HEAT EXCHANGE SIMULATION OF MOBILE BOTTLE CHILLER

RAKESH KAMALAKANNAN

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2019

HEAT EXCHANGE SIMULATION OF MOBILE BOTTLE CHILLER

RAKESH KAMALAKANNAN

THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF MANUFACTURING ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2019

UNIVERSITY OF MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: Rakesh Kamalakannan

Matric No: KQG170004

Name of Degree: Master of Manufacturing Engineering

Title of Project Paper/Research Report/Dissertation/Thesis: Heat Exchange Simulation of Mobile Bottle Chiller

Field of Study: Manufacturing Engineering and Testing

I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

[redacted] Date:

Subscribed and solemnly declared before,

Witness's Signature Date:

Name:

Designation:

HEAT EXCHANGE SIMULATION OF MOBILE BOTTLE CHILLER

ABSTRACT

The mobile bottle chiller is a conceptual design which makes the consumer to cool down the temperature of drinking fluid without actual refrigerator. This design with its unique ability to cool drinking fluid whenever needed with nominal cost requires the verification of its design specifications to achieve its major objective successfully. The design and simulation of this product involves the concept of heat exchange which is performed by means of a pure mechanical heat transfer mechanism. The major aspects like design specification and material selection are taken in various ratios and compared to establish the best out of others, also such simulation will give the major aspects which has to be considered while designing any system with similar functionalities. Creo parametric 2.0 a designing software and Ansys 16.2 are used to meet the design and simulation the need of this project. The key principle of this mobile bottle chiller is transferring the heat from drinking fluid to the coil and then to the ice cubes in the containers through the conduction process. In this study the major goal is to reduce the temperature of drinking fluid without altering its actual property or nature. Hence the product is designed, and simulation has been conducted to ensure the effective heat transfer by actual implemented concept.

Keywords: Heat exchange, Mobile Bottle Chiller, Creo parametric 2.0, Ansys 16.2.

PENYEJUK BOTOL MUDAH ALIH MENGGUNAKAN SIMULASI PERTUKARAN HABA

ABSTRAK

Chiller botol mudah alih adalah reka bentuk konseptual yang menjadikan pengguna untuk menyejukkan suhu cecair minum tanpa peti sejuk sebenar. Reka bentuk ini dengan keupayaan unik untuk menyejukkan cecair minuman apabila diperlukan dengan kos nominal memerlukan pengesahan spesifikasi reka bentuknya untuk mencapai matlamat utamanya dengan jayanya. Reka bentuk dan simulasi produk ini melibatkan konsep pertukaran haba yang dilakukan melalui mekanisme pemindahan haba mekanikal tulen. Aspek-aspek utama seperti spesifikasi reka bentuk dan pemilihan bahan diambil dalam pelbagai nisbah dan dibandingkan dengan menubuhkan yang terbaik dari orang lain, juga simulasi tersebut akan memberikan aspek-aspek utama yang perlu dipertimbangkan ketika mereka bentuk setiap sistem dengan fungsi serupa. Creo parametric 2.0 perisian reka bentuk dan Ansys 16.2 digunakan untuk memenuhi reka bentuk dan simulasi keperluan projek ini. Prinsip utama penyejuk botol mudah alih ini memindahkan haba dari cairan minum ke gegelung dan kemudian ke kiub ais dalam bekas melalui proses pengaliran. Dalam kajian ini matlamat utama adalah untuk mengurangkan suhu cecair minum tanpa mengubah sifat sebenar atau sifatnya. Oleh itu, produk direka bentuk, dan simulasi telah dijalankan untuk memastikan pemindahan haba berkesan oleh konsep yang dilaksanakan sebenar.

Kata kunci: Pertukaran haba, Pemanas Botol Mudah Alih, Creo parametrik 2.0, Ansys 16.2.

ACKNOWLEDGEMENTS

Being an atheist, I believe only in people around me, my confidence, and hard work that make me to pursue my goals. A heartfelt thanks to my supervisor, mentor and my well-wisher, Prof. Dr. Mohd Sayuti Ab Karim for being my support in tough times. To be in this stage I sacrificed many quintessential things in my life. I would say one name to who my soul belongs to is my appa Mr. P. Kamalakannan M.A., B.Ed., M. Phil., LLB. I solely dedicate this dissertation work to him. He was there in the moment when I got my B.E degree and I am proud that I managed to be in this final stage of my postgraduate degree despite of his last breath. His wish to give best education to his kids has been accomplished but I miss that face with smile and pride to see me at this stage.

I would like to mention my gratitude, loyalty and dedication of this work to a special person Mr. V. Senthil Kumar MSc., M.Ed., M.Phil. the only man to whom I can settle my life to mold after dad. He has been an excellent friend to my dad, and now being a best guardian for me and my family in hard times.

I would like to dedicate this work to my beloved brother Mr. T. Sathish (Sathish Bike Technician, chennai). His presence in my life is priceless and I am lucky to have such brother from another mother.

Also, I would like to thank my family and friends for their support. Special thanks to my UM friends and roommate for being an excellent support in my tough times.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

Δp	:	Pressure drop of the specimen
h_o	:	Heat transfer coefficient at the outer diameter
h_i	:	Heat transfer coefficient at the inner diameter
Re	:	Reynolds number
Pr	:	Prandtl number
Nu	:	Nusselt number
m	:	Mass flow rate of the fluid
v	:	Average Inlet Velocity of the fluid
C_p	:	Specific heat capacity of the fluid
ϵ	:	Enhancement Efficiency
q	:	Heat flux of the cartridge heater
T_{in}	:	Temperature of the Inlet fluid in the test section
T_{out}	:	Temperature of the Outlet fluid in the test section
T_{amb}	:	Ambient temperature of the fluid in the test section
S	:	Total Heat transfer area of the porous media
A_b	:	Area of the base plate
V	:	Voltage supply to the heater
I	:	Current supply to the heater
d_p	:	Average pore diameter of the metal foam
d_h	:	Spherical diameter of the pore
V	:	Volume of the metal foam used
Q_{loss}	:	Heat lost to the fluid from the heater
Q_{air}	:	Heat transferred to the working fluid
A	:	Heat transfer area

A_1	:	Heat transfer area of Design 1
A_2	:	Heat transfer area of Design 2
hn_1	:	Heat transfer coefficient at the localized point 1 in Design 1
hn_2	:	Heat transfer coefficient at the localized point 1 in Design 2
H_{n1}	:	Average heat transfer coefficient of the Design 1
H_{n2}	:	Average heat transfer coefficient of the Design 2
H_1	:	Overall heat transfer coefficient of Design 1
H_2	:	Overall heat transfer coefficient of Design 2
ε	:	Porosity of the Metal foam used
K_c	:	Thermal conductivity of copper
K_f	:	Thermal conductivity of the fluid
K_{Al}	:	Thermal conductivity of aluminum
v_1	:	Velocity Profile of the Design 1
v_2	:	Velocity Profile of the Design 2
P_1	:	Pressure Drop of Design 1
P_2	:	Pressure Drop of Design 2
D_h	:	Hydraulic Diameter of the test section
Q_{in}	:	Input power given to the heater
T_w	:	Surface temperature of the wall
T_b	:	Bulk fluid temperature
ΔT	:	Temperature Difference of the Outlet and inlet fluid
HE	:	Heat Exchanger

CHAPTER 1: INTRODUCTION

1.1 Project Background

The major motive constructing is heat exchanger is to make the warmth or high temperature of one medium to transfer its heat to another medium. In such case both mediums involve in trading of temperature and such phenomena is done by heat exchangers. A system can be subjected to Heat exchange in three possible form namely conduction, convection and radiation. In general, the heat transfer that takes place by means of radiation is not accepted as an actual heat exchange since there is no any solid form of proof to show the exchange of heat between the mediums. When a hot fluid transfers its warmth from one side of membrane with solid thickness to another side while flowing through it is known as conduction. The enhancement of conduction process lies in the thermal conductivity of membrane on which it transfers the warmth and the thickness of that solid membrane. But when it comes to heat exchanger convection plays the major role since the process will happen like a trading of heat between two mediums.

In heat exchangers the heat transfer is forced and compelled to happen between two mediums in this case it is between water or drinks and ice cubes. The fluid that supplied to the coil through inlet is forced to do the warmth transfer with ice trough the copper coil as it flows through the coil makes the better contact will inner coil surface.

1.2 Problem Statement

Conventional process of cooling the drinking fluid involves lot of cost and electronic refrigerators which are non-portable. Conventional refrigerators are environmentally unfriendly due to its chlorofluorocarbon release. Also, when we are choosing the material to store the water the material should be compatible for acidic and alkaline beverages since the fluid will be subjected to direct contact with material at most of the time. However, heat transfer between two compounds depends on various factors achieving optimum heat transfer through desired cooling medium to provide enough cooling effect is going to be a real challenge while designing mobile bottle chiller. The insulation period should be optimal to use it over some reasonable period in repeated cycle. In consumer point of view the product should provide optimal cooling to satisfy the consumer who using it. Another important consideration is that product should be with food grades and it must not have any contamination effects on fluid that gets processed inside the bottle.

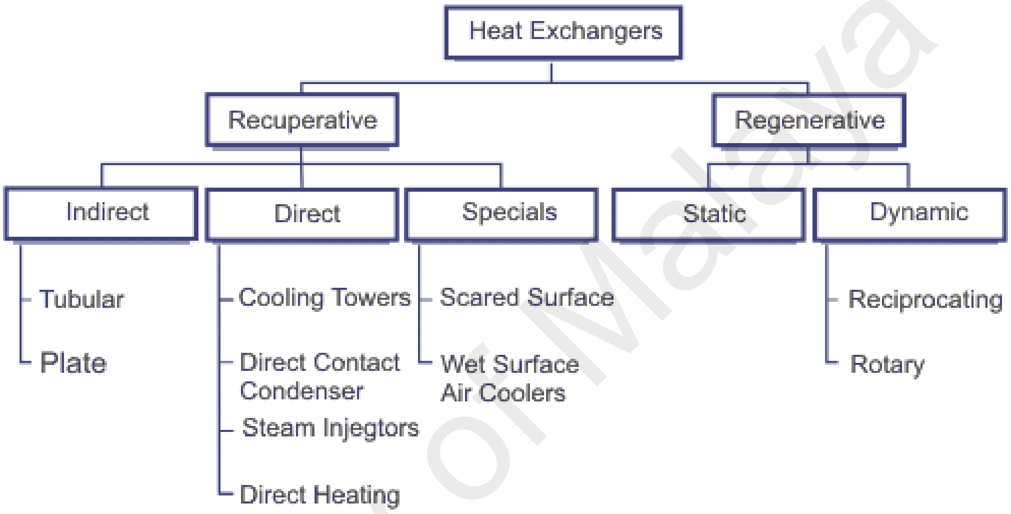


Figure 1.1: Categorization of Heat Exchangers

1.3 Project Objectives

The project objectives were identified based on few background studies and the conceptual idea of mobile bottle chiller.

i. To analyses the suitability of material for the desired purpose and the materials must be of food grades with best chilling and insulation capability.

ii. To establish the influence of material selection and design specification for improving the cooling rate of drinking fluid.

iii. The test the cooling capability of the cooling passage and thereby achieving the optimal cooling of drinking fluid.

iv. To analyze the insulation capability of bottle since it is going to be used for long period and repeatedly.

v. To establish its user-friendly capacity and methods to be used for cleaning and maintaining the bottle to achieve lasting durability and health safety values.

1.4 Project Scope

The helical coil implements in mobile bottle make it a compact and portable heat exchanger which enables the people to cool down their drinking fluid wherever needed. The product requires just few numbers of ice cubes which act as a secondary fluid which chips out the heat from warm drinking fluid that flows trough the coil. The fluid that cooled by this setup will give its original taste to its consumers since in no way it gets blend or mixed with ice cubes unlike actual method in practice. The project involves in designing the helical coil with outer shell, suitable material selection which has effective heat transfer capacity and simulation to evaluate the effectiveness of designed product.

CHAPTER 2: LITERATURE REVIEW

Over the period the food and beverage industry has gained the massive growth also food industry has become one of the nation's economic statue which play the important roles in both developed and developing countries. Biotechnology and chemical engineers invented lot of food processing and storing techniques by which exploration to different foods, tastes and method of cooking evolved in modern day peoples.

All these advancements are there but still it feels awkward and unpleasant while people using ice cubes to cool their drinks or any other type of beverages. Mixing of ice cubes with any fluid will alter the actual and originality of that drink. Obviously, it is like adding an extra amount of water to drinks to make it cool. In order to make this process clean the conceptual idea of mobile bottle chiller is developed which is very similar to the concept of heat exchanger. Since this project concentrates more on heat exchange the velocity and mass flow properties are approximated but various parameters that has a role in heat exchange process are prompted and used from previous studies.

2.1 An Overview of Heat Exchanger

The ability of heat exchanger being an eco-friendly system make it to stand out from other similar heat transfer system in the society. The requirement and necessity of heat exchangers also booming in modern days. People are even using it for various operations in day to day life like house-hold purposes, and cryogenic tasks. The major advantage of these exchangers is its ability to go compact and efficiency when compared to other systems. These heat exchangers have never recorded any harmfulness to the society over the past few years. The reason behind this huge success is in the fact that heat exchangers requires very less economical support for its process in the same time they are in no way be a cause of hazard to its atmosphere and society. The enhancement of heat exchanger's efficiency is a potential challenge that many researchers and scientists engaged in. Due to various boundaries and parameters the efficiency of such exchangers is very difficult to control and over rule. Previous research puts out lot of alternatives and design additions to sort out this enhancement issues but still these remains being an opportunity to pull in lot of investigations and researchers. This study is to understand the effects, parameters and investigations that has been conducted to enhance the efficiency of heat exchangers by researchers in various aspects.

2.1.1 General study on Heat Exchanger and Heat Transfer

(Christopher Ian Wright, 2014) broke down the viable administration of warmth exchange liquid blaze point temperature utilizing a Light End Removal Kit (LERK). If there should arise an occurrence of warmth exchangers, the structure up of light finishes is found in the warmth exchange liquids. These light-closes results in flame perils causing a noteworthy issue. A LERK has been introduced to avoid the development of the light closures. The adequacy of the LERK in reestablishing the mean shut blaze guide temperature toward stable dimensions is watched. These mean qualities are discovered near the estimations of virgin HTF. Introducing the LERK not just expands the life of a warmth exchange liquid, yet in addition stays away from the requirement for standard weakenings to raise the glimmer point temperature.

(Weikla et al., 2013) had played out a similar investigation of two sorts of warmth exchangers in particular Shell and Tube heat exchanger (STHE) and Coil wound warmth exchanger (CWHE) for the exceptional administration conditions (liquid salt administration). Besides, the uses of these CWHE in the warm vitality stockpiling plants are investigated. The outcomes acquired are that the CWHE have focal points over the STHE for the reasons like less warmth exchange territory, lower weight drop, lower siphoning cost and less number of shells and channeling. These arrangements have favorable circumstances like counteractive action against warm stuns.

(Neda Gilani et al., 2014) broke down a direct evaporative cooler with different indoor and open air cools. Numerical demonstrating has been done and the warm solace conditions have been accomplished. By raising the general mugginess of air, a littler warmth exchanger can be used for the warmth exchange purposes. It is discovered that the warm solace conditions accomplished when the temperatures and relative moistness are in the endorsed extents (27-47℃ and 10-60 %), confines the physical attributes and geometry of the evaporative cooler. The above survey results uncovered that the accomplishment of the warm solace conditions enhances the measure of the warmth exchangers. It is additionally proposed that CWHE could be favored over STHE relying upon the reasonableness.

2.1.2 Various configurations involved in enhancement of heat transfer

(Nopparat Katkhawa et al., 2013) examined the various kinds of dimple courses of action and dimple interims. They considered the warmth move qualities if there should be an occurrence of outside stream conditions. The flood of wind streams over the warmed surface with dimples. The speed of air stream shifts from 1 to 5 m/s. The temperature of the air stream and dimpled surfaces were estimated. Since the use of confuses, balances and Turbulizers for the customary upgraded heat move approaches results in a noteworthy weight drop of the stream, the dimples are liked. In this paper, the dimple courses of action (amazed and inline) with different dimple pitches are looked at and contemplated. The stunned dimple course of action (Dimple pitches – SL/D_{minor} = 1.875 and ST/D_{minor} = 1.875) had been found to give ideal warm obstruction about 21.7% superior to level plate.

(Srinivasan et al., 2014) had explored the approaches to improve the adequacy of the shell and cylinder heat exchangers by execution of Six sigma DMAIC (Define-Measure-Analysis-Improve-Control). Characterize stage – the Critical to Quality (CTQ) parameters are recognized. Measure Phase – the adequacy of the exchanger has been estimated as 0.61. Examination Phase – the explanations behind the adequacy decreases are recognized. Improve Phase – Existing structure has been adjusted by conceptualizing and the arrangements are distinguished. Control Phase – Strategies are prescribed for improving execution. The adequacy of the exchangers has been improved by recouping the warmth vitality of the fumes (pipe) gas by utilizing the roundabout balances moved over the cylinders. The money related benefit accomplished by following these procedures is about Rs. 0.34 million/year.

(Jiin-Yuh Jang et al., 2013) led an examination in regard to the range edge and area of the vortex generators gave in a plate–balance and cylinder heat exchanger with in-line and stunned courses of action. Square sort vortex generators are mounted behind these cylinders. Contrasting the plain surface and surface and vortex generators, the territory decrease proportion is better in surface with vortex generators. Length point run considered for vortex generators is from 30° to 60° and transverse area (Ly) extend is from 2mm to 20mm. In-line plans in above exchangers is increasingly viable in regard to warm exchange improvements. The writing audit results uncovered that the arrangement of bewilders in the warmth exchangers makes tremendous weight drop off the warmth exchange liquid. These restrictions can be overwhelmed by utilizing dimples, balances, full length contorted tapes and vortex generators.

2.1.3 Heat transfer enhancement by Nanofluids

(Ali Najah Al-Shamani et al., 2014) conducted investigation regarding the heat transfer due to turbulent flow of nanofluids (base fluid with nanoparticles Al_2O_3, CuO, ZnO and SiO_2) through rib-groove channel. Under constant temperature range, the computations are performed for different types of nanoparticles with different volume fractions (range 1-4%) using four different rib-groove shapes. The conclusion obtained from the paper is that the trapezoidal with increasing height in the flow direction Rib- Isosceles Trapezoidal groove (Trap + R-Trap G) provides the highest Nusselt number and best heat transfer rate.

(Iniyan et al., 2014) used a condensing unit of the air conditioner to analyze the heat transfer enhancement performance of nanofluid (Al_2O_3/ water and CuO/ water). The condenser consists of a tube in tube setup configurations. The cooling medium used in the analysis is nanofluid flowing in the outer side of the tube of condenser. The results from the study are summed up as that the CuO/ water nanofluid has more heat transfer rate than Al_2O_3/ water nanofluid. The Nusselt number of CuO/ water nanofluid had found to be 39.4% higher than the base fluid.

(Dustin R. Ray et al., 2014) had done a comparative study regarding the heat transfer performance of three nanofluids. These nanofluids have the same base fluid (60:40 ethylene glycol and water by mass) with different nanoparticles like Al_2O_3, CuO and SiO_2. This similar condition has been found in the cases of Automobile radiators. Some parameters like pumping power, heat transfer coefficients and surface area reductions are considered for the study. Nanofluid exhibits better heat transfer enhancement at 1% volumetric concentration. Among all the three nanofluids, the Al_2O_3 nanofluid exhibited the optimal conditions like the reduction of surface area by 7.4% and pumping power by 35.3%.

The investigation results indicated that the increase in Nusselt number increases the heat transfer rate. The glycerin based nanofluid (SiO_2-nanoparticle) showed the better heat transfer characteristics. The water based nanofluid (CuO/ water) showed better heat transfer performances.

2.1.4 Efficiency of compact Heat exchangers

(Tawat Samana et al., 2013) contemplated the improvement of the blade effectiveness of a strong wire balance by swaying heat pipe under constrained convection by methods for investigations. First they considered a wire – on – tube heat exchanger under constrained convection for the improvement of the blade proficiency of the strong wire balance. At that point they supplanted this wire balance with a swaying heat pipe containing R123. The testing setup was made with a breeze burrow which trades the warmth between the high temp water streaming inside the cylinder and air stream streaming crosswise over outside surface. The swaying heat pipe balance indicated 5% blade proficiency more than the traditional balances. Further realities like the mass stream rate and the geometrical parameters of warmth exchanger surface are considered. Besides, the air mass stream rate and the components of the warmth exchanger like the cylinder distance across; tube pitch, the wire breadth and wire pitch were observed to be parameters influencing the presentation of the air-side utilizing the constrained convection. Because of its higher proficiency, miniaturized scale channel heat exchangers (MCHX) have been used in the field of Heating, Ventilation, Air Conditioning and Refrigeration (HVAC and R). (Yanhui Hana et al., 2011) had examined about these exchangers. These warmth exchangers have higher warmth exchange rate, lower cost and conservative size. This paper has the dialog about the streamlining of the MCHX and the investigation of their points of interest and weaknesses. An endeavor to diminish their loads is completed. After the investigation of smaller scale direct warmth exchangers top to bottom, numerous issues identified with businesses can be settled.

(Mushtaq Ismael Hasan et al., 2012) had examined the hub heat conduction qualities of a microchannel heat exchanger. The isosceles right triangular warmth exchanger is considered for the examination. Scientific investigation of the warmth conduction in isolating divider for incompressible, 3D, laminar, relentless state stream is performed.

Utilizing limited volume and crossover differencing plan, the different parameters which have impact on pivotal warmth conduction were resolved. The expanding of the parameters like Reynolds number (Re), thickness of isolating divider (ts) and warm conductivity proportion (Kr) indicates increment in the pivotal warmth conduction. Further, the expanding of parameters like channel volume and the water driven measurement (Dh) diminishes the hub heat conduction.

(Valery Ponyavin et al., 2008) played out an investigation of the warmth exchange and liquid stream dissemination in a reduced fired warmth exchanger. It is discovered that the stream maldistribution because of structure constraints may result backward progression of liquids. This may influence the exhibition of the warmth exchangers. Various sorts of improved structures are dissected for the best possible liquid stream in exchanger in contemplations with a decreased weight drop esteems.

The rundown for the above survey results uncovered that the best possible plans for the liquid stream in conservative warmth exchangers is basic. The hub heat conduction influencing parameters are Reynolds number (Re), thickness of isolating divider (ts) and warm conductivity proportion (Kr).

2.2 Shell and coil type heat exchanger

In many Industries, the structuring and warm assessment of warmth exchangers is for the most part completed to diminish cost, material and vitality and to acquire greatest warmth exchange. The principle challenge in warmth exchanger configuration is to make it minimized and to get most extreme warmth move in least space. The aloof improvement system utilizing snaked tube has critical capacity in upgrading heat exchange by creating auxiliary stream in the curl. Because of upgraded heat exchange the investigation of stream and warmth move in helical loop tube is of crucial significance.

The principal endeavor has been made by (W.R. Dean, 1928) to depict numerically the stream in a wound cylinder. A first estimation of the unfaltering movement of incompressible liquid coursing through a curled pipe with a roundabout cross-area is considered in his examination. It was seen that the decrease in the rate of stream because of bend relies upon a solitary variable, K, which is equivalent to 2(Re) 2r/R, for low speeds and little r/R proportion. (Dravid et al., 1971) demonstrated that the power of optional stream created in the cylinder is the capacity of cylinder breadth (Di) and loop distance across (Dc).

(Naphon, P., 2007) researched the warm presentation and weight drop of a shell and helical snaked tube heat exchanger with and without helical pleated balances. (Naphon, P., and Wongwises, S., 2006) abridged the wonder of warmth exchange and stream qualities of single-stage and two-stage stream in bended cylinders including helically curled cylinders and spirally snaked cylinders.

(A.V. Kirpikov, 1957) contemplated the warmth move in helically loop heat exchanger considering curl arch and utilizing divider to mass temperature contrast and found a relationship for it. (C.M. White, 1929) has proceeded with the investigation of Dean for the laminar progression of liquids with various viscosities through bended channels with various ebb and flow proportions (δ). The outcome demonstrates that the beginning of choppiness did not rely upon the estimation of the Re or the De. He reasoned that the stream in bended channels is more steady than stream in straight pipes. White additionally contemplated the protection from stream as a component of De and Re. There was no distinction in stream opposition contrasted with a straight pipe for estimations of De under 11.6.

(Seban and McLaughlin, 1963) tentatively concentrated the warmth exchange for oil laminar stream and water fierce stream in consistently warmed HCTs ($0.0096 \leq \delta \leq$

0.0588). They presumed that the external outskirts has higher nearby Nusselt number than the internal with both being significantly higher than qualities for a straight pipe under similar conditions.

(Prabhanjan et al., 2002) contemplated the warmth exchange investigations of a helical curl drenched in a water shower. A diagnostic and trial think about has done by (Shokouhmand et al., 2008) done trial examination on shell and loop tube heat exchanger utilizing Wilson plot procedure and inward warmth exchange coefficient so got are found in great understanding.

(Pandey et al., 2010) consider hydrodynamic attributes of single-stage liquid stream inside a vertical helically wound container of ebb and flow proportion 0.012 is researched tentatively for the laminar stream routine for water and nitrobenzene. (Purandare et al., 2012) had done the similar examination of different connections given by various analysts. The general impacts of different parameters on warmth move coefficient associated with connections are contemplated.

2.2.1 Heat transfer characteristics of Helical coil

Convective warmth exchange is the exchange of warmth starting with one spot then onto the next by the development of liquids because of the distinction in thickness over a film of the encompassing liquid over the hot surface. Through this film heat exchange happens by warm conduction and as warm conductivity of most liquids is low, the principle obstruction lies there. Warmth exchange through the film can be upgraded by expanding the speed of the liquid streaming over the surface which results in decrease in thickness of film. The condition for rate of warmth exchange by convection under enduring state is given by,

$$\boldsymbol{Q = h\ A\ \Delta T} \qquad \textbf{Equation 1}$$

The estimation of 'h' relies on the properties of liquid inside the film locale; subsequently it is called 'Warmth Transfer Coefficient'. It relies upon the various properties of liquid, measurements of the surface and speed of the liquid stream (for example nature of stream).

The general warmth exchange coefficient is the general exchange rate of an arrangement or parallel mix of convective and conductive dividers. The 'general Heat Transfer Coefficient' is communicated regarding warm protections of every liquid stream. The summation of individual protections is the absolute warm obstruction and its backwards is the general warmth exchange coefficient, U.

$$\frac{1}{U} = \frac{1}{h_0} + \frac{A_0 1}{A_i h_i} + R_{f0} + \frac{A_0}{A_i} R_{f0} + R_{fi} + R_w \qquad \textbf{Equation 2}$$

Because of presence of the optional stream, the warmth exchange rates (and the liquid weight drop) are more prominent on account of a bended cylinder than in a relating straight cylinder at a similar stream rate and a similar temperature and same limit conditions.

2.2.1.1 Pros of coil typed heat exchanger

i. Helical loops give better warmth exchange qualities, since they have lower divider opposition and higher procedure side coefficient.

ii. The entire surface zone of the bended pipe is presented to the moving liquid, which disposes of the no man's lands that are a typical disadvantage in the shell and cylinder type heat exchanger.

iii. A helical loop offers a bigger surface territory in a generally littler reactor volume and a lesser floor region.

iv. The spring-like loop of the helical curl heat exchanger disposes of warm extension and warm stun issues, which helps in high weight tasks.

v. Fouling is nearly less in helical curl type than shell and cylinder type in light of more prominent choppiness made inside the bended funnels.

2.2.1.2 Cons of coil typed heat exchanger

i. For very receptive liquids or exceptionally destructive liquid curls can't be utilized, rather coats are utilized.

ii. Cleaning of vessels with loops is more troublesome than the cleaning of shells and coats.

iii. Coils assume a noteworthy job in choice of unsettling framework. Now and again the thickly pressed loops can make unmixed districts by meddling with liquid stream.

iv. The plan of the helical cylinder in cylinder type heat exchanger is additionally somewhat mind boggling and testing.

2.2.1.3 Applications of coil typed heat exchangers

Utilization of helical loop heat exchangers in various warmth exchange applications:

i. Helical loops are utilized for moving warmth in compound reactors in light of the fact that the warmth exchange coefficients are more prominent in helical curls when contrasted with different arrangements. This is particularly significant when synthetic responses have high warms of response are done and the warmth created (or devoured) must be exchanged quickly to keep up the temperature of the response. They are utilized generally in oil enterprises for various applications.

ii. The helical loops have a minimal arrangement, and in light of that they can be promptly utilized in warmth exchange application with space constraints, for instance, marine cooling frameworks, focal cooling, cooling of grease oil, steam ages in marine and mechanical applications.

iii. The helical curled warmth exchangers are utilized generally in nourishment and refreshment ventures, as in sustenance handling and pre-warming, purification of fluid sustenance things, and for putting away them at wanted temperatures.

iv. Helical loop heat exchangers are frequently utilized as condensers in utilized in HVACs because of their more prominent warmth exchange rate and minimal structure.

v. Helical wound cylinders are utilized widely in cryogenic industry for the liquefaction of gases.

vi. Used in hydro carbon preparing, recuperation of CO2, cooling of fluid hydrocarbons, likewise utilized in polymer enterprises for cooling purposes.

2.3 Factors of CFD analysis

Computational Fluid Dynamics, truncated as CFD, utilizes distinctive numerical strategies and various modernized calculations so as to take care of and examine issues that include the progression of liquids. The computations required to recreate the cooperation of liquids with surfaces characterized by limit conditions, and starting conditions are finished by the ANSYS Fluent v13.0. The Navier feeds conditions structure the premise of all CFD issues. Two condition models are utilized for the reproductions, and various models are examined beneath.

The progression condition, vitality condition and the Navier-Stokes energy condition oversee the progression of the liquid in the bend tubes

Coherence Equation gives the protection of mass and is given by

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho U_1}{\partial x_1} + \frac{\partial \rho U_2}{\partial x_2} + \frac{\partial \rho U_3}{\partial x_3} = 0 \qquad \textbf{Equation 3}$$

$$\frac{\partial U}{\partial x} + \frac{\partial v}{\partial x} = 0 \qquad \textbf{Equation 4}$$

What's more, for steady thickness, $\frac{\partial \rho}{\partial t} = 0$

The force balance, (Navier-Stokes conditions) pursues Newton's second law. The two powers following up on the limited component are the body and the surface powers. In CFD programs, the energy condition is given as

The force balance, (Navier-Stokes conditions) pursues Newton's second law. The two powers following up on the limited component are the body and the surface powers. In CFD programs, the energy condition is given as

$$\rho\left(u\frac{\partial U}{\partial x} + v\frac{\partial V}{\partial x}\right) = -\partial g - \frac{\partial p}{\partial x} + \mu\frac{\partial 2y}{\partial x2} \qquad \textbf{Equation 5}$$

The governing energy equation is given by

$$\rho C_p\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial x}\right) = k\frac{\partial 2T}{\partial y2} \qquad \textbf{Equation 6}$$

Choppiness is made in light of the shaky idea of the liquid stream. The stream winds up fierce for higher Reynolds number. In this model the k-ε (fierce energy vitality "k" and the violent dispersal "ε") model is utilized The physical elucidation of the ε condition is,

1. Aggregation of ε

2. Convection of ε by the mean speed

3. Creation of ε

4. Dispersal of ε

5. Dissemination of ε

The time steady for disturbance is resolved from the tempestuous motor vitality and scattering rate of violent active vitality (kinetic energy).

$$\boldsymbol{\tau} = \frac{\boldsymbol{k}}{\boldsymbol{\varepsilon}} \qquad \textbf{Equation 7}$$

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Work flow chart

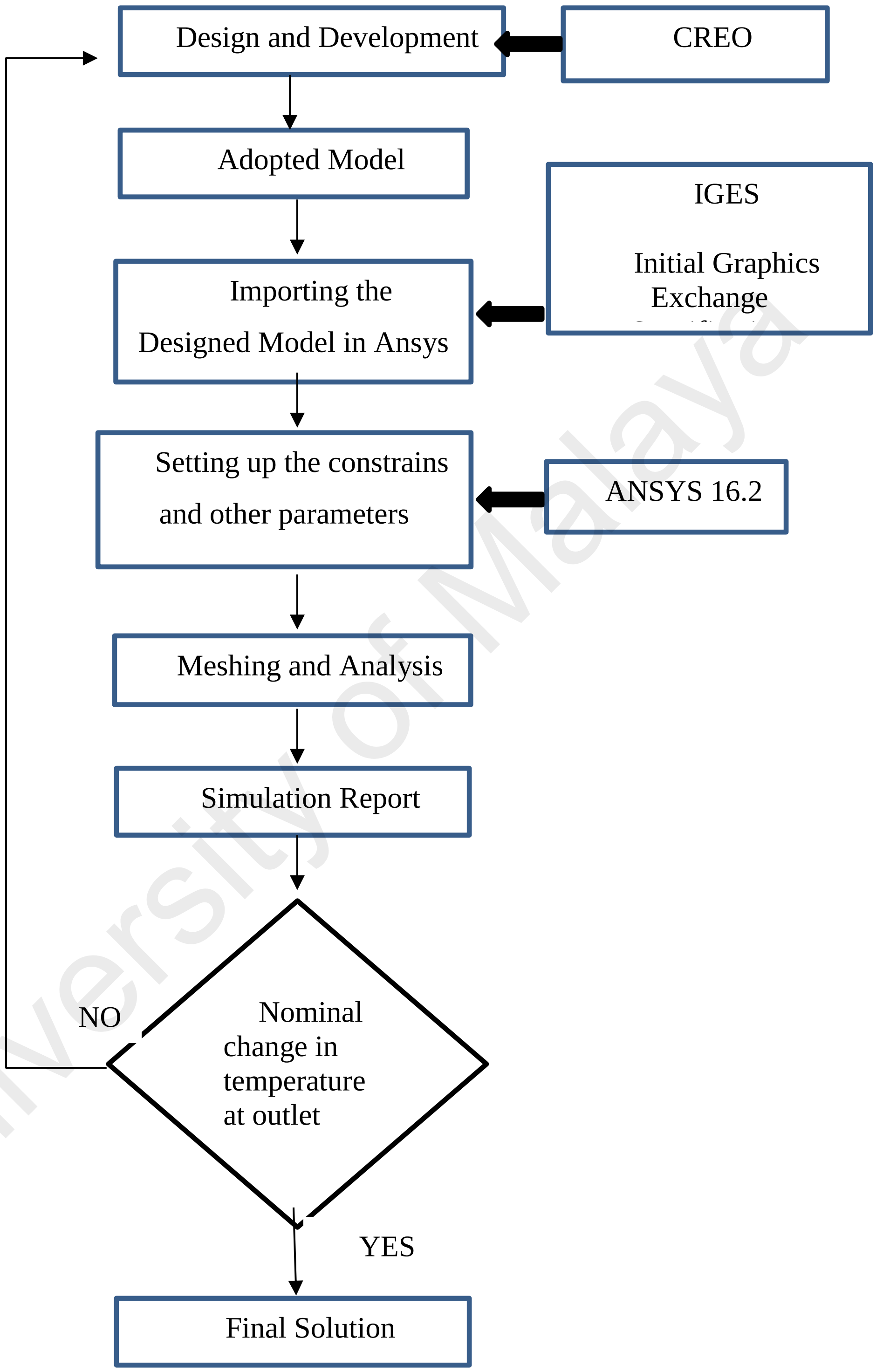


Figure 3.1: Design and Simulation flow chart

The research methodology clearly portrays the various steps and aspects that involves in the design and development of helical coil which are well equipped to fit-in inside the standard sized water bottles. The effective analysis procedures also clearly displayed with screenshots from ANSYS 16.2. The specifications and aspects that are taken into considerations are also illustrated in detail.

3.2 Design characteristics of helical coil

The major reason behind choosing the helical shape coil is that it has increased time of exposure of fluid to its surrounding. The ice cubes filled in the space of inner diameter of the coil will encourages the heat transfer from the fluid which is flowing through the coil. The coil with fluid inlet and outlet act as a heat exchanger which in turns give the cooled fluid in outlet. Cooling the drinking fluid in such manner will give the originality of the drinks without the influence of ice cubes on it. People in modern world are well evolved when it comes to tasting the food, providing the drinks with ice cubes mixed is already a failure plan although it is still in practice since ice cubes are easy to carry and available everywhere. Another alternative is refrigerator which is not at all possible to carry outside. This helical coil shaped heat exchanger design will help the consumers to hold up their drinks cool by using ice cubes but without dissolving it in drinks.

The helical coil for this product is designed with reference of few helical coil heat exchangers but the main design constrain is the coil must be fit-in inside a bottle (a shell which holds this coil inside). This design is very much like conventional heat exchangers which are used in industries over the period of years. The basic principle is same as the conventional heat exchangers as the decrease in temperature take place under the influence of mechanical heat transfer. The key part in design which make this product differs from conventional heat exchanger is its portable nature and cooling medium. The ice cubes are used to take away the heat from the drinking fluid, whereas in industries they use various medium to ensure the effective heat transfer.

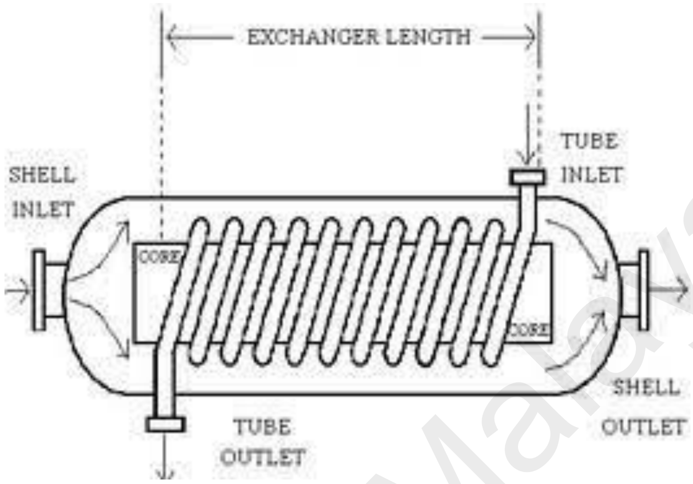


Figure 3.2: Conventional shell with helical coil Heat Exchanger design

3.3 Modelling of helical coil with outer shell

The demonstrating programming which is utilized here to display the helical curl is Creo Parametric 2.0. Creo Parametric is the standard in 3D CAD programming. It gives the broadest scope of amazing yet adaptable 3D CAD abilities to quicken the structure of parts and gatherings. Creo Parametric is a scoundrel cam programming broadly utilized for item plan and get together.

It is differing from AutoCAD in such a way that it is based on Parametric which means all the dimensions are Parametric which affect the actual part. For example, let us consider a line drawn in AutoCAD and Creo both. Now if we change the dimensions of the line then in AutoCAD it will not affect the line but in Creo it will also change the line. Join innovation, in Creo, gives leap forward capacities to improve profitability in multi-CAD situations. By empowering associations to productively solidify CAD frameworks and clients to team up more successfully crosswise over frameworks.

The dimensional specifications are assumed approximately with accordance to a normal water bottle whose volume is one liter. Since the concept of this research project is to portray the use of helical coil heat exchanger when it is design in a portable form, the dimensional accuracies are approximated and considered from previous products and designs.

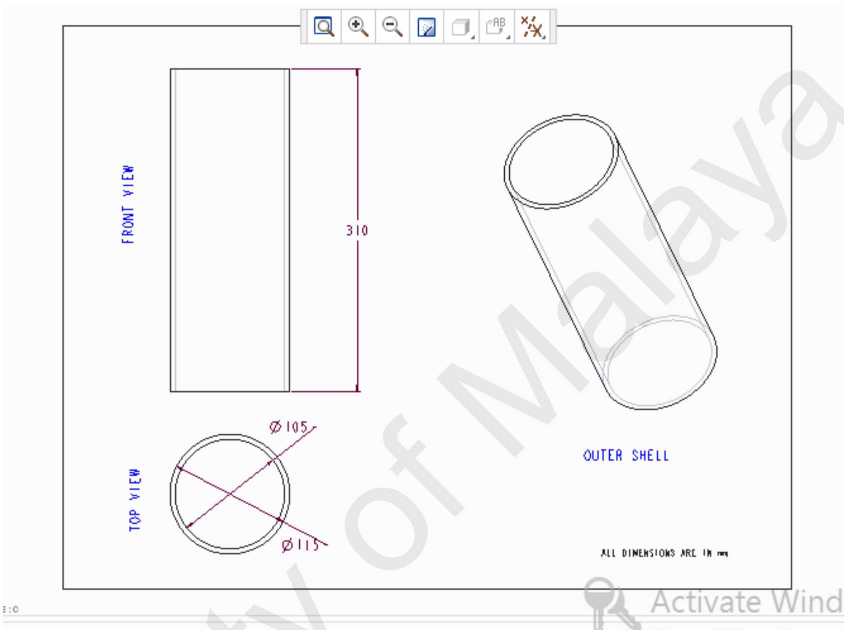


Figure 3.3: Wire Frame model of outer shell with dimensions in mm

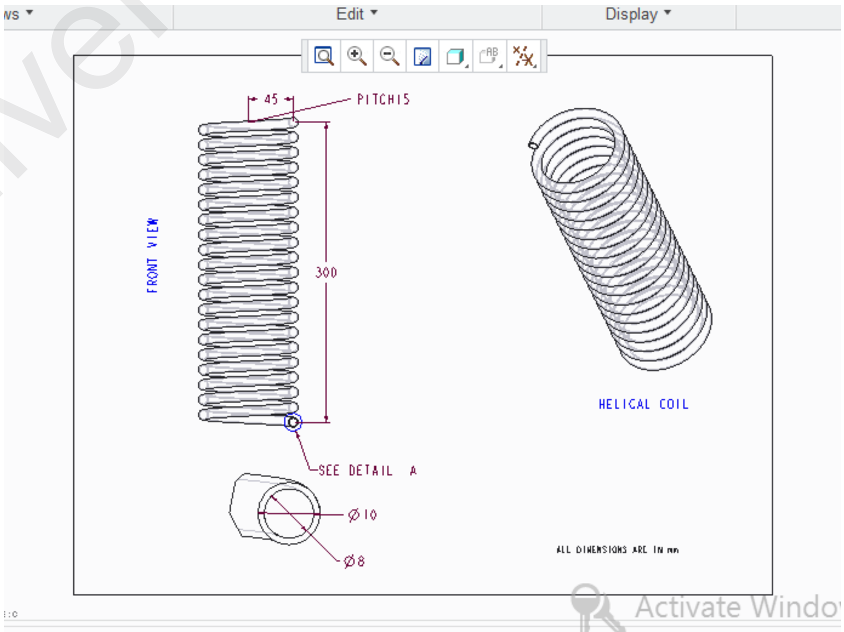


Figure 3.4: Wire Frame model of helical coil with dimensions in mm

3.3.1 Helical coil (Helical curl)

The helical coil is drawn with helical sweep command in Creo Parametric 2.0. The reference plane is selected, and the coil's inner and outer diameters are defined approximately which will somewhat matches enough to fit-in inside the existing water bottles.

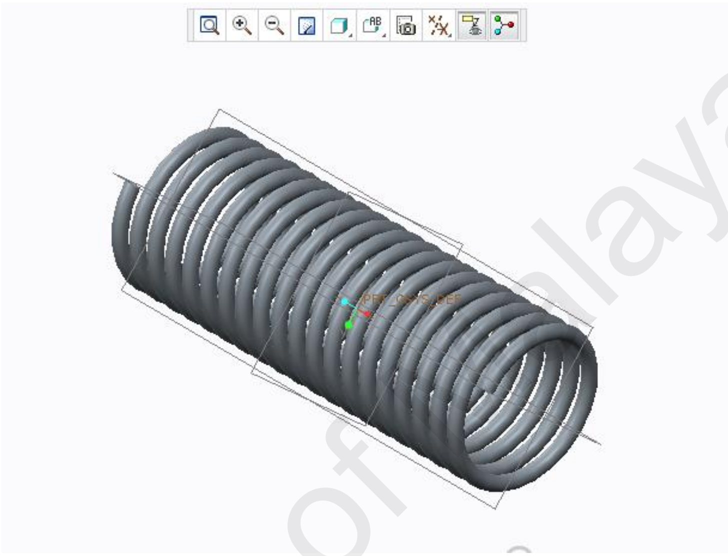


Figure 3.5: Helical coil model

3.3.2 Outer shell of helical coil

The outer shell of the helical must be rigid since it is portable and not a use and throws product. The outer shell should have certain level of thickness which in turns helps to get good insulation to provide effective cooling to the drinking fluid inside the coil which is placed inside the shell.

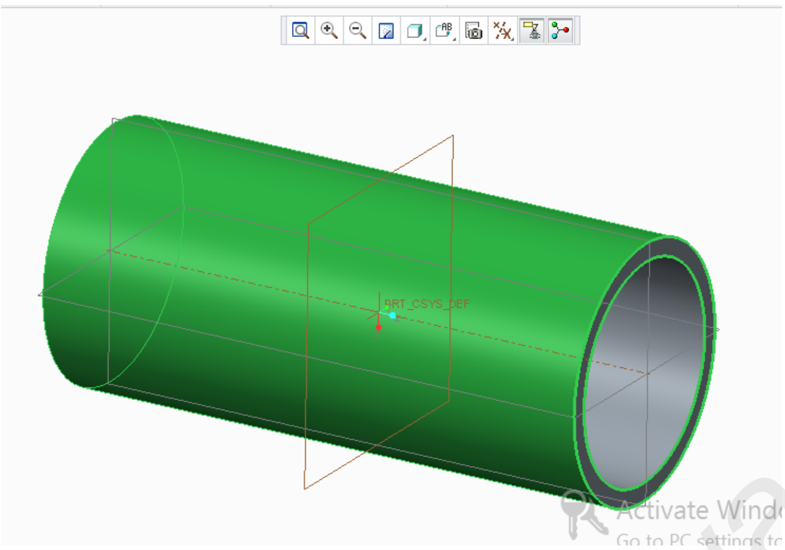


Figure 3.6: Outer shell model

3.3.3 Assembly of coil inside the shell

Creo parametric also provide the effective assembly future which helps to create the overall setup is made by fixing the helical coil inside the hollow shell.

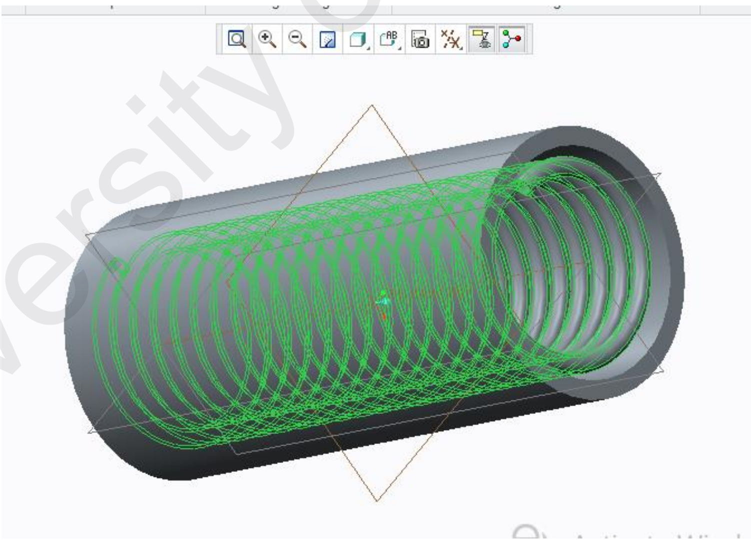


Figure 3.7: Overall setup of helical coil with shell

The figure above shows the structural design of mobile bottle chiller. The outer shell here act like a shield of simulation and rigid structure to hold and carry bottle anywhere, but at the same time it has no role in cooling the fluid which flows through inside the coil. Hence the heat exchange analysis is carried out only for the helical coil in the simulation software Ansys 16.2 whereas the outer shell is mentioned with the boundary conditions without the actual model while carrying out the analysis in Ansys.

3.4 CFD analysis

Computational Fluid dynamics (CFD) is the process in which one has to design the actual model with respective geometry and such kind of models can be altered and edited according to the requirements of CFD analysis. After such modifications and optimizations, the geometry is subject to discretization. Discretization is a process of dividing a part or geometry into numerous numbers of elements and nodes, when such separations are done it help in the CFD simulations and give the optimal accuracy in the output result. The whole process of CFD analysis takes place in a step by step process where the geometry is created and optimized in respect to CFD simulation requirements and then the fine mesh is generated. The boundary condition is assigned after the mesh which helps the meshed part to control what to do and how to behave under created atmosphere. Finally, the process is further proceeded with simulation run, solution, result and conclusion.

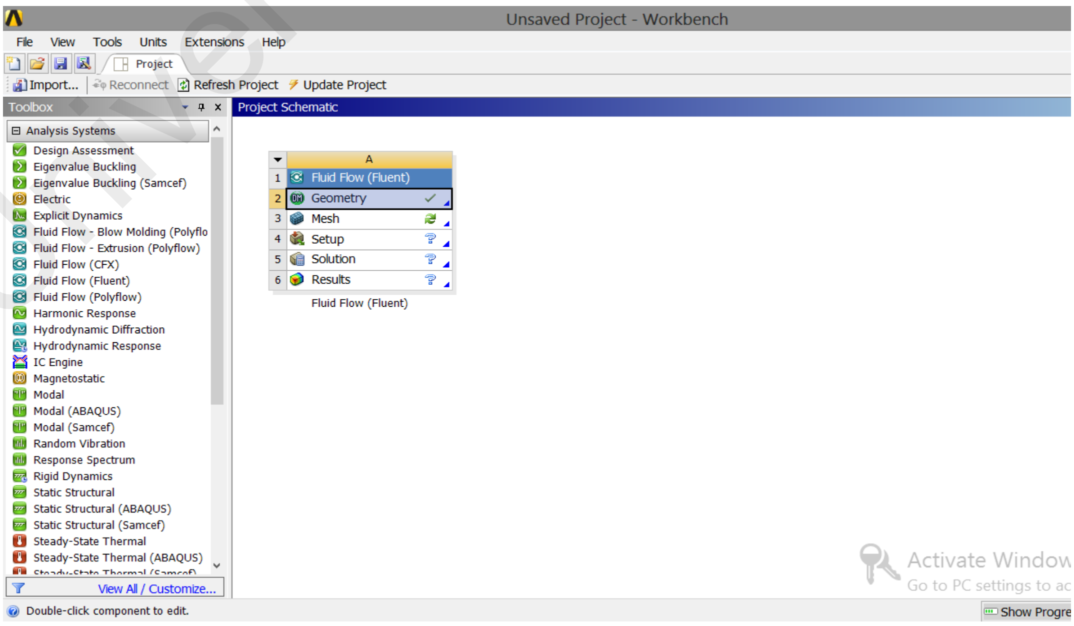


Figure 3.8: Fluid Flow analysis work flow page (CFD)

3.4.1 Geometry

The geometry of the part has been already created in a CREO package, it is generally more efficient to import it into ANSYS than to re-create it. The helical coil setup which is already modeled in CREO is imported into this ANSYS 16.2 for further analysis. This kind of introducing a created model into the new software is done with the help of an IGES format. This IGES format helps the user to import the solid model from any kind of designing software to analysis software. The Initial Graphics Exchange Specification (IGES) (articulated eye-jess) is a seller impartial record position that permits the computerized trade of data among PC helped structure (CAD) frameworks.

Table 3.1: Declaration of parts name and its state

part	Assigned name	State
1	Fluid inlet	Fluid
2	Fluid outlet	Solid (ice)
3	Coil surface	Solid (cu)

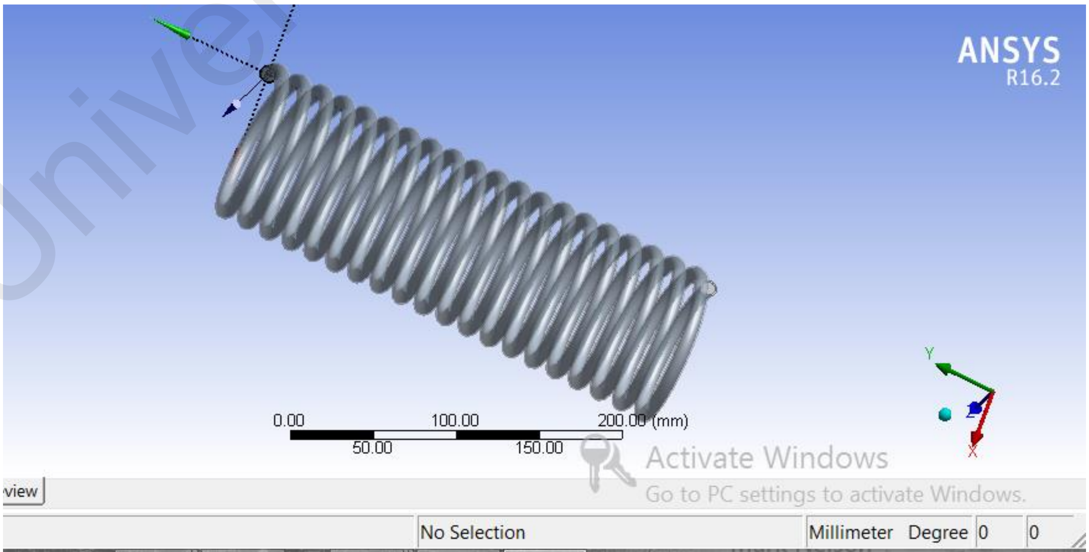


Figure 3.9: Importing geometry from Creo to Ansys by IGES

3.4.2 Mesh

The accuracy of output result lies in a relation of mesh and number of nodes and elements, it is like simulation accuracy is directly proportional to the number of elements and nodes generated in mesh. Initially the ordinary mesh is generated which will cover every part of model with Tetra and Hexahedral cells. To achieve a close to accuracy results the mesh is then converted to fine type which will cover up all the corners and especially at edges and parts which are located at region where boundary conditions are required. This organized and well structures mesh will ensure the results that do not deviates much from the accurate values and number of iterations are performed to get the stipulated and bonded output.

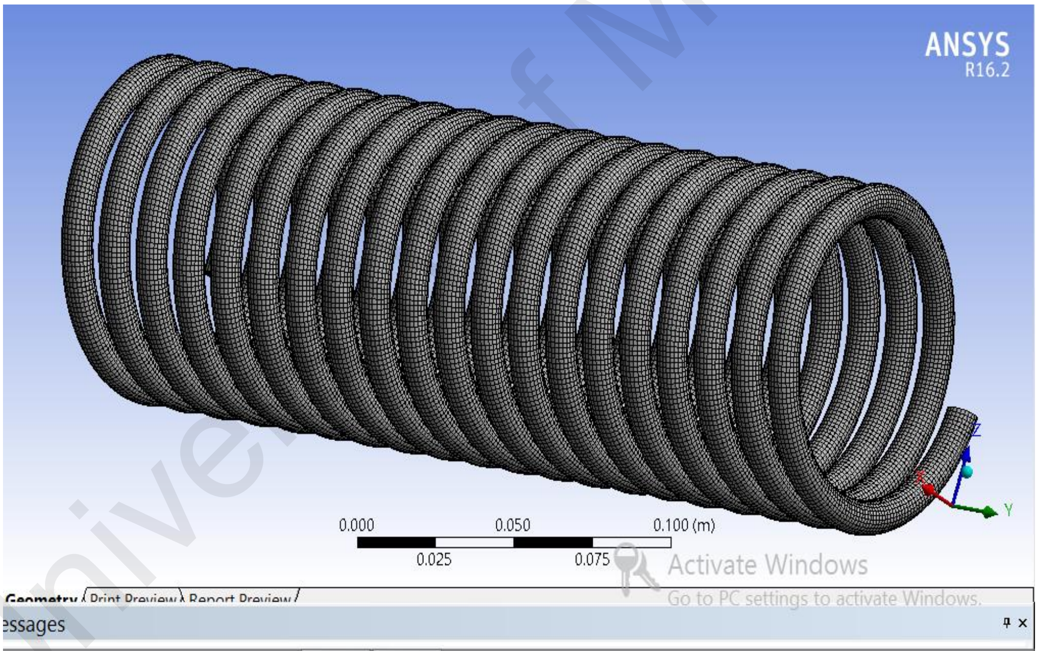


Figure 3.10: Mesh generated model

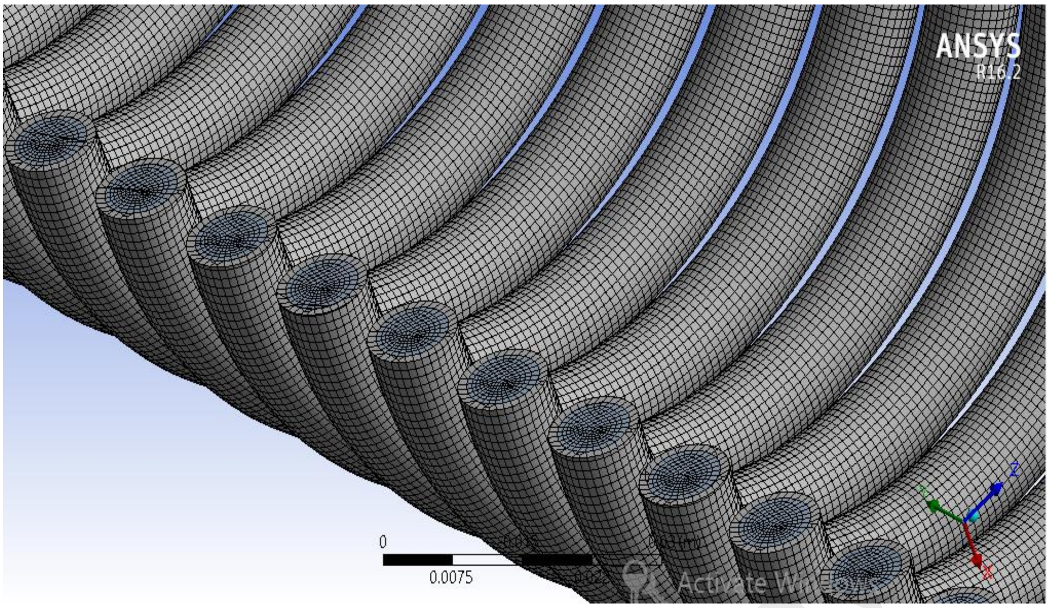
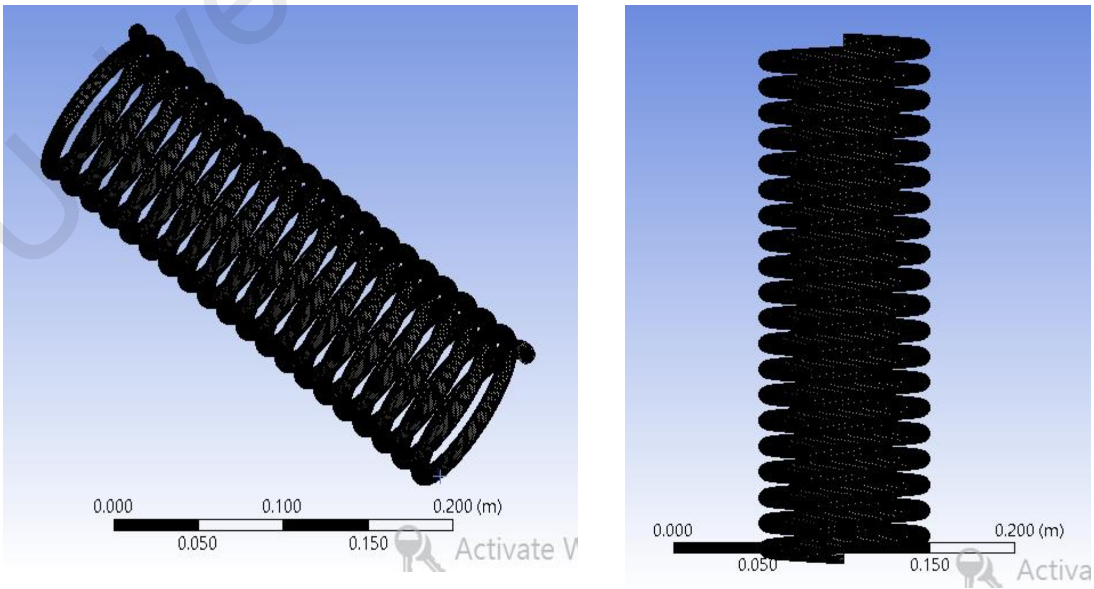


Figure 3.11: Cross section view of mesh generated model

After performing the normal mesh, the various contact regions are defined, and the sizing of mesh is switched to fine option (which increases the number of elements). Generally meshing is process of dividing the part model into numerous elements to analysis the behavior of that part under given boundary conditions. Larger numbers of elements give more accuracy in such case the mode is mesh is switched from coarse to fine will increase the number of elements thereby the accuracy.



(a) **(b)**

Figure 3.12: (a), (b) Model after generation of fine mesh

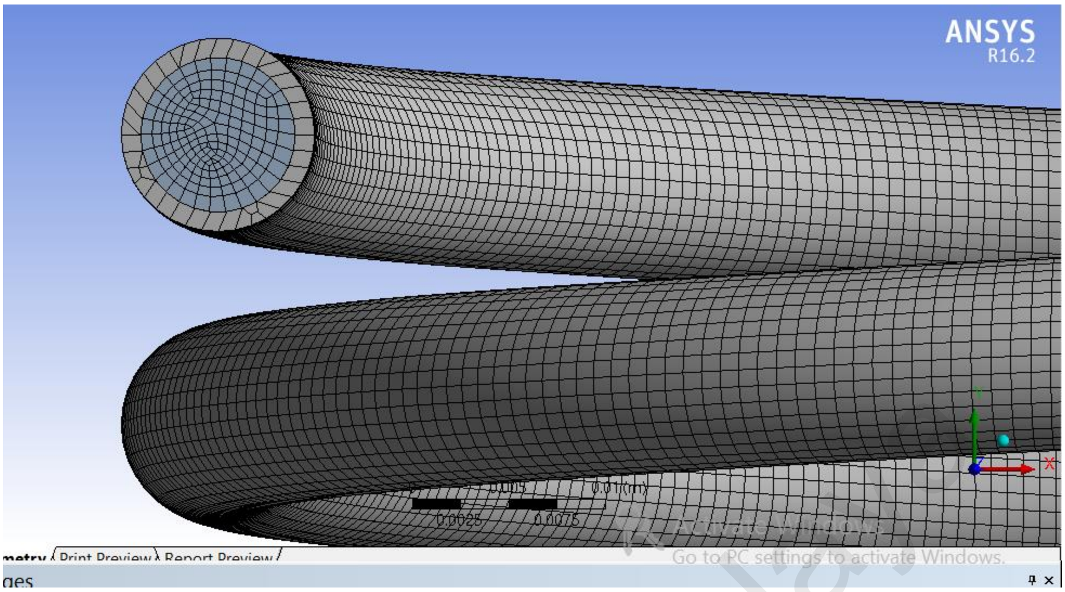


Figure 3.13: Fine view of fluid inlet after mesh

3.4.3 Y^+ values

y+ values assume a noteworthy job in disturbance demonstrating for the close divider treatment. y+ is a non-dimensional separation. It is as often as possible used to depict how coarse or fine a work is for a stream design. It decides the correct size of the cells close space dividers. The disturbance model divider laws have impediments on the y+ esteem at the divider. For example, the standard K-epsilon model requires a divider y+ esteem between roughly 300 and 100. A quicker stream close to the divider will create higher estimations of y+, so the lattice measure close to the divider must be diminished. y+ values for various divider medications are given in table underneath.

Table 3.2: y+ Values for various Wall Treatments

Wall treatment method	y^+ values	y^+ values at tube walls
Standard wall functions	$400 > y^+ > 30$	$5 > y^+$

Non-equilibrium wall functions	$100 > y^{+} > 30$	$5 > y^{+}$
Low Reynolds number model	$y^{+} \cong 1$	$1 > y^{+}$

The parameter obtained after fine mesh generated

Table 3.3: parameters of generated mesh

Parameters	**Description**
Relevance center	fine mesh
Smoothing	high
Size	4.021e-005m to 8.1e-005m
Pinch tolerance	3.9763e-005m
Nodes	181398
Elements	830554

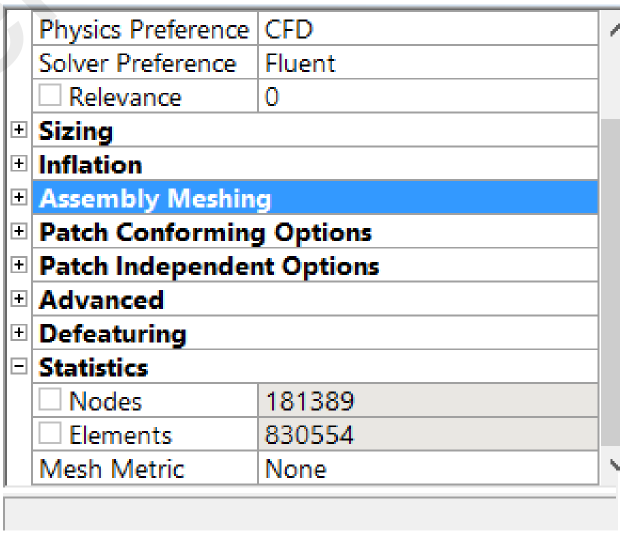


Figure 3.14: Nodes and Elements details after fine mesh

3.4.4 Named sections of mesh generated model

The mesh generated model is then given parts declaration which is also called naming the sections. In this project the helical coil hast five different named sections which are named by choosing geometry option and respective names are assigned for all parts. This naming of sections helps in fluent analysis and CFD analysis for assigning the boundary and cell zone condition for respective sections and regions. When CFD simulation is performed it requires the user to define various limits and constrains for the model under particular atmospheric condition. This naming also helps in solution phase of analysis to extract the needed results just by selecting the required sections.

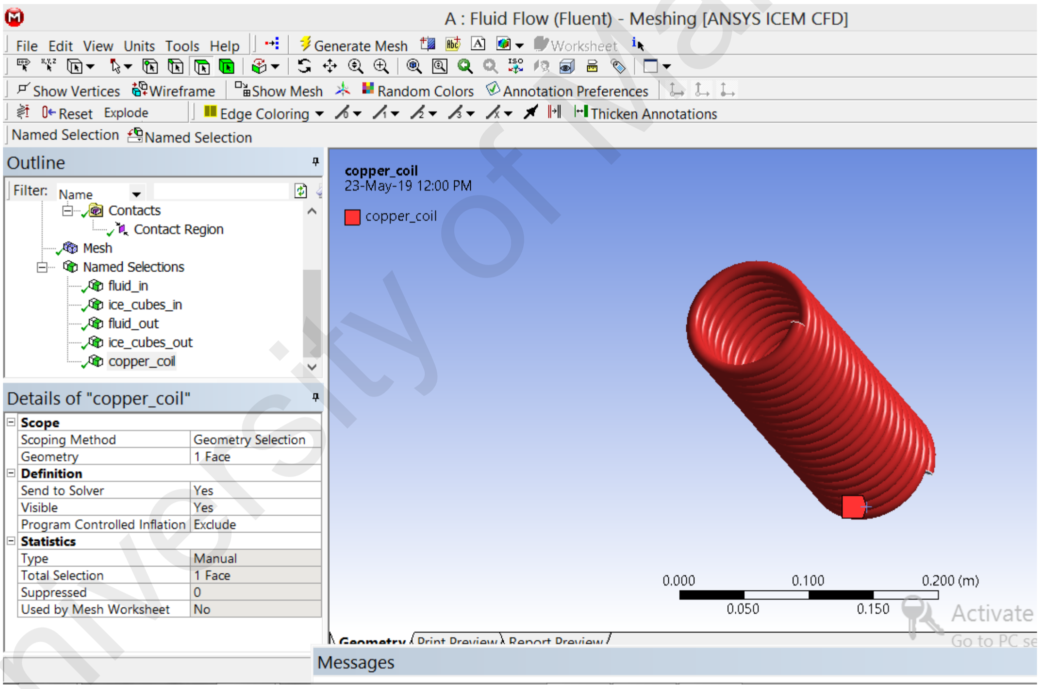


Figure 3.15: : Model with named sections

3.4.5 Simulation setup

The model with its named sections and fine mesh generated geometry is transfer to the fluent analysis page where the actual CFD simulation is performed. The pressure based investigation is initiated and the according to the coordinates the gravitational influence is assigned to the model. Here in helical coil the gravity is declared in the direction of y-axis with negative value since it pulls the medium towards down under its influence. The gravitational force vale assigned to y-axis is -9.81 m/s^2.

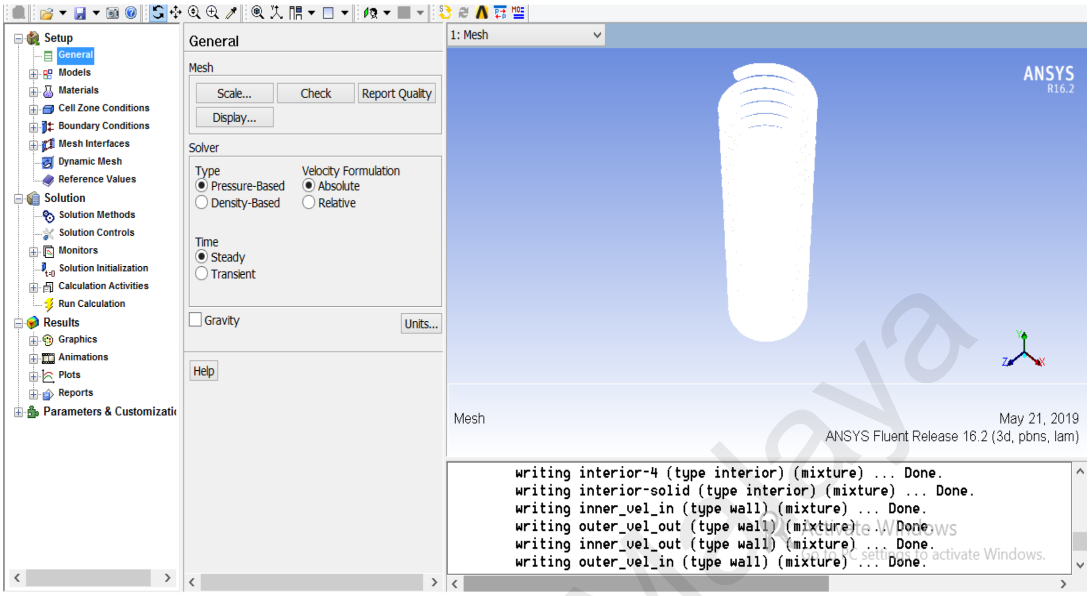


Figure 3.16: CFD analysis setup

3.4.6 Model setup

The model setup is done by setting up the energy in ON position. Viscous model is selected as standard wall function with "k-epsilon (2eqn)" model. Radiation model is changed to Discrete Ordinates since in this heat transfer process there is no any warmth gets transferred by means of radiation.

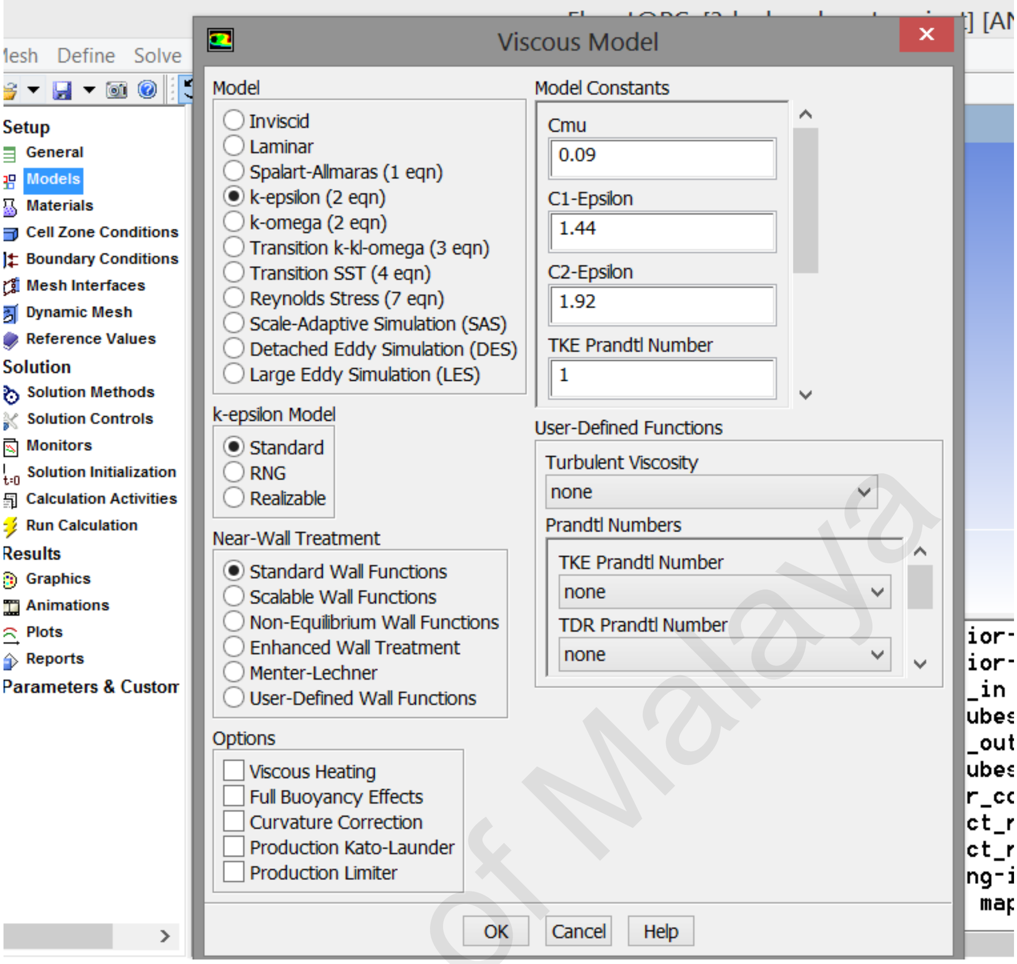
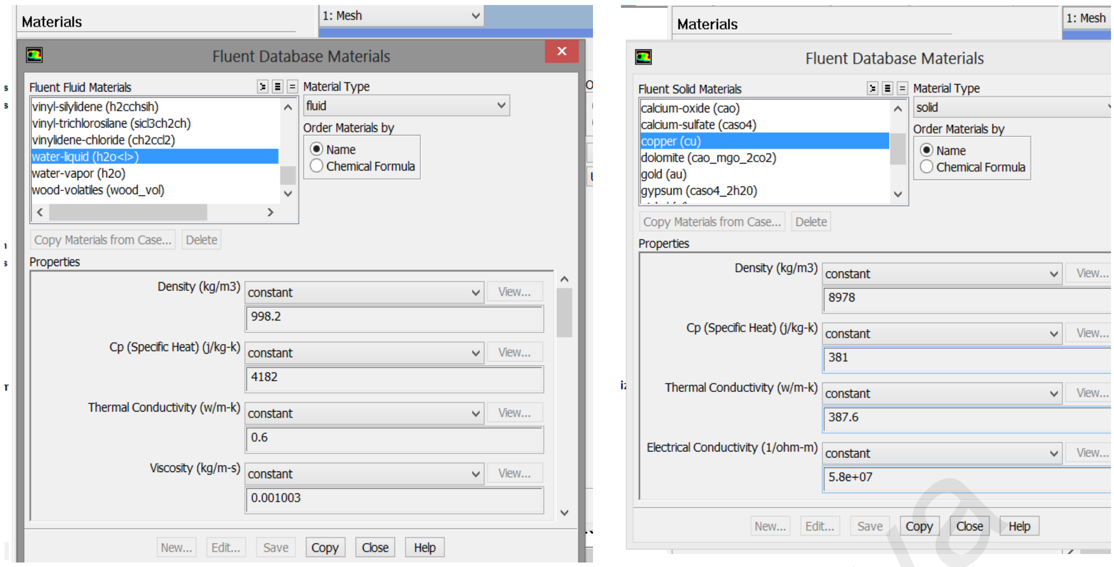


Figure 3.17: Defining the Model for CFD analysis

3.4.7 Materials

The material selection is done by using the material database options, under which the user can choose and copy the material with its default properties that are essential for simulation calculation. In this section we can able to fix the type of fluid or solid with its respective surface. Water with its chemical formula (H2O) and copper with it symbol (cu) is chosen from material database. The chosen material is assigned to the respective part by cell zone condition.



(a) (b)

Figure 3.18: (a), (b) Material database

3.4.8 Cell zone condition

The parts should be assigned with its respective material by which it is made off or to which it is going to be in contact with. In previous material database copper and water is chosen and it is assigned to its respective region to part.

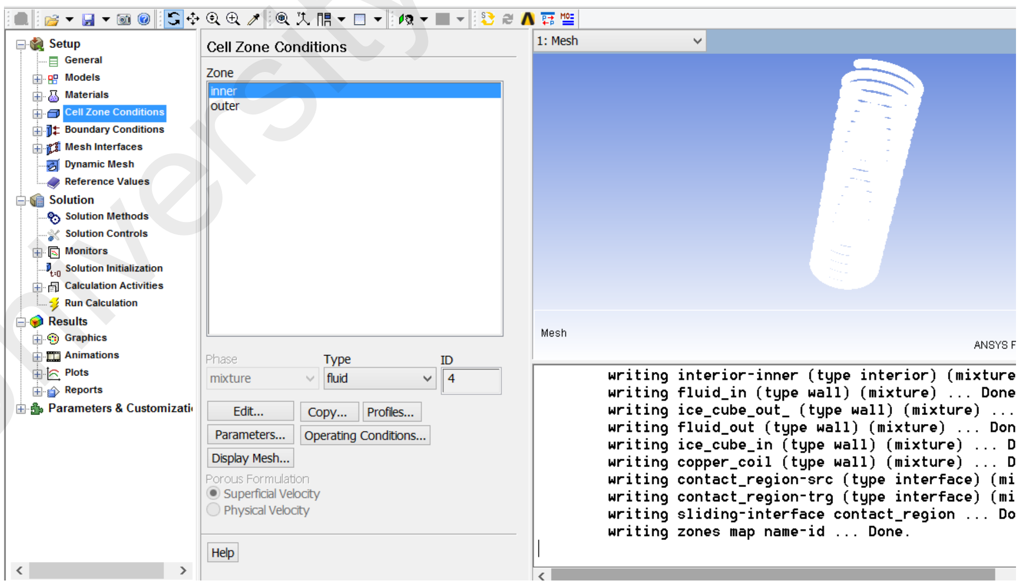


Figure 3.19: Allocating Cell zone condition

3.4.9 Boundary conditions

In this section the model is assigned with various boundary condition which guides the model how to behave while simulation is initialized. This mobile bottle chiller is designed in a way that water or drinks should flow through the coil and ice is placed inside the coil diameter. The flow in this model is considered as a unidirectional flow since the water and ice cubes are going to be delivery in same direction. The named sections are assigned with its suitable boundary condition. The copper coil walls are separately declared with temperature slightly less than a ice cube temperature (-4^{0}C). the table shown below will give the respective details and parameters assigned to each named section in the name of boundary condition.

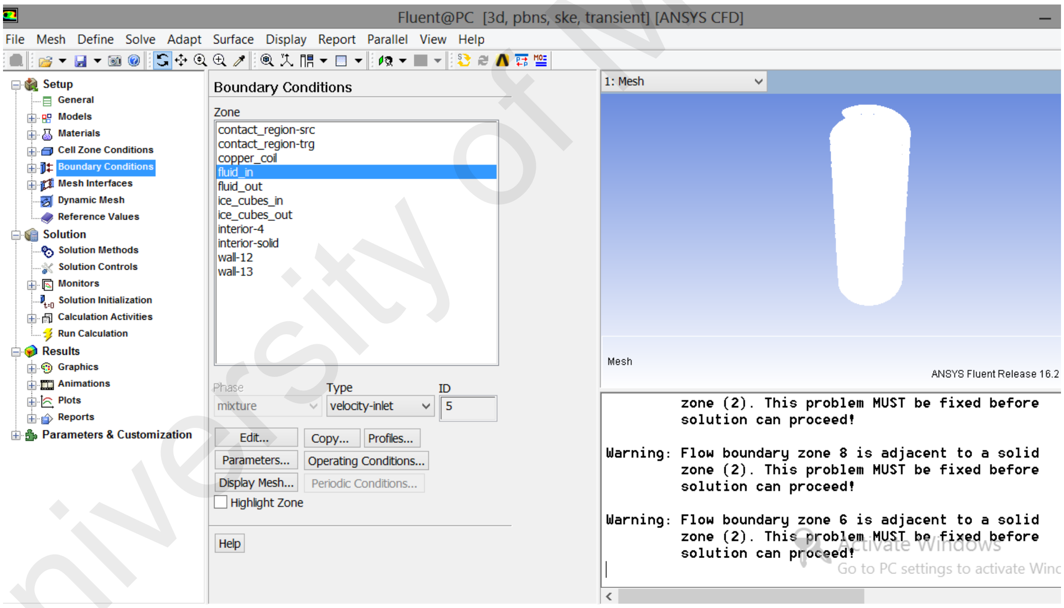


Figure 3.20: Boundary condition setup

Table 3.4: Boundary Conditions value declaration

Named selections	Boundary Condition	Velocity Magnitude	Turbulent Kinetic Energy	Turbulent Dissipation Rate	Temperature
Fluid in	Velocity In	0.0138 m/s	0.01 m^2/s^2	0.1 m^2/s^3	320 K (lukewarm)
Fluid Out	Pressure Out	-	-	-	-
Ice cubes in	Velocity In	0.001 m/s	0.01 m^2/s^2	0.1 m^2/s^3	270 K (ice cube)
Ice cubes out	Pressure Out	-	-	-	-

3.4.10 Reference values

Reference value is a set of parameters with default standard value that stored in a fluent analysis database for simulation calculation.

Table 3.5: Reference value details

Parameters	Values
Area	1 m^2
Density	998.2 kg/m^3
Length	39.37008 inch
Temperature	348 K
Velocity	0.9942 m/s
Viscosity	0.001003 kg/m-s
Ratio of specific heats	1.4

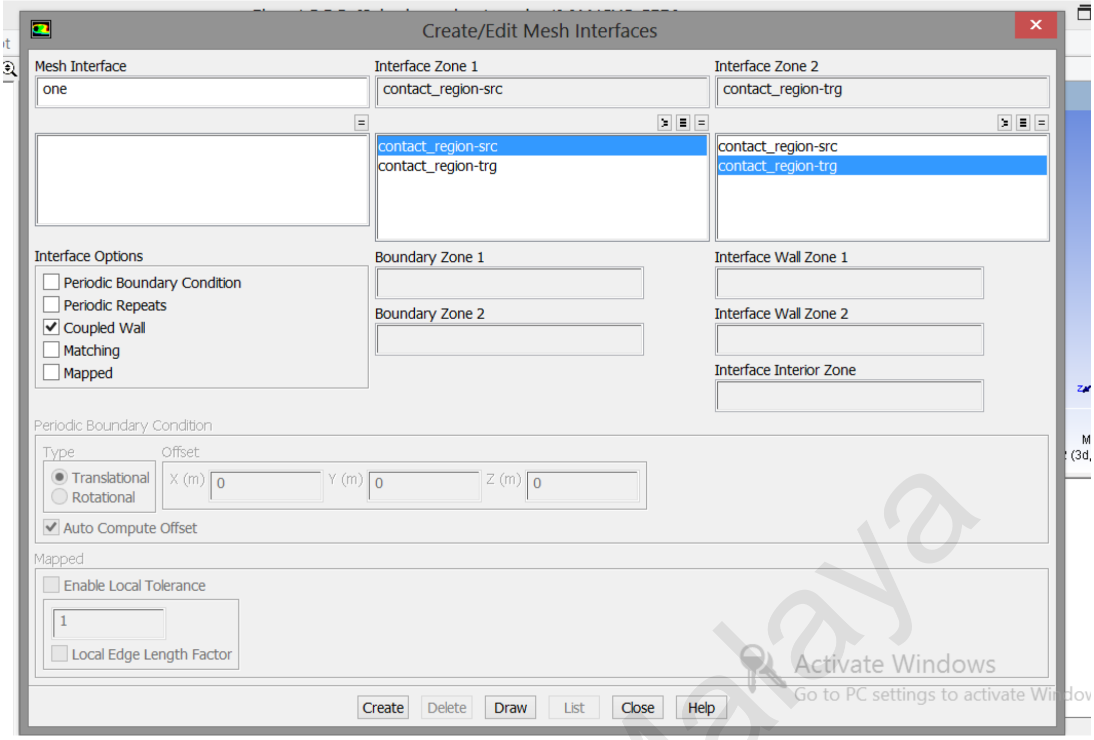


Figure 3.21: Setting up reference value and mesh interface

3.4.11 Solution method

The method that required by a user to declare and discuss the result is known as solution method. A user can prefer their own method to run the calculation.

Table 3.6: solution method setup details

Parameters	**Description**
Scheme	Simple
Gradient	Least Square Cell Based
Pressure	Standard
Momentum	Second Order Upwind
Turbulent Kinetic Energy	Second Order Upwind
Turbulent Dissipation Rate	Second Order Upwind

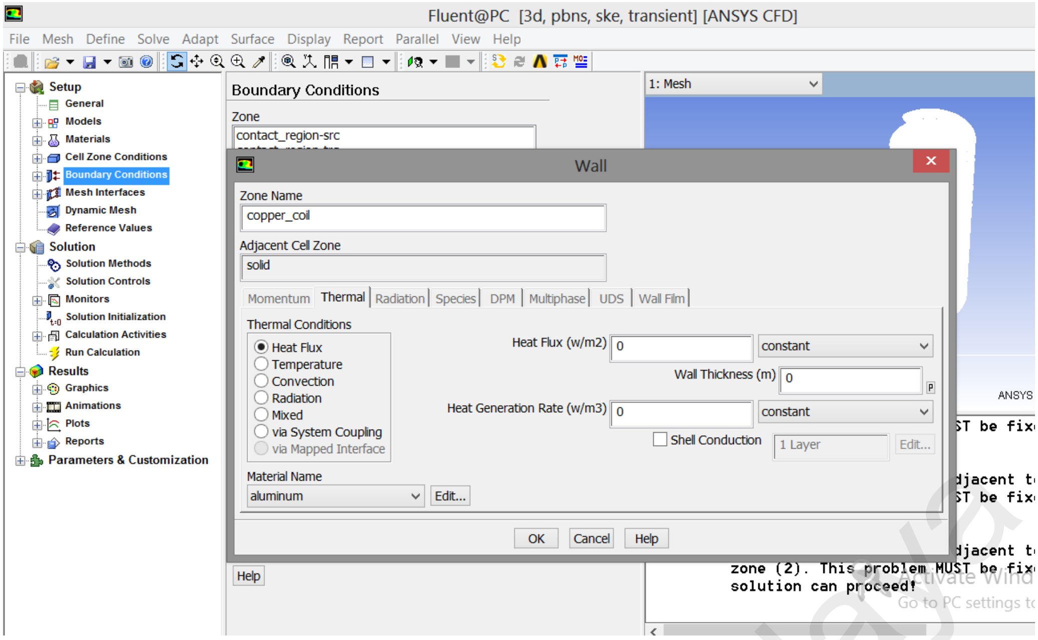


Figure 3.22: Solution method setup

3.4.12 Solution control and initialization

Under steady state condition the parameters like pressure, density, body forces, momentum, turbulent kinetic energy will have the following values.

Table 3.7: Steady state values of various factors

Parameters	**values**
Pressure	0.3 Pascal
Density	1 kg/m^3
Body forces	1 kg/m^2s^2
Momentum	0.7 kg-m/s
Turbulent kinetic energy	0.8 m^2/s^2

After fixing these default conditions and specifications the project is ready to run its iterations with the reference of cell zone and all other boundary conditions assigned previously. This standard initialization is started by choosing the inlet for the computation of solution.

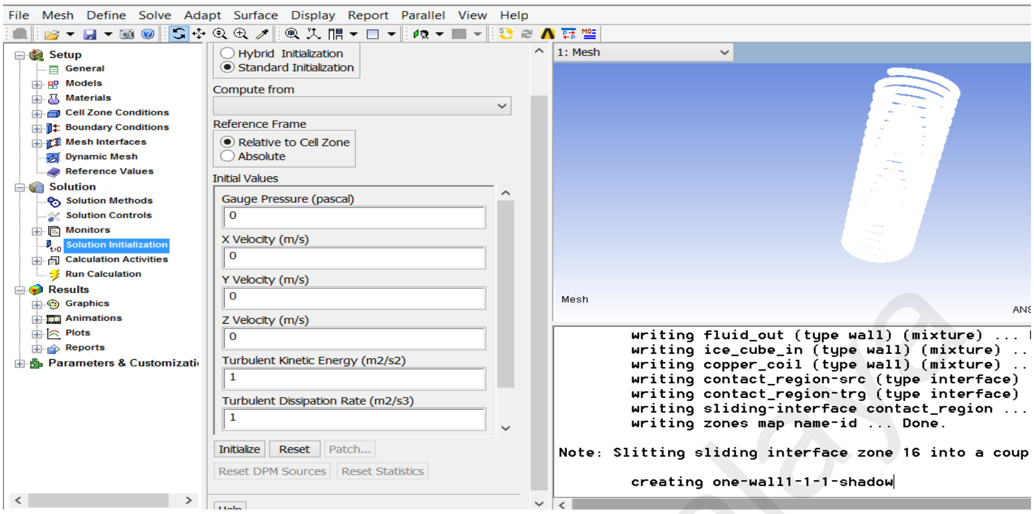


Figure 3.23: Solution Initialization

3.4.13 Measure of convergence

Measure of convergence is more like a mesh which in turns reflects in the accuracy of solution output, hence this section is strictly handled to get a good reliable result. The table below shows the residual value which improves the smooth measure of convergence throughout the simulation.

Table 3.8 : Variable and Residuals

Variables	**Residual**
Energy	E-9
Turbulent kinetic energy	E-5
Specific dissipation energy/ dissipation energy	E-5
x-velocity	E-6
y-velocity	E-6
z-velocity	E-6
Continuity	E-6

3.4.14 Run calculation

Run calculation section demands the number iteration which must be done under give cell zone and boundary conditions. It is fixed about 50 iterations for this mobile bottle chiller simulation.

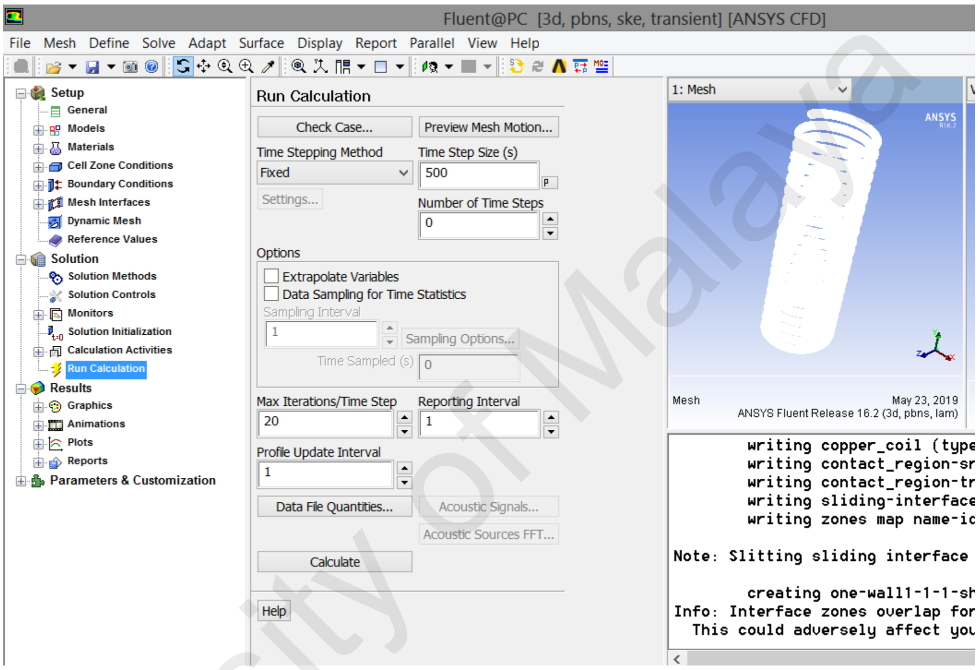


Figure 3.24: Run calculation Iteration setup

CHAPTER 4: RESULTS AND DISCUSSION

The simulation of mobile bottle chiller gives the result in various aspects like velocity, mass flow, energy etc. but in this case the major motive is to analyze whether the design serves its purpose or not. This project is conducted to examine the concept of cooling down the temperature of drinking water or other fluid on the go just with a bottle and some ice cubes. Hence the results are filter to temperature and heat transfer-based outputs which brings us the direct result like the cooling of drinking fluid takes place by this design or not.

4.1 Iterations

In this section the Ansys 16.2 fluent flow solved solutions are displayed and its behind the screen meanings are discussed briefly to conclude the result. The model underwent lot of iterations and time steps to produce the optimal accuracy in final output.

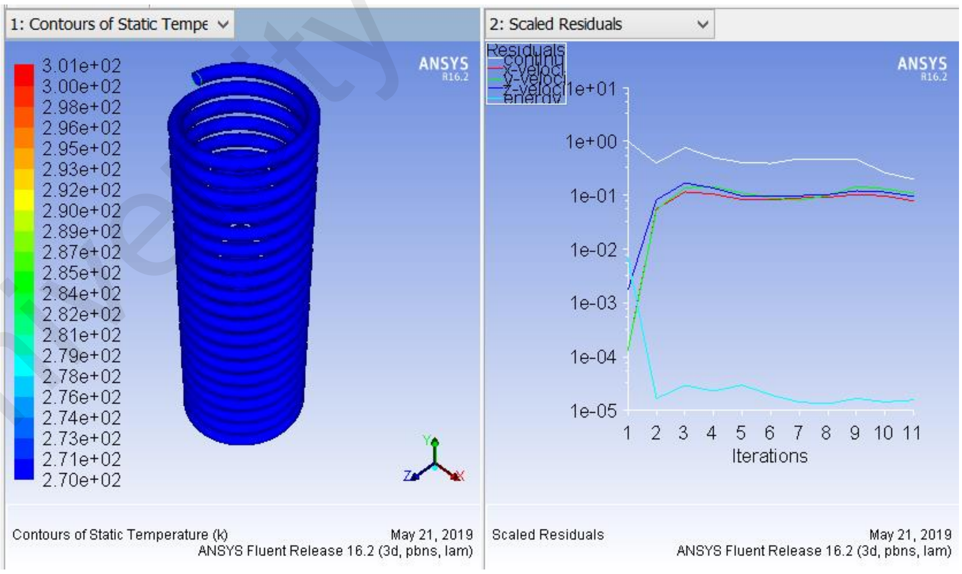


Figure 4.1: Iteration setup

4.2 Heat transfer from fluid to coil

The heat is known for its switching ability from one part to other when there exists the temperature difference between two parts. In this project the is no any forced heat transfer takes place, the objective to achieve the pure mechanical heat transfer takes place as there is a huge temperature difference between the coil and the fluid that flowing trough inside the helical coil.

As soon as the hot fluid or warm fluid enters the coil inlet the ice cold copper coil starts to absorb the warmth from inlet fluid which in turns changes the temperature of coil that is clearly showed in each displays give below. After attaining certain stage both the inner fluid and the coil will be at same temperature which will make the coil back to its ice cold temperature state since ice cubes are solid and needs the little amount of extra time to gets melted. The upcoming figures will clearly explains the state of heat exchange at various stages of analysis.

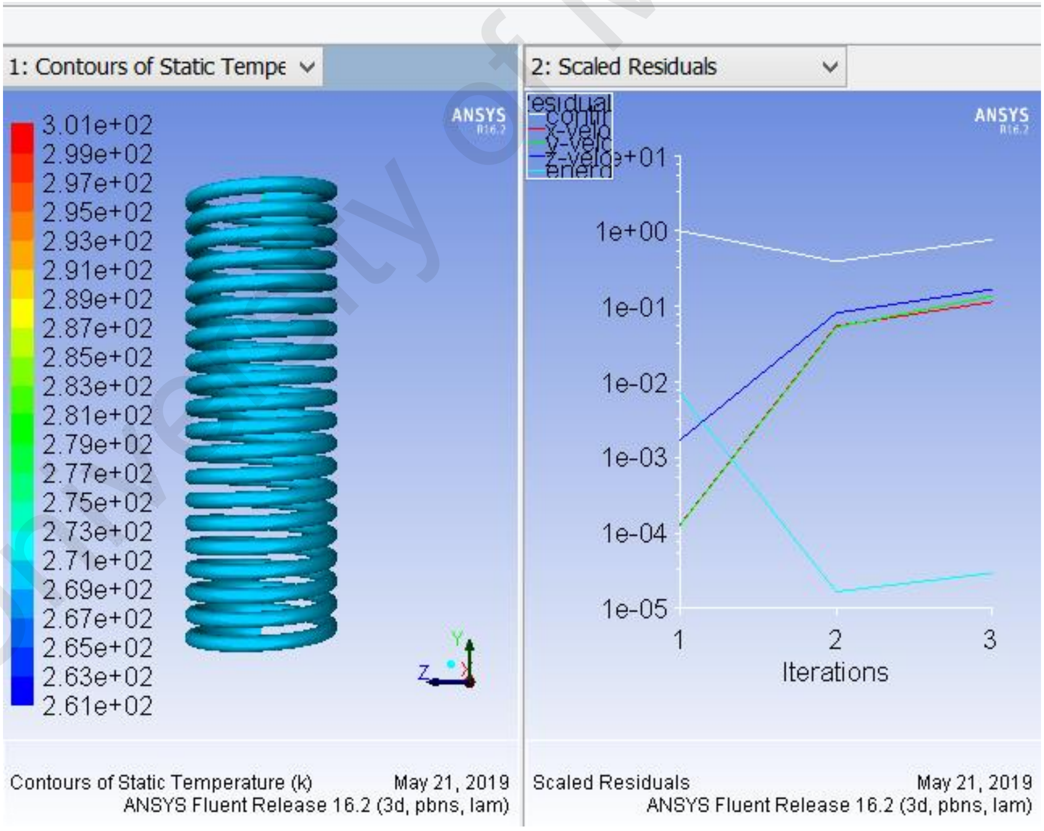


Figure 4.2: Contours of static temperature and scaled residuals display 1

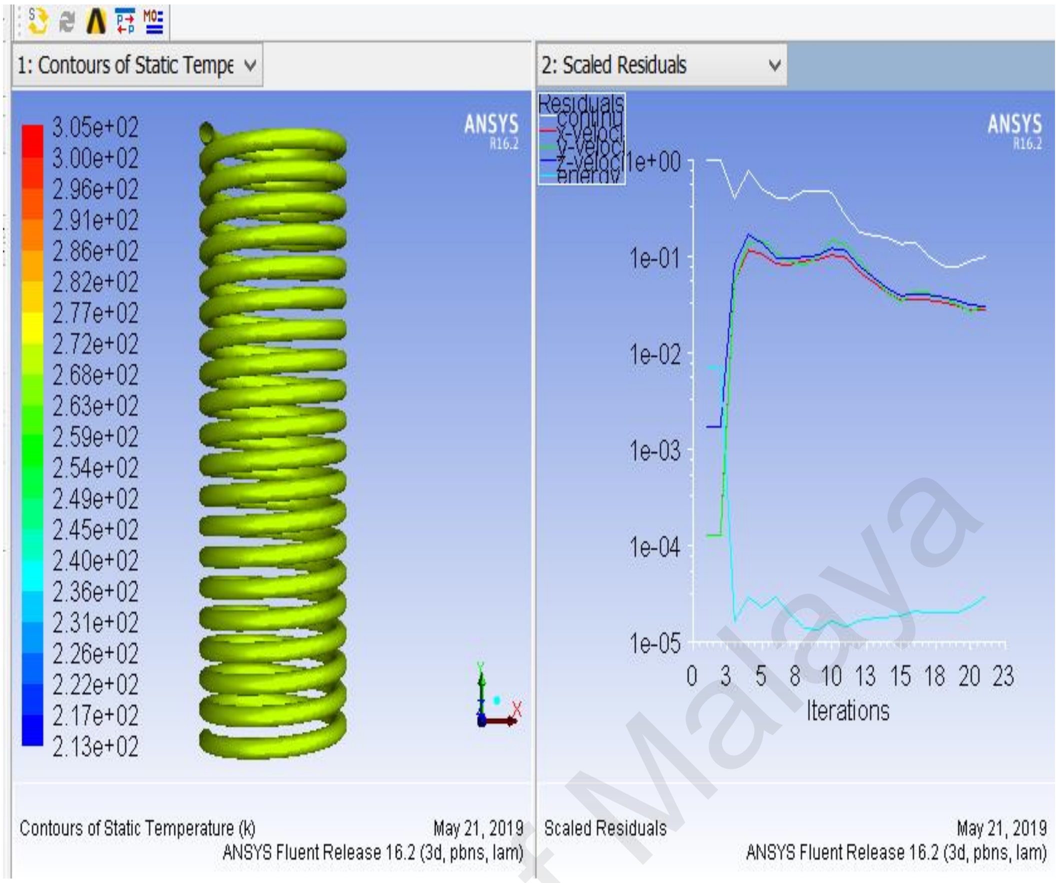


Figure 4.3: Contours of static temperature and scaled residuals display 2

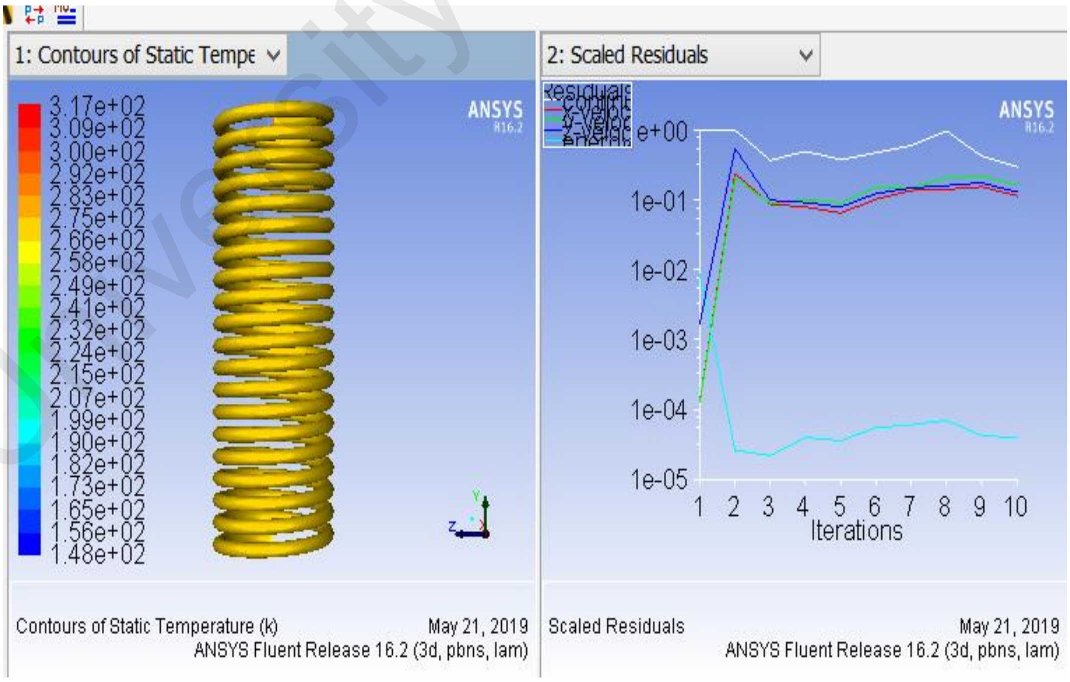


Figure 4.4: Contours of static temperature and scaled residuals display 3

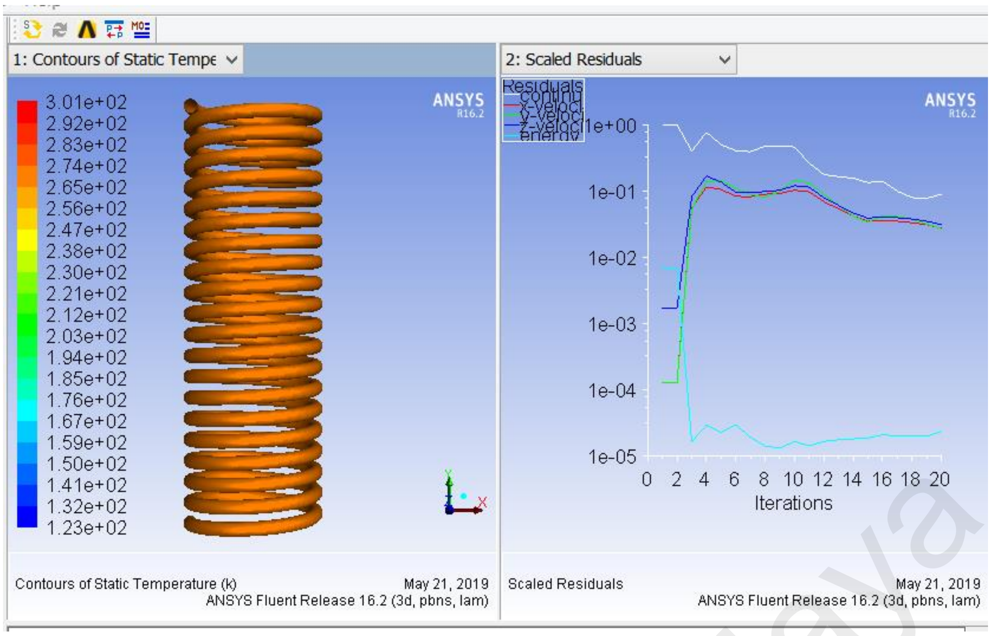


Figure 4.5: Contours of static temperature and scaled residuals display 4

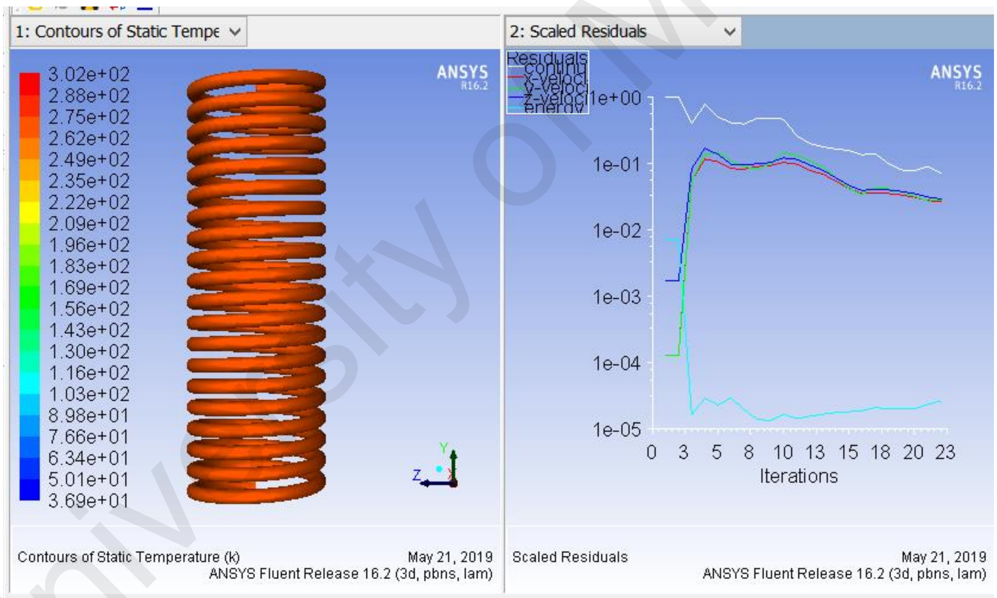


Figure 4.6: Contours of static temperature and scaled residuals display 5

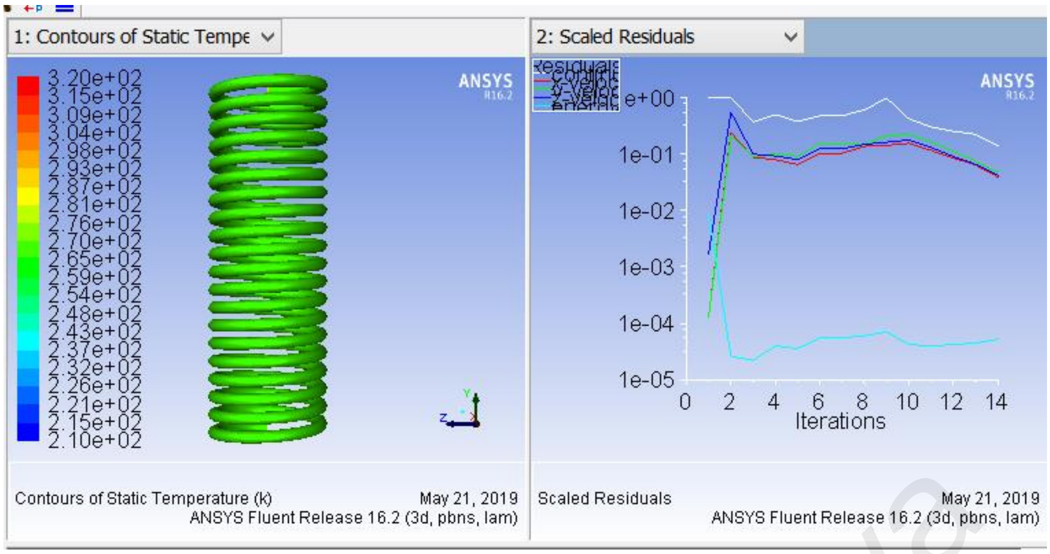


Figure 4.7: Contours of static temperature and scaled residuals display 6

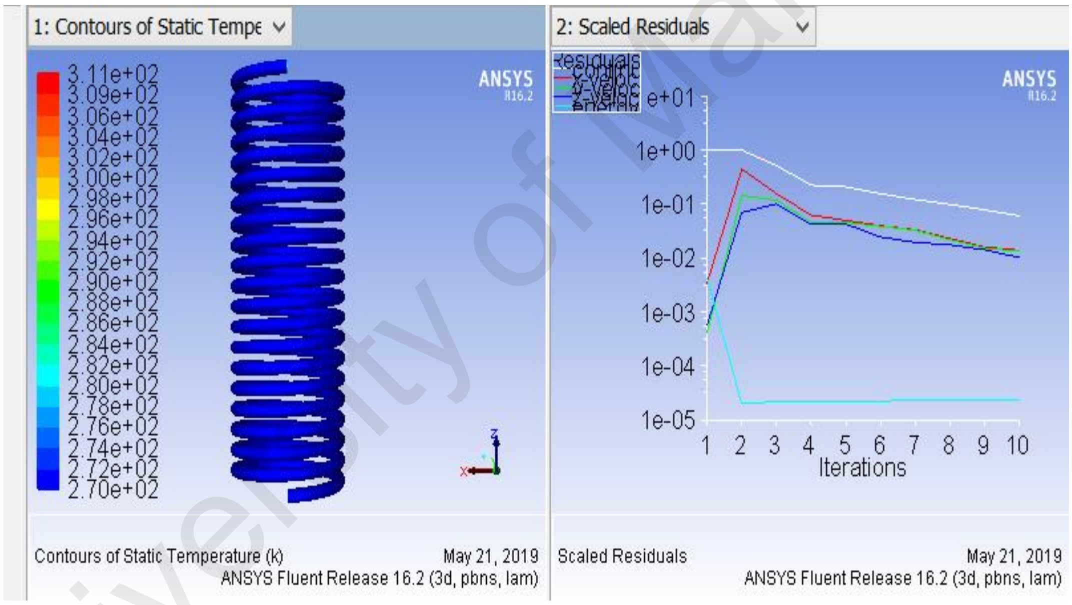


Figure 4.8: Contours of static temperature and scaled residuals display 7

4.3 Scaled residual

Residuals are the proportion of union of the iterative methodology. In CFD, after discretization, the incomplete differential conditions are changed over in to a lot of logarithmic conditions and each mathematical condition must be fathomed for individual control volume (Meshing the entire area into various sub spaces or control volumes).

Thus, residuals imply the neighborhood lopsided characteristics of any monitored field variable in individual control volumes.

In an iterative numerical arrangement, the lingering will never be actually zero. In any case, the lower the remaining quality is, the more numerically precise the arrangement. In FLUENT: the scaled residuals for progression, force, vitality and so forth should be characterized in the screen window, which are commonly known as Convergence criteria.

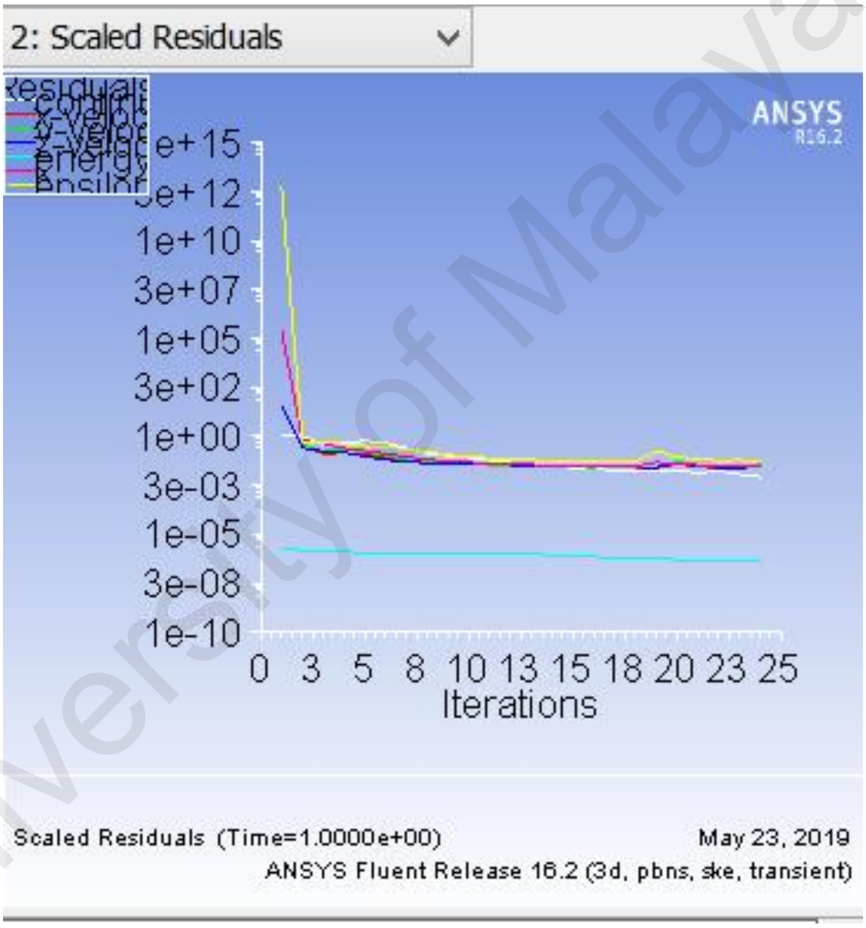


Figure 4.9: Scaled residuals

4.4 Report generation

Fluent analysis also shows the report of analysis and entire database that needed by its user to make sure the motive of project gives the result in positive manner. The required report is generated with surface integral process in which the static temperature and static velocity magnitudes are chosen.

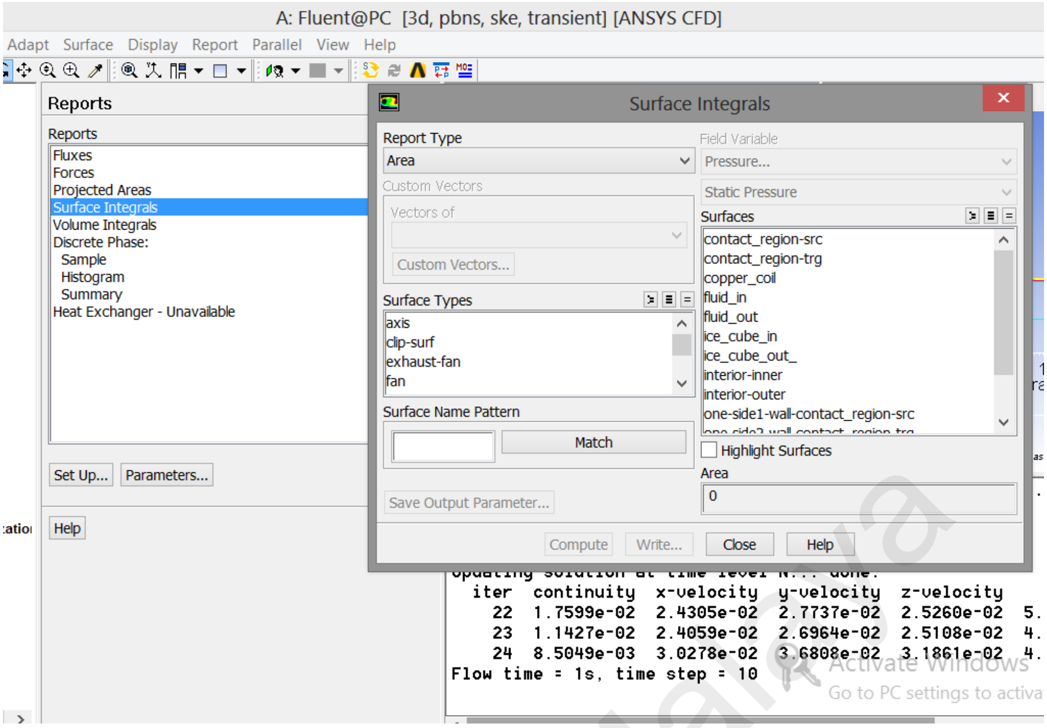


Figure 4.10: Surface Integral report generation

4.4.1 Temperature average report

The static temperature average report is generated with four named sections fluid in, fluid out, ice cubes in, and ice cubes out. These are all the sections to which the fluid and ice cubes makes the actual contact.

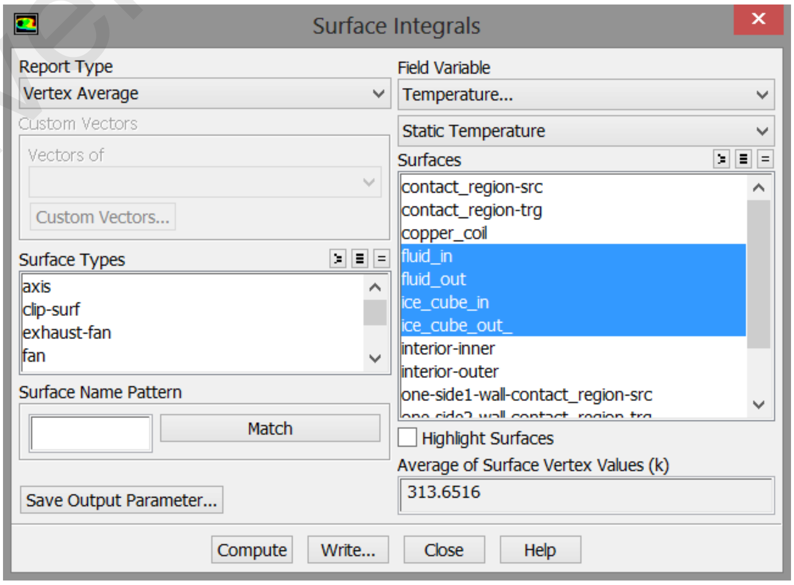


Figure 4.11: Static temperature report generation

Table 4.1: Static temperature report

Named sections	Static temperature (K)
Fluid in	329.99706
Fluid out	300.00246
Ice cubes in	300.00283
Ice cubes out	320.17419
Net	**313.65157**

The fluent generated static temperature report gives the generalized overall vertex values. When the data is deeply examined it shows the inlet fluid temperature is 330 K and exit temperature is 300 K which clearly shows the considerable amount of temperature reduction happened inside the helical coil for the inlet fluid.

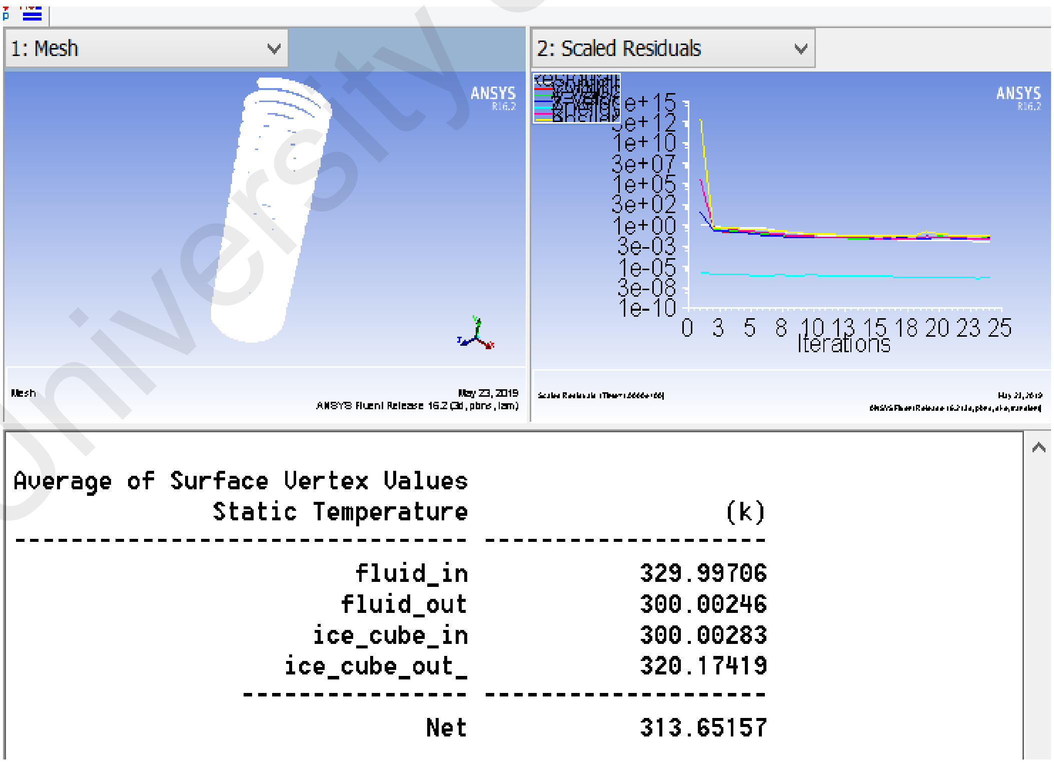


Figure 4.12: Average of surface vertex values (static temperature)

4.4.2 Velocity magnitude report

The velocity magnitude average report is generated with four named sections fluid in, fluid out, ice cubes in, and ice cubes out. These are all the sections to which the fluid and ice cubes makes the actual contact.

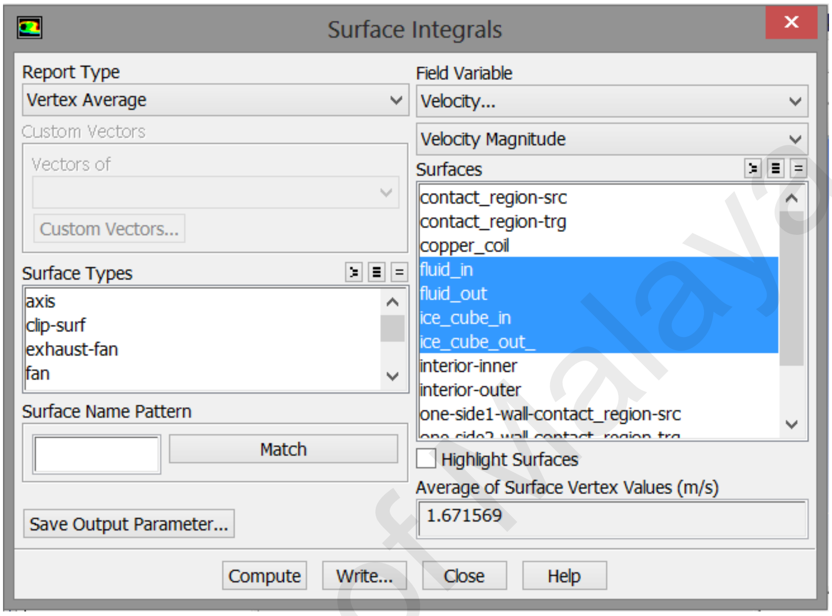


Figure 4.13: Velocity magnitude report generation

The table given below shows the named sections and the respective velocity magnitude vales.

Table 4.2: Velocity magnitude report

Named sections	Velocity magnitude (m/s)
Fluid in	1.6756767
Fluid out	2.9324324
Ice cubes in	0
Ice cubes out	0
Net	**1.6715686**

The fluent generated velocity magnitude report gives the generalized overall vertex values. When the data is deeply examined it shows the inlet fluid velocity is 1.7 m/s and exit velocity is 3m/s which clearly shows the influence of gravity force which is assigned at the initial stage of simulation toward downward Z-axis (-9.81 m/s^2). Both the ice cube in and out are showing o m/s which clearly shows that the soil cubes are filled in the cavity of helical coil which is not moving or flowing anywhere. These ice cubes stay in its position and helps to cool down the temperature of inlet fluid and then melts.

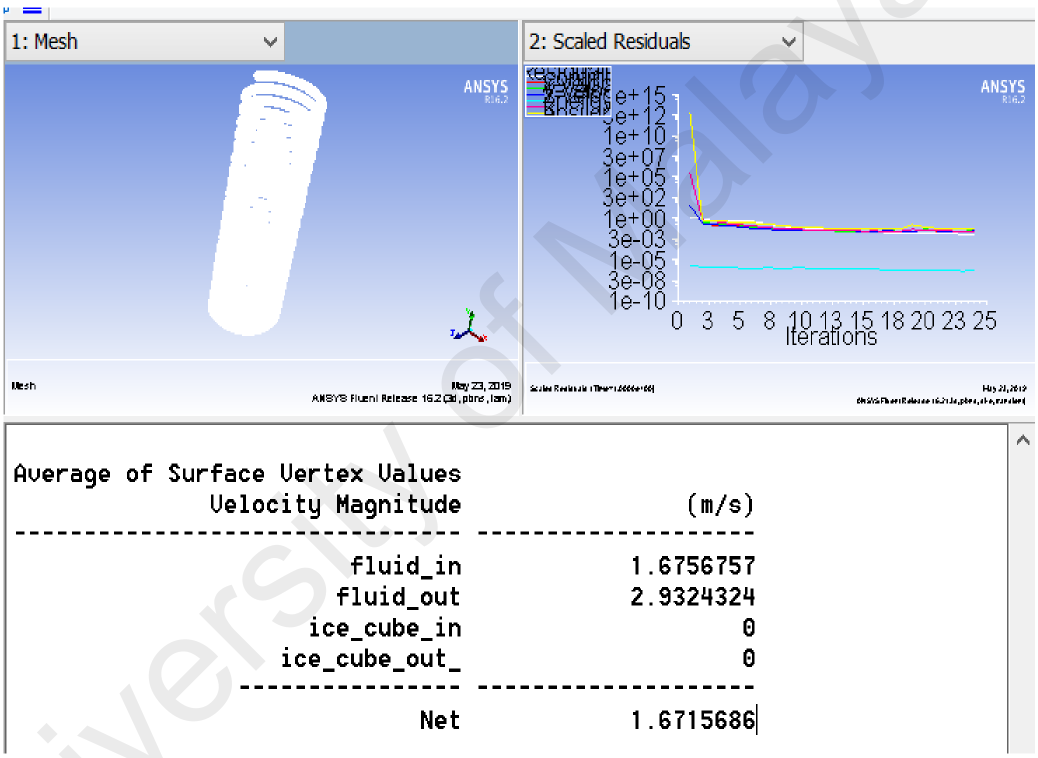


Figure 4.14: Average of surface vertex values (Velocity magnitude)

4.5 Graphics and animation

This section contains the computation of fluid flow from inlet to outlet in contact with coil's inner surface. As the fluid travels from inlet to outlet is leave its high temperature to the copper coil wall which is in ice cold temperature thereby the conduction and heat transfer takes place.

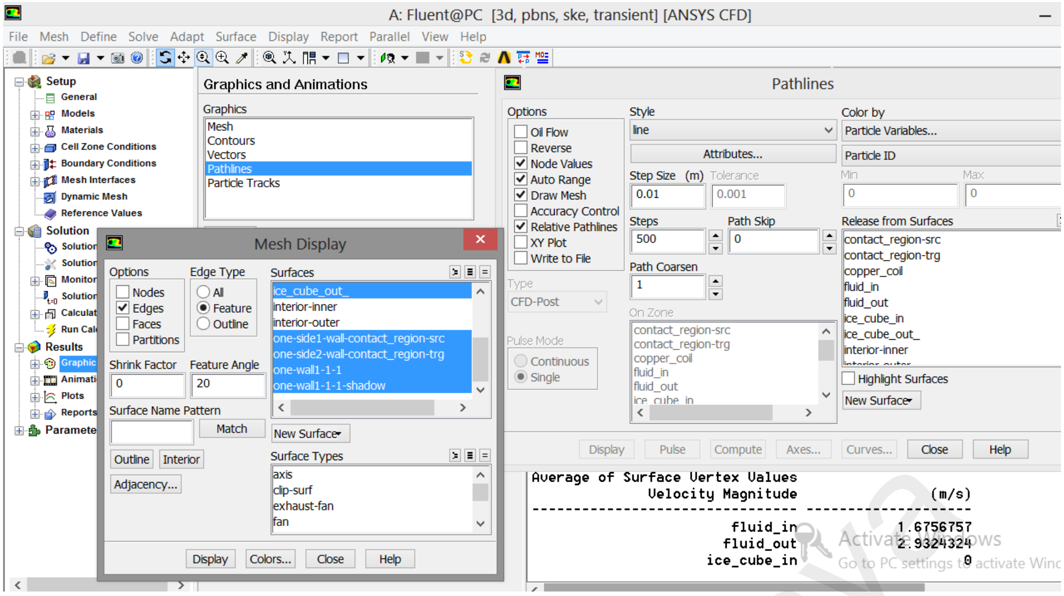


Figure 4.15: Graphics and animation setup

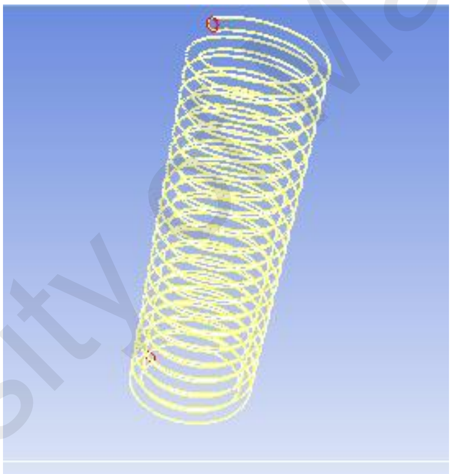


Figure 4.16: Path line display of helical coil

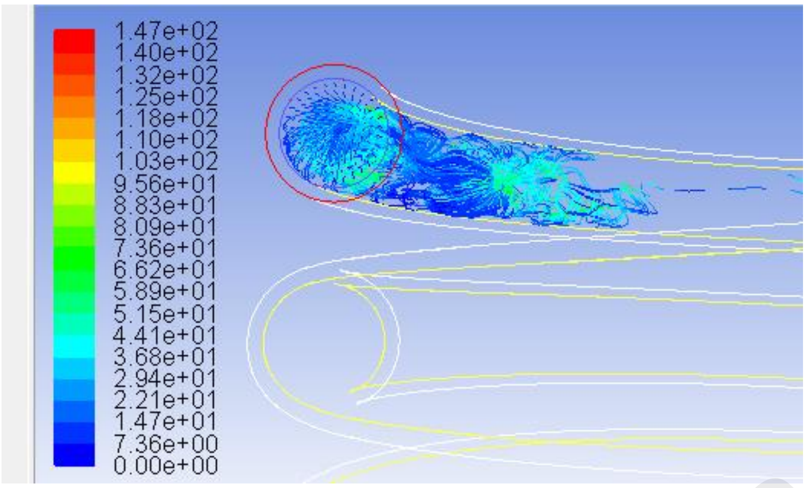


Figure 4.17: Fluid flow animation display 1

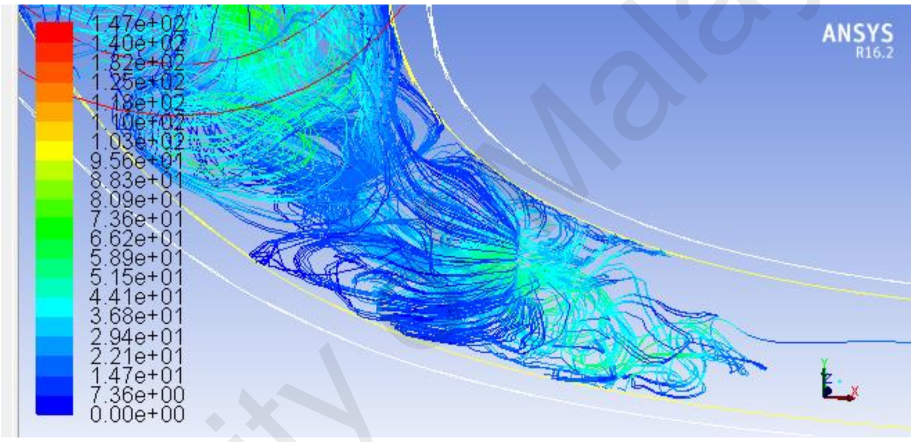


Figure 4.18: Fluid flow animation display 2

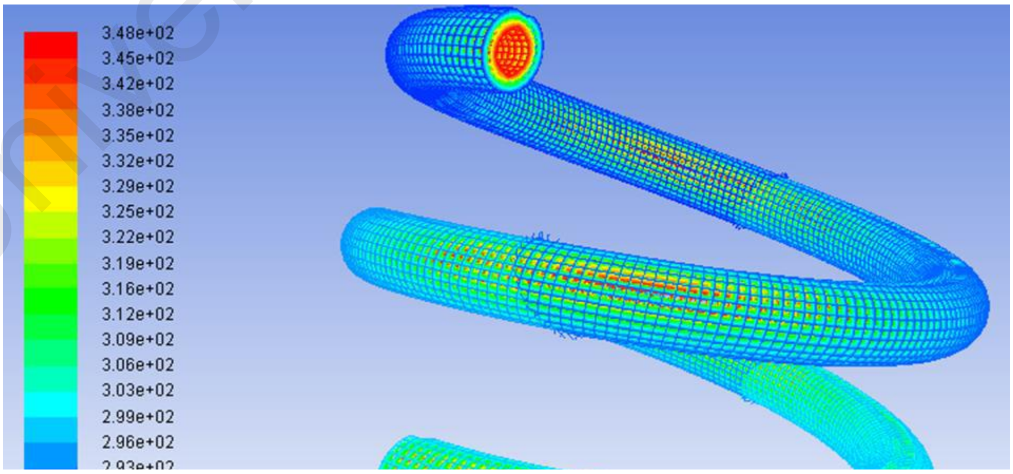


Figure 4.19: Contours of Static Temperature in K

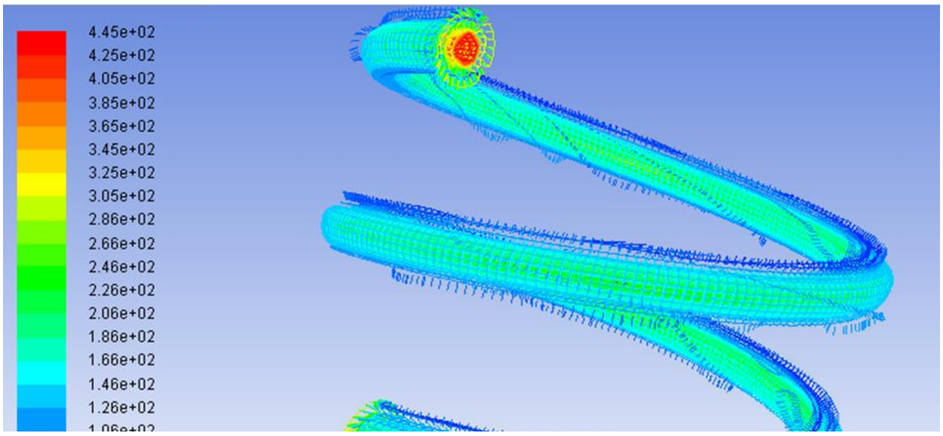


Figure 4.20: Contours of Effective Thermal Conductivity (w/m-K)

CHAPTER 5: CONCLUSION

The simulation of mobile bottle chiller gives the successive output as the temperature of fluid at outlet is reduced to a considerable amount to that of lukewarm inlet fluid. This project with its objective to reduce the temperature of drinking fluid without the influence of ice in it is achieved with the helical coil made of copper with coil specifications from previous studies and normal size of water bottles that are in practice. Since this is a conceptual design the future study can be conducted with more technical data and detailed investigations on its velocity factor, pressure factors and few more thermal parameters. Researchers can investigate on material selection and heat transfer rate under different conditions. In this simulation the coil is assigned with a common ice-cold temperature but in real practice it is not necessary for the coil to attain such temperature in all parts. The usage of ice cube and time duration up to which the bottle can keep the drinking fluid cold can also be another path of research. Dry ice and various type of ice are in the market which can also be an alternative to normal ice cube since there is not any mixing takes place. One of the major drawbacks which can be stated is the cleaning process of this mobile bottle chiller. Really it is complicate process to clean the inner surface of the copper coil.

Since this project act more like heat exchangers the thermal engineers might be interested implement this unique compact portable heat exchangers in any other field of research.

From this study it can be concluded that it is possible to design a heat exchanger in a compact size and make it potable. By using this bottle one can cool their drinking fluid anytime without changing its original taste. The reduction in temperature of drinking fluid is furthermore increased by increasing the contact region. Since this is a helical coil the contact region can be increased by increasing the length of the helical coil.

The heat transfer here is takes place by convection process the thickness factor come to the major parameter. Hence the changes made in length and thickness of coil will make the considerable changes in the output result.

REFERENCES

A.Vahabzadeh, D.D.Ganji and M.Abbasi, “Analytical investigation of porous pin fins with variable section in fully-wet conditions”, Case Studies in Thermal Engineering, Vol. 5, pp. 1–12, 2015.

Ali Najah Al-Shamani, K.Sopian, H.A.Mohammed, SohifMat, Mohd Hafidz Ruslan and Azher M.Abed, “Enhancement heat transfer characteristics in the channel with Trapezoidal rib–groove using nanofluids”, Case Studies in Thermal Engineering, Vol. 5, pp. 48–58, 2015.

Azher M.Abed, K.Sopian, H.A.Mohammed, M.A.Alghoul, Mohd Hafidz Ruslan, SohifMat and Ali Najah AlShamani, “Enhance heat transfer in the channel with V-shaped wavy lower plate using liquid nanofluids”, Case Studies in Thermal Engineering, Vol. 5, pp. 13–23, 2015.

Christopher Ian Wright, “Effective management of heat transfer fluid flash point temperatures using a light-ends removal kit (LERK)”, Case Studies in Thermal Engineering, Vol. 4, pp. 9–14, 2014.

Dustin R. Ray and Debendra K. Das, “Superior Performance of Nanofluids in an Automotive Radiator”, Journal of Thermal Science and Engineering Applications, Vol. 6/ 041002, pp. 1-16, 2014.

Guo-yan Zhou, Ling-Yun Zhu, Hui Zhu, Shan-tung Tu and Jun-jie Lei, “Prediction of temperature distribution in shell-and-tube heat Exchangers”, Energy Procedia, Vol. 61, pp. 799 – 802, 2014.

Jiin-Yuh Jang, Ling-Fang Hsu and Jin-Sheng Leu, "Optimization of the span angle and location of vortex generators in a plate-fin and tube heat exchanger", International Journal of Heat and Mass Transfer, Vol. 67, pp. 432–444, 2013.

K.Srinivasan, S.Muthu, S.R.Devadasan and C.Sugumaran, "Enhancing effectiveness of Shell and Tube Heat Exchanger through Six Sigma DMAIC phases", Procedia Engineering, Vol. 97, pp. 2064 – 2071, 2014.

M. C. Weikla, K. Braunb and J. Weiss, "Coil-wound heat exchangers for molten salt applications", Energy Procedia, Vol. 49, pp. 1054 – 1060, 2014.

M. Hatami, D.D.Ganji and M.Gorji-Bandpy, "Numerical study of finned type heat exchangers for ICEs exhaust waste heat recovery", Case Studies in Thermal Engineering, Vol. 4, pp. 53–64, 2014.

Mushtaq Ismael Hasan, Hayder Mohammed Hasan and Ghassan Adnan Abid, "Study of the axial heat conduction in parallel flow microchannel heat exchanger", Journal of King Saud University – Engineering Sciences, Vol. 26, pp. 122–131, 2014.

Neda Gilani and Amin Haghighi Poshtiri, "Heat Exchanger Design of Direct Evaporative Cooler Based on Outdoor and Indoor Environmental Conditions", Journal of Thermal Science and Engineering Applications, Vol. 6/ 041016, pp. 1-9, 2014.

Nopparat Katkhawa, Nat Vorayos, Tanongkiat Kiatsiriroat, Yottana Khunatorn, Damorn Bunturat and Atipoang Nuntaphan, "Heat transfer behavior of flat plate having 45° ellipsoidal dimpled surfaces", Case Studies in Thermal Engineering, Vol. 2, pp. 67–74, 2014.

P. Saneipoor, G. F. Naterer and I. Dincer, "Transient Temperature Response of Variable Flow Heat Exchangers in a Marnoch Heat Engine", Journal of Heat Transfer, Vol. 136/ 111801, pp. 1-8, 2014.

P.Eiamsa-ard, N.Piriyarungroj, C.Thianpong and S.Eiamsa-ard, "A case study on thermal performance assessment of a heat exchanger tube equipped with regularly-spaced twisted tapes as swirl generators", Case Studies in Thermal Engineering, Vol. 3, pp. 86–102, 2014.

R. M. Manglik, O. A. Huzayyin and M. A. Jog, "Fin Effects in Flow Channels of Plate-Fin Compact Heat Exchanger Cores", Journal of Thermal Science and Engineering Applications, Vol. 3/ 041004, pp. 1-9, 2011.

Shengqiang Bai, HongliangLu, TingWu, XianglinYin, XunShi and Lidong Chen, "Numerical and experimental analysis for exhaust heat exchangers in automobile thermoelectric generators", Case Studies in Thermal Engineering, Vol. 4, pp. 99–112, 2014.

Sunil Chamoli, "A Taguchi approach for optimization of flow and geometrical parameters in a rectangular channel roughened with V down perforated baffles", Case Studies in Thermal Engineering, Vol. 5, pp. 59–69, 2015.

Tawat Samana, Tanongkiat Kiatsiriroat and Atipoang Nuntaphan, "Enhancement of fin efficiency of a solid wire fin by oscillating heat pipe under forced convection", Case Studies in Thermal Engineering, Vol. 2, pp. 36–41, 2014.

Tonio Sant and Robert N. Farrugia, "Modeling the Energy Yield Enhancement From a Wind Turbine at a Deep Offshore Low Wind Site Through Combined Power and

Thermocline Energy Production", Journal of Solar Energy Engineering, Vol. 137/ 011002, pp. 1-8, 2015.

V. Chandraprabu, G. Sankaranarayanan, S. Iniyan, and S. Suresh, "Heat Transfer Enhancement Characteristics of Al2O3/Water and CuO/Water Nanofluids in a Tube in Tube Condenser Fitted With an Air Conditioning System—An Experimental Comparison", Journal of Thermal Science and Engineering Applications, Vol. 6/ 041004, pp. 1-5, 2014.

Valery Ponyavin, Yitung Chen, James Cutts, Merrill Wilson and Anthony E. Hechanova, "Calculation of Fluid Flow Distribution Inside a Compact Ceramic High Temperature Heat Exchanger and Chemical Decomposer", Journal of Fluids Engineering, Vol. 130/ 061104, pp. 1-8, 2008.

Yanhui Han, Yan Liu, Ming Lia and Jin Huang, "A review of development of micro-channel heat exchanger applied in air-conditioning system", Energy Procedia, Vol. 14 , pp. 148 – 153, 2012.