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Comparative study of bend pipe for circular section and ovality induced bend pipes

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Abstract: Pipes are used all over the world for the basic utility of transfer of small solids, gases, slurries and liquids. Sometimes the term pipes and tubes is interchangeably used, the difference remains. The cross-sectional variations of these flow components results in the variation of characteristics under pressurized conditions. In the manufacturing of bend pipes the control over the outer diameter is quiet easily possible, but the inner diameter variations can be expected. At the bend, the thinning of the exterior part of the bend and the thickening of the interior part is seen. In the subsequent study the comparative flow analysis of the bend pipe of a circular cross-section and the oval pipe is analyzed. The characteristics flow velocity change, turbulence induced, density and pressure variations, temperature change in its course are focused. ANSYS FLUENT is used for the analysis of a standalone pipe of specified dimensions.

1. Introduction

Bend pipes are used to change the course of flow, its quiet a regular thing that in a particular industry only a single compressing unit is present there but the industry needs compressed air at various locations so there the piping system comes into picture. While bending the pipe the extrados and the intrados are the critical layers in the bend pipe, the change in thickness results in the thickening of the intrados and the thinning of intrados in the bend pipe. In the manufacturing procedure used for manufacturing of the tubes and the pipes, it is convenient to have monitored outer dimensions of the intricate shape of the cross-section of the pipe, but the control over the inner dimensions is quiet challenging. The most widely used material is steel and its alloys but due to the relative costliness of steel various alternates have to be preferred in some of the applications. Some of the pipe bending methods are local induction bending, Rotary draw bend die, rotary compression bending. These methods are being used since long time [1]. A method was developed for bend pipes in which an attempt was made for restricting the deformation induced in the pipe during bending [2]. The viscous flow for various cross-section was developed by John Lekner mostly the elliptical and the triangular cross-section were studied and mathematical models were developed [3]. Some of the methods for correction of ovality were discussed by M Balachandran [4]. A similar kind of attempt was made by which analyzed the Inconel alloy for bend pipes [5]. Michel et al. analyzed the ovality and variable thickness for in plane bending moment for variation of loads [6]. Sumesh et al. found out the effects of a crack induced in stress variation as a result of internal pressure loading. The results for the intrados crown and extrados were shown. In this work we have considered a centrifugal compressors output as the input to the stand alone pipe system.

1.1 Assumptions: The material in the following discussion is considered to be isotropic, linearly elastic. The Initial flow of the standalone pipe system is assumed to be equal at the inlet plane and is equal to 5000m³/hr.



[7].The relative pressure at the inlet section is taken to be 5bars [8] The variation in the pipe dimension along the length is not considered. The length change of the extrados and the intrados is not considered. The bend is considered to be perfect elliptical. The bend angle is taken to be 132.62° [2].The bourdon effect, centrifugal forces at inlet, the effect of interface between the compressor and the inlet section of the pipe is not considered. Out of the plane bending is not considered. It is assumed that the amount of thickening is equal to the thinning.

2.Definations and theory

In a particular industry there is a single compressor unit set up and the compressed air is transported from this system to the locations where it is needed. Pipes play an important role in achieving this transfer. Currently circular pipes are used for the same. Near the bends the ovality comes into picture.

Nominal diameter (D): It is defined as the average of the maximum and the minimum diameter measured.

Percent Ovality (%O): It is defined as the ratio of the difference between maximum and minimum to the nominal diameter.

Thickening: The increase in the outer shell thickness of the pipe due to the manufacturing technique employed is termed as thickening.

Thinning: The decrease in the inner shell thickness of the pipe due to the manufacturing technique employed is termed as thinning.

$$\%O = \frac{D_{max} - D_{min}}{D_{nominal}} * 100 \quad \text{-----(1)}$$

$$D_{max} = D + 2X \quad \text{-----(3)}$$

$$\%O = \frac{D_{max} - D_{min}}{D_{max} + D_{min}} * 2 * 100 \quad \text{-----(2)}$$

$$D_{min} = D - 2X \quad \text{-----(4)}$$

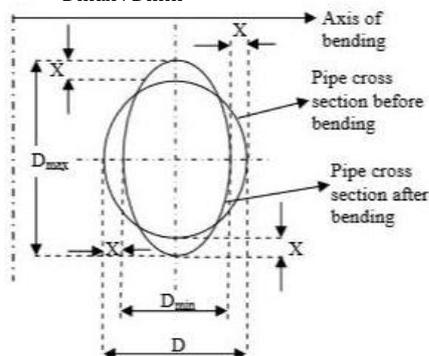
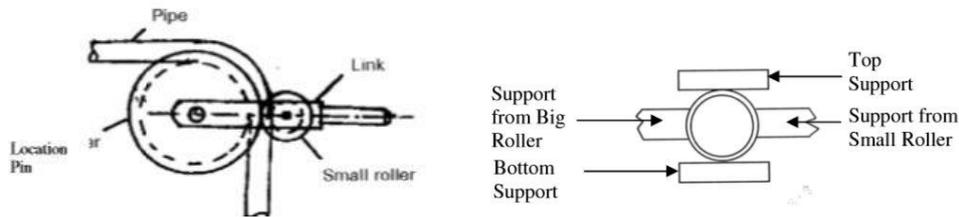


Figure: Case 1 (Ovality in pipe) [9]

Converting all the equation in a single equation in terms of X and D. %O is a function of $\frac{X}{D}$, Where the thickening and thinning is given by X. Here in this discussion we have kept the diameter constant thus it becomes a function of only X. The thickness considered for the components of outer diameter of 22mm. In this we have considered circular pipes with variable thickness. In the first manufacturing method the pipe bending is done for a 100mm radius, 100mm length on either side. There is no ovality restriction in this case. In the third case we have considered the ovality is restricted by using top and bottom support. The second and the third case is illustrated in the diagram below.

**Figure:** Case 2 (without ovality restriction)**Figure:** Case 3 (ovality restricted)

The percent ovality is calculated by measuring the change in dimension at particular location the ovalities are shown in the table below:

Ovality in Case 2	Ovality restricted in case 3	Thickness of the pipe
10.9%	6.93%	1.2mm
9.5%	5.55%	1.25mm
7.52%	5.51%	1.5mm
6.41%	4.88%	2mm

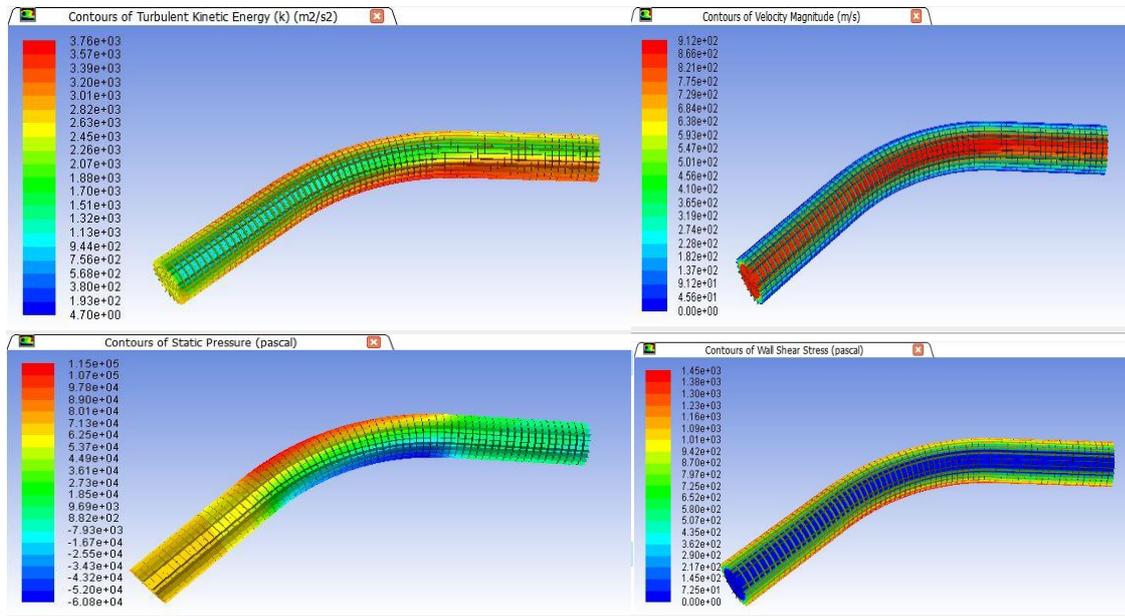
The models considered outer diameter is 22mm and the thickness considered is varied from 1.2 to 2mm and analyzed.

The basic steps involved in the analysis of the bend pipes are:

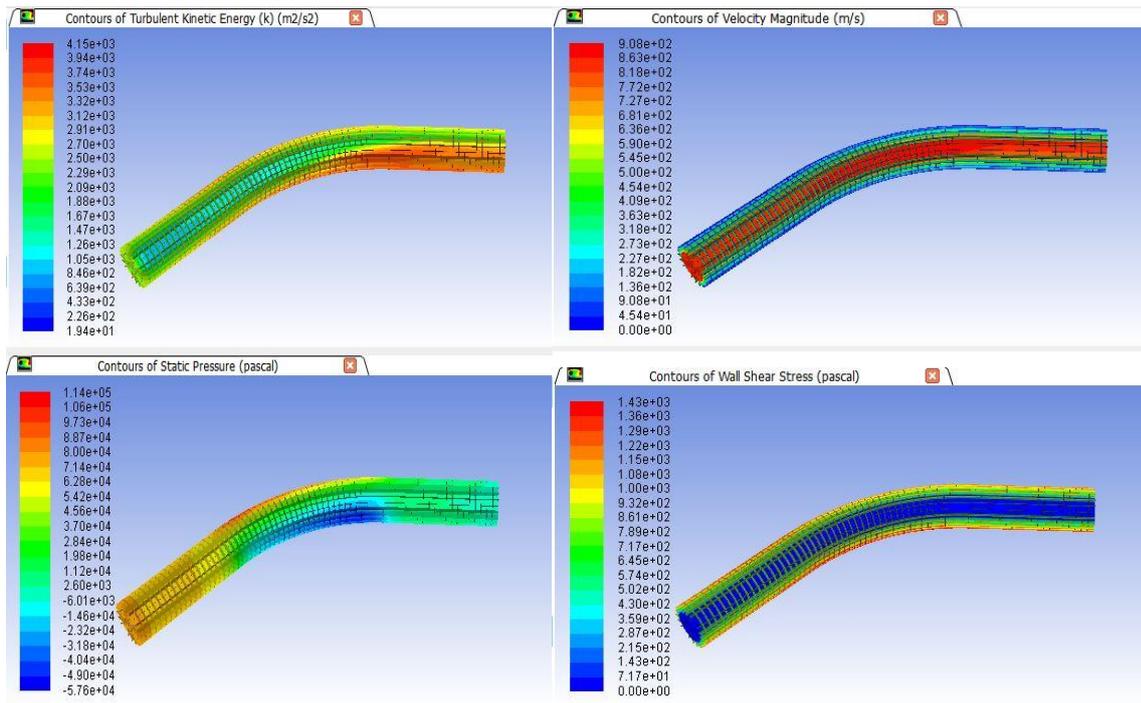
- The manufactured components giving the values of ovality for two different loading conditions as mentioned in the above chart.
- The models for the same were created for 100mm radius and 100 mm arm length of a bend pipe standalone system.
- Models were then analyzed in ANSYS FLUENT.
- The results obtained are shown in the results and discussion section and proper corresponding graphs were plotted.

3. Results and discussion:

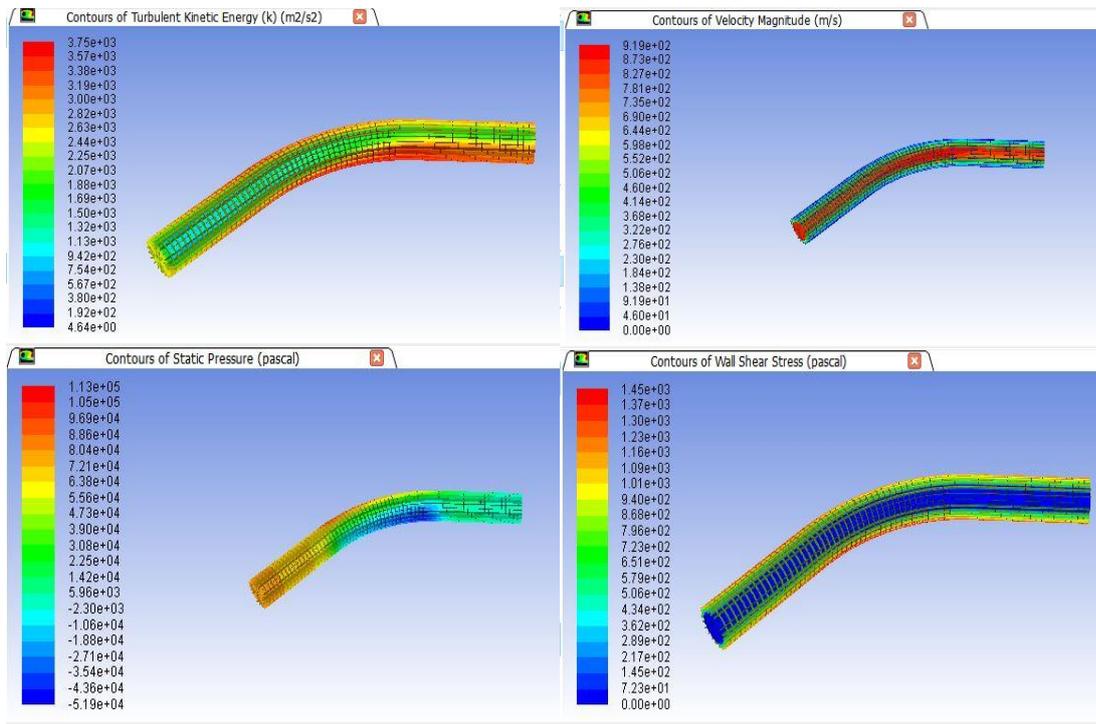
The pipe when analyzed for 1.2mm thickness with circular cross-section the results obtained were:



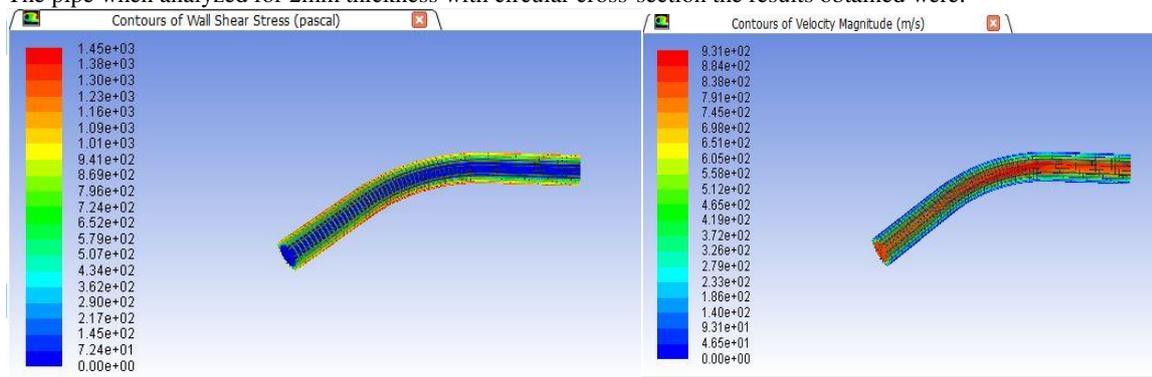
The pipe when analyzed for 1.25mm thickness with circular cross-section the results obtained were:

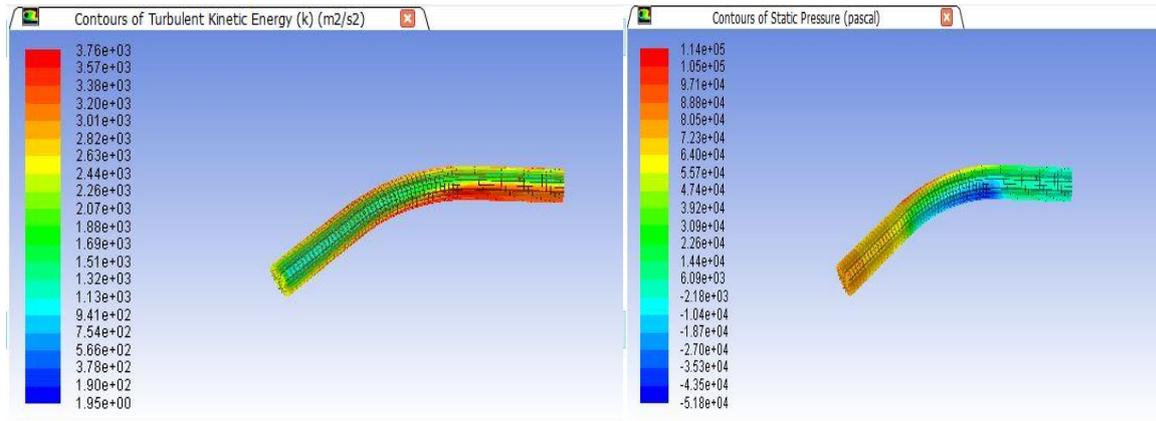


The pipe when analyzed for 1.5mm thickness with circular cross-section the results obtained were:



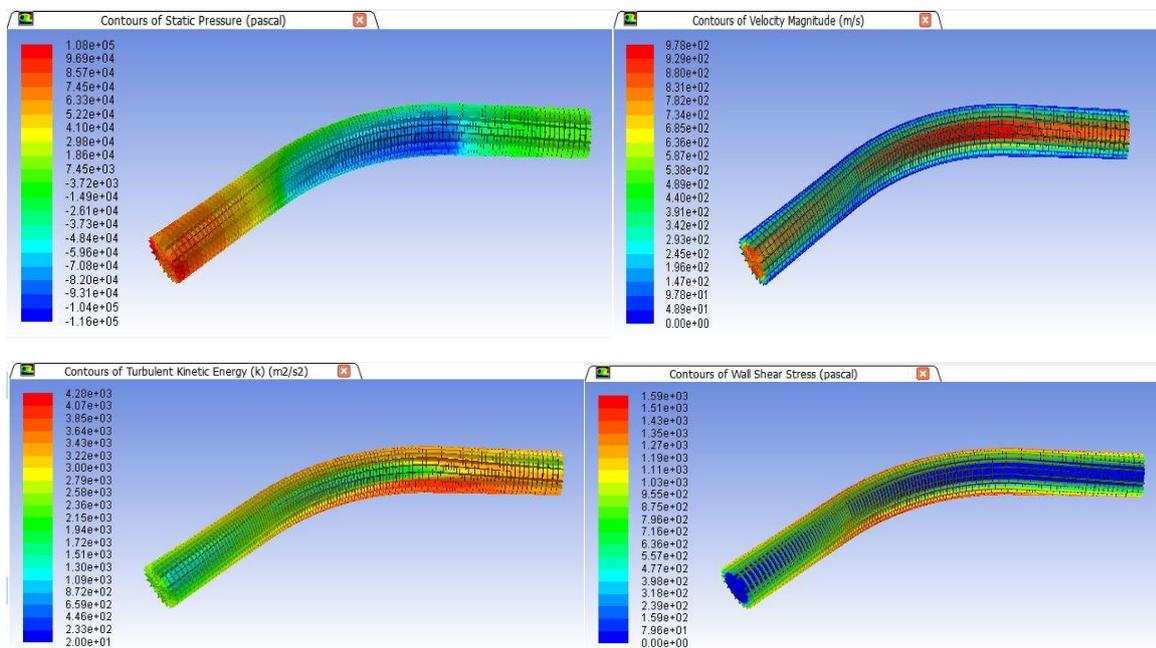
The pipe when analyzed for 2mm thickness with circular cross-section the results obtained were:



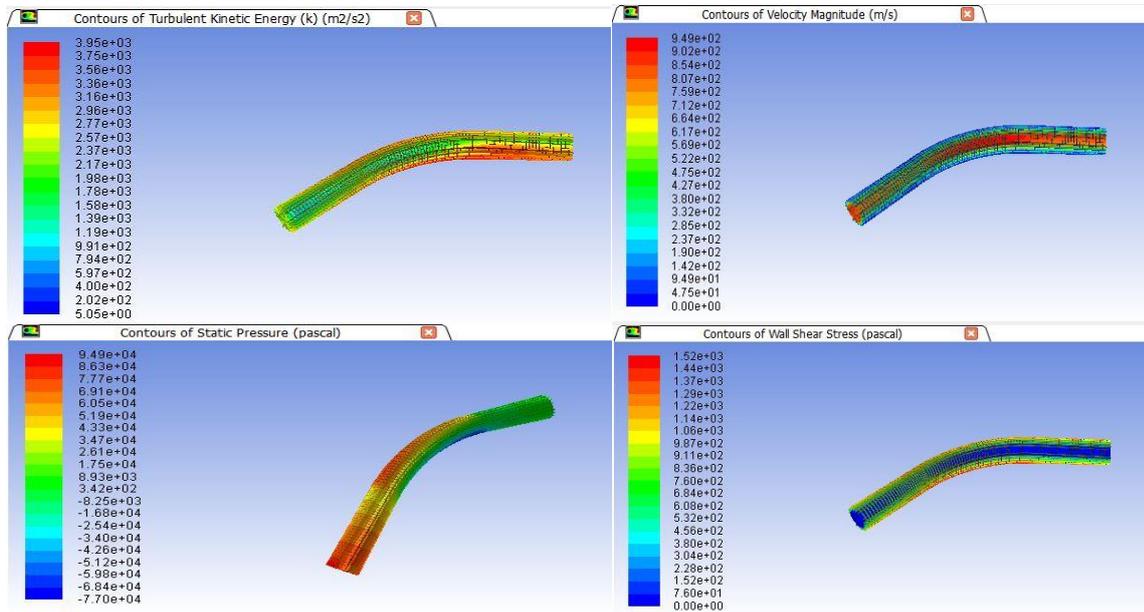


The

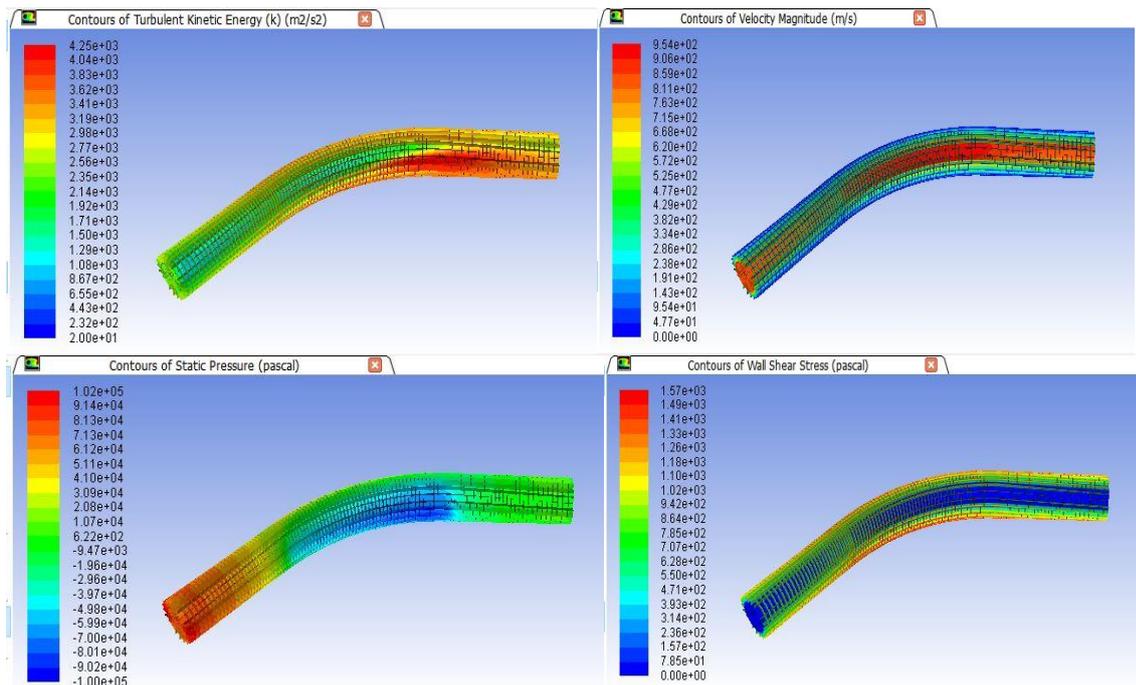
pipe when analyzed for 1.2mm thickness with Case 1 the results obtained were:



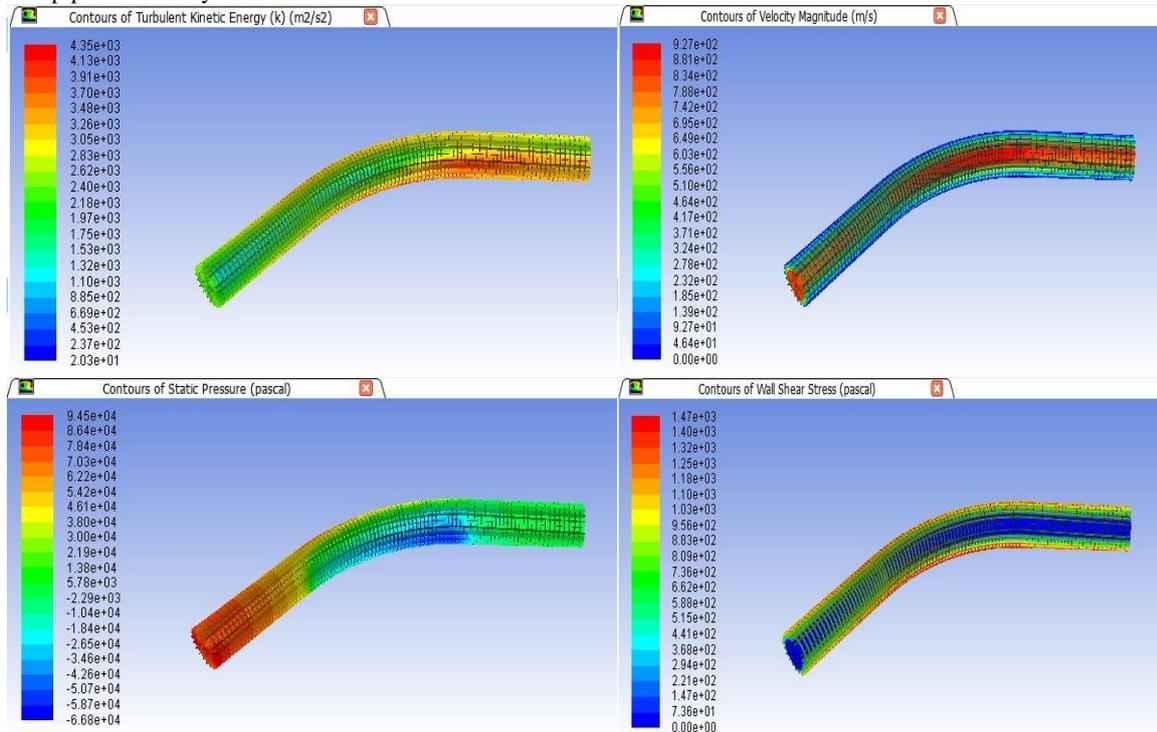
The pipe when analyzed for 1.25mm thickness with Case 1 the results obtained were:



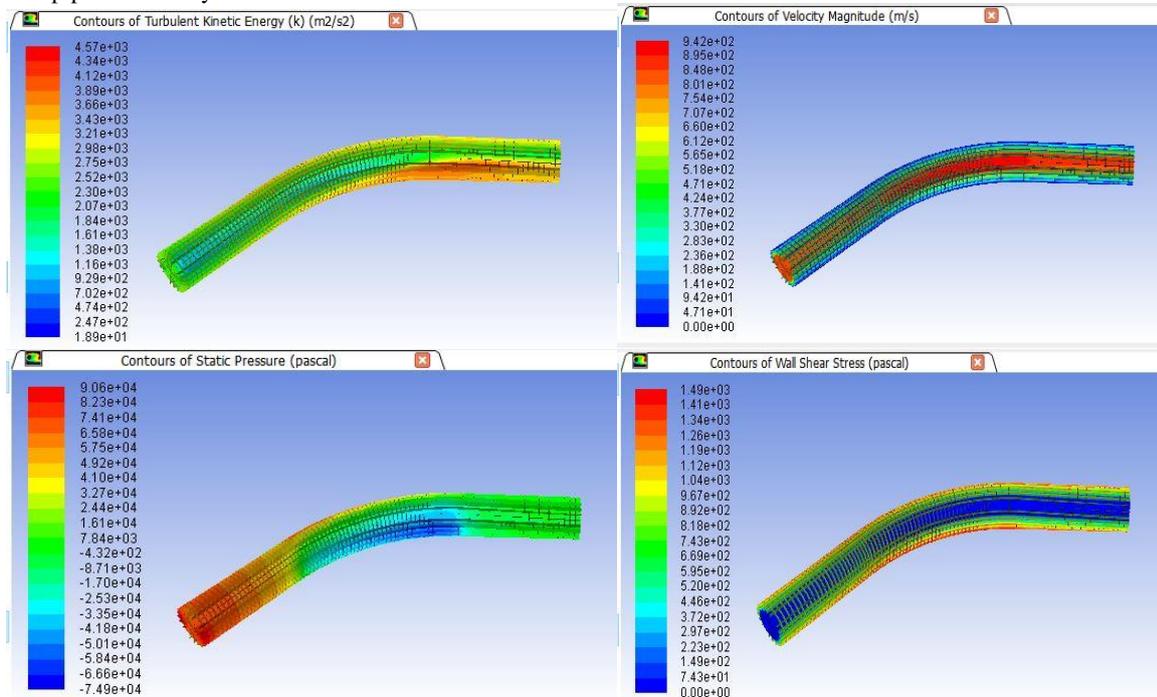
The pipe when analyzed for 1.5mm thickness with Case 1 the results obtained were:



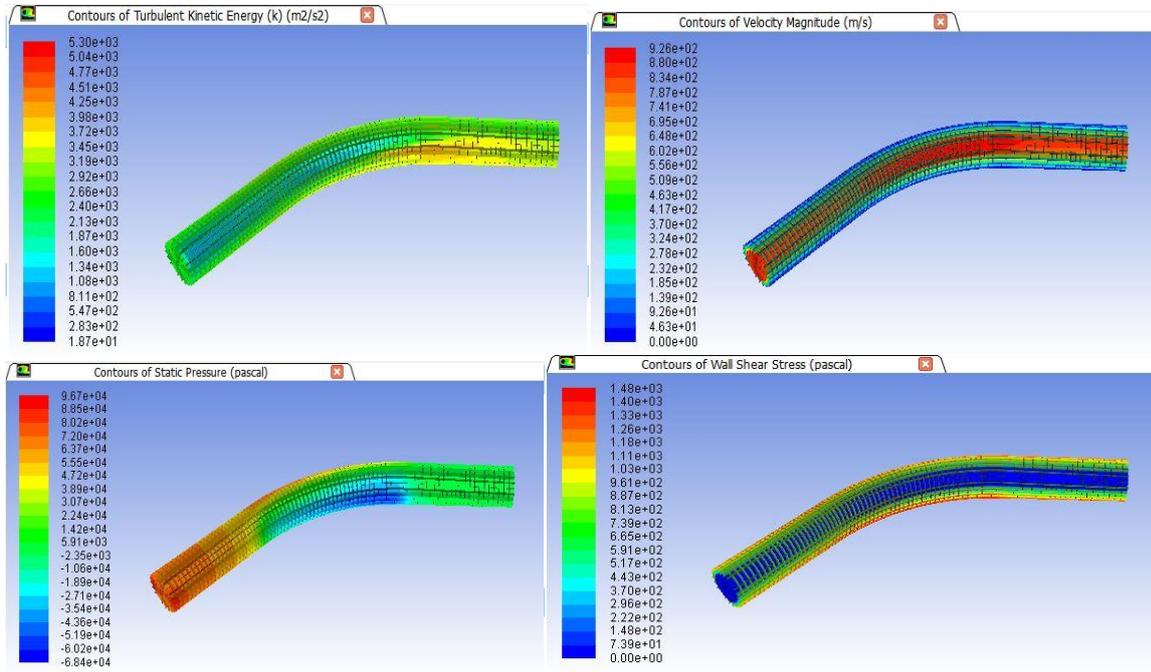
The pipe when analyzed for 2mm thickness with Case 1 the results obtained were:



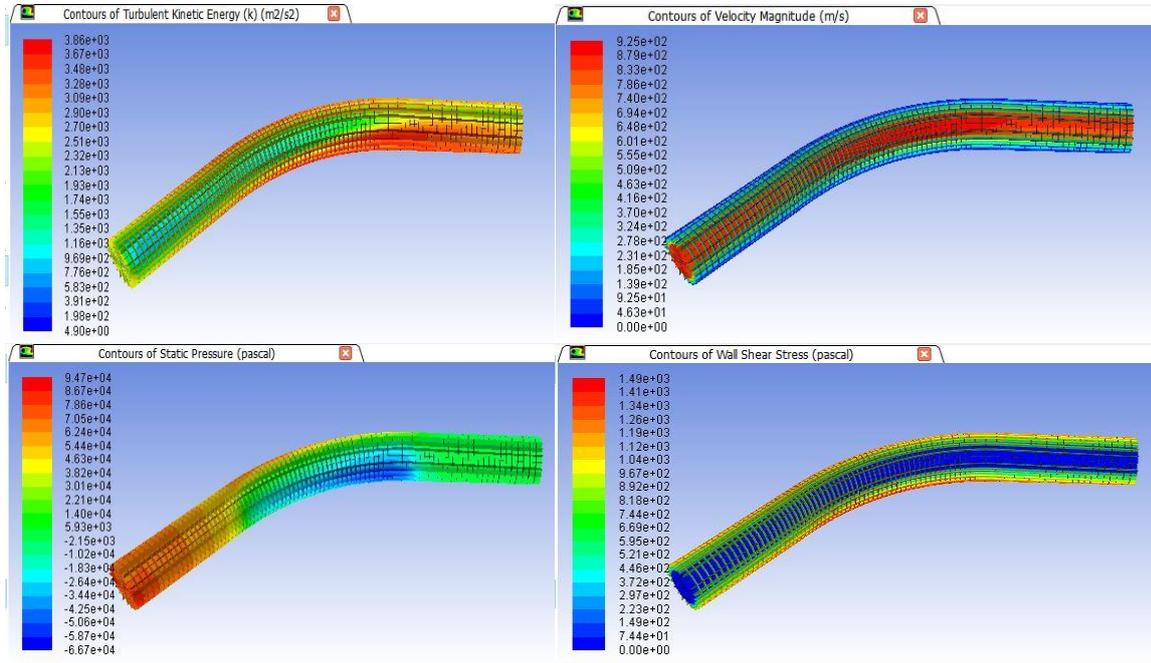
The pipe when analyzed for 1.2mm thickness with Case 2 the results obtained were:



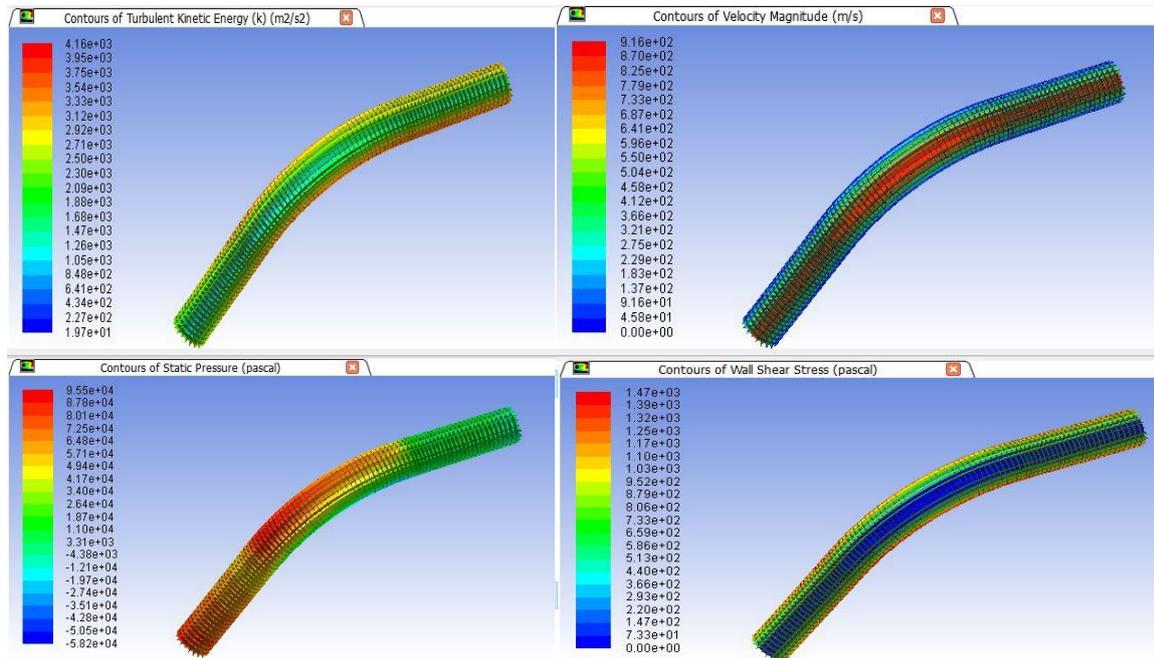
The pipe when analyzed for 1.25mm thickness with Case 2 the results obtained were:



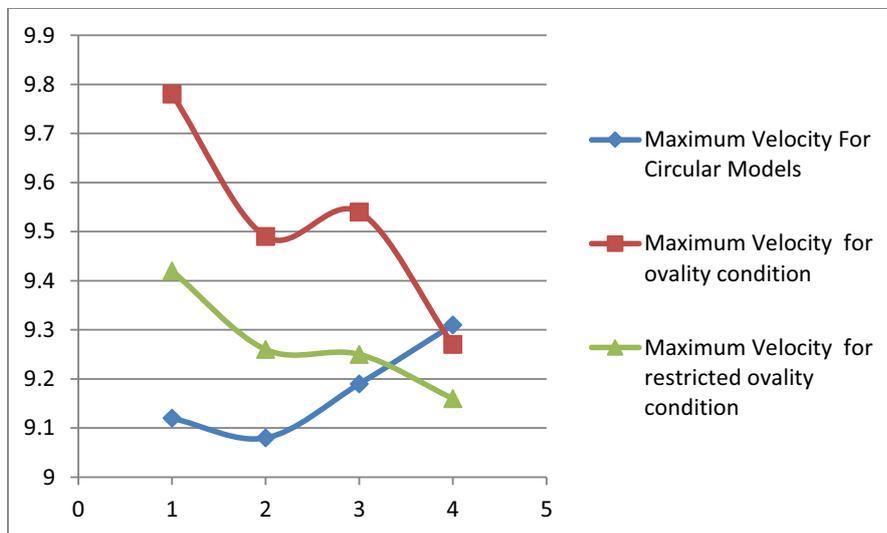
The pipe when analyzed for 1.5mm thickness with Case 2 the results obtained were:



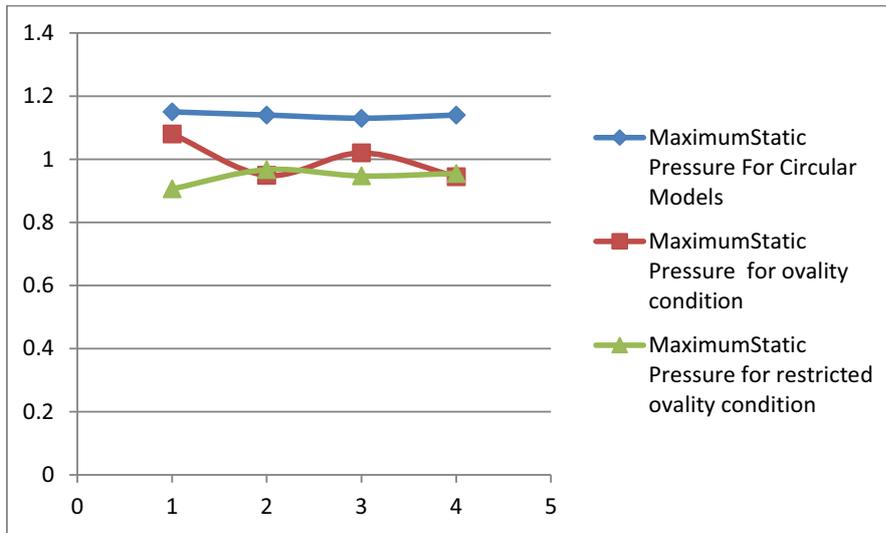
The pipe when analyzed for 2mm thickness with Case 2 the results obtained were:



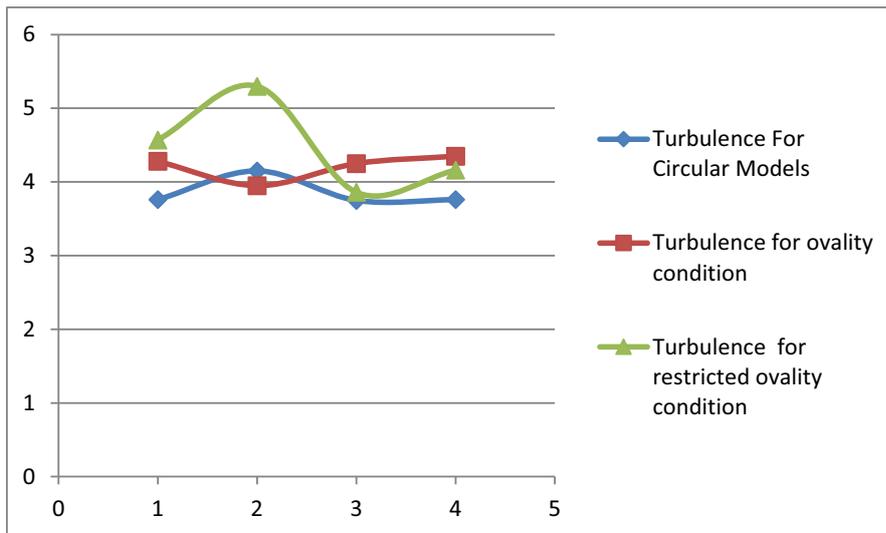
The Comparative graphs for the combined result of Static Pressure, Wall shear stress, Turbulence kinetic energy and the Velocity magnitudes are shown.



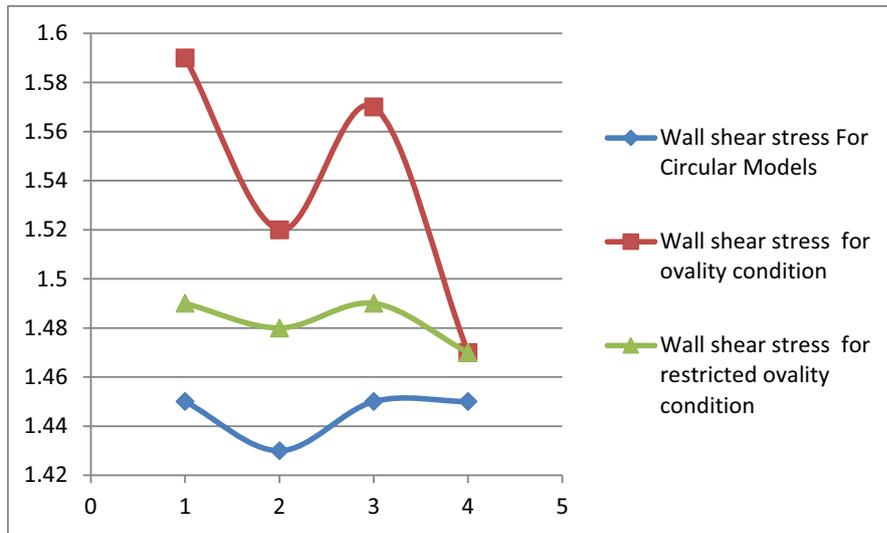
Graph 1: Maximum velocity (10²) m/s Vs Models prepared.



Graph 2: Maximum static pressure (10^4) Pa Vs Models prepared.



Graph 3: Maximum turbulent kinetic energy (10^3) m^2/s^2 Vs Models prepared.



Graph 4: Wall shear stress (10^3) Pa Vs Models prepared.

4. Conclusion: -

The Comparison for maximum velocity in circular, case 1 and case 2 is shown in the graph. The maximum value of velocity can be seen in the ovality condition that is the case 1. The circular section the maximum velocity goes on increasing as the thickness variation is seen but in case 1 and case 2 it decreases. The maximum pressure acting on the wall of the pipe is shown in the graph it shows that the maximum pressure in case 2 is less than the maximum pressure of case 1 thus showing that the ovality restriction reduces the pressure in the pipe system. The wall shear that is acting in the case of circular model is minimum and the case 1 is maximum but the wall shear for the restricted ovality condition that is the case 2 is intermediate to both which says that it is better to restrict the ovality than to allow free increase. The turbulence kinetic energy plots results show that the minimum turbulence for circular section. The restricted ovality condition shows better performance at high thickness.

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