STRUCTURAL AND FATIGUE ANALYSIS OF HIGH PRESSURE INDUSTRIAL GRADE PIPE BEND USING FLUID STRUCTURE INTERACTIONS

A Project Report Submitted in partial fulfilment requirements
for the award of the Degree of

BACHELOR OF ENGINEERING

In

MECHANICAL ENGINEERING

By

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ABSTRACT

All the industries will involve in the transport of fluids (raw or semi processed fluids) through pipe lines and since flow cannot always take place along straight line, pipes should certainly bend at required locations so as to facilitate the fluid flow in industry. The presence of pipe lines play vital role in water industry (running water lines, sewage treatment systems, industrial water needs, agriculture and irrigation, etc), oil industry (pipings to transfer gas, manufacturing of LPG, other non-toxic gases, pipe lines in refineries, cross-country crude oil lines, etc) In power plants (for carrying water to boiler and steam from boiler to turbine, for circulation cooling water or hot water in various components etc), in construction of ships, buildings, etc for proper transport of fluids. Pipe Bends are very important pipe fitting which are used very frequently for changing direction in piping system.

Analysing the flow in pipe bends will not only reveal the setbacks related to flow along curved portions (in terms of pressure drop, turbulence etc.) but also hints on opportunities to recover lost energy. In this work, major focus was laid on fluid flow with in a pipe bend and the response of pipe bend due to the flowing fluid. Thus, in addition to analysing the fluid flow within Ansys fluent, fluid's interaction with the walls of pipe bend were also analysed by employing a powerful tool called fluid structure interactions. This project also estimated the life of pipe bend and the region’s most prone for failure due to fluid flow.

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7.1 References

CHAPTER 01

INTRODUCTION

1. INTRODUCTION

All the industries will involve in the transport of fluids (raw or semi processed fluids) through pipe lines and since flow cannot always take place along straight line, pipes should certainly bend at required locations so as to facilitate the fluid flow in industry. The presence of pipelines play vital role in water industry (running water lines, sewage treatment systems, industrial water needs, agriculture and irrigation, etc.), oil industry (piping to transfer gas, manufacturing of LPG, other non-toxic gases, pipelines in refineries, cross-country crude oil lines, etc.) In power plants (for carrying water to boiler and steam from boiler to turbine, for circulation cooling water or hot water in various components etc), in construction of ships, buildings, etc. for proper transport of fluids.

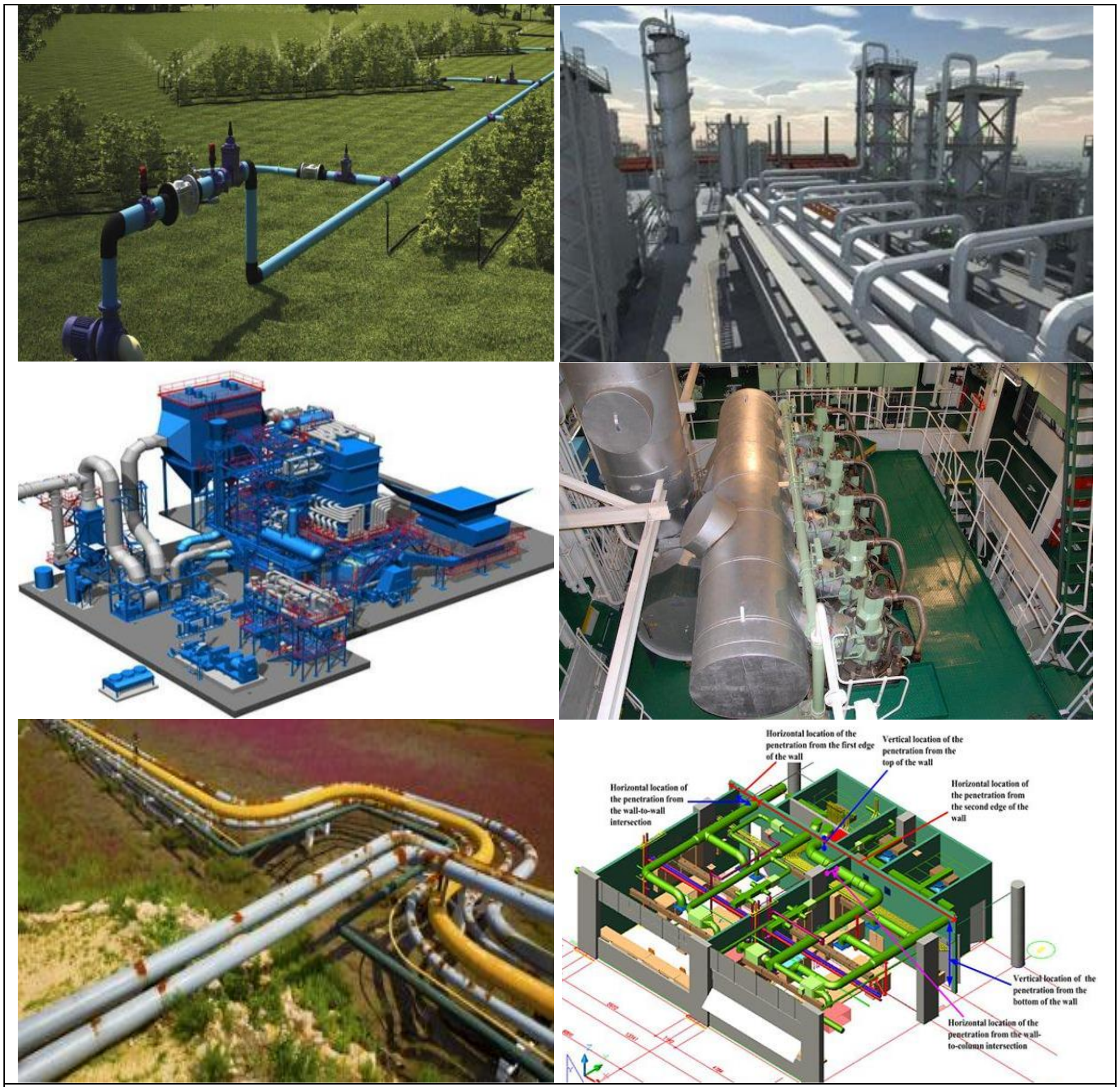


Fig : 1.1 Pipe bends in various industries

1.1 Pipe bend preparation:

Piping Elbows and Bends are very important pipe fitting which are used very frequently for changing direction in piping system. Piping Elbow and Piping bend are not the same, a bend is simply a generic term in piping for an “offset” – a change in direction of the piping. It signifies that there is a “bend” i.e., a change in direction of the piping (usually for some specific reason) – but it lacks specific, engineering definition as to direction and degree. Bends are usually made by using a bending machine (hot bending and cold bending) on site and suited for a specific need.

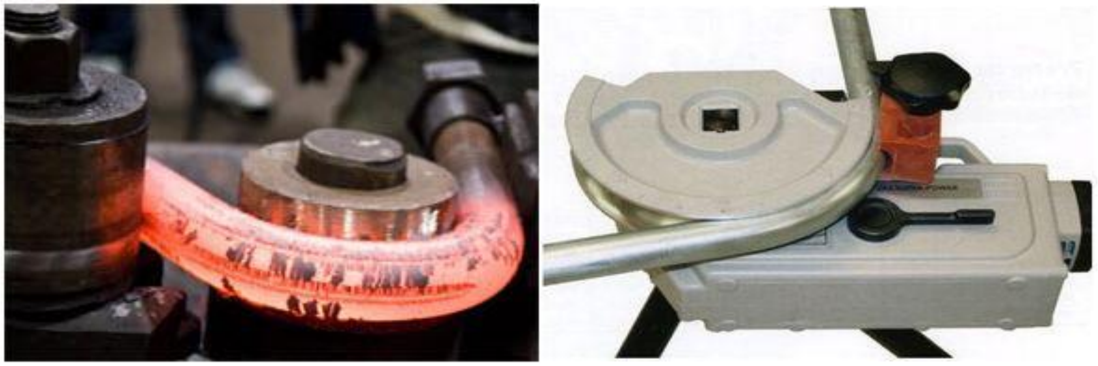


Fig : 1.2 Preparation of pipe bend

Use of bends are economic as it reduces number of expensive fittings. An ELBOW, on the other hand, is a specific, standard, engineered bend pre-fabricated as a spool piece (based on ASME B 16.9) and designed to either be screwed, flanged, or welded to the piping it is associated with. An elbow can be 45 degree or 90 degree. There can also be custom-designed elbows, although most are categorized as either “short radius” or long radius”.

Whenever the term elbow is used, it must also carry the qualifiers of type (45 or 90 degree) and radius (short or long) – besides the nominal size.

Elbows can change direction to any angle as per requirement. An elbow angle can be defined as the angle by which the flow direction deviates from its original flowing direction. Even though An elbow angle can be anything greater than 0 but less or equal to 90°But still a change in direction greater than 90° at a single point is not desirable. Normally, a 45° and a 90° elbow were both used while making piping layouts for such situations.

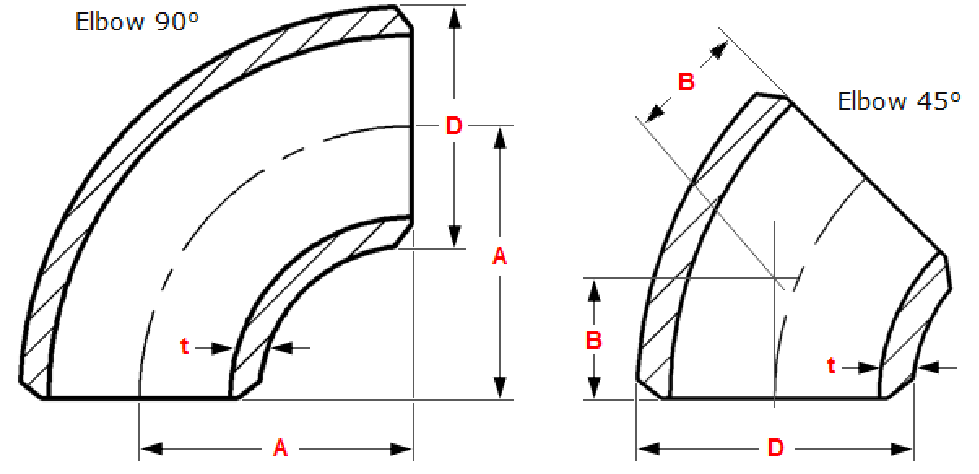


Fig : 1.3 Specifications of pipe bend

Elbow angle can be easily calculated using simple geometrical technique of mathematics. Pipe direction is changing at point A with the help of an elbow and again the direction is changing at the point G using another elbow.

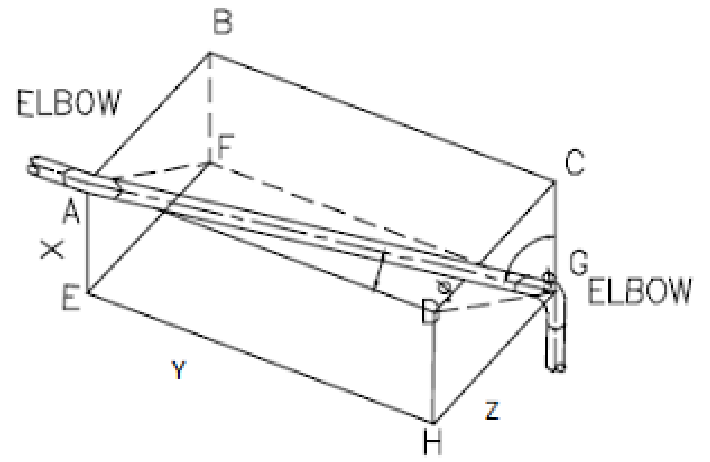


Fig : 1. 4 Example figure for elbow angle calculation

In order to find out the elbow angle at A, it is necessary to consider a plane which contains the arms of the elbow. If there had been no change in direction at point A, the pipe would have moved along line AD but pipe is moving along line AG. Plane AFGD contains lines AD and AG and elbow angle (phi) is marked which denotes the angle by which the flow is deviating from its original direction.

Considering right angle triangle AGD, tan(phi) = √(x2 + z2)/y

Similarly elbow angle at G is given by : tan (phi1)=√ (y2 +z2)/x

1.2 Elbow Radius:

Elbows or bends are available in various radii for a smooth change in direction which are expressed in terms of pipe nominal size expressed in inches. Elbows or bends are available in three radii,

a. Long radius elbows (Radius = 1.5D): used most frequently where there is a need to keep the frictional fluid pressure loss down to a minimum, there is ample space and volume to allow for a wider turn and generate less pressure drop.

b. Long radius elbows (Radius > 1.5D): Used sometimes for specific applications for transporting high viscous fluids likes slurry, low polymer etc. For radius more than 1.5D pipe bends are usually used and these can be made to any radius. However, 3D & 5D pipe bends are most commonly used

b. Short radius elbows (Radius = 1.0D): to be used only in locations where space does not permit use of long radius elbow and there is a need to reduce the cost of elbows. In jacketed piping the short radius elbow is used for the core pipe.

Here D is nominal pipe size in inches.

There are three major parameters which dictates the radius selection for elbow. Space availability, cost and pressure drop. Pipe bends are preferred where pressure drop is of a major consideration. Use of short radius elbows should be avoided as far as possible due to abrupt change in direction causing high pressure drop.

1.3 Minimum thickness requirement:

Whether an elbow or bend is used the minimum thickness requirement from code must be met. Code ASME B 31.3 provides equation for calculating minimum thickness required (t) in finished form for a given internal design pressure (P) as shown below:

$$t = \frac{PD}{2\left[\left(SEW / I\right) + PY\right]}$$

for inside bend radius $I = \frac{4\left(R_1 / D\right) - 1}{4\left(R_1 / D\right) - 2}$

for outside bend radius $I = \frac{4\left(R_1 / D\right) + 1}{4\left(R_1 / D\right) + 2}$

Where

R_1 = bend radius of welding elbow or pipe bend

D = outside diameter of pipe

W = weld joint strength reduction factor

Y = coefficient from Code Table 304.1.1

S = stress value for material from Table A-1 at maximum temperature

E = quality factor from Table A-1A or A-1B

Add any corrosion, erosion, mechanical allowances with this calculated value to get the thickness required

1.4 End Connections:

For connecting elbow/bend to pipe the following type of end connections are available

- Butt welded: Used along with large bore (>=2 inch) piping
- Socket welded: Used along with pipe size
- Screwed:
- Flanged:

1.5 Butt welded Elbows:

- Pipe is connected to butt welded elbow as shown in Fig. 4 by having a butt-welding joint.
- Butt welded fittings are supplied with bevel ends suitable for welding to pipe. It is important to indicate the connected pipe thickness /schedule while ordering. All edge preparations for butt welding should conform to ASME B16.25.
- Dimensions of butt welded elbows are as per ASME B16.9. This standard is applicable for carbon steel & alloy steel butt weld fittings of NPS 1/2” through 48”.

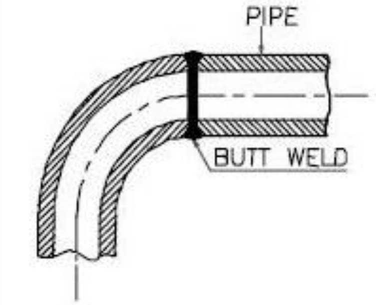


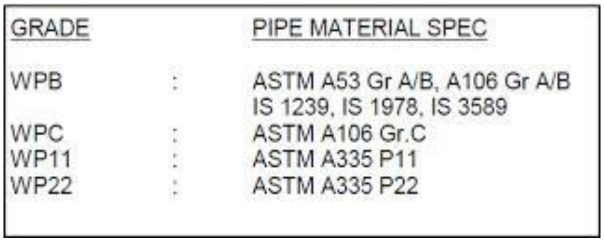
Fig: 1.5 A typical Butt-Welded Elbow

- Dimensions of stainless steel butt welded fittings are as per MSS-SP-43. Physical dimensions for fittings are identical under ASME B16.9 and MSS-SP-43. It is implied that the scope of ASME B16.9 deals primarily with the wall thicknesses which are common to carbon and low alloy steel piping, whereas MSS-SP-43 deals specifically with schedule 5S & 10S in stainless steel piping.
- Dimensions for short radius elbows are as per ASME B16.28 in case of carbon steel & low alloy steel and MSS-SP-59 for stainless steel.
- Butt welded fittings are usually used for sizes 2" & above. However, for smaller sizes up to 1-1/2" on critical lines where use of socket welded joints is prohibited, pipe bends are normally used. These bends are usually of 5D radius and made at site by cold bending of pipe. Alternatively, butt welded elbows can be used in lieu of pipe bends but usually smaller dia lines are field routed and it is not possible to have the requirement known at initial stage of the project for procurement purpose. So pipe bends are preferred. However, pipe bends do occupy more space and particularly in pharmaceutical plants where major portion of piping is of small dia. and layout is congested, butt welded elbows are preferred.
- Butt welded joints can be radiographed and hence preferred for all critical services.
- Material standards as applicable to butt welded fittings are as follows:

1.5 Pipe bend standards

1.5.1 ASTM A234: This specification covers wrought carbon steel & alloy steel fittings of seamless and welded construction. Unless seamless or welded construction is specified in order, either may be furnished at the option of the supplier. All welded construction fittings as per this standard are supplied with 100% radiography. Under ASTM A234, several grades are available depending upon chemical composition. Selection would depend upon pipe material connected to these fittings.

Some of the grades available under this specification and corresponding connected pipe material specification are listed below:



GRADE		PIPE MATERIAL SPEC
WPB	:	ASTM A53 Gr A/B, A106 Gr A/B IS 1239, IS 1978, IS 3589
WPC	:	ASTM A106 Gr.C
WP11	:	ASTM A335 P11
WP22	:	ASTM A335 P22

1.5.2 ASTM A403: This specification covers two general classes, WP & CR, of wrought austenitic stainless steel fittings of seamless and welded construction.

Class WP fittings are manufactured to the requirements of ASME B16.9 & ASME B16.28 and are subdivided into three subclasses as follows:

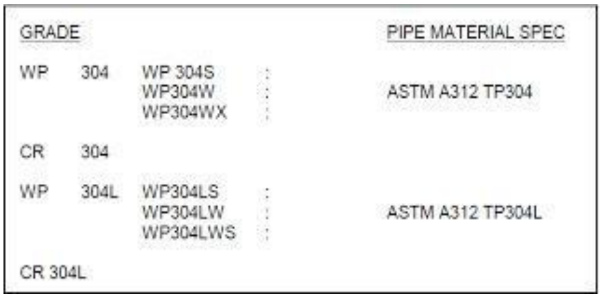
WP – Manufactured from seamless product by a seamless method of manufacture.

WP – W These fittings contain welds and all welds made by the fitting manufacturer including starting pipe weld if the pipe was welded with the addition of filler material are radiographed. However, no radiography is done for the starting pipe weld if the pipe was welded without the addition of filler material.

WP-WX These fittings contain welds and all welds whether made by the fitting manufacturer or by the starting material manufacturer are radiographed.

Class CR fittings are manufactured to the requirements of MSS-SP-43 and do not require non-destructive examination.

1.5.3 ASTM A403: Under this, several grades are available depending upon chemical composition. Selection would depend upon pipe material connected to these fittings. Some of the grades available under this specification and corresponding connected pipe material specification are listed below:



GRADE			PIPE MATERIAL SPEC
WP	304	WP 304S : WP304W : WP304WX :	ASTM A312 TP304
CR	304		
WP	304L	WP304LS : WP304LW : WP304LWS :	ASTM A312 TP304L
CR 304L			

1.5.4 ASTM A420:

- This specification covers wrought carbon steel and alloy steel fittings of seamless & welded construction intended for use at low temperatures. It covers four grades WPL6, WPL9, WPL3 & WPL8 depending upon chemical composition. Fittings WPL6 are impact tested at temp – 50° C, WPL9 at -75° C, WPL3 at -100° C and WPL8 at -195° C temperature.
- The allowable pressure ratings for fittings may be calculated as for straight seamless pipe in accordance with the rules established in the applicable section of ASME B31.3.
- The pipe wall thickness and material type shall be that with which the fittings have been ordered to be used, their identity on the fittings is in lieu of pressure rating markings.

1.6 Stress Intensification Factor (SIF):

The term Stress Intensification Factor or SIF indicates a multiplier of Bending and Torsional stresses. This Intensifier acts local to a piping Component (tees, elbows, bends, Olets ,etc.) and Its value depends on component geometry. The minimum value of SIF is 1.0. It is widely used by piping stress engineers in places where the actual stress calculation is quite difficult due to its difficult geometry (Varying thickness, cross section, curvature etc.) as unlike straight Pipes the simple Beam theory is not applicable. So in this situation it is required to assume additional stresses by suitably incorporating a SIF. The following article will provide an example of SIF calculation of piping elbow or piping bends following process piping code ASME B31.3.

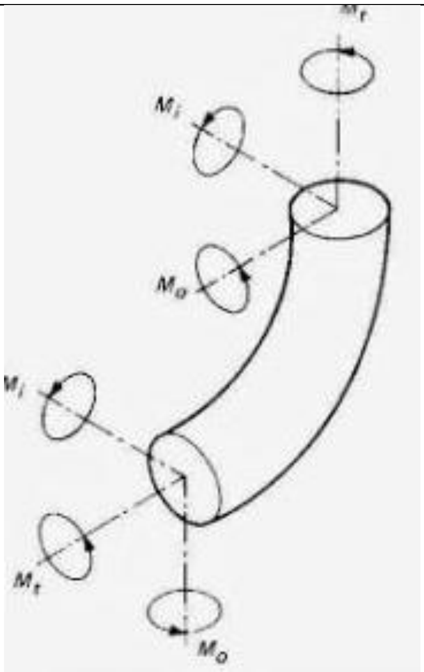


Fig : 1.6 Representation of pipe bend loading

1.7 Stress Intensification Factor for a Piping Bend/Elbow:

- In layman’s language the SIF of a bend or elbow can be defined as the ratio of bending stress of an elbow to that of straight pipe of same diameter and thickness when subjected to same bending moment. Whenever the same bending moment is applied to a bend because of ovalization the bending stress of the elbow will be much higher than that of straight pipe. That is why the SIF value will always be greater than or equal to 1.0 (for straight pipe).
- The process piping code ASME B 31.3 provides a simple formula to calculate the SIF of a bend or elbow. As per that code

SIF in-plane = 0.9 / h^(2/3)

SIF out-plane = 0.75 / h^(2/3)

Here h=T R1 / r2^2

h =Flexibility characteristics, dimensionless

T =Nominal wall thickness of bend, in

R1 =Bend radius, in

r2 =Mean radius of matching pipe, in

The in plane and out plane concept for a bend can be obtained from the attached figure from code or in layman’s language the same can be explained as follows:

The in-plane bending moment is the bending moment which causes elbow to close or open in the plane formed by two limbs of elbow.

In a similar way the out plane bending moment can be defined as the bending moment which causes one limb of elbow to move out of the plane keeping other limb steady.

From the above mentioned equations the following can be interpreted:

For the same pipe size and same pipe thickness

1. A short radius elbow is having more SIF as compared to a long radius elbow.
2. With increase in bend radius the SIF decreases and finally reaches to 1.0 for straight pipe.
3. The SIF for a 45-degree elbow and a 90-degree elbow is same as bend radius is same.
4. With increase in nominal pipe thickness or schedule the SIF of a bend (90 degree) keeps on decreasing till its value is equal to 1.0.

General requirements:

- Pipe and Fitting Material supplied must be strictly in accordance with the latest codes and standards, mentioned in the Material Requisition (MR or PR: Purchase Requisition) Scope of supply. This specification for pipes and fittings as detailed in subsequent points shall supplement the codes and other project specifications.
- All items must be supplied in accordance with proper wall thickness/ schedule as stated in the Purchase Requisition (PR). Wall thickness thinner or heavier than specified tolerance shall not be accepted.
- Vendor must specify the material type and grade together with NPS and schedule / wall thickness / class within the Material requisition – Scope of Supply for all piping components.
- Butt weld end preparation for pipes, fittings and flanges shall be as per ASME B16.25.
- 100% radiography has to be performed for all welded items to give a joint factor of 1.0. If not specified, Pipes and fitting shall be supplied seamless. Seamless is an acceptable alternative for welded pipe and fittings but vice-versa is not acceptable.

- The chemical analysis of Carbon Steel (CS) & Low Temperature Carbon Steel (LTCS) pipes and fittings, forgings, plates shall be in accordance with the applicable product standard with the following limitations:

  Carbon 0.23 Maximum wt% (pipes)

  Carbon 0.23 Maximum wt% (forgings)

  Carbon Equivalent (CE) shall not exceed 0.43%

  Where $CE = C + Mn/6 + (Cr+Mo+V)/5 + (Cu+Ni)/15$

The above formula for CE is applicable when the carbon content is greater than 0.12%

- CS & LTCS materials shall be fully killed and fine grained and shall be produced by a low sulphur and low phosphorus refining process. The components must be supplied in normalized or normalized and tempered condition.
- All Austenitic stainless steel, duplex stainless steel items must be supplied in solution annealed and quenched condition as per corresponding ASTM standard.
- Repair welding for parent plate / weld end flange is not accepted.
- The carbon content of SS 316 must be limited to 0.03%. All SS Materials specified as F 316 / WP 316/ Type 316 may be dual certified for both SS 316 & 316L, if specifically mentioned in the project specification.
- Austenitic stainless steel has to be capable of passing an intergranular corrosion test in accordance with ASTM A262, Practice E.
- All duplex stainless steel shall have ferrite content between 35% – 65% (volume fraction) on base metal and on heat affected zone to 35% – 70 % as per ASTM E562 four point count method.

1.8 Requirements for Pipes:

- Dimensions of CS / SS and Alloy steel (AS) pipe shall comply with ASME B36.10M or ASME B36.19M as applicable.
- CS pipes shall be supplied in double random lengths (11 to 13m) for pipe sizes 2” to 36”, and in single random lengths (5 to 7m) for pipe sizes 1.5” and smaller.

- SS, Duplex Stainless Steel (DSS) and Carbon Steel galvanized pipes shall be supplied in single random lengths (5 to 7m) for all pipe sizes.
- It is not permitted to join lengths of pipe by circumferential welds to make single or double random lengths.
- Plain end pipes must have square ends cut with burrs removed.
- All stainless steel pipes shall be supplied in solution annealed condition.
- All threaded & coupled pipes shall be supplied with ends threaded in accordance with ASME B1.20.1 (NPT).
- Each length of the threaded pipe shall be supplied with full coupling screwed hand tight at one end.
- Galvanizing of pipes shall be in accordance with ASTM A153. Threaded portion of pipes shall be free of galvanizing.
- Pipes shall be heat treated in accordance with product specification requirements after completion of all forming and welding operations.
- Carbon Steel & Low Temperature Carbon Steel (LTCS) Pipes shall be fully killed fine grained and shall be supplied in normalized or normalized and tempered condition.
- Welded pipe shall be supplied with single straight seam for sizes up to 36” and double straight seam for sizes greater than 36” subjected to approval from the contractor.
- Spiral seam welds are not acceptable.
- All DSS welded pipes with a wall thickness greater than 30 mm must be 100% ultrasonically examined.

1.9 Requirements for Fittings:

- Dimensions of butt welded fittings must be in accordance with ASME B16.9.
- Forged, threaded and socket welded fittings shall be in accordance with ASME B16.11.
- Other fittings dimensions shall comply with MSS SP-75, MSS SP-95, MSS SP-97 or BS 3799 as applicable.

- Vendor shall provide calculations as per ASME B31.3 for the fittings not covered under the above mentioned standards.
- Union dimensions shall be in accordance with BS 3799.
- All screwed fittings shall be threaded NPT in accordance with ASME B1.20.1.
- Branch reinforcing fittings (i.e. Elbowlets, Sockolets, weldolets, etc.) shall be designed in accordance with the requirements of ASME B31.3. The vendor shall submit drawings during bid stage and calculations for review and approval after award of contract.
- Butt weld elbows shall be long radius type (radius =1.5 nominal pipe size). Short radius elbows are not permitted.
- For reducing fittings specified with two schedules in the Inquiry / Purchase description, the first schedule refers to the larger end or run pipe, the second schedule refers to the smaller end or branch pipe.
- Fittings shall be forged to the final shape and size. Fittings shall not be machined from bar stock or solid forged billets without specific approval.
- Galvanizing of fittings shall be in accordance with ASTM A153. Threaded portion of fittings shall be supplied with threads free of galvanizing.
- Swage nipple shall be pipe swaged by forging only. Machining of bar stock, forgings or heavy wall pipe not permitted. Dimensions shall be in accordance with MSS-SP-95.
- All reduction sizes for tees and reducers to be in accordance with ASME B16.9.
- CS & LTCS fittings shall be fully killed and fine grained and shall be supplied in normalized or normalized and tempered condition.
- 100% of CS & LTCS welded fittings, with wall thickness greater than Sch 80 shall be examined by Magnetic Particle Examination for weld bevel ends. Acceptance standards shall be in accordance with ASME VIII Division 1, Appendix 6. This shall be done after final heat treatment.
- 100% of SS & DSS wrought fittings having wall thickness more than 20mm shall have the bevel and weld end over a width of 25mm, examined by Dye penetrant Method. Acceptance standards shall be in accordance with ASME VIII Division 1, Appendix 8.

- 100% of DSS welded fittings with a wall thickness greater than 30mm shall be 100% ultrasonically examined in accordance with ASME VIII Division 1.
- 100% of DSS forged fittings weld bevels shall be examined by Dye Penetrant inspection.
- 100% of CS, LTCS & SS forged fittings, with wall thickness greater than Sch 80 shall be examined by Magnetic Particle / Dye penetrant examination. Acceptance standards shall be in accordance with ASME VIII Division 1, Appendix 6 / 8. This shall be done after final heat treatment.

Positive material identification:

- Positive Material Identification (PMI) shall be conducted for all SS / CRA alloy piping items as per the project specification included in the Inquiry / Purchase requisition.

1.10 Special Requirements:

Sour service requirements:

- All materials specified for sour service shall, as a minimum, meet the requirements of NACE MR0175 / ISO 15156 – latest edition.
- All welded pipes / fittings in sour service shall be HIC tested, if required by the project specification. It shall be conducted for one pipe / fitting per heat in accordance with NACE TM-0284 Solution – A with acceptance criteria as specified in NACE MR-0175.

Impact test requirements:

- All CS, LTCS, welded austenitic and duplex stainless steel piping components shall be impact tested (for using in low temperature services) in accordance with ASME B31.3.
- For carbon steel pipes and fittings, the impact test temperature shall be the ‘minimum metal temperature’ as defined in the project. The impact test requirement and acceptance criteria shall be as per Cl. 323.2.2 and Cl. 323.3.5 of ASME B31.3 respectively.
- For welded SS and DSS items, the impact test temperature shall be the ‘minimum metal temperature’ as defined in the project but not more than (-101 Deg. C) and (-50 Deg. C) respectively. For SS items, the acceptance criteria shall be as per Cl. 323.3.5 of

ASME B 31.3. For DSS items, test results shall be at least 40 joules in transverse direction (for standard specimen 10 x 10 mm) as an average of three tests, one result may be lower but not less than 30 joules.

- For LTCS items, the impact test temperature shall be (-46 Deg. C). Test results shall be at least 27 joules as an average of three tests (for standard specimen 10 x 10 mm), one result may be lower, but not lower than 21 joules.

CHAPTER 02

LITERATURE REVIEW

2. LITERATURE REVIEW

N.C TANG [1], has employed Plastic-deformation theory to investigate the plastic deformation in pipe and tube bending. The major contribution of this paper is that it provides solutions to seven common tube-bending questions. In this paper, some practical formulae are developed to explain the phenomena in tube bending and their magnitudes are also derived. These are: (1) stresses in the bend; (2) wall thickness change; (3) shrinking rate at the tube section; (4) deviation of neutral axis; (5) feed preparation length of the bend; (6) bending moment, and (7) flattening. An experimental sample was also tested to illustrate that the results of the formulae are very similar to the experimental results.

D Z Wu and L Q Wang [2], worked on fluid-filled elbow pipe is simulated considering fluid-structure interaction (FSI) by the software ADINA. And the simulation results are validated through comparison with results obtained by other numerical solution. The results show that FSI affects the pipe-filled-water modal frequencies seriously, but have little effects on pipe vibration shapes, and the free vibration frequency of the fluid-filled pipe is lower than that of empty pipe. The pipe vibration amplitude and effective stress caused by fluid increase as the fluid velocity increase. Pipe continues vibrating after fluid velocity is steady, and the vibration is dispersing as time increase. The protection against vibration near the elbow is important because the maximum pipe deformation caused by fluid near the elbow. The maximum effective stress increases from 0 to 1.4MPa due to the fluid velocity increases from 0 to 20m/s in 5 seconds. So it is necessary to consider the FSI for fluid-filled pipe.

Mohammed Noorul Hussain, et.al, [3], analysed the stress occurring in its parts to make the design sturdy enough and to investigate the stress distribution in the pipe to reduce the defects in order to make the machine more efficient.

N. Dinesh et,al., [4], estimated effect of ovality by taking the internal fluid pressure and in plane bending moment into account. The optimum percentage of ovality which is desired for pipes has been estimated. The cross section of the pipes at the mid plane of the pipe bend is modelled with different percentages of ovality (six models) and structural analysis is performed. Based on the results (Deformation, Von Mises Stress and Stress Intensity) an optimum percentage of ovality is found out. In the present study the results are evaluated and compared for three factors deformation, stress intensity and percentage of ovality in the pipe bends.

Prasun Dutta, et.al, [5], has worked with Computational fluid dynamic (CFD) analysis of single phase turbulent flow was performed in a 90° pipe bend. After validation of present model against existing experimental results, the influence of Reynolds number on static pressure and velocity distributions at three different locations throughout the bend were studied. The standard k-ε turbulence model has been chosen for the present study. The results so obtained, are presented in graphical form. It was found that the static pressure and velocity profiles has a weak dependency on Reynolds number. Present study provides results to characterise the turbulent flow in 90° bend pipes.

Prasun Dutta et.al, [6], worked with the numerical study of single-phase turbulent flow through a 90° pipe bend using k-ε turbulence model. A detailed study has been carried out to investigate the effect of bend curvature on both axial velocity and static pressure distribution at different sections inside of pipe bend as well as adjacent sections of bend inlet (upstream) and outlet (downstream). Contour plots of both normalized axial velocity, static pressure as well as axial velocity profiles at different section are presented in graphical form. The effect of bend curvature on velocity and static pressure is clearly observed and discussed here.

CHAPTER 03

MODELLING

3. MODELLING

3.1 INTRODUCTION TO SOLIDWORKS:

SolidWorks is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes. SolidWorks currently markets several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product. SolidWorks is a solid modeller, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on Parasolid-kernel.

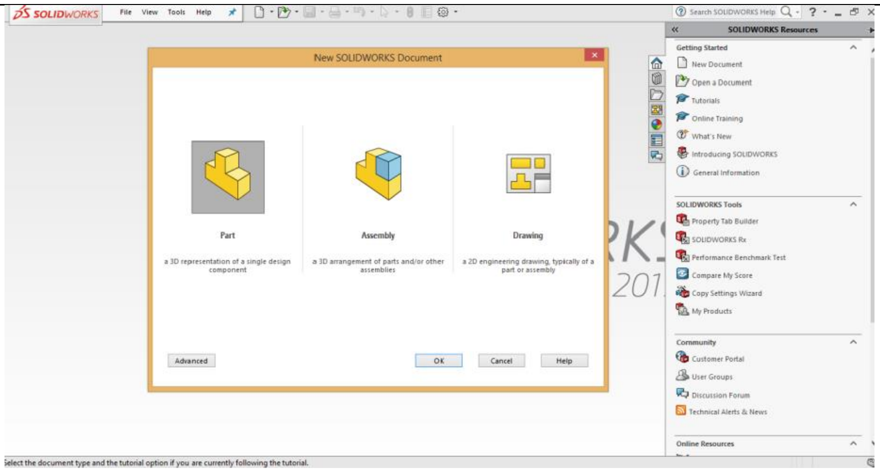
Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations which allows 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. SolidWorks allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the can.

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 SolidWorks 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 splines. 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 SolidWorks 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.

In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. SolidWorks also includes additional advanced mating features such as gear and cam follower mates, which allow modelled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, JIS, BSI and SAC).



Part: a 3D representation of a single design component

Assembly: a 3D arrangement of parts and/or other assemblies

Drawing: a 2D engineering drawing, typically of a part or assembly

Select the document type and the tutorial option if you are currently following the tutorial.

Fig 3.1 Selection of module in solidworks

The geometric model required for this work is prepared in SOLIDWORKS. While modelling the pipe bend, several factors were taken into account. The design of this elbow pipe bend was made so as to withstand 16 bar pressure which is usually witnessed in very specific high pressure industrial applications such as jet wash lines, high head hydro power schemes etc. Usually, piping of this grade recommends use of metal over PVC as piping material. In this work, the standard dimensions of pipe bend were taken from the calculations based on hydraulic piping standard handbook.

According to piping handbook, when a hose is bent between two points, it should not bend more than its minimum bend radius, under given maximum working pressure.

When hose is used beyond specified recommendations, unnecessary strain on the reinforcement and/or hose/coupling interface will shorten assembly life. Minimum bend radius for steel reinforced hose is determined under impulse testing and is specified on GS' data sheet for each hose type. A pipe should thus be bent only up to a certain bent radius for a given hose length. The relation between hose length and minimum bend radius is as follows.

$$L = \left(R + \frac{d_{\infty}}{2} \right) \frac{2\pi\alpha}{360} + 2S$$

Where L is hose length

R is bend radius (in mm)

d_{∞} is outside diameter (in mm)

α is bent angle (in degrees)

S is straight hose portion on coupling (in mm)

Fig: 3.1 Model of pipe bend

3.2 SPECIFICATIONS FOR THE MODEL:

Based on the above criteria, the pipe bend specifications were fixed as follows:

Parameters	Dimensions (m)
Outer Diameter	0.037
Inner diameter	0.03
Length of pipe	0.32
Thickness	0.007

Table 1: specifications of model

3.3 PROCEDURE FOR PREPARING THE MODEL:

1. Start the drawing by taking the top plane in the part module of solid works
2. Draw a rhombus with 0.16m as major diameter and 0.08 as minor diameter. Then apply fillet a fillet of radius 0.01m.
3. At a distance of 0.06m from the centre draw a circle of radius 0.02m on either sides on the major axis. Exit the sketch and extrude the figure to a distance of 0.01m
4. Take one face of the extruded figure and start a new sketch. Draw 2 circles of dia 0.037 and 0.03m respectively. Now go to features—extruded cut—and the click up to surface and select the opposite surface of extruded rhombus.
5. Select the extruded rhombus, take front plane and start a new sketch.
6. Draw a line of length 0.16m in positive y axis and from that end point draw another line of same length in positive x axis. Apply a fillet of radius 0.05m.
7. Start a new sketch by taking swept area in the YZ plane and draw a circle of dia 0.03m concentric to the existing one. Sweep cut along the pipe centre line.
8. Take a new plane 0.16m away from right plane as reference plane and repeat steps 1 and 2 to get the final modelling of required pipe bend with fixtures.

CHAPTER 04

ANALYSIS

4.0 ANALYSIS

4.1 INTRODUCTION TO ANSYS:

The analysis of this pipe bend was done in ANSYS software. ANSYS offers a comprehensive software suite that spans the entire range of physics, providing access to virtually any field of engineering simulation that a design process requires. Organizations around the world trust ANSYS to deliver the best value for their engineering simulation software investment.

Simulation-driven product development takes engineering simulation to another level - the unequalled depth and breadth of this software coupled with its unmatched engineered scalability, comprehensive multi-physics foundation and adaptive architecture set this technology apart from other CAE tools. These ANSYS advantages add value to the engineering design process by delivering efficiency, driving innovation and reducing physical constraints, enabling simulated tests that might not be possible otherwise.

The first part of the analysis is carried out in ANSYS Fluent, to determine the pressure and temperature distribution trends prevailing on the inner walls of pipe bend. ANSYS Fluent software contains the broad physical modelling capabilities needed to model flow, turbulence, heat transfer, and reactions for industrial applications—ranging from air flow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing, and from clean room design to wastewater treatment plants. Fluent covers a broad reach, including special models with capabilities to model in-cylinder combustion, aero-acoustics, turbo-machinery and multiphase systems

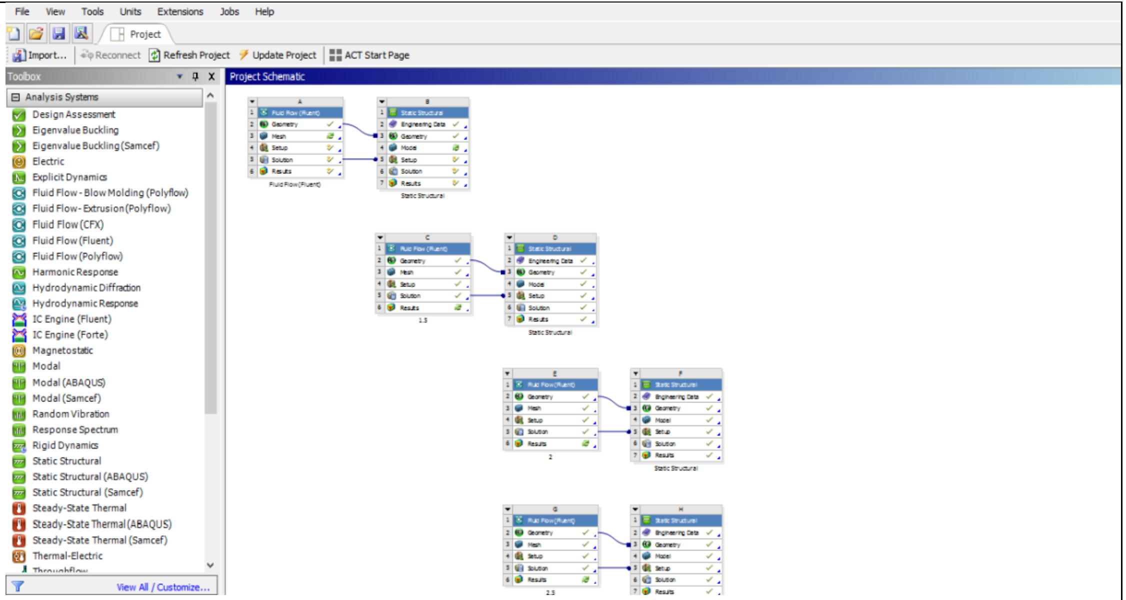


Fig 4.1 Ansys workbench interface

The results from CFD analysis were imported to ANSYS structures, to determine the stresses acting on the pipe bend and thereby to estimate the life of pipe bend taking into account, the fatigue loading. This process is repeated for various velocities of fluid flow (v = 1 m/s, v = 1.5 m/s, v = 2 m/s, v =2.5 m/s,) so as to analyse the effect of velocity on the life of pipe bend along with other input parameters.

4.2 INTODUCTION TO CFD:

Computational Fluid Dynamics (CFD) is the analysis of fluid flows using numerical solution methods. Using CFD, you are able to analyse complex problems involving fluid-fluid, fluid-solid or fluid-gas interaction. Engineering fields where CFD analyses are frequently used are for example aerodynamics and hydrodynamics, where quantities such as lift and drag or field properties as pressures and velocities are obtained. Fluid dynamics is involved with physical laws in the form of partial differential equations. Sophisticated CFD solvers transform these laws into algebraical equations and are able to efficiently solve these equations numerically Computational Fluid Dynamics (CFD) is the analysis of fluid flows using.

CFD analyses have a great potential to save time in the design process and are therefore cheaper and faster compared to conventional testing for data acquisition. Furthermore, in real life tests a limited amount of quantities is measured at a time, while in a CFD analysis all desired quantities can be measured at once, and with a high resolution in space and time.

Because CFD analyses approximate a real physical solution, it should be noted that these CFD analyses cannot fully exclude physical testing procedures. For verification purposes tests should still be performed.

A CFD analysis basically consists of the following three phases:

Pre-processing

In this phase the problem statement is transformed into an idealized and discretized computer model. Assumptions are made concerning the type of flow to be modelled (viscous/inviscid, compressible/incompressible, steady/non steady). Other processes involved are mesh generation and application of initial- and boundary conditions.

During pre-processing

- The geometry and physical bounds of the problem can be defined using computer aided design (CAD). From there, data can be suitably processed (cleaned-up) and the fluid volume (or fluid domain) is extracted.
- The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform, structured or unstructured, consisting of a combination of hexahedral, tetrahedral, prismatic, pyramidal or polyhedral elements.

Solving

The actual computations are performed by the solver, and in this solving phase computational power is required. There are multiple solvers available, varying in efficiency and capability of solving certain physical phenomena.

Post-processing

Finally, the obtained results are visualized and analysed in the post processing phase. At this stage the analyst can verify the results and conclusions can be drawn based on the obtained results. Ways of presenting the obtained results are for example static or moving pictures, graphs or tables.

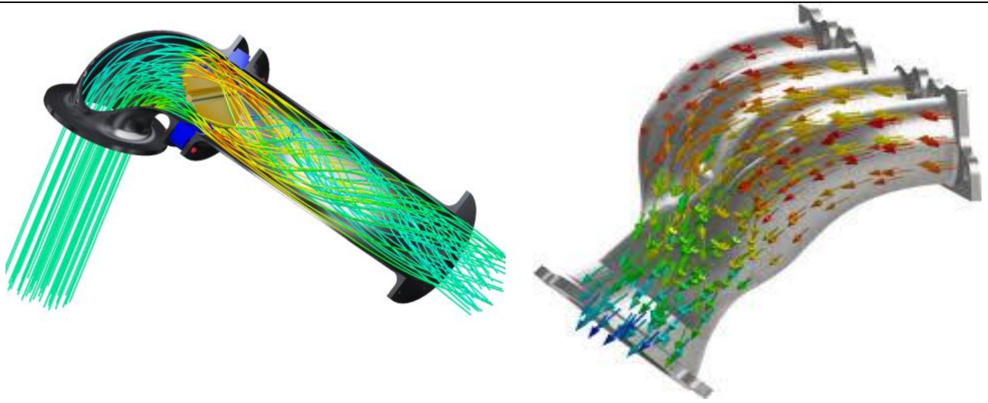


FIG: 4.2 EXAMPLES OF CFD

4.3 Meshing:

Meshing is defined as the process of dividing the whole component into a number of elements so that whenever the load is applied on the component it distributes the load uniformly called as meshing.

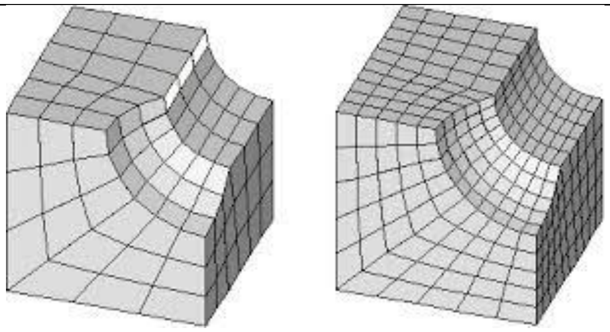


Fig:4.3 figure showing coarse and fine mesh

With Meshing:

- If the load is applied to the structure or a body and the body is considered to be meshed, then the load is distributed uniformly on the entire structure.
- After Meshing, the entire structure is divided into a number of elements and each element having its own stiffness while loading.
- Adding all those elements stiffness, you can get the Global Stiffness Matrix with which you can calculate the stress developed in the structure etc.
- If the Von-moises stress is less than the yield stress of the material, then the product analysed is safe, else it is of failure type.

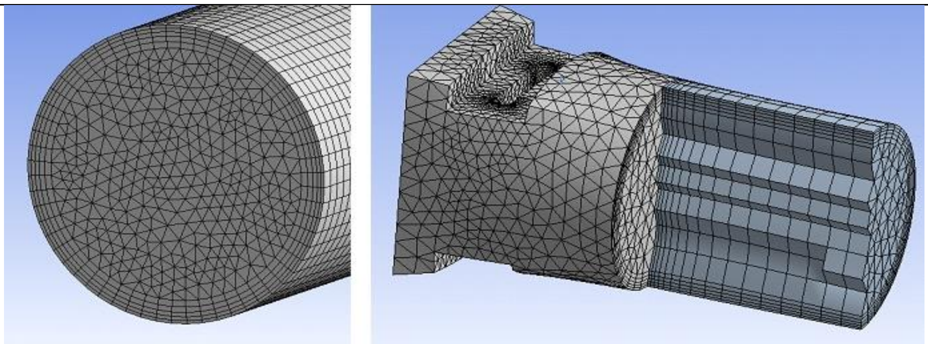


Fig:4.4 figure showing meshing of a component

Without Meshing:

If you are applying the load on the body which is not meshed, then the load distribution is not uniform and you may get the irregular or faulty results.

Types of elements in meshing:

The basic types of cell shapes are of two types. They are as follows-

1) Two dimensional
2) Three dimensional

1) Two-dimensional:

There are two types of two-dimensional cell shapes that are commonly used. These are the triangle and the quadrilateral.

Computationally poor elements will have sharp internal angles or short edges or both.

Triangle :

This cell shape consists of 3 sides and is one of the simplest types of mesh. A triangular surface mesh is always quick and easy to create. It is most common in unstructured grid

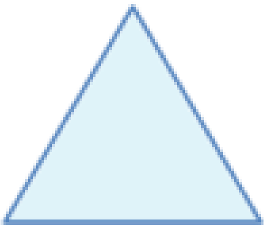


Fig:4.5 triangular elements in meshing

Quadrilateral :

This cell shape is a basic 4 sided one as shown in the figure. It is most common in structured grids. Quadrilateral elements are usually excluded from being or becoming concave.

Fig:4.6 quadrilateral elements in meshing

2) Three-dimensional:

The basic 3-dimensional element are the tetrahedron, quadrilateral pyramid, triangular prism, and hexahedron. They all have triangular and quadrilateral faces. Extruded 2-dimensional models may be represented entirely by prisms and hexahedra as extruded triangles and quadrilaterals.

In general, quadrilateral faces in 3-dimensions may not be perfectly planar. A nonplanar quadrilateral face can be considered a thin tetrahedral volume that is shared by two neighbouring elements.

Tetrahedron:

A tetrahedron has 4 vertices, 6 edges, and is bounded by 4 triangular faces. In most cases a tetrahedral volume mesh can be generated automatically**.**

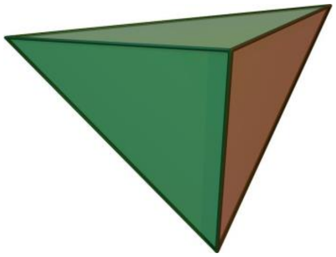


Fig:4.7 tetrahedron elements in meshing

Pyramid :

A quadrilateral-based pyramid has 5 vertices, 8 edges, bounded by 4 triangular and 1 quadrilateral face. These are effectively used as the transition elements between square and triangular faced elements and other in hybrid meshes and grids**.**

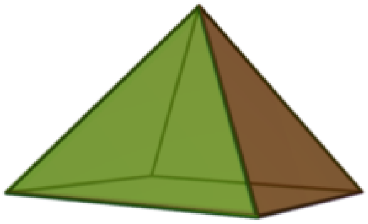


Fig:4.8 pyramid elements in meshing

Triangular prism:

A triangular prism has 6 vertices, 9 edges, bounded by 2 triangular and 3 quadrilateral faces. The advantage with this type of layer is that it resolves boundary layer efficiently.

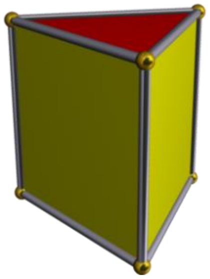


Fig:4.9 triangular prism elements in meshing

- **Hexahedron :**

- A hexahedron , a topological cube, has 8 vertices, 12 edges, bounded by 6 quadrilateral faces. It is also called a **hex** or a **brick**. For the same cell amount, the accuracy of solutions in hexahedral meshes is the highest.
- The pyramid and triangular prism zones can be considered computationally as degenerate hexahedrons , where some edges have been reduced to zero. Other degenerate forms of a hexahedron may also be represented.

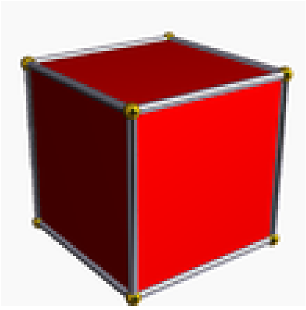


Fig:4.10 hexahedron elements in meshing

4.4 BRICK AND TETRA MESHING COMPARISON:

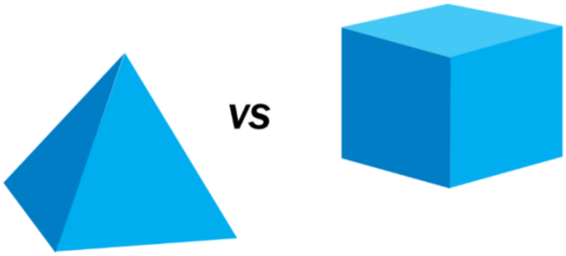


Fig: 4.11 Comparison of tetra and brick mesh

- The number of elements and nodes generated by a brick mesh are of the order of 1/2 and 1/50 in comparison to a tetra mesh. A brick mesh reduces the solution time and results in the ease of handling the model on a workstation.
- Analysis type like crash or nonlinear give preference to brick mesh due to number of nodes and mesh flow line.
- The time consumed in brock meshing is more and requires experience, hard work and a lot of patience too.
- Over the years the algorithm for tetra meshing has improved accuracy while there is not much difference in tetra 10 and brick 8 elements.

4.5 BOUNDARY CONDITIONS AND SETUP:

FOR VELOCITY OF 1M/S:

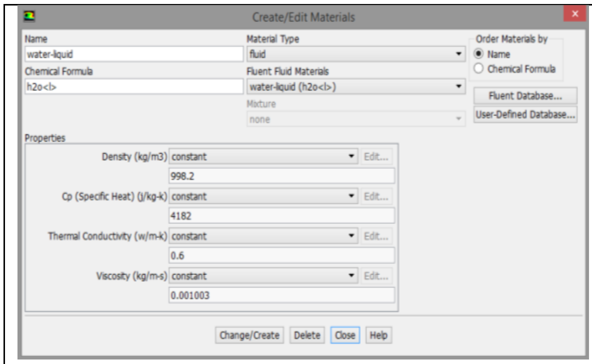
The following are the boundary conditions and setup conditions for both CFD and Structural analysis respectively.

CFD ANALYSIS:

- Velocity inlet = 1m/s
- Temperature inlet =340k
- The properties of fluid considered for simulating the flow of fluid inside the pipe bend is as shown in figure 4.12
- Here for meshing the fluid flowing inside the pipe bend, brick (hex-)meshing is considered. Meshing of the fluid flowing inside the pipe bend is as shown in the figure 4.13. The following the meshing properties observed:

Number of mesh elements: 17690

Number of nodes: 18939



Create/Edit Materials

Name: water-liquid

Material Type: fluid

Order Materials by: ● Name ○ Chemical Formula

Chemical Formula: h2o<l>

Fluent Fluid Materials: water-liquid (h2o<l>)

Mixture: none

Properties

Density (kg/m3): constant, 998.2

Cp (Specific Heat) (j/kg-k): constant, 4182

Thermal Conductivity (w/m-k): constant, 0.6

Viscosity (kg/m-s): constant, 0.001003

Fig 4.12 fluid inlet conditions

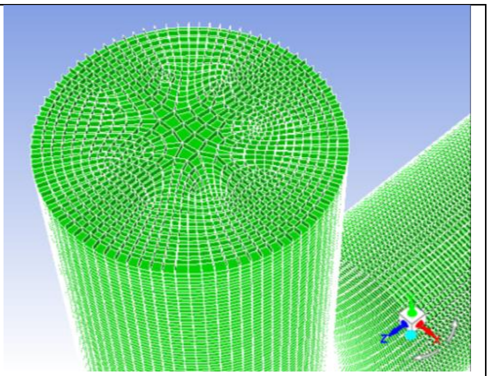


Fig : 4.13 fluid mesh

STRUCTURAL ANALYSIS:

- The centre of gravity of the pipe bend where the weight of the entire pipe bend is supposed to be acting at. It is as shown in the figure 4.14.

- The fixtures of the pipe bend being rigidly fixed as they are usually riveted or bolted to a pipe or a wall. It is represented in the figure 4.15.

- The type of mesh considered for pipe bend structure is a tetra mesh. Type of mesh and quality of mesh are as shown in the figures 4.16& 4.17 respectively. The properties of mesh are as follows:

Number of elements: 313234

Number of nodes: 474508

- The figure 4.18 shows the internal surface of the pipe bend through which fluid is flowing. The results from the fluent analysis are taken as the input boundary conditions for the pipe bend structural analysis

- The imported body temperatures from the results obtained during CFD analysis as shown in the figures 4.19 & 4.20 respectively.

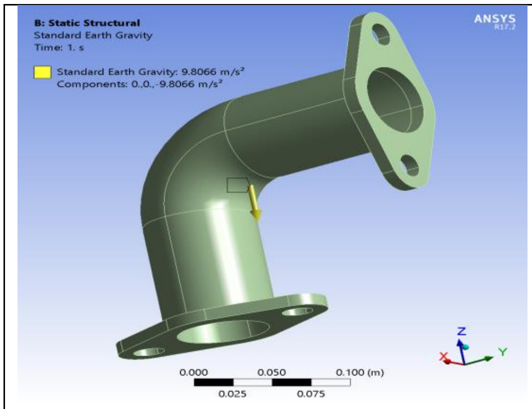
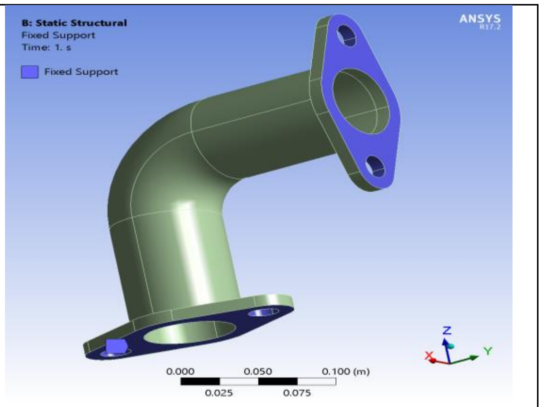
	

Fig: 4.14 Centre of gravity of pipe bend	**Fig : 4.15 Fixing the geometries**

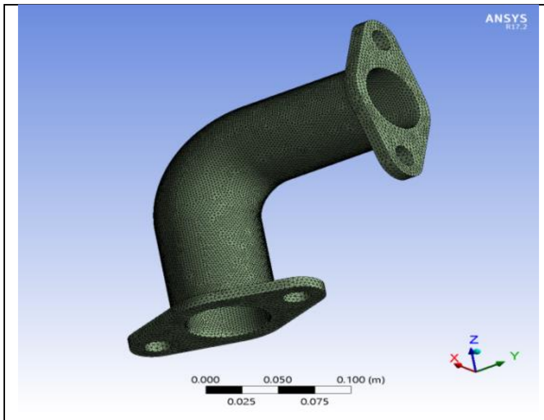
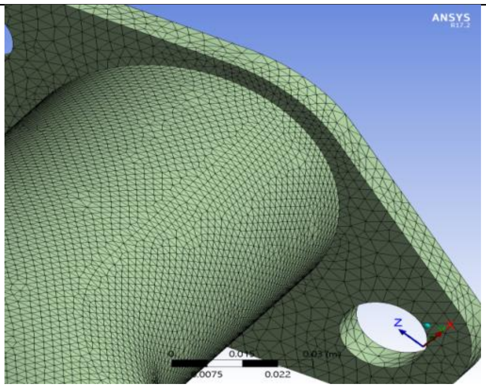
	

Fig : 4.16 Mesh of pipe bend	**Fig: 4.17 Quality of mesh**

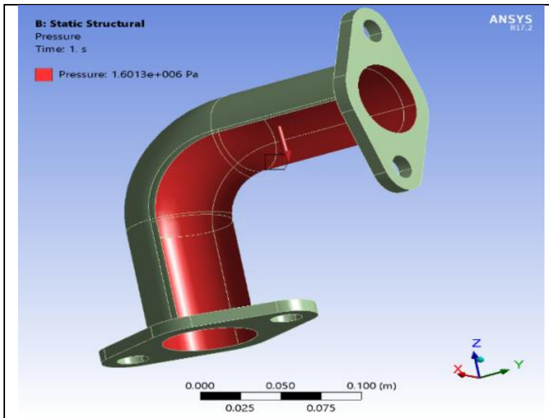


Fig : 4.18 Surface in contact with fluid

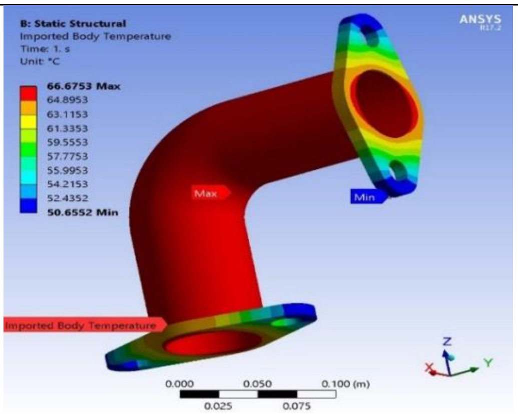


Fig:4.19 Temperature distribution of pipe

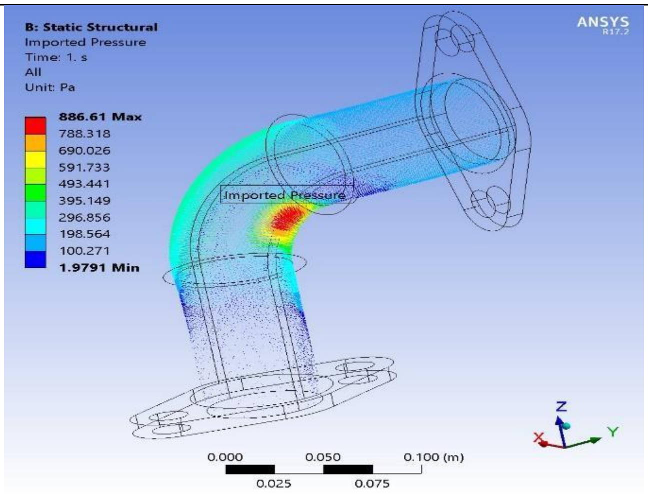


Fig: 4.20 Pressure distribution in pipe bend

FOR VELOCITY OF 1.5M/S:

The following are the boundary conditions and setup conditions for CFD and structural analysis respectively

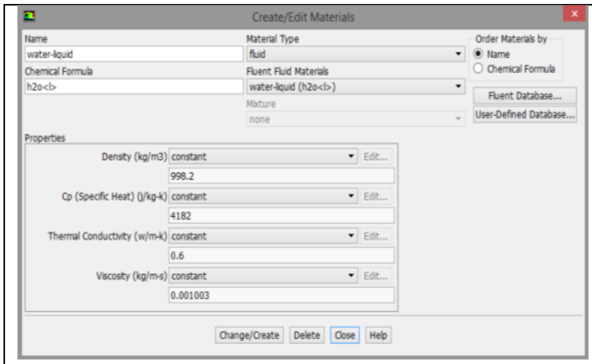
CFD ANALYSIS:

- Velocity at inlet = 1.5m/s
- Temperature at inlet = 340k
- The properties of fluid considered for simulating the flow of fluid inside the pipe bend is as shown in figure 4.21.

- Here for meshing the fluid flowing inside the pipe bend, brick (hex-)meshing is considered. Meshing of the fluid flowing inside the pipe bend is as shown in the figure 4.22. The following the meshing properties observed:

  Number of mesh elements: 17690

  Number of nodes : 18939



Name: water-liquid
Material Type: fluid
Chemical Formula: h2o<l>
Fluent Fluid Materials: water-liquid (h2o<l>)
Mixture: none

Properties
Density (kg/m3): constant
998.2
Cp (Specific Heat) (j/kg-k): constant
4182
Thermal Conductivity (w/m-k): constant
0.6
Viscosity (kg/m-s): constant
0.001003

Fig 4.21 Fluid inlet conditions

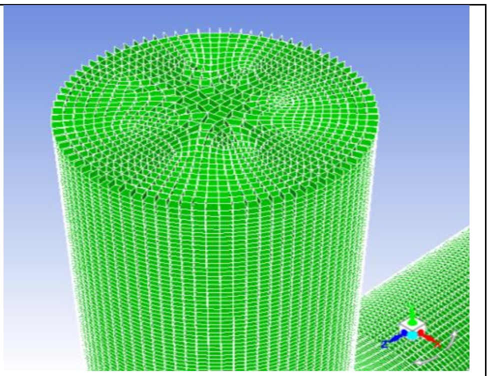


Fig: 4.22 Fluid mesh

STRUCTURAL ANALYSIS:

- The centre of gravity of the pipe bend where the weight of the entire pipe bend is supposed to be acting at. It is as shown in the figure 4.23.
- The fixtures of the pipe bend being rigidly fixed as they are usually riveted or bolted to a pipe or a wall. It is represented in the figure 4.24.
- The type of mesh considered for pipe bend structure is a tetra mesh. Type of mesh and quality of mesh are as shown in the figures 4.25 & 4.26 respectively. The properties of mesh are as follows:

  Number of elements: 313234

  Number of nodes: 680134

- The figure 4.27 shows the internal surface of the pipe bend through which fluid is flowing. The results from the fluent analysis are taken as the input boundary conditions for the pipe bend structural analysis.
- The imported body temperatures from the results obtained during CFD analysis as shown in the figures respectively 4.28 & 4.29.

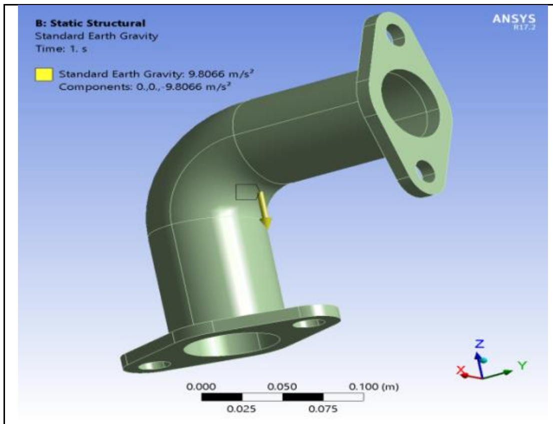


Fig : 4.23 centre of gravity

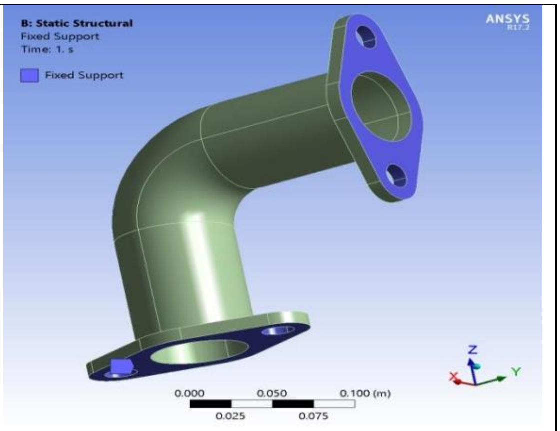


Fig : 4.24 fixing the geometry

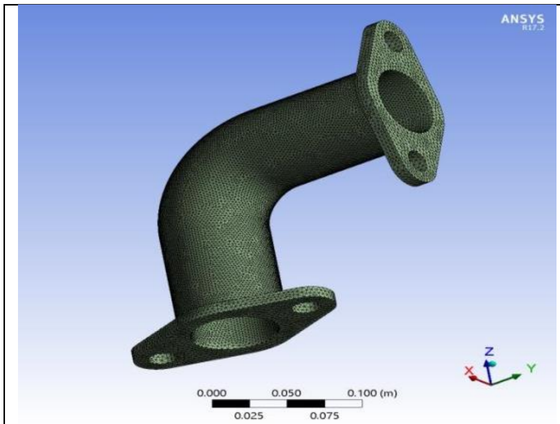


Fig : 4.25 meshing of pipe bend

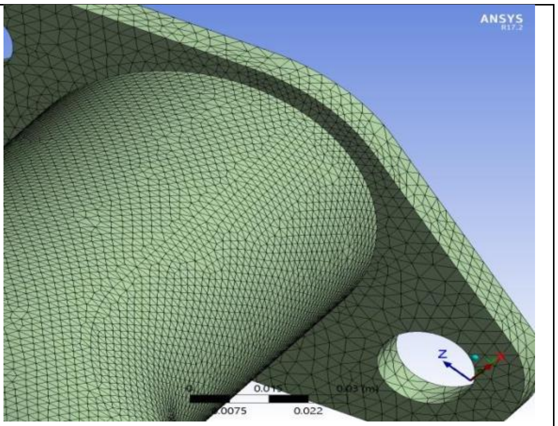


Fig : 4.26 Quality of mesh

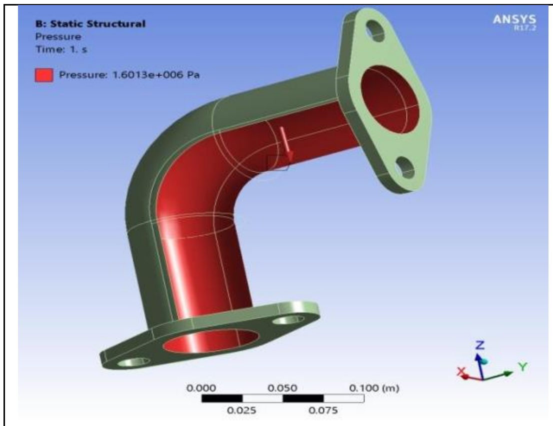


Fig : 4.27 Surface in contact with fluid

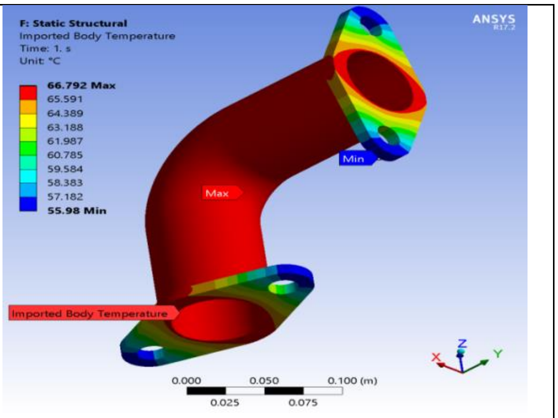


Fig : 4.28 Temperature distribution

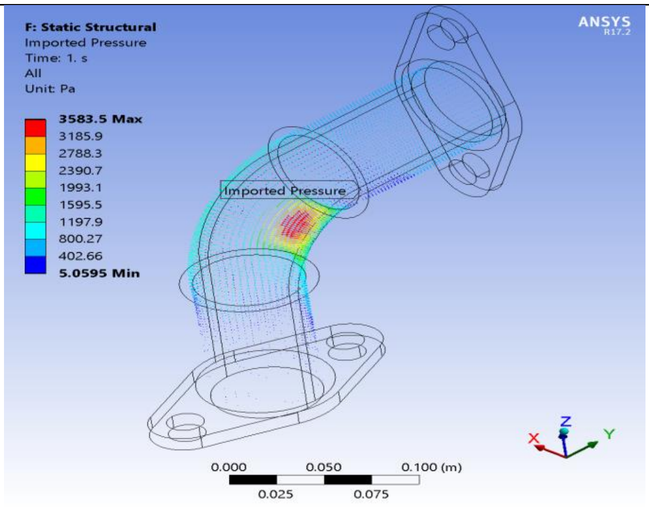


Fig : 4.29 pressure distribution in pipe bend

FOR VELOCITY OF 2M/S:

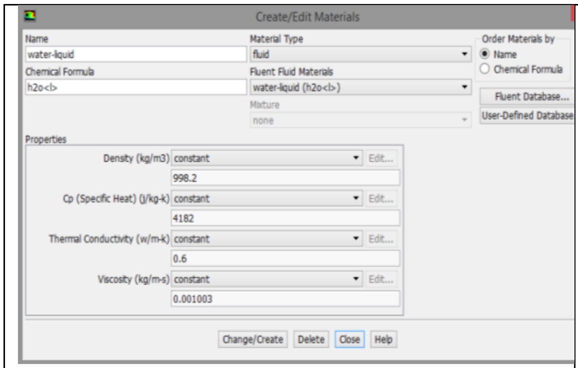
The following are the boundary conditions and setup conditions for CFD and structural analysis respectively

CFD ANALYSIS:

- Velocity at inlet = 2m/s
- Temperature at inlet = 340k
- The properties of fluid considered for simulating the flow of fluid inside the pipe bend is as shown in figure 4.**30**.
- Here for meshing the fluid flowing inside the pipe bend, brick (hex-)meshing is considered. Meshing of the fluid flowing inside the pipe bend is as shown in the figure 4.31.. The following the meshing properties observed:

  Number of mesh elements: 17690

  Number of nodes : 18939



Create/Edit Materials

Name: water-liquid

Chemical Formula: h2o<l>

Material Type: fluid

Fluent Fluid Materials: water-liquid (h2o<l>)

Mixture: none

Order Materials by: ● Name ○ Chemical Formula

Properties

Density (kg/m3): constant 998.2

Cp (Specific Heat) (j/kg-k): constant 4182

Thermal Conductivity (w/m-k): constant 0.6

Viscosity (kg/m-s): constant 0.001003

Fig : 4.30 Fluid inlet conditions

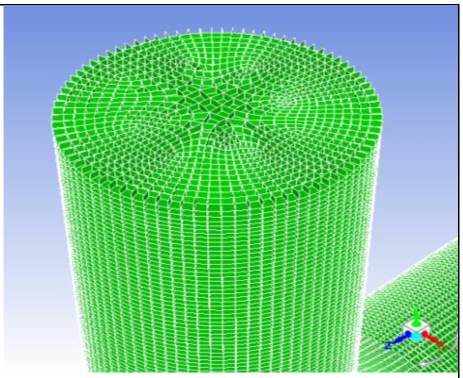


Fig : 4.31 Fluid mesh

STRUCTURAL ANALYSIS:

- The centre of gravity of the pipe bend where the weight of the entire pipe bend is supposed to be acting at. It is as shown in the figure 4.32.
- The fixtures of the pipe bend being rigidly fixed as they are usually riveted or bolted to a pipe or a wall. It is as shown in the figure 4.33.
- The type of mesh considered for pipe bend structure is a tetra mesh. Type of mesh and quality of mesh are as shown in the figures 4.34 & 4.35 respectively. The properties of mesh are as follows:

  Number of elements: 279316

  Number of nodes: 655257
- The figure 4.36 shows the internal surface of the pipe bend through which fluid is flowing. The results from the fluent analysis are taken as the input boundary conditions for the pipe bend structural analysis.
- The imported body temperatures from the results obtained during CFD analysis as shown in the figures 4.37 & 4.38 respectively.

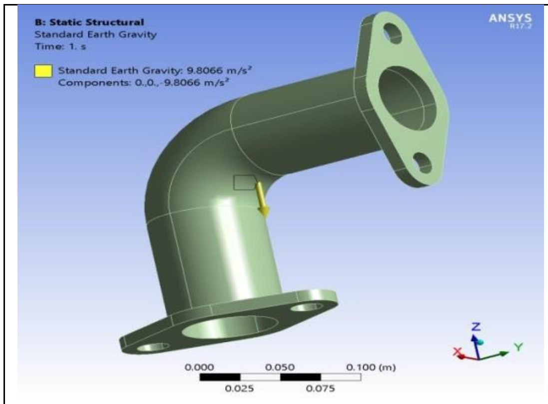


Fig : 4.32 Centre of gravity of pipe bend

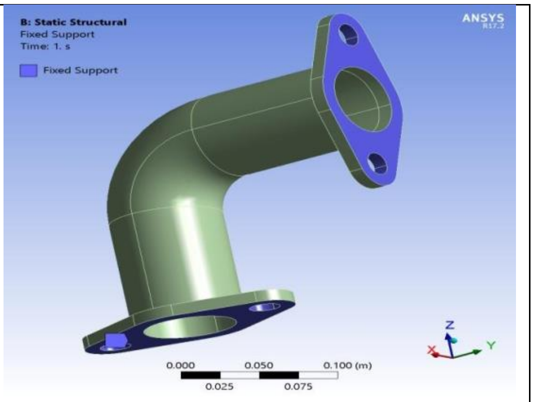


Fig : 4.33 Fixing the geometry

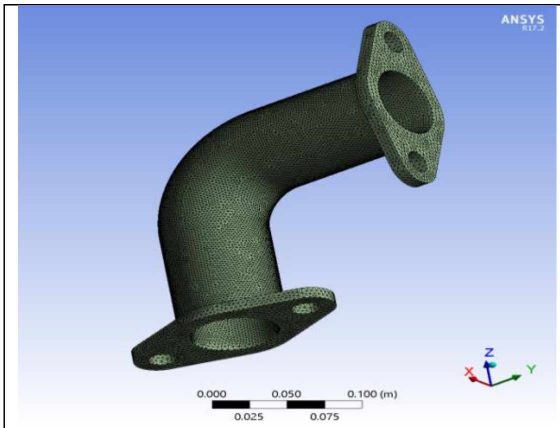


Fig : 4.34 Meshing of pipe bend

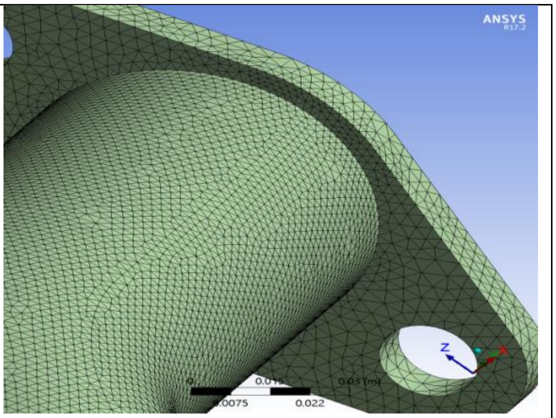


Fig : 4.35 Quality of mesh

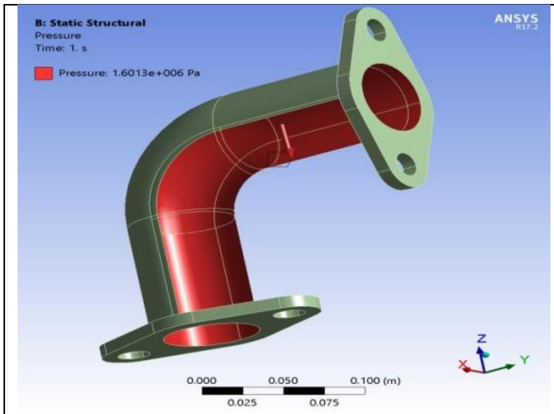


Fig :4.36 Surface in contact with fluid

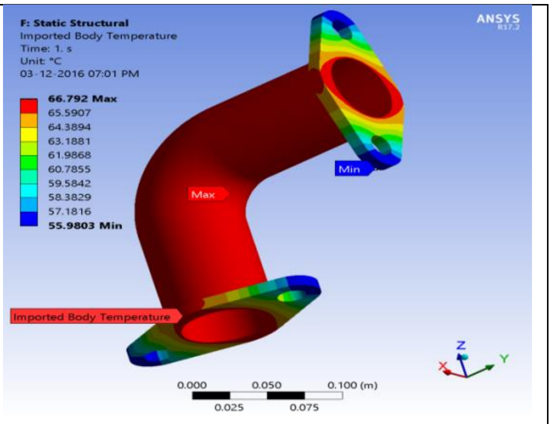


Fig:4.37 Temperature distribution in pipe

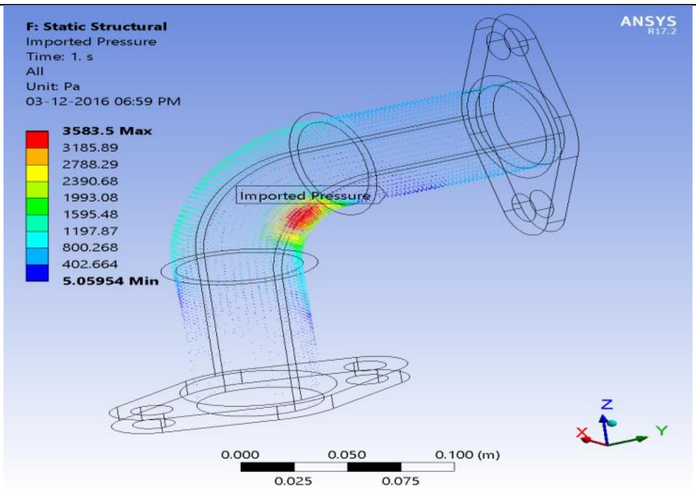


Fig : 4.38 Pressure distribution in pipe bend

FOR VELOCITY OF 2.5M/S:

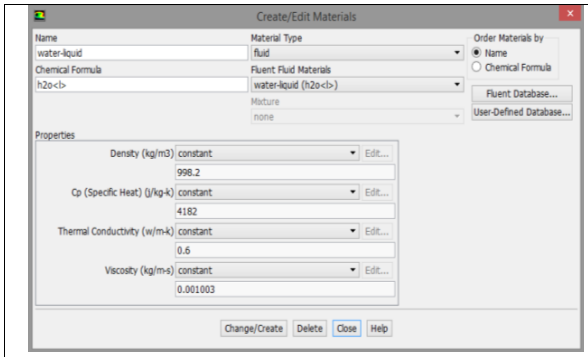
The following are the boundary conditions and setup conditions for CFD and structural analysis respectively

*CFD ANALYSIS***:**

- Velocity at inlet = 2m/s
- Temperature at inlet = 340k
- The properties of fluid considered for simulating the flow of fluid inside the pipe bend is as shown in figure 4.39.
- Here for meshing the fluid flowing inside the pipe bend, brick (hex-)meshing is considered. Meshing of the fluid flowing inside the pipe bend is as shown in the figure 4.40. The following the meshing properties observed:

Number of mesh elements: 17690

Number of nodes : 18939



Name: water-liquid

Material Type: fluid

Order Materials by: ● Name ○ Chemical Formula

Chemical Formula: h2o<l>

Fluent Fluid Materials: water-liquid (h2o<l>)

Mixture: none

Properties

Density (kg/m3): constant, 998.2

Cp (Specific Heat) (j/kg-k): constant, 4182

Thermal Conductivity (w/m-k): constant, 0.6

Viscosity (kg/m-s): constant, 0.001003

Fig: 4.39 Inlet conditions of fluid

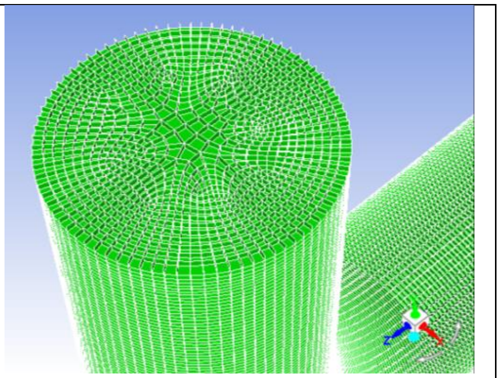


Fig: 4.40 Fluid mesh

STRUCTURAL ANALYSIS:

- The centre of gravity of the pipe bend where the weight of the entire pipe bend is supposed to be acting at. It is as shown in the figure 4.41.
- The fixtures of the pipe bend being rigidly fixed as they are usually riveted or bolted to a pipe or a wall. It is represented in the figure 4.42.
- The type of mesh considered for pipe bend structure is a tetra mesh. Type of mesh and quality of mesh are as shown in the figures 4.43 & 4.44 respectively. The properties of mesh are as follows:

Number of elements: 313234

Number of nodes: 474508

- The figure 4.45 shows the internal surface of the pipe bend through which fluid is flowing. The results from the fluent analysis are taken as the input boundary conditions for the pipe bend structural analysis.
- The imported body temperatures from the results obtained during CFD analysis as shown in the figures 4.46 & 4.47 respectively.

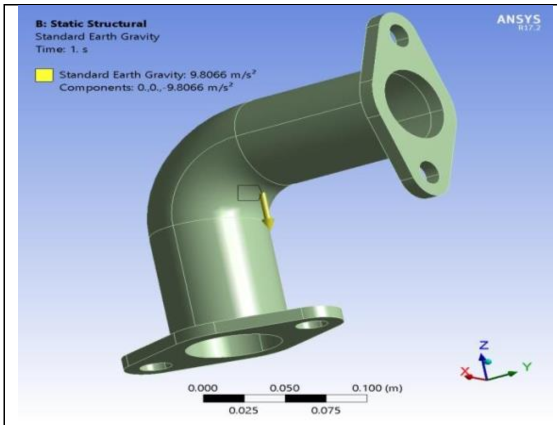
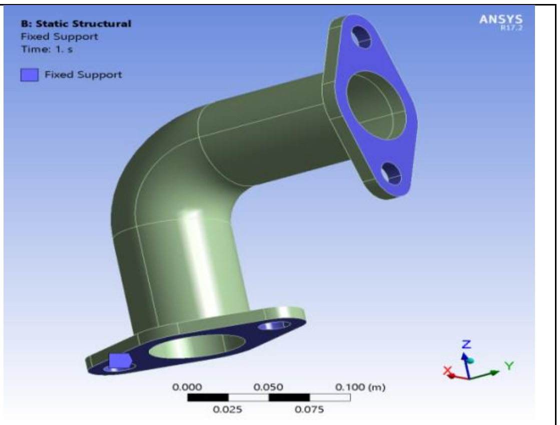
	

Fig : 4.41 Centre of gravity of pipe bend	**Fig: 4.42 Fixing geometry of pipe bend**

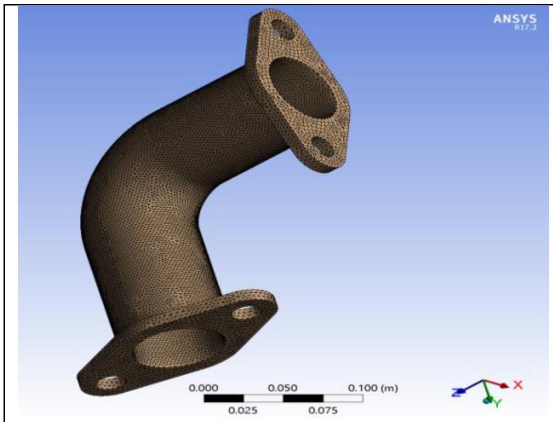
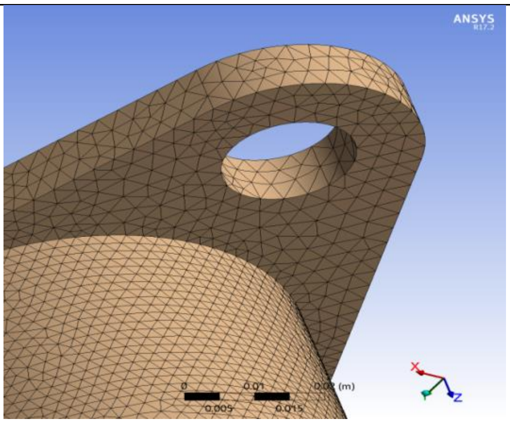
	

Fig : 4.43 Meshing of pipe bend	**Fig: 4.44 Quality of mesh**

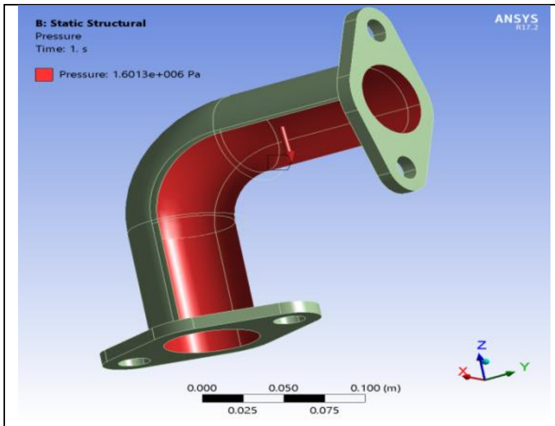


Fig 4.45 Surface in contact with fluid

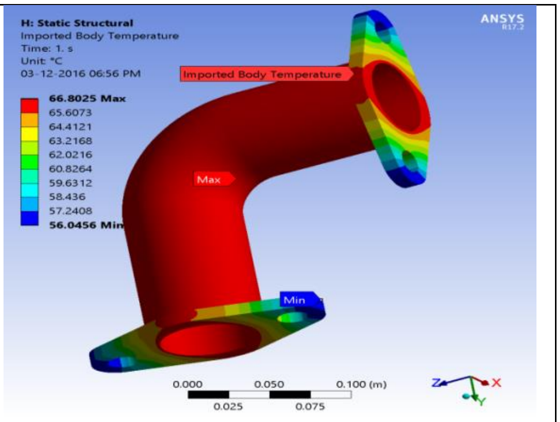


Fig4.46 Temperature distribution in pipe

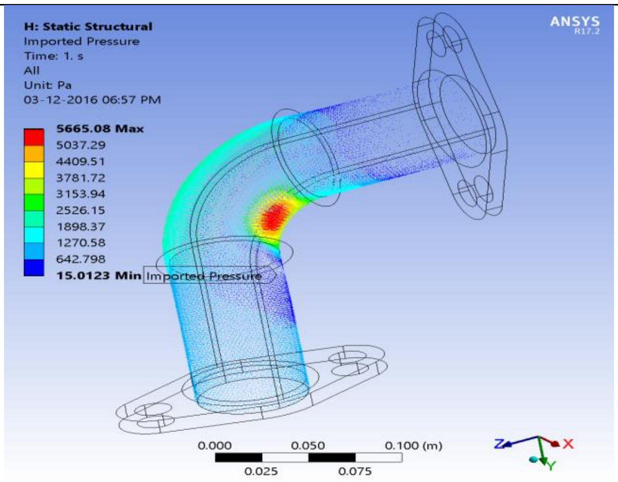


Fig : 4.47Pressure distribution in pipe bend

CHAPTER 05

RESULTS & DISCUSSIONS

5.RESULTS

FOR VELOCITY OF 1 M/S:

CFD ANALYSIS:

- Velocity profile for the fluid is as shown in the figure 5.1 . It can be observed that maximum velocity is observed near the bend because of turbulence. The maximum velocity observed is 1.62m/s and the minimum velocity observed is 3.49e-3 m/s.
- The figure 4.19 shows temperature distribution for the pipe bend. It can be observed that the maximum temperature is observed along the pipe surface through which fluid is flowing and the maximum temperature is 66.6753◦c. The least temperatures are observed at the outermost surfaces on the fixtures with the minimum temperature of 50.6552 ◦ c.
- The figure 4.20 shows pressure distribution on the pipe bend. Maximum amount of pressure is observed near the pipe bend where the weight of the pipe is acting. The maximum pressure is found to be 886.61pa and the minimum pressure is observed along the pipe surface near the fixtures with a value of 1.9791pa.

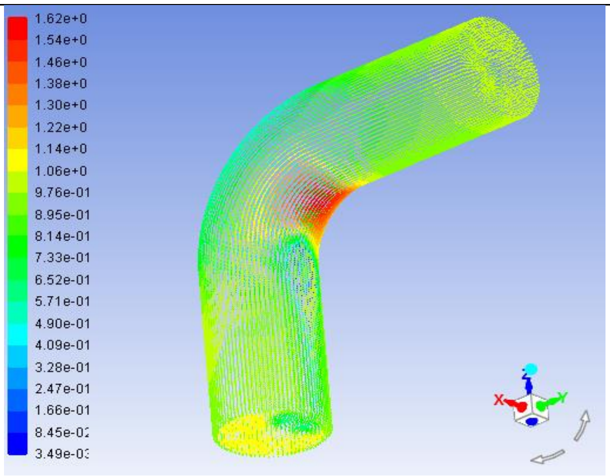


Fig : 5.1 Velocity profile of fluid

STRUCTURAL ANALYSIS:

- The figure 5.2 shows total deformations in a pipe bend due to fluid flowing. It can be observed that maximum deformation is at the outermost circumference and the inner most circumference whereas fixtures had minimum deformations. The maximum deformation is 0.12457e-3 m and minimum deformation is 0m.

- The figure 5.3 shows equivalent stresses developed in the pipe bend. It can be observed that the maximum stresses were observed near the fixtures. The maximum stress observed is 4.1065e8 pa and minimum stress developed is 1.5271e5 pa.
- The figures 5.4 & 5.5 shows the life cycle of the pipe bend. It can be observed that the fixtures where it is bolted is the part with lowest life cycle. It is due to vibrations being developed after continuous use. Maximum life of parts is 6.5849e5 cycles and minimum life is 23278 cycles.

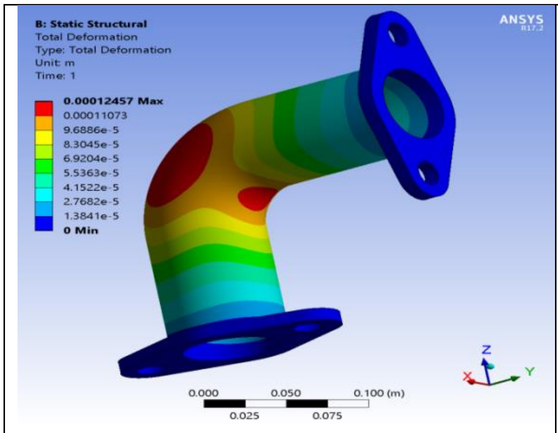


Fig : 5.2 Deformations in pipe bend

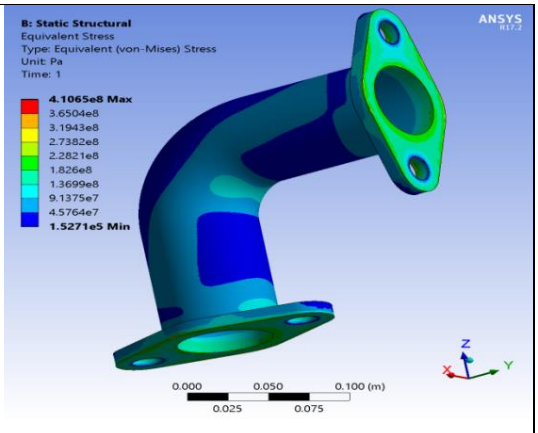


Fig: 5.3 Stress distribution in pipe bend

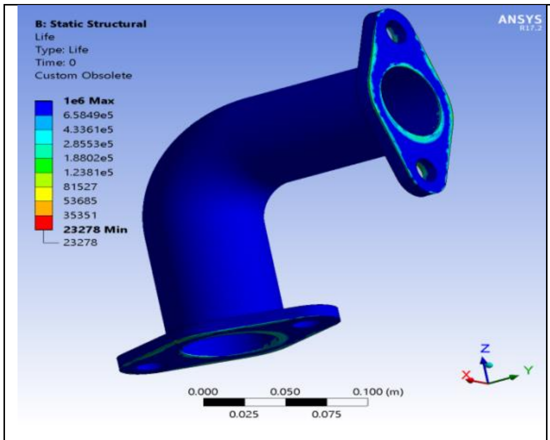


Fig : 5.4 Life cycle of pipe bend

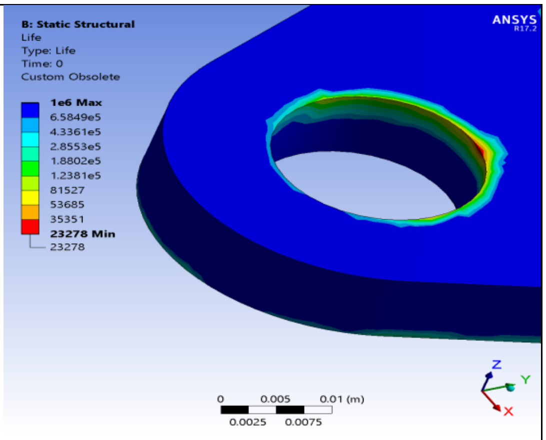


Fig : 5.5 Failure in pipe bend

FOR VELOCITY OF 1.5 M/S:

CFD ANALYSIS:

- Velocity profile for the fluid is as shown in the figure 5.6. It can be observed that maximum velocity is observed near the bend because of turbulence. The maximum velocity observed is 2.45 m/s and the minimum velocity observed is 5.07e-3 m/s.
- The figure 4.28 shows temperature distribution for the pipe bend. It can be observed that the maximum temperature is observed along the pipe surface through which fluid is flowing and the maximum temperature is 66.792◦c. The least temperatures are observed at the outermost surfaces on the fixtures with the minimum temperature of 55.98◦c.
- The figure 4.29 shows pressure distribution on the pipe bend. Maximum amount of pressure is observed near the pipe bend where the weight of the pipe is acting. The maximum pressure is found to be 3583.5pa and the minimum pressure is observed along the pipe surface near the fixtures with a value of 5.0595pa.

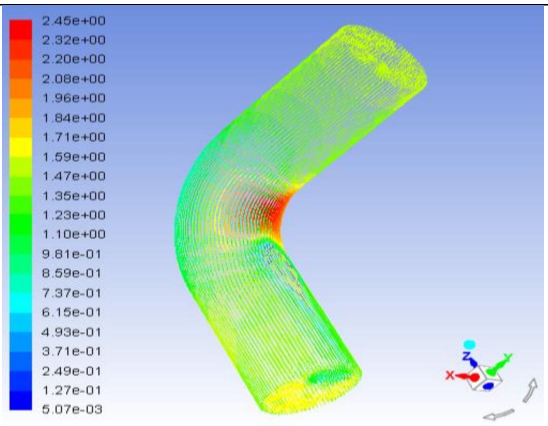


Fig : 5.6 Velocity profile of fluid

STRUCTURAL ANALYSIS:

- The figure 5.7 shows total deformations in a pipe bend due to fluid flowing. It can be observed that maximum deformation is at the outermost circumference and the inner most circumference whereas fixtures had minimum deformations. The maximum deformation is 0.1257e-3 m and minimum deformation is 0m.

- The figure 5.8 shows equivalent stresses developed in the pipe bend. It can be observed that the maximum stresses were observed near the fixtures. The maximum stress observed is 4.4788e8 pa and minimum stress developed is 1.3197e5 pa.
- The figures 5.9 & 5.10 shows the life cycle of the pipe bend. It can be observed that the fixtures where it is bolted is the part with lowest life cycle. It is due to vibrations being developed after continuous use. Maximum life of parts is 6.4322e5 cycles and minimum life is 18846 cycles.

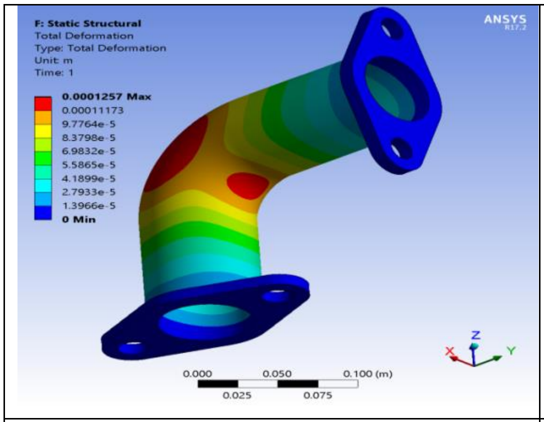


Fig : 5.7 Deformation in pipe bend

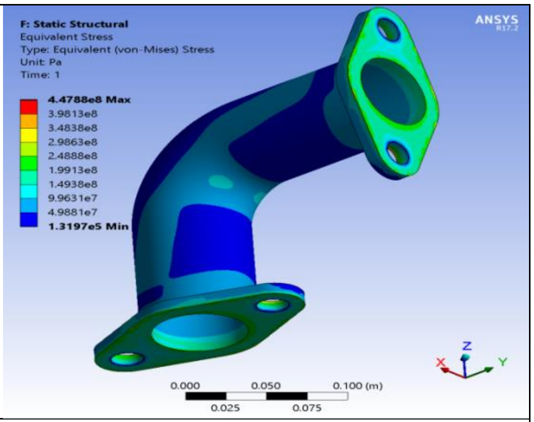


Fig : 5.8 Stress distribution in pipe bend

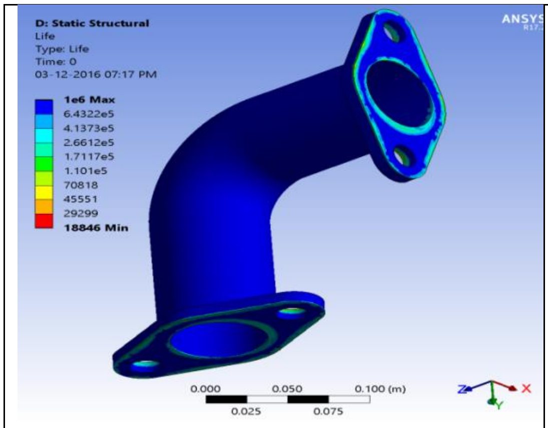


Fig : 5.9 Life cycle of pipe bend

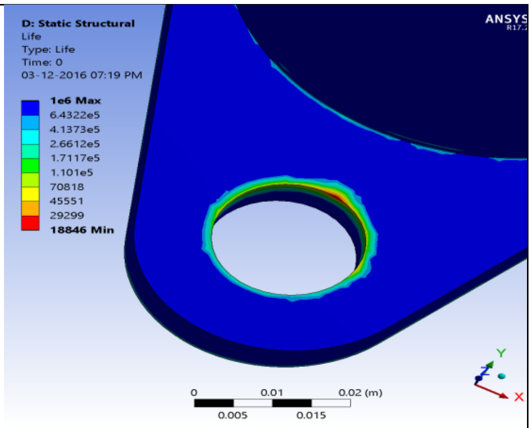


Fig :5.10 Failures in pipe bend

FOR VELOCITY OF 2 M/S:

CFD ANALYSIS:

- Velocity profile for the fluid is as shown in the figure 5.11. It can be observed that maximum velocity is observed near the bend because of turbulence. The maximum velocity observed is 3.27 m/s and the minimum velocity observed is 7.16e-3 m/s.
- The figure 4.37 shows temperature distribution for the pipe bend. It can be observed that the maximum temperature is observed along the pipe surface through which fluid is flowing and the maximum temperature is 66.792◦c. The least temperatures are observed at the outermost surfaces on the fixtures with the minimum temperature of 55.9803 ◦ c.
- The figure 4.38 shows pressure distribution on the pipe bend. Maximum amount of pressure is observed near the pipe bend where the weight of the pipe is acting. The maximum pressure is found to be 3583.5pa and the minimum pressure is observed along the pipe surface near the fixtures with a value of 5.05954pa.

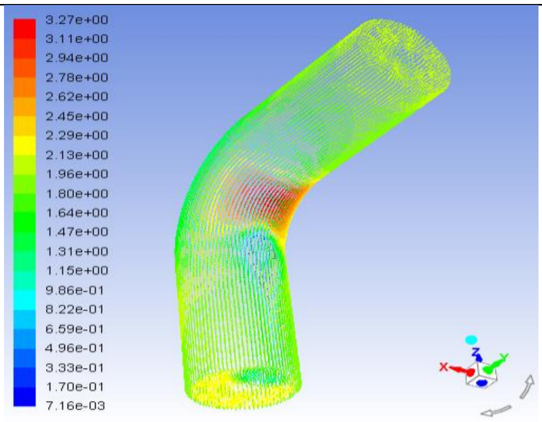


Fig :5.11 Velocity profile of fluid

STRUCTURAL ANALYSIS:

- The figure 5.12 shows total deformations in a pipe bend due to fluid flowing. It can be observed that maximum deformation is at the outermost circumference and the inner most circumference whereas fixtures had minimum deformations. The maximum deformation is 0.12576e-3 m and minimum deformation is 0m.

- The figure 5.13 shows equivalent stresses developed in the pipe bend. It can be observed that the maximum stresses were observed near the fixtures. The maximum stress observed is 4.3713e8 pa and minimum stress developed is 1.6876e5 pa.
- The figure 5.14 & 5.15 shows the life cycle of the pipe bend. It can be observed that the fixtures where it is bolted is the part with lowest life cycle. It is due to vibrations being developed after continuous use. Maximum life of parts is 6.423e5 cycles and minimum life is 18604 cycles.

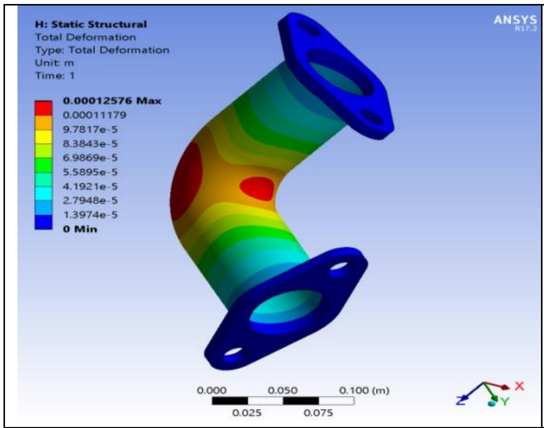


Fig : 5.12 Deformation in pipe bend

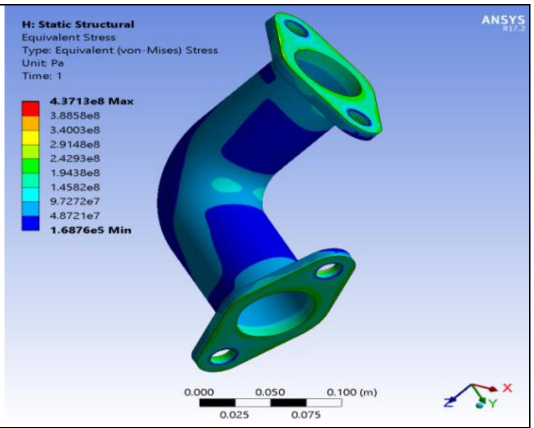


Fig : 5.13 Stress distribution in pipe bend

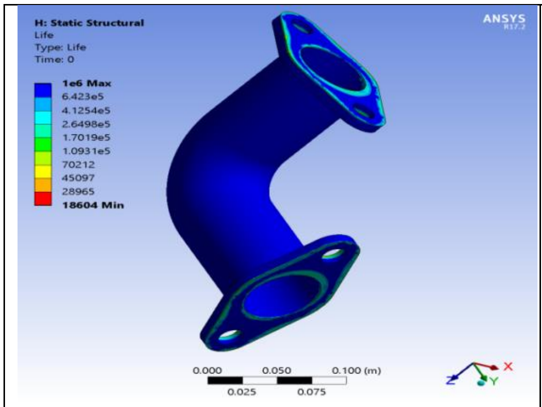


Fig :5.14 Life cycle of pipe bend

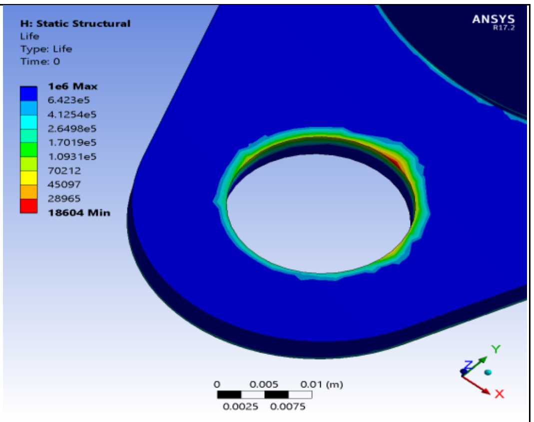


Fig :5.15 failure of pipe bend

FOR VELOCITY 2.5 M/S:

CFD ANALYSIS:

- Velocity profile for the fluid is as shown in the figure 5.16. It can be observed that maximum velocity is observed near the bend because of turbulence. The maximum velocity observed is 4.09 m/s and the minimum velocity observed is 9.00e-3 m/s.

- The figure 4.46 shows temperature distribution for the pipe bend. It can be observed that the maximum temperature is observed along the pipe surface through which fluid is flowing and the maximum temperature is 668052◦c. The least temperatures are observed at the outermost surfaces on the fixtures with the minimum temperature of 56.0456◦c.
- The figure 4.47 shows pressure distribution on the pipe bend. Maximum amount of pressure is observed near the pipe bend where the weight of the pipe is acting. The maximum pressure is found to be 5665.08pa and the minimum pressure is observed along the pipe surface near the fixtures with a value of 15.0123.

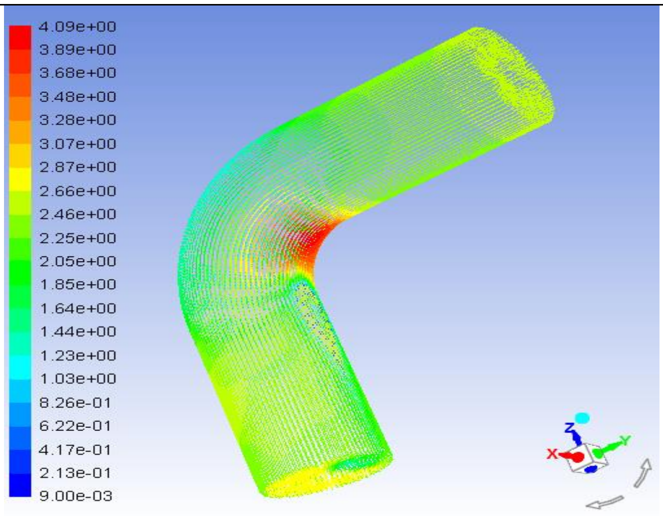


Fig : 5.16 Velocity profile of fluid

STRUCTURAL ANALYSIS:

- The figure 5.17 shows total deformations in a pipe bend due to fluid flowing. It can be observed that maximum deformation is at the outermost circumference and the inner most circumference whereas fixtures had minimum deformations. The maximum deformation is 0.12576e-3 m and minimum deformation is 0m.
- The figure 5.18 shows equivalent stresses developed in the pipe bend. It can be observed that the maximum stresses were observed near the fixtures. The maximum stress observed is 4.3713e8 pa and minimum stress developed is 1.6876e5 pa.
- The figure 5.19 & 5.20 shows the life cycle of the pipe bend. It can be observed that the fixtures where it is bolted is the part with lowest life cycle. It is due to vibrations

being developed after continuous use. Maximum life of parts is 7.4786e5 cycles and minimum life is 17120 cycles.

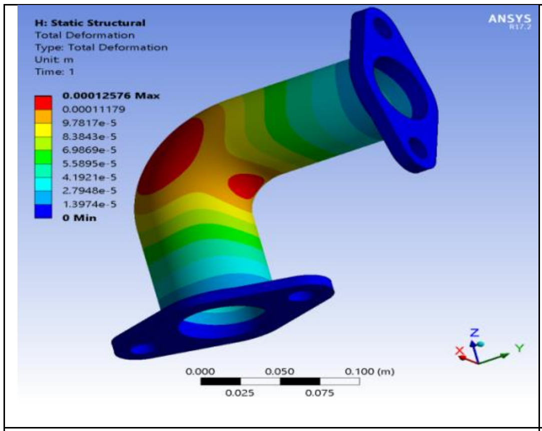


Fig :5.17 Deformation in pipe bend

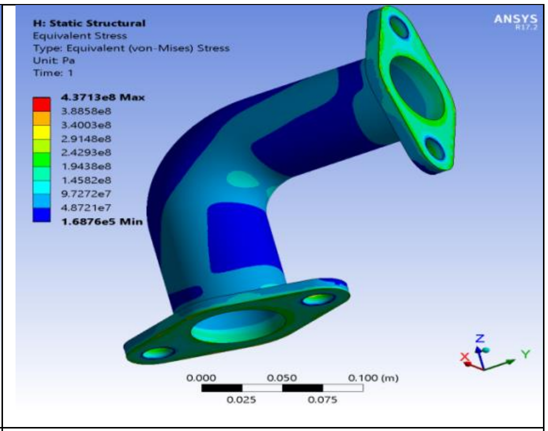


Fig : 5.18 Stress distribution in pipe bend

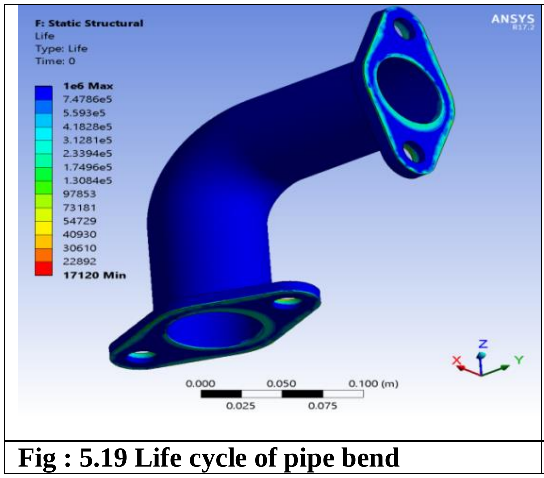


Fig : 5.19 Life cycle of pipe bend

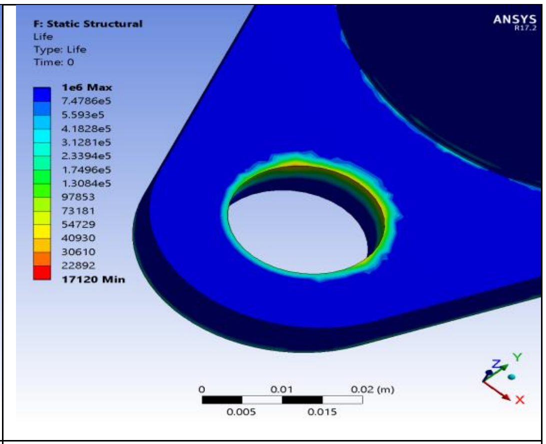


Fig : 5.20 Failures in pipe bend

VELOCIT	DEFORMATION	STRESS	LIFE CYCLE

Y	**(M)**		**(Pa)**			
	MAX	**MIN**	**MAX**	**MIN**	**MAX**	**MIN**
V=1 M/S	0.12457e-3	0	4.1065e8	1.5271e5	6.5849e5	23278
V=1.5M/S	0.1257e-3	0	4.4788e8	1.3197e5	6.4322e5	18846
V=2M/S	0.12576e-3	0	4.3713e8	1.6876e5	6.423e5	18604
V=2.5M/S	0.12576e-3	0	4.3713e8	1.6876e5	7.4786e5	17120

Table 2: comparison of results

CHAPTER 06

CONCLUSIONS

CHAPTER 07

REFERENCES

REFERENCES

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