



Alternative Energy Projects - Using Convection Currents for Generation of Electricity

Sahar Sanaei

Supervisor: Mr. Suha Rawhani

This final year project report was submitted in partial fulfillment of the requirements for the Bachelor of Science Degree in Chemical Engineering at Bahá'í Institute for Higher Education (BIHE)

Fall 2021 Term

Abstract

To make people's lives easier, it is necessary to be able to use basic technologies and ideas, one of which can be a tube that generates electricity with convection currents induced by solar energy to use for homes when electricity is not available. The main goal of this project is to design a simple and cheap device that is suitable for the residential market that can generate electricity through convective currents.

This study tests the technical feasibility of generating electricity through artificially induced convective currents flowing through a tube. Comparing some alternatives in the design of such tubes for strength and sustainability of the induced convection current will be the subject of some mathematical simulations using ANSYS simulation software. Keep in mind that ANSYS Fluent does not have a specific analytical solution for modeling natural convection, but it arises from the direct solution of Navier-Stokes and energy differential equations.

Also, we have considered a pipe with length of 4 meters, a diameter of 0.15 meters, and a wall thickness of 0.02 meters for a family whose average power consumption is approximately 900 kW per month in a one-story house or apartment. We examined this simulation at air velocities of 0.1 m/s, 0.3 m/s, 0.5 m/s, 1 m/s, 1.5 m/s, 2 m/s.

In this project, we examined three materials: PVC, steel, and aluminum. We examined the information and prices of these three items to get the final result more carefully. The tubes we simulated with those dimensions were examined in various shapes such as plain, conical, spiral, ribbed, perforated, cubic, and venturi to produce 1kWh of electricity with the help of convection current and a generator of electricity.

We examined the types of wind generators in small sizes that can be easily purchased from family markets and in the cheapest case so that this generator can be easily installed and used. Best results in the simulated options were obtained with a ribbed pipe design, with an estimated cost of \$ 275.00.

Table of Contents

List of Figures	3
List of Tables	5
1. Acknowledgments	6
2. Introduction	7
2.1 Mechanism of Heat transfer	7
2.1.1 Conduction	8
2.1.2 Convection	8
2.1.3 Radiation	8
2.2 Energy	8
2.3 Power	8
2.4 Convection	8
2.4.1 Mechanisms of Natural Convection	8
2.5 Boundary layer of forced and natural convection	9
2.6 Alternative Energy	10
2.6.1 Wind	10
2.6.2 The General Mechanism of Wind Formation	11
2.6.3 History of Wind Energy Use	11
2.7 Wind Turbine Electrical Generator	11
2.8 Blade Element Momentum (BEM)	12
2.9 Pipe design	12
3. Review of the Previous Works	13
3.1 Solar Chimney	13
3.1.1 Mathematical	14
3.1.2 Diagram Solar Chimney	15
3.2 Wind Turbines	15
3.2.1 Diagram of Wind Turbine	17
4. Methodology	18
4.1 Governing Equations	18
4.1.1 Analysis of the Grashof number and natural convection	18
4.1.2 Natural Convection over Surfaces	19
4.1.3 Natural Convection Correlations	19

4.1.4	Vertical Cylinders	20
4.1.5	Laminar Flow.....	21
4.1.6	Turbulent Flow	22
4.1.7	Radiation.....	24
4.1.8	Energy	26
4.1.9	Navier-Stocks	26
4.2	Geometry.....	26
4.2.1	Draft and Graphics	28
4.3	Meshing.....	32
4.4	Fluid Flow (fluent).....	34
5.	Results and Discussion	36
5.1	Diagrams and Tables of Simulated Pipes.....	36
5.2	Wind Generator	44
6.	Conclusion	48
7.	Recommendations and Suggestions for Future Work	49
8.	References and Bibliography	50
9.	Appendix.....	52
9.1	Venturi 1	52
9.2	Venturi 2	59
9.3	Perforated Pipe	65
9.4	Ribbed Pipe	71
9.5	Cubic Pipe	77
9.6	Conical Pipe	83
9.7	Helical Pipe	89

List of Figures

Figure 1: Heat Transfer.....	7
Figure 2: Natural Convection heat transfer	9

Figure 3: Boundary layer profiles. a) Velocity and temperature profiles for external natural convection flow. b) Velocity and temperature profiles for external forced convection flow (upward flow). c) Velocity profile for internal flow	10
Figure 4: Diagram of the proposed solar double-chimney power plant design: (a) a three-dimensional view, (b) view from the top section, (c) cross-sectional view	13
Figure 5: Illustrations of the energy balance equations of the SDCPP. Zone 1 is the solar air heating, and Zone 2 is the solar chimney and cooling tower (CT).....	14
Figure 6: Solar chimneys of different height.....	15
Figure 7: HAWT vs VAWT	16
Figure 8: Pros and Cons of HAWTS and VAWTS.....	16
Figure 9: Diagram Wind Turbine	17
Figure 10: Velocity and temperature profile for natural convection flow over a hot vertical plate. $Gr_{critical} = 109$	19
Figure 11: (a) Laminar flow occurs in layers without mixing. Notice that viscosity causes drag between layers as well as with the fixed surface. (b) An obstruction in the vessel produces turbulence. Turbulent flow mixes the fluid. There is more interaction, greater heating, and more resistance than in laminar flow.	22
Figure 12: The graphic shows laminar flow of fluid between two plates of area A . The bottom plate is fixed. When the top plate is pushed to the right, it drags the fluid along with it.....	22
Figure 13: Flow is laminar in the large part of this blood vessel and turbulent in the part narrowed by plaque, where velocity is high. In the transition region, the flow can oscillate chaotically between laminar and turbulent flow.....	23
Figure 14: Radiation.....	25
Figure 15: a) Pipe, b) Perforated Pipe, c) Cube Pipe, d) Conical Pipe, e) Ribbed Pipe, f) Venturi 1, g) Venturi 2, h) Helical Pipe	27
Figure 16: Ribbed Pipe.....	28
Figure 17: Draft and Graphics	32
Figure 18: Pipe Meshing	32
Figure 19: Meshing	33
Figure 20: Meshing Quality	33
Figure 21: Orthogonal Quality	34
Figure 22: a) 0.1 m/s Aluminum Pipe, b) 0.1 m/s PVC Pipe, c) 0.1 m/s Steel Pipe	36
Figure 23: 0.3 m/s Pipe.....	36
Figure 24: 0.5 m/s Pipe.....	37
Figure 25: 1 m/s Pipe	37
Figure 26: 1.5 m/s Pipe	38
Figure 27: 2 m/s Pipe.....	38
Figure 28: Velocity Contour of Ribbed Pipe	44

List of Tables

Table 1: Length of the Pipe.....	12
Table 2: Empirical correlations for the average Nusselt number for natural convection over surfaces	21
Table 3: Pipe Data	27
Table 4: Reynolds Number	34
Table 5: Variable thermal and physical properties of air (Viscosity of Air, Dynamic and Kinematic, 2022)	35
Table 6: Summary of Materials.....	35
Table 7: Outlet velocity in the pipe in different materials and different velocities	39
Table 8: Percentage of input and output velocity of Pipe	39
Table 9: Outlet velocity in the Perforated Pipe in different materials and different velocities.....	39
Table 10: Percentage of input and output velocity of Perforated Pipe	40
Table 11: Outlet velocity in the Cube Pipe in different materials and different velocities	40
Table 12: Percentage of input and output velocity of Cube Pipe	40
Table 13: Outlet velocity in the Ribbed Pipe in different materials and different velocities	41
Table 14: Percentage of input and output velocity of Ribbed Pipe	41
Table 15: Outlet velocity in the Venturi 1 in different materials and different velocities	41
Table 16: Percentage of input and output velocity of Venturi 1	42
Table 17: Outlet velocity in the Venturi 2 in different materials and different velocities.....	42
Table 18: Percentage of input and output velocity of Venturi 2.....	42
Table 19: Outlet velocity in the Helical Pipe in different materials and different velocities	43
Table 20: Percentage of input and output velocity of Helical Pipe.....	43
Table 21: Outlet velocity in the Conical Pipe in different materials and different velocities	43
Table 22: Percentage of input and output velocity of Conical Pipe.....	44
Table 23: Type of wind turbine generators	45
Table 24: Generators in size 165mm and 220mm	46
Table 25: Price of Material	47
Table 26: Protected total price	47

1. Acknowledgments

My deep gratitude goes first to my supervisor, Mr. Suha Rawhani, for his training and patience. My perception also extends to Sahar Bayani for mentoring the technical elements of this project. I would also like to express my sincere grasp to the Chemical Engineering Department of BIHE for providing me with the chance to study, and for all the support they provided in my education process. Thanks additionally go to my buddies for their genuine kindness and desirable humor. Last however not least, I would like to thank my dear family who has been a constant supply of love, support, inspiration, and strength in all these years.

2. Introduction

Alternative energy is energy that is collected from renewable resources that are naturally replenished on a human timescale. It includes sources such as sunlight, wind, the movement of water, and geothermal heat. Although most renewable energy sources are sustainable, some are not. For example, some biomass sources are considered unsustainable at current rates of exploitation. Renewable energy often provides energy for electricity generation to a grid, air and water heating/cooling, and stand-alone power systems. We have turned to renewable energies, which other energies such as oil and gas have caused a lot of pollution and have troubled the life of mankind. All renewable energies need the world's great source of sunlight, except for geothermal energy.

Wind Energy captures the natural wind in our environment and converts the air's motion into mechanical energy. Wind is caused by differences in atmospheric pressure. Wind speeds vary based on geography, topography, and season. As a result, there are some locations better suited for wind energy generation than others. In general, wind speeds are higher near the coast and offshore since there are fewer objects like vegetation, mountains, and buildings to slow them down. (Origin of winds, 2010) (Global Wind Speeds, 2001)

The mechanism used to convert air motion into electricity is referred to as a turbine. A turbine is a large structure with several spinning blades. These blades are connected to an electromagnetic generator that generates electricity when the wind causes the blades to spin. (2009)

ANSYS Fluent is used to create a mathematical model. In this software, different types of pipes are simulated (finned pipes, grooved pipes, perforated pipes, etc.) as well as the thickness and other issues of the pipes are examined to suggest the better ones for generating air currents with the highest strength and longest periods of continuous flow.

All houses have gutters for rainwater. One of the goals of our project is to be able to create something like a gutter so that it can be easily installed and families with an average consumption of 900 kW per month can be provided with some of this electricity.

2.1 MECHANISM OF HEAT TRANSFER

Heat transfer mechanisms are the ways by which thermal energy can be transferred between objects, and they all rely on the basic principle that kinetic energy or heat wants to be at equilibrium or at equal energy states. There are three different ways for heat transfer to occur: conduction, convection, and radiant heat (often referred to as radiation, but that's a more general term that includes many other phenomena). (Heat transfer mechanisms, n.d.) All three heat transfer mechanisms are used and are involved in the process of this project.



Figure 1: Heat Transfer

2.1.1 Conduction

Conduction is the simplest heat transfer model in terms of being able to create a mathematical explanation for what's happening. It is the movement of kinetic energy in materials from higher-temperature areas to lower-temperature areas through a substance. The molecules will simply give their energy to adjacent molecules until an equilibrium is reached. Conduction models do not deal with the movement of particles within the material.

2.1.2 Convection

Convection is heat transfer through fluid (like air or water) motion. The difference between conduction and convection is the motion of a material carrier; convection is the movement of the thermal energy by moving hot fluid (as opposed to making other material hot by wiggling atoms). Usually, this motion occurs as a result of differences in density and temperature. Warmer particles are less dense, so particles with higher temperatures will move to regions where the temperature is cooler and the particles with lower temperature will move to areas of higher temperature. The fluid will remain in motion until equilibrium is reached.

2.1.3 Radiation

Heat transferred by radiation is called radiant heat. Like light, radiant heat is radiant energy, and does not necessarily require a medium to carry it. This form of energy transfer is facilitated through a type of electromagnetic radiation. All moving charged particles emit electromagnetic radiation. This emitted wave will travel until it hits another particle. The particle that receives this radiation will receive it as kinetic energy. Particles will receive and emit radiation even after everything is at the same temperature, but it's not noticed due to the fact that the material is at equilibrium at this point.

2.2 ENERGY

Energy refers to an object or an individual's ability to do work. The amount of time that one can work defines their energy. Therefore, like power, time is a crucial factor when determining energy. In scientific terms, energy is transferred from one object to another. The SI unit of energy is Joules, which can also be expressed as watt-hour. (Power and Energy, n.d.)

2.3 POWER

Power is defined as the rate at which a specific work is done and for which energy is transmitted. In essence, it refers to the production or consumption of energy per unit time.

Any object that transfers higher energy in a limited time can be termed to possess greater power. The SI unit of power is Watts, which is Joule/second. (Power and Energy, n.d.)

2.4 CONVECTION

In natural convection, the fluid action takes place with the aid of natural ability such as buoyancy. Since the fluid velocity related with natural convection is fairly low, the warmth switch coefficient encountered in natural convection is additionally low.

2.4.1 Mechanisms of Natural Convection

Consider a hot object uncovered to cold air. The temperature of the outside of the object will drop (as a result of heat transfer with cold air), and the temperature of adjoining air to the object will rise. Consequently, the object is surrounded with a thin layer of hotter air and warmth will be transferred from this layer to the outer layers of air.

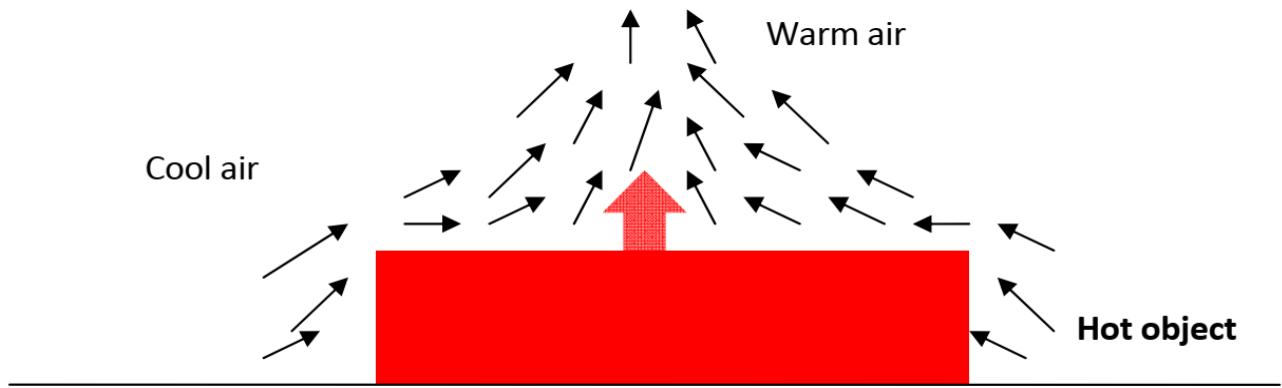


Figure 2: Natural Convection heat transfer

The temperature of the air adjoining the warm object is higher, consequently, its density is lower. As a result, the heated air rises. This movement is referred to as the natural convection current. Note that in the absence of this movement, heat transfer would be by means of conduction only and its price would be tons lower.

2.5 BOUNDARY LAYER OF FORCED AND NATURAL CONVECTION

If a vertical warm plate is located in a lower-temperature fluid, a boundary layer profile will be observed close to the surface. The boundary layer of natural and compelled convection for this case are proven in Figure 3.a and 3.b. The magnitude of the natural convection heat transfers between a surface and a fluid is directly related to the flow rate of the fluid induced by natural convection. The higher the flow rate, the higher the heat transfer rate. The flow rate in the case of natural convection is established by the dynamic balance of buoyancy and friction.

Assume a plate at the temperature T_{wall} , which is immersed in a quiescent fluid at the temperature T_{bulk} , where ($T_{\text{wall}} > T_{\text{bulk}}$). The fluid close to the plate is less dense than the fluid that is further removed. Buoyancy forces, therefore, induce a natural convection boundary layer in which the heated and lighter fluid rises vertically, entraining heavier fluid from the quiescent region. The resulting velocity distribution is unlike that of forced convection boundary layers and depends on the fluid viscosity. In particular, the velocity is zero at the surface as well as at the boundary due to viscous forces. It must be noted natural convection also develops if ($T_{\text{wall}} < T_{\text{bulk}}$), but, in this case, a fluid motion will be downward.

The presence and magnitude of natural convection also depend on the geometry of the problem. The presence of a fluid density gradient in a gravitational field does not ensure the existence of natural convection currents. This problem is illustrated in the following figure, where a fluid is enclosed by two large, horizontal plates of different temperatures ($T_{\text{upper}} \neq T_{\text{lower}}$). (Convection, n.d.)

Temperature profile indicates that the fluid temperature rises towards the late. Since density and temperature are inversely proportional, the fluid next to the plate is lighter and starts to cross vertically upward as a result of buoyancy forces.

In each forced and natural cases, the fluid speed subsequent to the plate is zero because of the no-slip condition. Nevertheless, the pace profile increases monotonically in forced convection, however in the case of natural convection, the velocity is zero at the different quit of the boundary layer due to the presence of stagnant fluid. The natural convection velocity profile is comparable to that of an inside go with the flow (Figure 3.c) with the distinction that the speed profile in an inside float is symmetric, however for natural convection is now not symmetric.

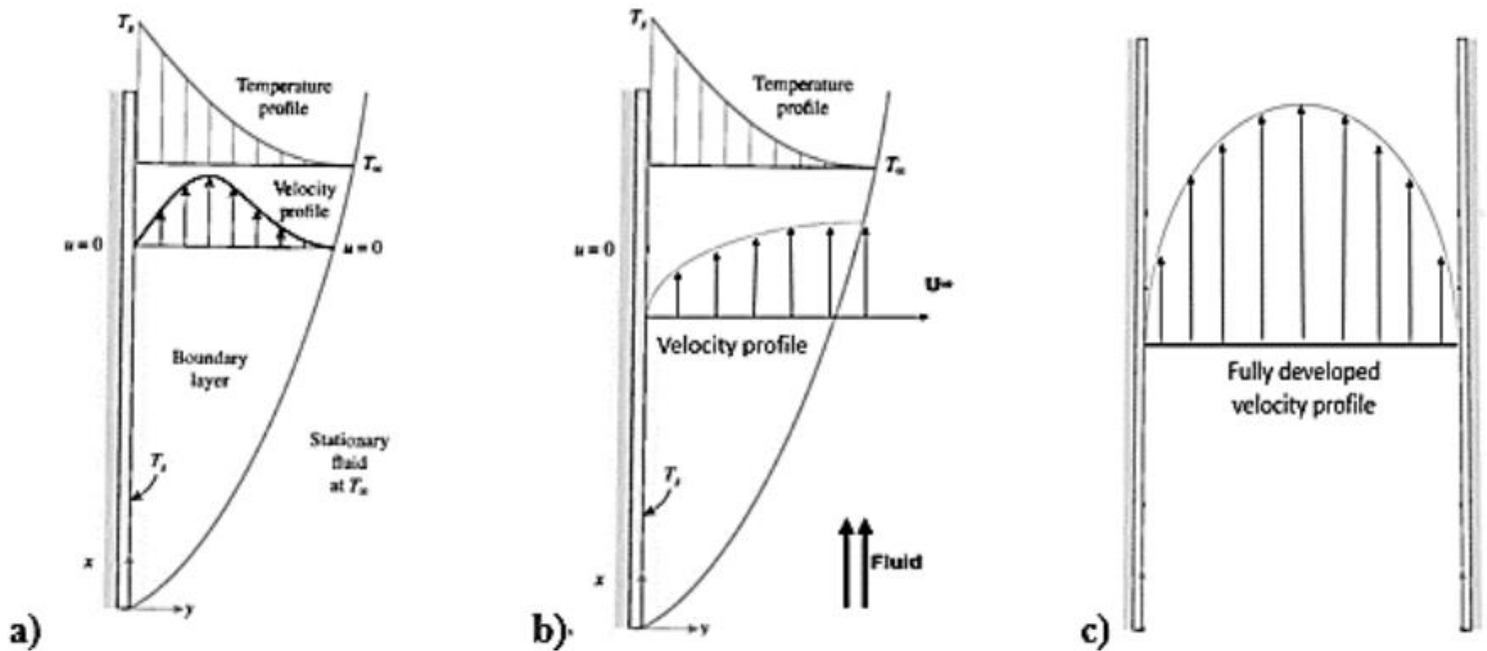


Figure 3: Boundary layer profiles. a) Velocity and temperature profiles for external natural convection flow. b) Velocity and temperature profiles for external forced convection flow (upward flow). c) Velocity profile for internal flow

2.6 ALTERNATIVE ENERGY

Alternative energy is energy that does not come from fossil fuels, and thus produces little to no greenhouse gases like carbon dioxide (CO₂). This means that energy produced from alternative sources does not contribute to the greenhouse effect that causes global warming and climate change.

These energy sources are referred to as “alternative” because they represent the alternative to coal, oil, and natural gas, which have been the most common sources of energy since the Industrial Revolution. These fossil fuels emit high levels of CO₂ when burned to produce energy and electricity. Alternative energy, however, should not be confused with renewable energy, although many renewable energy sources can also be considered alternative. Solar power, for example, is both renewable and alternative because it will always be abundant and it emits no greenhouse gases.

Alternative energy here includes hydroelectric energy, solar energy, geothermal energy, wind energy, nuclear energy, and biomass energy.

2.6.1 Wind

The movement of air on the surface of the earth causes the warm air to rise and replace the cold air. The intensity of their wind depends on changes in air pressure and temperature. Wind is simply moving air. The main source of wind energy is provided by the energy of the sun and the movement of the earth. Wind or moving air has significant kinetic energy.

More generally, the movement of gas in the atmosphere is called wind; Winds are generally classified based on the degree of strength, speed, type of force that causes them to occur, and the geographical location where they occur. Winds usually occur in the continent of Asia because the extent of this continent is large and there is no sea in the middle of it, so it has a very cold winter and a very hot summer. (tebian, n.d.)

2.6.2 The General Mechanism of Wind Formation

The general mechanism of wind formation is the movement of air mass from a high pressure area to a low pressure area. This phenomenon occurs for various reasons, the most important of which you will see below. Onshore winds blow sunlight all day long on the sea surface as well as the sandy or rocky surface of the beach.

During the day, the air above the land is heated earlier and with the decrease in density, the air mass moves upwards. This pressure drop on the coast causes the wind to blow from the sea towards the land. On the other hand, at night, the land surface cools earlier than the sea, and as a result, the direction of the wind is reversed at night. The temperature difference between the equator and the poles also occurs on a wider scale, similar to the phenomenon of coastal winds.

At the equator, the sun shines directly and the surface air is much warmer than other latitudes, especially the poles. So the air currents go between the equator and the northern and southern regions. If there was no movement of the earth, these winds would only blow in the north-south direction.

Earth's positional motion The earth rotates around itself every 24 hours. The movement of the earth by creating centrifugal force causes wind and changes the direction of the wind. So that air masses move to the right in the northern hemisphere and to the left in the southern hemisphere.

2.6.3 History of Wind Energy Use

The Chinese used wind energy to transport water 200 years before Christ. In the 11th century, Middle Eastern people used windmills to produce flour and cook food. Later, the Dutch used these mills as a tool to drain the water of lakes and marshes.

In the 19th century, wind damage was used to supply water needed for agriculture and animal husbandry and later for electricity generation. In addition, windmills have also been used to cut wood in sawmills. Also, the invention of sailing boats and the use of wind energy for movement led to the conquest of the seas by humans.

With the industrial revolution and the emergence of oil and coal, wind energy was forgotten until in the 1970s, due to the problems of oil shortage, energy consumption sources were again directed towards renewable energies, and in this regard, windmills were again considered. they got.

The old windmills have been transformed into modern wind turbines. By using these turbines, mankind converted the kinetic energy of the wind into electrical energy. With the advancement of science, the output power and dimensions of wind turbines have changed. (tebian, n.d.)

2.7 WIND TURBINE ELECTRICAL GENERATOR

A wind turbine generator is a machine that is capable of transforming kinetic wind energy into electric energy. The wind moves the shovels of the wind turbine and, through a mechanical gear system, it rotates the rotor so that the rotational mechanical energy of the rotor is transformed into electrical energy by the generator. (R.C Bansala, November 2002)

The negative impacts of using wind energy are mostly present in the construction phase, which affects directly or indirectly the ecosystem (specially vegetation and fauna). However, current wind turbine generators (for instance, with 40 to 50 m diameter) only affect about 5% of the field where they are installed, and hence, most of the space can be given its initial use. Another negative impact often attributed to wind energy is acoustic pollution, which seems to be overcome nowadays. Wind turbine generators are installed at a distance avoiding the inhabitants to be exposed to noise exceeding

45 dB, which generally corresponds to distance of less than 1,000 meters. (Katsaprakakis, June 2012) Generally, wind turbine generator farms provide with benefits that make them attractive, among them the following: First, they contribute to the greenhouse effect decrease and the air pollution reduction; And second, the increase of these centrals in the world yields a reduced global dependence on fossil fuels. (Dincer, June 2000)

The rotors of wind turbines with a horizontal axis based on how they are positioned in the direction of the wind (upwind or downwind), hub design, rotor speed control (stall or pitch) (pitch), the number of blades (usually two or three and even five blades) and how to control the direction of the turbine with the wind, the yaw system is categorized.

2.8 BLADE ELEMENT MOMENTUM (BEM)

The Blade Element Momentum (BEM) theory is a model used to evaluate the performance of a propelling or extracting turbine on the basis of its mechanical and geometric parameters as well as the characteristics of the interacting flow. (Jeremy Ledoux, 2021)

2.9 PIPE DESIGN

This design is such that it can supply daily electricity to a building. According to the table below, the length of this design varies for different apartments.

Table 1: Length of the Pipe

Length (m)	Diameter (m)	Number of building floors
1-3	0-0.1	1
3-6	0.1-0.2	3
100	0.2-0.5	20

In this design, we considered a length of 4 meters for pipes and examined different types and materials (PVC, Steel and Aluminum). This design works in such a way that it is connected to the wall outside the house and the air inside the pipe is heated by radiation, and due to the specific weight of hot air that tends upwards (convection), the air speed inside the pipe increases and causes it to work. The wind generator and through it 1 kilowatt per hour of energy is produced.

In future sections, we will examine a number of wind generators based on minimum speed and price to average speed. Moreover, we also examine the results obtained from different types of pipes at different speeds so that we can offer the best pipe design and pipe material.

3. Review of the Previous Works

In the past, we have built various structures in this regard, such as (wind turbine, Solar Chimney, etc.). In the following, we will explain these structures and finally we will simulate our design and explain it in detail. The reason I cannot bring past work in this section is because the design idea is new.

Of the 340 W/m^2 of solar radiation that reaches the Earth, an average of 77 W/m^2 is returned to space by impact with clouds and the atmosphere, and another 23 W/m^2 is reflected by the whiteness of the surface, that leaves 240 W/m^2 per square meter of solar energy for the Earth's energy budget.

3.1 SOLAR CHIMNEY

The solar chimney power plant (SCPP) is one of the most promising technologies, with a simple design and low-cost advantages for power and desalination production (Zhou, Wang, & Ochieng, 2010) (Dhahri & Omri, 2013). The SCPP is the best solution to tackle the challenges of clean energy demand and freshwater shortage. It was a conceptual model until it was piloted and tested successfully in Spain during the 1980s when Schlaich built his optimized design that can produce electrical power in the range of 100–200 MW (Schlaich, 1995). The basic design of the SCPP consists of three essential modules: a solar collector, a power mechanical conversion unit, and a very long chimney. The solar radiation coming from sunlight heats the air between the solar collector and the ground. This will decrease the air's density and increase the pressure, which in turn will significantly increase the air's velocity. The change in air physical properties drives it to move upward through the chimney with very high kinetic and thermal energies. The air mass flow with high-energy content passes through the blades of the turbine, producing electrical energy.

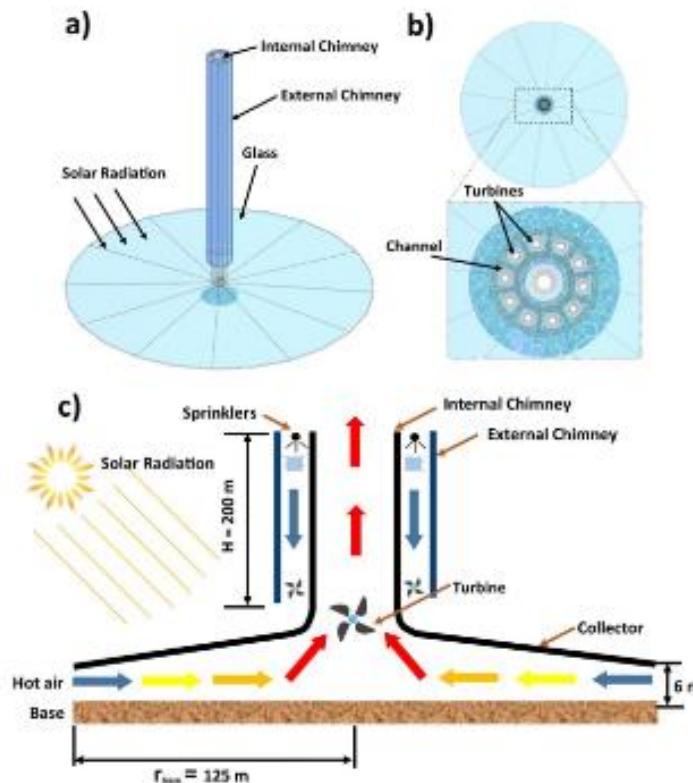


Figure 4: Diagram of the proposed solar double-chimney power plant design: (a) a three-dimensional view, (b) view from the top section, (c) cross-sectional view

The SDCPP operates in two modes: SCPP mode and CT mode. The SCPP mode starts off evolved when the solar irradiation heats the air below the collector. As the air temperature rises, it expands underneath the collector, developing a temperature gradient that extends from the entrance of the collector to the bottom of the IC. As shown in Fig.5c, the changes in the temperature profile of the cold air (blue lines) to warm air (red lines) end results in the motion of air thru the collector. Due to the temperature and pressure distinction between the bottom and the top of the IC the hot air moves up to the pinnacle of the chimney and exits to the surroundings. The velocity of the air exiting the IC is structured on the temperature distinction between the air inside the IC and the air outside the IC. The movement of the hot air within the chimney allows for electricity switch with the turbine blades at the bottom of the chimney (i.e., the air's kinetic strength transfers to mechanical electricity and then to electrical energy).

3.1.1 Mathematical

A mathematical model was once developed to investigate the overall performance and predict the behavior of the proposed SDCPP system. The mathematical mannequin consists of power and mass balance equations presented in this section. These equations are additionally introduced in the sketch in Fig.6. The design shows the two zones of the SDCPP mode: solar heating, and chimney. In this section, we will examine only the Solar Chimney calculations.

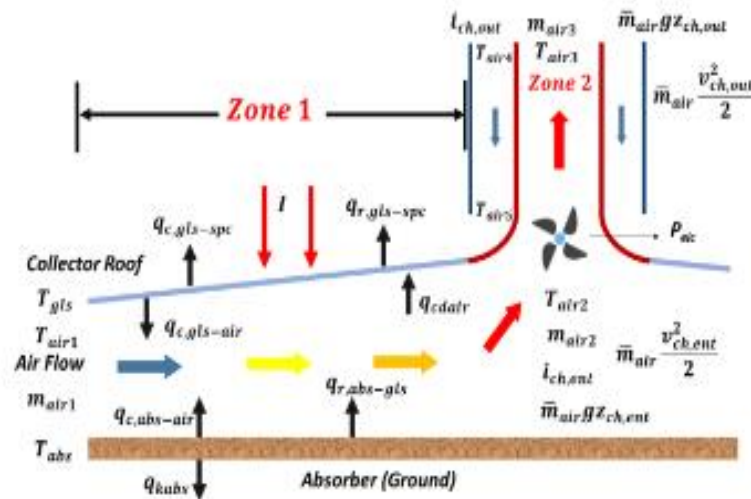


Figure 5: Illustrations of the energy balance equations of the SDCPP. Zone 1 is the solar air heating, and Zone 2 is the solar chimney and cooling tower (CT).

The mass balance equation for the air in and out of the chimney is as follows:

$$\rho_{ch,ent} V_{ch} A_{in} = \rho_{out} V_{ch,out} A_{out}$$

For the IC zone, the energy balance equations when the SDCPP is operating in SCPP mode are as follows:

$$P_{elc} = \bar{m}_{air} \left[\left(\frac{v_{ch,ent}^2}{2} + gz_{ch,ent} + i_{ch,ent} \right) - \left(\frac{v_{ch,out}^2}{2} + gz_{ch,out} + i_{ch,out} \right) \right]$$

To calculate the enthalpy (Nizetic, Ninic, & Klarin, 2008) of the air entering the IC ($i_{ch,ent}$):

$$i_{ch.ent} = T_{air} + \omega_2(2501.3 + 186T_{air})$$

To calculate the velocity of the air as it enters the IC, the following equation was used (Zuo, Zheng, Li, & Sha, 2011):

$$V_{ch} = \sqrt{2gH_{ch} \frac{T_{ch,ent} - T_{out}}{T_{out}}}$$

The output power produced by the turbine at the bottom of the IC was calculated as follows (Zuo, Zheng, Li, & Sha, 2011):

$$P_{elc} = \frac{1}{2} \rho_{en,ch} C_f A_{ch} V_{ch}^3$$

where C_f is the turbine efficiency, set at 0.42.

To calculate the system efficiency for electricity production, the following was used:

$$\eta = \frac{P_{elc}}{\frac{1}{4} \pi (D_{col}^2 - D_{ch}^2) I}$$

3.1.2 Diagram Solar Chimney

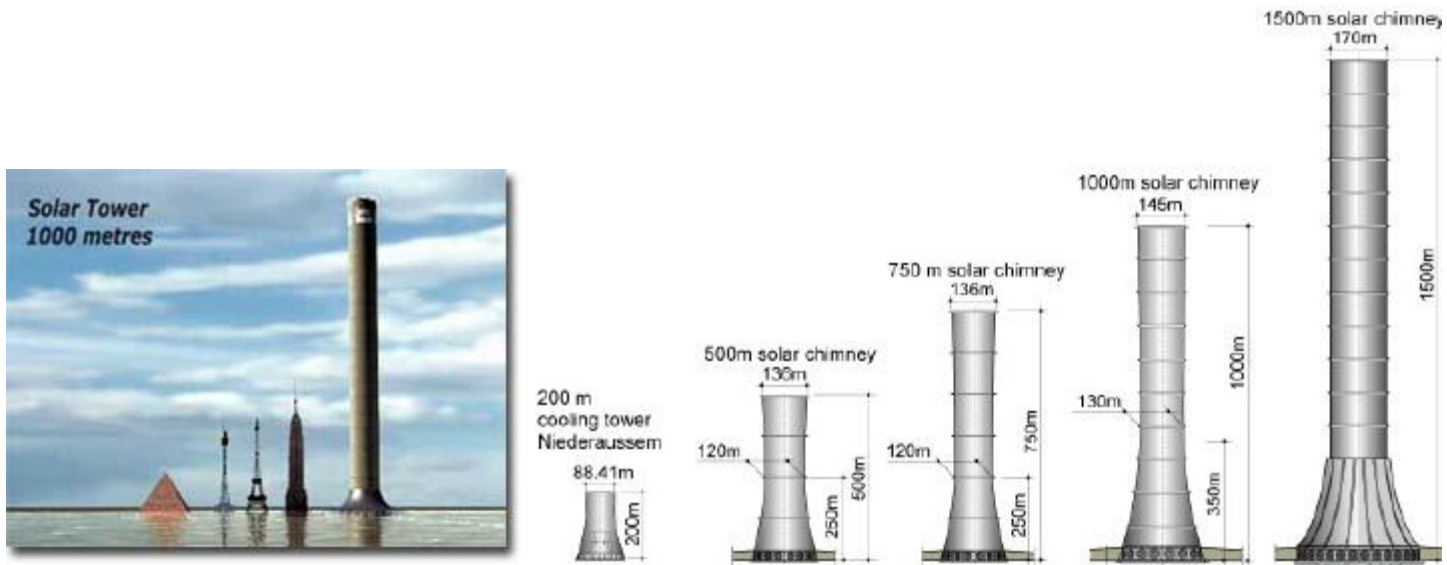


Figure 6: Solar chimneys of different height

3.2 WIND TURBINES

A wind turbine is a power-generating device that is pushed by the kinetic electricity of the wind. Wind generators normally fall into one of two categories: Horizontal axis wind generators (HAWTs) and vertical axis wind turbines (VAWTs). HAWTs, the extra frequent type, consist of propeller-like rotors fixed around a central hub and dealing with into the wind, like a windmill. In a VAWT, blades surround the pressure shaft of the turbine. The system resembles a giant push mower laid on its facet and extending into the sky. Both types use bladed rotors of more than a few designs using a shaft to a generator that makes use of electromagnetic induction to produce a voltage.

Vertical wind turbine blades are between 40 and 70 meters. In a smaller scale, if it is used, it should be between 4 and 20 meters in order to be suitable in terms of price so that it can be used inside the pipe.



Figure 7: HAWT vs VAWT

In the following, we show the advantages and disadvantages of these two turbines.

HAWTS	VAWTS
- Advantages - Taller tower means higher speeds - High efficiency - Most are self-starting - Ability to wing warp, which gives the turbine blades the best angle of attack - Disadvantages - Difficult to transport - Difficult to install (require tall cranes and skilled operators)	- Advantages - Lower construction and transportation costs - Most effective at hilltops and ridgelines. - typically less noise compared to HAWTs - Easy to maintain, generator components typically located on the ground - Disadvantages - Less efficient - Low starting torque and may require energy to start turning - lower wind speeds due to shorter structure

Figure 8: Pros and Cons of HAWTS and VAWTS

3.2.1 Diagram of Wind Turbine

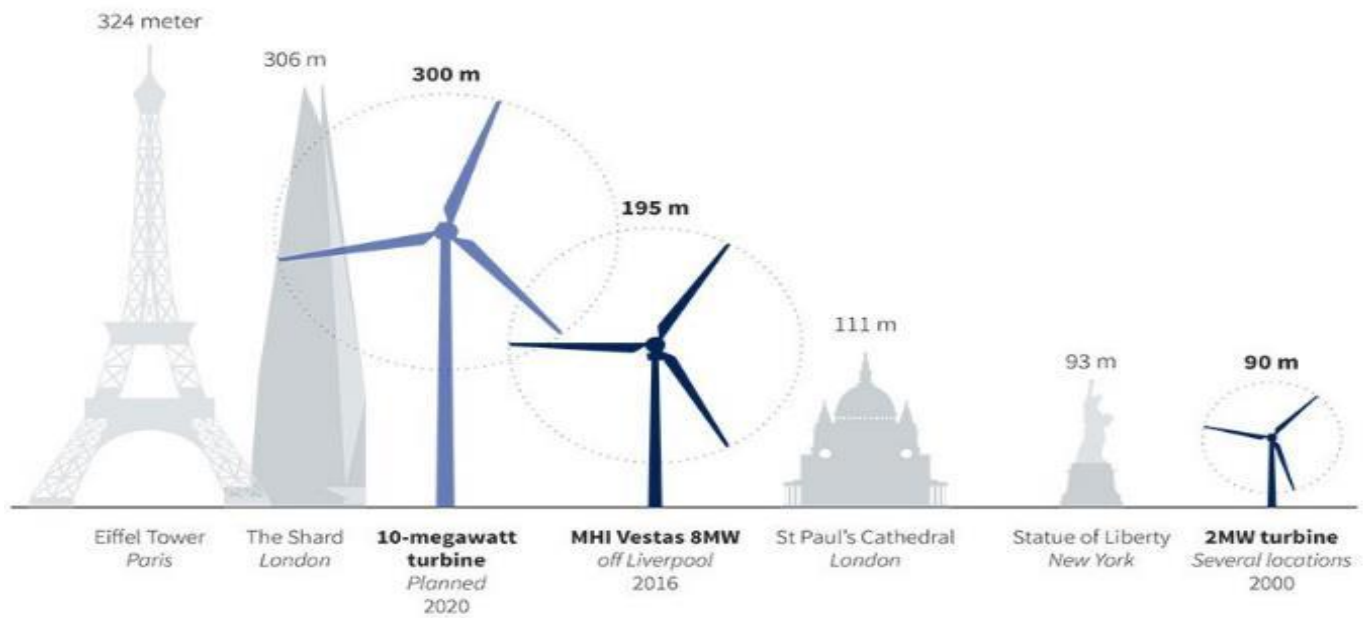


Figure 9: Diagram Wind Turbine

4. Methodology

Can it choose a Microscale model to be installed almost like a gutter outside the house so that it is closer to the sun's heat so that it can absorb more of the sun's heat with the speed of air transfer outside and inside the tube, it can move a turbine propeller that is sufficient and the amount generate enough electricity for use home?

To address this question as a reality, 8 pipe models were used with the software that below. Because our software is limited, it cannot perform more calculations than the default one. This simulation is simulated in macrocycle in such a way that it can be connected outside the house to the wall of the house with a distance of 0.5 meters so that it can absorb the heat of the sun more or it can be installed in the middle of the yard.

In this study, ANSYS Fluent code has been used for simulation purposes. ANSYS fluent is engineering simulation software, computer-aided engineering, CAE, and one of the most popular business CFD software packages. ANSYS Fluent has a sizeable number of abilities that are developed by way of world-renowned experts and supported by means of extremely skilled engineers. (D. Maity, 2020)

In ANSYS Workbench, we started by way of selecting the type of us to learn about “Fluid glide analysis (Fluent).” There are 5 foremost steps in device education and analysis of Fluent modeling, consisting of geometry, mesh, setup, solution, and results. In the following sections, we will describe the important points of our simulation setup. In this software, different types of pipes are simulated (Ribbed pipes, Helical tubes, Perforated pipes, etc.). The thickness and other issues of the pipes are examined to suggest the better ones for generating air currents with the highest strength and longest periods of continuous flow.

In this software, different techniques and models are used, one of which is discrete ordinates, which must be used in this simulation and project.

4.1 GOVERNING EQUATIONS

The governing equations of a mathematical model describe how the structured variables exchange when one or more of the unbiased variables change.

4.1.1 Analysis of the Grashof number and natural convection

Grashof number is a dimensionless group. It represents the ratio of the buoyancy force to the viscous force acting on the fluid:

$$Gr = \frac{\text{buoyancy forces}}{\text{viscous forces}} = \frac{g\Delta\rho V}{\rho v^2} = \frac{g\beta\Delta TV}{\rho v}$$

$$Gr = \frac{g\beta(T_s - T_\infty)L^3}{v^2}$$

Where

g = gravitational acceleration, m/s^2

β = coefficient of volume expansion, $1/\text{K}$ ($\beta = 1/T$ for ideal gases)

T_s = temperature of the surface, $^\circ\text{C}$

T_{∞} = temperature of the fluid sufficiently far from the surface, °C

L = characteristic length of the geometry, m

ν = kinematics viscosity of the fluid, m^2/s

The role played by Reynolds number in forced convection is performed through the Grashof number in natural convection. The necessary Grashof number is determined to be about 10^9 for vertical plates. Thus, the go with the flow regime on a vertical plate will become turbulent at Grashof range larger than 10^9 . The heat transfer price in natural convection is expressed by Newton's law of cooling as: $Q'_{conv} = h A (T_s - T_{\infty})$ (Yunus A. Cengel, Grashof Number)

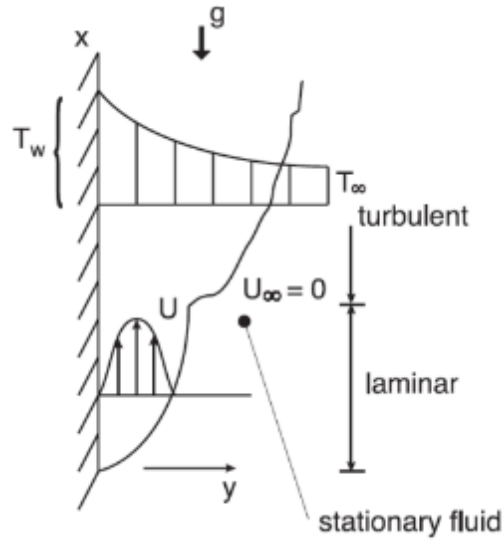


Figure 10: Velocity and temperature profile for natural convection flow over a hot vertical plate. $Gr_{critical} = 10^9$

4.1.2 Natural Convection over Surfaces

Natural convection on a surface depends on the geometry of the surface as well as its orientation. It also depends on the variation of temperature on the surface and the thermophysical properties of the fluid. The velocity and temperature distribution for natural convection over a hot vertical plate are shown in Fig.10.

Note that the velocity at the part of the boundary layer will become zero. It is anticipated when you consider that the fluid past the boundary layer is stationary. The shape of the velocity and temperature profiles, in the cold plate case, remains the same but their direction is reversed.

4.1.3 Natural Convection Correlations

The complexities of the fluid flow make it very difficult to obtain simple analytical relations for natural convection. Thus, most of the relationships in natural convection are based on experimental correlations.

The Rayleigh number is defined as the product of the Grashof and Prandtl numbers:

$$Ra = Gr Pr = \frac{g\beta(T_s - T_{\infty})}{\nu^2} Pr = \frac{g\beta(T_s - T_{\infty})L^3}{\nu\alpha}$$

Hence the Rayleigh number itself may also be viewed as the ratio of buoyancy forces and (the products of) thermal and momentum diffusivities.

The Nusselt number in natural convection is in the following form:

$$Nu = \frac{hL}{k} = C(GrPr)^n = C Ra^n$$

Natural convection heat transfer correlations are usually expressed in terms of the Rayleigh number raised to a constant n multiplied by another constant C , both of which are determined experimentally. (Yunus A. Cengel, Natural Convection over Surface)

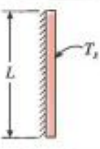
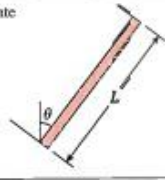
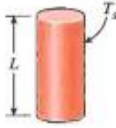
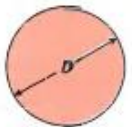
4.1.4 Vertical Cylinders

An outer surface of a vertical cylinder can be treated as a vertical plate when the diameter of the cylinder is sufficiently large so that the curvature effects are negligible. This condition is satisfied if

$$D \geq \frac{35L}{Gr^{1/4}}$$

When this criteria is met, the relations for vertical plates can also be used for vertical cylinders. Nusselt number relations for slender cylinders that do not meet this criteria are available in the literature. Table 1 in Cengel book lists these constants for a variety of geometries. (Yunus A. Cengel, Vertical Cylinders)

Table 2: Empirical correlations for the average Nusselt number for natural convection over surfaces

Geometry	Characteristic length L_c	Range of Ra	Nu
Vertical plate 	L	10^4 – 10^9 10^{10} – 10^{13} Entire range	$Nu = 0.59Ra_L^{1/4}$ $Nu = 0.1Ra_L^{1/3}$ $Nu = \left\{ 0.825 + \frac{0.387Ra_L^{1/4}}{[1 + (0.492/Pr)^{9/16}]^{1/4}} \right\}^2$ (complex but more accurate)
Inclined plate 	L		Use vertical plate equations for the upper surface of a cold plate and the lower surface of a hot plate Replace g by $g \cos \theta$ for $0 < \theta < 60^\circ$
Horizontal plate (Surface area A and perimeter p) (a) Upper surface of a hot plate (or lower surface of a cold plate)  (b) Lower surface of a hot plate (or upper surface of a cold plate) 	A_s/p	10^4 – 10^7 10^7 – 10^{11}	$Nu = 0.59Ra_L^{1/4}$ $Nu = 0.1Ra_L^{1/3}$ $Nu = 0.27Ra_L^{1/4}$
Vertical cylinder 	L		A vertical cylinder can be treated as a vertical plate when $D \geq \frac{35L}{Gr_L^{1/4}}$
Horizontal cylinder 	D	$Ra_D \leq 10^{12}$	$Nu = \left\{ 0.6 + \frac{0.387Ra_D^{1/4}}{[1 + (0.559/Pr)^{9/16}]^{1/4}} \right\}^2$
Sphere 	D	$Ra_D \leq 10^{11}$ $(Pr \geq 0.7)$	$Nu = 2 + \frac{0.589Ra_D^{1/4}}{[1 + (0.469/Pr)^{9/16}]^{1/4}}$

4.1.5 Laminar Flow

Fig.6 shows schematically how laminar and turbulent flow differ. Layers flow without mixing when flow is laminar. When there is turbulence, the layers mix, and there are significant velocities in directions other than the overall direction of flow. The lines that are shown in many illustrations are the paths followed by small volumes of fluids. These are called streamlines. Streamlines are smooth and continuous when flow is laminar, but break up and mix when flow is turbulent. Turbulence has two main causes. First, any obstruction or sharp corner, such as in a faucet, creates turbulence by imparting velocities perpendicular to the flow. Second, high speeds cause turbulence. The drag both between adjacent layers of fluid and between the fluid and its surroundings forms swirls and eddies, if the speed is great enough. We shall concentrate on laminar flow for the remainder of this section, leaving certain aspects of turbulence for later sections.

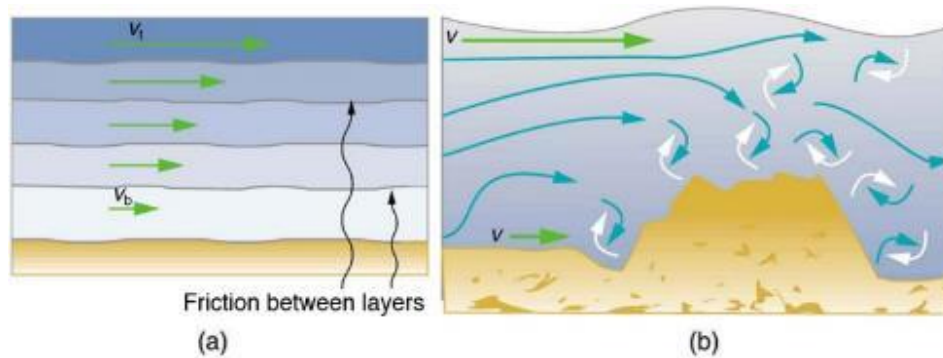


Figure 11: (a) Laminar flow occurs in layers without mixing. Notice that viscosity causes drag between layers as well as with the fixed surface. (b) An obstruction in the vessel produces turbulence. Turbulent flow mixes the fluid. There is more interaction, greater heating, and more resistance than in laminar flow.

A force F is required to keep the top plate in Fig.7 moving at a constant velocity v , and experiments have shown that this force depends on four factors. First, F is directly proportional to v (until the speed is so high that turbulence occurs—then a much larger force is needed, and it has a more complicated dependence on v). Second, F is proportional to the area A of the plate. This relationship seems reasonable since A is directly proportional to the amount of fluid being moved. Third, F is inversely proportional to the distance between the plates L . This relationship is also reasonable, L is like a lever arm, and the greater the lever arm, the less force that is needed. Fourth, F is directly proportional to the coefficient of viscosity, η . The greater the viscosity, the greater the force required. These dependencies are combined into the equation.

$$F = \eta \frac{vA}{L}$$

which gives us a working definition of fluid viscosity η . Solving for η gives: (Laminar Flow, 2022)

$$\eta = \frac{FL}{vA}$$

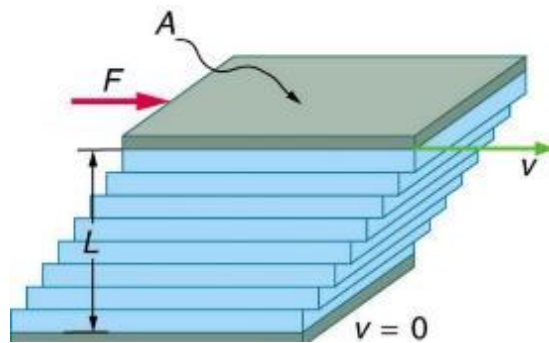


Figure 12: The graphic shows laminar flow of fluid between two plates of area A . The bottom plate is fixed. When the top plate is pushed to the right, it drags the fluid along with it.

4.1.6 Turbulent Flow

The first characteristic of turbulent flow is that the fluid speed field varies considerably and irregularly in both role and time. Due to this feature, there is no specific approach to fixing turbulent problems, so it depends on statistical

methods. The different characteristic is the capability to mix and amplify quotes of momentum a good deal greater efficaciously than a related laminar flow. Turbulent flows occur at high Reynolds numbers.

Given that Re number is the ratio of inertia forces to viscous forces, the instabilities are due to the interplay of viscous terms and nonlinear inertia phrases in the equations of motion. Since high levels of fluctuating vorticity represent turbulent flows, the subsequent necessary attribute is rotational and 3-dimensional vorticity fluctuations. Turbulent flows are usually dissipative and continuum that is governed via the equations of fluid mechanics. At last, turbulence is a characteristic of fluid flows, not of fluids. (I. Most, 1877)

According to the reality that there is no universal, single ideal turbulence model, the preference between these models depends on quite a few considerations such as the physics of the flow, the stage of accuracy required, the handy computational resources, and the amount of time available for the simulation. ANSYS Fluent presents turbulence modeling competencies in an unparalleled breadth of models. There are ten turbulence models reachable in Fluent, described below. (C. Lenin, 2012) (Zhai, 2020)

An occlusion, or narrowing, of an artery, such as shown in Fig. 13, is likely to cause turbulence because of the irregularity of the blockage, as well as the complexity of blood as a fluid. Turbulence in the circulatory system is noisy and can sometimes be detected with a stethoscope, such as when measuring diastolic pressure in the upper arm's partially collapsed brachial artery. These turbulent sounds, at the onset of blood flow when the cuff pressure becomes sufficiently small, are called Korotkoff sounds. Aneurysms, or ballooning of arteries, create significant turbulence and can sometimes be detected with a stethoscope. Heart murmurs, consistent with their name, are sounds produced by turbulent flow around damaged and insufficiently closed heart valves. Ultrasound can also be used to detect turbulence as a medical indicator in a process analogous to Doppler-shift radar used to detect storms.

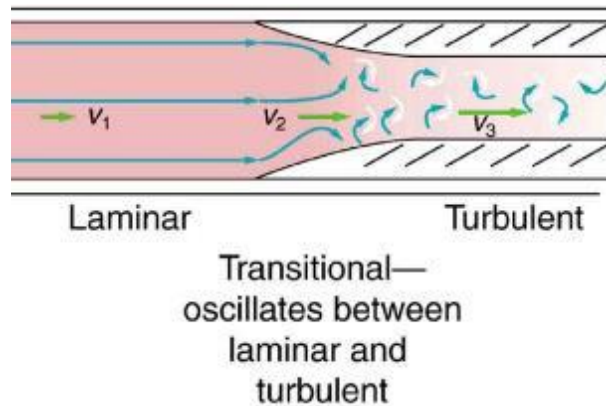


Figure 13: Flow is laminar in the large part of this blood vessel and turbulent in the part narrowed by plaque, where velocity is high. In the transition region, the flow can oscillate chaotically between laminar and turbulent flow.

An indicator called the Reynolds number N_R can reveal whether flow is laminar or turbulent. For flow in a tube of uniform diameter, the Reynolds number is defined as $N_R = \frac{2\rho v r}{\eta}$

Where ρ is the fluid density, v its speed, η its viscosity, and r the tube radius. The Reynolds number is a unitless quantity. Experiments have revealed that N_R is related to the onset of turbulence. For N_R below about 2000, flow is laminar. For N_R above about 3000, flow is turbulent. For values of N_R between about 2000 and 3000, flow is unstable—that is, it can be laminar, but small obstructions and surface roughness can make it turbulent, and it may oscillate randomly between being laminar and turbulent. The blood flow through most of the body is a quiet, laminar flow. The exception is

in the aorta, where the speed of the blood flow rises above a critical value of 35 m/s and becomes turbulent. (Turbulent Flow, 2022)

4.1.6.1 The k - ε model

The k - ε model is regularly occurring for external flow problems around complex geometries and additionally for industrial functions due to its sensible convergence rate and fantastically low memory requirements. However, it does no longer function nicely in the areas of damaging strain gradients, strong curvature to the flow, or jet flow. The basic thinking of this mannequin is to model turbulent kinetic energy, k , and dissipation price of turbulent kinetic energy, ε , and then relate the lacking statistics of size and time scales to these quantities to compute eddy viscosity as an algebraic expression of these two parameters. The k - ε mannequin depends on the assumption that eddy viscosity can be related to a time and size scale that suggests turbulence. (Murphy, 1984) (Sodja, 2007)

4.1.6.2 The k -omega model

The K-omega model is one of the most normally used turbulence models. It is a two-equation model, which means, it includes two extra transport equations to signify the turbulent houses of the flow. This lets in a two-equation mannequin to account for historic effects like convection and diffusion of turbulent energy.

The first transported variable is turbulent kinetic energy, k . The 2d transported variable, in this case, is the particular dissipation, omega. It is the variable that determines the scale of the turbulence, whereas the first variable, k , determines the electricity in the turbulence. (K-omega models, 2011)

4.1.7 Radiation

All matter at a nonzero temperature emits thermal radiation. This emission is due to changes in the electron configurations of the atoms or molecules, and the energy is transported via electromagnetic waves (or photons). Unlike conduction or convection, radiation does not require the presence of a material medium and can occur in vacuum. The rate of energy release per unit area (W/m^2) is called the surface emissive power E . Stefan-Boltzman law gives the upper limit of the emissive power of an ideal radiator or blackbody:

$$E_b = \sigma T_s^4$$

$$\sigma = 5.67 \times 10^{-8} W/m^2 K^4$$

where T_s is the absolute temperature of the surface.

The heat flux emitted by a real body is less than that of a black body and is given by

$$E = \varepsilon \sigma T_s^4$$

where $0 \leq \varepsilon \leq 1$ is the emissivity. It is a measure of how effectively a surface emits energy relative to a black body. It depends on the material of the surface and its finish.

Irradiation, G , is the sum of all incident radiation on a body from its surroundings, a portion or all of which maybe absorbed by the body. The rate at which radiant energy is absorbed per unit surface area can be evaluated using

$$G_{abs} = \alpha G$$

where $0 \leq \alpha \leq 1$ is the absorptivity. If $\alpha < 1$ and the surface is opaque, portions of the irradiation are reflected. However, if the surface is semitransparent, a portion of the irradiation may also be transmitted.

Consider the radiation exchange between a small surface at T_1 and a much larger isothermal surface at T_2 completely surrounding the smaller surface. Assuming the surface to be a gray surface (i.e., for which $\alpha = \varepsilon$), then the net rate of radiation heat transfer (per unit area) from the surface can be expressed as:

$$q_{rad}'' = \frac{q}{A} = \varepsilon E_b(T_s) - \alpha G = \varepsilon \alpha (T_1^4 - T_2^4)$$

The above equation represents the difference between the thermal energy being released due to radiation emission and that which is being absorbed. The net radiation heat transfer can also be expressed as:

$$q_{rad} = h_r A (T_1 - T_2)$$

where the radiation heat transfer coefficient h_r is $h_r = \varepsilon \alpha (T_1 + T_2)(T_1^2 + T_2^2)$

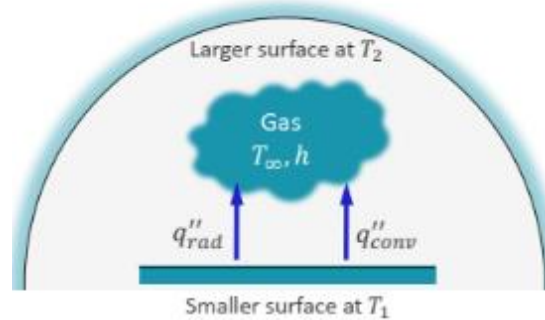


Figure 14: Radiation

4.1.7.1 The DO model

The discrete ordinates (DO) technique uses a discrete representation of the directional version of the radiative intensity, solving the equation of radiative transfer for a set of discrete directions. This approach is a finite differencing of directional dependence of the equation of radiative transfer.

The DO mannequin transforms the equation of radiative transfer into a transport equation for radiation intensity. For every course $\vec{s}$, the mannequin solves one transport equation with an answer approach equal to that used for the fluid waft and energy equations.

$$\nabla \cdot \frac{dI(\vec{r}, \vec{s})}{ds} + (a + \mu_s)I(\vec{r}, \vec{s}) = aI_b(\vec{r}) + \frac{\mu_s}{4\pi} \int_0^{4\pi} I(\vec{r}, \vec{s}') \varphi(\vec{s}', \vec{s}) d\Omega'$$

Fluent makes use of a variant of the DO mannequin known as the finite quantity method. It has the gain to prevent the false scattering and ray outcomes that can occur with the DO method. Mainly its use is desired because it ensures the conservation of radiative energy, unlike the traditional DO method. This approach uses finite strong perspective volumes as an alternative to finite differences.

There are two implementations accessible for the DO mannequin in Fluent: uncoupled and electricity coupled. The uncoupled one solves the equations for energy and radiation intensities with the aid of one. In the coupled approach, the

discrete electricity and depth equations are solved simultaneously at each cell. The important gain is that it speeds up the simulation for certain instances involving high optical thicknesses or scattering coefficients. (BELEY, 2016)

4.1.8 ENERGY

In order to simulate a conjugated heat transfer problem, for example, natural convection modeling, it is needed to reflect on consideration on the Energy equation. ANSYS Fluent solves the electricity equation in the following form:

$$\frac{\partial}{\partial t}(\rho E) + \nabla \cdot (\vec{v}(\rho E + p)) = \nabla \cdot \left(k_{eff} \nabla T - \sum_j h_j \vec{J}_j + (\bar{\tau} \cdot \vec{v}) \right) + S_h$$

Where k_{eff} is the wonderful conductivity and $\vec{J}_j$ is the diffusion flux of species j. On the right-hand side of the equation, respectively, the first time period represents conduction power transfer, the second the species diffusion, and the third the viscous dissipation. Lastly, S_h consists of the heat of the chemical reaction. (ANSYS Fluent Theory Guide, 2013)

4.1.9 NAVIER-STOCKS

ANSYS Fluent solves the following equations for mass equilibrium, also recognized as the continuity equation

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = S_m$$

This equation is the popular shape of the mass survival equation that is valid for incompressible and compressible flows. The source, S_m , is a mass that is added from the 2d scattered phase to the continuous phase. In our modeling S_m is zero.

Conservation of momentum in an inertial reference frame is defined as;

$$\frac{\partial}{\partial t}(\rho \vec{v}) + \nabla \cdot (\rho \vec{v} \vec{v}) = -\nabla p + \nabla \cdot (\bar{\tau}) + \rho \vec{g} + \vec{F}$$

Where p is the static pressure, $\bar{\tau}$ is the stress tensor, and $\rho \vec{g}$ and $\vec{F}$ are the gravitational body force and external body forces. (ANSYS Fluent Theory Guide, 2013)

For a 3-dimensional system, we have three unbiased momentum equations for the directions x, y, and z. The mixture of the continuity equation and these three momentum equations is frequently acknowledged as the Navier-Stock equations.

4.2 GEOMETRY

In the ANSYS Workbench, the Geometry option is selected. The geometry created using ANSYS DesignModeler is shown in Fig.14. First, a circle is drawn in ZXplane, and with the Extrude option, select the plane and give it height, then finally generate it.

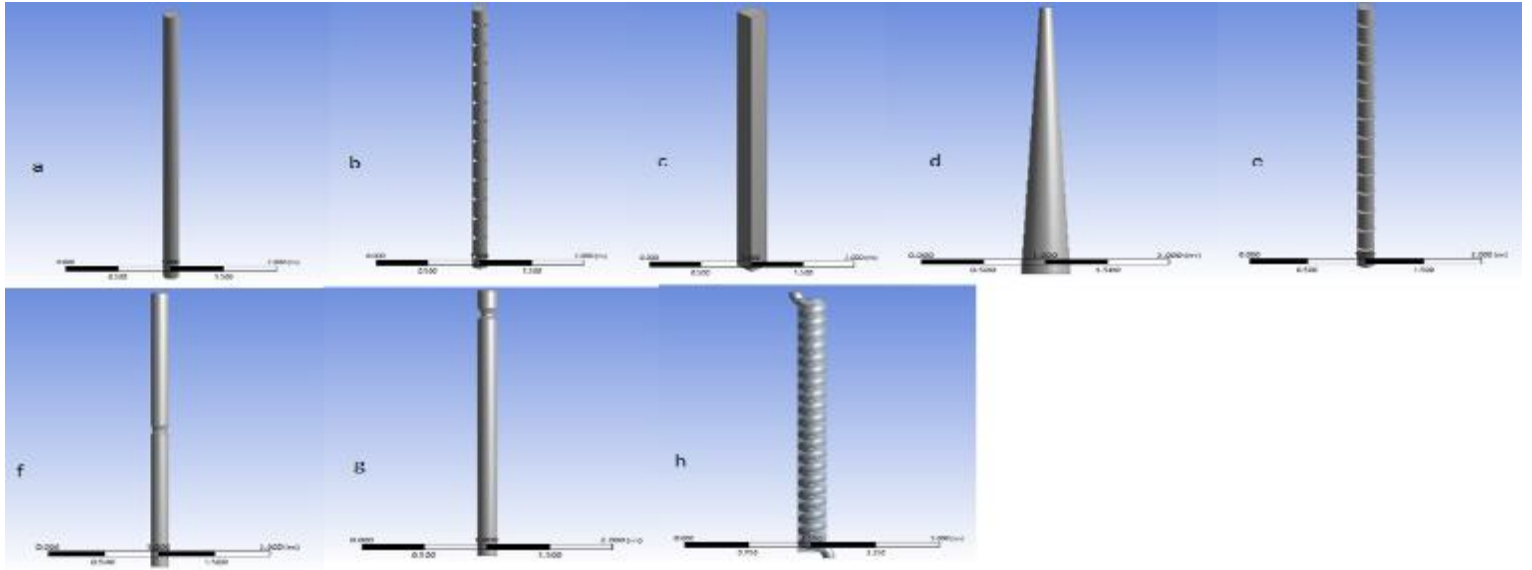


Figure 15: a) Pipe, b) Perforated Pipe, c) Cube Pipe, d) Conical Pipe, e) Ribbed Pipe, f) Venturi 1, g) Venturi 2, h) Helical Pipe

Table 3: Pipe Data

a		b		c		d		e		f,g		h	
L (m)	4	L(m)	4	L(m)	4	L(m)	4	L(m)	4	L(m)	4	L(m)	4
r (m)	0.075	r(m)	0.075	r(m)	0.1	r _{inlet} (m), r _{outlet} (m)	0.1, 0.0025	r(m)	0.075	r(m)	0.075	r(m)	0.075
th (m)	0.02	th(m)	0.02	th(m)	0.02	th(m)	0.02	th(m)	0.02	th(m)	0.02	th(m)	0.02
T ₁ (°C)	25	T ₁ (°C)	25	T ₁ (°C)	25	T ₁ (°C)	25	T ₁ (°C)	25	T ₁ (°C)	25	T ₁ (°C)	25
T _{sun} (°C)	30	T _{sun} (°C)	30	T _{sun} (°C)	30	T _{sun} (°C)	30	T _{sun} (°C)	30	T _{sun} (°C)	30	T _{sun} (°C)	30

In Fig. 16, the ribs of the pipe are placed vertically inside the pipe and their size is 3 mm and 13 ribs are placed along the length of the pipe. For the perforated pipe, 54 holes with a radius of 0.005 meters have been considered.

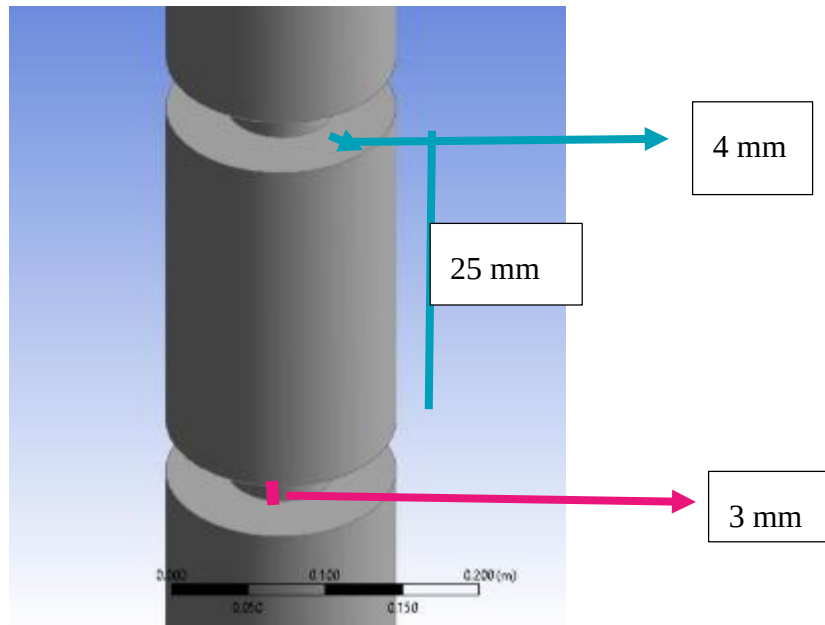
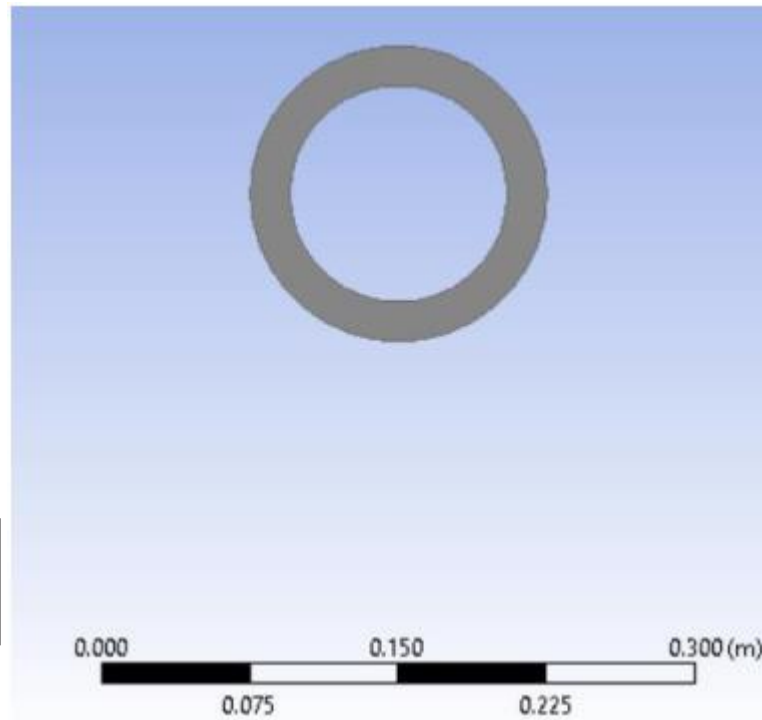


Figure 16: Ribbed Pipe

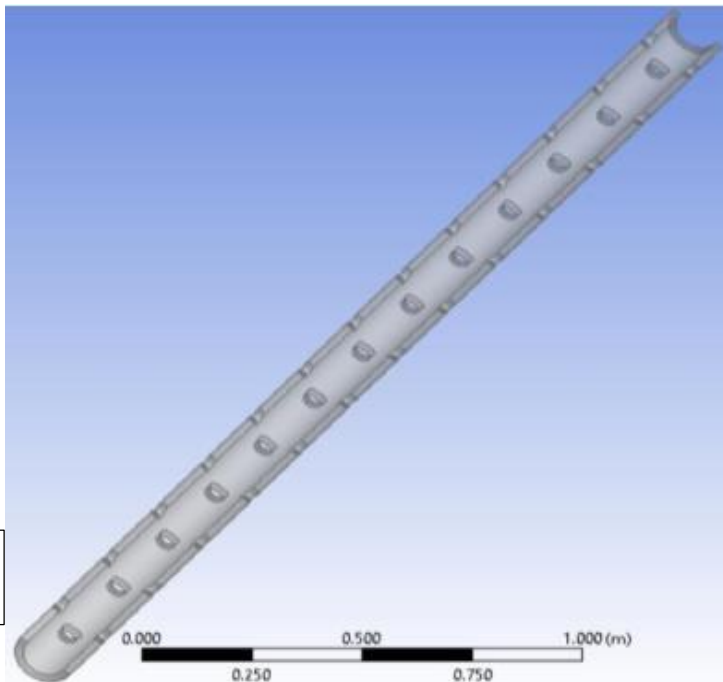
4.2.1 Draft and Graphics

To demonstrate pipe geometry more clearly, vertical and horizontal sections of various pipes are shown in Fig. 17(a) to 17 (k).

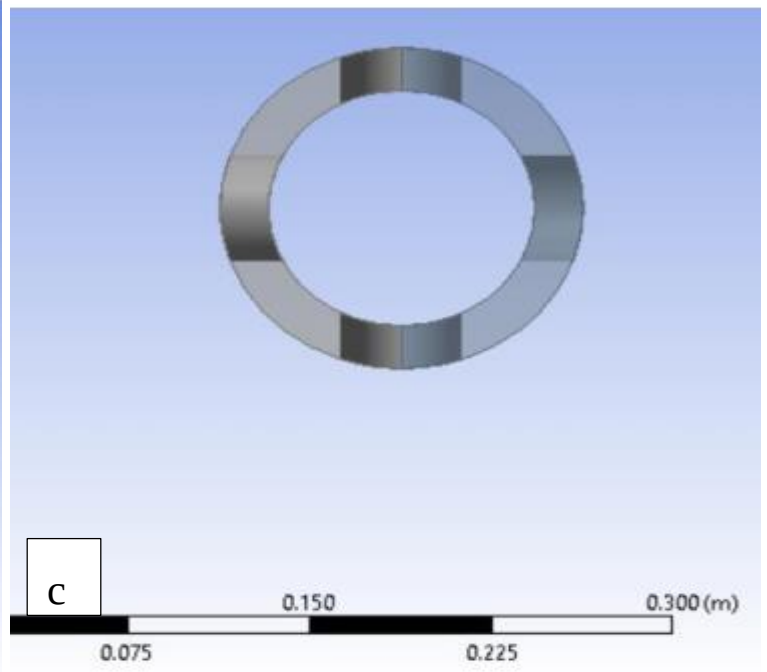
a



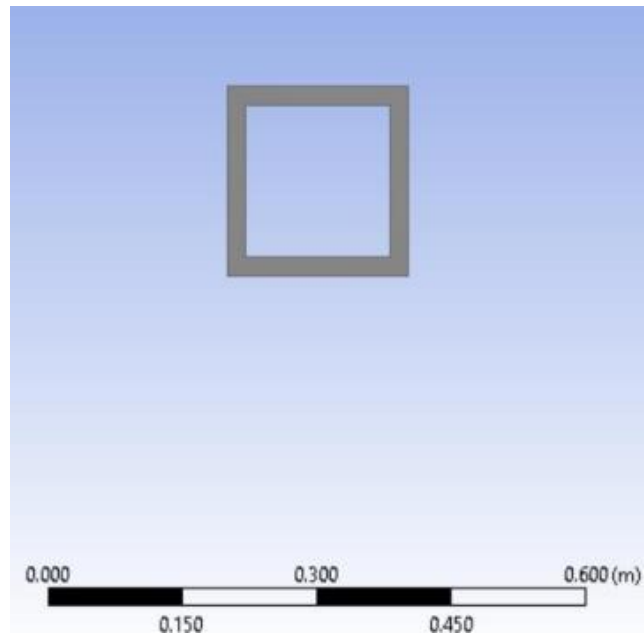
b



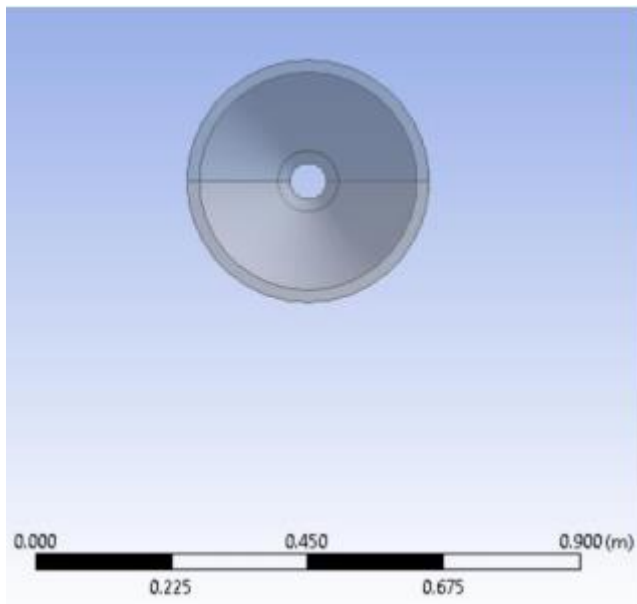
c



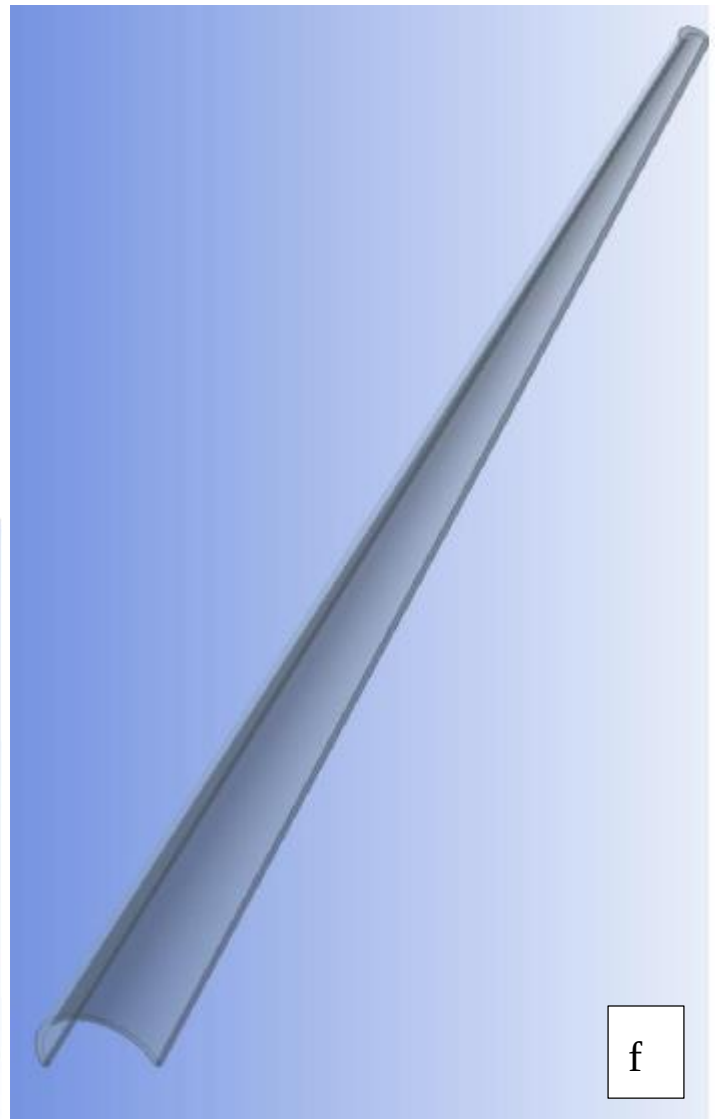
d



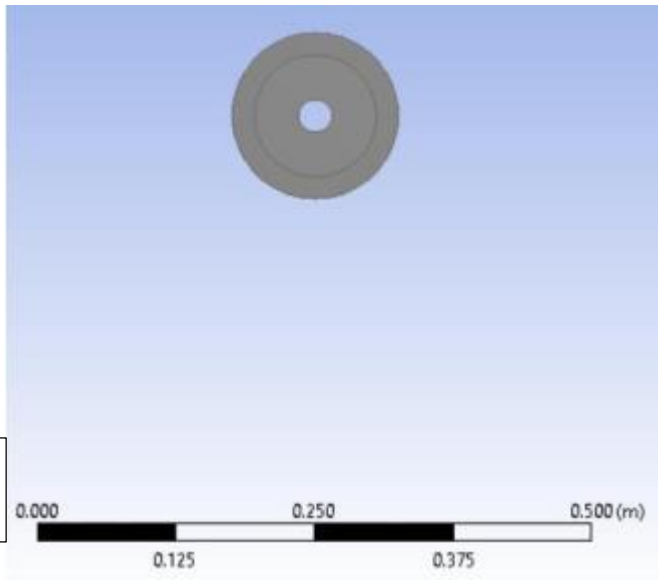
e



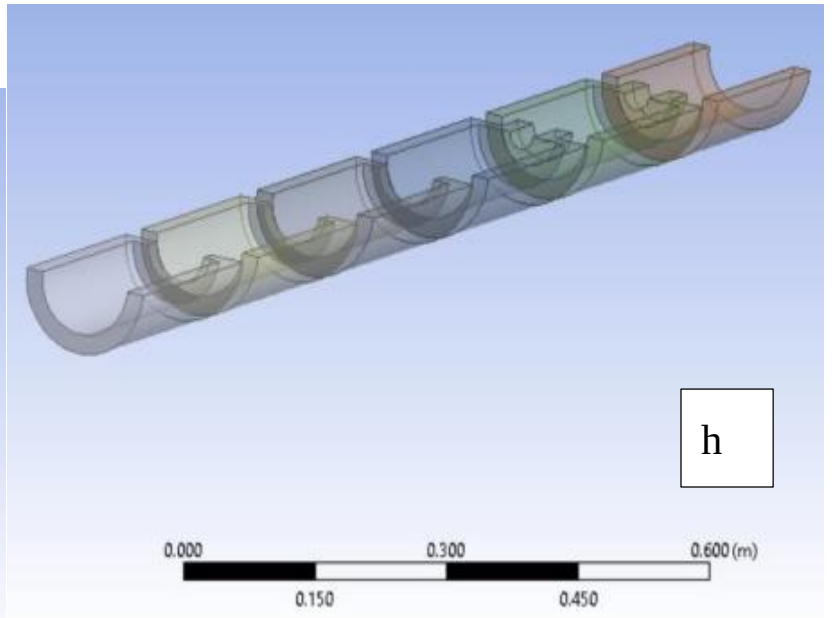
f



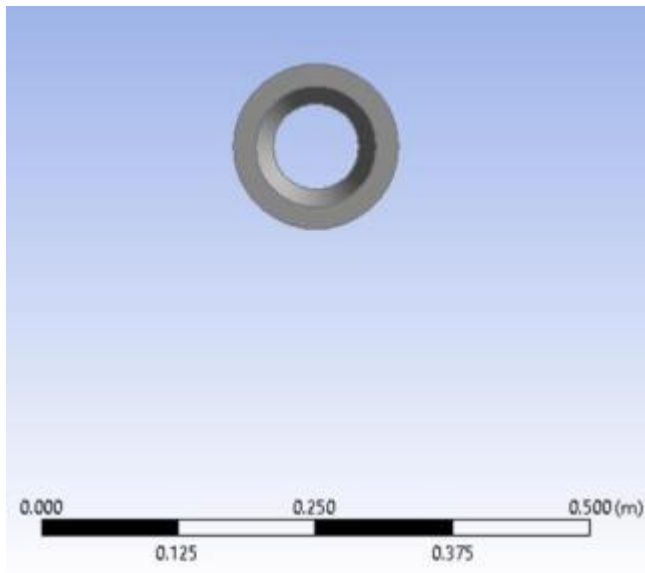
g



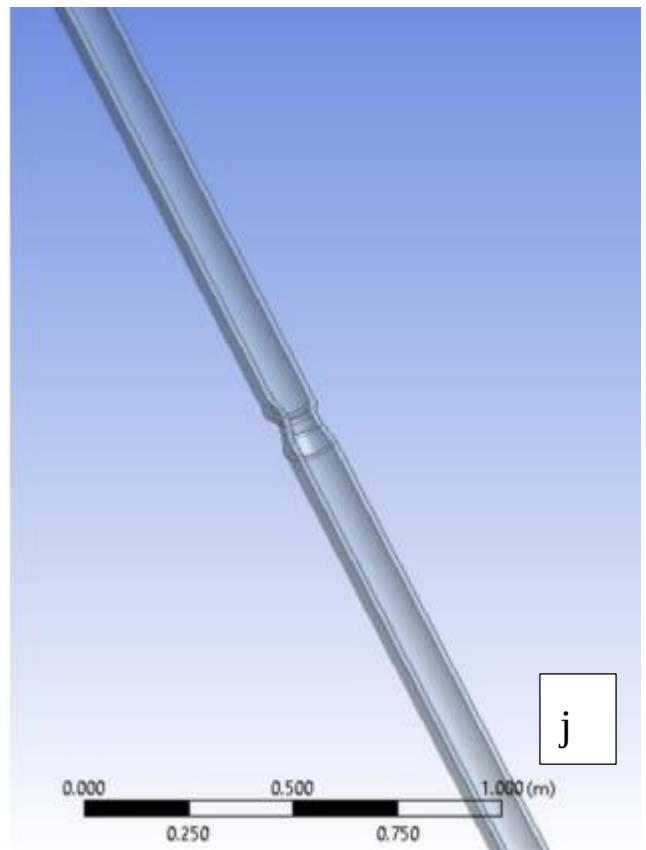
h



i



j



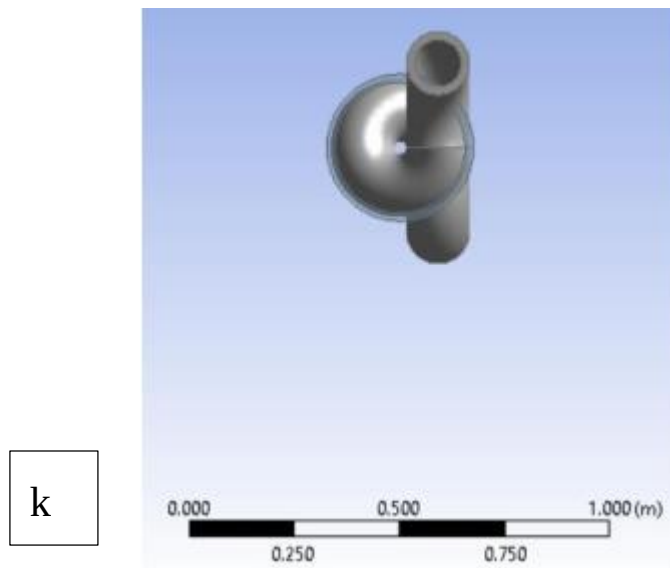


Figure 17: Draft and Graphics

4.3 MESHING

After generating the geometry in the DesignModeler, it is imported to the ANSYS Meshing to operate the mannequin discretization. Various thing sizes are used for different domains of the model, depending on their significance and sensitivity. Different meshing aspects such as physique and facet sizing, inflation, and sweep are used to improve the fine of our mesh. All pipe meshes were standard. To cite the meshes, we put all of them below.

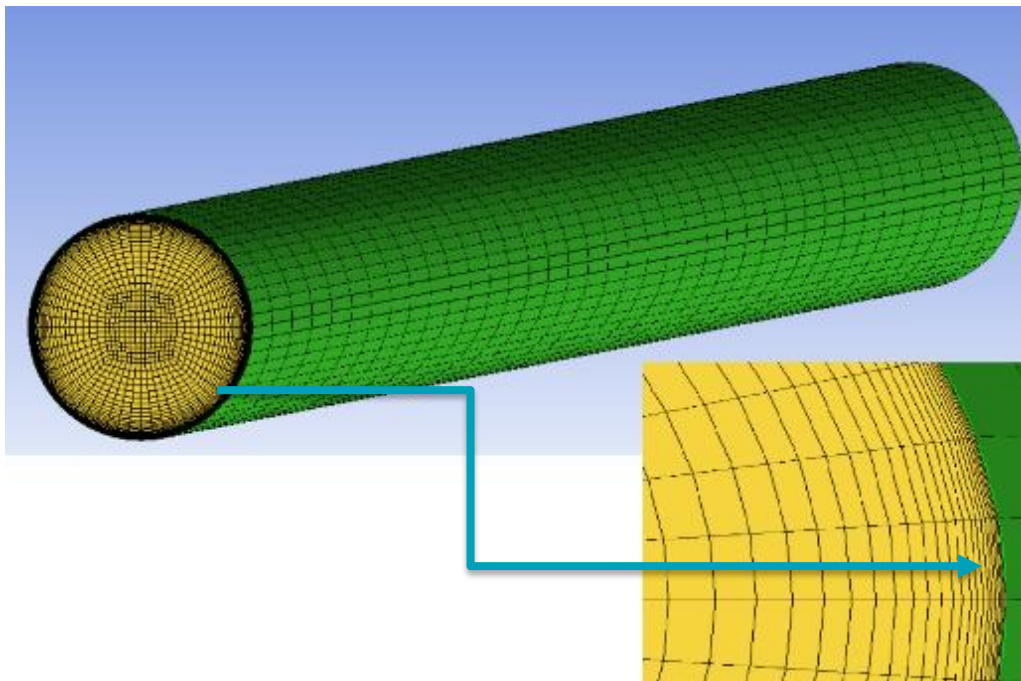


Figure 18: Pipe Meshing

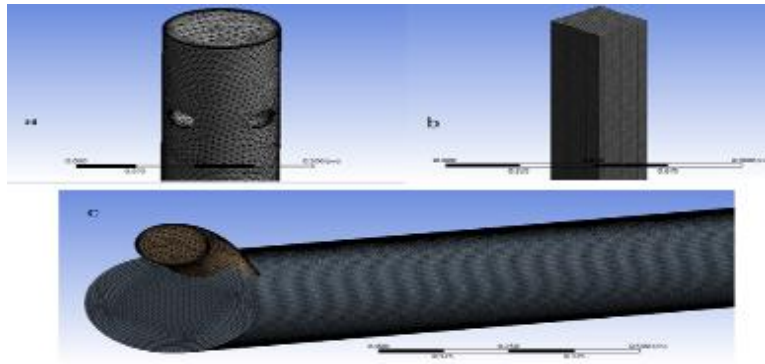


Figure 19: Meshing

The boundary layer mesh is particularly necessary for our modeling, and this is good sized because there are very small adjustments in its measurement and there are many variations in the results. Accurate modeling of the gadget requires a thin-walled mesh. One of the parameters that help us decide the size of the boundary layer primarily based on the mannequin stipulations is the dimensionless wall distance, additionally called y^+ , which is defined as follows:

$$y^+ \equiv \frac{u_* y}{\nu}$$

Where y is the distance to the wall and the nearby kinematic viscosity of the fluid is denoted by means of ν and u_* denotes the friction velocity at the nearest wall and is described as follows: (nejad, 2006)

$$u_* = \sqrt{\frac{\tau_{wall}}{\rho}}$$

And to ensure the correct meshing of the pipe, we use the Pre Mesh Quality section, which can be seen in the Fig.17, meshing quality.



Figure 20: Meshing Quality

The quality of other meshes was also completely standard, which you can see below. All mesh qualities are as standard as Fig.18.

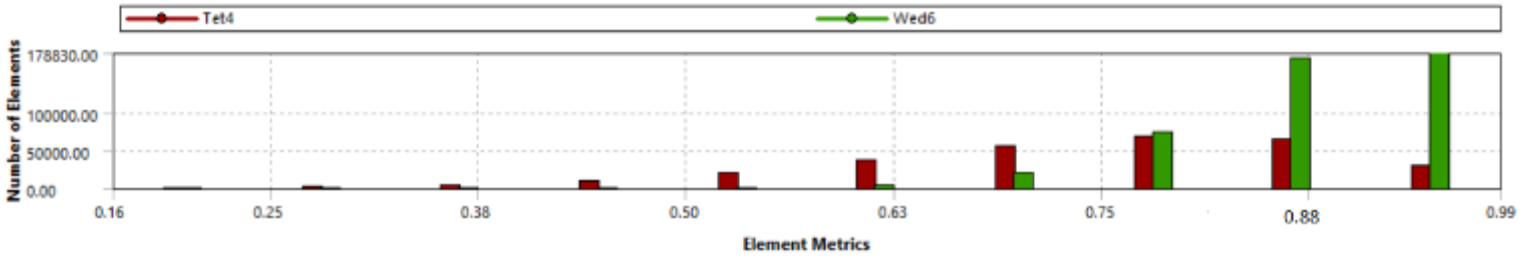


Figure 21: Orthogonal Quality

The orthogonal quality also varies from zero to 1, which is one of the absolute best qualities. If the minimal orthogonal first-rate is under 0.01, Fluent will now not take delivery of the enter mesh. However, for fast convergence, the significantly higher imply price is anticipated to be at least 0.7. The minimum orthogonal quality for our modeling is 0.155057 with an average of 0.572631. These parameters are nicely inside the universal vary for orthogonal quality. (ANSYS Fluent Theory Guide, 2013) This quality indicates that we have broken our mesh with high accuracy and our mesh is of high quality.

4.4 FLUID FLOW (FLUENT)

After completing the meshing, go to the fluent section in ANSYS, and in the fluent launcher section, select the double-precision and parallel options and use all 12 CPUs for the best simulation solution. After opening the Fluent workbench in the general section, select the pressure and steady-state options and consider the gravity of the ground in the Y -9.81 m/s² section. In the models section, we turned on the energy option and set the viscous section to laminar or turbulent according to the Reynolds number in Table 4. In the radiation section, according to the location of Iran (longitude = 53.688 degrees, latitude = 32.4279 degrees, and time zone = 5.5). We also considered the amount of time the sun shines on the pipe 13 hours a day. Moreover, we considered the color of the pipe to be black and placed it in the relevant section in ANSYS.

Fair Weather Conditions:

Sun Direction Vector: X: -0.808188, Y: 0.231135, Z: -0.541672

Sunshine Fraction: 1

Direct Normal Solar Irradiation (at Earth's surface) [W/m²]: 935.748

Diffuse Solar Irradiation - vertical surface: [W/m²]: 67.4607

Diffuse Solar Irradiation - horizontal surface [W/m²]: 59.254

Ground Reflected Solar Irradiation - vertical surface [W/m²]: 56.6123

$$Re = \frac{VD}{\nu}$$

Table 4: Reynolds Number

Re	velocity inlet(m/s)
Laminar	0.1
2300<Re<4000	0.3
Turbulent	0.5
Turbulent	1
Turbulent	1.5

Turbulent	2
-----------	---

We went to the materials section and considered the fluid as air and set the amount of data according to Table 5 to calculate all the points more accurately. In the solid part, we placed PVC, Steel, and Aluminum materials according to Table 6.

Table 5: Variable thermal and physical properties of air (Viscosity of Air, Dynamic and Kinematic, 2022)

Data Point	T (°C)	ρ (kg/m ³)	k (W/mK)	μ (kg/ms)
1	5	1.269	0.02401	1.754×10^{-5}
2	10	1.246	0.02439	1.778×10^{-5}
3	15	1.225	0.02476	1.802×10^{-5}
4	20	1.204	0.02514	1.825×10^{-5}
5	25	1.184	0.02551	1.849×10^{-5}
6	30	1.164	0.02588	1.872×10^{-5}
7	35	1.145	0.02625	1.895×10^{-5}
8	40	1.127	0.02662	1.918×10^{-5}
9	45	1.109	0.02699	1.941×10^{-5}
10	50	1.092	0.02735	1.963×10^{-5}
11	60	1.059	0.02808	2.008×10^{-5}
12	70	1.028	0.02881	2.052×10^{-5}
13	80	0.9994	0.02953	2.096×10^{-5}
14	90	0.9718	0.03024	2.139×10^{-5}
15	100	0.9458	0.03095	2.181×10^{-5}

Table 6: Summary of Materials

Material	ρ (kg/m ³)	k (W/mK)	C _p (J/kgK)
PVC	1350	0.17	900
Steel	8030	16.27	502.48
Aluminum	2719	202.4	871

In the next part, we went to the Cell Zone and boundary condition section and set the flow in the air and started the inlet speed according to Table 4 from 0.1 m/s and advanced to 2 m/s, and for all three types of materials we had, these We calculated. In the results section, we deal with the obtained graphs and numbers, as well as the average speed of generators and prices.

5. Results and Discussion

According to the items mentioned in section 4 of the Methodology, the results are shown in the form of graphs. Of course, it is important that these diagrams are only for simple pipes in different materials and different speeds. I have provided the rest of the diagrams in the Appendix to this section so that you can see all the diagrams of all the shapes of the pipes. In the following, we have included the prices and types of generators, and we have also obtained the information of a generator from the manufacturer and evaluated it.

5.1 DIAGRAMS AND TABLES OF SIMULATED PIPES

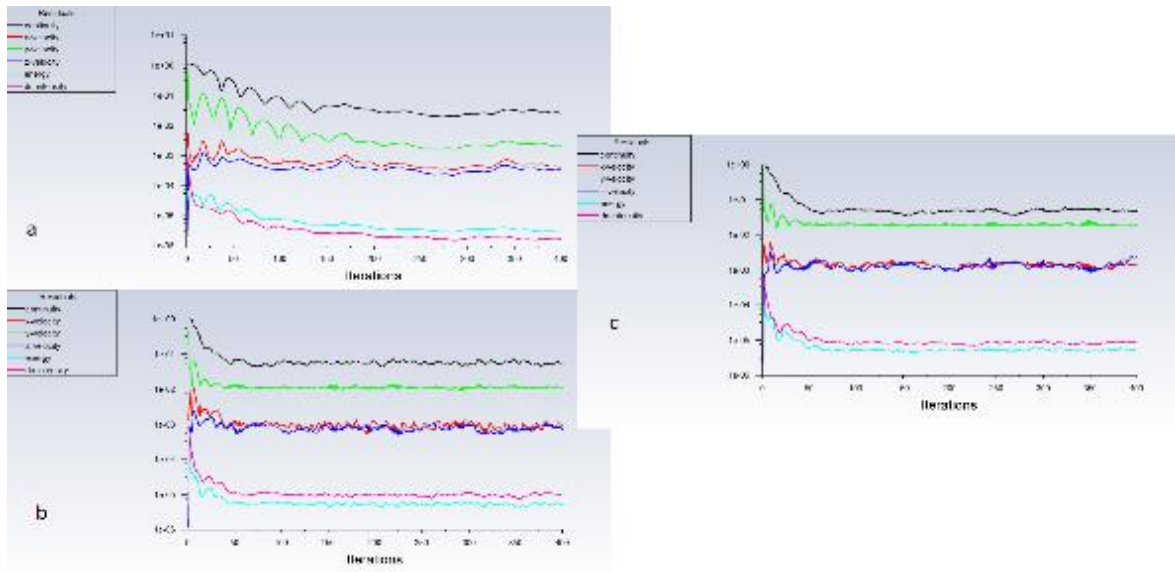


Figure 22: a) 0.1 m/s Aluminum Pipe, b) 0.1 m/s PVC Pipe, c) 0.1 m/s Steel Pipe

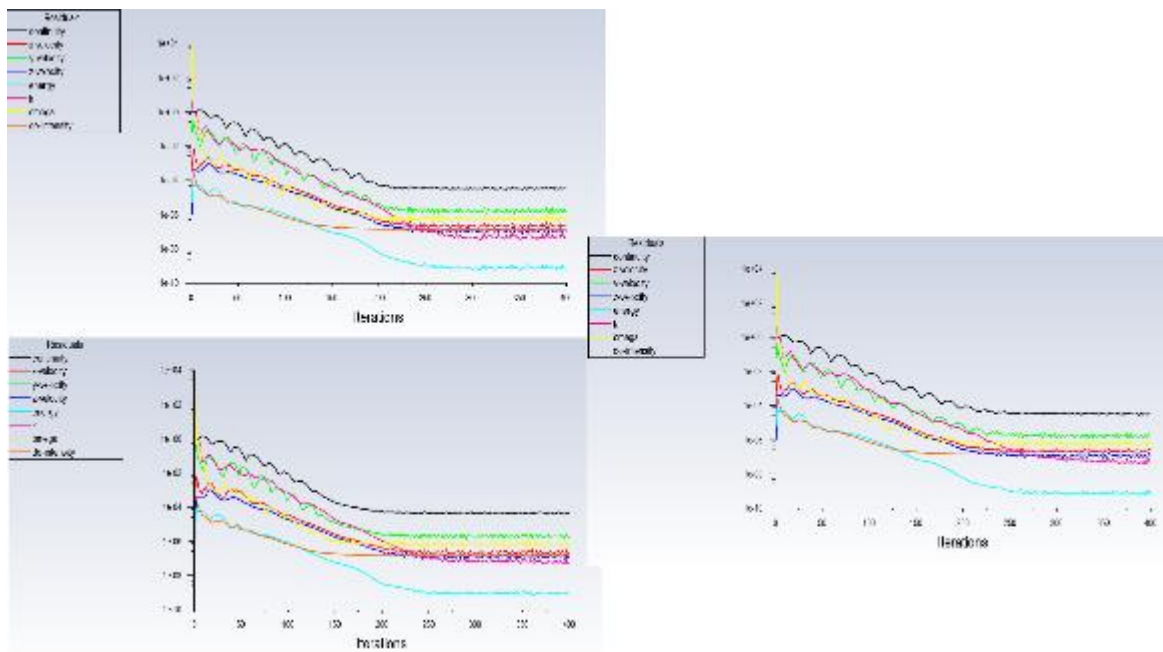


Figure 23: 0.3 m/s Pipe

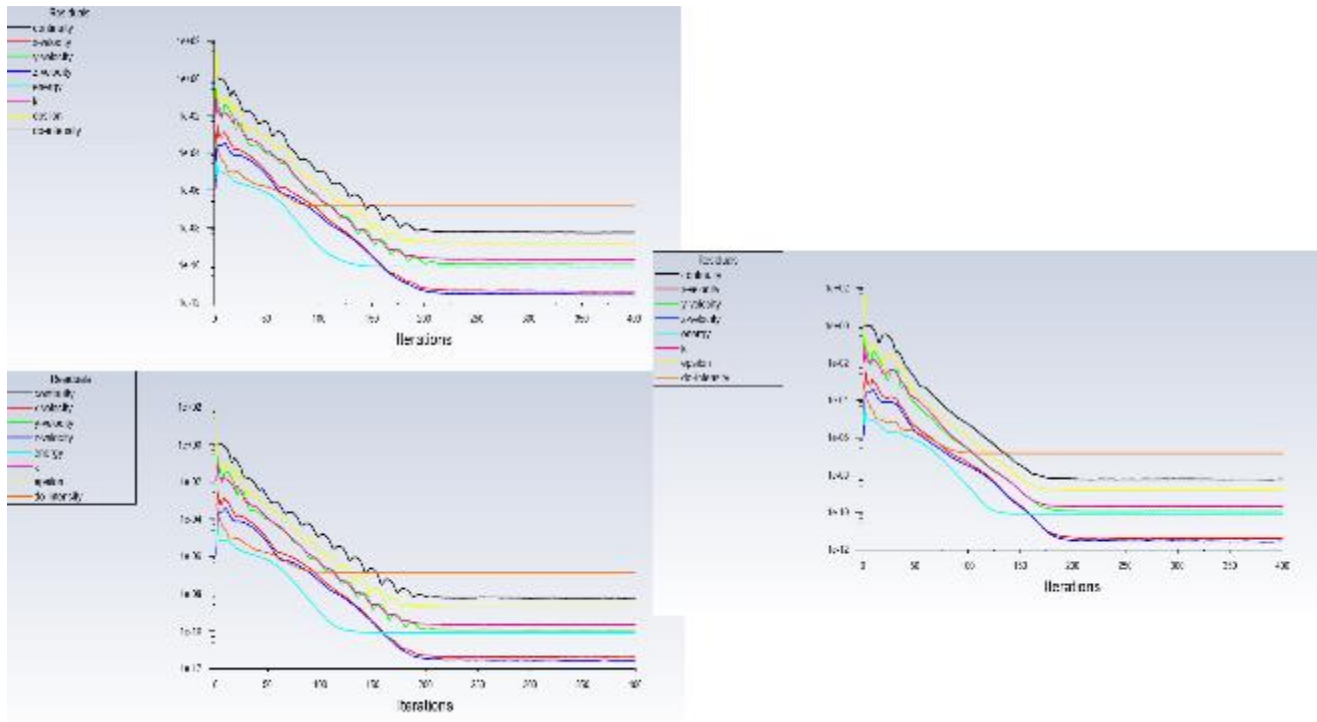


Figure 24: 0.5 m/s Pipe

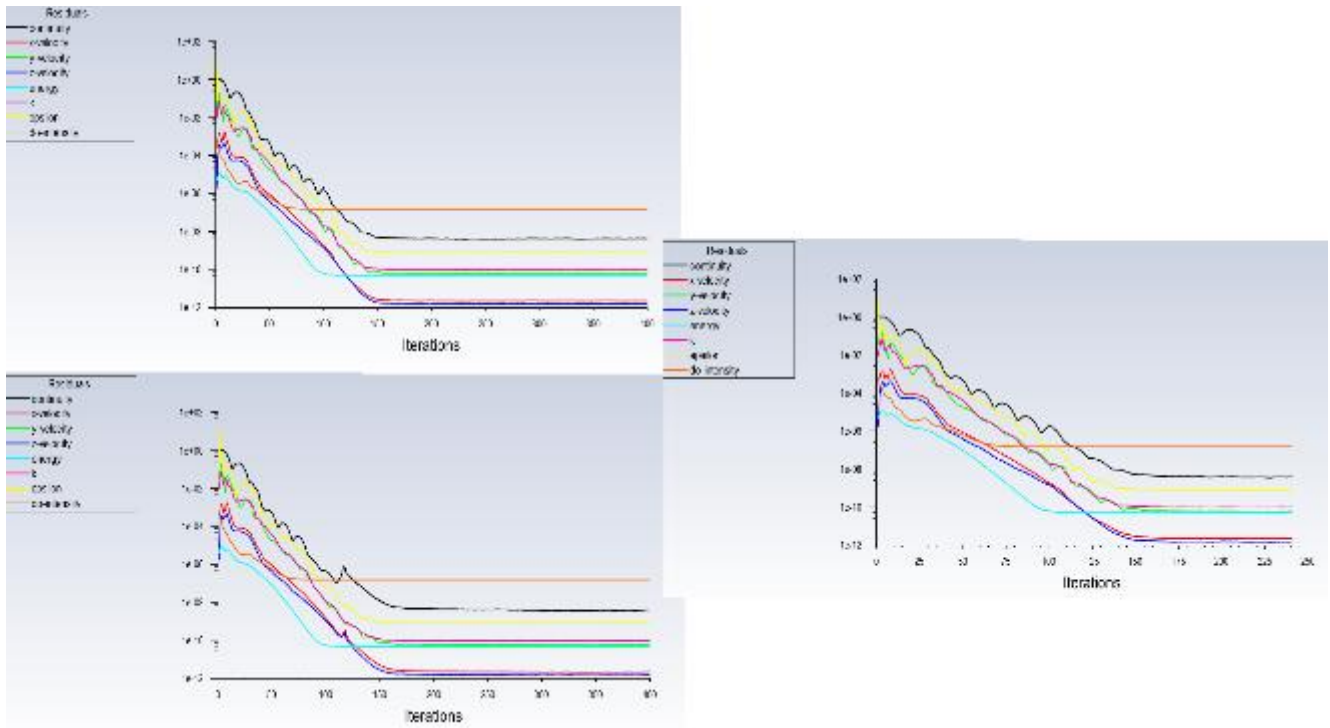


Figure 25: 1 m/s Pipe

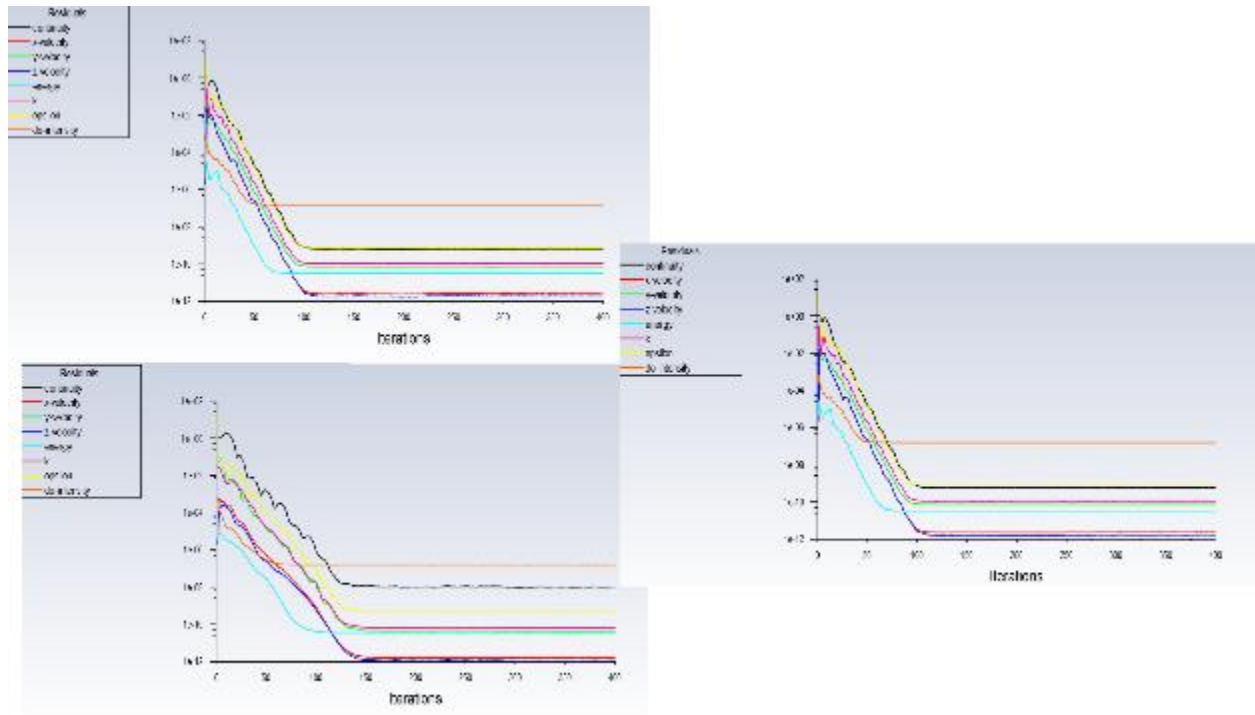


Figure 26: 1.5 m/s Pipe

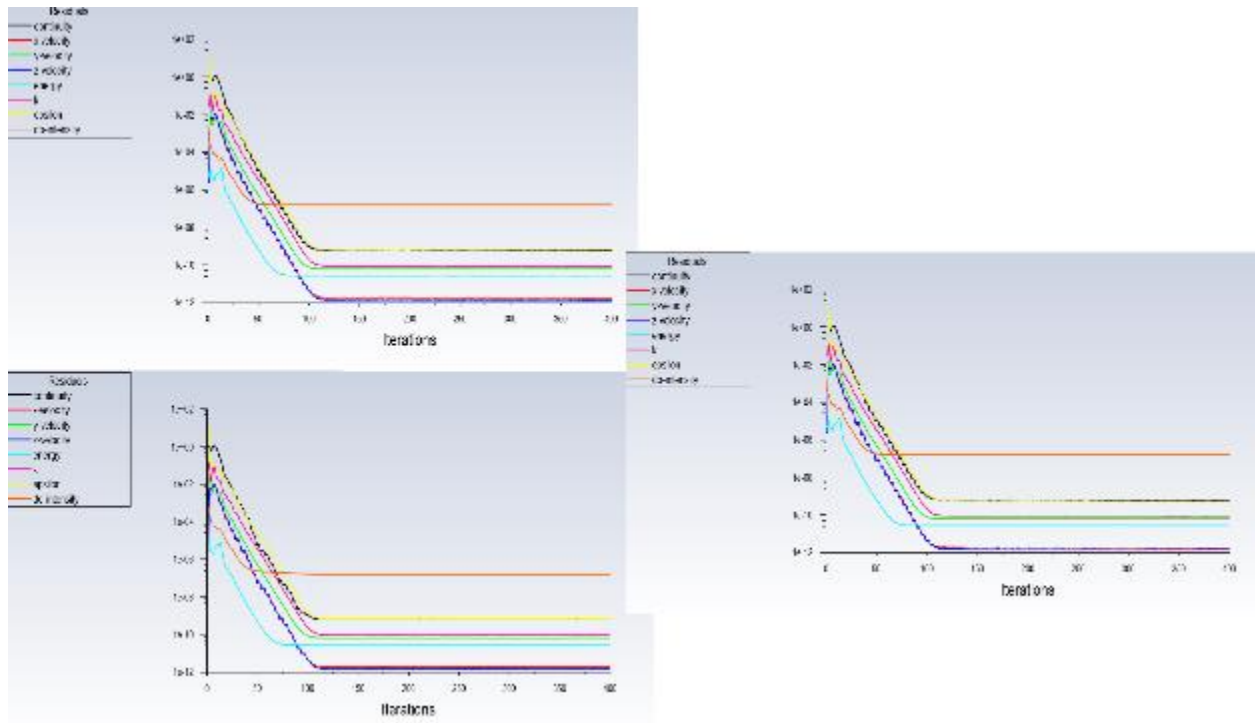


Figure 27: 2 m/s Pipe

The results obtained from Fig.22-27 can be seen in Table 7 and also in Table 8, you can see the percentage of input and output velocity.

Table 7: Outlet velocity in the pipe in different materials and different velocities

		PVC	Steel	Aluminum
Re	velocity inlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)
Laminar	0.1	0.424	0.424	0.424
2300<Re<4000	0.3	0.477	0.477	0.477
Turbulent	0.5	0.582	0.582	0.582
Turbulent	1	0.895	0.896	0.896
Turbulent	1.5	1.246	1.250	1.250
Turbulent	2	1.617	1.619	1.619

Table 8: Percentage of input and output velocity of Pipe

PVC	Steel	Aluminum
323.898%	323.735%	323.741%
58.845%	58.891%	58.892%
16.332%	16.407%	16.408%
-10.535%	-10.448%	-10.447%
-16.909%	-16.695%	-16.694%
-19.135%	-19.071%	-19.070%

Then, in order to get the best efficiency, we examined the perforated pipe in PVC, steel and aluminum and came to the conclusion that this pipe does not give us a suitable amount of output velocity. You can see the results in Tables 9 and 10. As you can see, aluminum gives the best results in this pipe, but it is not a good option compared to other pipes.

Table 9: Outlet velocity in the Perforated Pipe in different materials and different velocities

		PVC	Steel	Aluminum
Re	velocity inlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)
Laminar	0.1	0.106	0.107	0.108
2300<Re<4000	0.3	0.240	0.239	0.241
Turbulent	0.5	0.394	0.395	0.395
Turbulent	1	0.884	0.887	0.887
Turbulent	1.5	1.377	1.339	1.339
Turbulent	2	1.762	1.649	1.786

Table 10: Percentage of input and output velocity of Perforated Pipe

PVC	Steel	Aluminum
5.947%	7.119%	8.154%
-19.962%	-20.494%	-19.731%
-21.162%	-21.034%	-21.024%
-11.598%	-11.263%	-11.306%
-8.171%	-10.719%	-10.727%
-11.881%	-17.551%	-10.694%

After the results of the perforated pipe, we decided to evaluate the cubic pipe with a size of 0.2 meters in diameter. The results can be seen in Tables 11 and 12. In this pipe, PVC material has the best efficiency. We know the reason is the amount of energy loss in other species. In our opinion, aluminum pipe is known because it can easily absorb light and can easily transfer it around.

Table 11: Outlet velocity in the Cube Pipe in different materials and different velocities

Re	PVC		Steel	Aluminum
	velocity inlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)
Laminar	0.1	0.1057	0.1058	0.1058
2300<Re<4000	0.3	0.3015	0.3012	0.3012
Turbulent	0.5	0.5019	0.5015	0.5014
Turbulent	1	1.0023	1.0019	1.0019
Turbulent	1.5	1.5026	1.5022	1.5022
Turbulent	2	2.0028	2.0024	2.0024

Table 12: Percentage of input and output velocity of Cube Pipe

PVC	Steel	Aluminum
5.679%	5.845%	5.824%
0.513%	0.407%	0.404%
0.378%	0.291%	0.290%
0.231%	0.188%	0.187%
0.173%	0.145%	0.145%
0.140%	0.121%	0.120%

Tables 13 and 14 show the ribbed tube, which gives us the best range at all speeds. Of course, it should be noted that the rib of this pipe is parallel and vertical, and this pipe in aluminum is the best choice for construction and implementation of this project.

Table 13: Outlet velocity in the Ribbed Pipe in different materials and different velocities

	PVC		Steel	Aluminum
Re	velocity inlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)
Laminar	0.1	0.325	0.320	0.323
2300<Re<4000	0.3	0.790	0.791	0.791
Turbulent	0.5	1.132	1.233	1.217
Turbulent	1	2.421	2.403	2.403
Turbulent	1.5	3.647	3.647	3.646
Turbulent	2	5.035	5.048	5.048

Table 14: Percentage of input and output velocity of Ribbed Pipe

PVC	Steel	Aluminum
225.44%	220.13%	223.10%
163.41%	163.73%	163.73%
126.42%	146.53%	143.39%
142.10%	140.27%	140.28%
143.10%	143.11%	143.08%
151.74%	152.40%	152.38%

After this ribbed pipe, according to the lessons we had in the past in fluids, we came across a device called Venturi and decided to evaluate this type of pipe as well. This equipment is examined in two ways, one in the middle of the pipe and the other at the end of the pipe. We placed it and realized that the tube whose venturi was placed in the middle gives us a significant result. You can see the results of these two tubes from Table 15 to 18.

Table 15: Outlet velocity in the Venturi i in different materials and different velocities

	PVC		Steel	Aluminum
Re	velocity inlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)
Laminar	0.1	0.669	0.669	0.669
2300<Re<4000	0.3	0.726	0.725	0.725
Turbulent	0.5	0.855	0.855	0.855
Turbulent	1	1.215	1.215	1.215
Turbulent	1.5	1.615	1.616	1.616

Turbulent	2	2.126	2.128	2.128
-----------	---	-------	-------	-------

Table 16: Percentage of input and output velocity of Venturi 1

PVC	Steel	Aluminum
569.337%	569.029%	569.082%
141.871%	141.806%	141.831%
71.046%	71.078%	71.084%
21.470%	21.520%	21.527%
7.659%	7.722%	7.722%
6.325%	6.383%	6.384%

Table 17: Outlet velocity in the Venturi 2 in different materials and different velocities

		PVC	Steel	Aluminum
Re	velocity inlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)
Laminar	0.1	0.628	0.627	0.626
2300<Re<4000	0.3	0.692	0.696	0.699
Turbulent	0.5	0.960	0.966	0.971
Turbulent	1	1.671	1.667	1.627
Turbulent	1.5	1.889	2.261	2.098
Turbulent	2	2.694	2.890	2.677

Table 18: Percentage of input and output velocity of Venturi 2

PVC	Steel	Aluminum
528.359%	527.491%	525.914%
130.724%	131.838%	132.856%
92.030%	93.230%	94.168%
67.104%	66.668%	62.692%
25.923%	50.708%	39.879%
34.724%	44.488%	33.842%

Finally, we simulated a pipe that is helical. The reason for this could be that the barrels of the gun are helical in order to increase the speed of the bullet and hit the target more accurately. We also decided to test this type of pipe with wind flow and natural convection flow and its final results can be seen in the table below.

Table 19: Outlet velocity in the Helical Pipe in different materials and different velocities

PVC		Steel		Aluminum
Re	velocity inlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)
Laminar	0.1	0.128	0.129	0.132
2300<Re<4000	0.3	0.380	0.381	0.381
Turbulent	0.5	0.588	0.590	0.590
Turbulent	1	1.237	1.243	1.243
Turbulent	1.5	1.880	1.887	1.888
Turbulent	2	2.543	2.553	2.553

Table 20: Percentage of input and output velocity of Helical Pipe

PVC	Steel	Aluminum
27.823%	28.646%	32.084%
26.706%	27.061%	27.131%
17.611%	17.970%	17.973%
23.742%	24.258%	24.264%
25.313%	25.830%	25.837%
27.174%	27.649%	27.655%

Table 21: Outlet velocity in the Conical Pipe in different materials and different velocities

PVC		Steel		Aluminum
Re	velocity inlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)	velocity outlet(m/s)
Laminar	0.1	1.777	1.777	1.777
2300<Re<4000	0.3	5.289	5.291	5.291
Turbulent	0.5	8.748	8.751	8.751
Turbulent	1	17.411	17.414	17.414
Turbulent	1.5	26.034	26.038	26.056
Turbulent	2	34.661	34.671	34.666

Table 22: Percentage of input and output velocity of Conical Pipe

PVC	Steel	Aluminum
1676.69%	1676.64%	1676.63%
1663.05%	1663.66%	1663.67%
1649.68%	1650.16%	1650.17%
1641.09%	1641.40%	1641.42%
1635.59%	1635.89%	1637.10%
1633.03%	1633.56%	1633.32%

According to the above tables, the best selected pipe can be ribbed pipe made of aluminum because it gives us the best efficiency in all velocities. In this simulation, the air flow is more turbulent up to rib number 8, which can be due to the existing pressure as well as the density in the air flow, which pressure has not been investigated in the simulation, and the error can be caused by this part.

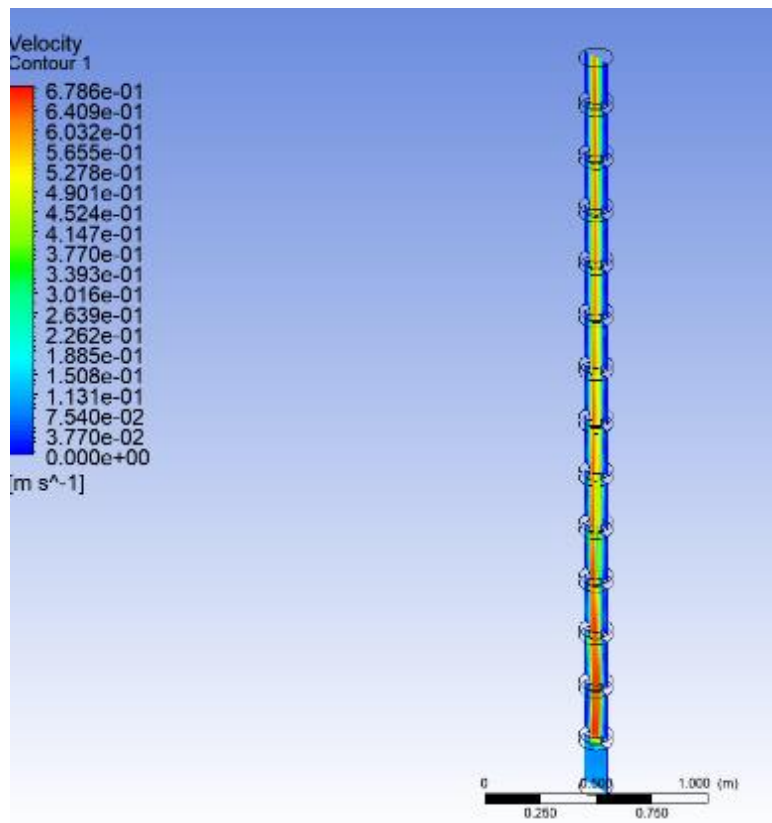


Figure 28: Velocity Contour of Ribbed Pipe

5.2 WIND GENERATOR

According to the table below, you can see that there are different types of wind generators, some of which have been selected to select the appropriate voltage, and according to them, we have been in contact with several companies, and

finally, according to Table 23, we were able to Select the appropriate generator designs. And we asked the company for the price, and they told us Table 23 and its final description.

Table 23: Type of wind turbine generators

Name	Wind speed (m/s)	Price \$
1. PRODUCT FEATURES (توربین های بادی ژنراتور بادی, n.d.)	3	60.60
2. Altinel Energy (ژنراتور برق بادی, n.d.)	2.5	75.00
3. Mars Rock Power (تولید ژنراتور توربین بادی, n.d.)	2	813.28
4. Pikasola (Pikasola Wind Turbine Generator Kit 400W 24V with 5 Blade, Wind Generator Kit with Charge Controller, Wind Power generator for Marine, RV, Home, Windmill Generator Suit for Hybrid Solar Wind System, n.d.)	2.5	800.00
5. Pikasola (Pikasola Wind Turbine 200W max 220W 12V 5 Blade Wind Vertical Axis Generator 3 Phase AC Permanent Magnet Generator Wind Turbine Kit with Controller for Hybrid Wind Solar System, n.d.)	1.5	840.00
6. Automaxx (Windmill (DB-400) 400W 12V Wind Turbine Generator kit, n.d.)	3	800.00
7. Automaxx (Automaxx Windmill 600W (12V/24V) (50A/25A) Wind Turbine Generator kit Wind Power MPPT Charge Controller Included (Amp, Volt & Watt Display) + Automatic and Manual Braking System. DIY Installation, n.d.)	2	800.00
Average	2.35	598.41

Table 24: Generators in size 165mm and 220mm

	Item No.	Rated Power/ Rated RPM	Rated Output Voltage	Diameter (MM)	Rated Torque (N/M)	Unit price (1PCS- 10PCS)	Unit price (11PCS- 50PCS)
TGET220	TGET220-I-1kW-1000R	1kW/1000R	According to your request	220	10	USD460	USD435
	TGET220-I-0.5kW-500R	0.5kW/500R			10		
	TGET220-I-0.2kW-350R	0.2kW/350R			6		
	TGET220-I-0.1kW-200R	0.1kW/200R			5		
TGET165	TGET165-I-1kW-2800R	1kW/2800R	According to your request	165	4	USD275	USD270
	TGET165-I-0.5kW-1500R	0.5kW/1500R			3.2	USD240	USD235
	TGET165-I-0.3kW-850R	0.3kW/850R			3.4		
	TGET165-I-0.1kW-500R	0.1kW/500R			2		
	TGET165-I-0.05kW-250R	0.05kW/250R			1.9		

According to the table above It looks like the 165 mm, model TGET165-I-1kW-2800R, would be the most suitable for most of our requirements. About the model which we select: TGET165-I-1kW-2800R

Inner rotor PMG: Three phase cables come from fixed housing shell, Shaft runs

Diameter: 165mm

Width: 69mm

Rated power: 1 kW/2800 R

Rated output voltage: 220VAC three phase output (If we do not accept 220VAC as output, we can produce the generator with nominal output voltage according to our request)

It is USD275/PC FOB Shanghai from 1PC to 10PCS

It is USD270/PC FOB Shanghai from 11PCS to 50PCS

The advantage of Axial flux coreless generator: Low starting torque
The running torque at rated power output: around 4 nm

Table 25: Price of Material

Material	Price \$
PVC	3.87
Steel	14.51
Aluminum	3.03

The prices obtained from the equipment and generators are written in the table below.

Table 26: Protected total price

Material	Generator	Price \$
PVC	TGET165-I-1kW-2800R	278.87
Steel	TGET165-I-1kW-2800R	289.51
Aluminum	TGET165-I-1kW-2800R	278.03

Costs excluding electrical installations (rectifiers, batteries, fittings, etc.). This is the best result when the equipment costs less than \$ 300.

6. Conclusion

In this project, we were able to achieve the desired result to some extent, evaluated the pipes in different materials and models, and finally selected the pipe that had higher efficiency. Also, according to the data we had, we checked the appropriate generator from the manufacturers to generate 1 kWh of electricity for us. In this project, we used the ANSYS Fluent Computational Package (CFD) to simulate a variety of pipes with materials (PVC, Steel, and Aluminum) to deliver the convection flow to the generator in the form of laminar and turbulent air streams and generate electricity.

Following this process, was obtained the average speed of wind generators and also inquired about the generator that matched our structure from the manufacturer so that we could calculate it economically. This structure can be considered the best available option from the designs simulated for home use due to the price and amount of electricity generated.

Best result can be from an aluminum ribbed pipe and helical pipe, 4 meters long, 0.15 meters diameter 0.02 meters wall thickness in combination with permanent magnet generator with a total cost of \$275.

7. Recommendations and Suggestions for Future Work

For students who are interested in continuing this work, they can complete the following:

- Simulation of pipes that are flexible in such a way that when air enters from the bottom of the pipe, this pipe increases in diameter so that it can transfer a large volume of air inside it to increase the efficiency relatively higher.
- Simulation of a pipe whose outlet is conical and on top of which a wind turbine is placed to have the greatest effect on the turbine.
- A tube should be designed in which a rod or a triangle is placed inside to direct the air inside the tube upwards more quickly or this design works the other way around.
- They can simulate the material of other pipes and other colors so that they can choose the best

pipe.

There are other suggestions that are not specific to students, such as:

- Installing a generator to mechanical air vent that in addition to cooling the air in the house also generate electricity.
- Installing a generator and a turbine in micro solar chimneys that are connected to the house.
- Placing a series of wind generators and industrial wind turbines suitably positioned in or near mine shafts where the diameter of these shafts can be several meters and rock face temperature up to 65 degrees Celsius, There, the air inside these mines when it hits rocks, it gets hotter and rises due to its specific gravity, and can be a good idea for generating electricity in those areas.

8. References and Bibliography

- (n.d.). Retrieved from <https://byjus.com/physics/convection-currents/>
- (n.d.). Retrieved from tebian: <https://article.tebyan.net/474157/%D8%A8%D8%A7%D8%AF-%DA%86%DA%AF%D9%88%D9%86%D9%87-%D8%AA%D8%B4%DA%A9%DB%8C%D9%84-%D9%85%DB%8C-%D8%B4%D9%88%D8%AF-%D8%B9%D9%84%D9%88%D9%85-%D9%BE%D8%A7%DB%8C%D9%87-%D9%87%D9%81%D8%AA%D9%85>
- (2009). Retrieved from https://studentenergy.org/source/wind/?gclid=EAlaIQobChMI_eDk-onD8wIVgYvICh3HdgWgEAAYBCAAEgJxEPD_BwE
- (2013). In *ANSYS Fluent Theory Guide* (pp. 724–746).
- ANSYS Fluent Theory Guide. (2013).
- Automaxx Windmill 600W (12V/24V) (50A/25A) Wind Turbine Generator kit Wind Power MPPT Charge Controller Included (Amp, Volt & Watt Display) + Automatic and Manual Braking System. DIY Installation.* (n.d.). Retrieved from amazon: https://www.amazon.com/dp/Bo1HGJH4O2/ref=emc_b_5_t
- BELEY, N. (2016, January 12). The DO model. *Thesis*, p. 14 and 15.
- C. Lenin, E. a. (2012). “Computational Fluid Dynamic Simulation of Vertical Axis Hydrokinetic Turbines”.
- Convection.* (n.d.). Retrieved from nuclear-power: <https://www.nuclear-power.com/nuclear-engineering/heat-transfer/convection-convective-heat-transfer/natural-convection-free-convection/>
- D. Maity, P. S. (2020). Proceedings of the 63rd Congress of ISTAM 2018. In *Advances in Fluid Mechanics and Solid Mechanics Proceedings of the 63rd Congress of ISTAM 2018*.
- Dhahri, A., & Omri, A. (2013). A review of solar chimney power generation technology. In *Int. J. Eng. Adv. Technol* (pp. 1–17).
- Dincer, I. (June 2000). “Renewable energy and sustainable development: a crucial review,”. In *Renewable and Sustainable Energy Reviews* (pp. 157–175).
- Global Wind Speeds.* (2001). Retrieved from NASA Surface Meteorology and Solar Energy: <https://earthobservatory.nasa.gov/images/1824/global-wind-speed>
- Heat transfer mechanisms.* (n.d.). Retrieved from Energy Education: https://energyeducation.ca/encyclopedia/Heat_transfer_mechanisms
- I. Most, G. S. (1877). “The Flow of Natural Gas,” *Sci. Am.*
- Jeremy Ledoux, S. R. (2021). Analysis of the Blade Element Momentum Theory. *Society for Industrial and Applied Mathematics*, p. 1.
- Katsaprakakis, D. A. (June 2012). “A review of the environmental and human impacts from wind parks. A case study for the Prefecture of Lasithi, Crete,”. In *Renewable and Sustainable Energy Reviews* (pp. 2850–2863).

K-omega models. (2011, October 12). Retrieved from CFD Online: https://www.cfd-online.com/Wiki/K-omega_models

Laminar Flow. (2022, 2 20). Retrieved from Libretexts:

[https://phys.libretexts.org/Bookshelves/College_Physics/Book%3A_College_Physics_\(OpenStax\)/12%3A_Fluid_Dynamics_and_Its_Biological_and_Medical_Applications/12.04%3A_Viscosity_and_Laminar_Flow_Poiseuilles_Law#:~:text=Flow%20is%20proportional%20to%20pressur](https://phys.libretexts.org/Bookshelves/College_Physics/Book%3A_College_Physics_(OpenStax)/12%3A_Fluid_Dynamics_and_Its_Biological_and_Medical_Applications/12.04%3A_Viscosity_and_Laminar_Flow_Poiseuilles_Law#:~:text=Flow%20is%20proportional%20to%20pressur)

Murphy, J. D. (1984). *Turbulence modeling*. Washington.

nejad, M. S. (2006). In *Introduction to the concepts of turbulent flows and their modeling*. Tehran.

Nizetic, S., Ninic, N., & Klarin, B. (2008). Energy. In *Analysis and feasibility of implementing solar chimney power plants in the Mediterranean region* (pp. 1680–1690).

Origin of winds. (2010). Retrieved from National Weather Service:

<https://www.srh.noaa.gov/jetstream//synoptic/wind.htm>

Pikasola Wind Turbine 200W max 220V 12V 5 Blade Wind Vertical Axis Generator 3 Phase AC Permanent Magnet Generator Wind Turbine Kit with Controller for Hybrid Wind Solar System. (n.d.). Retrieved from amazon: https://www.amazon.com/dp/B07ZPSGJZK/ref=emc_b_5_t?th=1

Pikasola Wind Turbine Generator Kit 400W 24V with 5 Blade, Wind Generator Kit with Charge Controller, Wind Power generator for Marine, RV, Home, Windmill Generator Suit for Hybrid Solar Wind System. (n.d.). Retrieved from amazon: https://www.amazon.com/Pikasola-Turbine-Generator-Controller-Windmill/dp/B08JGJJPD2/ref=sr_1_1_sspa?keywords=Wind+Generators+for+Home+Use&qid=1641460000&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFXVkozTFVOTjM4MkomZW5jcnlwdGVkSWQ9QTA5MjM4NDYyVzFLTk

Power and Energy. (n.d.). Retrieved from vedantu: <https://www.vedantu.com/physics/difference-between-power-and-energy>

R.C Bansala, T. B. (November 2002). “On some of the design aspects of wind energy conversion systems,”. In *Energy Conversion and Managemen* (pp. 2175–2187).

Schlaich, J. (1995). *The solar chimney: Electricity from the sun*, Edition Axel Menges. Stuttgart, Germany.

Sodja, J. (2007). “Turbulence models in CFD”.

Turbulent Flow. (2022, 2 20). Retrieved from Libretexts:

[https://phys.libretexts.org/Bookshelves/College_Physics/Book%3A_College_Physics_\(OpenStax\)/12%3A_Fluid_Dynamics_and_Its_Biological_and_Medical_Applications/12.05%3A_The_Onset_of_Turbulence](https://phys.libretexts.org/Bookshelves/College_Physics/Book%3A_College_Physics_(OpenStax)/12%3A_Fluid_Dynamics_and_Its_Biological_and_Medical_Applications/12.05%3A_The_Onset_of_Turbulence)

Viscosity of Air, Dynamic and Kinematic. (2022). Retrieved from engineer sedge:

https://www.engineersedge.com/physics/viscosity_of_air_dynamic_and_kinematic_14483.htm

what-is-conduction. (n.d.). Retrieved from byjus: <https://byjus.com/physics/heat-transfer-conduction-convection-and-radiation/#what-is-conduction>

Windmill (DB-400) 400W 12V Wind Turbine Generator kit. (n.d.). Retrieved from amazon:

<https://www.amazon.com/Windmill-DB-400-400W-Turbine-Generator/dp/BooRG2TF6U>

Yunus A. Cengel, A. J. (n.d.). Grashof Number. In *Heat and Mass Transfer* (p. 537 and 538).

Yunus A. Cengel, A. J. (n.d.). Natural Convection over Surface. In *Heat and Mass transfer* (p. 538 and 539).

Yunus A. Cengel, A. J. (n.d.). Physical Mechanism of Convection. In *Heat and Mass Transfer Cengel* (p. 378).

Yunus A. Cengel, A. J. (n.d.). Vertical Cylinders. In *Heat and Mass transfer* (p. 541).

Zhai, Z. (2020). Computational Fluid Dynamics for Built and Natural Environments.

Zhou, X., Wang, F., & Ochieng, R. (2010). A review of solar chimney power technology. In *Renew. Sustain. Energy Rev* (pp. 2315–2338).

Zuo, L., Zheng, Y., Li, Z., & Sha, Y. (2011). Desalination. In *Solar chimneys integrated with sea water desalination* (pp. 207–213).

توربین های بادی ژنراتور بادی (n.d.). Retrieved from Iran Tejarat: <https://iran-tejarat.com/Ads2204/Sch3043842/%D8%B3%D8%A7%D8%AE%D8%AA+%D8%AA%D9%88%D8%B1%D8%A8%DB%8C%D9%86+%D8%A8%D8%A7%D8%AF%DB%8C.html>

تولید ژنراتور توربین بادی (n.d.). Retrieved from Malltina: <https://malltina.com/product/mlt-3837552>

ژنراتور برق بادی (n.d.). Retrieved from ParsCenter: <http://parscenter.com/Product/227543>

9. Appendix

9.1 VENTURI 1

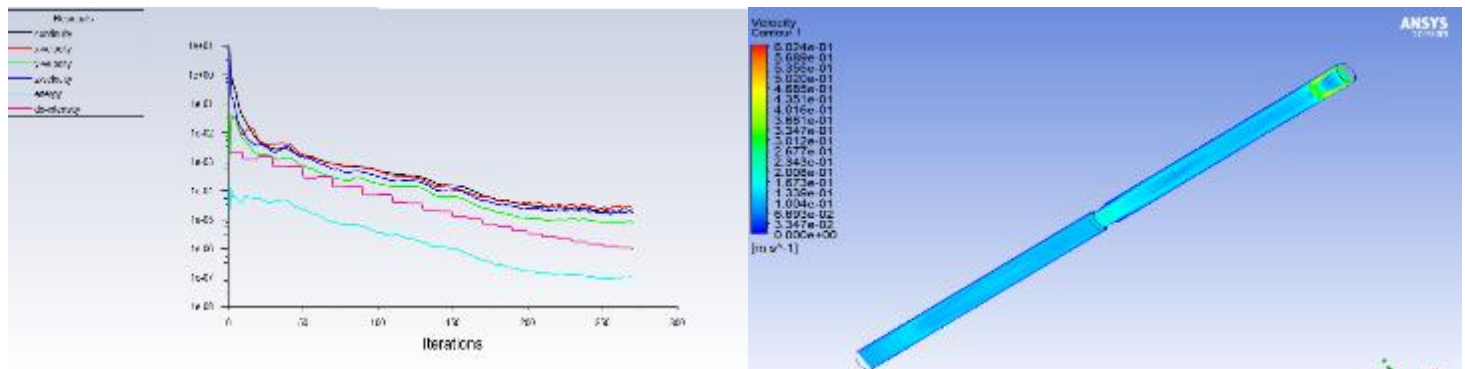


Figure 29: o.1 m/s Aluminum

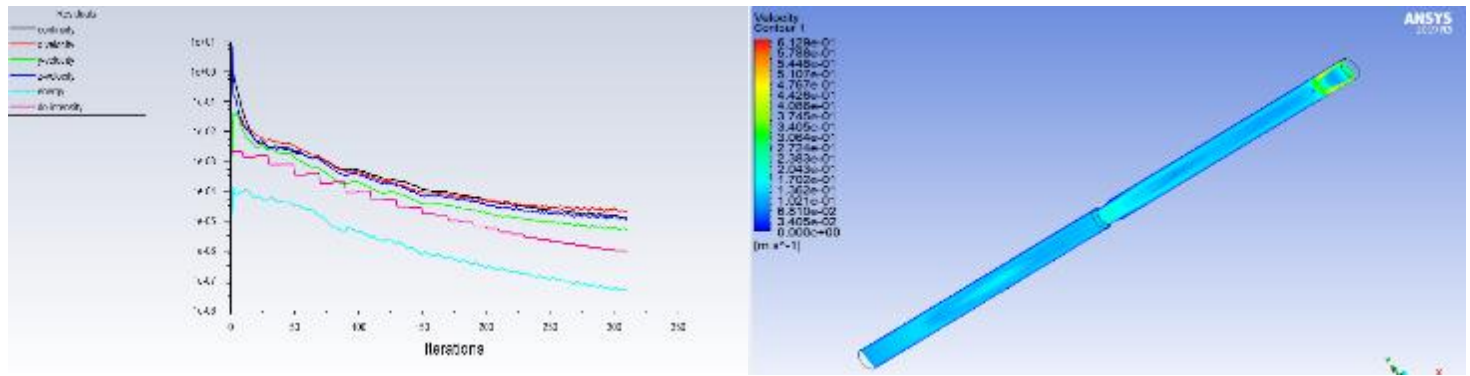


Figure 30: 0.1 m/s PVC

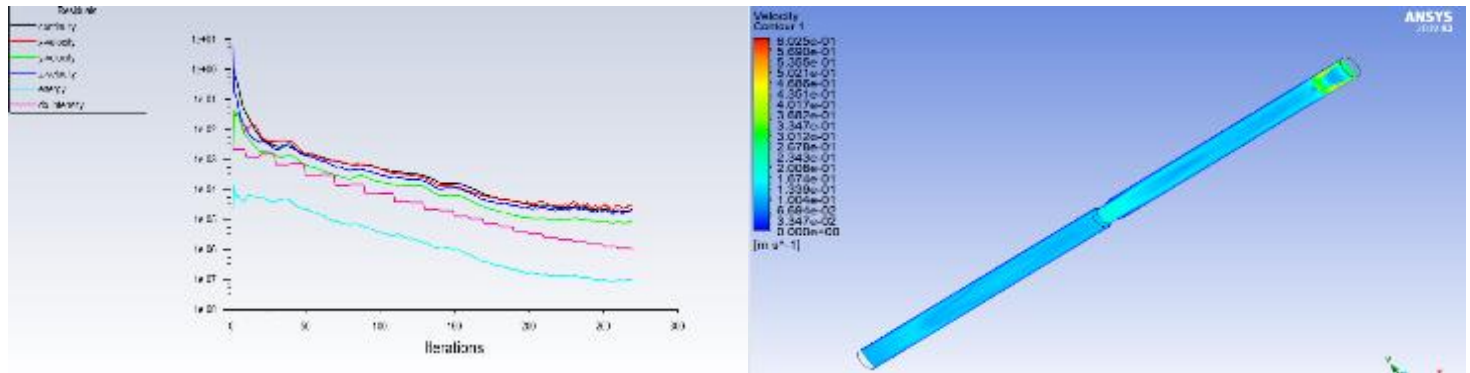


Figure 31: 0.1 m/s Steel

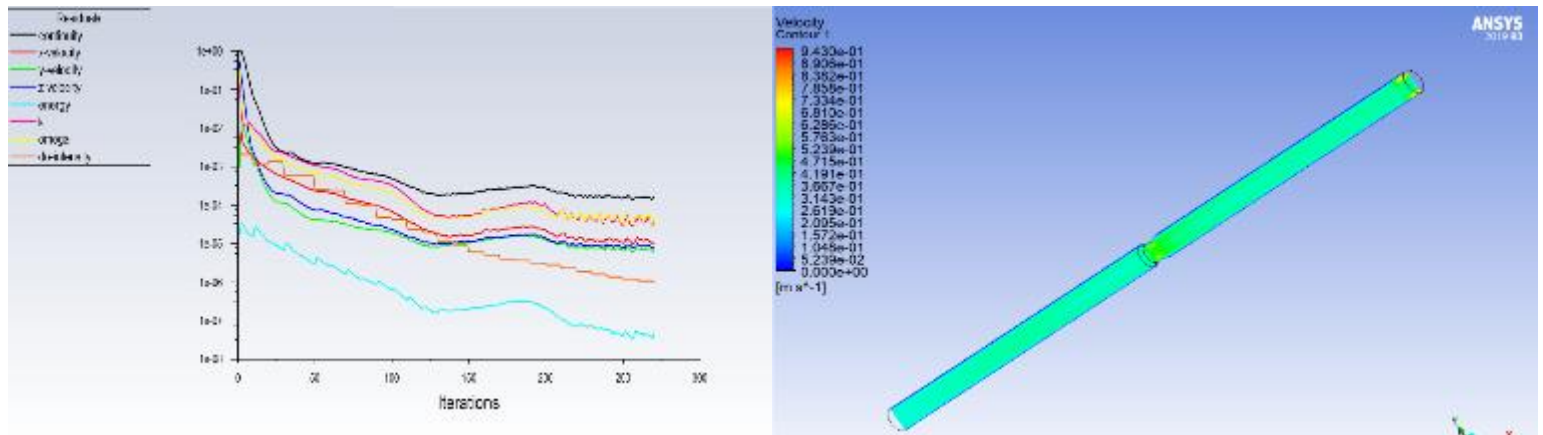


Figure 32: 0.3 m/s Aluminum

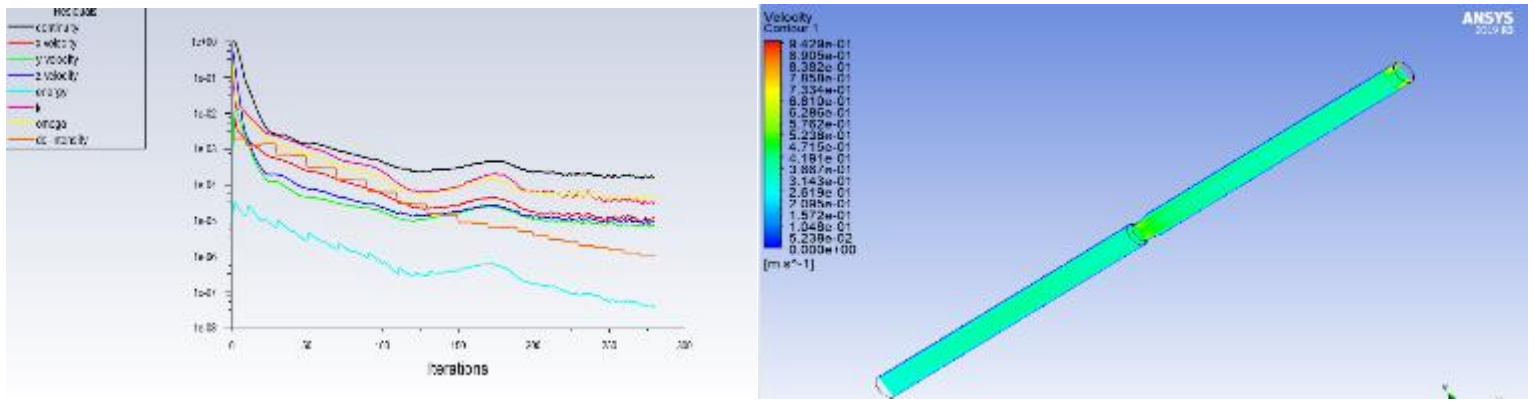


Figure 33: 0.3 m/s PVC

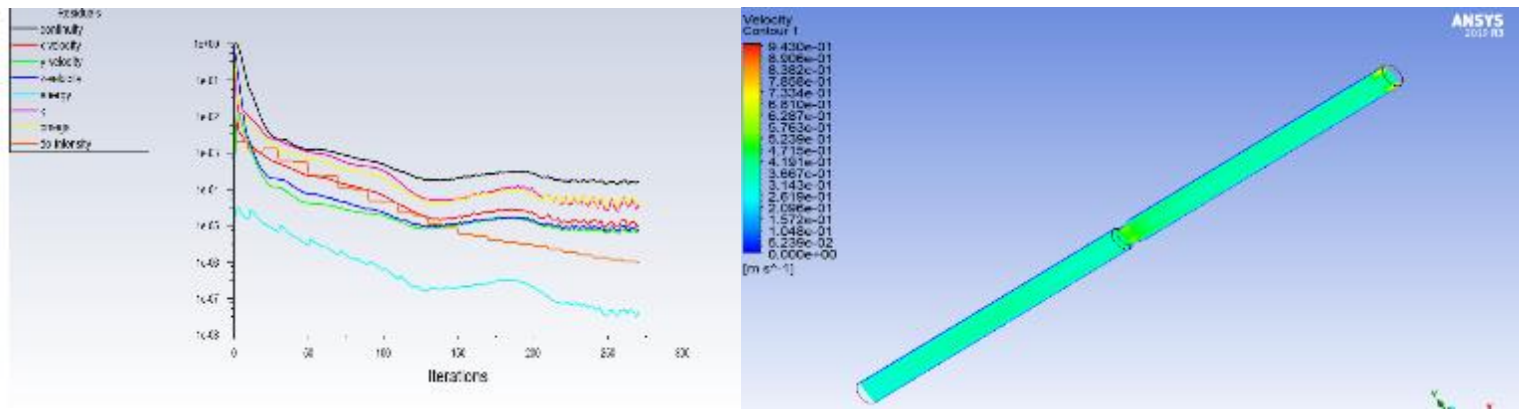


Figure 34: 0.3 m/s Steel

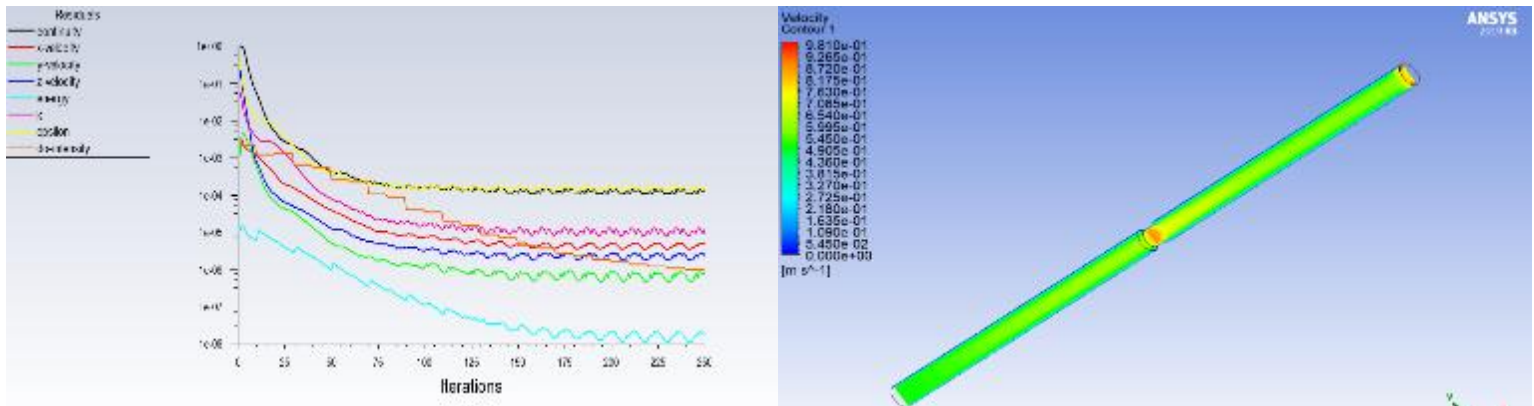


Figure 35: 0.5 m/s Aluminum

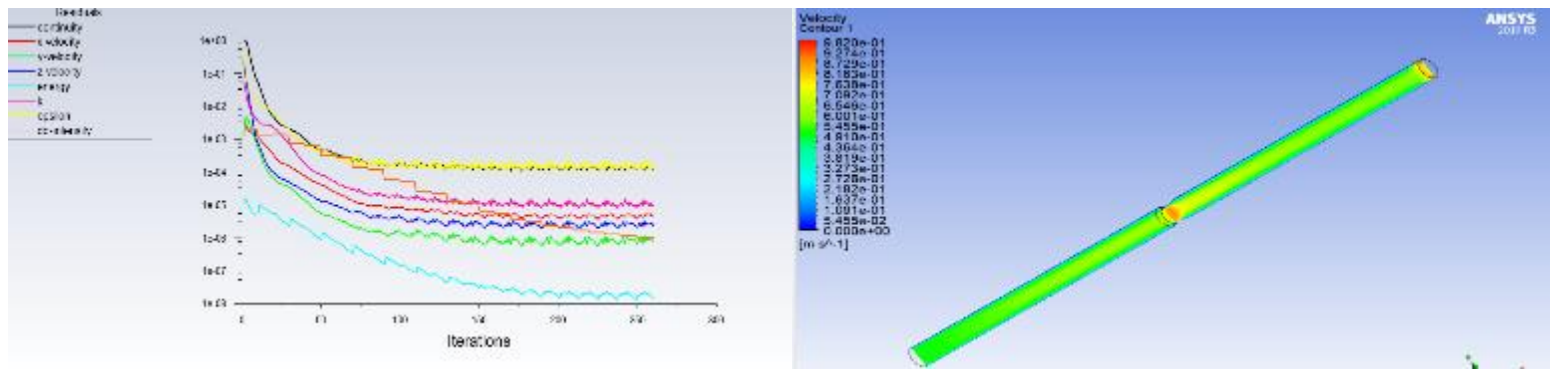


Figure 36: 0.5 m/s PVC

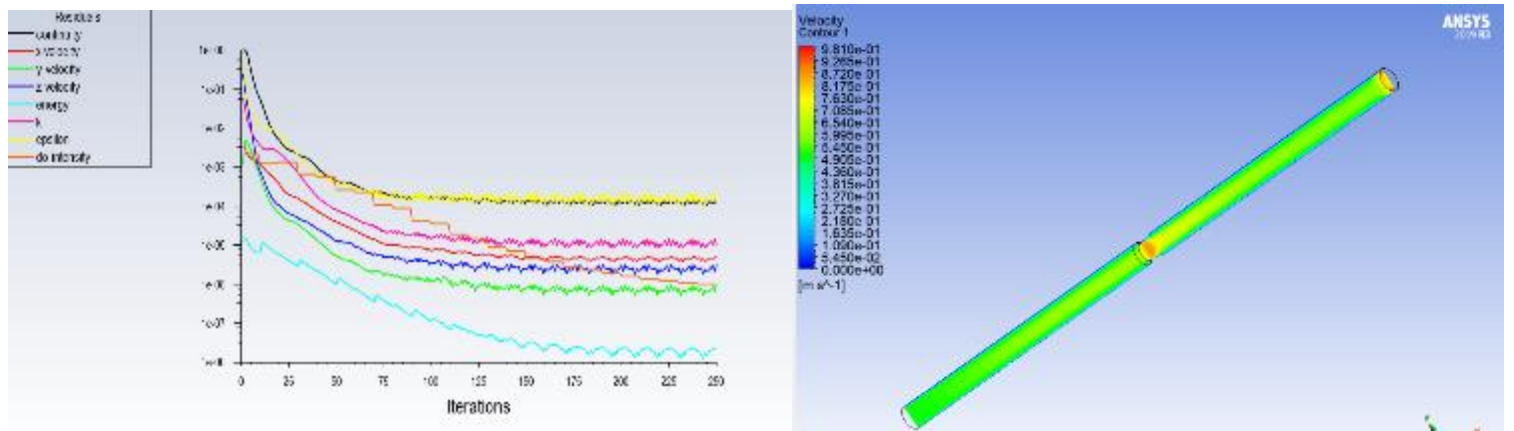


Figure 37: 0.5 m/s Steel

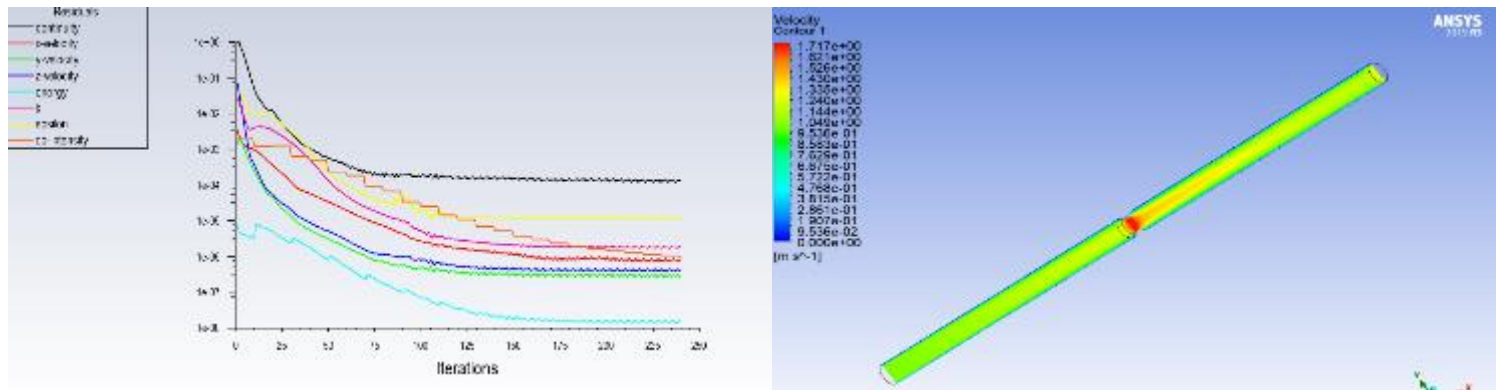


Figure 38: 1 m/s Aluminum

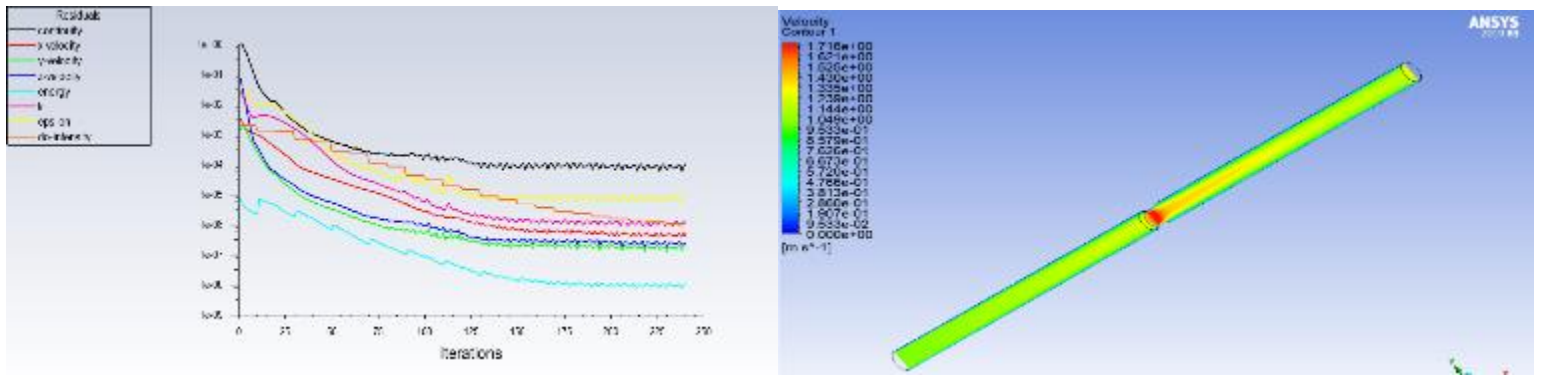


Figure 39: 1 m/s PVC

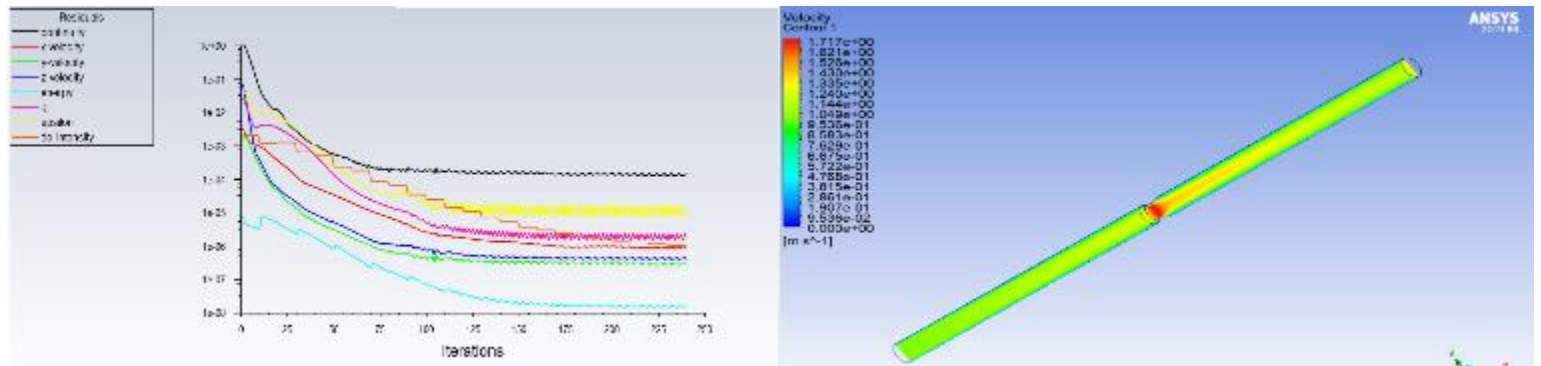


Figure 40: 1 m/s Steel

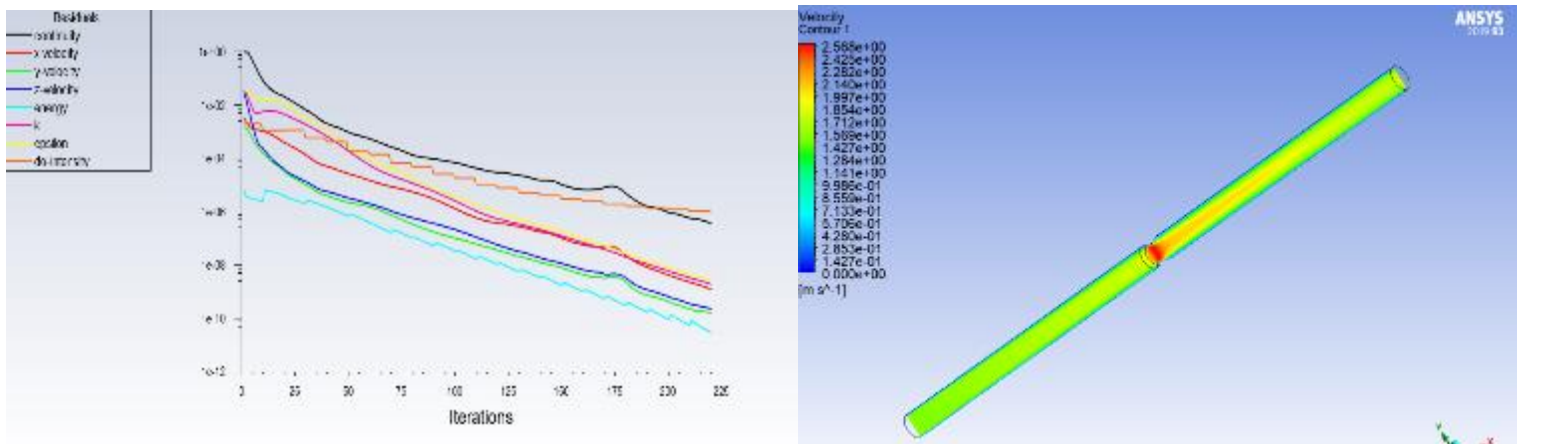


Figure 41: 1.5 m/s Aluminum

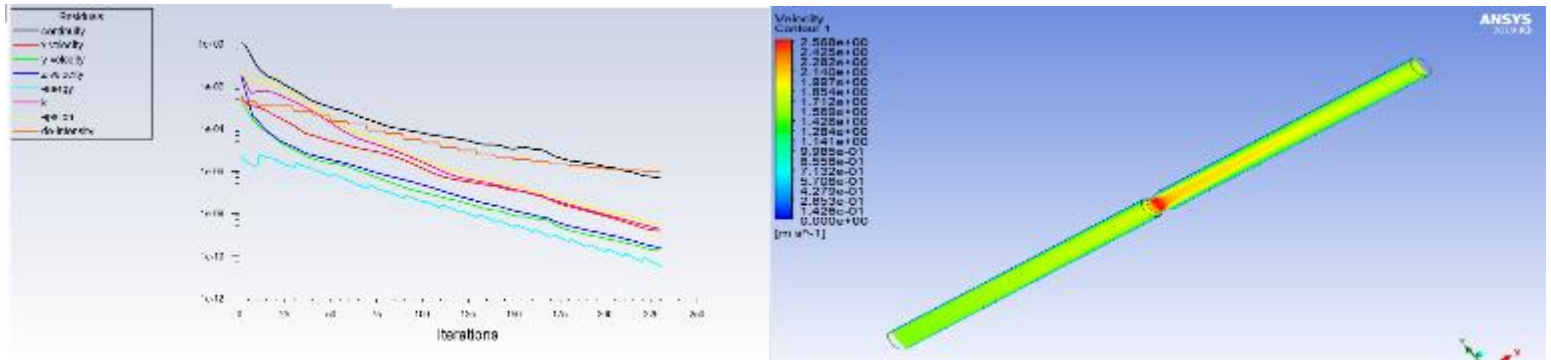


Figure 42: 1.5 m/s PVC

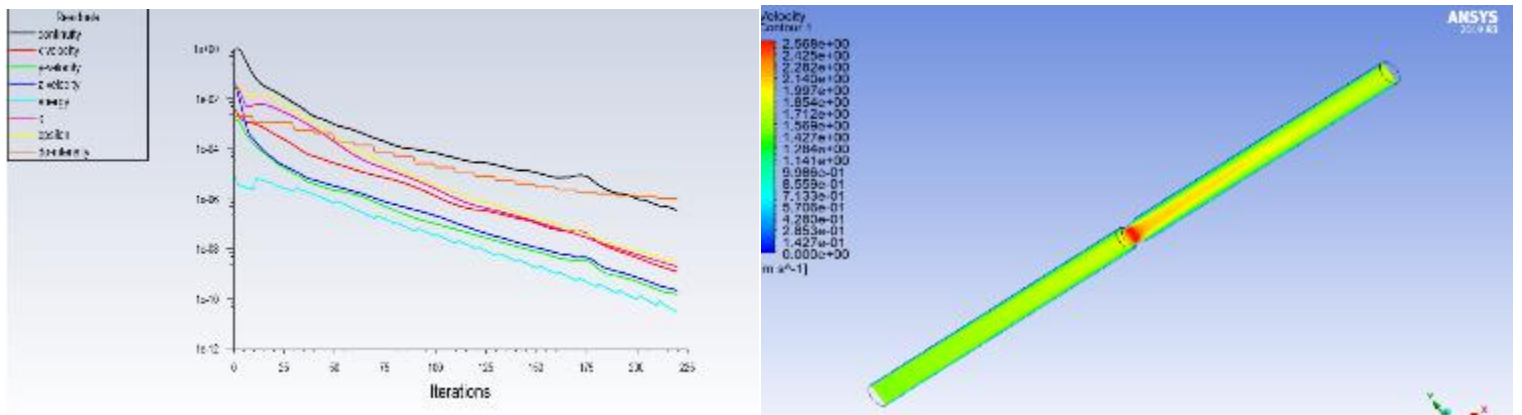


Figure 43: 1.5 m/s Steel

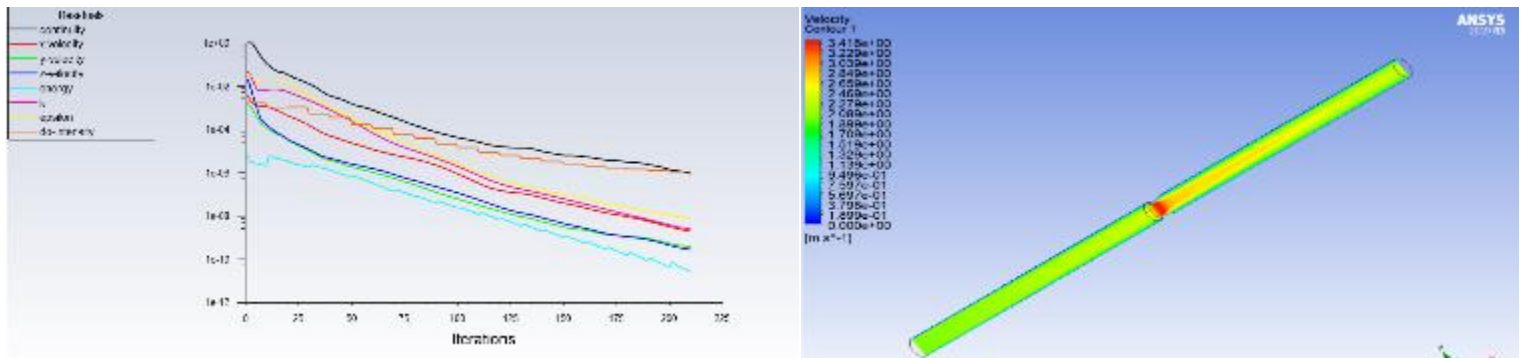


Figure 44: 2 m/s Aluminum

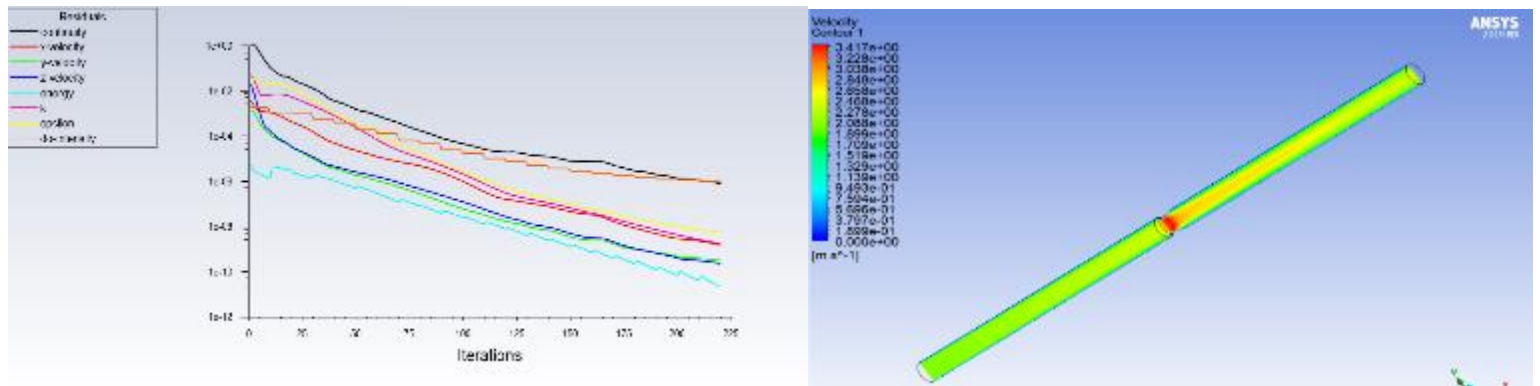


Figure 45: 2 m/s PVC

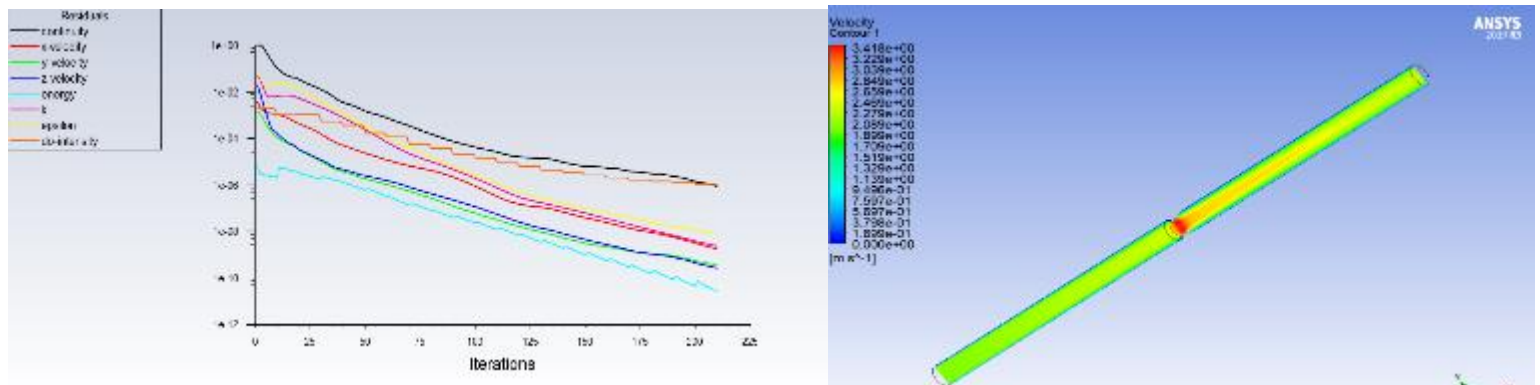


Figure 46: 2 m/s Steel

9.2 VENTURI 2

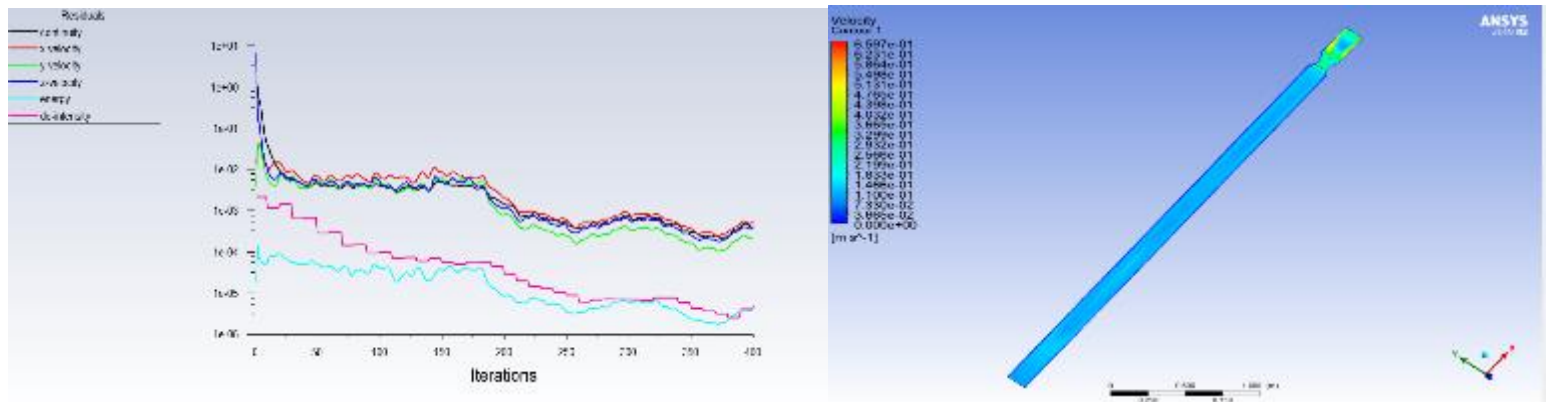


Figure 47: 0.1 m/s Aluminum

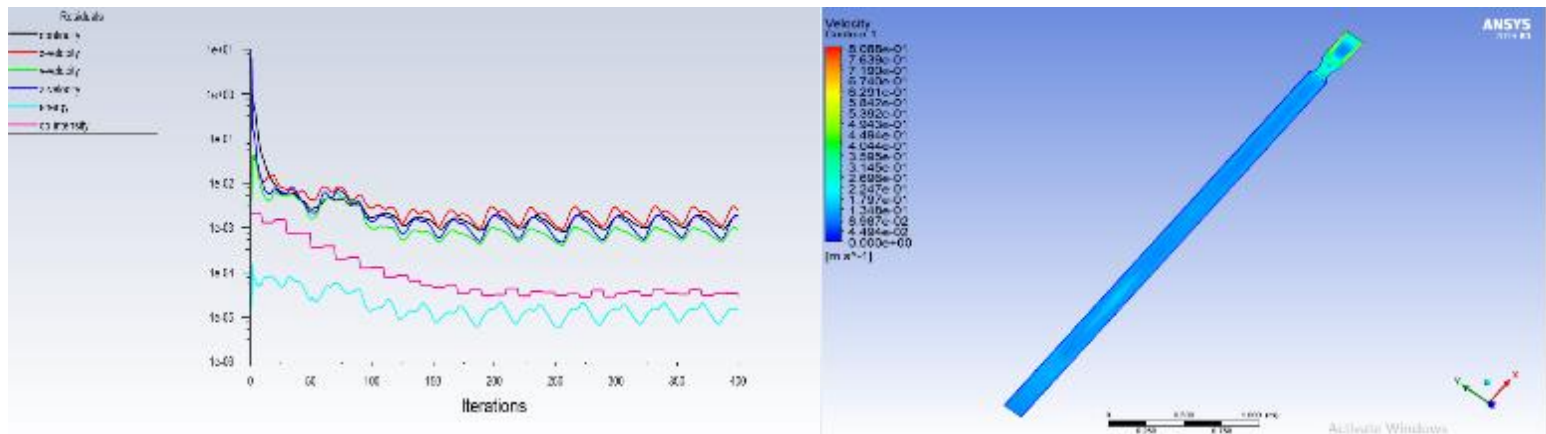


Figure 48: 0.1 m/s PVC

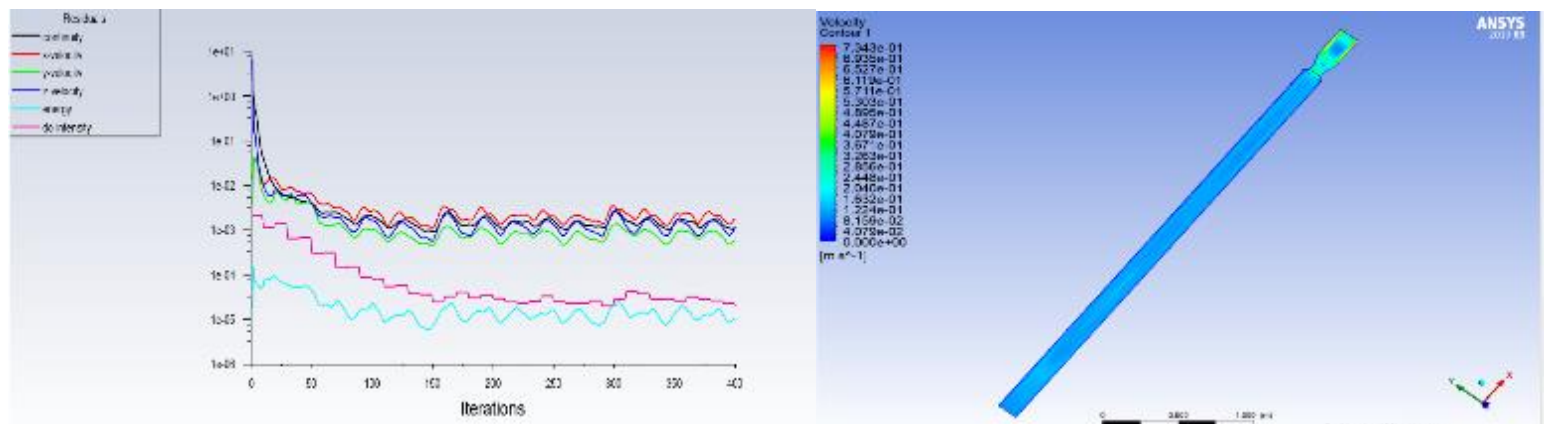


Figure 49: 0.1 m/s Steel

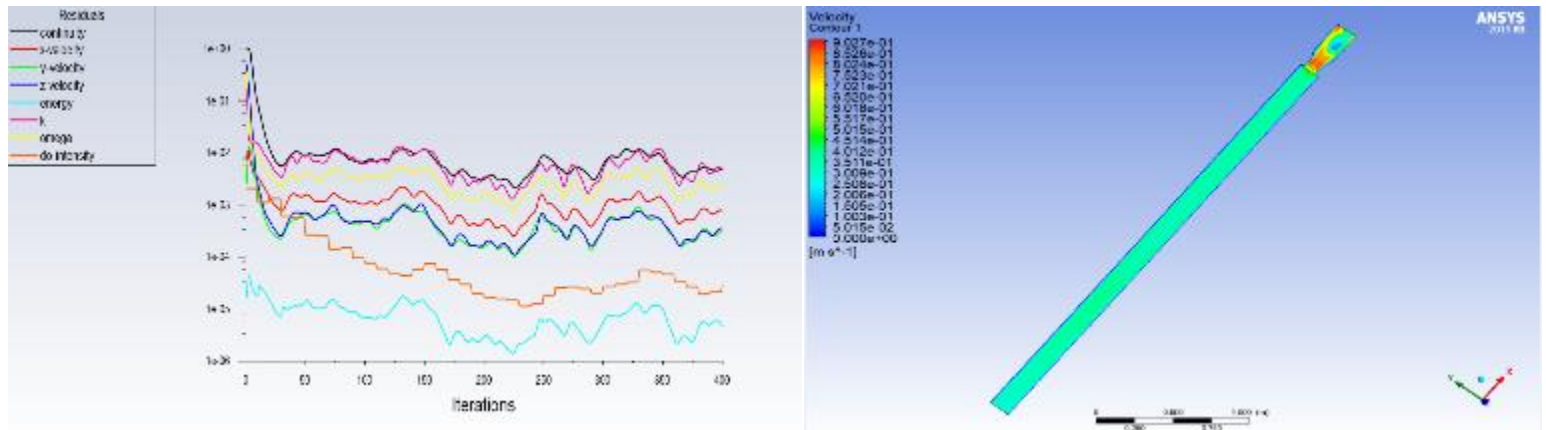


Figure 50: 0.3 m/s Aluminum

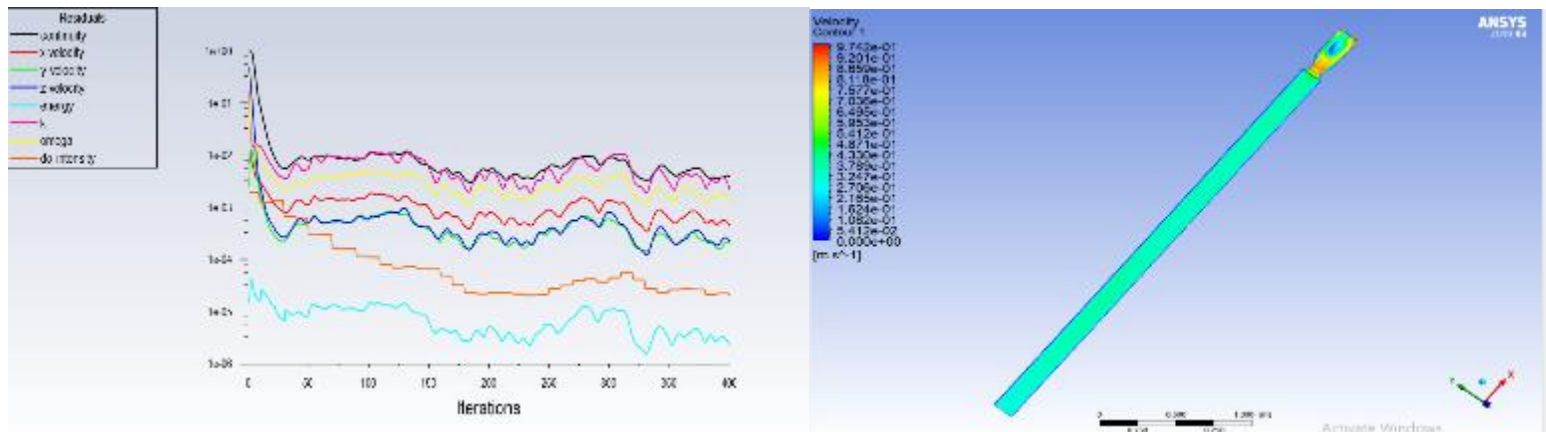


Figure 51: 0.3 m/s PVC

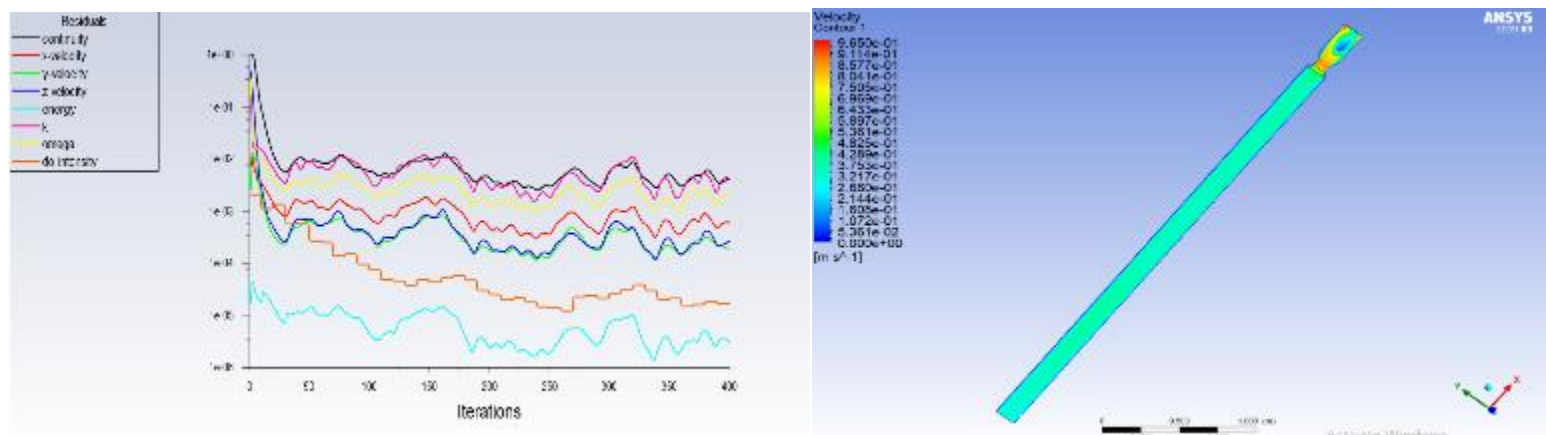


Figure 52: 0.3 m/s Steel

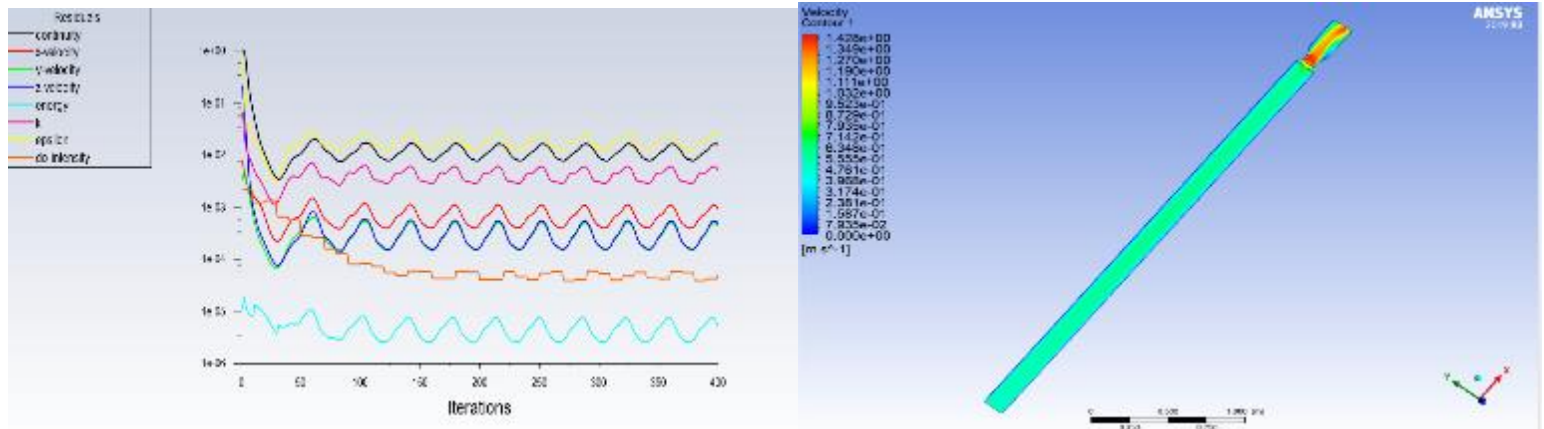


Figure 53: 0.5 m/s Aluminum

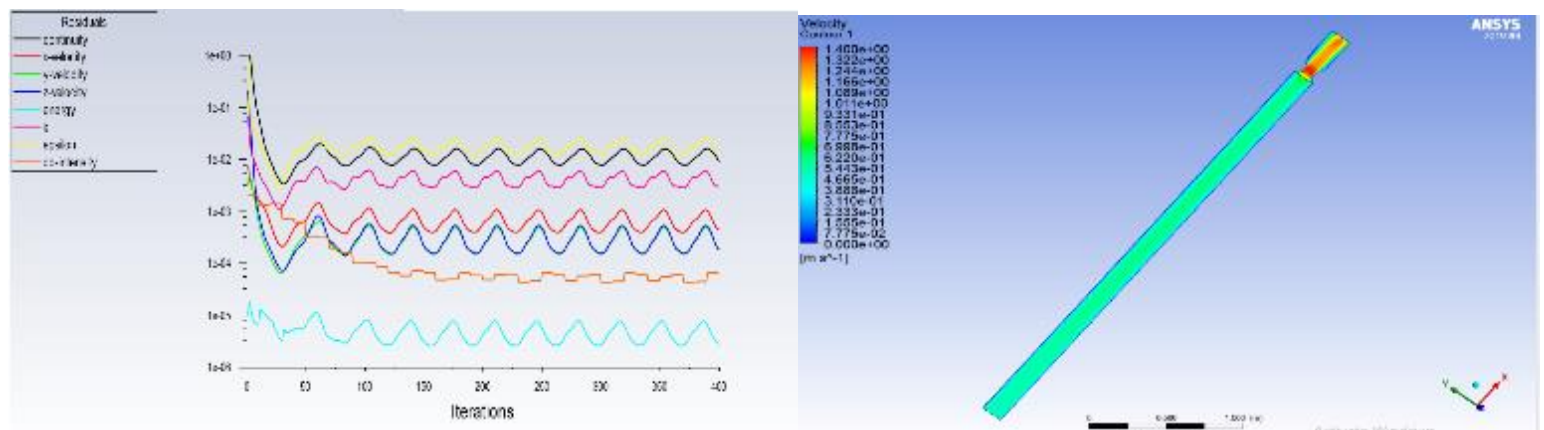


Figure 54: 0.5 m/s PVC

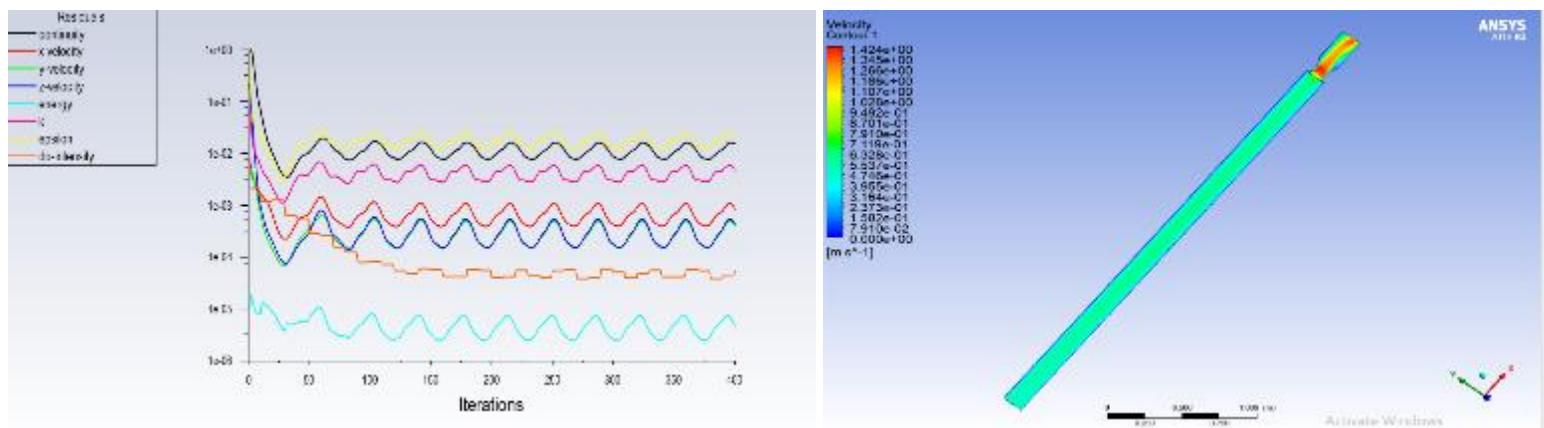


Figure 55: 0.5 m/s Steel

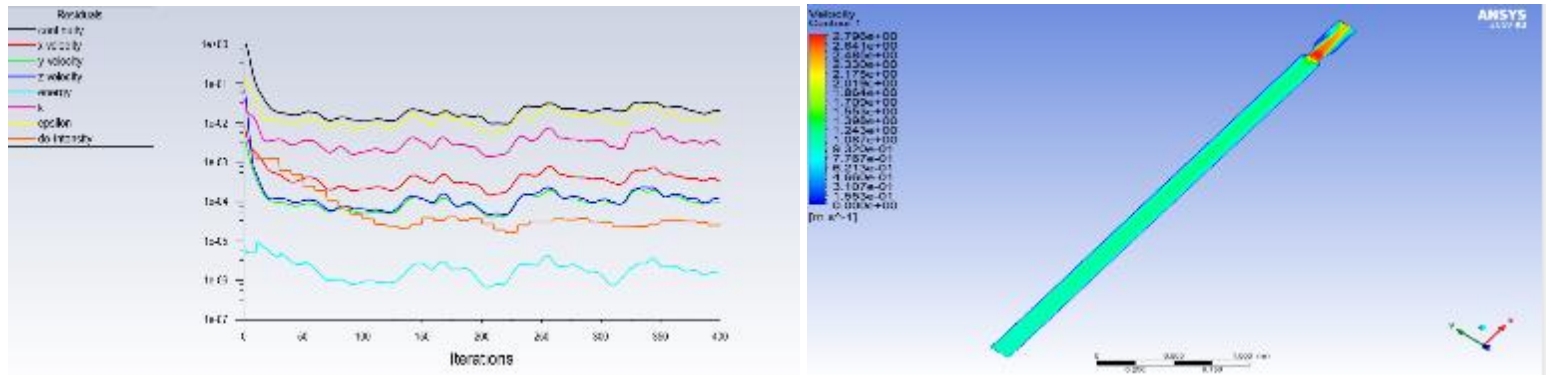


Figure 56: 1 m/s Aluminum

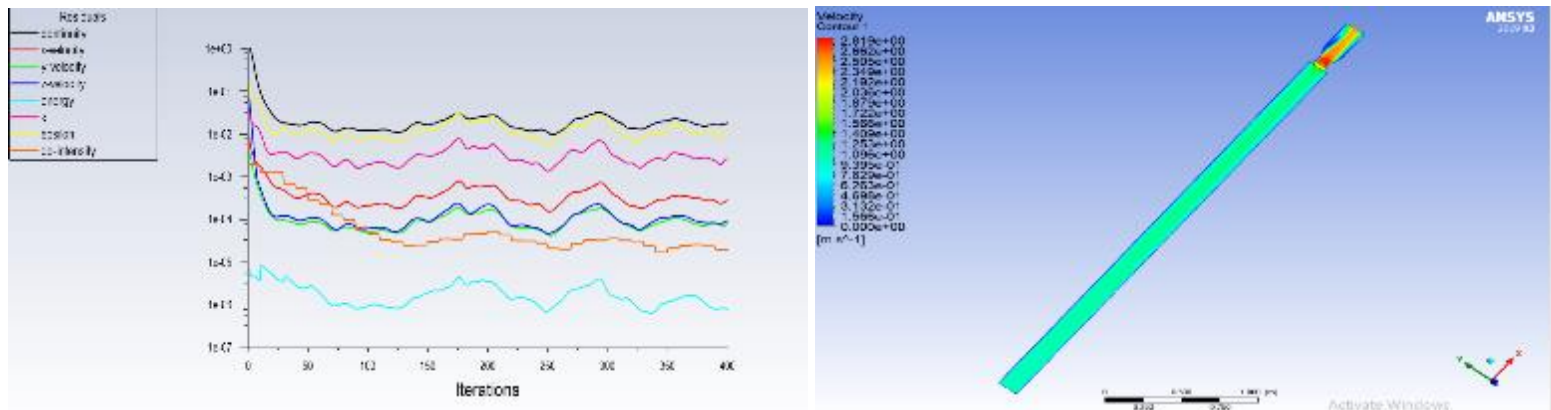


Figure 57: 1 m/s PVC

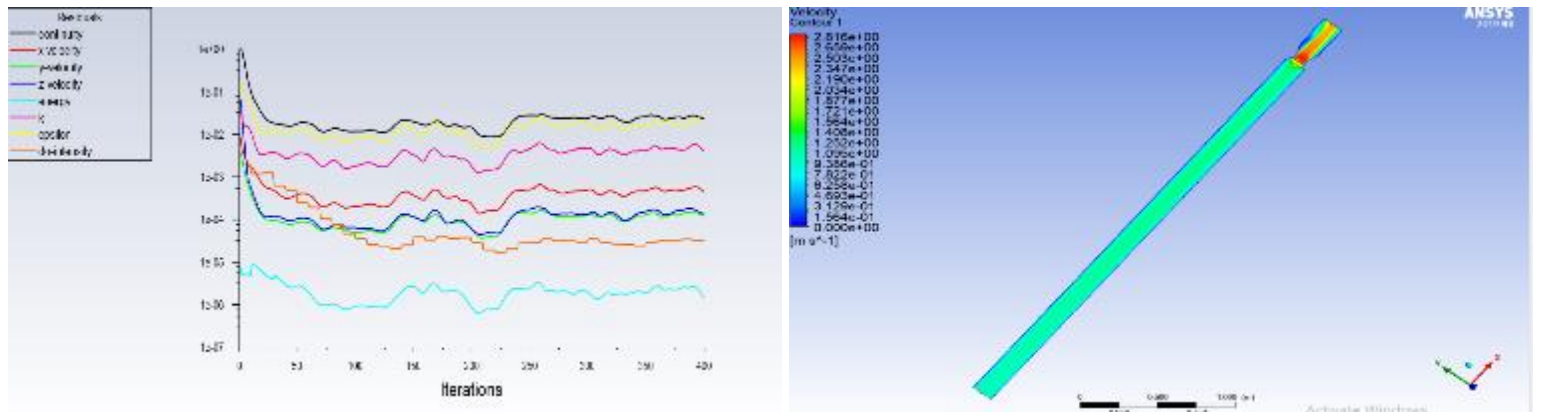


Figure 58: 1 m/s Steel

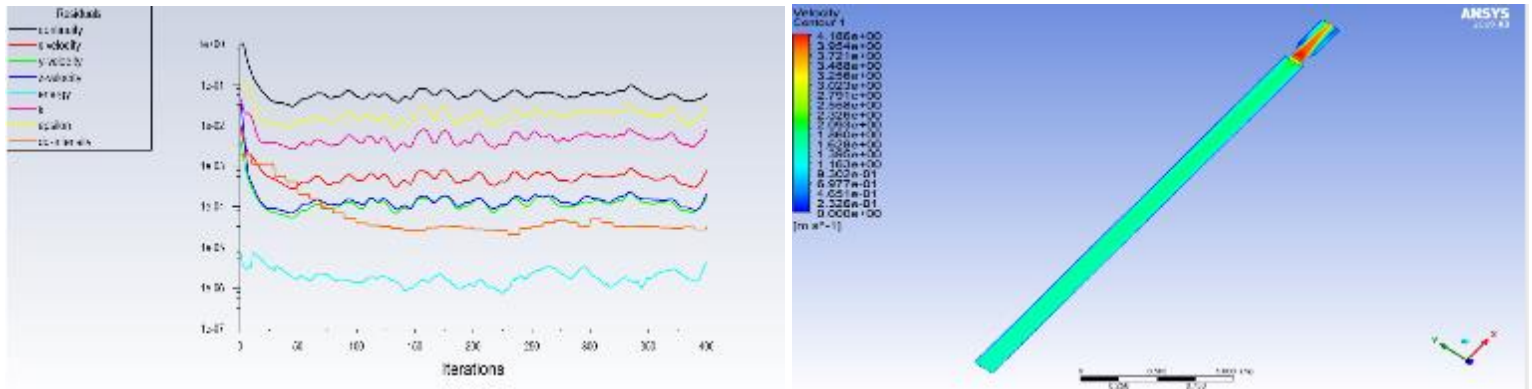


Figure 59: 1.5 m/s Aluminum

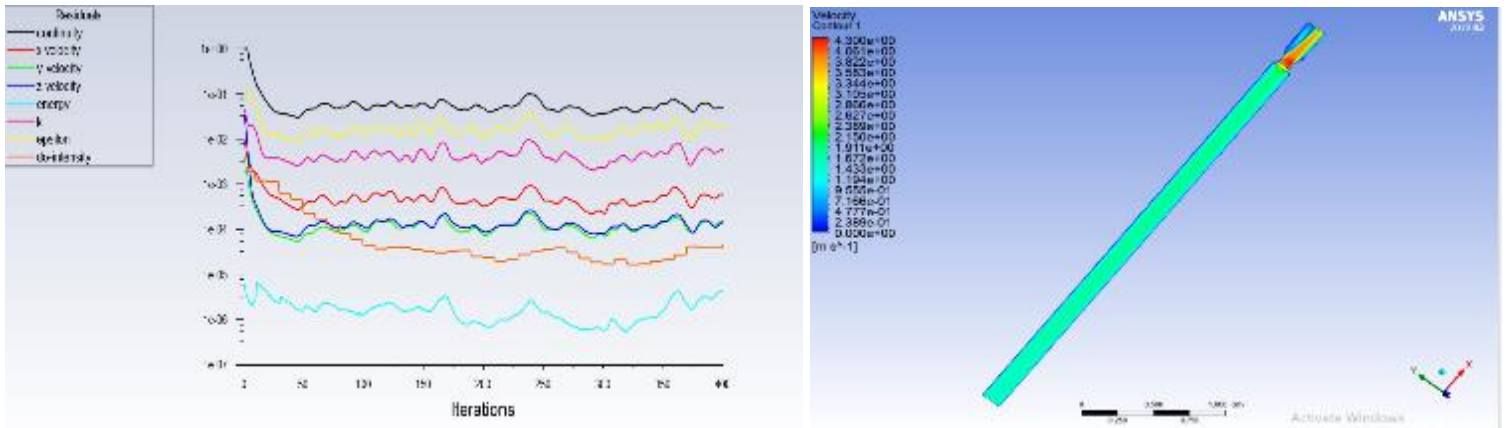


Figure 60: 1.5 m/s PVC

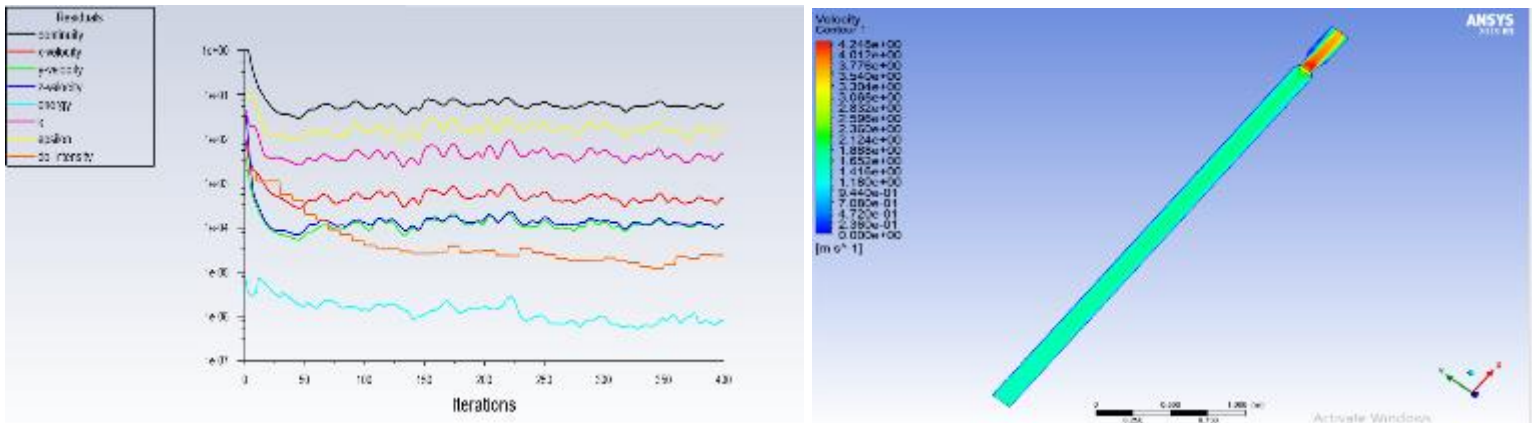


Figure 61: 1.5 m/s Steel

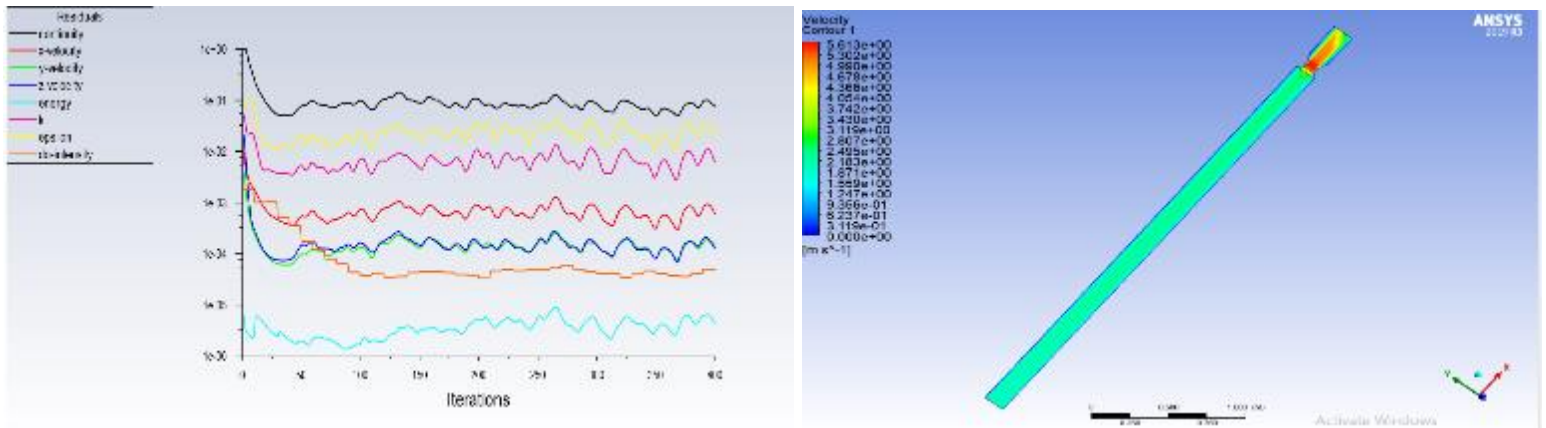


Figure 62: 2 m/s Aluminum

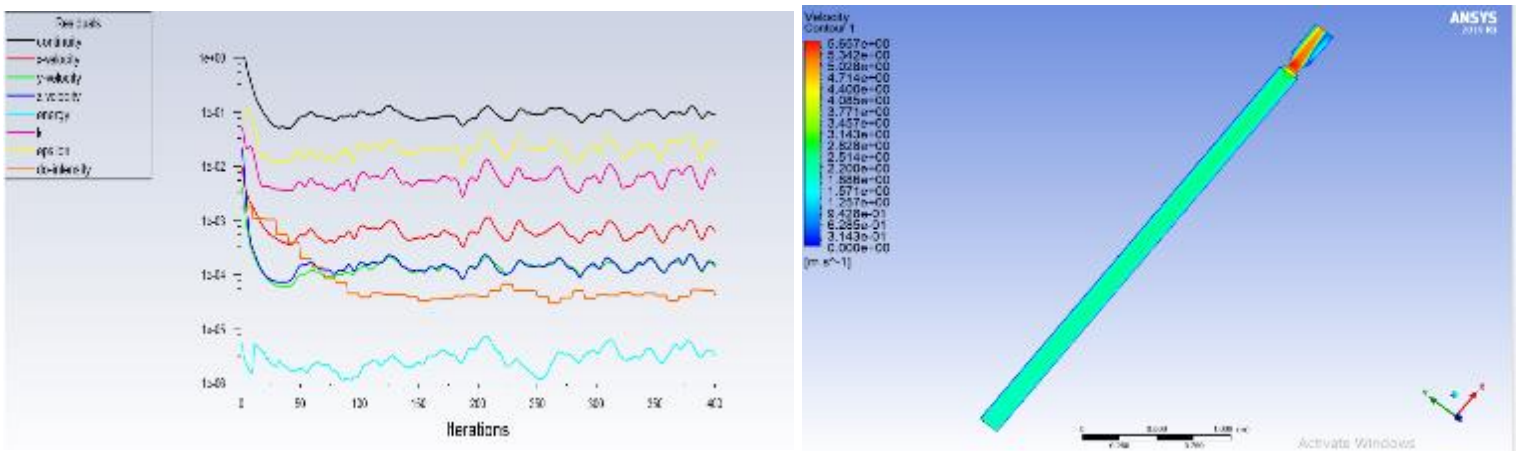


Figure 63: 2 m/s PVC

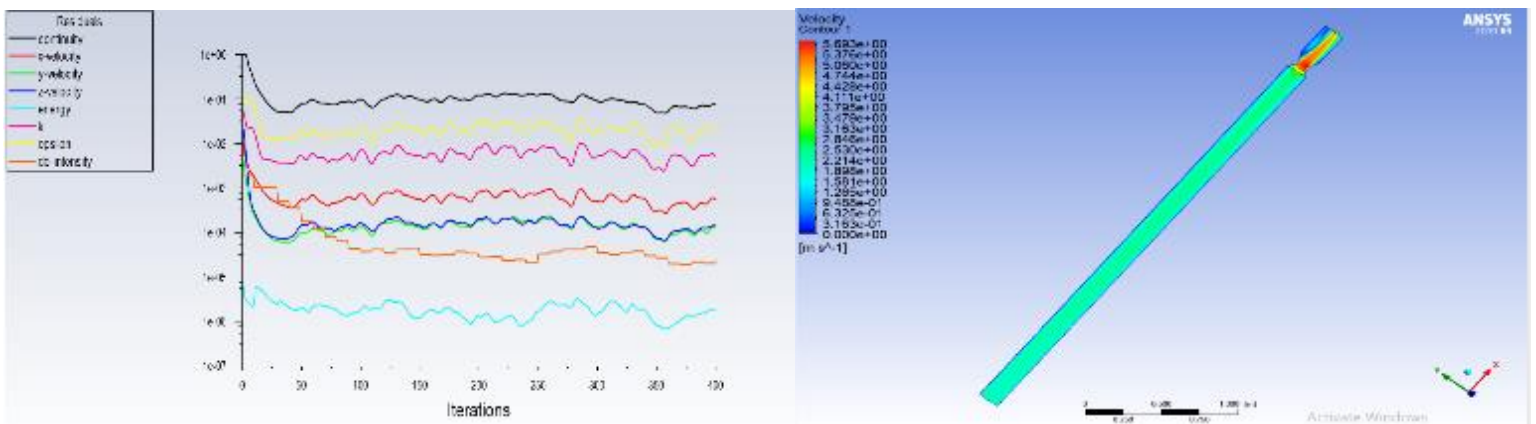


Figure 64: 2 m/s Steel

9.3 PERFORATED PIPE

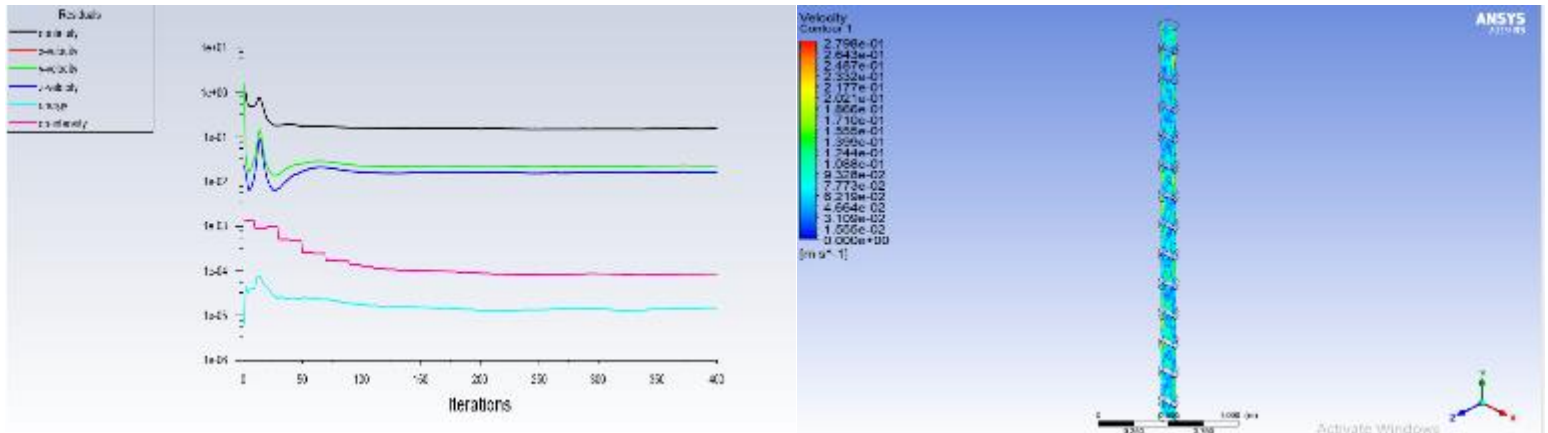


Figure 65: 0.1 m/s Aluminum

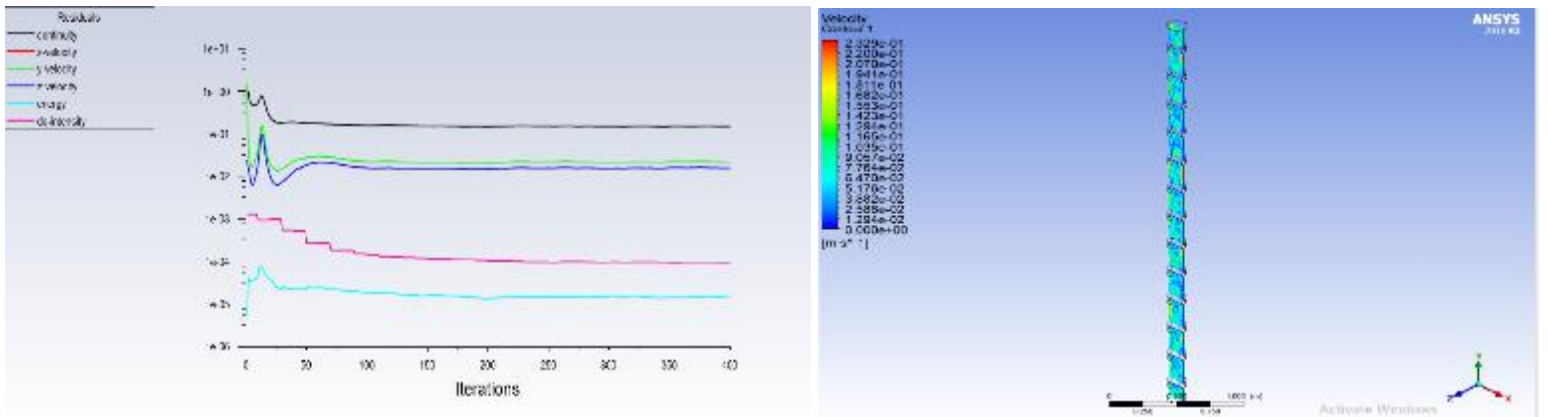


Figure 66: 0.1 m/s PVC

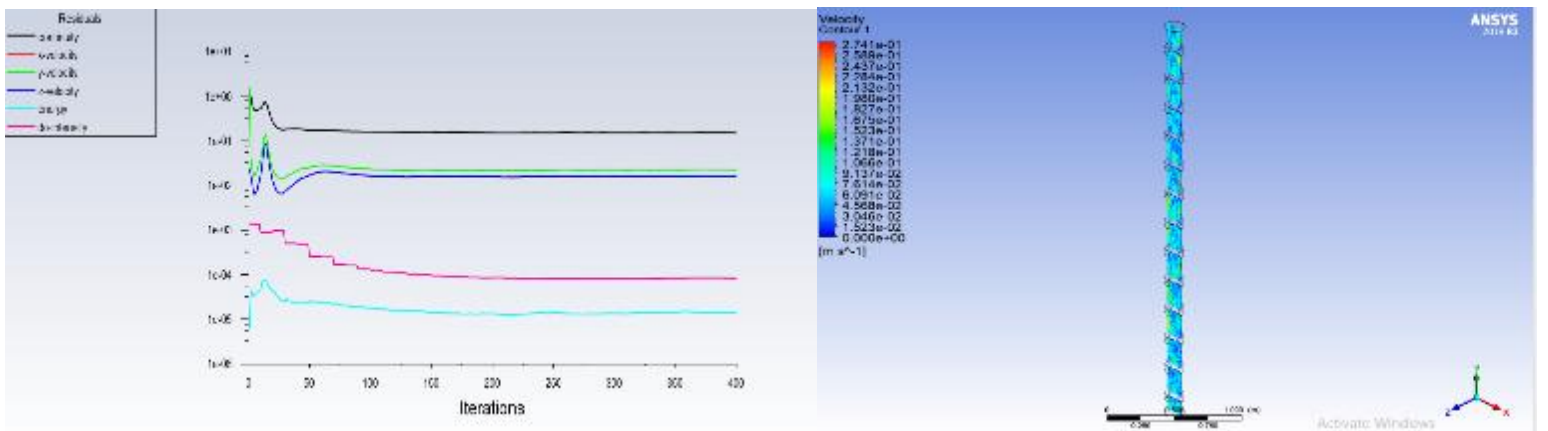


Figure 67: 0.1 m/s Steel

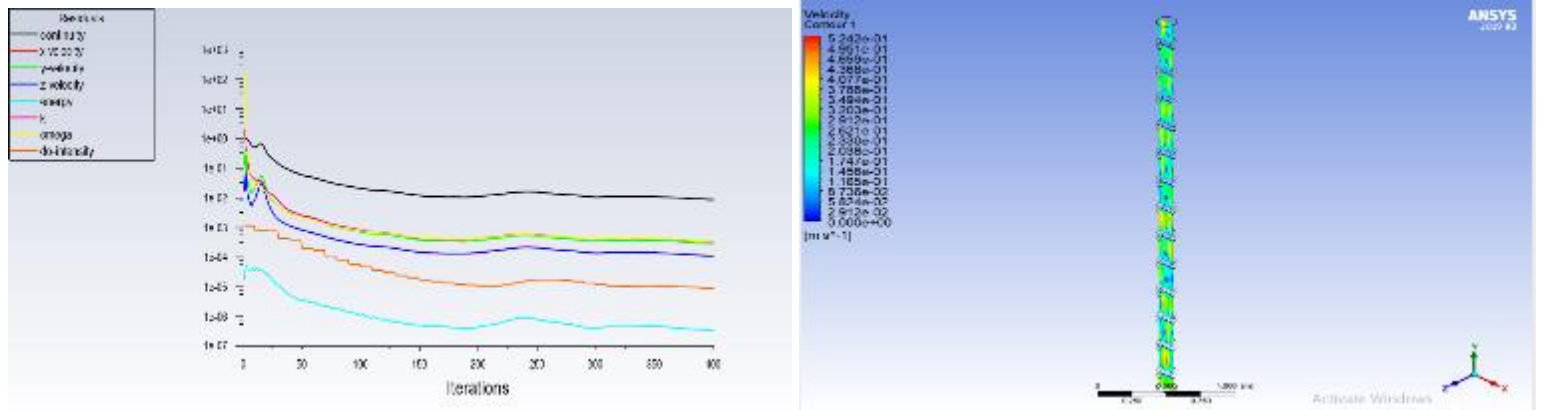


Figure 68: 0.3 m/s Aluminum

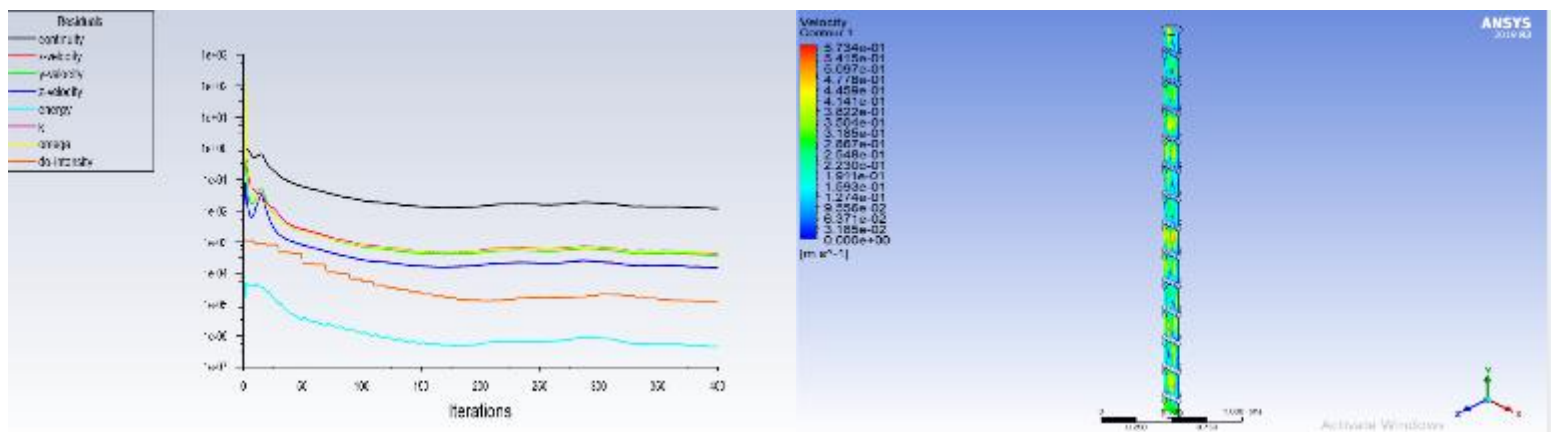


Figure 69: 0.3 m/s PVC

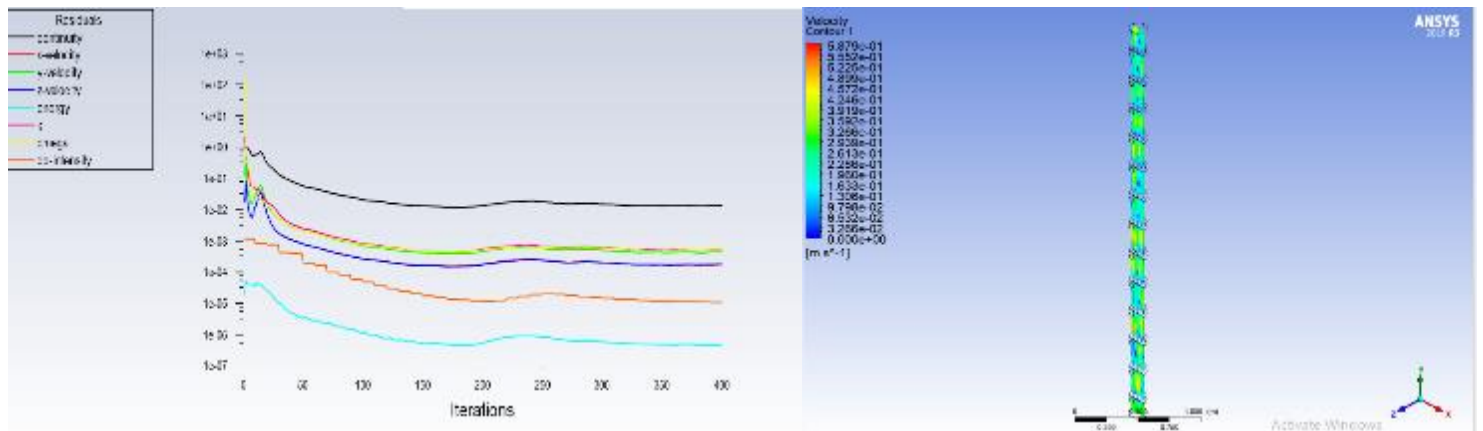


Figure 70: 0.3 m/s Steel

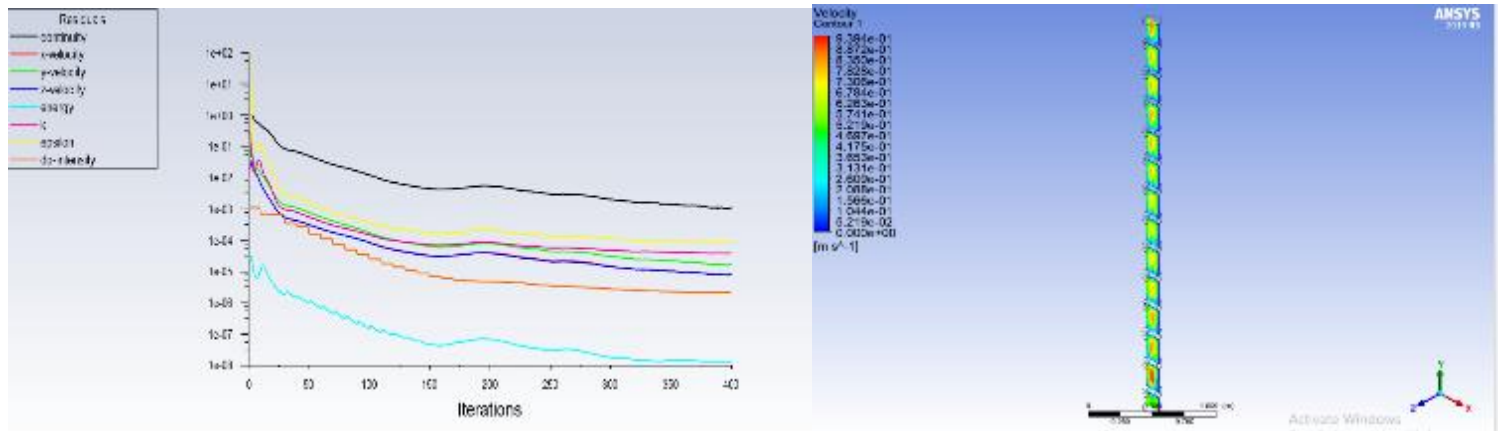


Figure 71: 0.5 m/s Aluminum

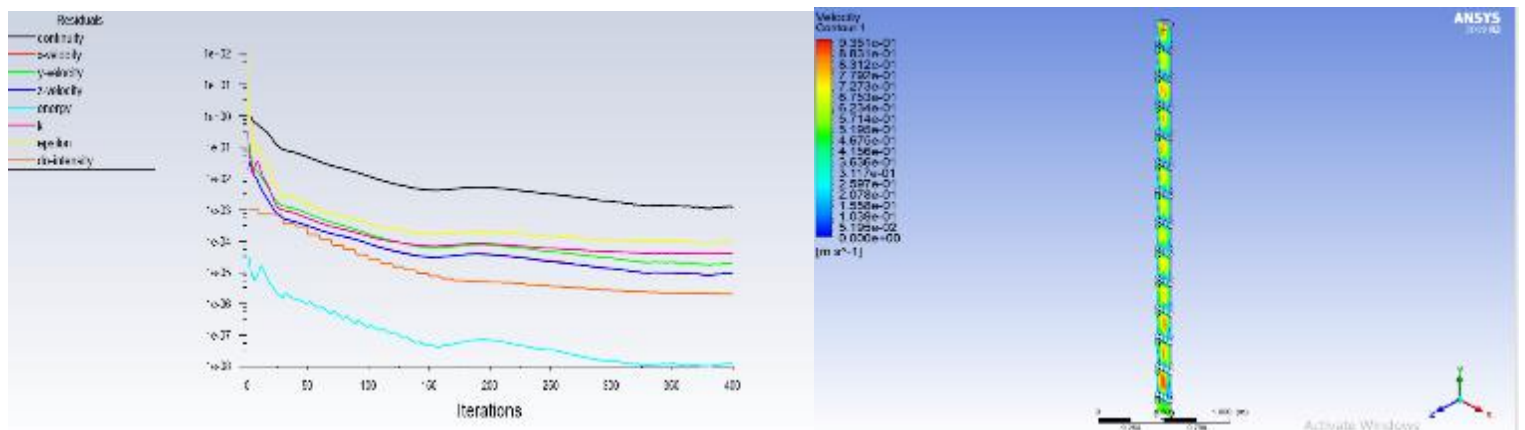


Figure 72: 0.5 m/s PVC

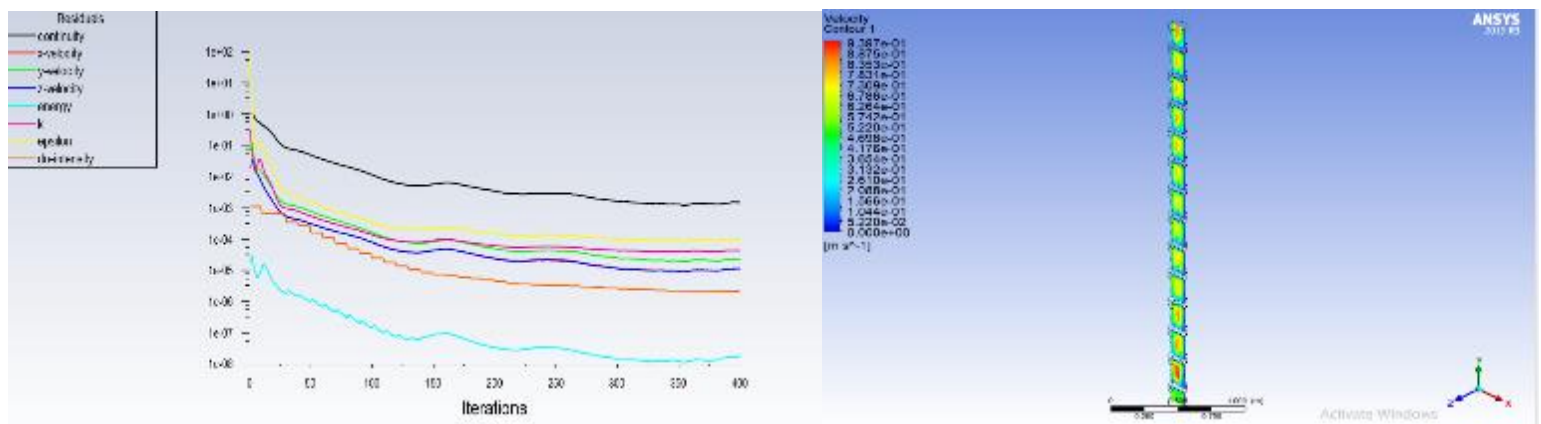


Figure 73: 0.5 m/s Steel

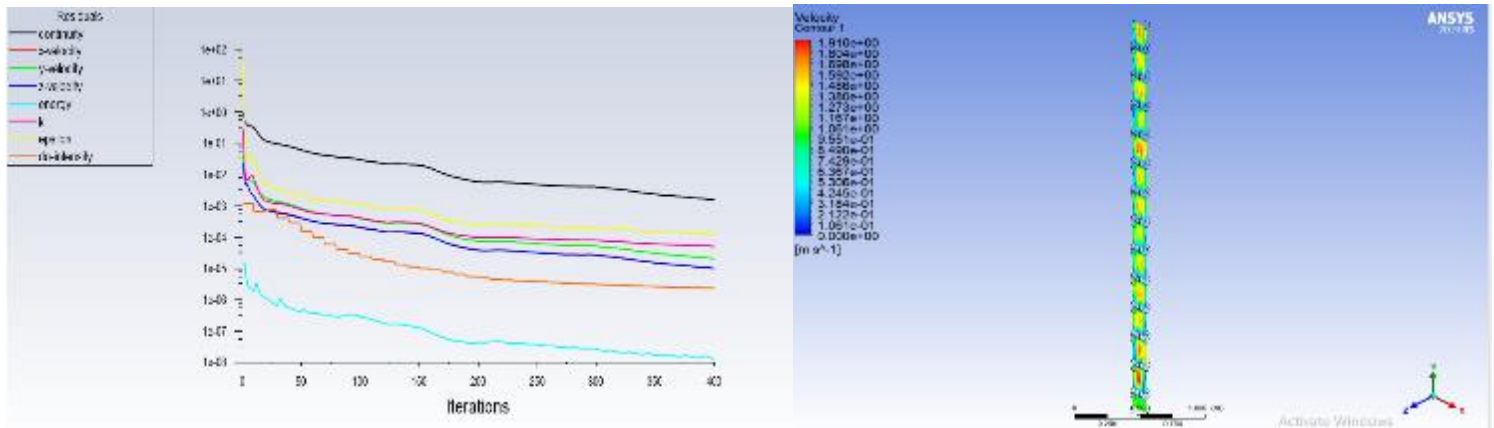


Figure 74: 1 m/s Aluminum

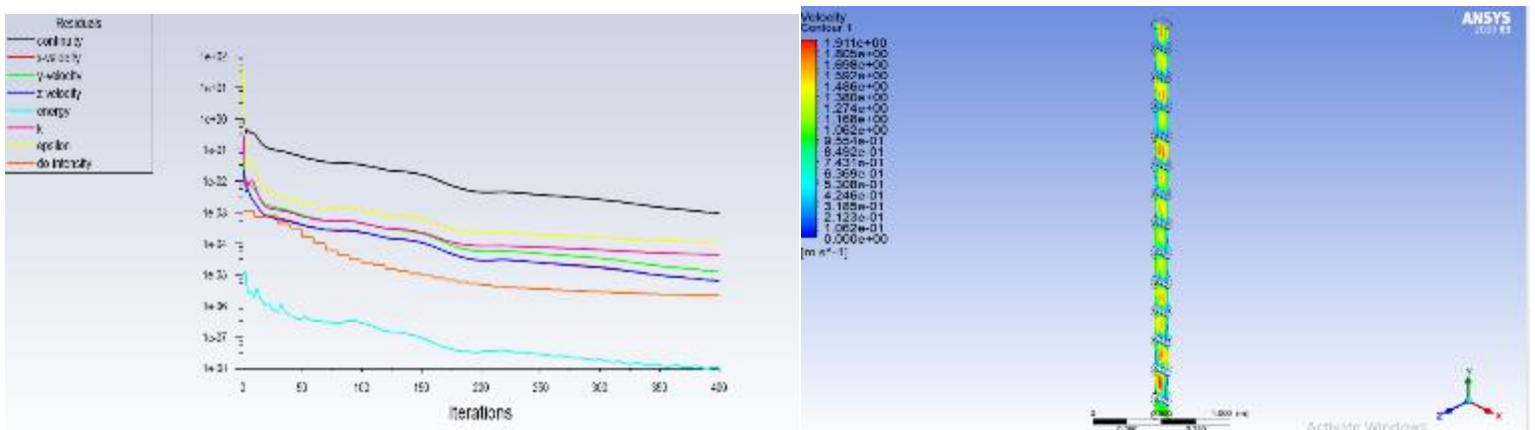


Figure 75: 1 m/s PVC

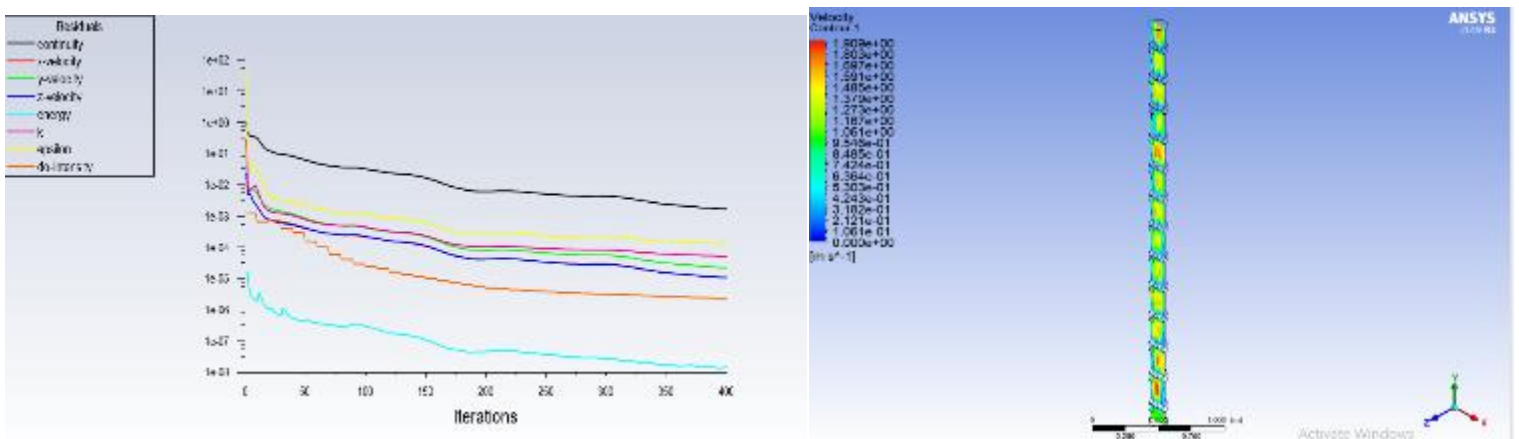


Figure 76: 1 m/s Steel

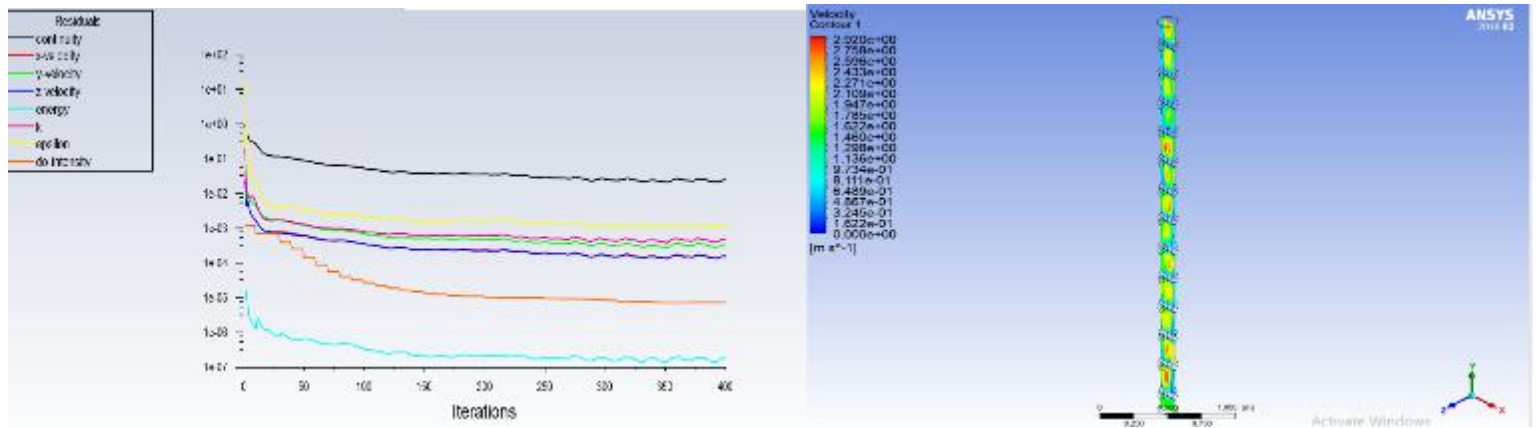


Figure 77: 1.5 m/s Aluminum

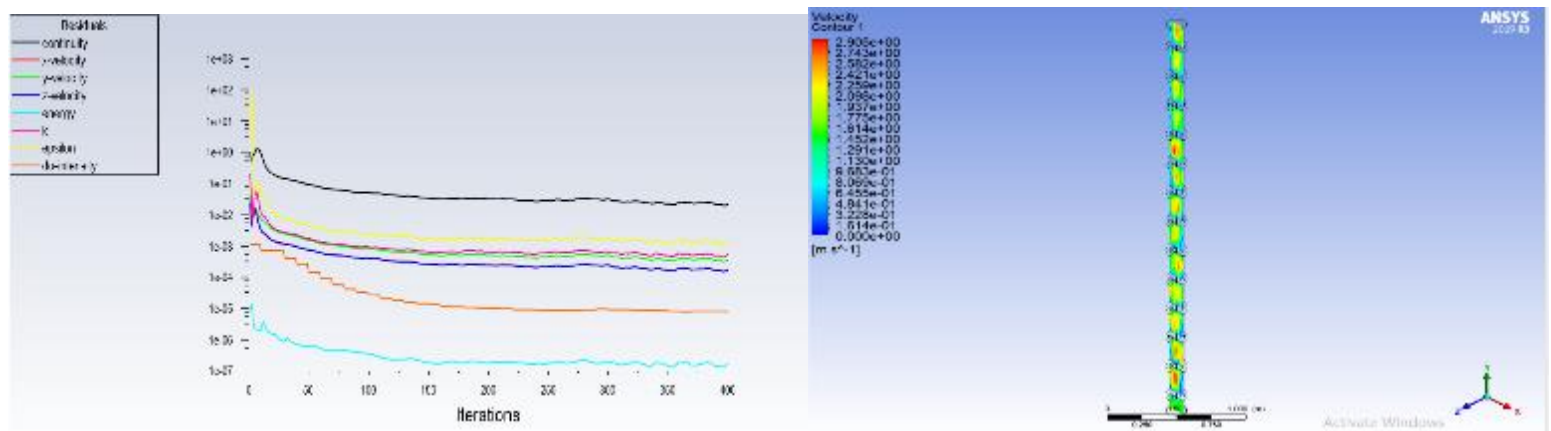


Figure 78: 1.5 m/s PVC

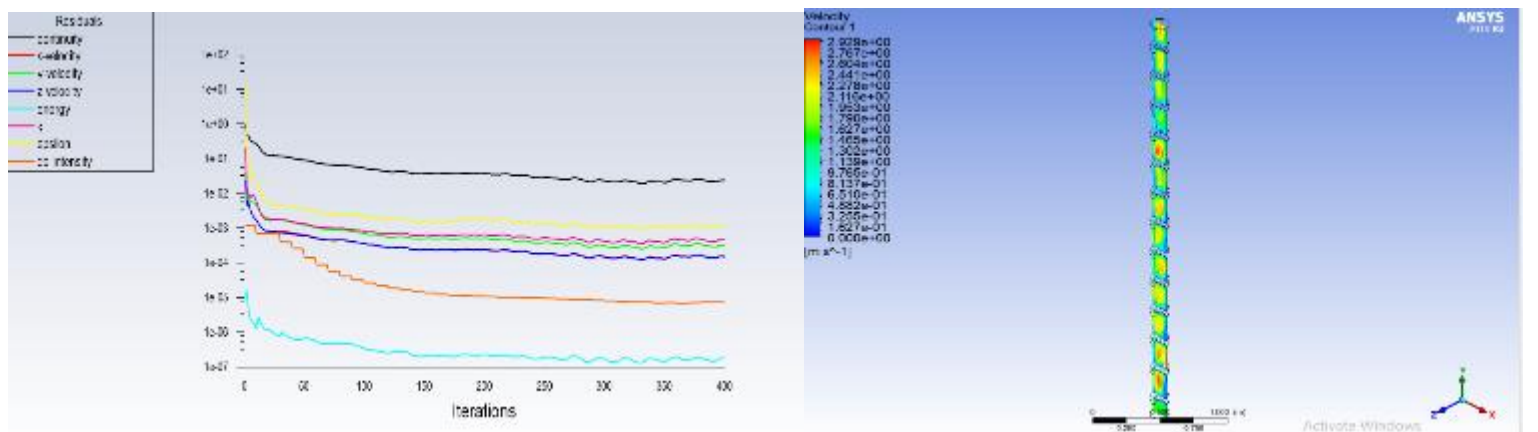


Figure 79: 1.5 m/s Steel

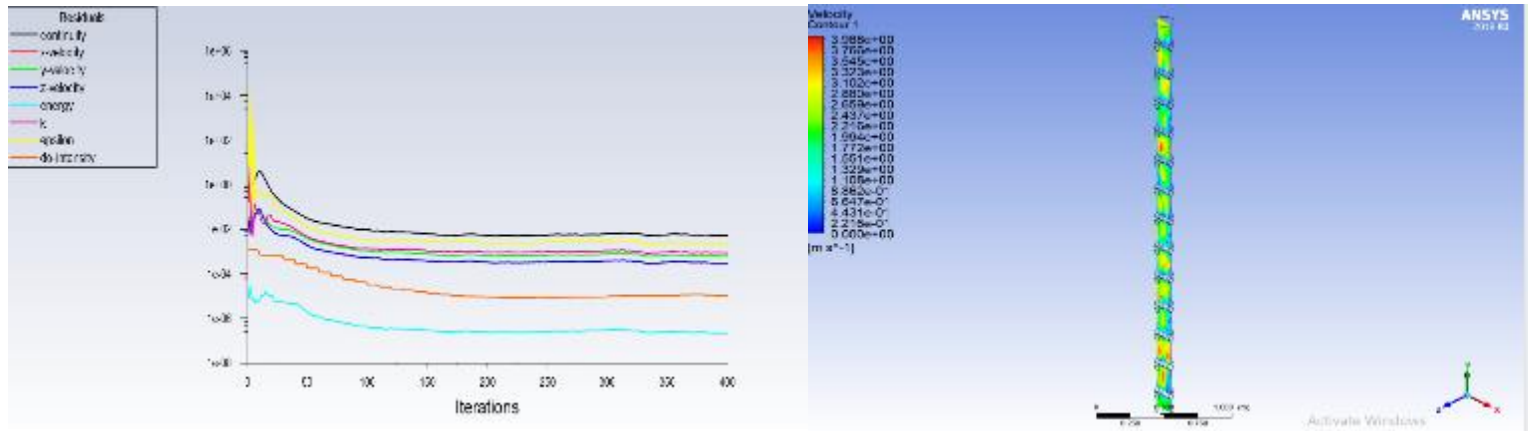


Figure 80: 2 m/s Aluminum

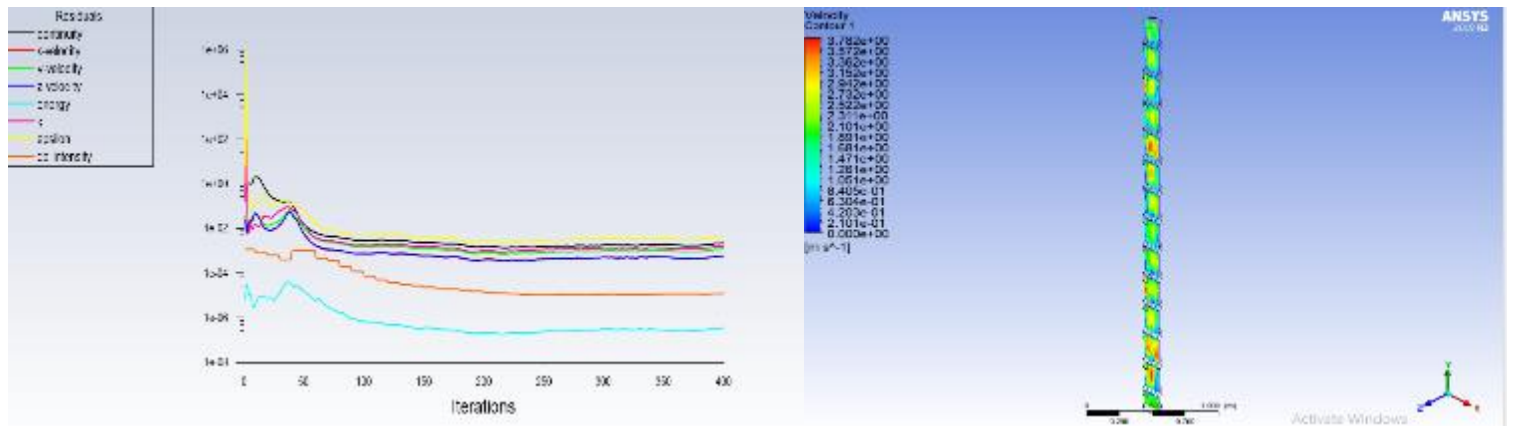


Figure 81: 2 m/s PVC

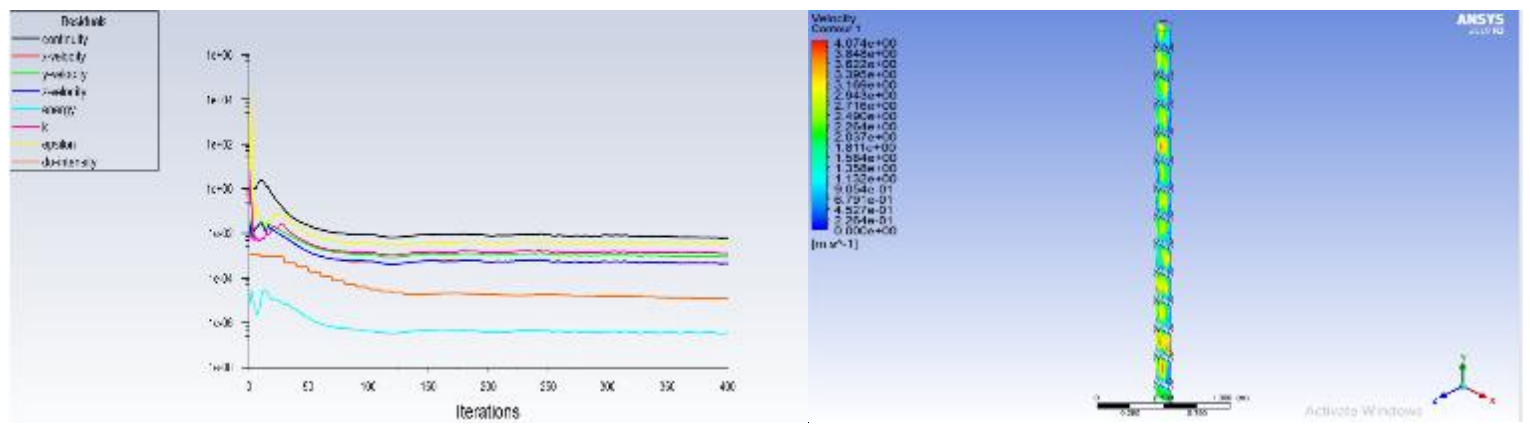


Figure 82: 2 m/s Steel

9.4 RIBBED PIPE

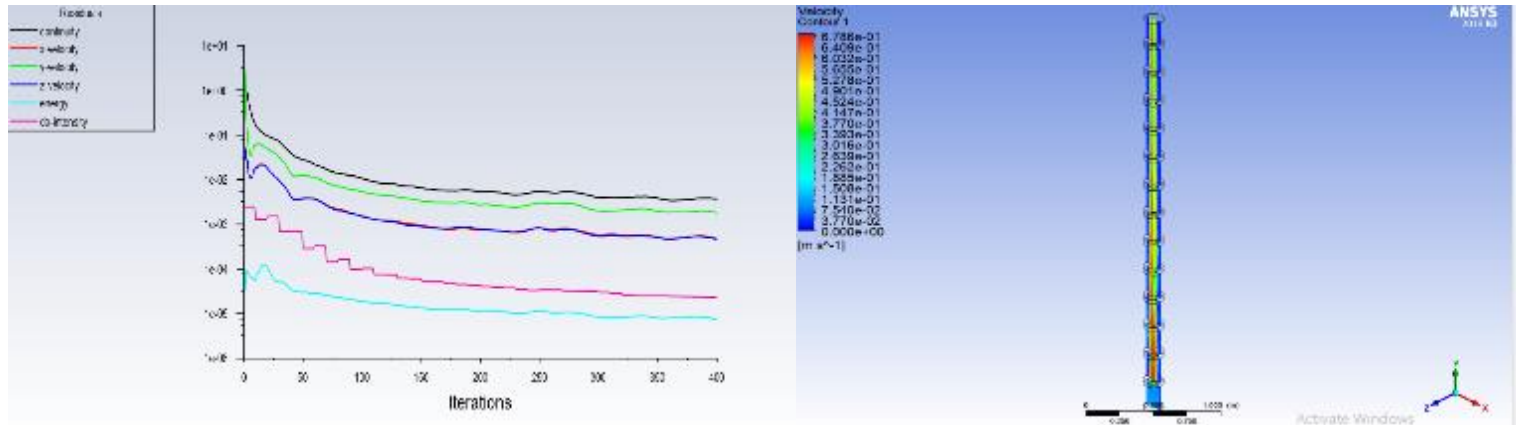


Figure 83: 0.1 m/s Aluminum

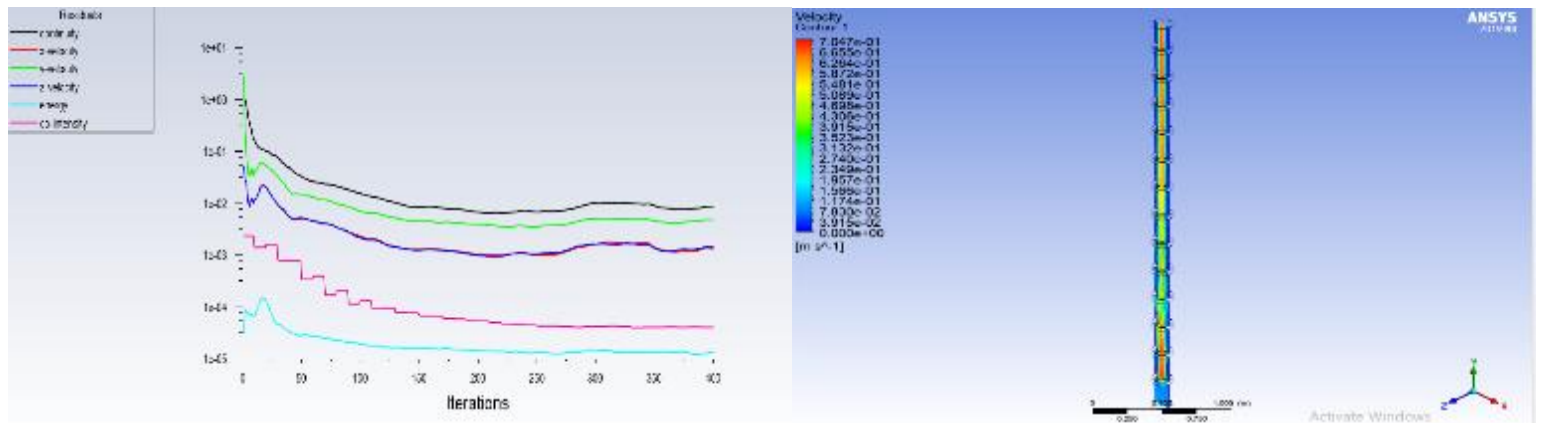


Figure 84: 0.1 m/s PVC

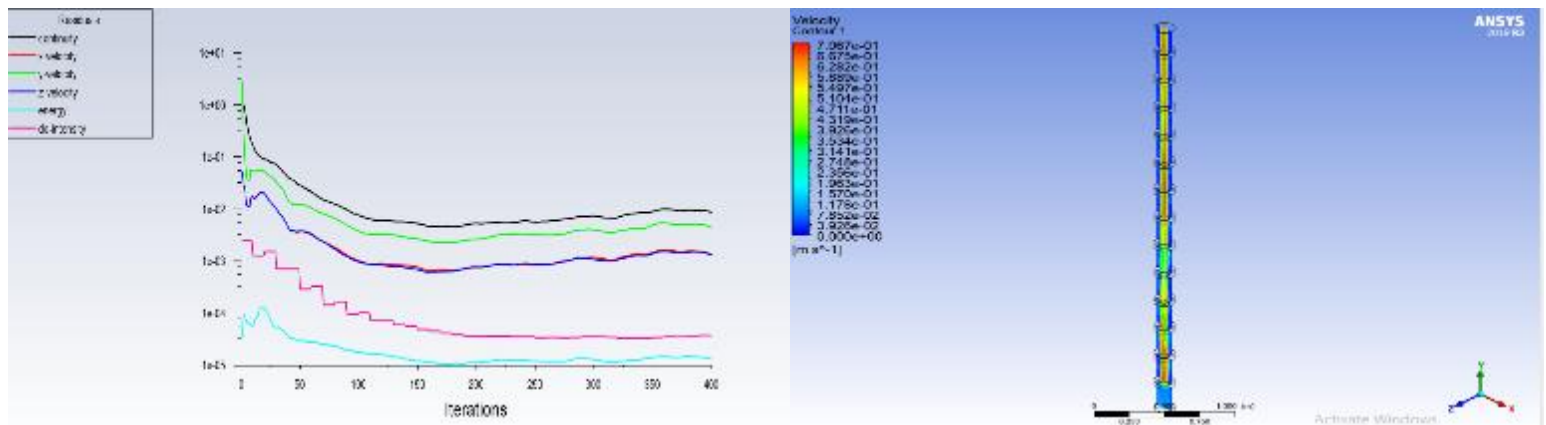


Figure 85: 0.1 m/s Steel

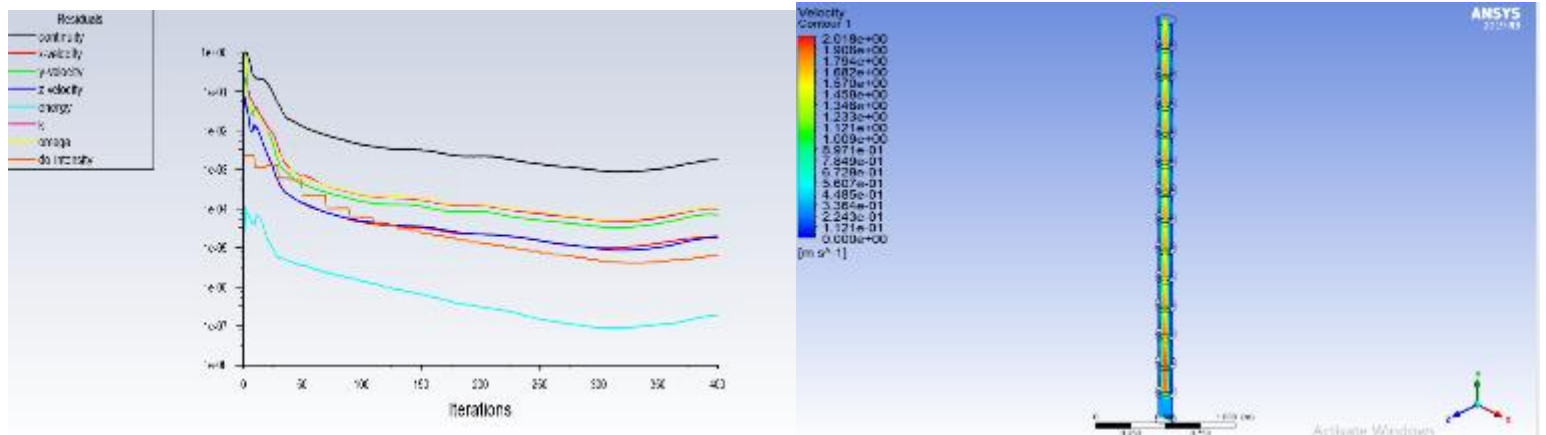


Figure 86: 0.3 m/s Aluminum

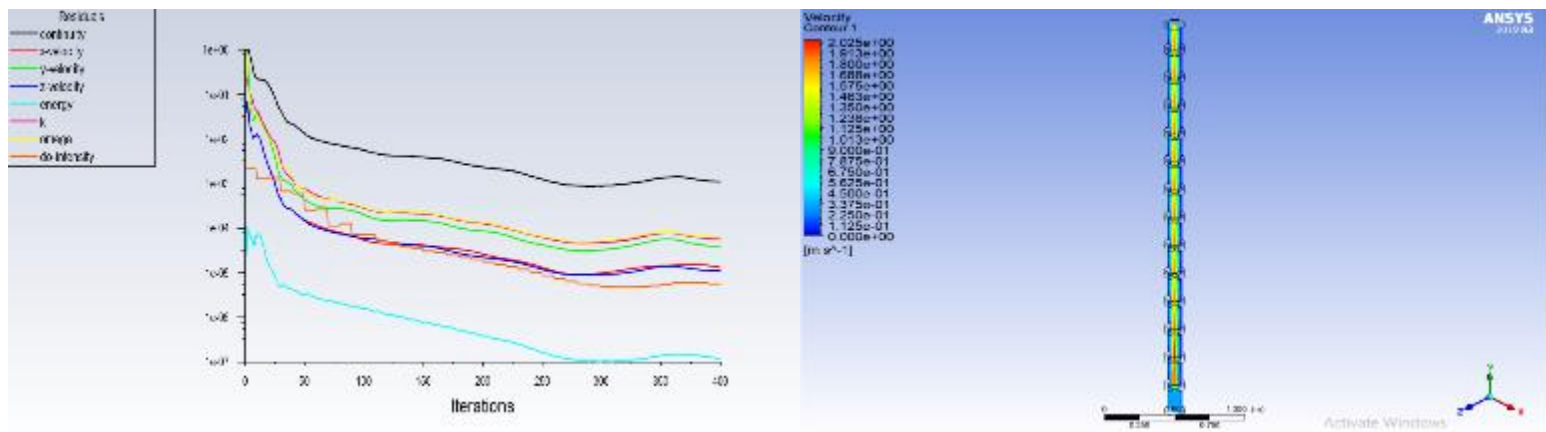


Figure 87: 0.3 m/s PVC

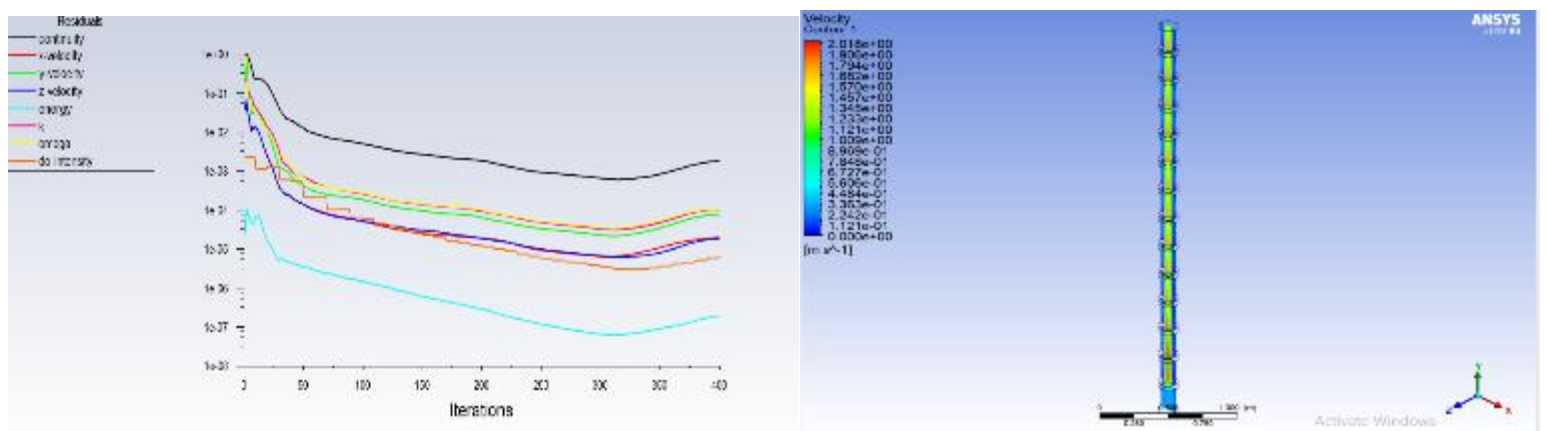


Figure 88: 0.3 m/s Steel

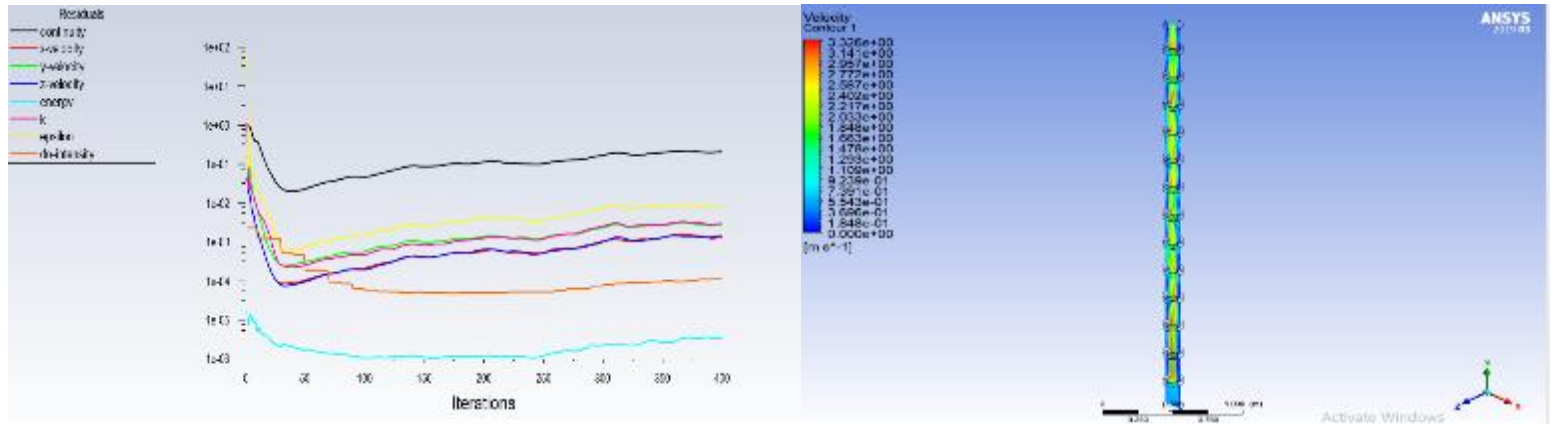


Figure 89: 0.5 m/s Aluminum

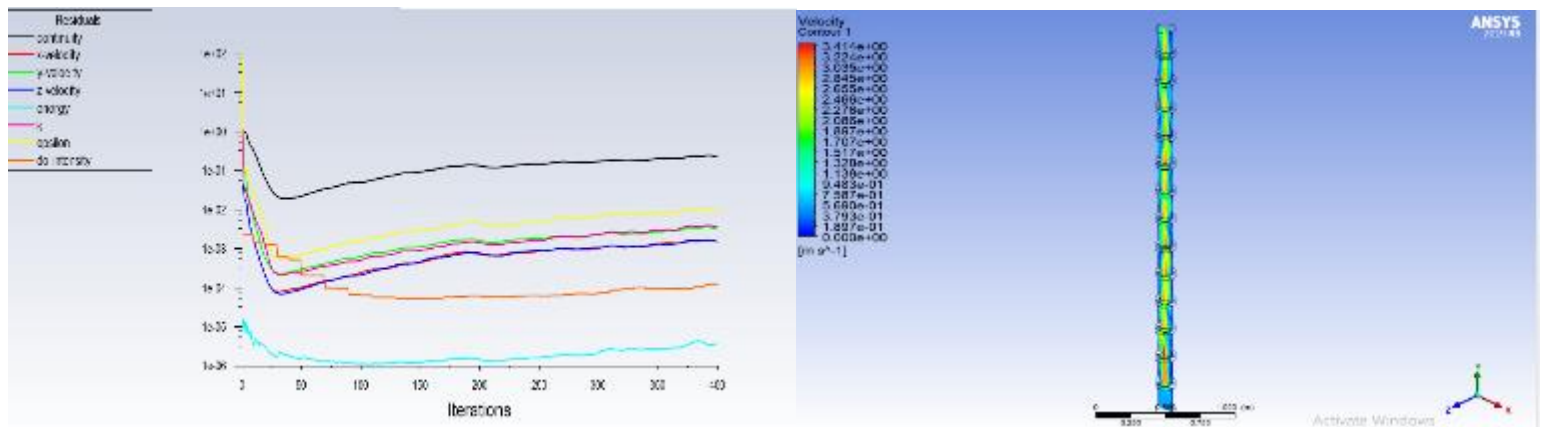


Figure 90: 0.5 m/s PVC

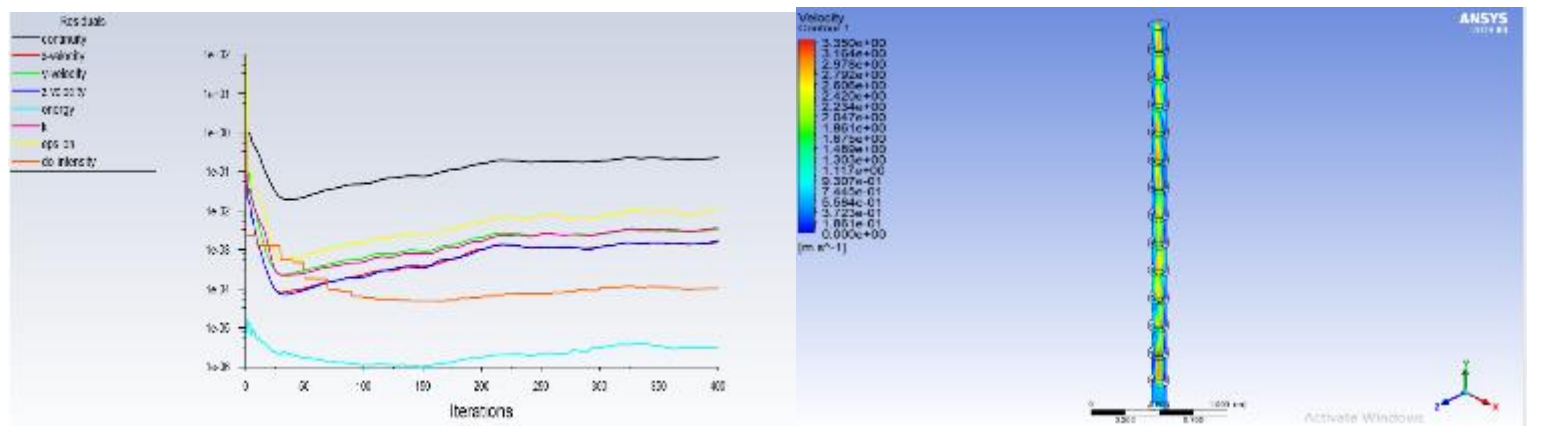


Figure 91: 0.5 m/s Steel

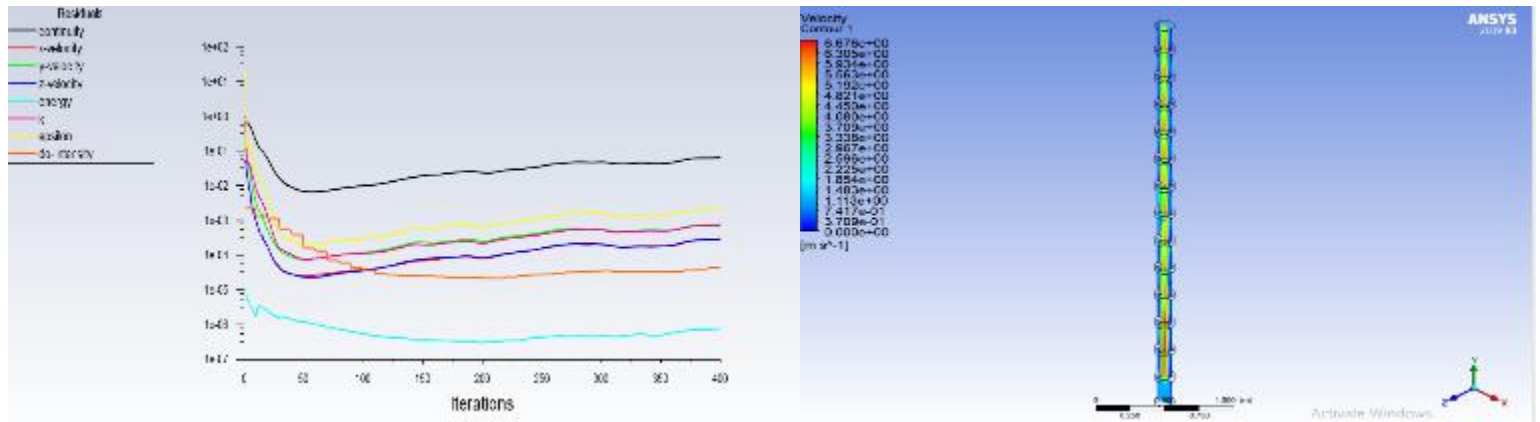


Figure 92: 1 m/s Aluminum

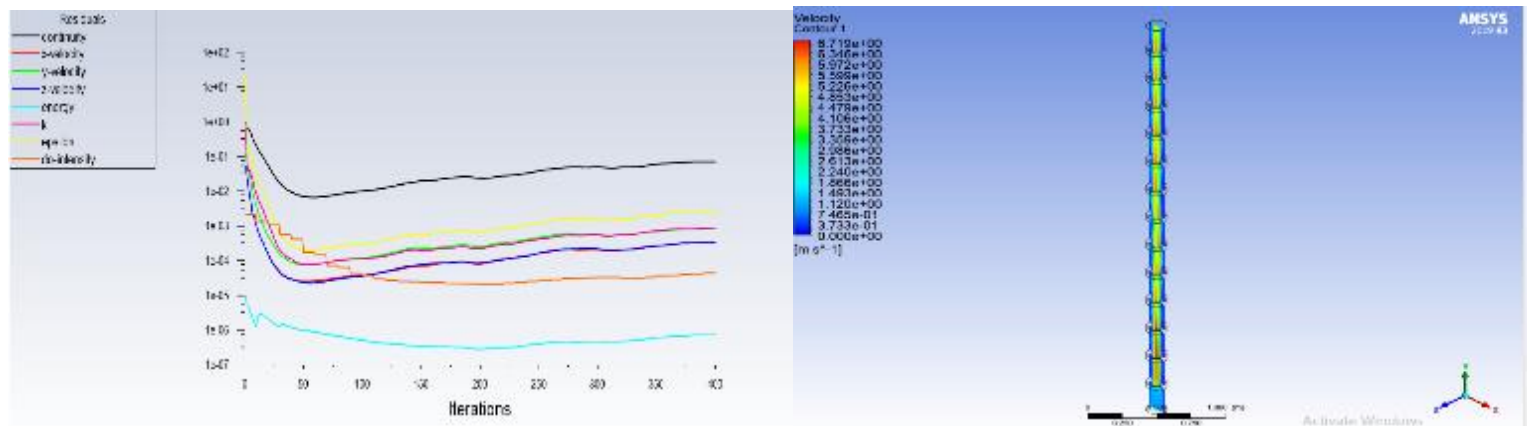


Figure 93: 1 m/s PVC

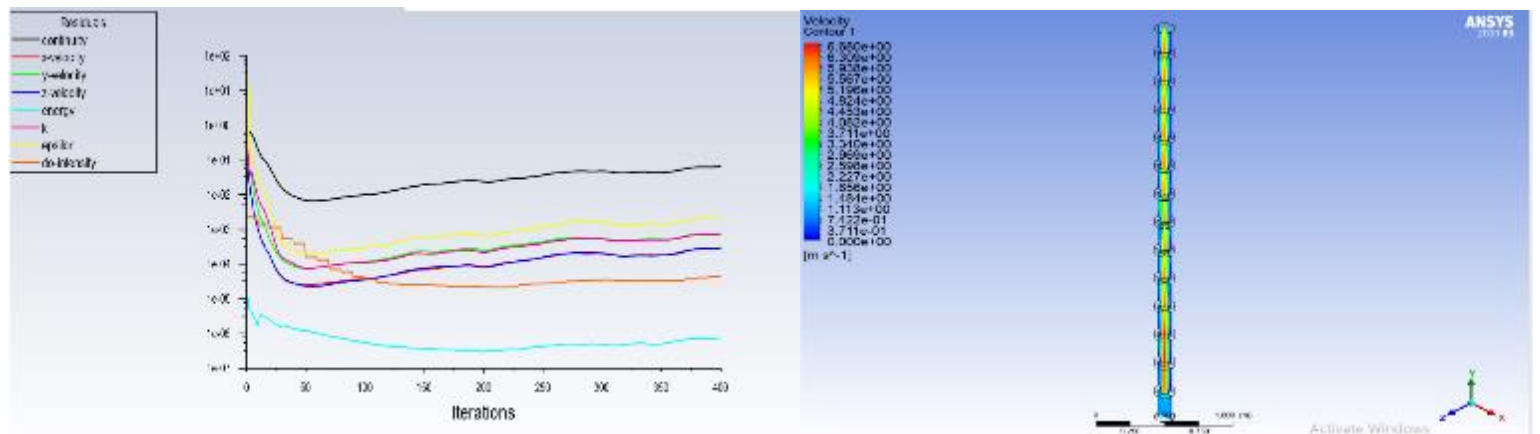


Figure 94: 1 m/s Steel

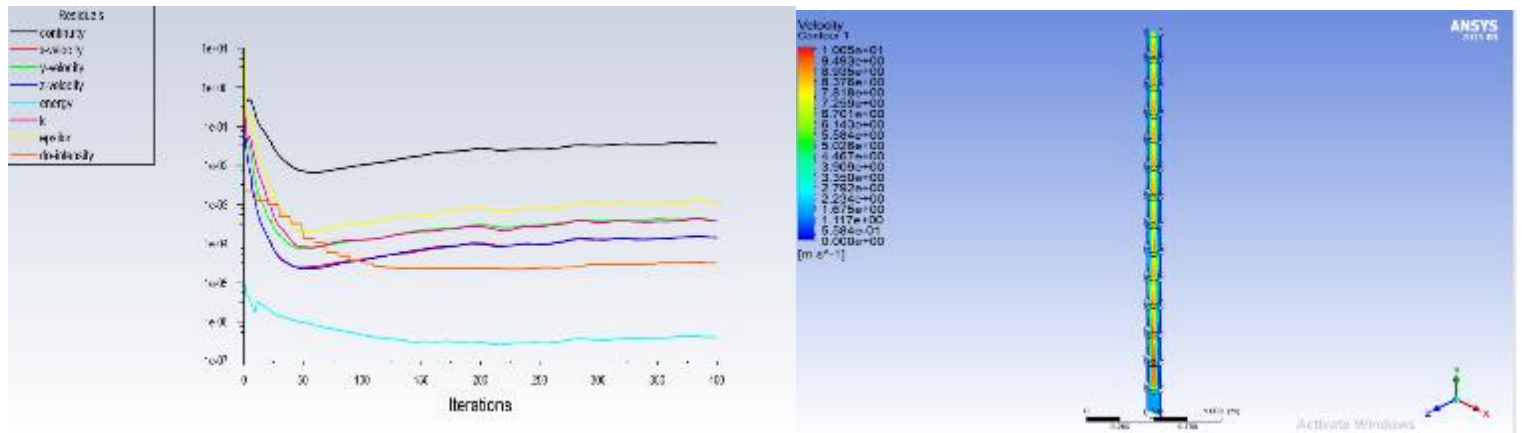


Figure 95: 1.5 m/s Aluminum

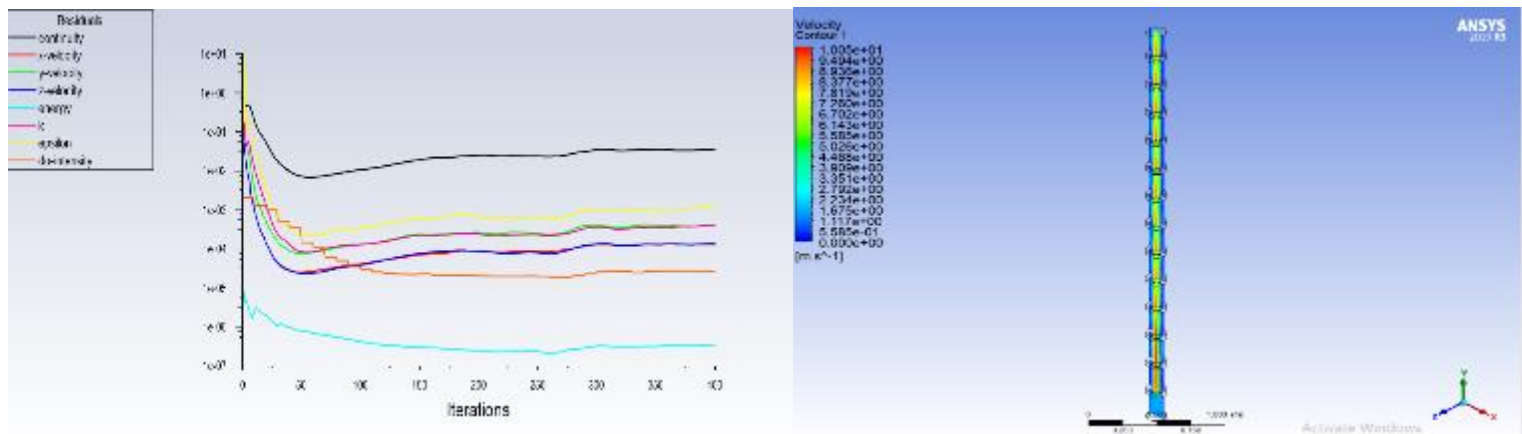


Figure 96: 1.5 m/s PVC

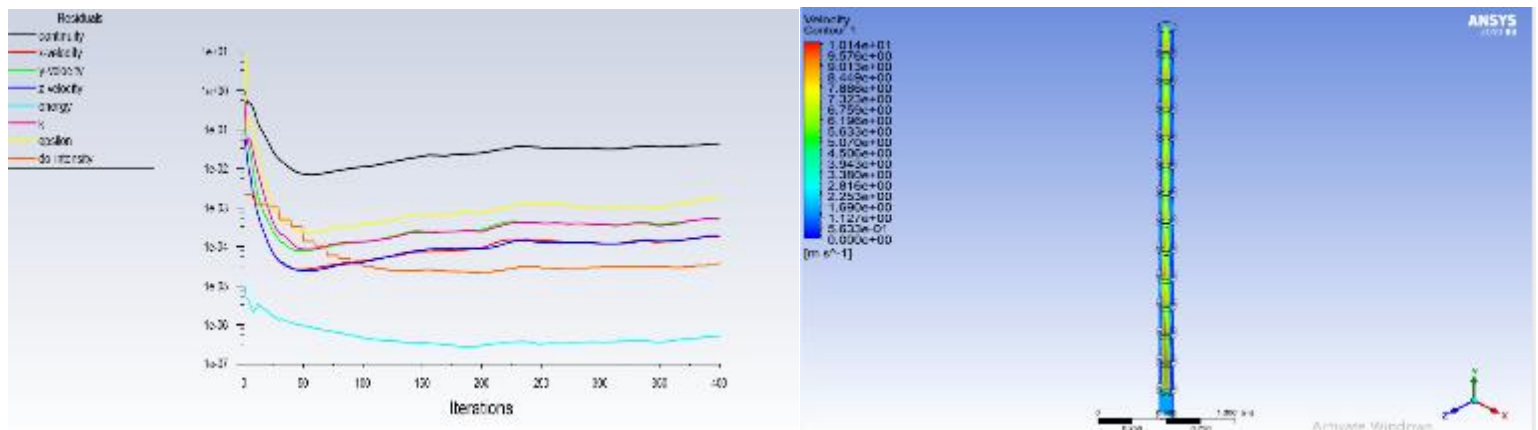


Figure 97: 1.5 m/s Steel

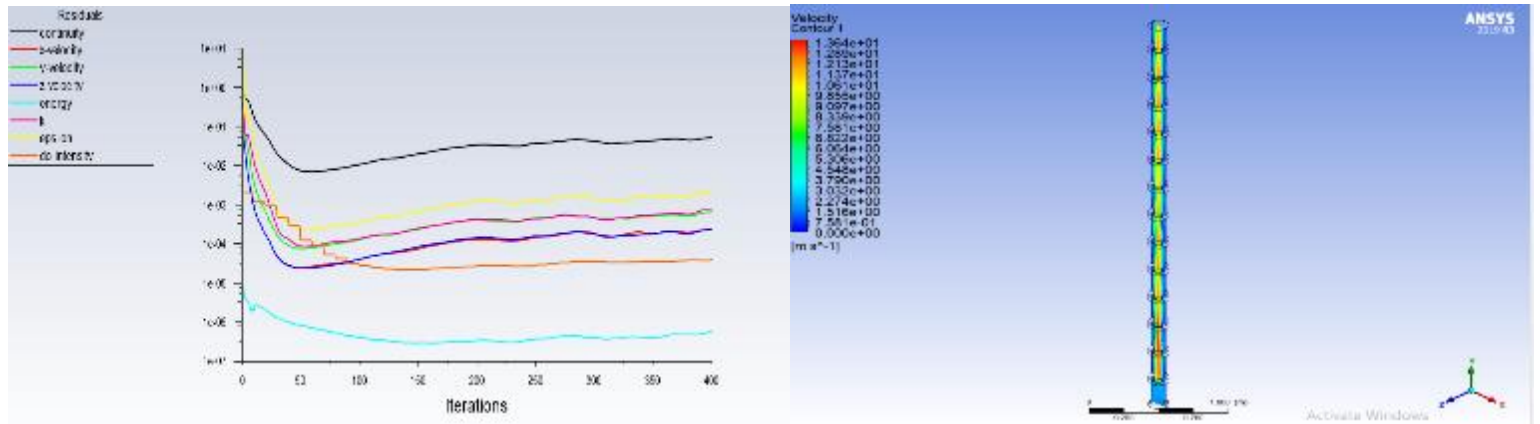


Figure 98: 2 m/s Aluminum

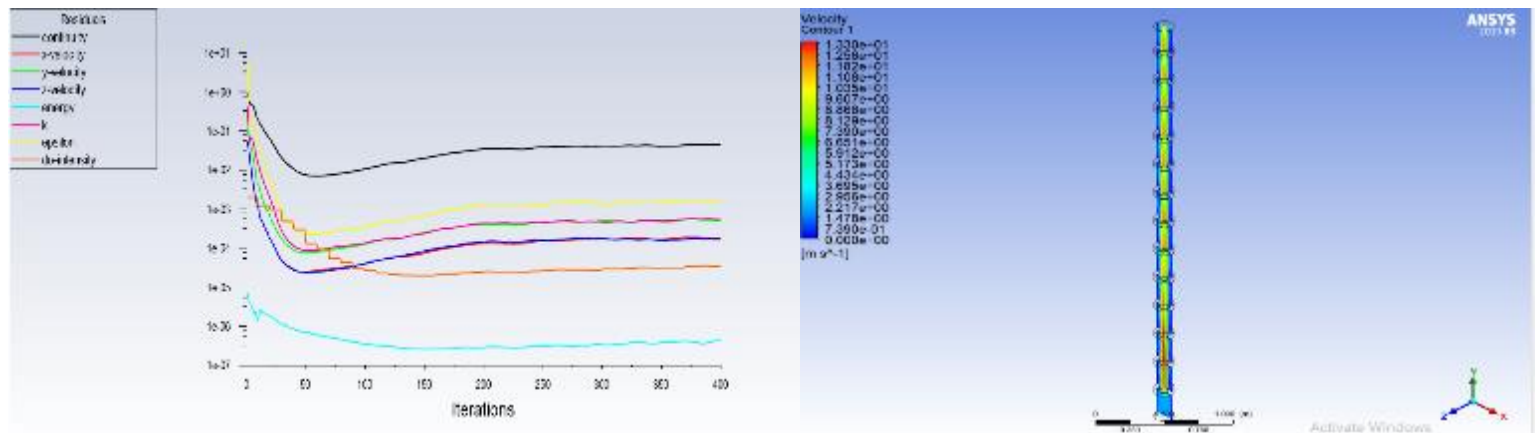


Figure 99: 2 m/s PVC

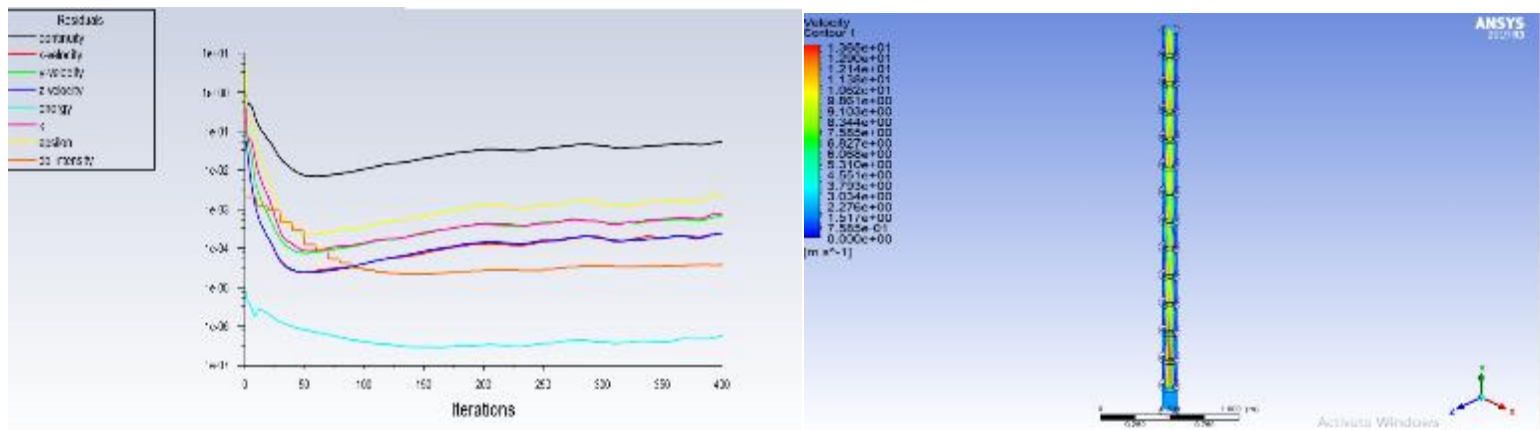


Figure 100: 2 m/s Steel

9.5 CUBIC PIPE

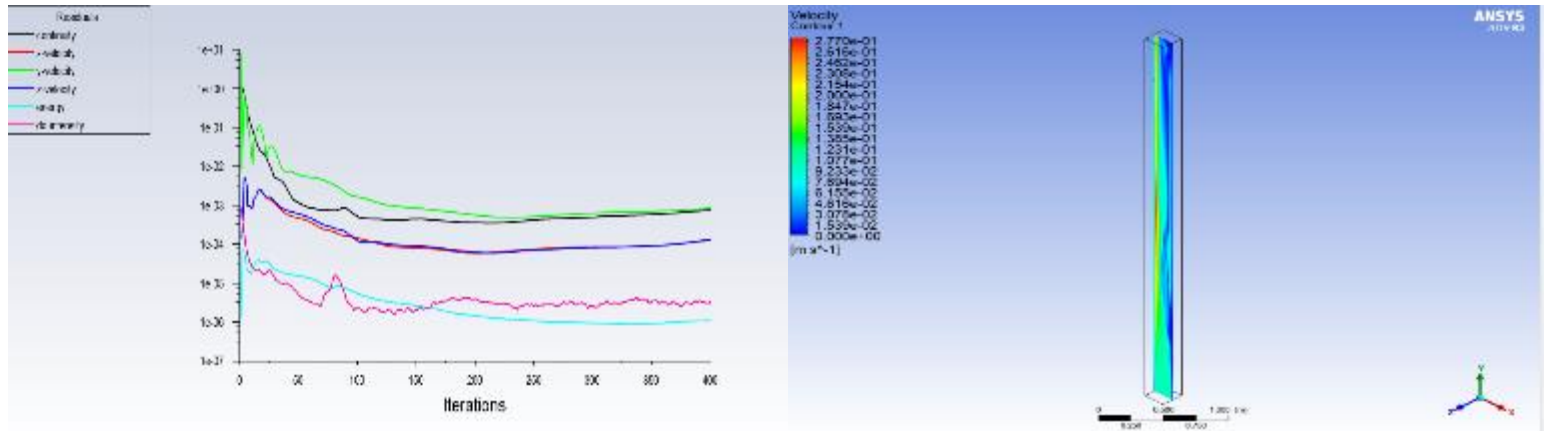


Figure 101: 0.1 m/s Aluminum

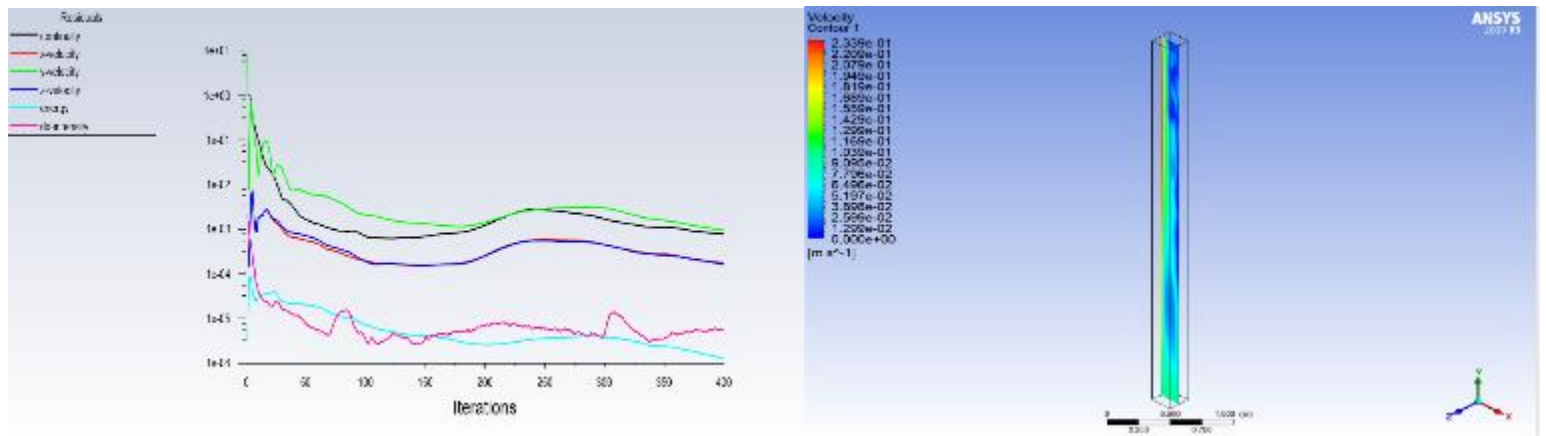


Figure 102: 0.1 m/s PVC

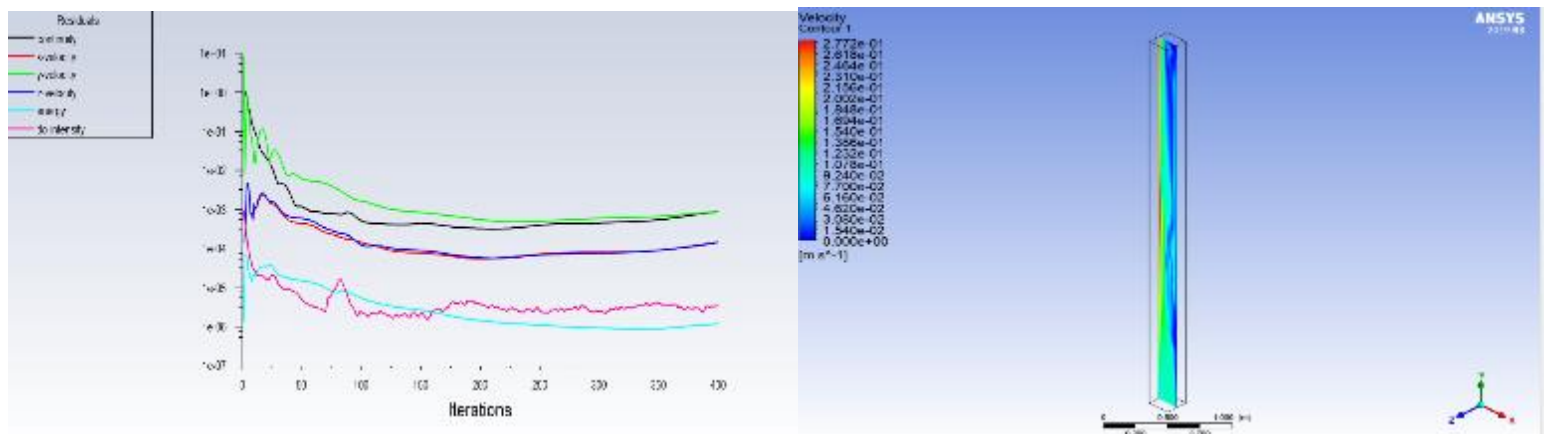


Figure 103: 0.1 m/s Steel

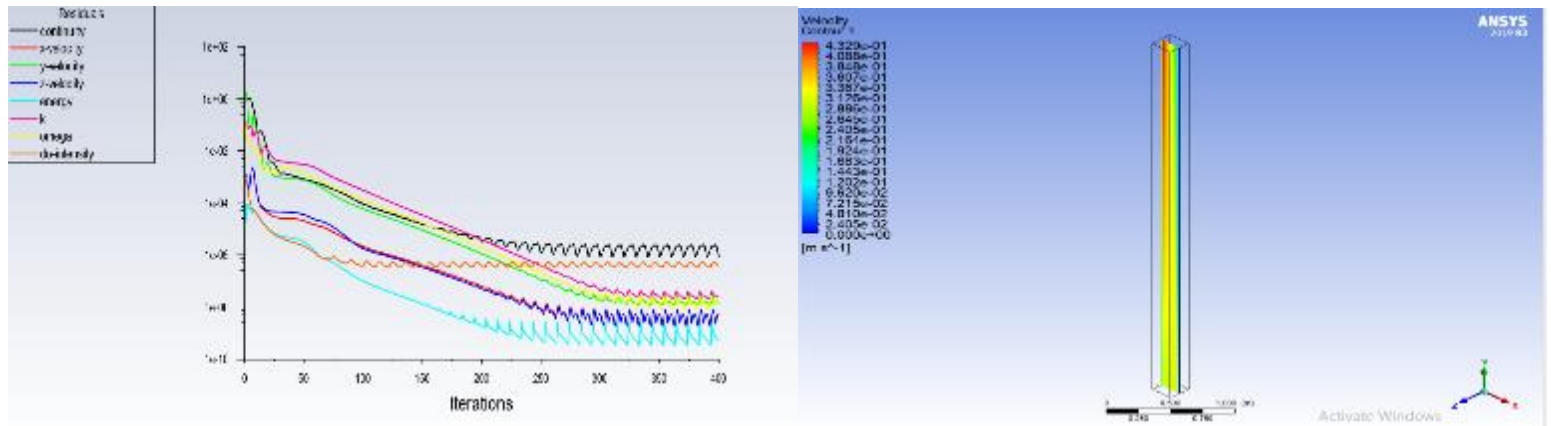


Figure 104: 0.3 m/s Aluminum

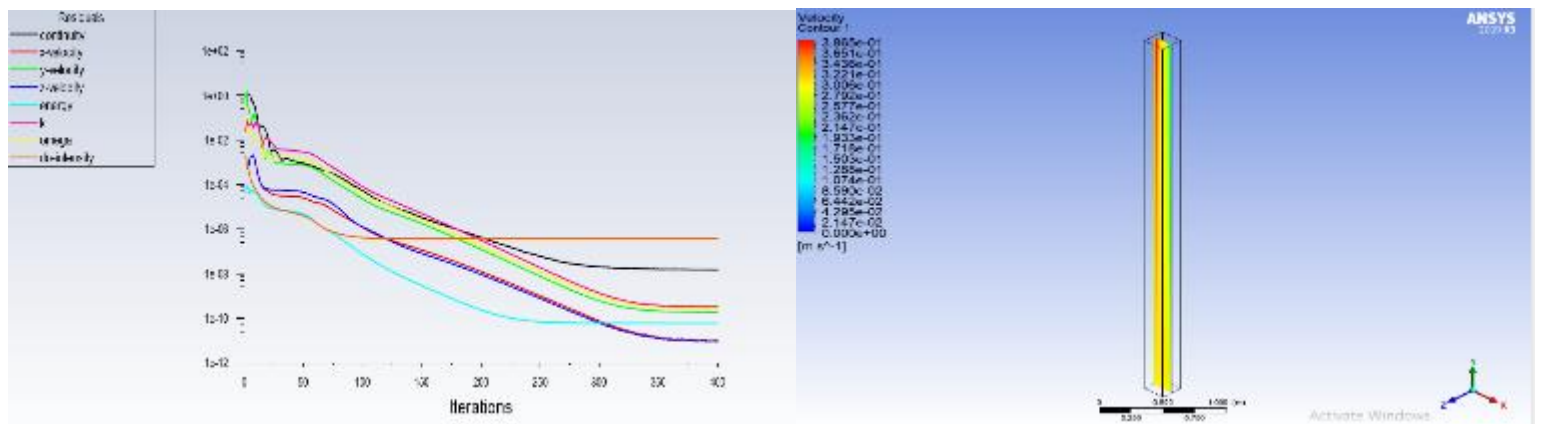


Figure 105: 0.3 m/s PVC

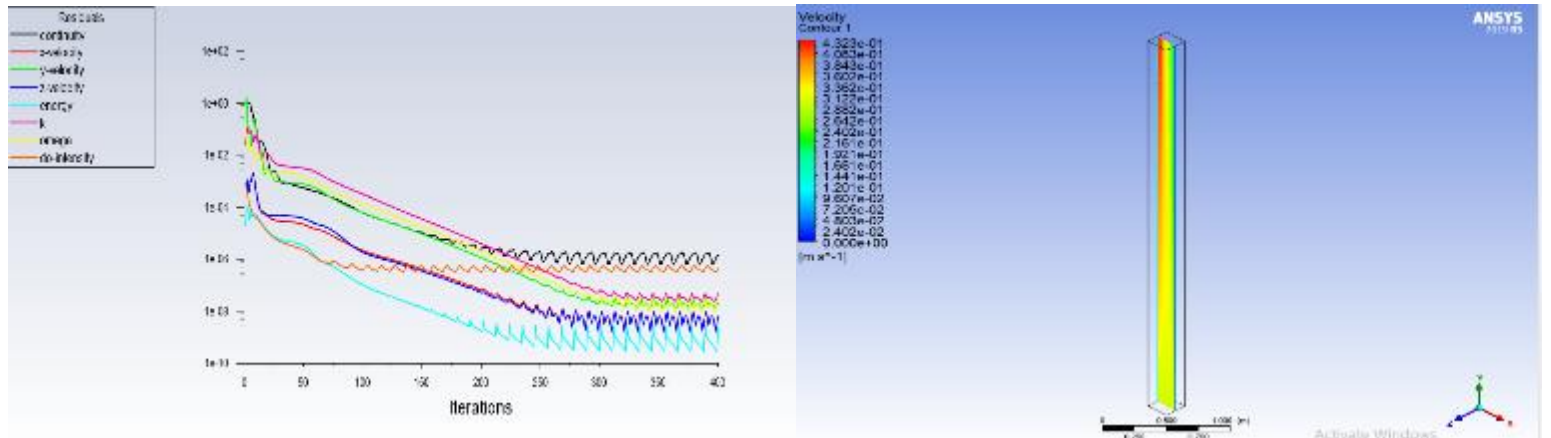


Figure 106: 0.3 m/s Steel

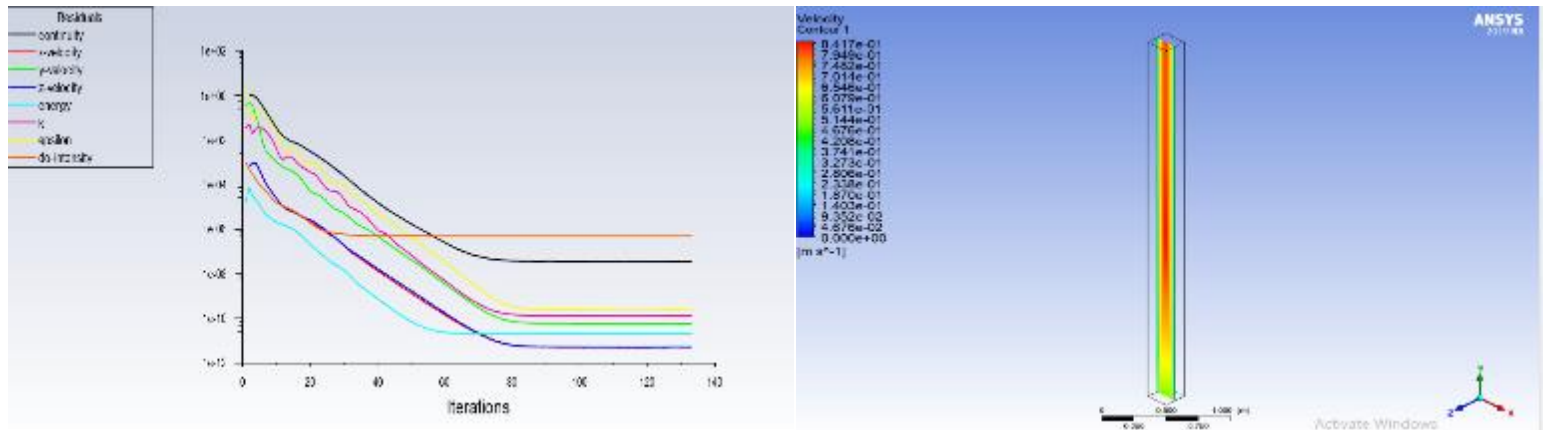


Figure 107: 0.5 m/s Aluminum

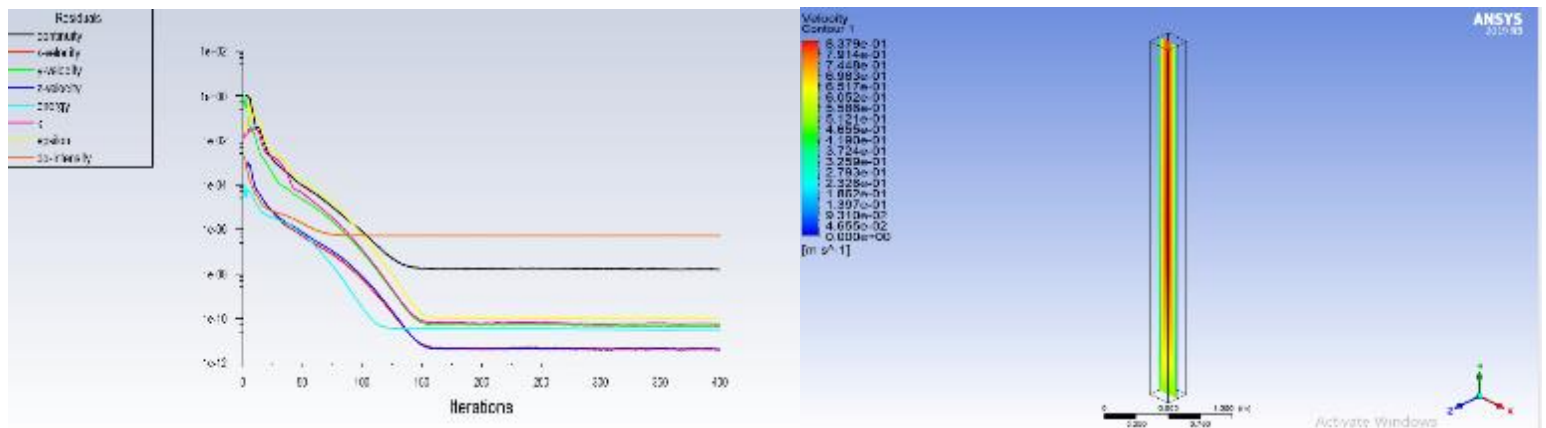


Figure 108: 0.5 m/s PVC

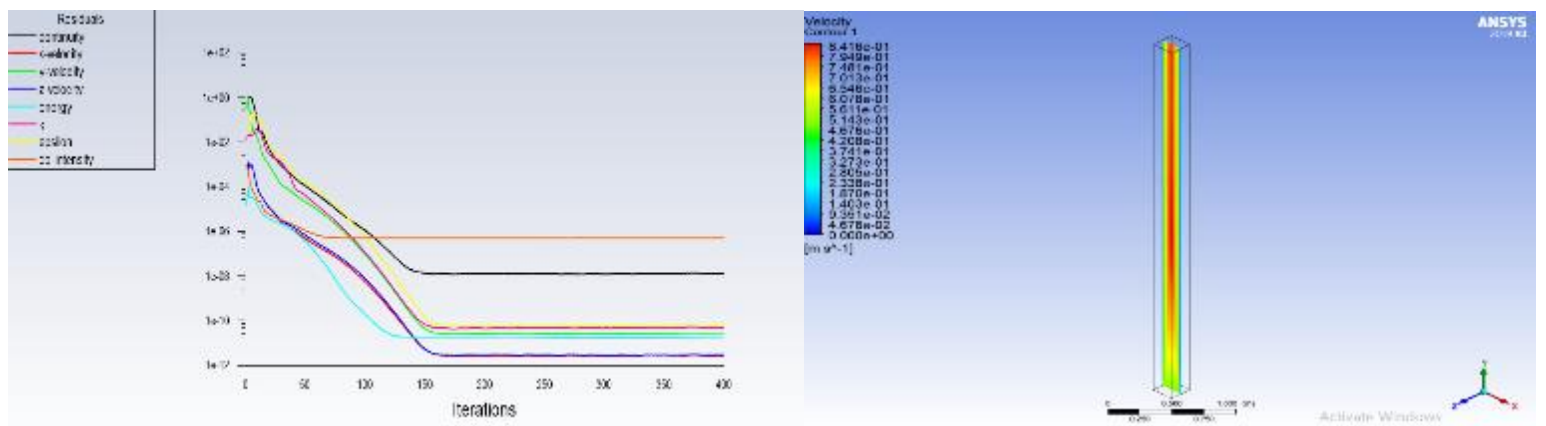


Figure 109: 0.5 m/s Steel

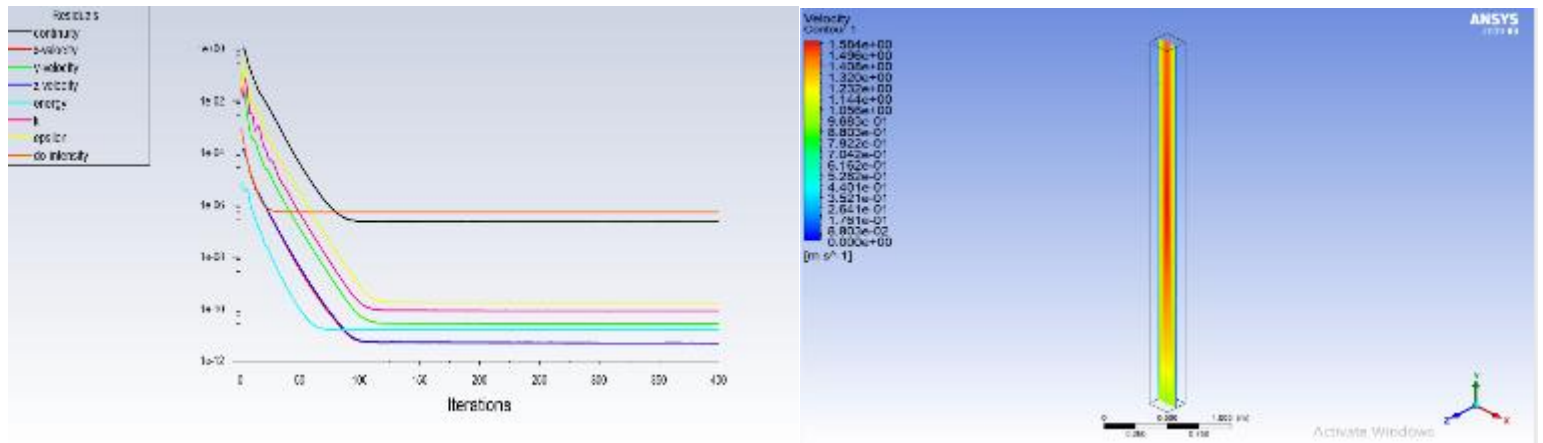


Figure 110: 1 m/s Aluminum

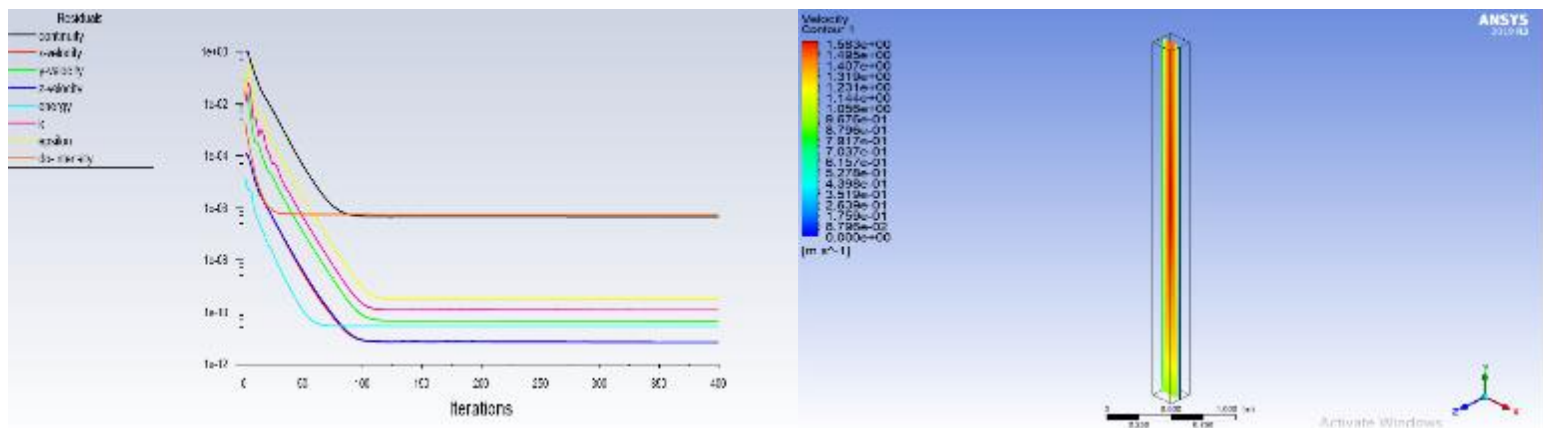


Figure 111: 1 m/s PVC

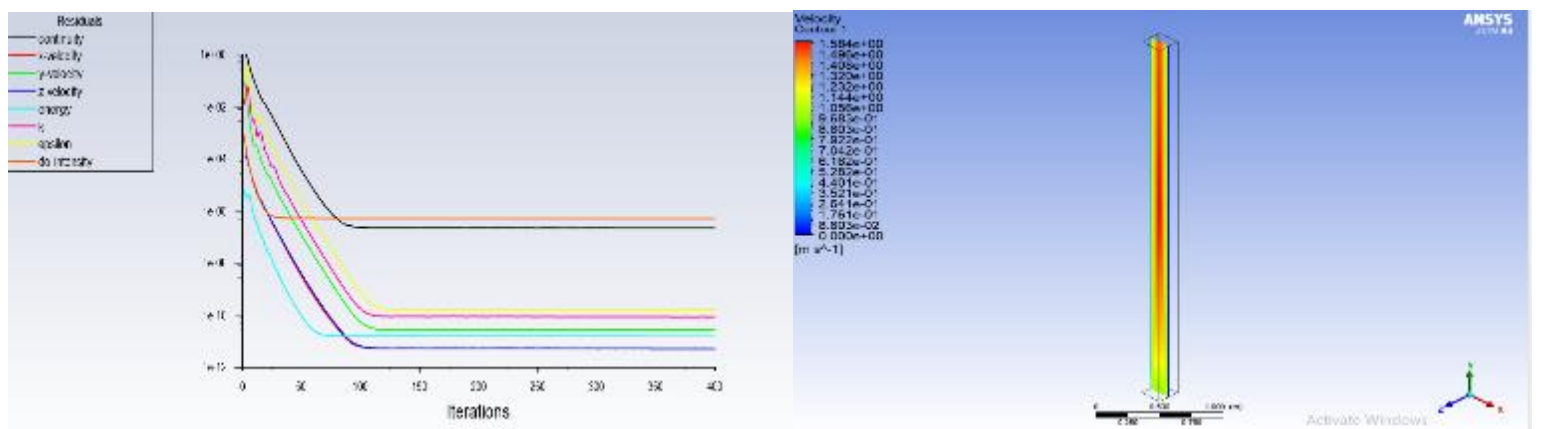


Figure 112: 1 m/s Steel

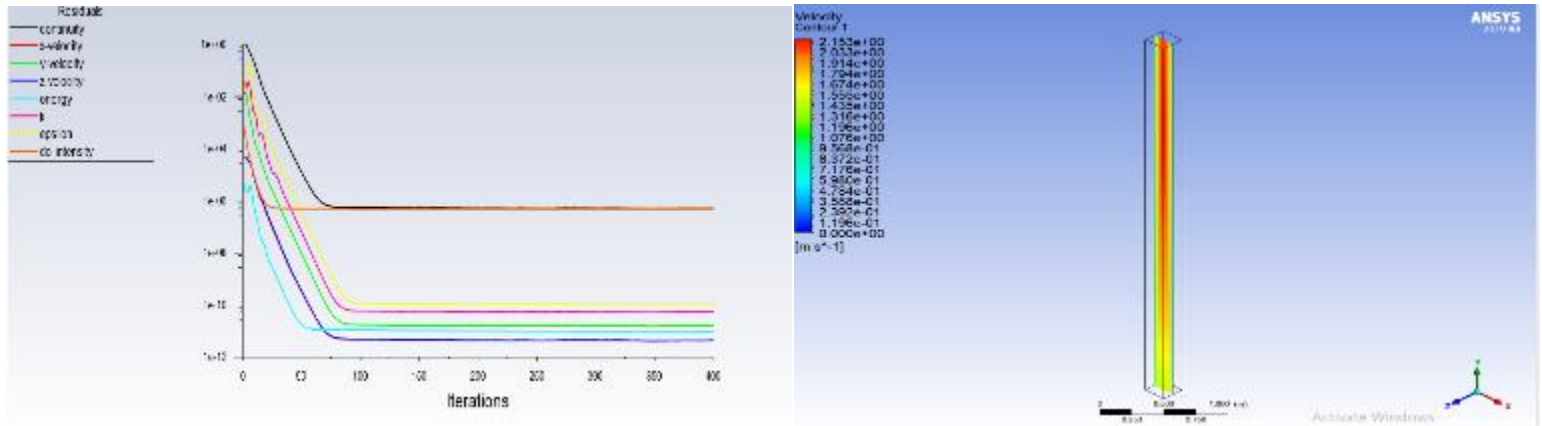


Figure 113: 1.5 m/s Aluminum

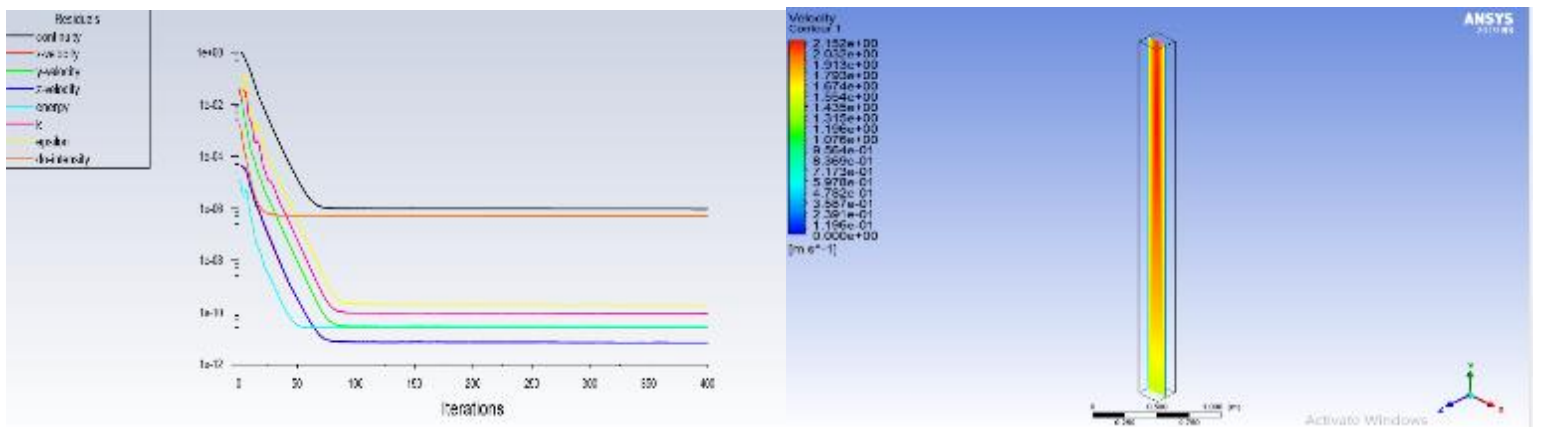


Figure 114: 1.5 m/s PVC

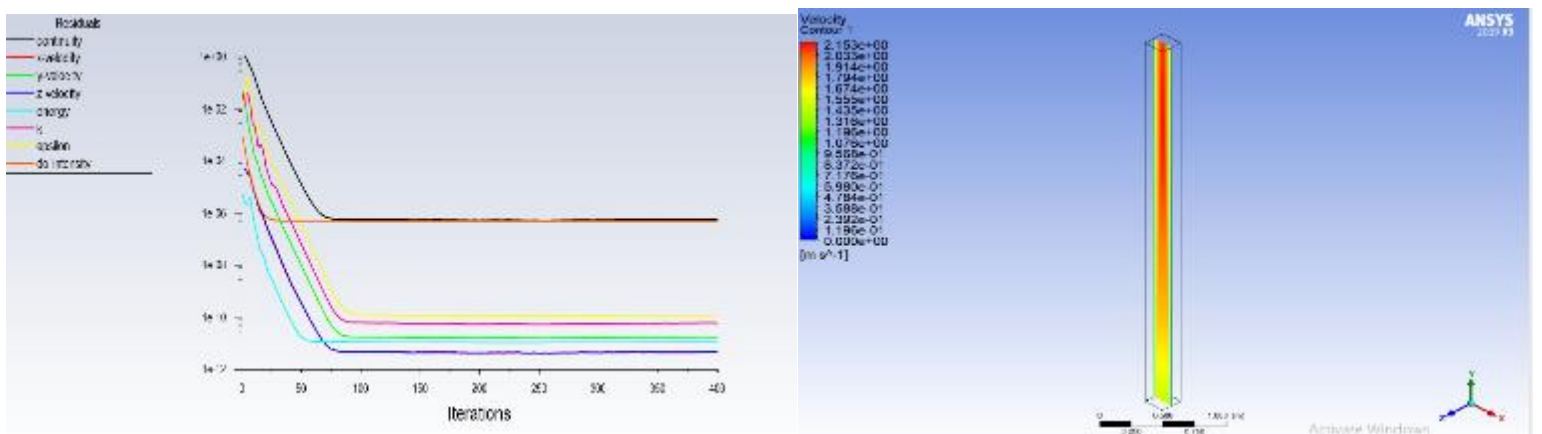


Figure 115: 1.5 m/s Steel

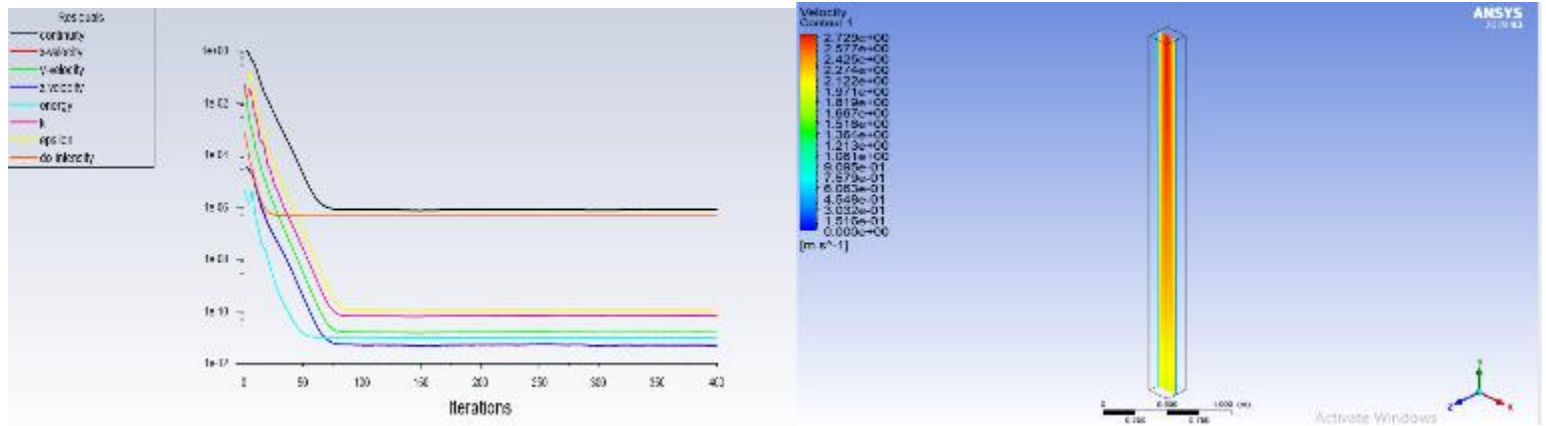


Figure u6: 2 m/s Aluminum

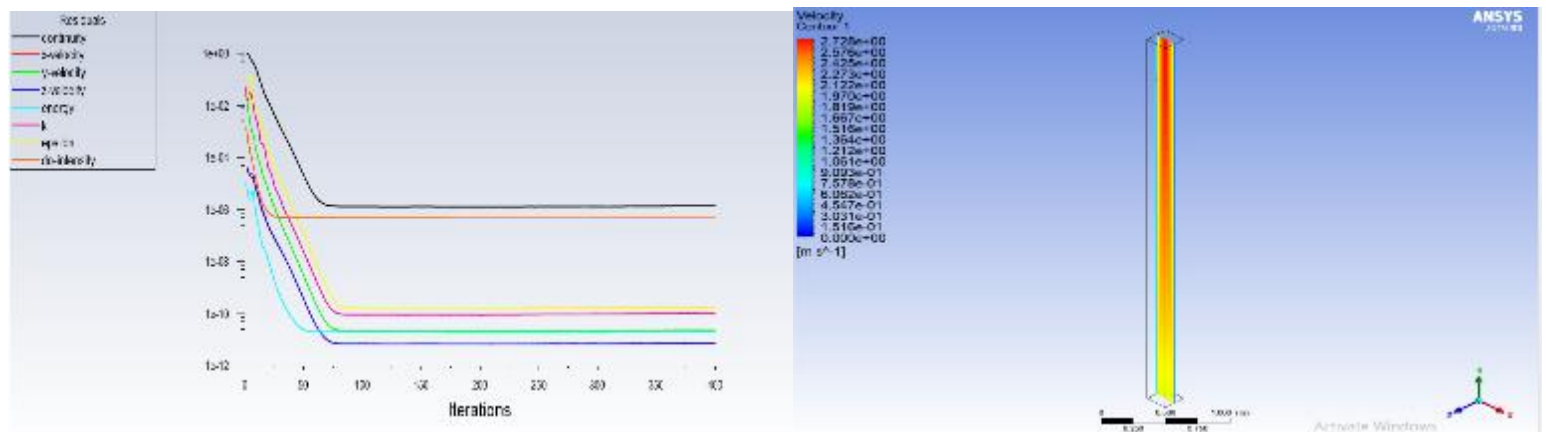


Figure u7: 2 m/s PVC

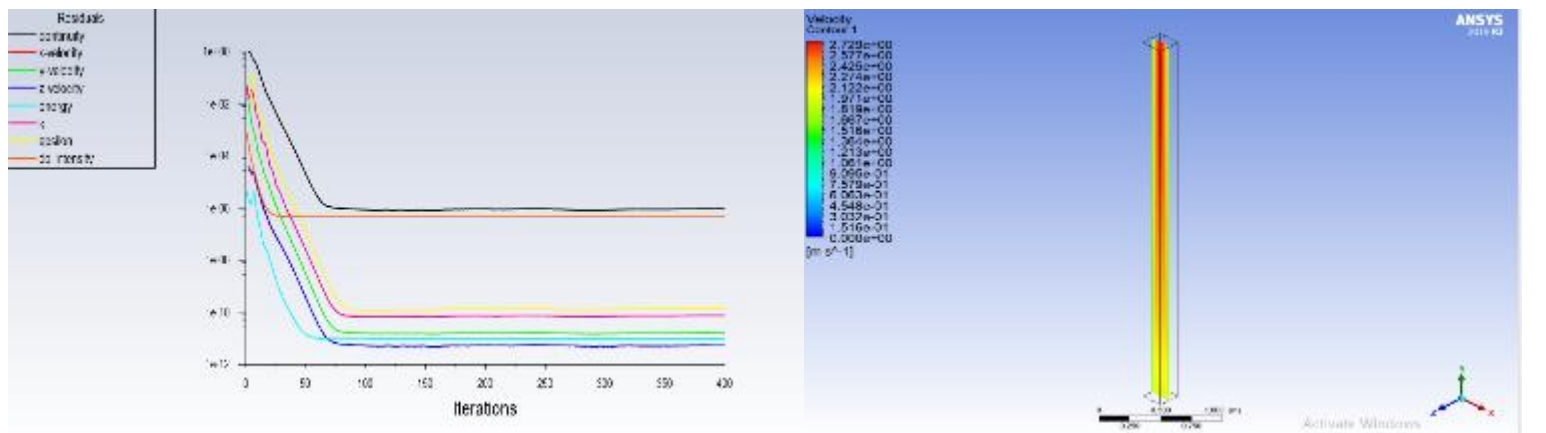


Figure u8: 2 m/s Steel

9.6 CONICAL PIPE

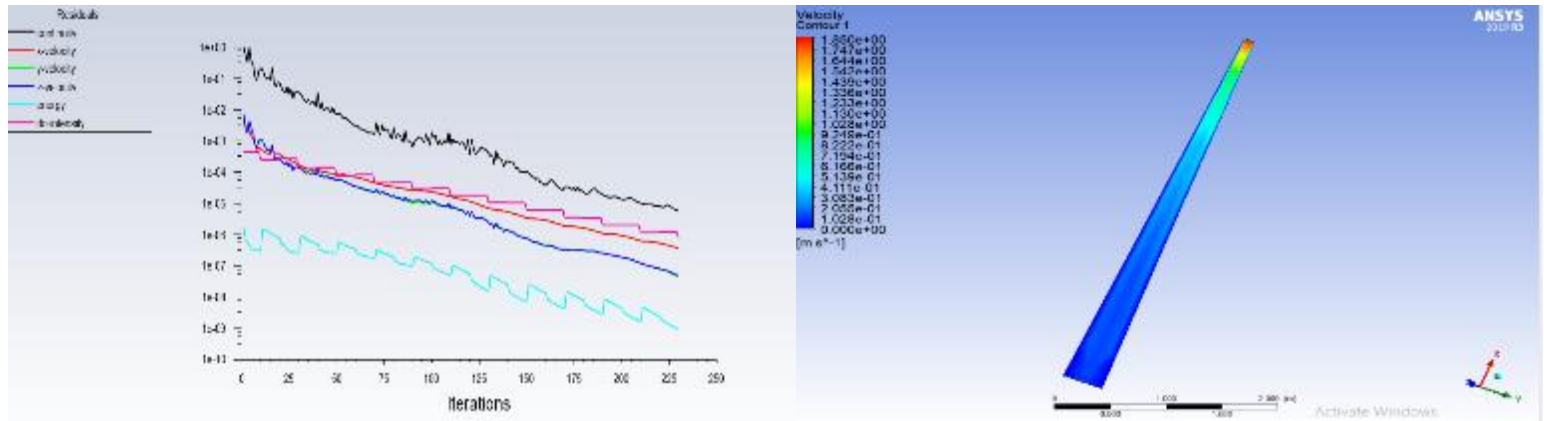


Figure 119: 0.1 m/s Aluminum

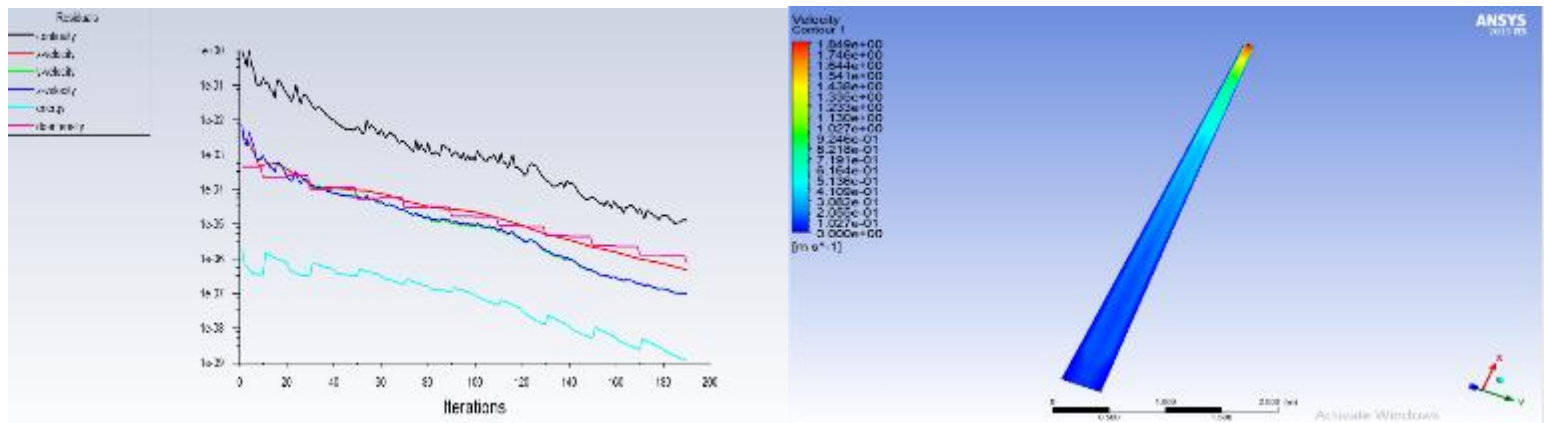


Figure 120: 0.1 m/s PVC

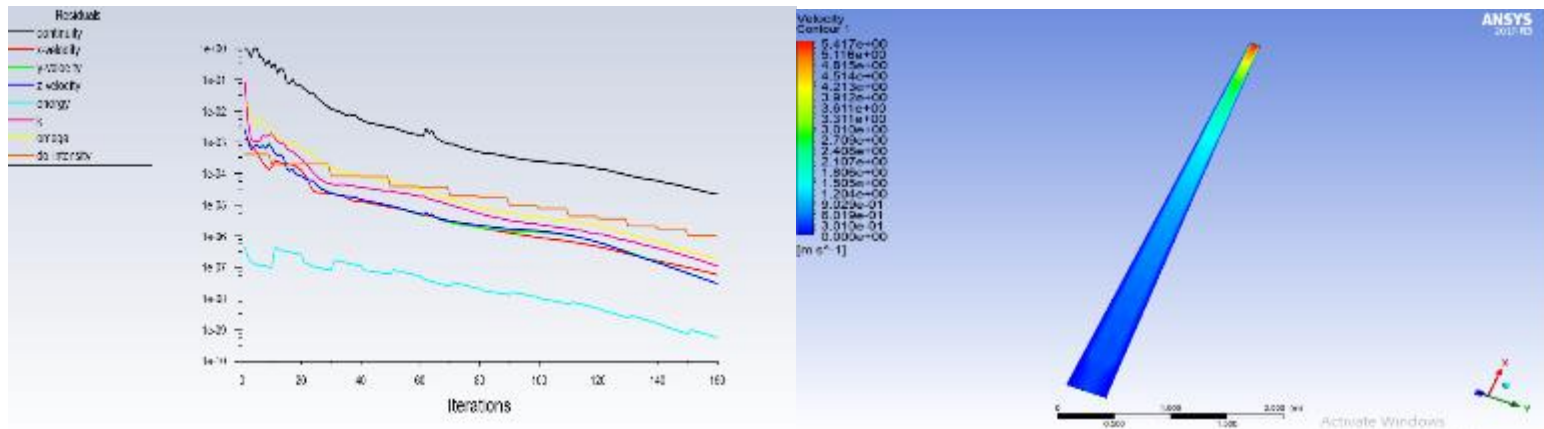


Figure 121: 0.1 m/s Steel

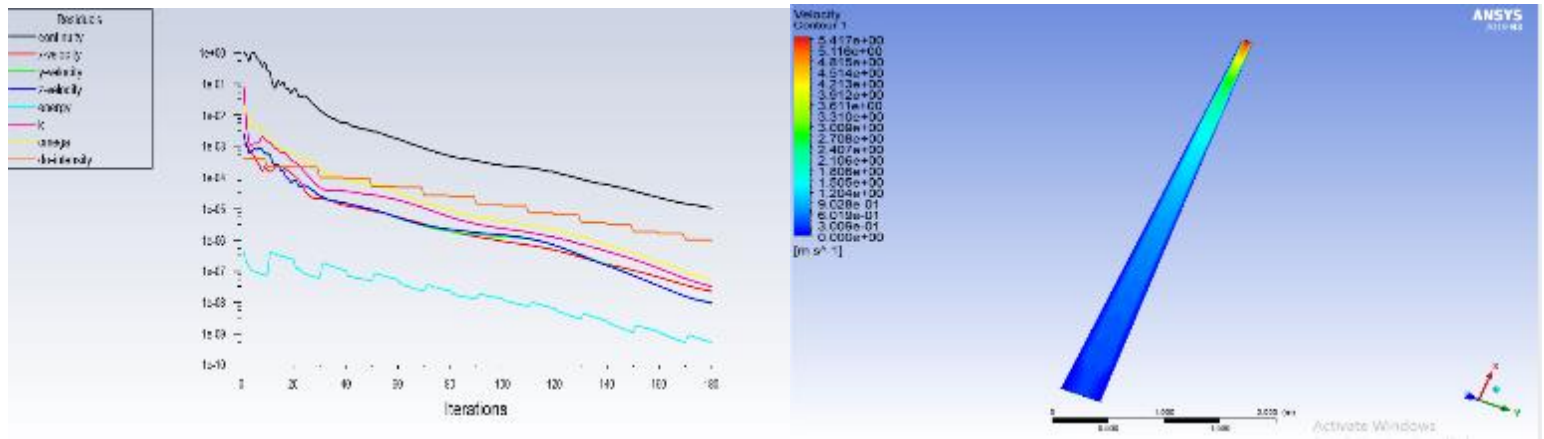


Figure 122: 0.3 m/s Aluminum

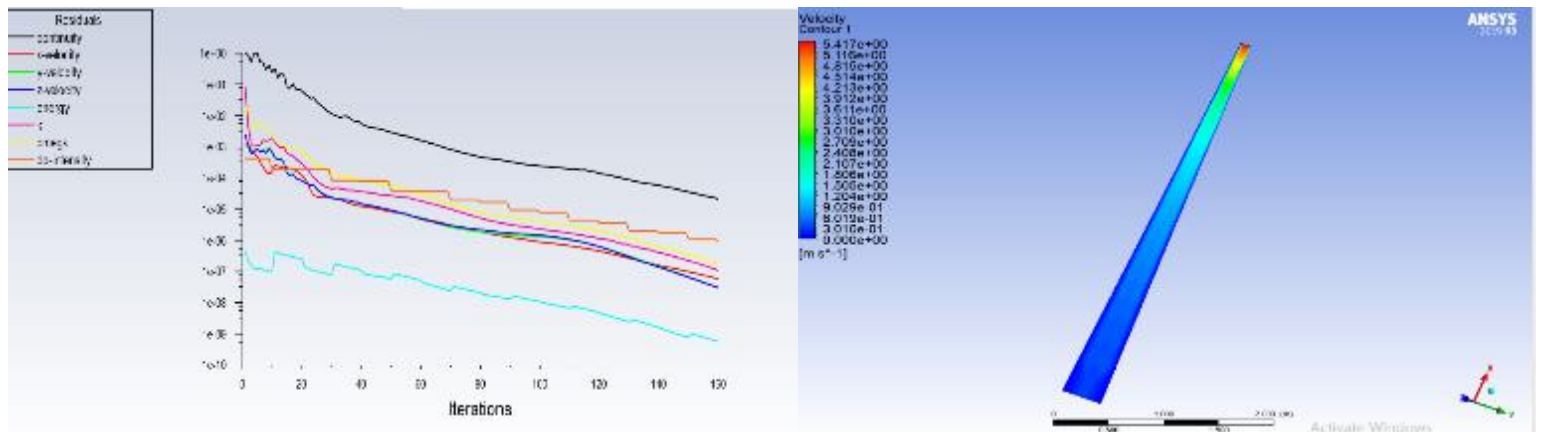


Figure 123: 0.3 m/s PVC

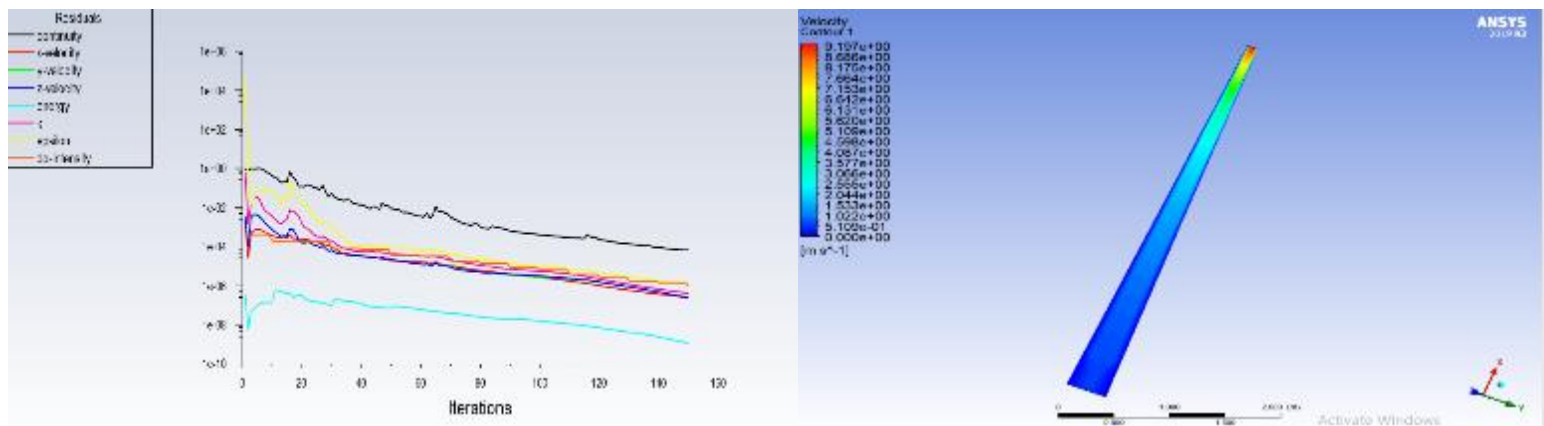


Figure 124: 0.3 m/s Steel

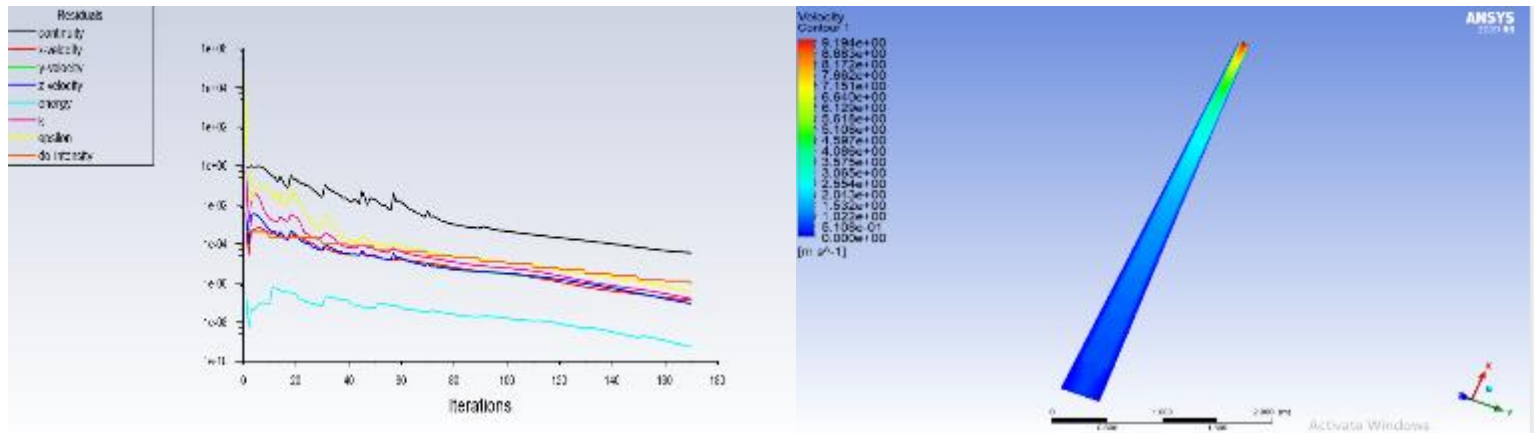
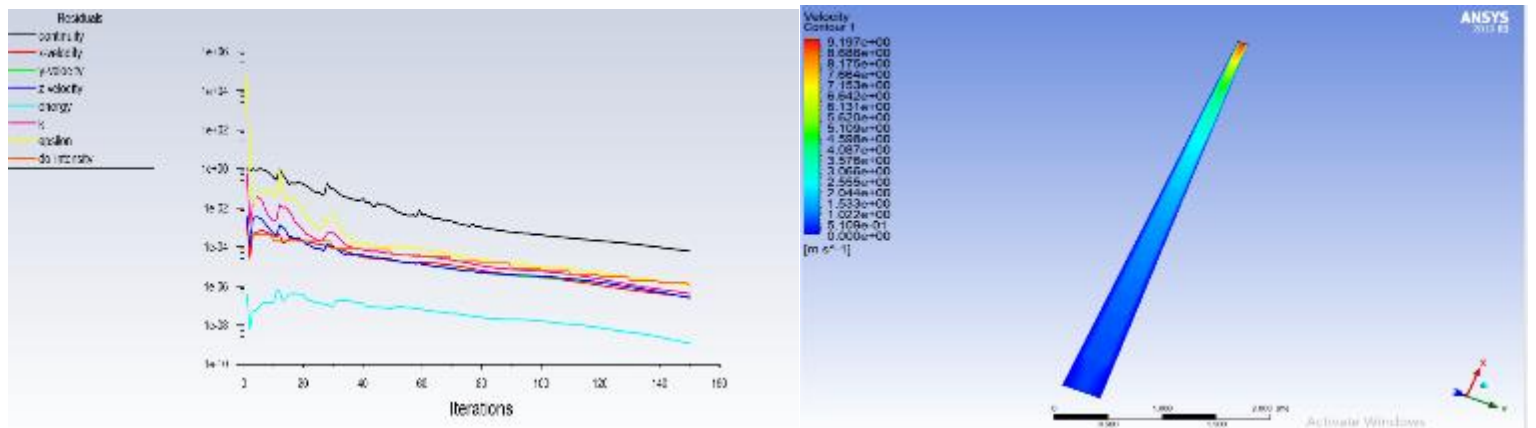


Figure 125: 0.5 m/s Aluminum



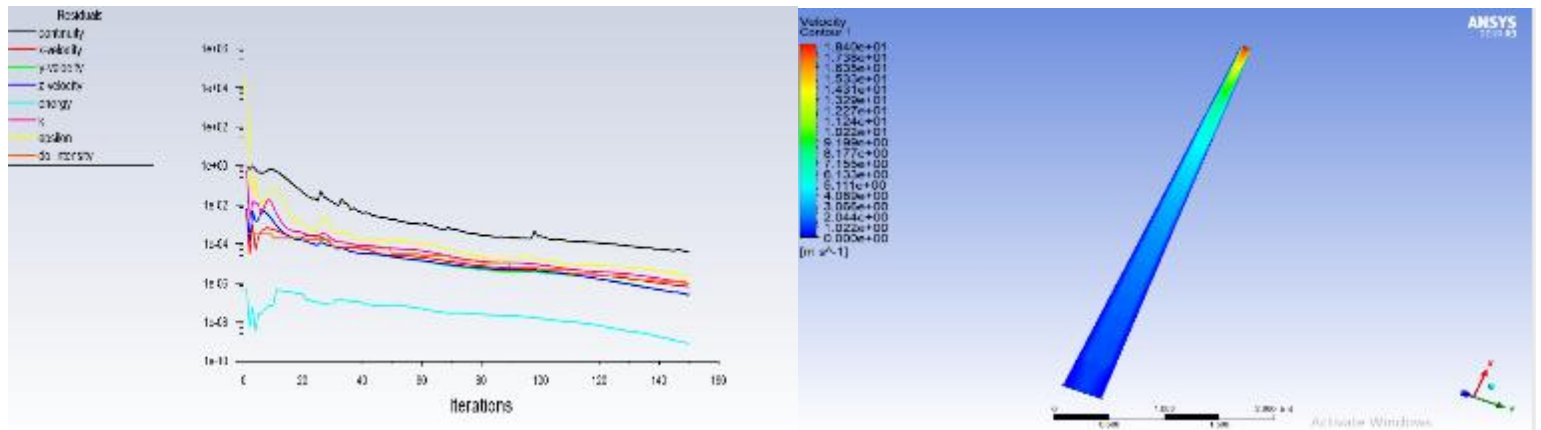


Figure 128: 1 m/s Aluminum

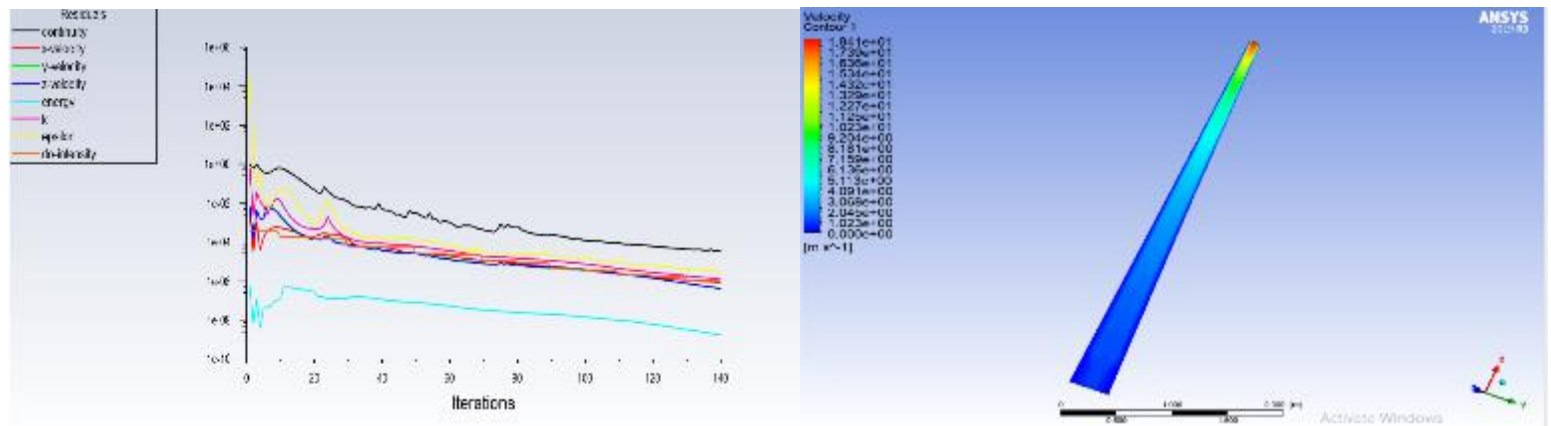


Figure 129: 1 m/s PVC

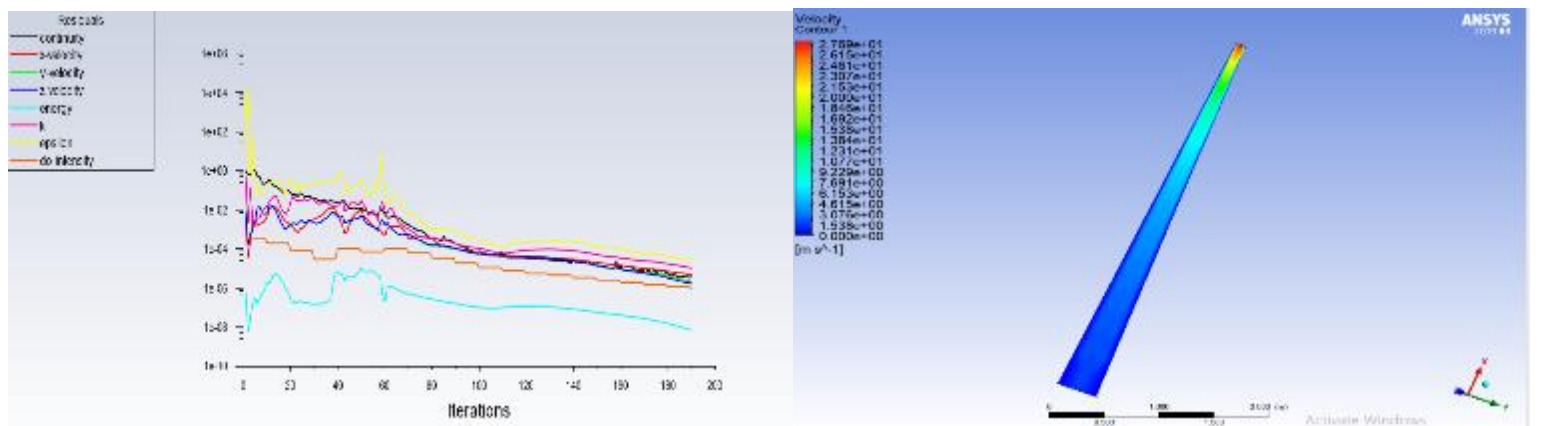


Figure 130: 1 m/s Steel

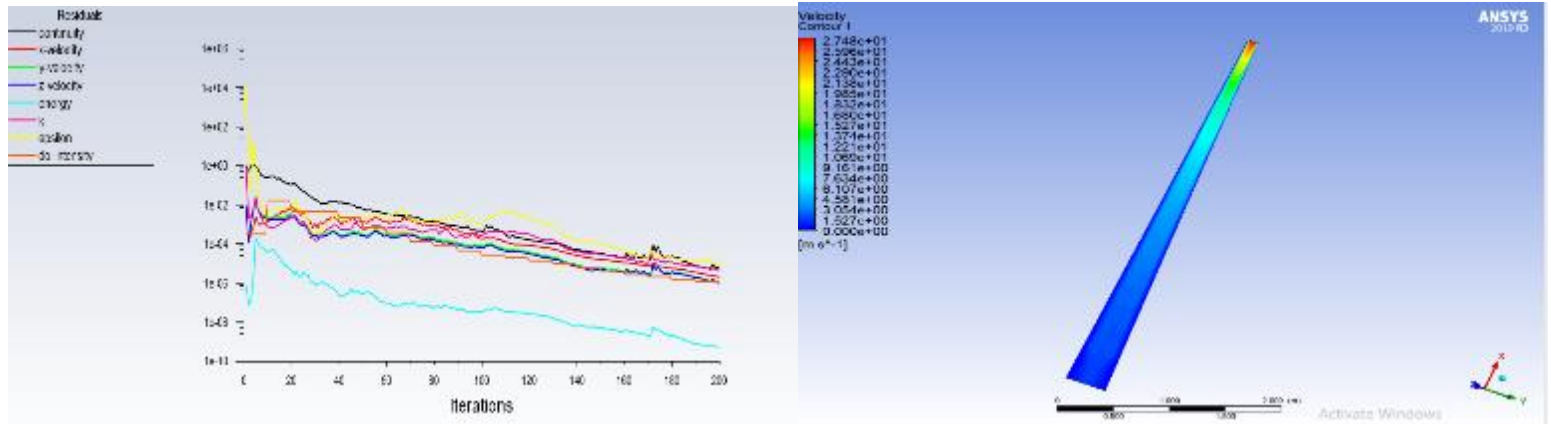


Figure 131: 1.5 m/s Aluminum

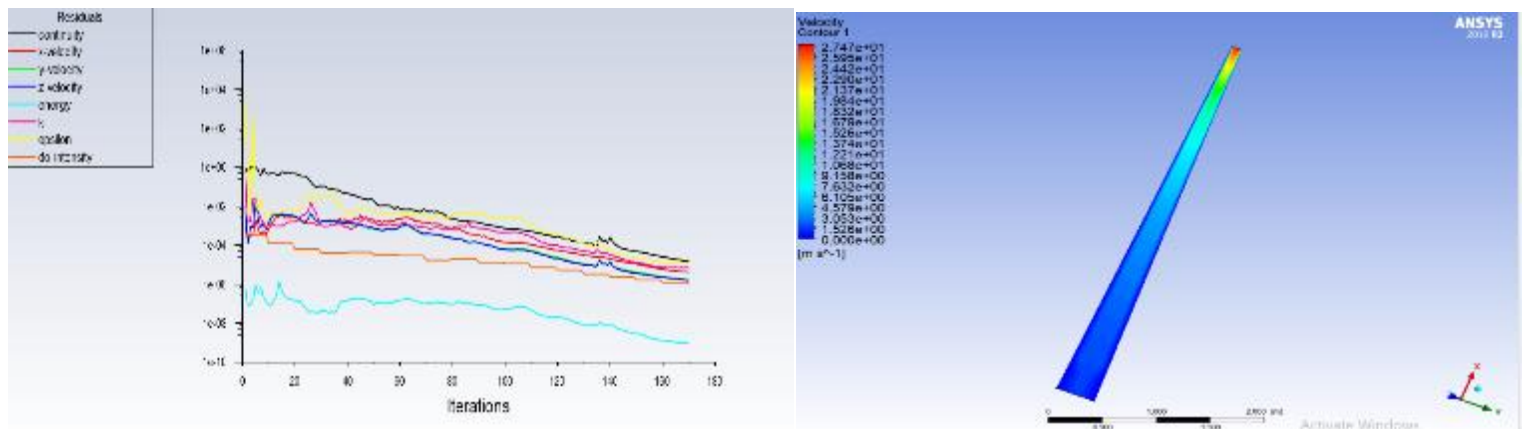


Figure 132: 1.5 m/s PVC

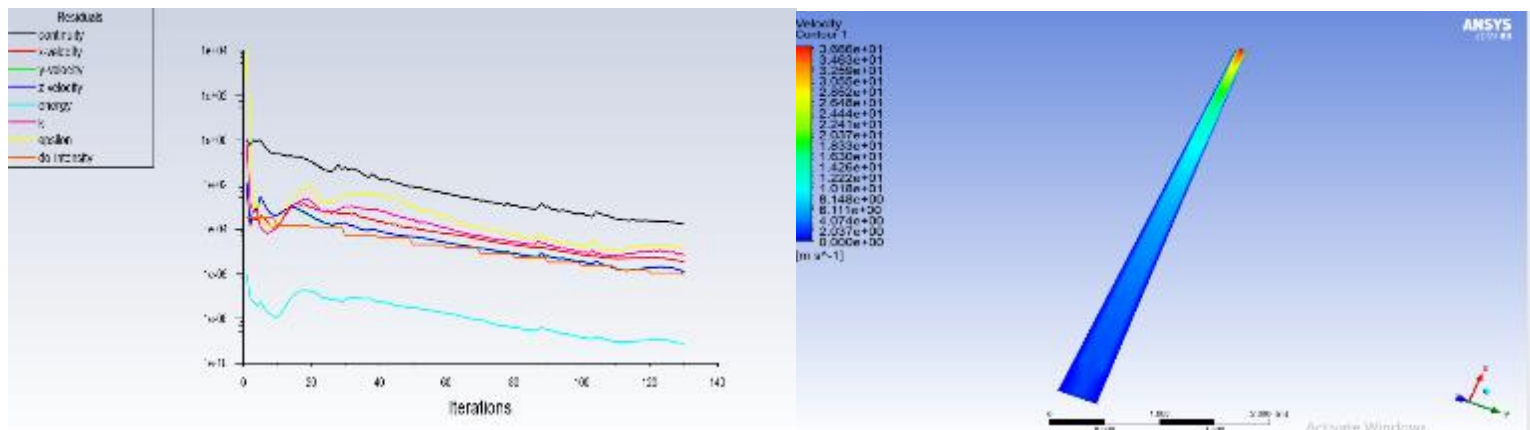


Figure 133: 1.5 m/s Steel

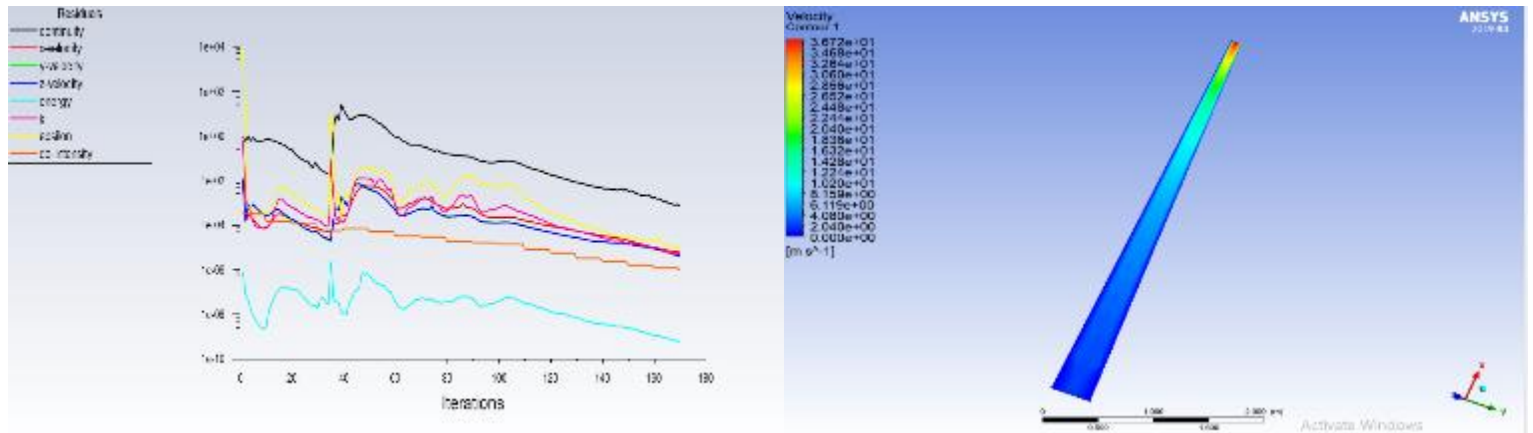


Figure 134: 2 m/s Aluminum

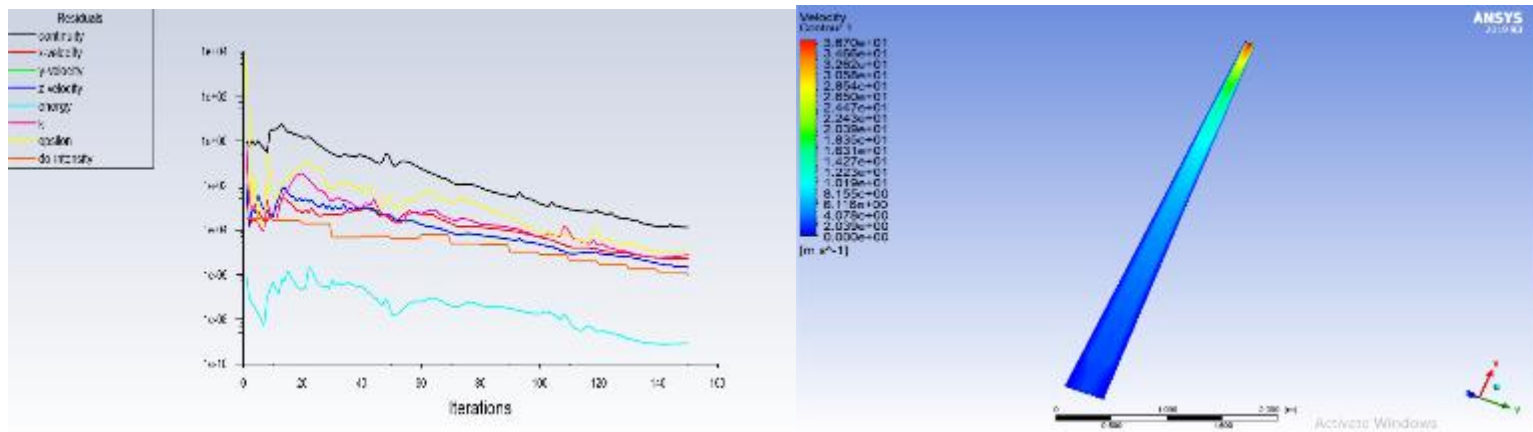


Figure 135: 2 m/s PVC

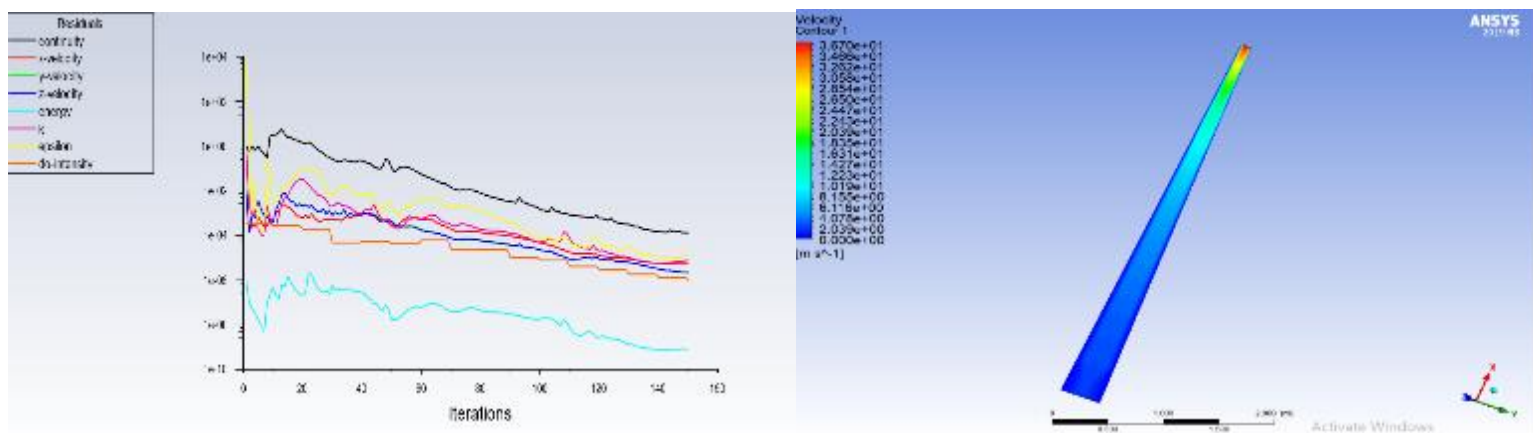


Figure 136: 2 m/s Steel

9.7 HELICAL PIPE

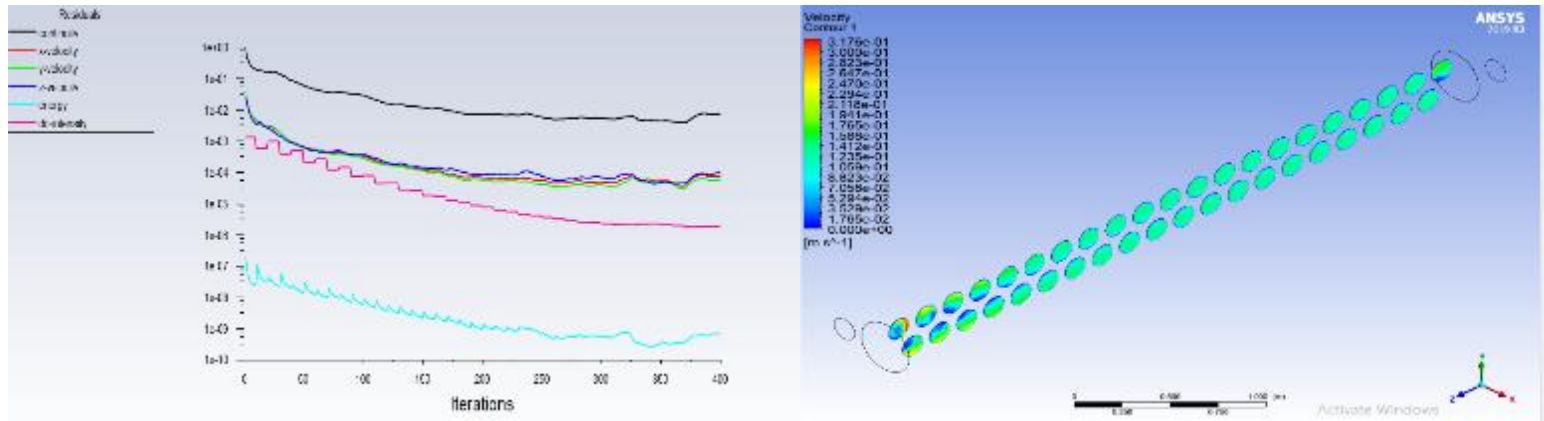


Figure 137: 0.1 m/s Aluminum

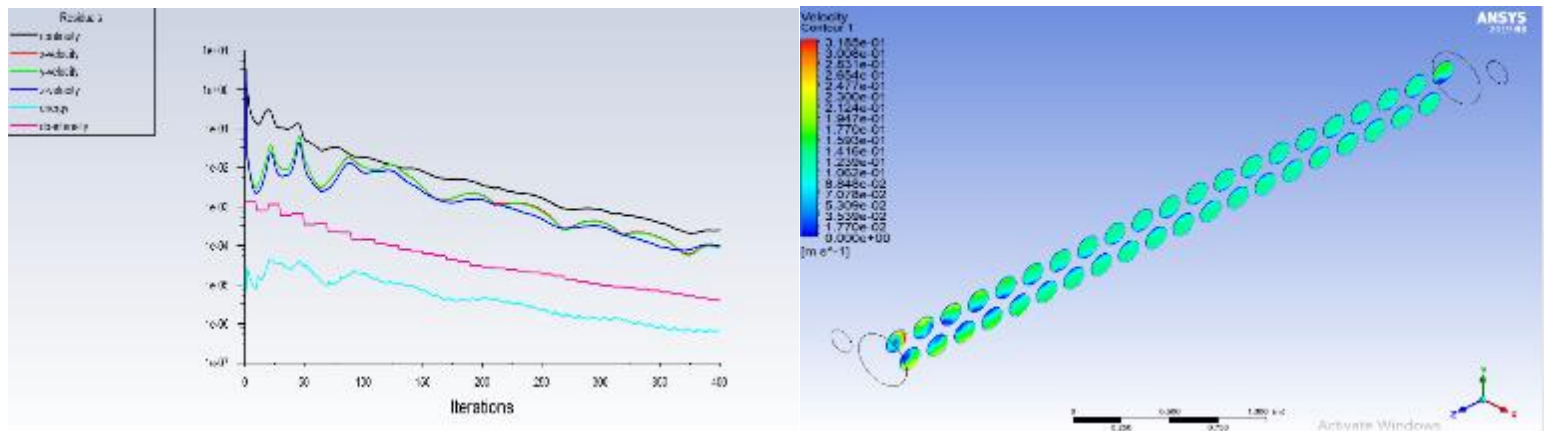


Figure 138: 0.1 m/s PVC

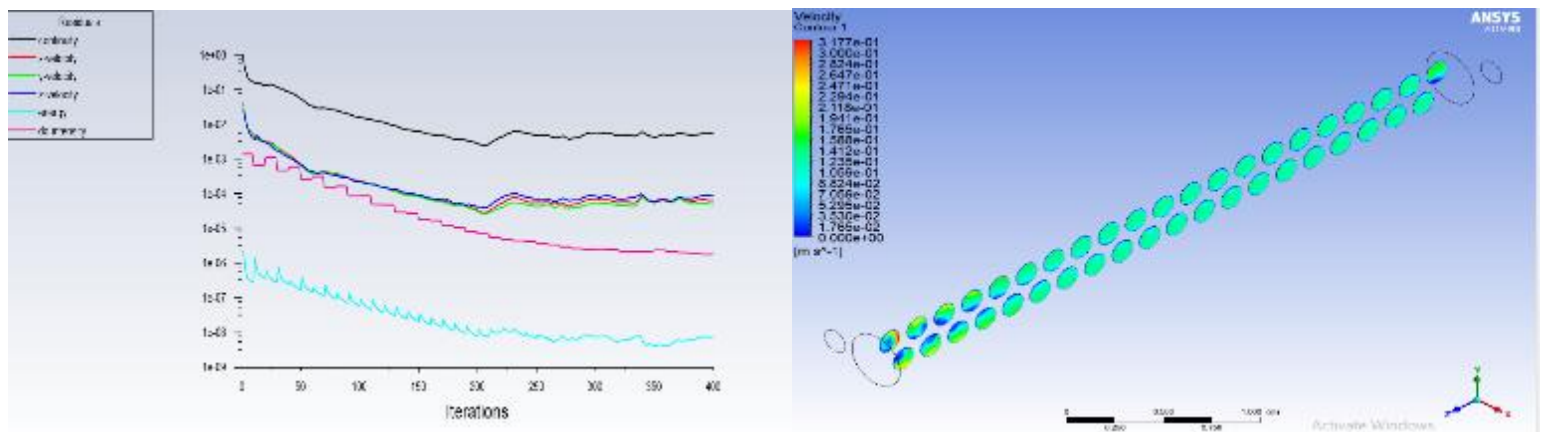


Figure 139: 0.1 m/s Steel

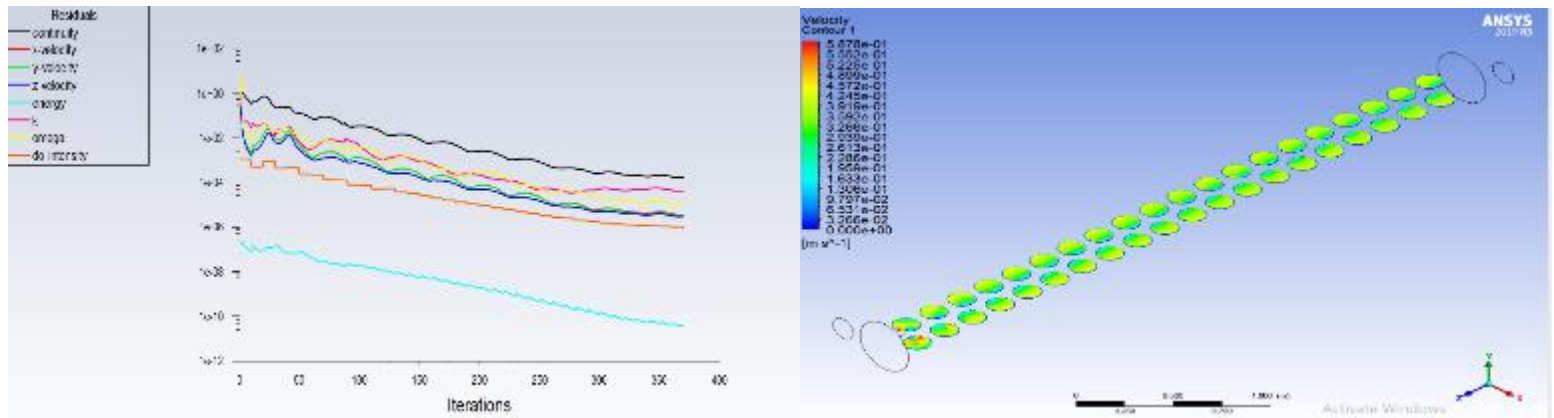


Figure 140: 0.3 m/s Aluminum

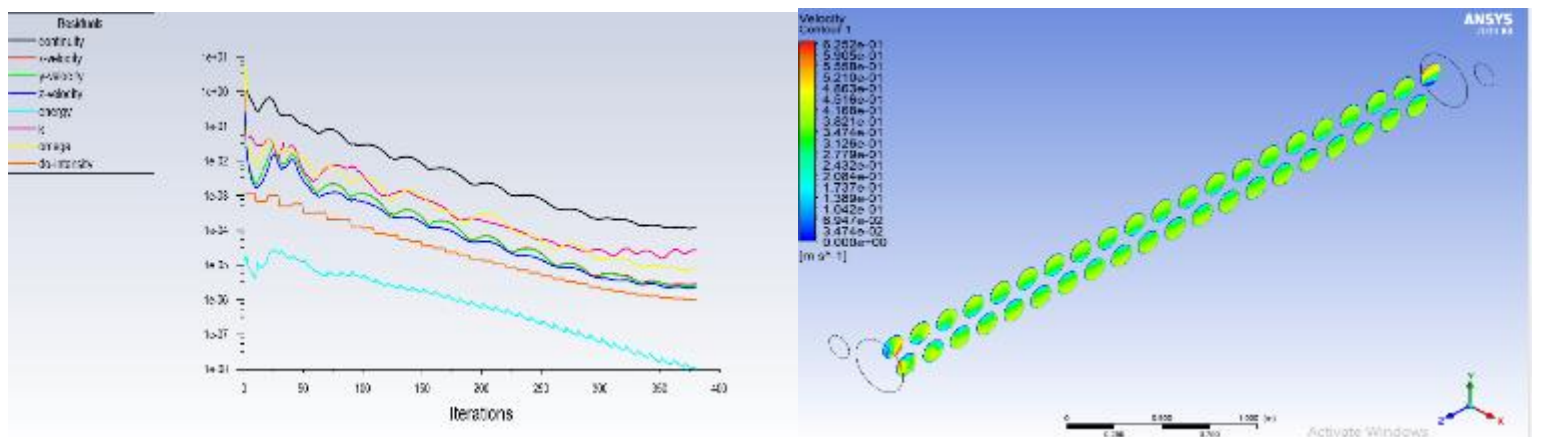


Figure 141: 0.3 m/s PVC

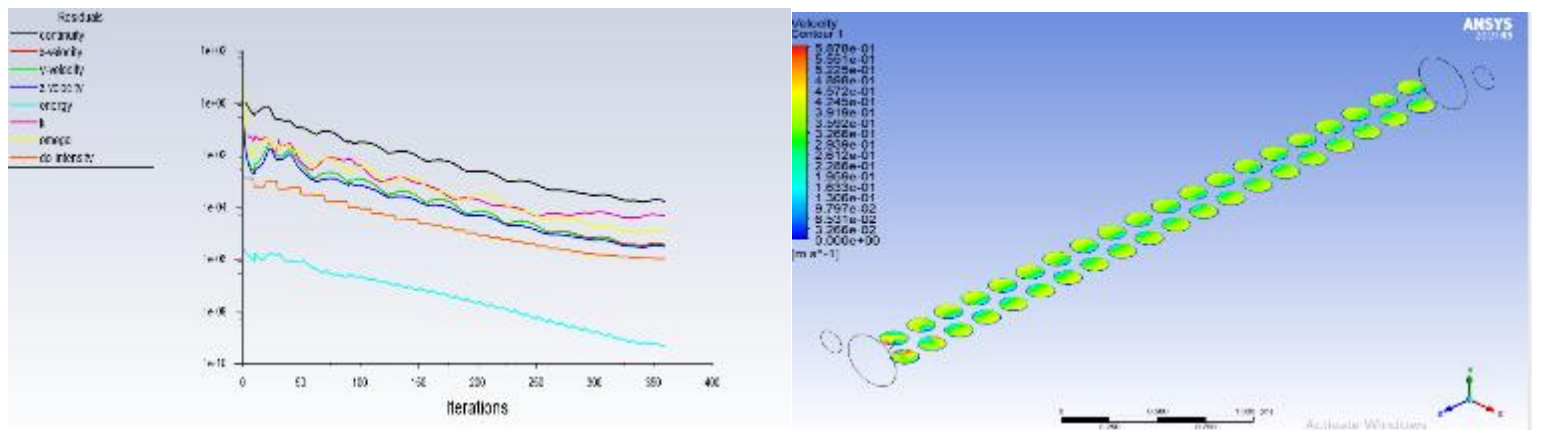


Figure 142: 0.3 m/s Steel

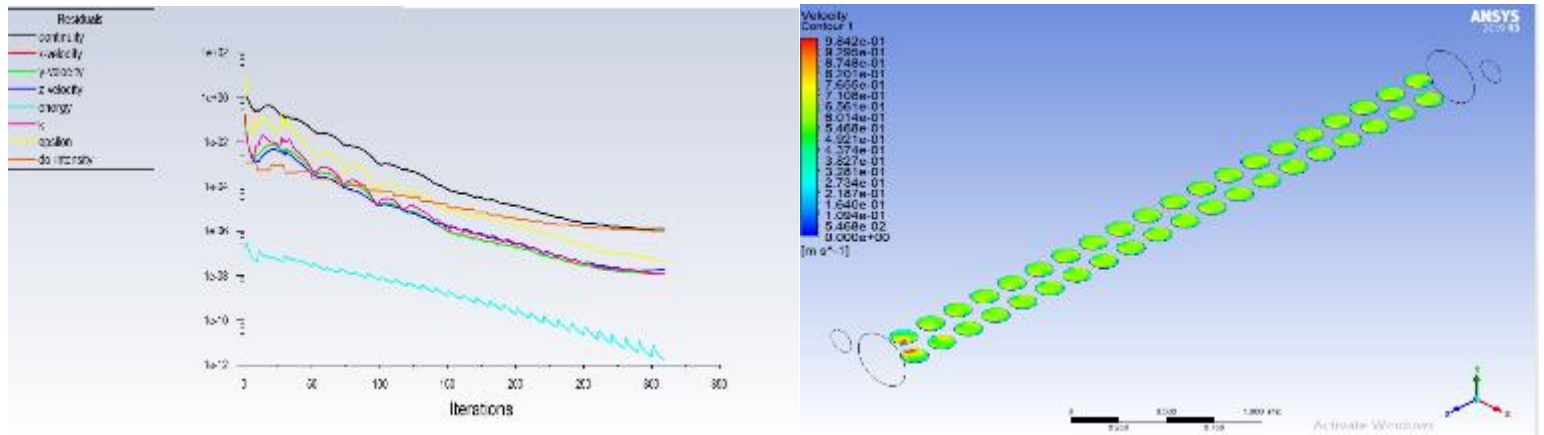


Figure 143: 0.5 m/s Aluminum

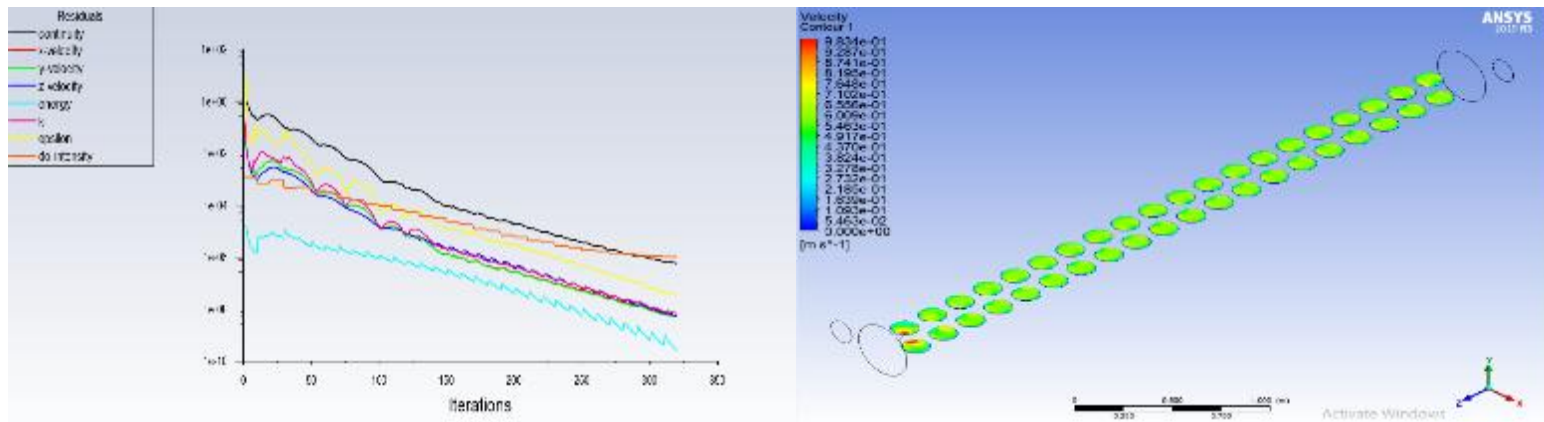


Figure 144: 0.5 m/s PVC

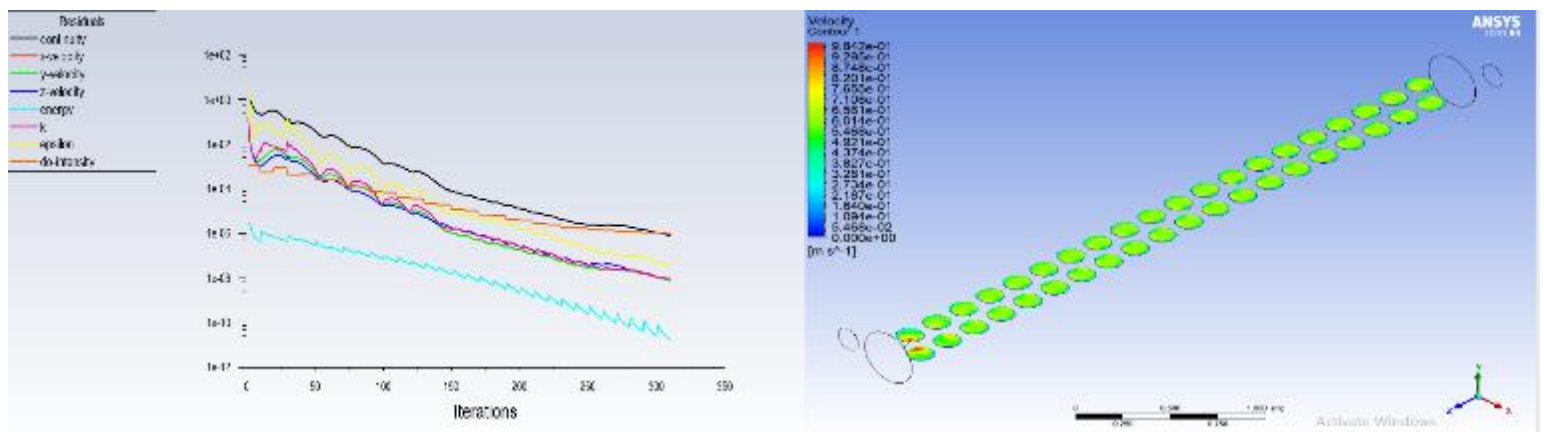


Figure 145: 0.5 m/s Steel

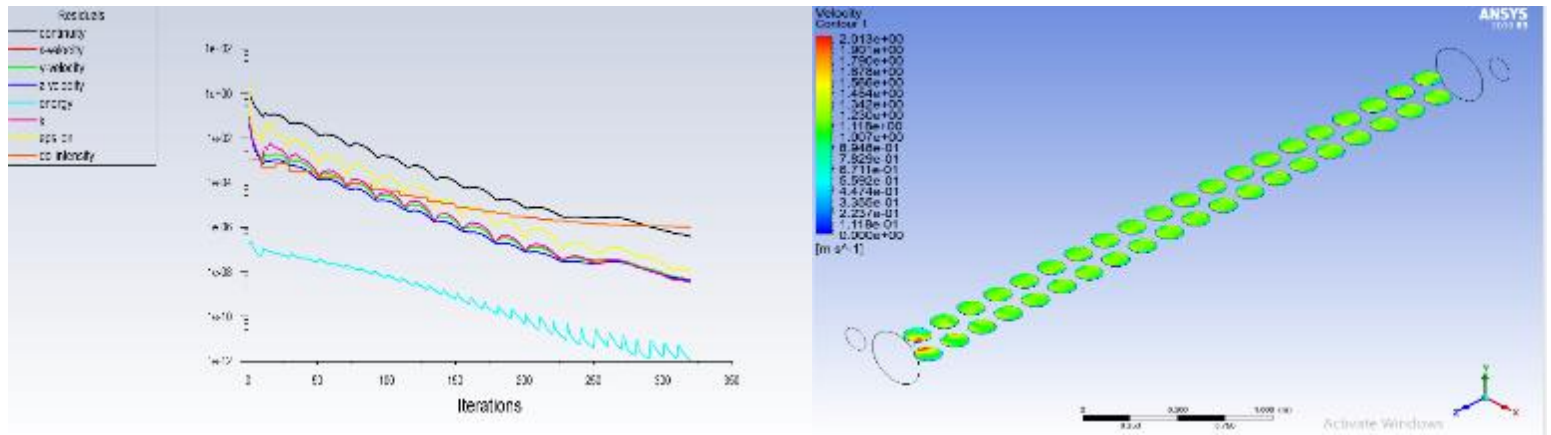


Figure 146: 1 m/s Aluminum

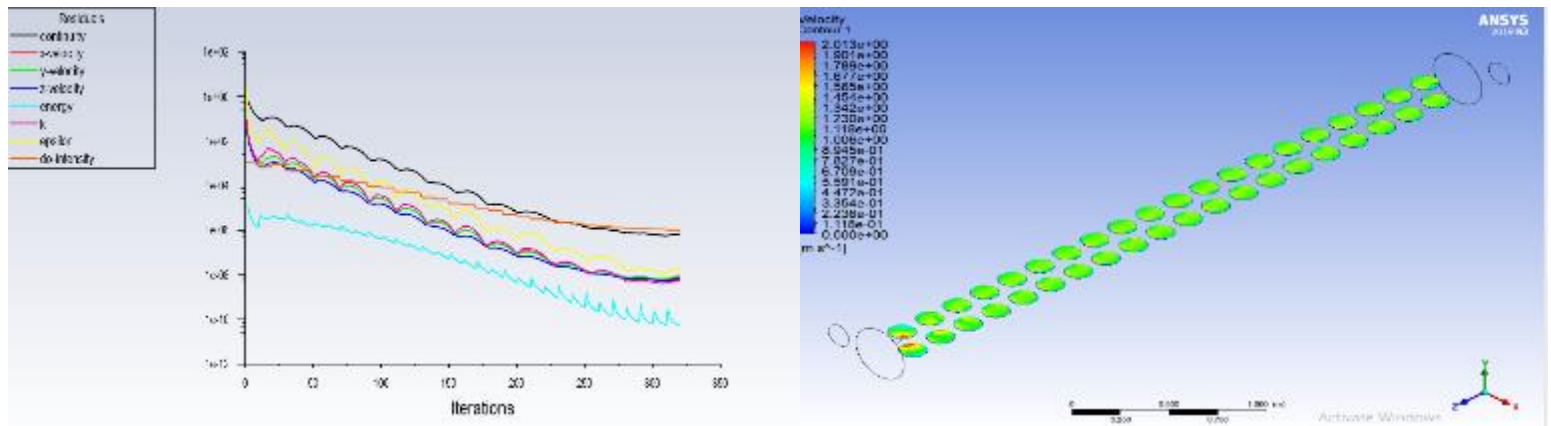


Figure 147: 1 m/s PVC

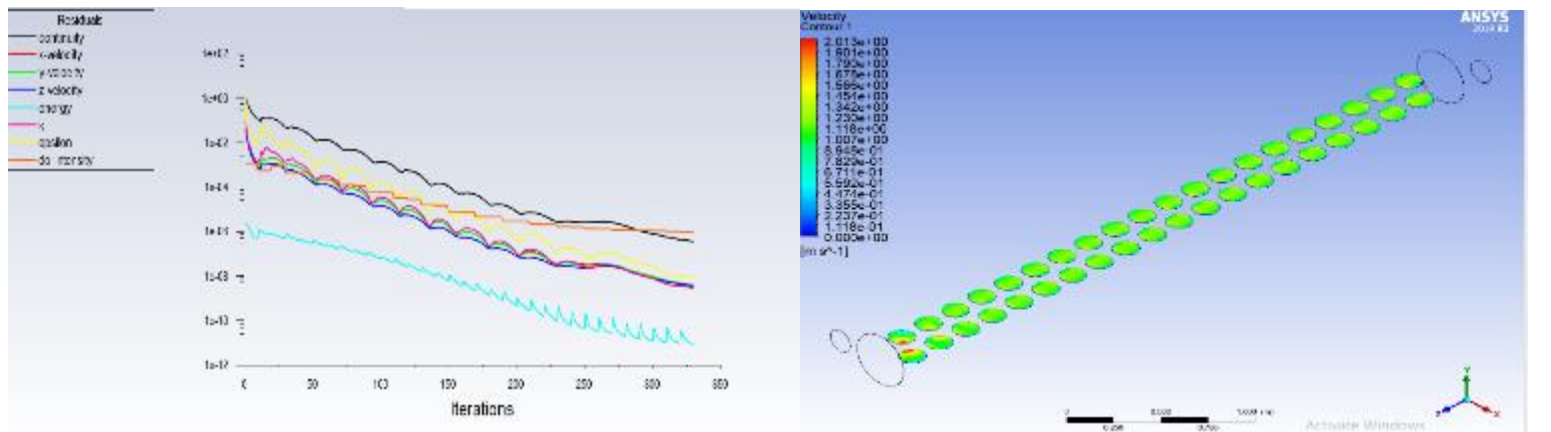


Figure 148: 1 m/s Steel

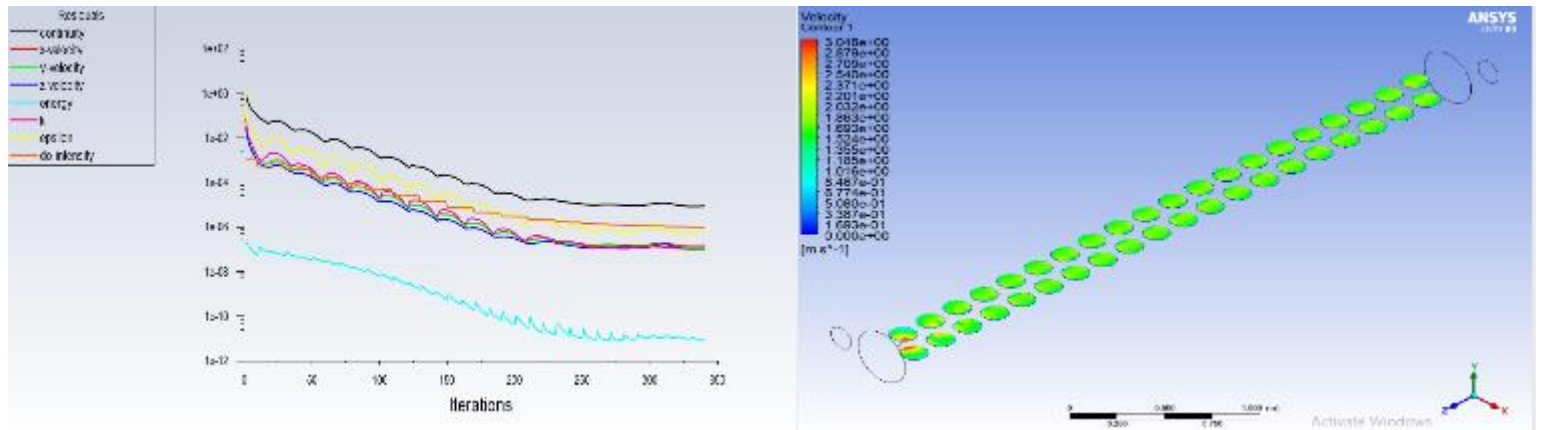


Figure 149: 1.5 m/s Aluminum

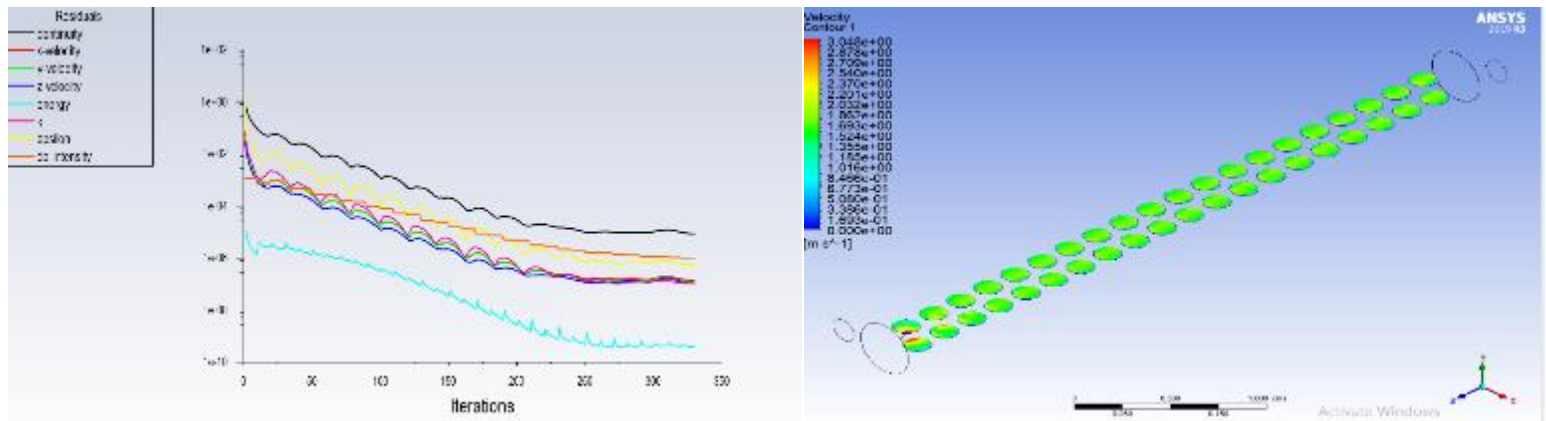


Figure 150: 1.5 m/s PVC

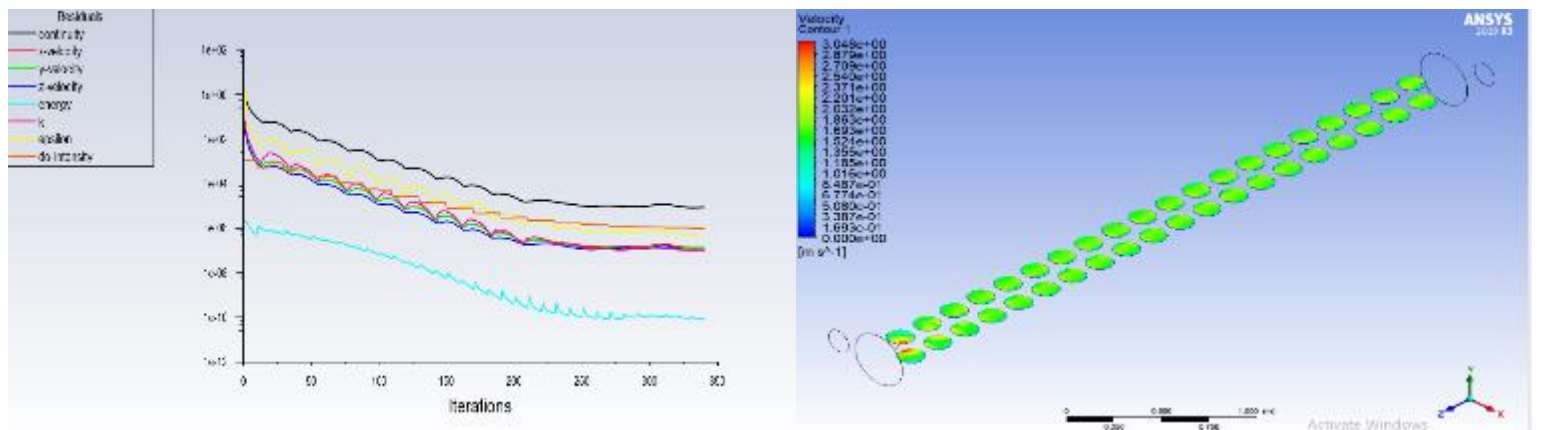


Figure 151: 1.5 m/s Steel

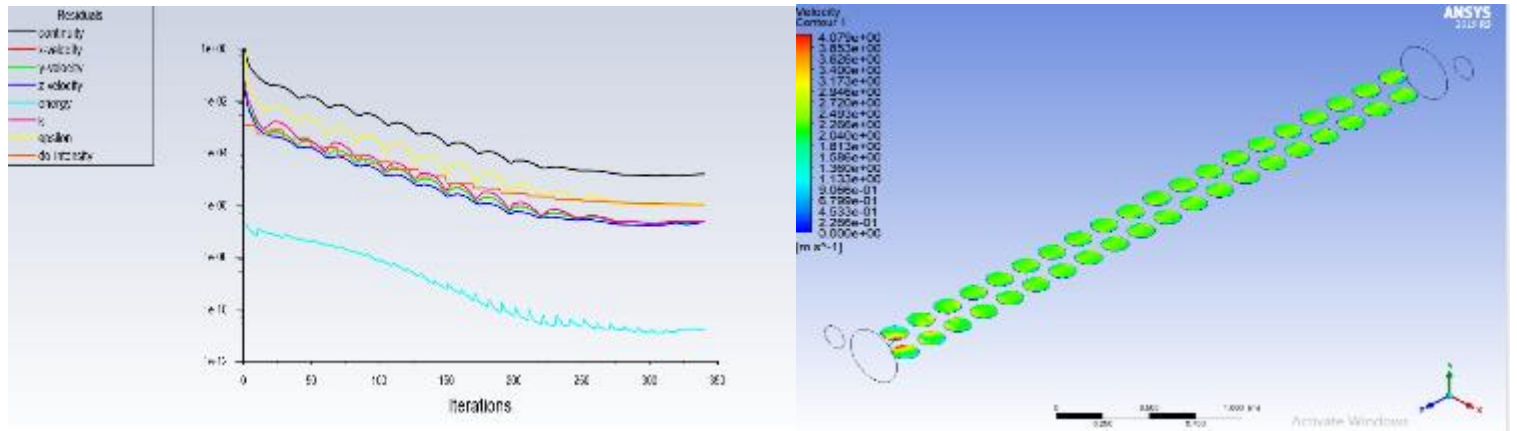


Figure 152: 2 m/s Aluminum

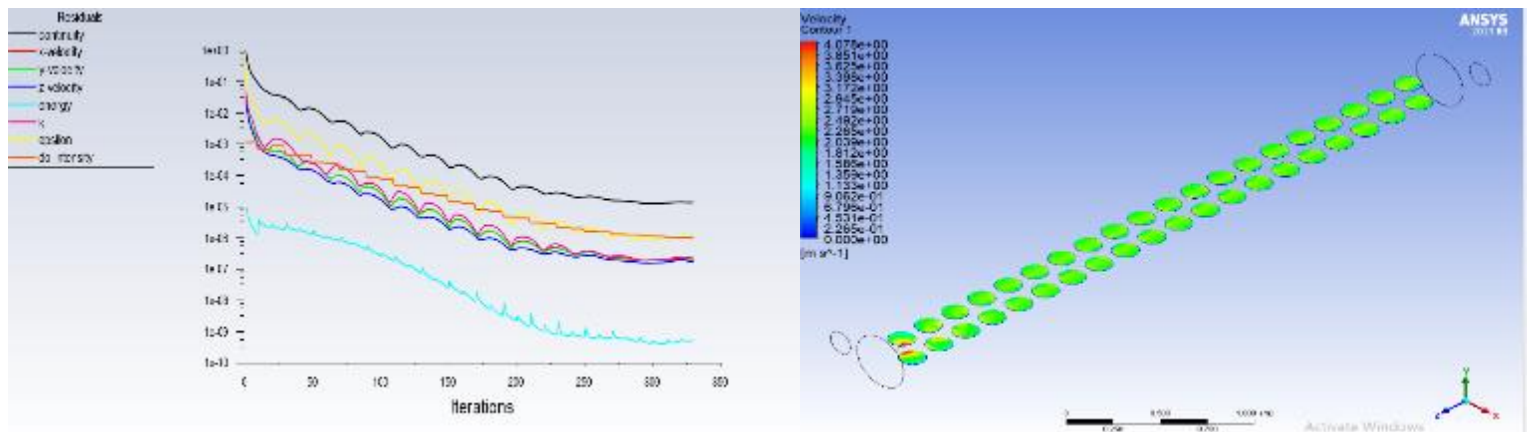


Figure 153: 2 m/s PVC

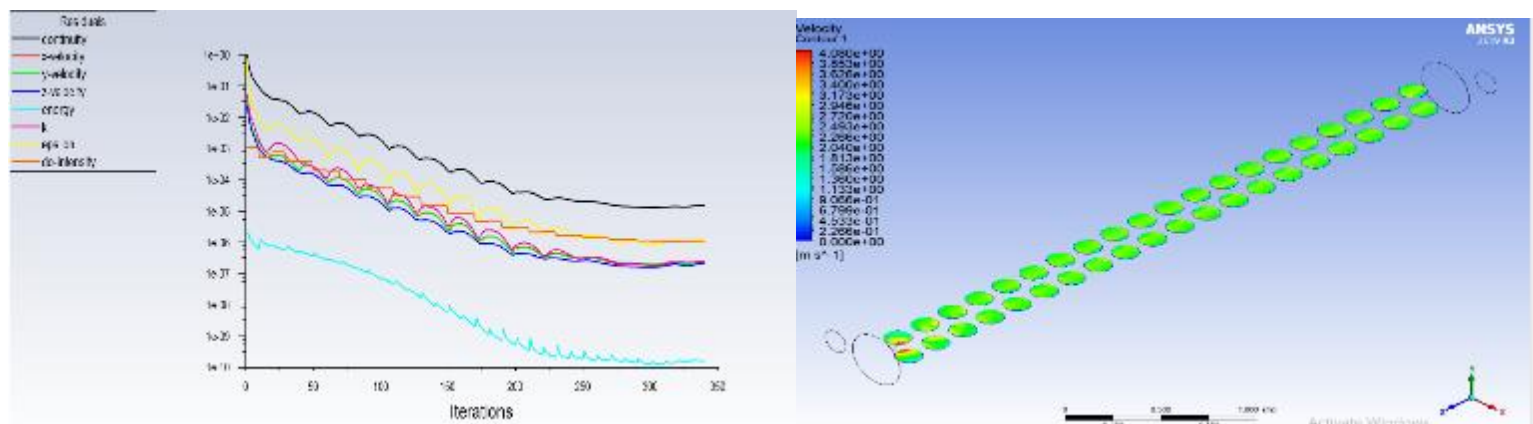


Figure 154: 2 m/s Steel