ISSN No:-2456-2165

CFD Analysis of Non-Circular Coaxial Jet

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Abstract:- Coaxial jets are produced when two miscible streams of fluids are emitted with different speeds in the same directions from an inner and a concentric outer into a region of fluid with which each of the streams is freely miscible. Using the Coaxial jet concept, using velocity ratio and varying shape of the co flow jet to estimate the variation of turbulence and floe characteristics. Using Ansys FLUENT software for CFD analysis. The major part of the project involves turbulence flow field and flow characteristics of different non-circular shapes and are compared to the circular shape.

Keyword:- *Fuel Injector, Circular Coaxial Jet, Non-Circular Coaxial Jet, Flow Characteristics, Turbulence Characteristics).*

I. INTRODUCTION

Coaxial jets are widely used in mixing of the fluids. Coaxial jets produced when two miscible streams of fluid are emitted with different speeds in the same direction from an inner and a concentric outer into a region of fluid with which each of the streams is freely miscible. The phenomenon of mixing is a subject of crucial importance in devices involving chemically reacting flows. In these devices, the flow field produced by a Jet discharging into a stagnant or moving (either in the parallel or the cross-direction) fluid is the most common configuration in current use.

Coaxial jets can be used as injector, Nozzle inlet, Nozzle exit of the engine and throat section, etc., Using the coaxial jet concept, we can vary the Inlet and outlet velocity flow, Area ratio and shape of the jet to estimate the variation of turbulence and flow characteristics during the working process. The flow field generated by Coaxial jets can be investigated using Experimental Values and Numerical analysis.

The Coaxial jets can be divided into the initial merging, the intermediate merging and the outer potential core disappears. The fully merged zone occurs downstream of the reattachment point which is the point where the locus of the mean velocity intercepts the jet axis. Between the two zones is the intermediate merging zone where the two mixing regions meet. The potential core of inner circle and outer circle in the jet in which the centreline velocity remains essentially constant and equal to the centreline velocity at the nozzle exit. The inner mixing will be larger compared to the outer mixing region.

II. FUEL INJECTOR

Fuel injectors are devices that are responsible for spraying (injecting) the right amount of fuel into the engine, so that a suitable air/fuel mixture is created for optimal combustion. In this project the fuel injector design is based on the coaxial jet concept.

A Fuel injector of coaxial jet shaped is a part of modern engines that deliver fuel to the engines combustion chamber, directly or indirectly. In injector the coaxial jets are used for the fuel and oxidizer mixing with a proper mixing velocity ratio, the area ratio depends on the velocity ratio, while the area ratio varies as when there is a change in the velocity ratio of the jet.

For smaller engines, inlet-port fuel injection can increase the power output of an engine by merely reducing the temperature of the air charge, thereby increasing the density of the fuel and air mix. In most cases a 10 percent increase in power is achieved without any change to compression ratios or engine RPM as something the carburettor cannot do.

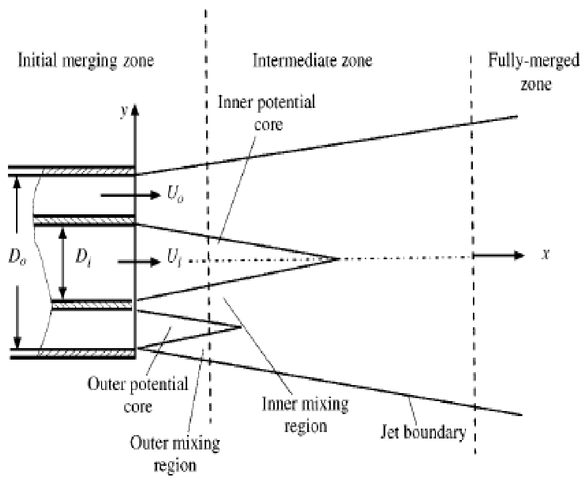

Fig 1:- Flow Field Diagram of Coaxial jet configuration

Varying the Primary inlet shapes and with constant Secondary inlet and velocity and are compare with the circular shape. using Ansys FLUENT the simulation of the turbulence flow field and flow characteristics are determined.

III. NUMERICAL DETAILS

The first step was to do literature review of the topic. So, I searched for some previous works done in this topic and got myself familiar with the topic. The second step was to gather the required software's for this which in this case was ANSYS FLUENT-CFD Analysis systems.

ANSYS Workbench is a software environment for performing structural, thermal, and electromagnetic analyses. It focuses on geometry creation and optimization, attaching existing geometry, setting up the finite element model, solving, and reviewing results. Some textual and visual manuals to learn ANSYS. Then, I modelled Circular coaxial jet and obtained the flow characteristic and turbulent characteristics from the Analysis results.

❖ *Methodology*

The methodology adopted and research design taken under consideration will be discussed in this chapter. The details of the computational studies adopted are discussed below

A. Geometry

The coaxial nozzle shapes are designed using ANSYS student design modeler 19. The coaxial jet designed by varying the shape of secondary (outer) nozzle with fixed primary (inner) nozzle. For the simulation. The shape varying of the primary nozzle are manipulated using hydraulic diameter which is used for calculation to find different shapes with same volume. The outer nozzle diameter D_o = 17.8 mm and the inner nozzle diameter are D_i = 12.7. The length and diameter for the circular domain are 24 D_i and 15 D_i . Outer jet diameter is modeled for different shaped based on hydraulic diameter. Hydraulic diameter is mathematically represented as follows,

$$D_h = \frac{4[\,Area\ of\ cross\ section]}{Perimeter}\ \text{mm}$$

The values necessary for creating a three dimensional geometry was calculated and tabulated.

SKETCH (CIRCLE)	DIMENSIONS (mm)
Inner Diameter	12.7
Outer Diameter	17.8
Thickness	1

Table 1:- For circle-circle coaxial jet

SKETCH (SQUARE)	DIMENSIONS (mm)
Inner Diameter	12.7
Outer Diameter	15.8
Inner Thickness	1

Table 2:- For Square-Circle coaxial jet

SKETCH (ELLIPSE)	DIMENSIONS (mm)
Inner Diameter	12.7
Outer Diameter	X – 9.9,Y – 7.9
Inner Thickness	1

Table 3:- For Ellipse-Circle coaxial jet

SKETCH (RECTANGLE)	DIMENSIONS (mm)
Inner Diameter	12.7
Outer Diameter	X–16.8,Y– 14.8
Inner Thickness	1

Table 4:- For Rectangle-Circle coaxial jet

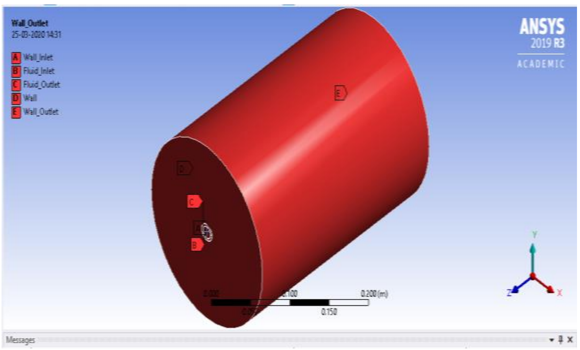

Fig 2:- Geometry of Circle-circle coaxial jet Domain

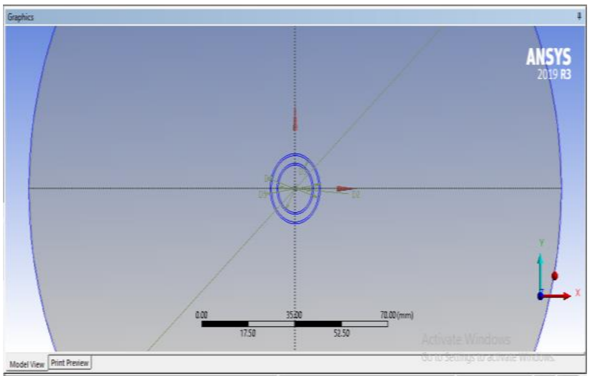

Fig 3:- Geometry of the circle-circle coaxial jet

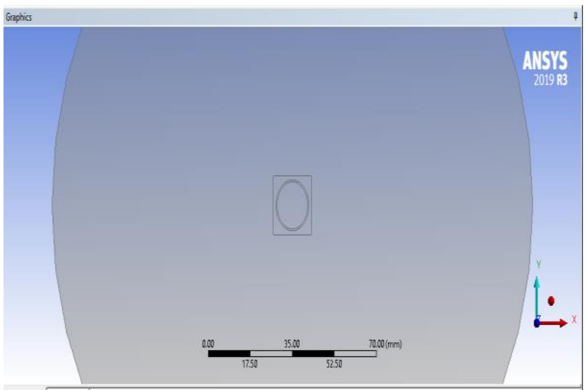

Fig 4:- Geometry for Square-circle Coaxial jet

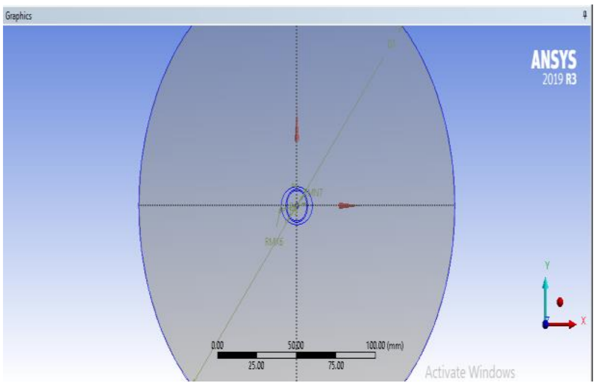

Fig 5:- Geometry for Ellipse-circle Coaxial jet

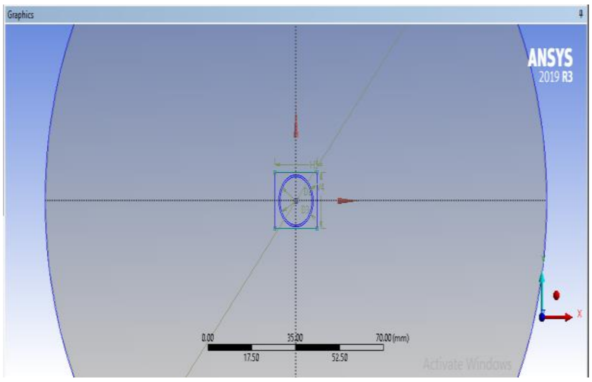

Fig 6:- Geometry of Rectangle-circle coaxial jet

B. Computational Methods

The four coaxial nozzle shapes are designed. The meshing was the important phenomenon in pre-processing as it discretizes the entire domain into small units for obtaining accurate results. For each of the nozzle the mesh is done with grid sensitivity analysis.

The solver method used in this study is Ansys FLUENT Student Version 19. In this simulation study the linear two-equation formulation are used to calculate the flow from the jet exit.

C. Boundary Conditions:

Meshing was followed by specification of boundary conditions for the model created which should be done in the Ansys. The modelled file should be exported as 3D mesh file and saved for processing.

The inlet which was taken as mass flow inlet, Velocity inlet and Velocity Outlet portion. The domain inlet is Pressure inlet and Pressure outlet was considered at domain outside of our model, other boundaries are considered as wall. Through domain the flow is passed for the estimation of the flow characteristics. The conditions were given in table.

Boundary Name	Boundary Type
Coaxial jet surface	Wall(Domain)
Circular coaxial jet	Symmetry
Geometry	3-D Model
Model	Viscous K-epsilon Model
Material	Fluid – Air Solid - Aluminium
Boundary Conditions	Primary Fluid Secondary Fluid Wall (Domain)
Primary Fluid velocity	208 m/s
Secondary Fluid Velocity	177 m/s
Velocity Ratio	1.17
Temperature	Constant
Methods	Second Order Upwind

Table 5:- Boundary conditions

IV. RESULTS AND DISCUSSION

In this chapter we are going to discuss on the method we followed during analysis and results we obtained for the analysis of the Circular and Non-Circular coaxial jet. The result for the analysis of the circular and non-circular coaxial jet is displayed in the table. The flow characteristic and the turbulence flow values are presented to the understanding of the circle-circle, Square-circle, ellipse-circle, rectangle-circle coaxial jet.

From the simulation the results for the cicular coaxial jet is shown in Figures listed below, which have value shown from minimum value to the maximum value throughout the section.

The Velocity Contour for the circle-circle coaxial jet is shown in Figure 5.1, the maximum velocity flow through the Inlett is 209.4 m/s

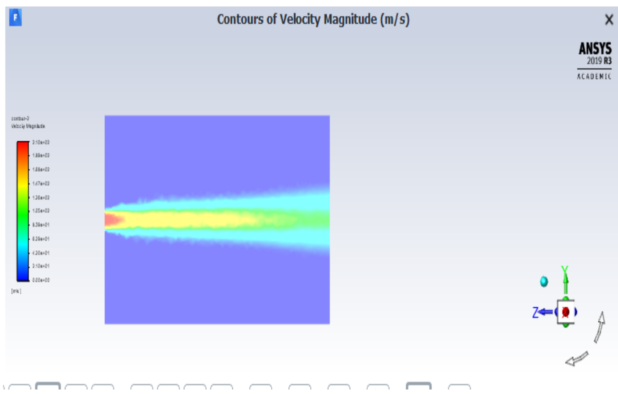

Fig 7:- Velocity of the circle-circle coaxial jet

The Velocity Contour for the square-circle coaxial jet is shown in Figure 5.2, the maximum velocity flow through the inlet is 210.76 m/s

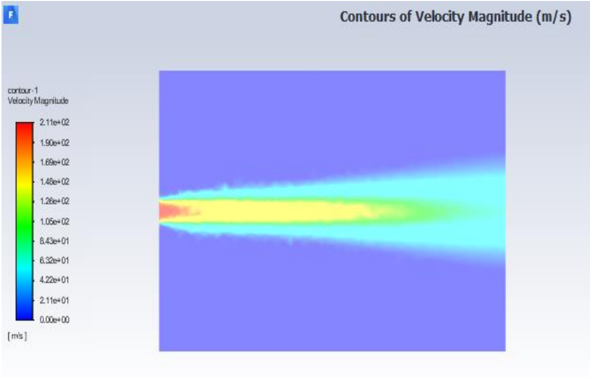

Fig 8:- Velocity of the Square-circle coaxial jet

The Velocity Contour for the Ellipse-circle coaxial jet is shown in Figure 5.3, the maximum velocity flow through the inlet is 209.66 m/s

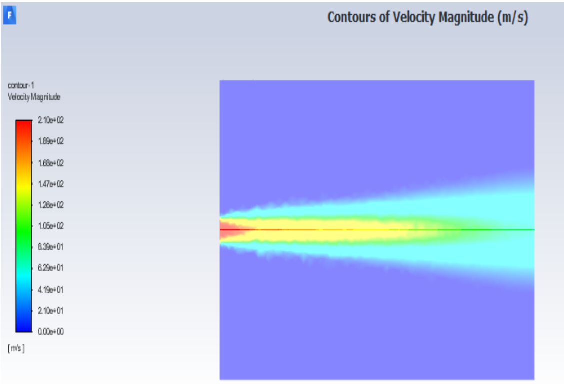

Fig 9:- Velocity of the ellipse-circle coaxial jet

The Velocity Contour for the Rectangle-circle coaxial jet is shown in Figure 5.4, the maximum velocity through the Inlet is 211.38 m/s

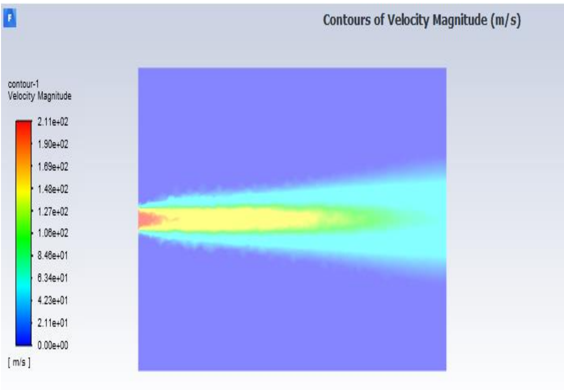

Fig 10:- Velocity for the Rectangle-circle coaxial jet

The Turbulence Kinetic Energy for circle-circle coaxial jet is shown in Figure 5.5, the Maximum turbulent kinetic energy is 400.8 m^2/s^2

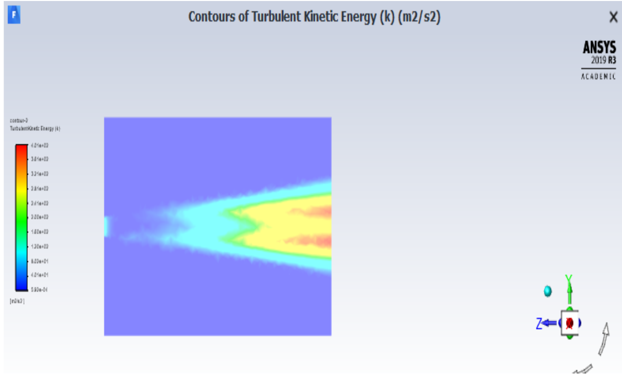

Fig 11:- Turbulence Kinetic energy for circle-circle coaxial jet

The Turbulence Kinetic Energy for Square-circle coaxial jet is shown in Figure 5.6, the Maximum turbulent kinetic energy is 619.63 m^2/s^2

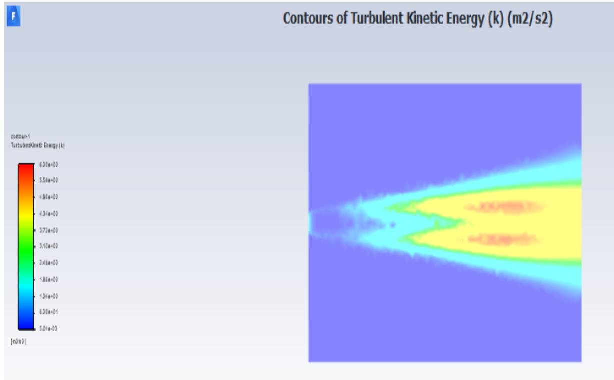

Fig 12:- Turbulence Kinetic energy for Square-circle coaxial jet

The Turbulence Kinetic Energy for Ellipse-circle coaxial jet is shown in Figure 5.7, the Maximum turbulent kinetic energy is 577.22 m^2/s^2

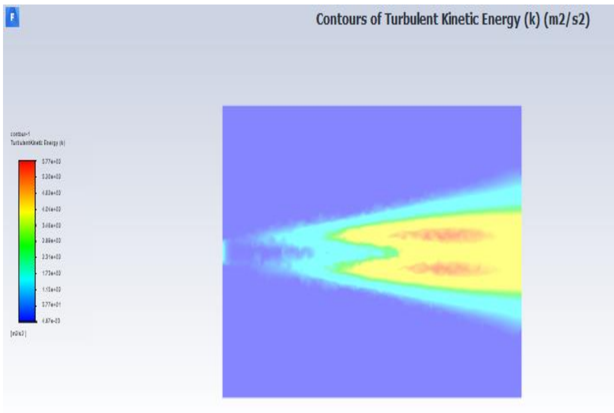

Fig 13:- Turbulence Kinetic energy for Ellipse-circle coaxial jet

The Turbulence Kinetic Energy for Rectangle-circle coaxial jet is shown in Figure 5.8,the Maximum turbulent kinetic energy is 599.69 m^2/s^2

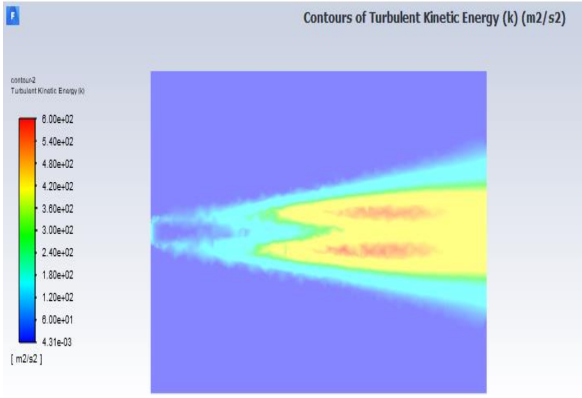

Fig 14:- Turbulence Kinetic energy for Rectangle-circle coaxial jet

Turbulence Intensity for the circle-circle coaxial jet is shown in Figure 5.9, the turbulence intensity for circle-circle is 2.0718- 1634.97 %

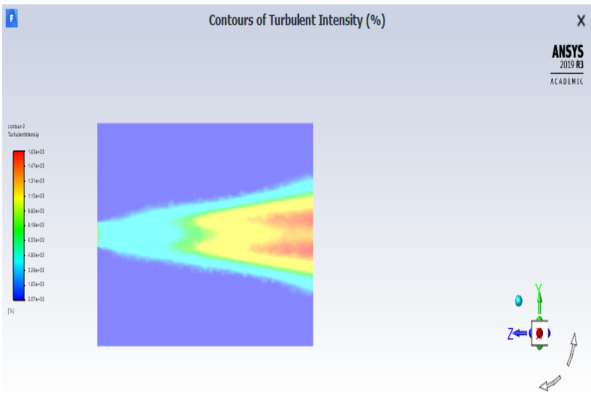

Fig 15:- Turbulence Intensity for circle-circle coaxial jet

Turbulence Intensity for the Square-Circle coaxial jet is shown in Figure 5.10, the turbulence intensity for Square-circle is 6.800 – 2032.28 %

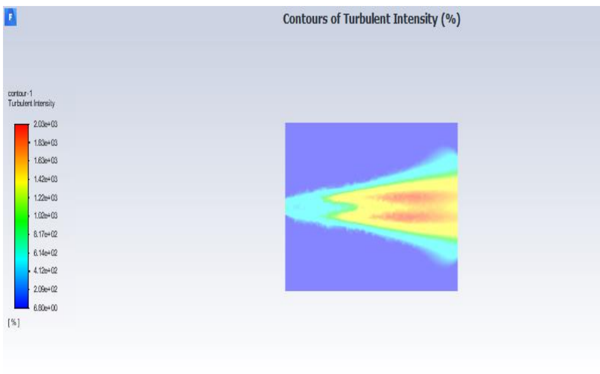

Fig 16:- Turbulence Intensity for Square-circle coaxial jet

Turbulence Intensity for the Ellipse-circle coaxial jet is shown in Figure 5.11, the turbulence intensity for Ellipse-circle is 6.80 – 1961.114%

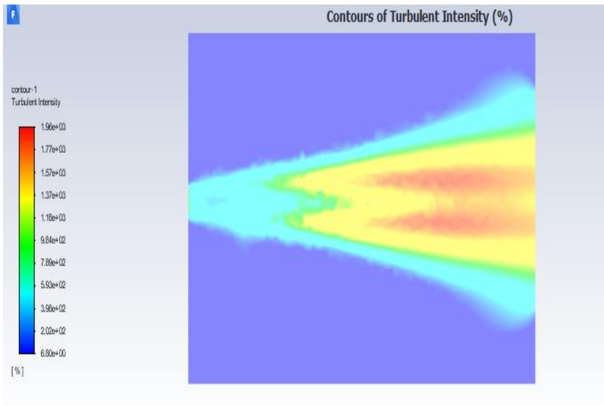

Fig 17:- Turbulence Intensity for Ellipse-circle coaxial jet

Turbulence Intensity for the Rectangle-circle coaxial jet is shown in Figure 5.12, the turbulence intensity for Rectangle circle is 7.24 – 1998.065 %

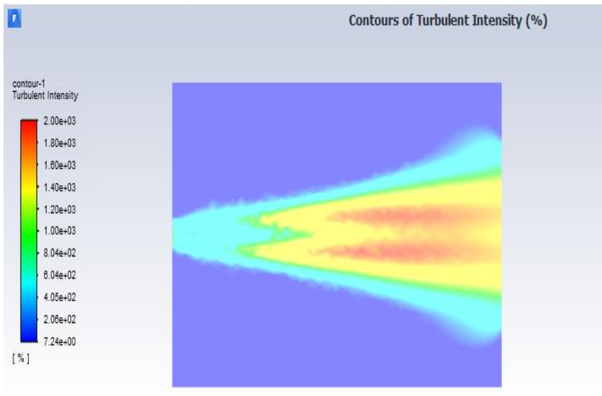

Fig 18:- Turbulence Intensity for Rectangle-circle coaxial jet

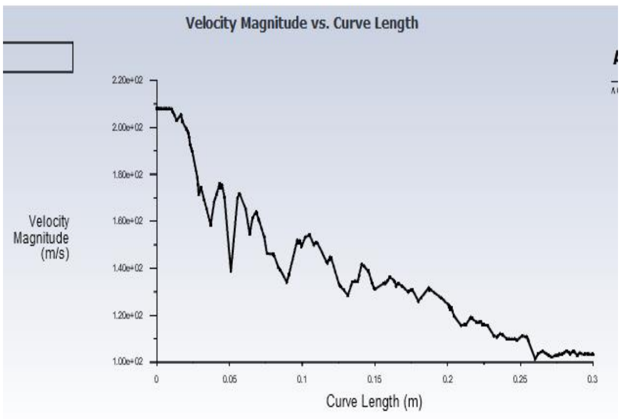

Fig 19:- Velocity plot for Circle-Circle coaxial jet

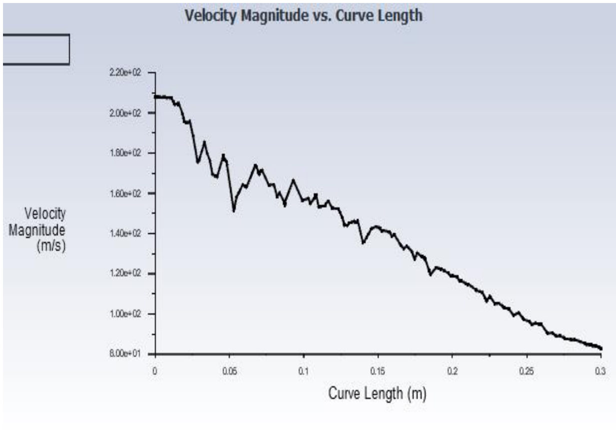

Fig 20:- Velocity plot for Square-Circle coaxial jet

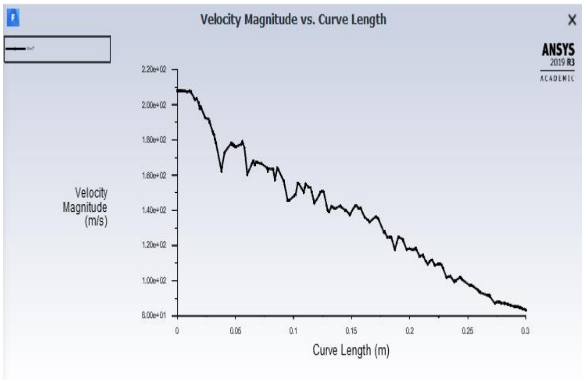

Fig 21:- Velocity plot for Ellipse-Circle coaxial jet

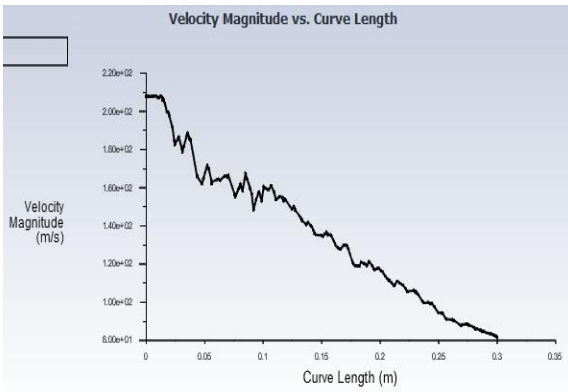

Fig 22:- Velocity plot for Rectangle-Circle coaxial jet

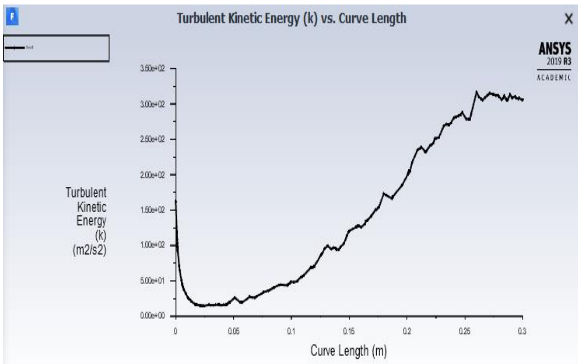

Fig 23:- Turbulent Kinetic Energy plot for Circle-circle coaxial jet

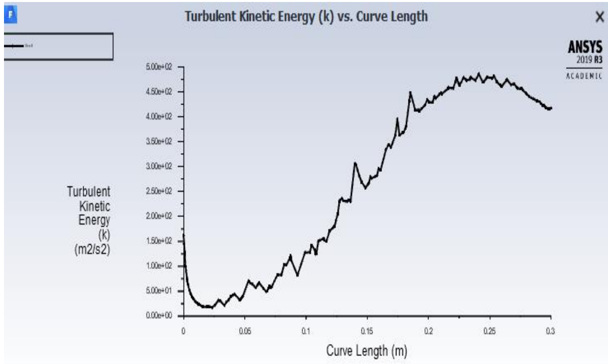

Fig 24:- Turbulent Kinetic Energy plot for Square-Circle coaxial jet

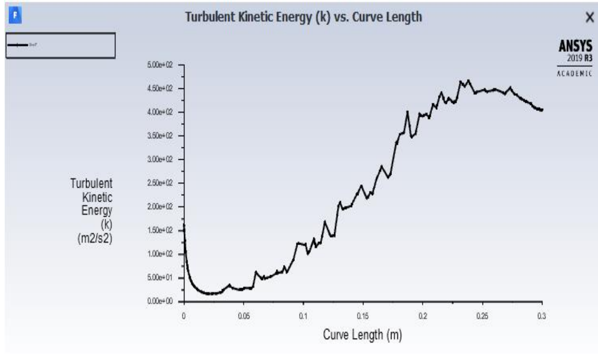

Fig 25:- Turbulent Kinetic Energy plot for Ellipse-Circle coaxial jet

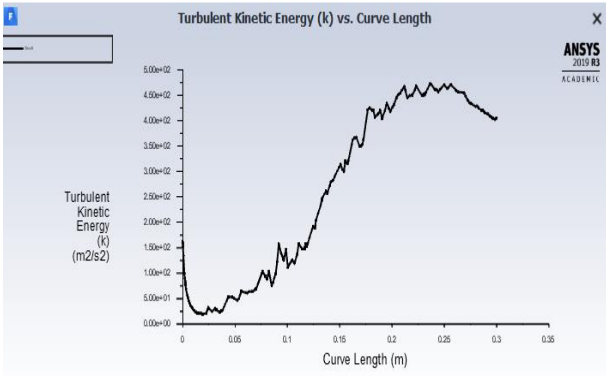

Fig 26:- Turbulent Kinetic Energy plot for Rectangle-Circle coaxial jet

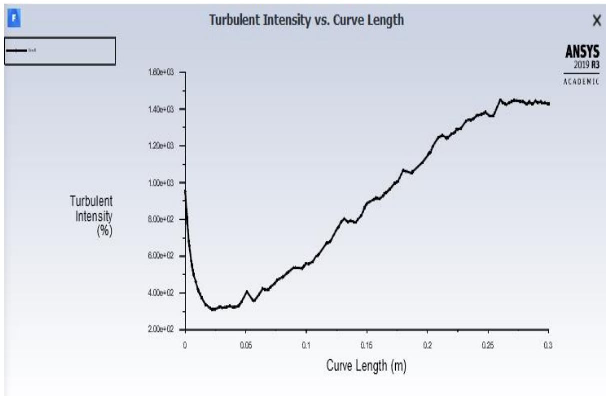

Fig 27:- Turbulent Intensity plot for Circle-Circle coaxial jet

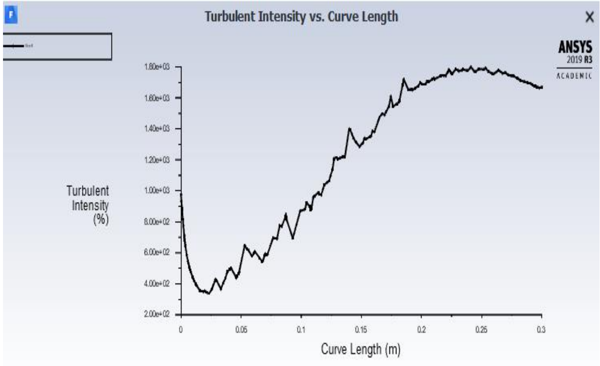

Fig 28:- Turbulent Intensity plot for Square-Circle coaxial jet

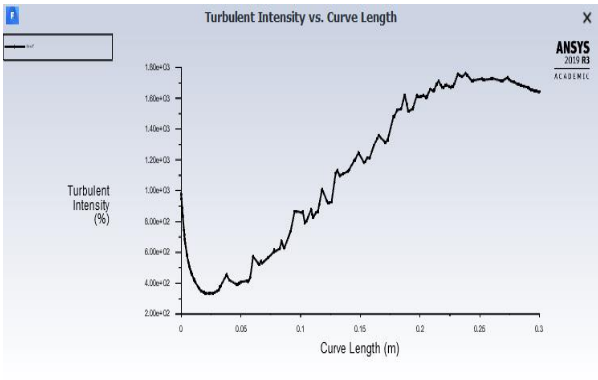

Fig 29:- Turbulent Intensity plot for Ellipse-Circle coaxial jet

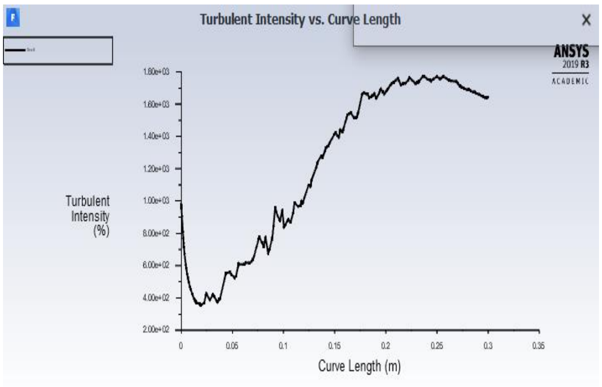

Fig 30:- Turbulent Intensity plot for Rectangle-Circle coaxial jet

In this chapter the results for CFD analysis of the circular and Noncircular coaxial jet were done. The flow characteristics and turbulence flow characteristics for the circle-circle, square-circle, ellipse-circle, rectangle-circle coaxial jet and the graph plot for velocity, turbulence kinetic energy, turbulent intensity for the coaxial jets is been displayed in the figures above. The result obtained for circular and non-circular coaxial jet. The flow characteristics and turbulence flow characteristics results are shown in the table.

Boundary Name	**Boundary Type**
Coaxial jet surface	Wall(Domain)
Circular coaxial jet	Symmetry
Geometry	3-D Model
Model	Viscous K-epsilon Model
Material	Fluid – Air Solid - Aluminium
Boundary Conditions	Primary Fluid Secondary Fluid Wall (Domain)
Primary Fluid velocity	208 m/s
Secondary Fluid Velocity	177 m/s
Velocity Ratio	1.17
Temperature	Constant
Methods	Second Order Upwind

Table 6:- Values and Characteristics of Flow and turbulence

From the result the values for velocity variation, turbulence kinetic energy, turbulent intensity was found, its certain that the turbulence kinetic energy is more for non-circular coaxial (square-circle) jet than the circular coaxial jet, and the turbulence intensity is low for ellipse-circle compared to other non-circular coaxial jets.

The potential core for the Rectangle-circle and ellipse-circle is lesser compared to the other circle-circle and square-circle coaxial jet. So the mixing in Rectangle and ellipse is quick than the other coaxial jets.

V. CONCLUSION

The major conclusions derived from to analysis are,

- The work shown the analysis results for circular and non-circular coaxial jet were done.
- Modeling of different shape of co-axial fuel injector is based on hydraulic diameter of the coaxial jet
- As the circle-circle coaxial jet will be present to compared with the shape changed coaxial jet
- From the obtained results there is good turbulence in non-circular shape compared to circular shape
- Turbulence characteristics such as turbulence kinetic energy, turbulence intensity, and velocity profiles are shown in the above graph.
- The potential core for the non-circular is lesser than the circular coaxial jet.

ACKNOWLEDGEMENT

I would like to show my gratitude to Dr. R. Ashokan, Head, school of aeronautical engineering and My Internal Guide Dr. P. Manivannan, for continually guiding and actively participating in my project to complete the work with valuable suggestions. I also would thank all the technical and teaching staff of the school of Aeronautical science for their extended support.

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