COMPUTATIONAL FLUID DYNAMICS SIMULATIONS OF PIPE ELBOW FLOW

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Abstract

One problem facing today's nuclear power industry is flow-accelerated corrosion and erosion in pipe elbows. The simulations are being performed using the FLUENT commercial software developed and marketed by Fluent, Inc. The model geometry and mesh were created using the ANSYS software, also from Fluent, Inc. This report documents the results of the simulations that have been made to date; baseline results employing the RNG k-ε turbulence model are presented. The predicted value for the diametrical pressure coefficient is in reasonably good agreement with published correlations. Plots of the velocities, pressure field, wall shear stress, and turbulent kinetic energy adjacent to the wall are shown within the elbow section.

INTRODUCTION

The basic concept of a geothermal piping design is to safely and economically transport steam, brine, or two- phase flow to the destination with acceptable pressure loss. The piping associated with geothermal power plant can be divided in piping inside the power plant and the piping in the steam field. Piping in the steam field consists of pipelines connecting the production wells to the separation station and those that run cross-country from the separation station to the power plant, and lastly to reinjection wells. The cross-country pipelines run on top of ridges, up and down steep hill slopes, cross roads, areas threatened by earthquakes, wind, rain and landslides. Geothermal piping system has to be flexible enough to allow thermal expansion but also stiff enough to withstand the seismic and operational load actions. The steam field model used is a wet field as the piping encountered in this model covers most, if not all the possible types of fluids and piping that could be expected in any geothermal system. The wet steam field system consists of:

1. Two-phase flow piping which collects the fluid from several wellhead and sends them to the separator;
2. The separator vessel;
3. The steam pipelines which take the steam from the separator to the power plant;
4. The brine pipelines which take the separated brine from the vessel to a well pad where the fluid is re-injected into several wells;
5. Miscellaneous cross-country piping includes the instrumental air lines, the water- supply line and also the condensate line.

A regular elbow has a female hub or FIP connection on both ends. A hub is a female ABS, PVC or copper pipe receptacle; FIP denotes "Female Iron Pipe" threads, that is, it receives threaded MIP iron, brass or plastic pipe on both ends. FIP is also known as FPT, Female Pipe Thread, and MIP is also known as MPT, Male Pipe Thread. Collectively, these are known as National Pipe Thread (NPT) fittings.

Instead, a street elbow has a female fitting (hub or FIP) on one end and a male pipe or MIP fitting on the other end. The advantage of the street elbow is that it can be connected directly to another fitting without having to use an additional short connecting piece called a pipe nipple. Street elbows are available in 90°, 45° and 22.5° bends. They can be used in water supply, drainage, sewers, vents, central vacuum systems, compressed air and gas lines, HVAC, sump pump drains, and any location where plumbing fittings would be used to join sections of pipe. The Natural Gas and Propane Installation Code of Canada (B149.1) states "...a street elbow or a street tee shall not be used in a piping system.

Two aspects of the design process of geothermal piping systems that must be considered are the process of preparing the design and the deliverables. The scope of this paper will be in the piping for the steam field and the process of preparing the design divided in the following main categories: design criteria, produce process flow diagram, define control philosophy, separator location, route selection, dimension design, pressure design, load design, design codes and pipe stress analysis. An elbow is installed between two lengths of pipe (or tubing) to allow a change of direction, usually a 90° or 45° angle; 22.5° elbows are also available. The ends may be machined for butt welding, threaded (usually female), or socketed. When the ends differ in size, it is known as a reducing (or reducer) elbow.

A 90º elbow, also known as a "90 bend", "90 ell" or "quarter bend", attaches readily to plastic, copper, cast iron, steel, and lead, and is attached to rubber with stainless-steel clamps. Other available materials include silicone, rubber compounds, galvanized steel, and nylon. It is primarily used to connect hoses to valves, water pumps and deck drains. A 45º elbow, also known as a "45 bend" or "45 ell", is commonly used in water-supply facilities, food, chemical and electronic industrial pipeline networks, air-conditioning pipelines, agriculture and garden production, and solar-energy facility piping. Elbows are also categorized by length. The radius of curvature of a long-radius (LR) elbow is 1.5 times the pipe diameter, but a short-radius (SR) elbow has a radius equal to the pipe diameter. Short elbows, widely available, are typically used in pressurized systems, and in physically tight locations. Long elbows are used in low-pressure gravity-fed systems and other applications where low turbulence and minimum deposition of entrained solids are of concern. They are available in acrylonitrile butadiene styrene (ABS plastic), polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), and copper, and are used in DWV systems, sewage, and central vacuum systems.

An elbow provides a change in material-flow direction. This adds pressure losses to the system due to impact, friction and re-acceleration. As product enters the inlet of the elbow, it typically continues moving straight ahead to the first impact zone. The product is then deflected at an angle toward the outlet of the elbow. The deflection angle is determined by the elbow design, the products characteristics, the conveying velocity and specific load. In many designs, the product will hit one or more secondary impact zones before exiting the elbow. Impact forces can cause severe degradation of fragile or breakage-sensitive products, generating a large amount of fines or dust and creating quality issues. Heat-sensitive products, such as plastic pellets, can overheat on the contact surface this can result in unwanted tails or streamers on the pellet or film build-up on the surface of the elbow. This can eventually lead to product contamination. Abrasive products can cause wear, leading to work-out elbowsand system leaks and causing maintenance and safety issues 90degree elbows also called "90 bends or 90 ells", are manufactured as SR (short radius) elbows and LR (Long Radius) elbows. SR elbows have a center-to-face dimension of 1.0 x diameter and are typically used in tight areas where clearances are an issue. LR elbows have a center to face dimension of 1.5 x diameter and are the more common type and used when space is available and flow is more critical 45 degree elbows also called "45 bends or 45 ells are typically made as LR (long radius) elbows.

APPLICATIONS OF PIPE ELBOWS:

Various applications of pipe elbows are as follows:

- They are manufactured to be used in flow lines for gases, fluids in industrial processes, medical, construction and many other specialized applications.
- The elbows are constructed of heavy materials for rigid applications like extreme high/low temperature resistance etc.
- The elbows are specifically designed for use on process and control systems, instrumentation, and equipment used in chemical, petroleum, fluid power, electronic and pulp and paper plants.

CLASSIFICATION

TYPES OF 900 ELBOWS:

90 deg elbows are manufactured as SR (short radius) elbows and LR (long radius) elbows: SR (Short Radius) Elbows: These elbows have a center-to-face dimension of 1.0 X diameter. They are typically used in tight areas where clearance is the main issue LR (Long Radius) Elbows: These elbows have a center-to-face dimension of 1.5 X diameter. They are the most common type of elbow and used when space is available and flow is more critical.Reducing Elbow: A reducing elbow is a type of fitting which is used to join two pieces of pipe of different sizes. The reducing elbow is so called because it looks like a reducing piece and elbow combined into one. Reducing elbows have different sized openings on each end and hence they can connect two different sized pipes. They are available in different materials, sizes, finishes and colors.

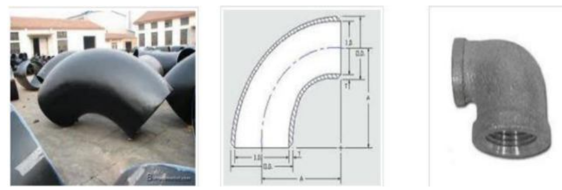


Figure:1 45deg Elbow Pipe.

450 Pipe Elbow: 45 Pipe Elbow is also known as "45 bends". The 45 pipe elbow is used to connect tubes at a 45 deg pipe angle. As the name suggests, this is a pipe fitting device which is bent in such a way to produce 45deg change in the direction of flow of the fluid/gas in the pipe. Like a 90deg elbow, the 45deg pipe elbow also attaches readily to pipes of various materials like plastic, copper, cast iron, steel, lead, rubber etc. They are typically made as LR(long radius) elbows. These types of elbows are available in various sizes. They are available with different male to female BSP thread connections. Providing a wide choice of colors, these 45deg elbows can be manufactured to meet different specifications in terms of size and diameter.

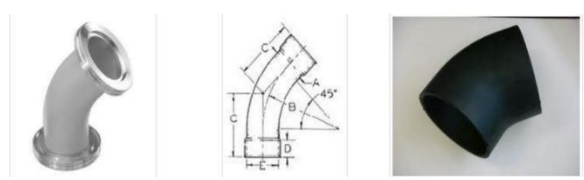


Fig:2 Reducing Elbow.

MALE PIPE ELBOWS & FEMALE PIPE ELBOWS:

Male pipe elbows and female pipe elbows are popular tube fittings which provide an angled change in the direction of a tubing run. Whilea male pipe elbow is used to connect fractional tube to female tapered pipe thread, a female elbow is used to connect fractional tube to male NPT thread. These types of tube fittings like male elbows and female elbows have been specifically designed for use on instrumentation, process and control systems and equipment employed in chemical, petroleum, fluid power, electronic, pulp and paper plants.

Fig:3 Male and Female Elbow Pipes.

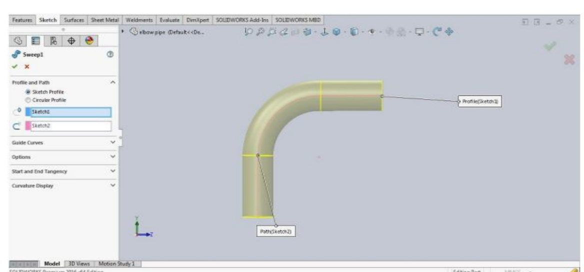
SOLIDWORKS INTRODUCTION

Solid works mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows TM graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent. Design intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. Solid Works allows you to specify that the hole is a feature on the top surface, and will then honor your design intent no matter what the height you later gave to the can. several factors contribute to how we capture design intent are Automatic relations, Equations, added relations and dimensioning. Features refer to the building blocks of the part. They are the shapes and operations that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. This shape is then extruded or cut to add or remove material from the part. Operation-based features are not sketch-based, and include features such as fillets, chamfers, shells, applying draft to the faces of a part, etc. Building a model in Solid Works usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and spines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of Solid Works means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

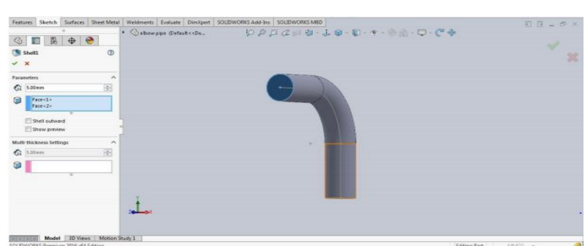
MODELING OF ELBOW PIPE

1 Modeling of Elbow Pipe

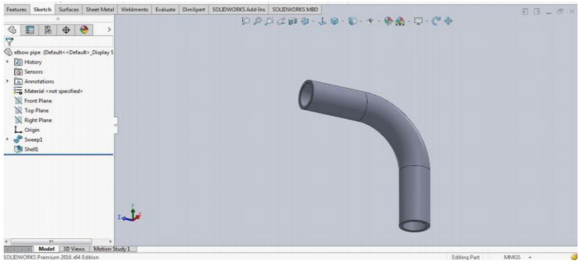
Swept Boss



Shell



Final View



INTRODUCTION TO FLOW SIMULATION

FLOW SIMULATION

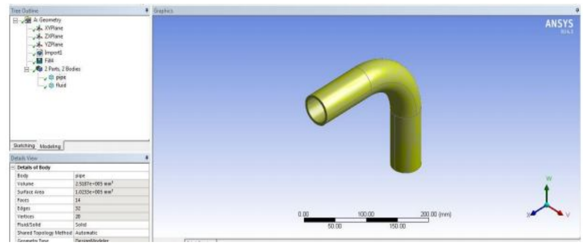
Computational fluid dynamics (CFD) study of the system starts with the construction of desired geometry and mesh for modeling the dominion. Generally, geometry is simplified for the CFD studies. Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modeling starts with the describing of the boundary and initial conditions for the dominion and leads to modeling of the entire system. Finally, it is followed by the analysis of the results, conclusions and discussions.

INTRODUCTION TO ANSYS

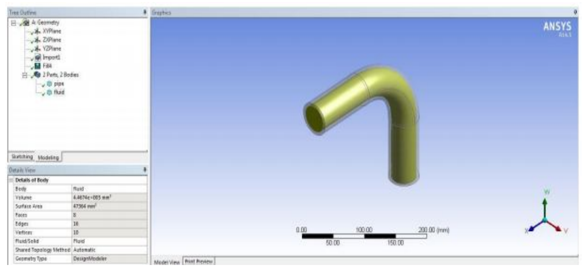
ANSYS 14.5 delivers innovative, dramatic simulation technology advances in every major Physics discipline, along with improvements in computing speed and enhancements to enabling technologies such as geometry handling, meshing and post-processing. These advancements alone represent a major step ahead on the path forward in Simulation Driven Product Development. But ANSYS has reached even further by delivering all this technology in an innovative simulation framework ,ANSYS Workbench14.5The ANSYS Workbench environment is the glue that binds the simulation process; this has not changed with version.14.5 In the original ANSYS Workbench, the user interacted with the analysis as a whole using The platform's project page: launching the various applications and tracking the resulting files employed in the process of creating an analysis. Tight integration between the component applications yielded unprecedented ease of use for setup and solution of even complex multiphysics simulations.

CFD ANALYSIS OF ELBOW PIPE

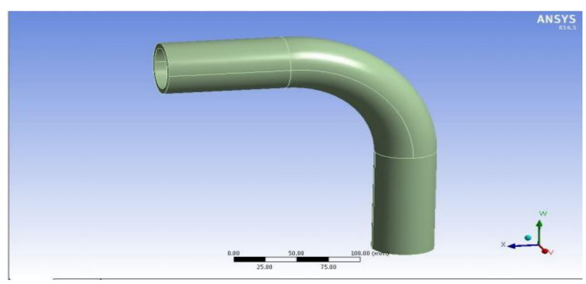
Pipe:



Water:



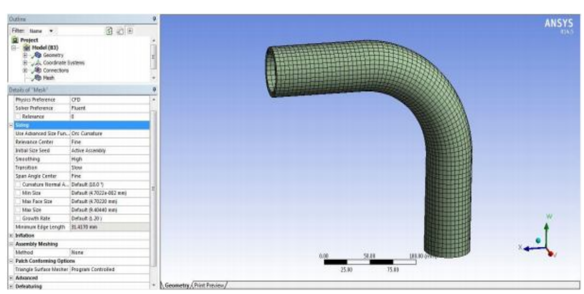
Model:



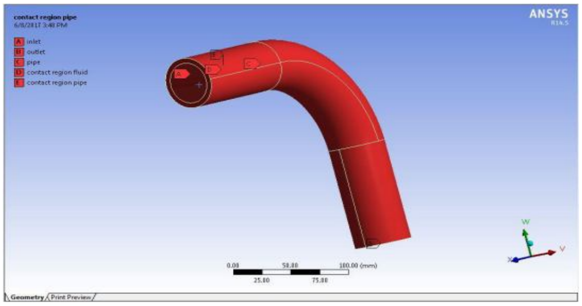
Mesh quality:

```
Mesh Quality:
 Orthogonal Quality ranges from 0 to 1, where values close to 0 correspond to low quality.
Minimum Orthogonal Quality =  3.33965e-01
Maximum Aspect Ratio =  9.70485e+00
```

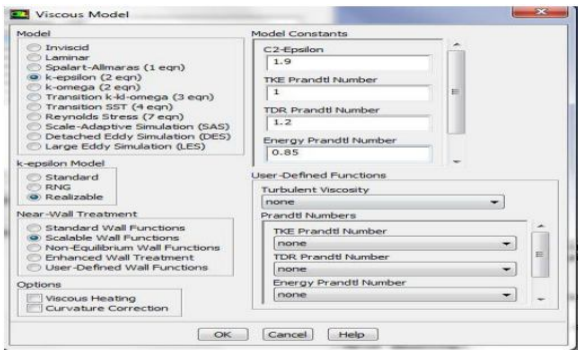
Mesh:



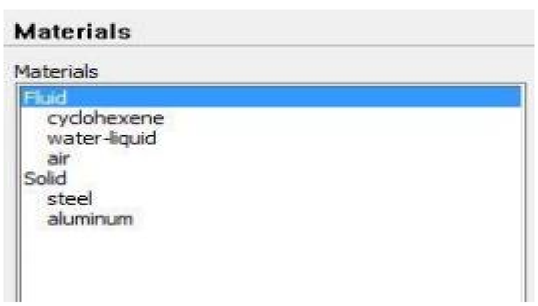
Name selection:



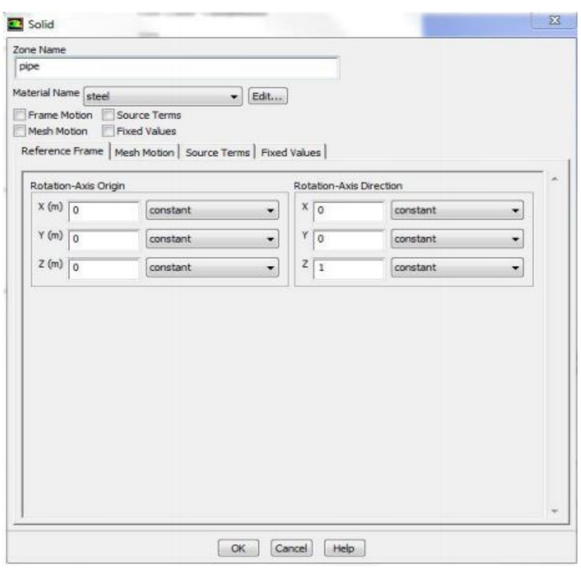
Flow model:



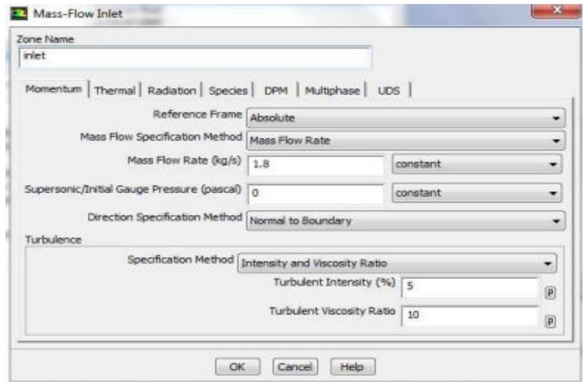
Materials:



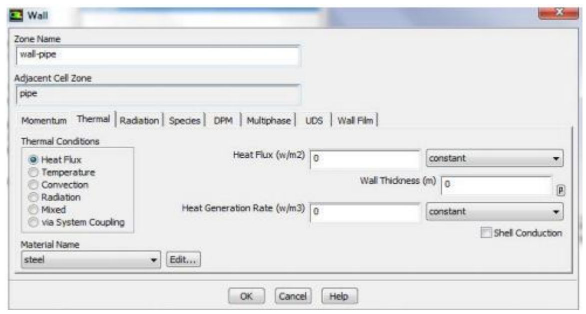
Pipe:



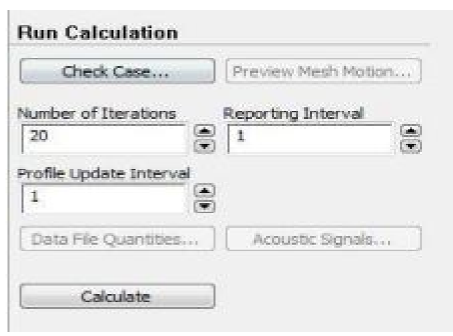
Inlet:



Pipe:



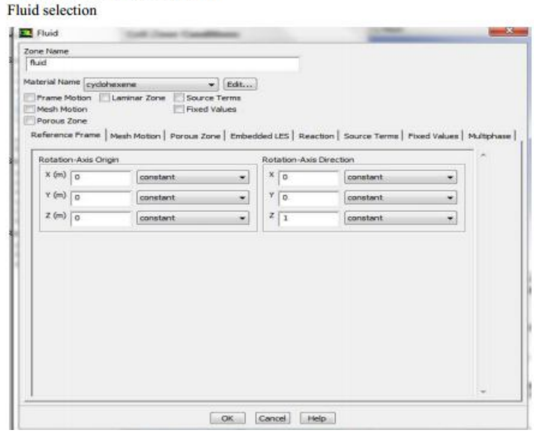
Run:



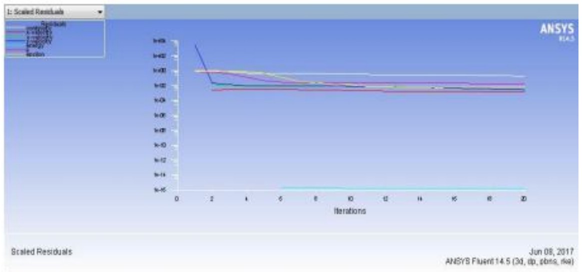
Analysis Results:-

FOR HYDROCARBON (CYCLOHEXENE C6H10)

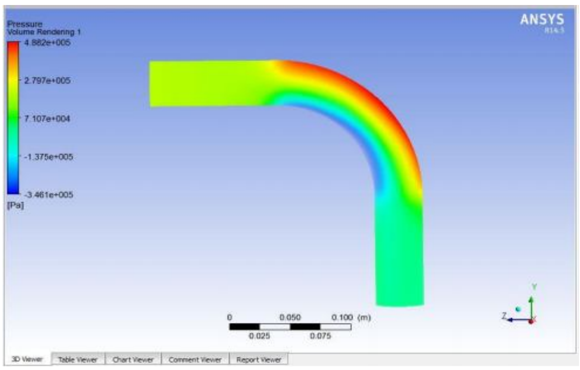
1. Hydrocarbon(cyclohexane c6h10):
   Fluid selection



Iteration:

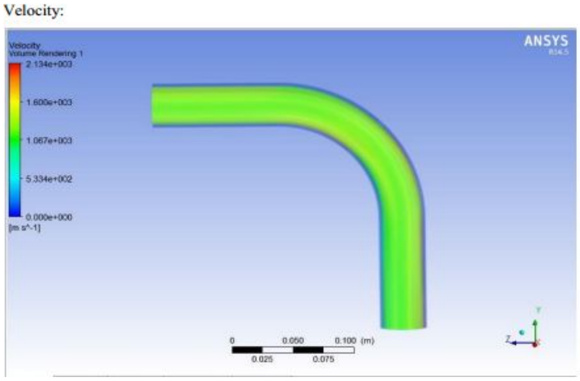


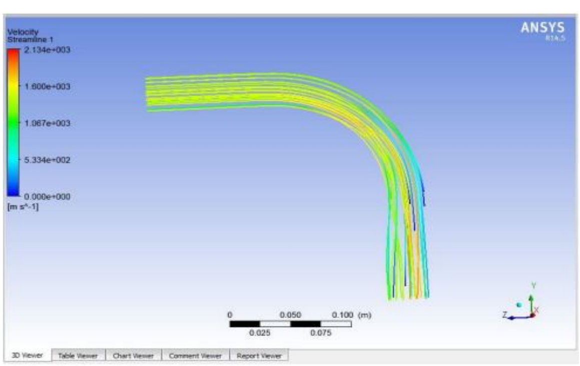
Pressure:



Maximum of Facet Values Static Pressure	(pascal)
contact_region_fluid	491146.66
inlet	198977.69
interior-fluid	490986.53
Net	491146.66

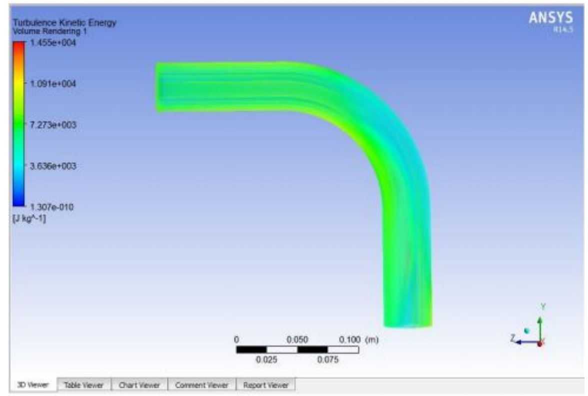
Velocity:





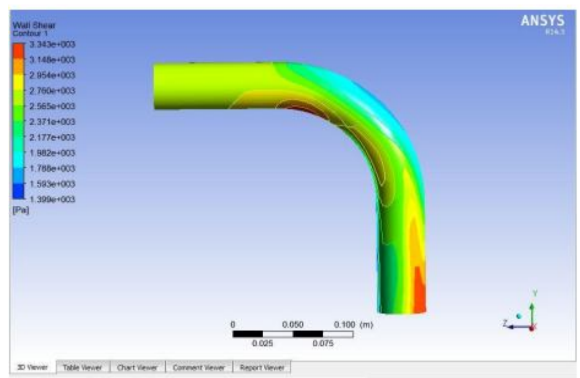
Maximum of Facet Values Velocity Magnitude	(m/s)
inlet	1446.4351
interior-fluid	2160.7141
outlet	2060.854
Net	2160.7141

Turbulent kinetic energy:



Maximum of Facet Values Turbulent Kinetic Energy (k)	(m2/s2)
contact_region_fluid	9685.1777
inlet	7845.6538
interior-fluid	18615.725
outlet	9685.1777
Net	18615.725

Shear stress:

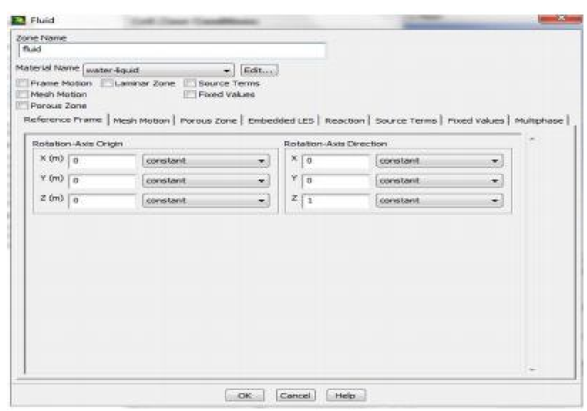


Maximum of Facet Values Wall Shear Stress	(pascal)
contact_region_fluid	3350.4741

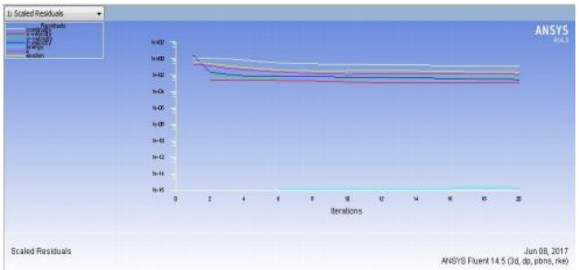
FOR WATER

WATER:

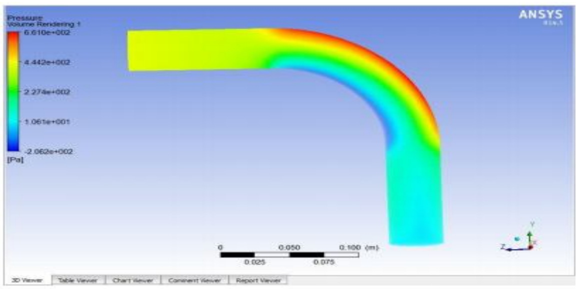
Fluid selection:



Iteration:

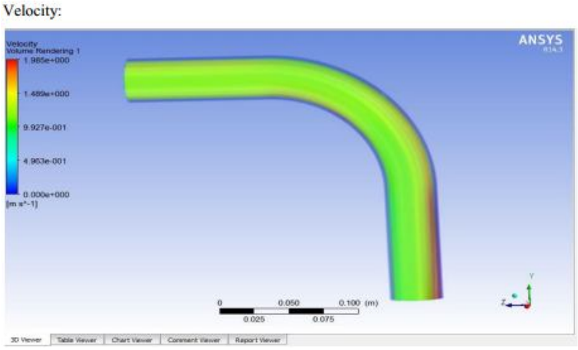


Pressure:



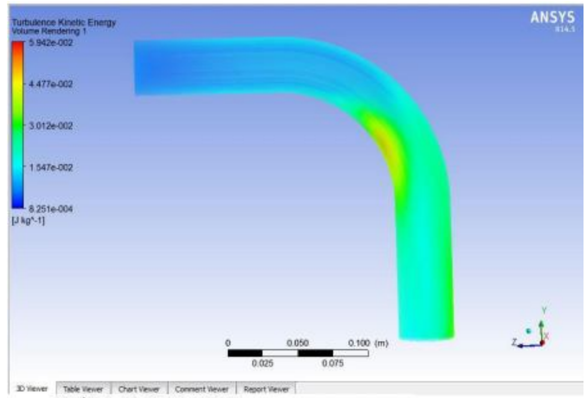
Maximum of Facet Values Static Pressure	(pascal)
contact_region_fluid	662.28687
inlet	413.26242
interior-fluid	662.22595
Net	662.28687

Velocity:



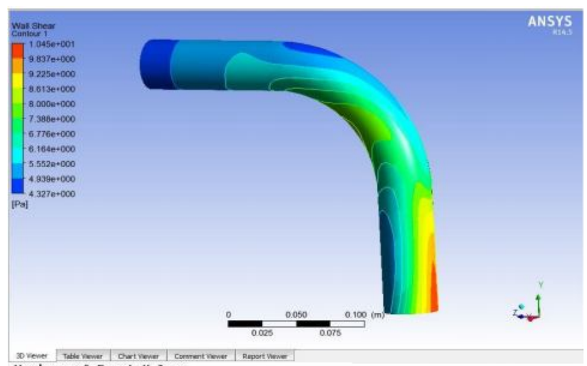
Maximum of Facet Values Velocity Magnitude	(m/s)
inlet	1.4490433
interior-fluid	1.9902722
outlet	1.9831328
Net	1.9902722

Turbulent kinetic energy:



Maximum of Facet Values Turbulent Kinetic Energy (k)	(m2/s2)
contact_region_fluid	0.039063182
inlet	0.0078739738
interior-fluid	0.073490493
outlet	0.03350183
Net	0.073490493

Wall Shear stress:



Maximum of Facet Values Wall Shear Stress	(pascal)
contact_region_fluid	10.574208

RESULTS

Results for Elbow Pipe for Hydrocarbon

1 Pressure:

Maximum of Facet Values Static Pressure	(pascal)
contact_region_fluid	491146.66
inlet	198977.69
interior-fluid	490986.53
Net	491146.66

2 Velocities:

Maximum of Facet Values Velocity Magnitude	(m/s)
inlet	1446.4351
interior-fluid	2160.7141
outlet	2060.854
Net	2160.7141

3 Turbulence Kinetic Energy

Maximum of Facet Values Turbulent Kinetic Energy (k)	(m2/s2)
contact_region_fluid	9685.1777
inlet	7845.6538
interior-fluid	18615.725
outlet	9685.1777
Net	18615.725

4 Wall Shear Stress

Maximum of Facet Values Wall Shear Stress	(pascal)
contact_region_fluid	3350.4741

RESULTS FOR ELBOW PIPE FOR WATER

.1 Pressures

Maximum of Facet Values Static Pressure	(pascal)
contact_region_fluid	662.28687
inlet	413.26242
interior-fluid	662.22595
Net	662.28687

2 Velocities

Maximum of Facet Values Velocity Magnitude	(m/s)
inlet	1.4490433
interior-fluid	1.9902722
outlet	1.9831328
Net	1.9902722

3 Turbulence Kinetic Energy

Maximum of Facet Values Turbulent Kinetic Energy (k)	(m2/s2)
contact_region_fluid	0.039063182
inlet	0.0078739738
interior-fluid	0.073490493
outlet	0.03350183
Net	0.073490493

4 Wall Shear Stress

Maximum of Facet Values Wall Shear Stress	(pascal)
contact_region_fluid	10.574208

CONCLUSION

¬ Brief study about elbow pipe its applications and importance in industrial purpose is studies in this project

¬ 3d model of elbow pipe is generated by using Solid works 2016 software.

¬ Generated 3d model is transfer to the Ansys workbench 14.5 software for analysis by converting it to a neutral file IGES.

¬ Computational fluid dynamic analysis is performed on elbow pipe by using FLUENT module in ansys software.

¬ Two different fluid one is water and another one a Hydrocarbon fluid such as cyclohexene (c6h10) is used as fluid flow inside elbow pipe.

¬ Boundary conditions such as inlet velocity wall conditions flow types etc applied on model

¬ Pressure, velocity, shear stress on wall and turbulent kinetic energy inside of elbow pipe is got as result after solve.

¬ Counters of Pressure, velocity , shear stress on wall, turbulent kinetic energy inner surface of elbow pipe is shown in fihures ,and there values are noted and tabulated.

¬ Thus the CFD ANALYSIS on elbow pipe is done and there results are studies and noted for two different fluid**.**

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