. Enormous pipelines send oil and flammable gas many miles. Blood circles all through the human body by means of courses and veins. Cooling water in a motor is conveyed by hoses to radiator pipes, where it is cooled as it moves [52]. Nuclear power in a pressure driven space warming framework is moved to the streaming water in the kettle and afterward communicated through lines to the proper spots. Therefore, stream examination through pipes is a vital concern. The progression of fluid through pipelines is likewise significant in an assortment of viable designing applications, for example, expulsion processes, shape filling, food, milk, and drug matter handling, and a lot more creation processes. To help with exploratory and mathematical assessments of such streams, the stream in a barrel shaped channel can be utilized as a delegate proving ground since it includes perhaps of the least difficult calculation. A large part of the crucial comprehension of violent free shear layers and isolated inside streams in Newtonian liquids has come from investigations of course through a roundabout channel. Choppiness model designers definitely stand out enough to be noticed on these streams, and to assess and work on their reproductions, they involved a tube shaped channel as a key calculation [53].

3.1 RELATED WORKS

Literature survey is classified into several topics with respect to the need of present study. Starting from the preparation and property analysis of Nanofluids, heat transfer study of Nanofluids, effect of tube inserts in a tubular heat exchanger and the performance of Nanofluids along with the tube inserts. Some recent review articles from [6] and [7] illustrated the challenges faced by the several researchers during preparation methods of Nanofluids. The above mentioned authors also listed the preparation method, volume concentration selected by the researchers, stability analysis and properties measurement methods followed by the researchers in detail. Lie et al [8] reviewed the effect of different inserts used in heat exchanger. They reported the list of tube inserts along with the enhancement details due to its swirl flow generation in the flow field. The working fluid in their study was water and air. [9] reviewed the heat transfer effect of Nanofluids in which the convective heat transfer characteristics of different Nanofluids with different volume fraction were listed. [10] reviewed the effect of different inserts along with the combination of different Nanofluids with various volume concentrations in tube heat exchanger. The above review articles highlight the recent research conducted in the area of Nanofluids and tube inserts for the past one decade. Each of the papers zeroed in on the exploratory impacts of warm conductivity, nanofluid thickness, whirl stream production of cylinder embeds, and constrained convective intensity move. A few recently distributed works including the utilization of nanofluids are depicted in the segments that follow [11]. A survey of the writing shows that some exploration on Nanofluids heat move in tube heat exchangers fitted with embeds has been finished at the public and global levels. Nonetheless, it is perceived that this is a somewhat neglected field for directing examination examinations [12].

3.2 MOTIVATION

The essential objective of intensity move examination in heat exchangers is to diminish energy utilization through rating investigation and size through estimating examination. The objective of rating investigation is to benefit from the framework with minimal measure of info. To put it another way, bringing down energy use. Measuring examination is utilized to decide an improved strategy to accomplish greatest framework minimization while as yet considering imaginative plan changes in the framework. Heat transfer analysis methods, to analyze any type of heat exchanger, developed along with the modern technology. Many researchers contributed in the development of heat transfer analysis techniques. In this, one of the technique is to increase the properties of working fluid and producing new class of working fluid with the help of modern technology. Remarkable developments in the field of nanotechnology provide an opportunity to produce new working fluid called Nanofluids for thermal equipment. Initially, it was prepared by [1] in Argonne national laboratory located in United States. [1] first prepared nano sized particle separately and then added it into the base fluid like water with different volume concentrations. The final solution is prepared at various concentrations by mixing the nanoparticles to water.

3.3 PROPOSED SYSTEM

Impinging jet has evolved as a primary source for controlled cooling as well as heating of a surface due to its exceptional ability to enhance heat transfer rate in a wide variety of industrial processes. The flow characteristics of impinging jet are complex in nature and subsequently heat transfer from the surface subjected to such a flow is significantly variable. When contrasted with other intensity move applications that don't include stage change, the impinging plane utilizes liquid and accomplishes higher exchange rates. The considerably higher intensity move coefficient is inferable from neighborhood diminishing of the impingement limit layer, which takes into consideration a quicker pace of surface intensity move. Therefore, significant exploration has been led on heat move by means of fly impingement. Study of flow characteristics of jet impinging configuration is alone a wide area of interest. The studies of impinging jet heat transfer have reported an extensive variation in convective heat transfer coefficients for identical experimental parameters. Therefore, it is comprehended that the small change in nozzle exit flow structure will have a significant influence on heat transfer characteristics on the impinging surface. The overall objective of the present research is to investigate heat transfer and flow characteristics of swirling impinging jet. The work presented in the report consists of three sections. The first section describes the study conducted on heat transfer to an impinging jet. The various parameters influencing the heat transfer rate are presented and discussed.

3.4 NUMERICAL MODELING

3.4.1 Setup and Boundary Conditions

The equation for swirl flow and heat transfer in concentric cylinders describes the flow of a fluid in a cylindrical region with an inner and outer wall. The flow is described by a set of governing equations that relate the velocity and pressure of the fluid to the temperature and thermal properties of the walls. These equations are used to calculate the rate of heat transfer between the walls and the fluid, as well as the pressure drop across the region. The governing equation for swirl flow and heat transfer in concentric cylinders is given by:

$$R_{eh} = \frac{U\infty h}{v}, R_{eh} < 10$$

$$h = min\left(\frac{(10-1)v}{U_{inf}}, \frac{(10-1)\alpha}{U_{inf}}\right)$$

$$U_{max} = 5U_{inf} \tag{3.1}$$

$$\Delta t = \leq \frac{h}{U_{max}}$$

$$\Delta t = \frac{h}{2U_{max}}$$

where u is the velocity vector, p is the pressure, t is time, T is the temperature, ρ is the density, ν is the kinematic viscosity, and α is the thermal diffusivity.

3.4.2 Wall Conditions

The wall conditions equation for swirl flow and heat transfer in concentric cylinders is an equation that describes the wall temperature of a fluid as it flows between two concentric cylinders. It is derived from a combination of momentum and heat transfer equations that describe the swirl flow of the fluid and the heat transfer across the wall of the inner cylinder. The equation is used to analyze the wall temperature profile of a swirling flow of fluid between two concentric cylinders and is useful in the design of heat exchangers, thermal storage systems, and other heat transfer applications.

$$W_w = -2\frac{\psi_{w+1} - \psi_w}{h^2} = \frac{-2(\psi_{i-1,j} + \psi_{i+1,j} + \psi_{i,j-1} + \psi_{i,j+1})}{h^2} \tag{3.2}$$

3.4.3 Bulk Fluid

The bulk fluid equations are a set of equations that describe the behavior of a rotating, swirling fluid flow within two concentric cylinders. These equations are used to model a variety of fluid flow phenomena, such as vortices, turbulence, and heat transfer. The equations are based on the assumption of a steady-state, incompressible, laminar, and inviscid flow. The equations are solved using numerical methods such as finite difference or finite element methods.

$$u_{i,j}^{n} = \frac{\psi_{i,j+1}^{n} - \psi_{i,j-1}^{n}}{2h}$$

$$u_{i,j}^{n} = \frac{\psi_{i,j-1}^{n} - \psi_{i,j+1}^{n}}{2h} \quad (3.3)$$

The mass liquid conditions for twirl stream and intensity move in concentric chambers are coordinated into three significant conditions: mass preservation, force protection, and energy preservation. As per the preservation of mass condition, the pace of mass change in the framework is equivalent to the pace of mass stream in (or out) of the framework. As per the preservation of energy condition, the pace of progress of force in the framework approaches the net power working on the framework. As per the preservation of energy condition, the pace of progress of energy in the framework rises to the pace of intensity move into (or out of) the framework. The boundary conditions at the inner and outer cylinders are also important in determining the behavior of the flow. The inner cylinder is usually assumed to be a solid, stationary wall, while the outer cylinder is usually assumed to be a rotating wall with a constant angular velocity. The boundary conditions must be specified for each of the equations. In addition to the three main equations, additional equations are needed to fully describe the swirl flow and heat transfer in concentric cylinders. These equations include the equation of state, the equation of motion, and the equation of energy. Together, these equations form a complete set of equations that can be used to accurately model the behavior of the fluid flow and heat transfer in concentric cylinders.

3.4.4 Outflow Boundary

The outflow boundary equations for swirl flow and heat transfer in concentric cylinders are mathematical equations that are used to describe the two-dimensional, axisymmetric, turbulent flow and heat transfer of a swirling fluid in a confined space between two concentric cylinders. The equations take into consideration the effect of the swirl on the flow and the heat transfer characteristics of the system. The equations can be used to predict the velocity, temperature, and pressure distributions of the fluid as it travels through the concentric cylinders. The equations are derived from the Navier-Stokes equations and the energy equation. The equations are used to simulate the flow of the fluid and the heat transfer characteristics in the system. The equations can also be used to analyze the thermal performance of the system.

$$\omega_{i,j} = \omega_{i-1,j}$$

Upper/Lower Boundaries:

$$\psi = constant = 0 \tag{3.4}$$

$$\omega = 0$$

A system of equations may be used to represent turbulent swirl flow and heat transfer in concentric cylinders. The Navier-Stokes equations, the energy equation, and the turbulent kinetic energy equation comprise this system of equations. The Navier-Stokes equations describe momentum conservation and are used to calculate velocity and pressure fields. The energy equation defines energy conservation and is used to calculate the temperature field. The turbulent kinetic energy equation is used to calculate turbulent viscosity and explains turbulent kinetic energy.

3.4.5 Calculation of Total Heat Transfer from Cylinder

The rate of heat transmission from a heated inner cylinder to a cold outer cylinder is described by the equation for swirl flow and heat transfer in concentric cylinders. This is accomplished by solving the equations of motion, energy conservation, and flow boundary conditions. The Navier-Stokes equations explain the flow and may be used to compute the velocity, pressure, and temperature fields. By integrating the heat flow throughout the whole length of the cylinders, the total heat transfer rate is computed. The equations are helpful for simulating heat transfer in heat exchangers, boilers, and nuclear reactors.

$$T(t) = -k\frac{\vartheta T}{\vartheta n} \tag{3.5}$$

The heat transfer coefficients at the inner and outer surface of the inner tube are calculated using Wilson plots. The flow of hot fluid in the inner tube is varied from 0.1 lpm to 1 lpm with an interval of 0.1 lpm by maintaining the annulus flow rate constant.

4. RESULTS AND DISCUSSION

Helical curl heat exchangers are generally used in refrigeration frameworks, food handling frameworks, and intensity recuperation frameworks. Helical loops have higher intensity move rates than straight lines, particularly in the laminar system. The stream properties of helical loops are very confounded, and thus, heat transmission is incredibly factor. The bend of the line produces diffusive powers on the moving liquid, bringing about an optional stream design opposite to the essential hub stream. This optional stream design is frequently made out of two vortices that convey liquid from the internal mass of the cylinder to the focal point of the cylinder and afterward to the external wall. At the point when it arrives at the external wall, follow it back to the inward wall. Moreover, winding of helically curled tubes muddles the temperature and speed fields. The stream in helical cylinders with bend and twist is as yet being examined, and the progressions in the speed and temperature fields brought about by optional stream are not completely perceived.

4.1 EXPERIMENTAL SETUP AND PROCEDURE

Tests were completed to decide the impact of different variables on the intensity move coefficient. The significant boundaries overseeing heat move attributes are, as recently expressed, the Reynolds number, Prandtl number, Senior member number, nondimensional pitch, range of arch, and ebb and flow proportion. The elements of the helical curl tube in the cylinder heat exchanger picked for the trial examination are displayed in Table 4.1.

Mathematical recreations were performed utilizing the limited volume-based program ANSYS Familiar, and the outcomes give supportive knowledge into the warm and stream properties. Familiar's form heat move method is utilized to work out heat move. Reynold number, Prandtl number, Dignitary number, non-layered pitch, internal cylinder distance across, and cross part of the inward cylinder are the not entirely settled to make sense of the intensity move properties of helical loops. The following area talks about the trial arrangement and study approach.

Table 4.1: Dimensions of Coil Used in The Present Study.

Parameter	Value(mm)
Outside diameter of inner tube (d_o)	9.5
Inside diameter of inner tube (d_i)	7.9
Wall thickness of both inner and outer tubes (t)	0.8
The outside diameter of the outer tube (D_o)	15.9
Inside diameter of outer tube (D_i)	14.3
The radius of curvature of the helical coil (R)	235.9
Pitch of the helical coil varied from (P)	16 - 144
Length of the coil (L)	2960

4.2 RESULTS

Elements that were significant to this project that the group did not produce was the filename sorting algorithm used by the video generation Python file. This algorithm was found on Stack Overflow. A number of MATLAB and Python functions were also used with regards to plotting and formatting that the group did not write. Plots were made showing the temperature field, how the stream function changes over time, and the vorticity values. These give insight into why the temperature field changes in the way that it does. On the next few pages, there are screenshots from the two simulations that were run. The screenshots are from the flow at steady state. The plot at the top of each screenshot is the stream function. The middle plot is the vorticity, and the bottom plot is the temperature in Kelvin. Along with these, there are plots of Temperature and x Velocity of the flow along the centerline from when the flow has reached steady state.

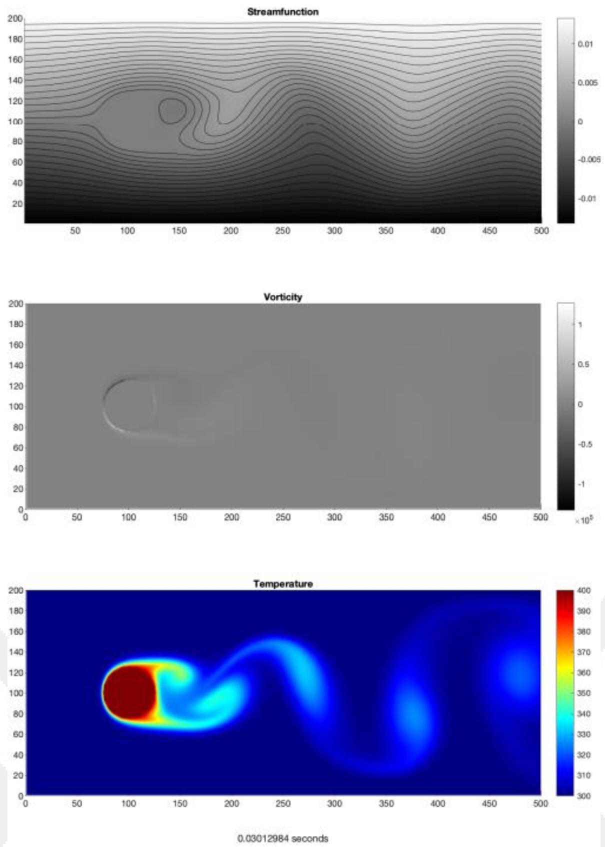

Figure 4.1: Part 1 Simulation After 56,550 Time Steps

In the simulation for Part 1, the vorticies only start to form after around 10,000 time steps. Initially, the flow is symmetrical about the line y = 100. The vorticies start to form at the t = 0.0084s mark. After the vorticies form, they grow until the flow reaches dynamic equilibrium. From this point on, the flow does not change its behaviour. There is a small area of hot fluid around the cylinder.

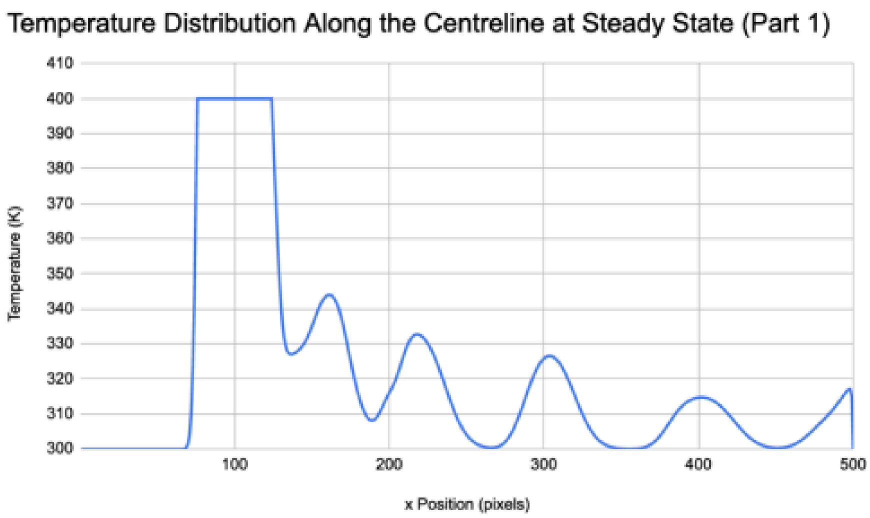

Figure 4.2: Temperature Along Centerline at Steady State (part 1).

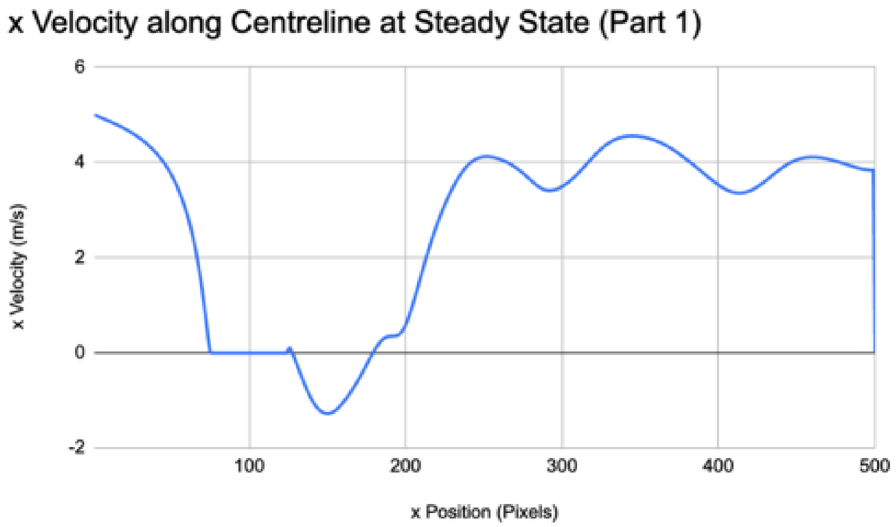

Figure 4.3: x Velocity Along Centerline at Steady State (part 1).

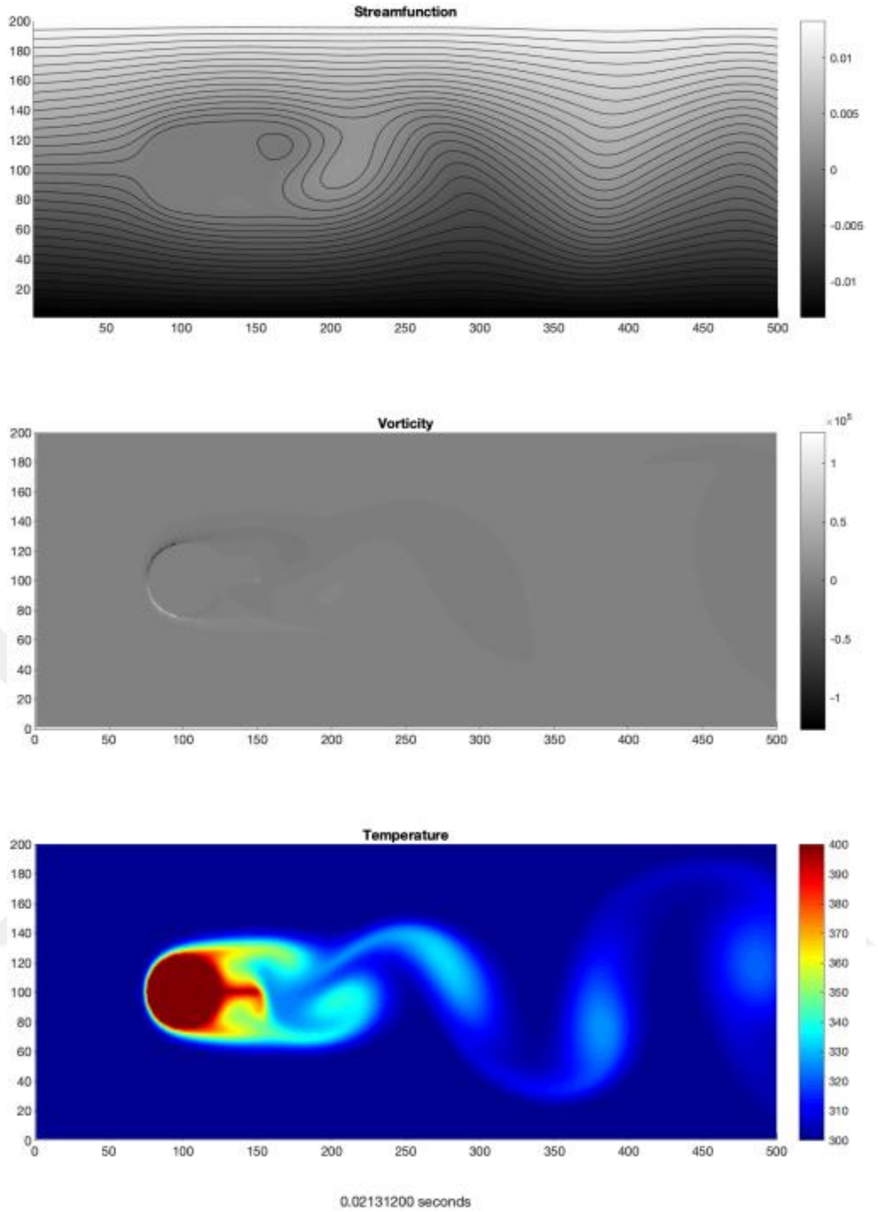

Figure 4.4: Part 2 Simulation After 40,000 Time Steps.

In the part 2 simulation, the behavior is very similar to that of Part 1. Initially, the flow is symmetrical about the line y = 100. Vorticies start to form from the t = 0.0106s point. This is 0.0022s later than they form in Part 1. From here, they grow until they are fully developed where the flow reaches its dynamic equilibrium and remains constant in time from that point on. The main difference between this flow and Part 1 is that the vorticies are slightly smaller and they begin further downstream than they do in Part 1. From the vorticity plots, it can be seen that the vorticity in Part 2's flow fields is much more concentrated in the center of the shedding flow. This is seen in the contrast of the clockwise and counter-clockwise vorticities' colors (In Part 2: more white and black, in Part 1: more gray). The fin on the back of the cylinder in Part 2 has caused there to be a much more noticeably large area of hot fluid on the downstream side of the cylinder.

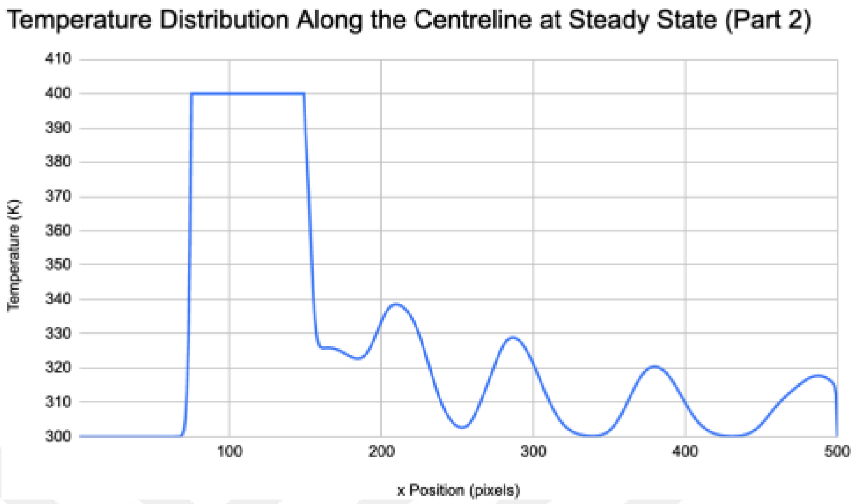

Figure 4.5: Temperature Along Centerline at Steady State (part 2).

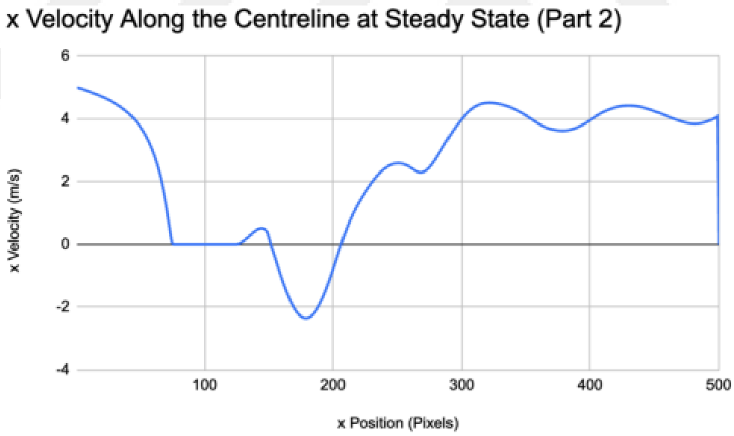

Figure 4.6: x Velocity Along Centerline at Steady State (part 2).

4.3 DISCUSSION

Although the group faced challenges with Python's inefficiencies, they were able to gain valuable insights into simulating flows during their project. The experience of writing a fluid simulation from scratch provided the group with a solid foundation in the basics of simulating flows, as this had not been attempted before. This project gave invaluable insight into one way of going about doing this. While there are undoubtedly many more complex pieces of software that can handle simulations that are of a much higher level, it is useful to understand how the governing equations can be manipulated into equations that can be used without a PDE solver.

The simulation of Part 1 took 11 hours to run 60,000 time steps. Part 2 took a little bit more than 7 hours to run 40,000 time steps. This was about 30 times better than if Python was used without the non-trivial Python optimization methods. This is a big reason as to why we would strongly recommend that future students do this project in MATLAB as opposed to Python. The run time was able to be cut down by a factor of 3 by only saving a picture of the simulation every 50 time steps and saving all the data for every time-step that is a multiple of 1,000. A feature was added to the code that allowed for the simulation to start again from any multiple of 1,000 time steps thanks to this method of saving the data. This was useful for moments where our computers let us down in areas such as battery life and logging off due to being idle for too long.

The simulation for this project was reasonably valid. In each part, once the flow had reached equilibrium, the heat flux through a surface around the cylinder was tested and compared to the heat flux through a vertical surface near the outflow boundary. Over time, the difference between these values was negligible. This gave the group confidence that the simulation was valid because energy was conserved from the point where it entered the flow to when it exited the flow at the rightmost boundary. This simulation has it's limitations in terms of components that would be introduced in an equivalent 3 dimensional simulation. One aspect that the group was surprised about was how fast the flow became unsteady and started to have shedding vorticies. The Part 1 simulation only simulates 0.03 seconds of the flow. This is surprising because of how little time it takes for the vorticies to appear and reach a dynamic equilibrium in a flow with a low Reynolds number.

The group was also surprised by how relatively cool the flow remained directly behind the cylinder in Part 1. Even at the end of the simulation, the temperature of the fluid at a distance of one third of the radius is still at 300K. This is surprising because of how low the Reynolds number is. From previous work in fluids, the group knew that the flow had not become turbulent and expected it to behave in a way that resembled inviscid flow, since the velocity gradients are low. However, it was seen that this is not the case. Even at low Reynolds numbers the flow will start to create vorticies.

A possible next step for this simulation is to simulate in 3D or to change the simulation to incorporate compressible and high Reynolds number flows. We have made a number of simplifications in order to write and execute this code in a manageable time frame but this takes away from the versatility of the simulation.

5. CONCLUSIONS AND FUTURE WORKS

5.1 CONCLUSION

The stream and intensity move around a solitary jewel molded chamber were examined for a laminar incompressible stream at an unassuming Reynolds number (1 6 Re 6 70) and a Prandtl number of Pr 14 0:7 all through an extensive variety of pinnacle points (33 6 a 6 120). The drag coefficient of a jewel not entirely set in stone to be similar to that of a round chamber for Re 6 10. With regards to prior study, diminishing the pinnacle point emphatically raises the vital Reynolds number comparing to the initiation of wake distribution. On account of a round chamber, the increment of distribution is corresponding to the Reynolds number. As far as intensity move, the dissemination of the neighborhood heat transition is found to have more than one nearby most extreme and a significant change around the equator point, which is predictable with earlier work on heat move from a square chamber. At the point when the zenith point is brought down, the relating Nusselt number versus the customary Reynolds number abatements. For the entire Reynolds range, the Nusselt number and drag coefficient of a jewel shape with a 14 90 are almost indistinguishable from those of a roundabout chamber. New connections are introduced to describe the drag coefficient, distribution length, and variance in the Nusselt number.

The stream downstream of the step is confounded, with whirlpools, cross over streams, speed slopes, and other spatial stream designs made by the presence of a chamber. A more prominent information on how the chamber communicates with the move toward produce spatially fluctuated streams downstream prompts the estimation of its properties. Coming up next are the review's primary discoveries: Distribution zone: Three distribution zones were seen in the BFSF 1: the principal on the lower wall in laminar and fierce systems; the second on the upper wall for Reh > 300; and the third on the lower wall in the early piece of the temporary system. In laminar stream, the chamber drove the essential distribution district upstream to the step's corner, shortening its length, though BFSF 2 missing the mark on second distribution zone at the top wall. The third distribution zone was found in the BFSF 2 in any event, for laminar and violent stream when a chamber was situated at a breadth distance from the step edge and farther upstream than in the BFSF 1. The size of the third distribution zone in violent stream was not exactly in laminar stream. The third distribution zone was missing on the grounds that the chamber was situated far away from the step or more or beneath the step. Wake from a chamber: The move toward laminar stream changed the 2D stream structure past the chamber, bringing about a topsy-turvy wake dissemination. Most of these vortices moved toward the chamber beneath. At the point when a chamber was put along or over the step edge in tempestuous stream, stream streaming over the chamber stifled the improvement of the von Kármán vortex road, two vortices of changing widths created behind the chamber, and their area relocated towards the base wall. Since the chamber was arranged underneath the step, its way of behaving was indistinguishable from that of BFSF 1. Streamwise speed: In light of the chamber's low cross-area downstream, the speed expanded. In both laminar and fierce systems, the greatest speed moved towards the channel's middle. Dissemination of skin contact: The skin grinding coefficient at the base wall is connected with the wall shear pressure. The recycling stream caused a negligible worth of skin grating coefficient (Cf, min) at the base wall. In both laminar and fierce stream, a base worth of skin erosion coefficient (Cf, min) was recorded close to the lower part of the BFSF 1. In any case, because of the two distribution zones in the BFSF 2, two least pinnacles of skin grinding coefficient (Cf, min)1 and (Cf, min)2 were identified at Reh > 75. The chamber downstream of the step created a lot more prominent least and most extreme skin grinding coefficient values at the base wall than the step alone. Pressure appropriation: The chamber impacted the tension circulation along the base wall. The base and most extreme tension coefficient values in the BFSF 2 were lower than in the BFSF 1. The typical worth of tension coefficients downstream of the reattachment point, in any case, was lower than in the BFSF 2. Besides, the step changed the dispersion of the chamber's surface strain by moving the most elevated pressure zone to the highest point of the chamber.

5.2 FUTURE WORKS

In the last segment, it is shown that a likeness between jewel molded chambers with different zenith points (90 6 h 6 120) is feasible assuming that the reference speed for computing the stream Reynolds number depends on the most noteworthy vorticity close to the chamber's equator point. Subsequently, the Nusselt numbers breakdown on an expert bend that is just subject to this 'powerful' Reynolds number. Past and momentum examination might recommend that the key speed scale to address convection at the point of interaction where move happens isn't the far field speed, yet rather the speed scale brought about by vorticity.

This finding reveals new insight into the examination and depiction of intensity or mass exchanges from 2D or 3D items. Later on, it would be intriguing to contrast Nusselt number changes with this Reynolds number detailing for different calculations and Prandtl numbers.

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