Advances In Multidisciplinary & Scientific Research
A Multidisciplinary & Interdisciplinary Journal
Volume 8, No 1, March 2022 Series

Investigating the Effect of Coriolis Force In A Vibrating Pipeline

[1*]Bori, Ige, [1]Mudjere, Kingsley, [1]Okegbile, Olawale James, [1]Ayo, Samuel Adinoyi & [2]Bako, Sunday
[1]Department of Mechanical Engineering, Federal University of Technology Minna, Nigeria
[2]Department of Mechanical Engineering, Nuhu Bamalli Polytechnic, Zaria, Nigeria
* Corresponding Author E-mail: ige.bori@futminna.edu.ng
Phone: +2349032502267

ABSTRACT

Pipelines conveying fluids are bound to vibrate during operation and if not properly handled from the design stage, there will be tendency of failure. This paper aims at studying the behavior of a pipe under the influence of a coriolis force for when conveying crude oil and natural gas only. A pipe under fixed ends condition was considered using finite element method based on Hamilton principle to determine the deformation mode shape behavior pattern, and this was validated using ANSYS software simulations. It was observed that the pipe exhibited the same behavioral pattern for crude oil when Coriolis force was enabled in both the finite element method and the ANSYS software simulation method. On the other hand, it was observed that the pipe exhibited the same behavioral pattern for crude oil when coriolis force was not enabled in both the finite element method and the ANSYS software simulation method, though the ANSYS simulation method tend to exhibit a more uniform and accurate pattern than the finite element method because of the two elements considered in the finite element method. It is a known fact that the higher the number of elements, the more accurate the finite element results would be. In view of this limitation, it was recommended that for similar works to be carried out in future, the number of elements should be increased more than two for more accurate results.

Keywords: Coriolis Force, Finite Element Analysis, ANSYS Simulation

Aims Research Journal Reference Format:
Bori, I, Mudjere, K., Okegbile, O.J., Ayo, S.A. & Bako, S. (2022): Investigating The Effect Of Coriolis Force In A Vibrating Pipeline. Advances in Multidisciplinary and Scientific Research. Vol. 8. No. 1, Pp 17–32
DOI: dx.doi.org/10.22624/AIMS/V8N1P2

1. INTRODUCTION

In the design of pipeline filled with flowing fluid, it is imperative that the vibration properties of the pipeline are analyzed to prevent excessive vibration of the pipelines as this could cause damages to the pipeline and even to the tie – in equipments. On the other hand, vibrations of pipeline are also important as it dampens the vibration wave that would have otherwise passed on to the equipment. The vibration of pipeline could be as a result of so many factors which include, coriolis force. Pipeline network are used to transport fluid such as stabilized crude oil, gas, water and even steam. Persson (1998) noted that the earth's pull downwards along with its angular velocity ω_e results in the expression $2\omega_e \times v_r$ which is referred to as the coriolis acceleration.

When mass, m is multiplied with the coriolis acceleration, we have the term $2m\omega_e$ x v_r which is called the coriolis force. Researchers (Gong et. al (2021), Koriko et. al. (2020), Lee et al. (2017), Liang and Chan (2005), Housner (1952), Naguleswaran and William (1968)) have carried out researches on corolis forces and have highlight its effect on a given medium. Housner (1952) carried out investigation to determine the effect of high wind velocities in an oil pipeline. It was found that when the frequency of vibration of the pipe due to the velocity of the fluid, coincides with the natural frequency of the pipe, the pipe can become buckled as a result of the vibration been magnified.

Also Naguleswaran and William (1968) carried out an investigation using the same principles as Housner (1952) but it was obtained that a very high fluid velocity in the pipe causes the pipe to vibrate. Olunloyo et al.(2007) derived the Euler-Bernoulli beam governing equation to show the different effects such as transverse acceleration, pressurization, rotary inertia, temperature changes, coriolis acceleration and change in cross-sectional area. it was shown that changes in cross-sectional area is the main cause of pipe walking, and the Increase in temperature changes can lead to an increase in the axial displacement with the maximum displacement been seen at the end of the pipe. Also that the axial velocity that carries the fluid increases, the natural frequencies steadily decreases to zero, and the level of displacement for the same temperature change decreases with increase in the diameter of the pipe.

Gong et. al (2021) noted that Coriolis forces decreases salinity along a given channel by decreasing the vertical advection and increasing the vertical mixing of saly dynamics, which results in a decreased salt intrusion. The effect of coriolis force in vibration is sometimes neglected by some pipeline designers thinking that its effect is negligible but this actually has an impact in the vibration of the pipeline as it adds to the internal and external force applied to the pipeline thereby increasing the overall load on the pipeline. Therefore, this work tends to address this stated problem to enhance the optimum performance of pipeline and it tie-in equipment. The work aimed to investigate the effect of coriolis force in the vibration of fluid filled pipeline using a finite element theoretical method and ANSYS software simulation.

The vibration of pipelines is the centre focus of all pipelines problem in most of the oil companies in the world and it is very important to solve the vibration problem so as to preserve the life of the pipeline and the tie – in equipment. In solving this vibration problem, different numerical methods are used which includes Finite Element Method. It is very significant to know the degree to which the pipeline carrying flowing fluid is vibrating or deflecting which may be as a result of the effect of coriolis force, as this will help pipeline design Engineers in solving pipeline vibration problems. Furthermore, the extent to which coriolis force can cause vibration in the pipelines can only be appreciated as it will help to reduce the failure of the pipelines due to excessive vibration as experienced currently. The pipeline design Engineers will have to put the effect of coriolis force into consideration when designing any pipelines depending on the kind of fluid to be transmitted through the pipelines.

2. MATERIALS AND METHOD

This research provides a framework and simulation model that evaluates and investigates the effect of coriolis force in the vibration of pipeline containing flowing fluids (crude oil, natural gas and oxygen). Unlike the work done by Abayomi and Winifred (2021) using Eyring-Powell fluid equations to study the significance of coriolis force over a rotating non-uniform surface; this present work was based on the Hamilton Principle highlight the possible factors such as deflection, frequencies at various speeds, force and moment using fixed end condition. ANSYS software was used for the simulation and to validate the results obtained from derived finite element method.

2.1 Matrix Formulations

The differential equation of motion can be expressed as;

$$EIy'''' = -2\rho v\acute{y}' - \rho v^2 y'' - m\ddot{y} \quad 1$$

Let the shape function beam theory in terms spatial shape function of $N_i(x)$ and time coefficient dependent as $\Delta_i(t)$ be given as;

$$g(x,t) = \sum_{i=1}^{n} Y_i(t)N_i(x) = Y(t)N(x) \quad 2$$

The formula for bending moment of a fixed-fixed end pipe is given as;

$$M = \frac{w}{12}(6Lx - L^2 - 6x^2) \quad 3$$

The differential equation of motion expressed in equation 1 in the form of equation 2 above can be stated in terms of the derived shape functions and in matrix form as;

$$\delta J = \int_0^T \{\delta Y\}^T [([m]\{\ddot{Y}\} + ([k] + [D])\{Y\} + [C]\{\grave{Y}\}])\boldsymbol{dt} \quad 4$$

In the matrix equation, the notation *m, k, D,* and *C* are represented as;

$$m_{ij} = \int_0^l (m)N_iN_j dx\ ,\ k_{ij} = \int_0^l EIN''_iN''_j dx,\ D_{ij} = \int_0^l \rho\, v^2 N''_i N_j dx,\ C_{ij} = \int_0^1 2\rho v\, N''_i N''_j dx$$

If an external load is applied on the pipe, then the work done on it can be represented in the form below;

$$\delta W = \int_0^l \{\delta Y\}^T \{R\} dt \quad 5$$

Where $\boldsymbol{R}$ is to be calculated for each type of loading.

Combining equation 3 and equation 4 we have dynamic equations for a free element as;

$$([m]\{\ddot{Y}\} + ([k] + [D])\{Y\} + [C]\{\grave{Y}\}]) = \{\boldsymbol{R}\} \quad 6$$

When the derivative of the shape function is taken to the second order and applied to m_{ij}, k_{ij}, D_{ij}, C_{ij} where N_i, N'_i, N''_i (i = 1 to 4) and N_j, N'_j, N''_j (j= 1 to 4), we obtained the stiffness matrix, mass matrix, the fluid flow induced centrifugal force matrix and the damping matrix as follows:

$$[k_{ij}] = (EI)\begin{bmatrix} \frac{12}{L^3} & \frac{6}{L^2} & -\frac{12}{L^3} & \frac{6}{L^2} \\ \frac{6}{L^2} & \frac{4}{L} & -\frac{6}{L^2} & \frac{2}{L} \\ -\frac{12}{L^3} & -\frac{6}{L^2} & \frac{12}{L^3} & -\frac{6}{L^2} \\ \frac{6}{L^2} & \frac{2}{L} & -\frac{6}{L^2} & \frac{4}{L} \end{bmatrix} \quad 7$$

The stiffness matrix

$$[m_{ij}] = (m)\begin{bmatrix} \frac{13L}{35} & \frac{11(L^2)}{210} & \frac{9L}{70} & -\frac{13(L^2)}{420} \\ \frac{11(L^2)}{210} & \frac{L^3}{105} & \frac{13(L^2)}{420} & \frac{-L^3}{140} \\ \frac{9L}{70} & \frac{13(L^2)}{420} & \frac{13L}{35} & -\frac{11(L^2)}{210} \\ -\frac{13(L^2)}{420} & \frac{-L^3}{140} & -\frac{11(L^2)}{210} & \frac{L^3}{105} \end{bmatrix} \quad 8$$

The mass matrix

$$[C_{ij}] = (2\rho v)\begin{bmatrix} -\frac{1}{2} & -\frac{L}{10} & -\frac{1}{2} & \frac{L}{10} \\ \frac{L}{10} & 0 & -\frac{L}{10} & \frac{L^2}{60} \\ \frac{1}{2} & \frac{L}{10} & \frac{1}{2} & -\frac{L}{10} \\ -\frac{L}{10} & \frac{-L^2}{60} & \frac{L}{10} & 0 \end{bmatrix} \quad 9$$

The Damping matrix.

$$[D_{ij}] = (\rho * v^2)\begin{bmatrix} -\frac{6}{5L} & -\frac{1}{10} & \frac{6}{5L} & -\frac{1}{10} \\ -\frac{1}{10} & -\frac{2L}{15} & \frac{1}{10} & \frac{L}{30} \\ \frac{6}{5L} & \frac{1}{10} & -\frac{6}{5L} & \frac{19}{10} \\ -\frac{1}{10} & \frac{L}{30} & \frac{19}{10} & -\frac{2L}{15} \end{bmatrix} \quad 10$$

The flow induced centrifugal force matrix

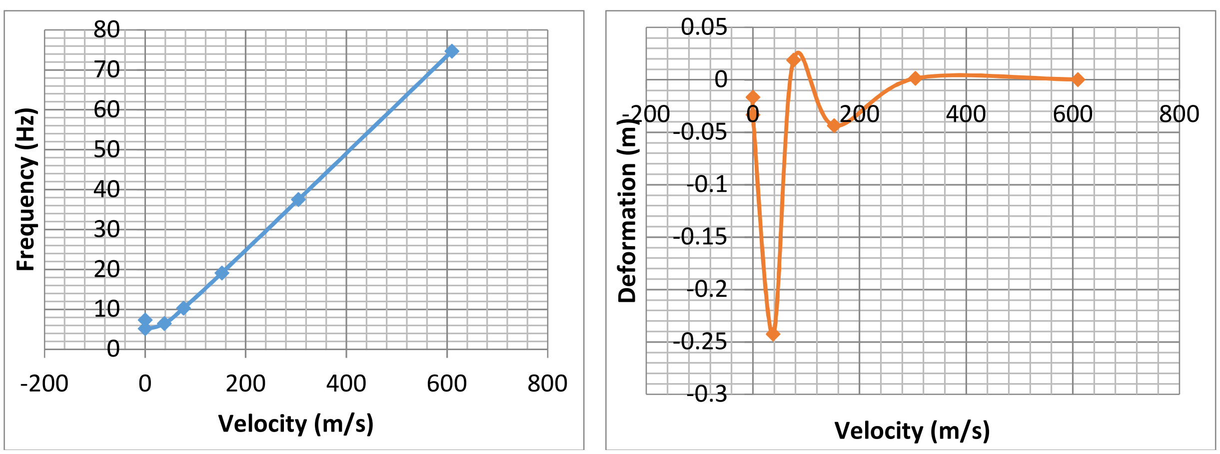
3.0 RESULTS AND DISCUSSION

3.1 Results Crude Oil Analysis

3.1.1 Results from Finite Element Method for crude oil Analysis

The results obtained from the finite element method were plotted in Figure 1. The results obtained from the finite element method clearly showed the behavior of the pipe as represented in the graphs for frequency and deformation. From Figure 1(a) and (b), it was observed that the deformation behavior pattern is not regular as the velocity is increased from 0m/s to 609.6m/s and the frequency tend to increase as the velocity increases except a decrease that was noticed from empty pipe to 0m/s fluid filled. In Figure 1(b), it was observed that there is a decrease in deformation between empty pipe and when the pipe is filled with fluid at 0m/s.

As the velocity of flow increases from 0m/s to 38.1m/s, there is a further decrease in the deformation but there was an increase in deformation as the velocity increases from 38.1m/s to 76.2m/s. As the velocity increases from 76.2m/s to 152.4m/s, there was a decrease in the deformation of the pipe and there was an increase in the deformation of the pipe as the velocity increases from 152.4m/s to 304.8m/s. As the velocity increases from 304.8m/s to 609.6m/s, there is a decrease in the deformation of the pipe which could be as a result of the presence of coriolis force. The deformation behavioral pattern of the pipe tend to agree with findings of Durrani (2001).



(a) (b)

Figure 1: (a) Frequency against Velocity from FEM with Coriolis force for Crude Oil, (b) Deformation against Velocity from FEM with Coriolis force for Crude Oil

3.1.2 Results from ANSYS Software for crude oil Analysis

The results obtained from the ANSYS analysis were plotted as shown in Figure 2(a), Figure 2(b), Figure 3(a), Figure 3(b) and Figure 4(a) below. The values analyzed were the maximum values of deformation against the velocity in the static structure analysis and the modal analysis.

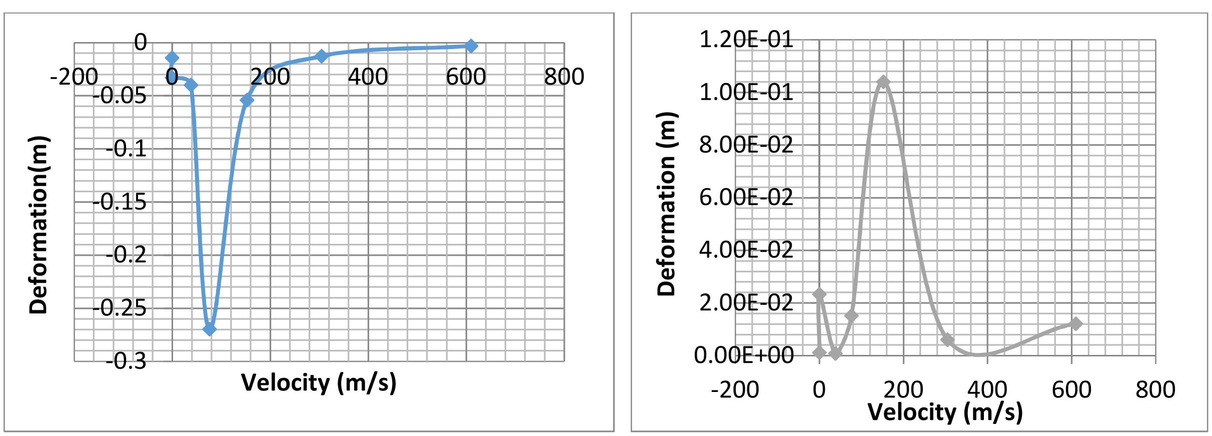
3.1.3 Static Structure Analysis

In the static structure ANSYS analysis, the results of the deformation behavior and the normal stress behavior were analyzed as shown below (Figure (5), (6), (7), (8), (9), (10), (11), (12)).

The results obtained from the ANSYS simulation also showed the behavior of the pipe as represented in the Static Structure as shown in figures 2(b), 3(a) and (b). In figure 2(b), it was observed that the deformation increases from 1.16e-3m when the pipe is empty to 2.33e-2m when the pipe was filled with the fluid at zero velocity. When the fluid velocity was increased from zero to 38.1m/s, the deformation decreases to 7.58e-4m, when the velocity increases to 76.2m/s, the deformation increases to 1.51e-2m, thereafter when the velocity increases to 152.4m/s, the deformation increase to 1.04e-1m and later decreases to 6.06e-3m when the velocity increases to 304.8m/s and increases to 1.21e-2m when the velocity increases to 609.6m/s. The deformation behavioral pattern of the pipe in the static structure ANSYS analysis does not seem to agrees with the deformation behavior pattern of the Finite Element Method.

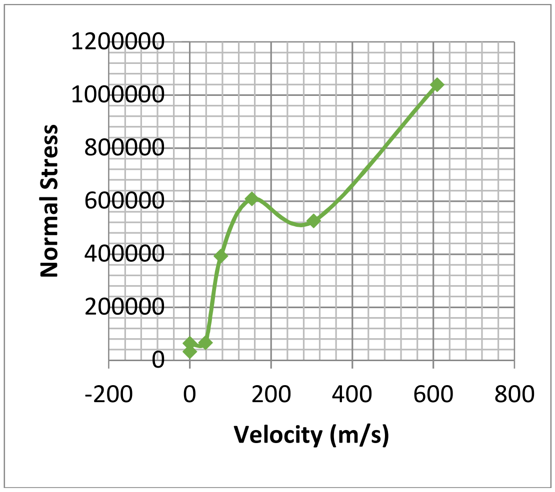
Furthermore, in Figure 3(a) it was observed that the normal stress increases from 31406N/m^2 when the pipe is empty to 62909N/m^2 when the pipe is filled with fluid at zero velocity. As the velocity of flow increases from zero to 38.1m/s the normal stress increases to 66103N/m^2. Thereafter the normal stress increases to 3.9265e5N/m^2 when the flow velocity increases to 76.3m/s also as the flow velocity increases to 152.4m/s, the normal stress increases to 6.0805e5N/m^2. At 304.8m/s, the normal stress decreases to 5.2454e5N/m^2 and later increases to 1.0387e6 when the flow velocity increases to 609.6m/s.

In Figure 3(b), the graphical behavior of the deformation against the normal stress shows the same irregular pattern as the deformation and normal stress graph which goes to show that the deformation is a function of the normal stress because deformation in vibration problems is as a result of the accumulation of stresses in the pipeline.

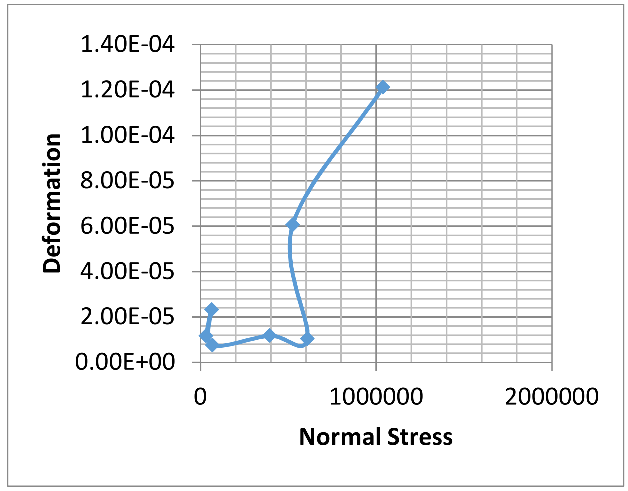


(a) (b)

Figure 2: (a) Deformation against Velocity from FEM without Coriolis force for Crude Oil.
(b) Deformation against Velocity from ANSYS Analysis for Static structure when there is no coriolis effect.



(a)

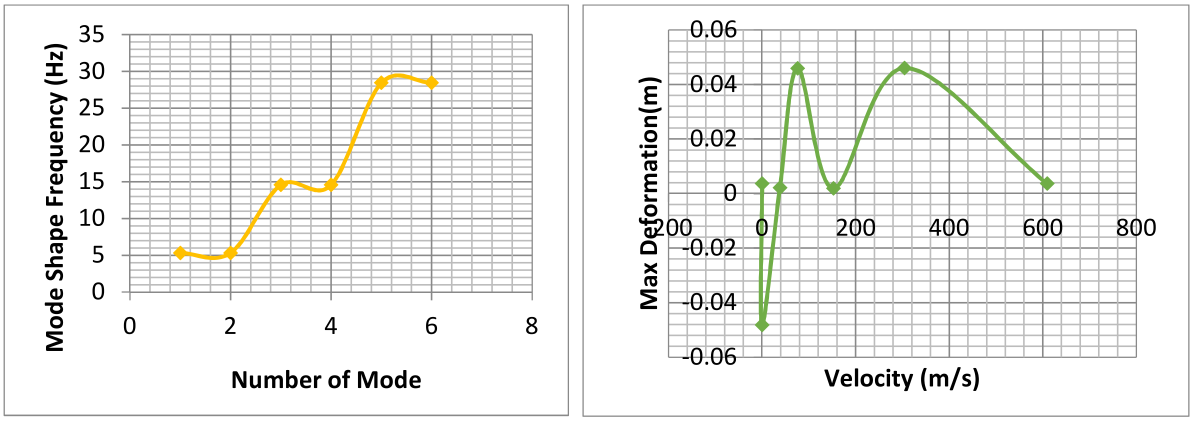


(b)

Figure 3: (a) Normal Stress against Velocity from ANSYS Analysis for Static structure for Crude Oil. (b) Deformation against Normal Stress from ANSYS Analysis for Static structure for Crude Oil

Figure 4(a) below shows the Mode Shape Frequency against Velocity for Modal Analysis with Coriolis Force for Crude Oil. While Figure 4(b) shows Modal values of Deformation against Velocity with Coriolis Force for Crude Oil. The results obtained from the ANSYS modal analysis (Figure 4(a) and (b)) exhibit a closer deformation behavioral pattern as that exhibited by the deformation pattern in the finite element method as shown in Figures 4(b). The deformation decreases from 0.003672m to -0.04824 as the empty pipe is filled with the fluid at zero velocity.

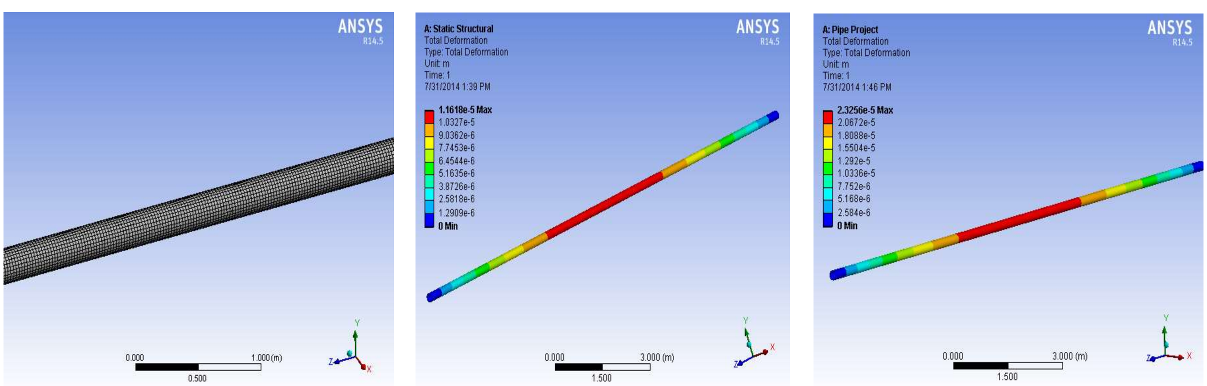
This deformation was later increased to 0.002106 as the velocity increases to 38.1m/s and thereafter increases to 0.045913m as the flow velocity increased to 76.2m/s. The deformation is further decreased to 0.001913m as the flow velocity increased to 152.8m/s and an increase to 0.046015m was experienced as the flow velocity increased to 304.8m/s. Finally, as the flow velocity increases to 609.6m/s, the deformation decreases to 0.003575m. The behavior of the modal deformation validates the deformation behavior of the finite element method which also agrees with the findings of Durrani (2001). The results are also justified by the contour plot in Figure (7), (8), (9), (10), (110 and Figure (12).



(a) (b)

Figure 4 (a): Mode Shape Frequency against Velocity from Modal Analysis with Coriolis Force for Crude Oil. (b) Deformation against Velocity from ANSYS Modal Analysis with Coriolis force for Crude Oil

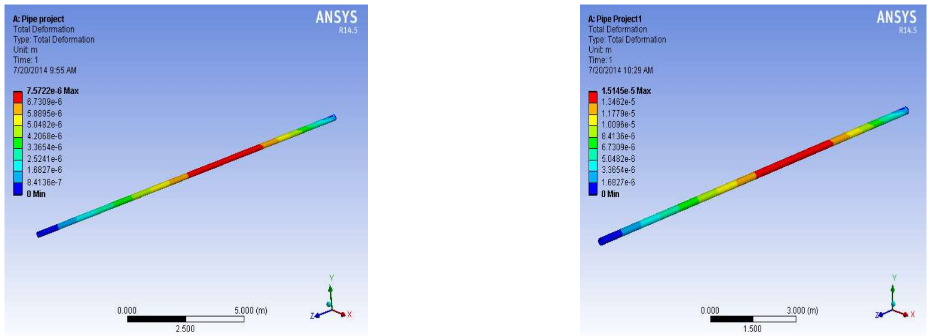
Comparing the calculated value from the finite element method and the values from the ANSYS modal analysis, It was observed that there is no much difference in the deformation behavior of the pipe in both methods as the flow velocity of the fluid varied. Both methods shows that there is an irregular wave motion in the deformation of the pipe, and are similar in behavior which was due to the influence of coriolis force as can be seen in Figure 1(b) and Figure 4(b). In Figure 2(a) and Figure 4(b), the graphical pattern only agree with Figure 1(b) and Figure 4(b) a little as they do not incorporate coriolis force effect.



(a) (b) (c)

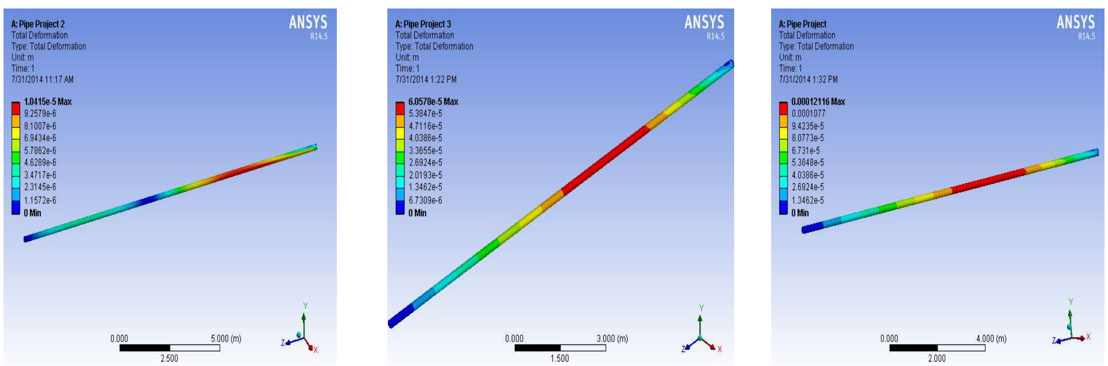
Figure 5: (a) Pipe meshed with a Solid Brick 8 Node 185 in a Crude Oil static structure Analysis. Total Deformation behavior of the pipe when subjected to (b) Pipe Self Load (c) Pipe and Fluid weight in a Crude Oil static structure Analysis.

Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal
Volume 8, No 1, March 2022 Series



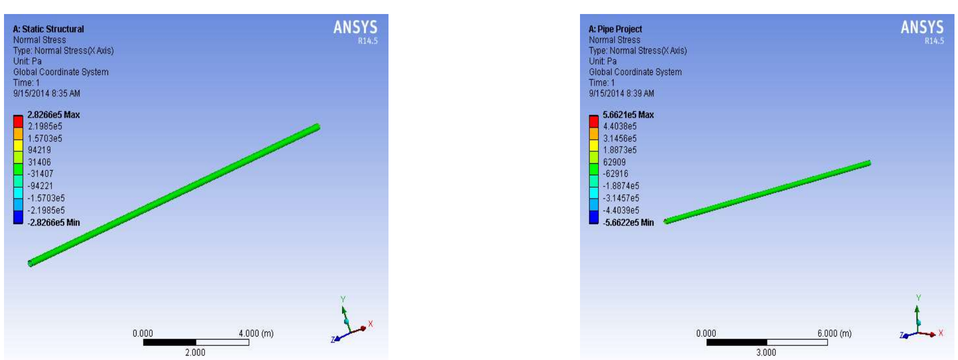
(a) (b)

Figure 6: Total Deformation behavior of the pipe when subjected to different velocities (a) v =38.1 m/s (b) v = 76.2 m/s in a Crude Oil static structure Analysis.

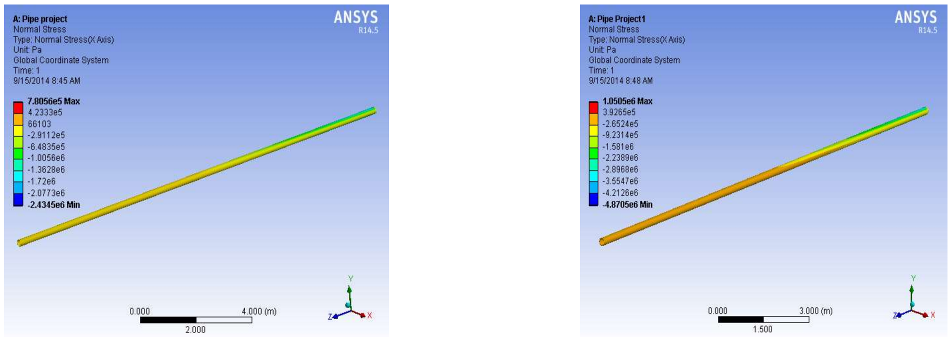


(a) (b) (c)

Figure 7: Total Deformation behavior of the pipe when subjected to different velocities (a) v = 152.4 m/s (b) v = 304.8 m/s in a Crude Oil static structure Analysis. (c) Total Deformation Behavior of the Pipe when subjected to 609.6m/s in a Crude Oil Static Structure

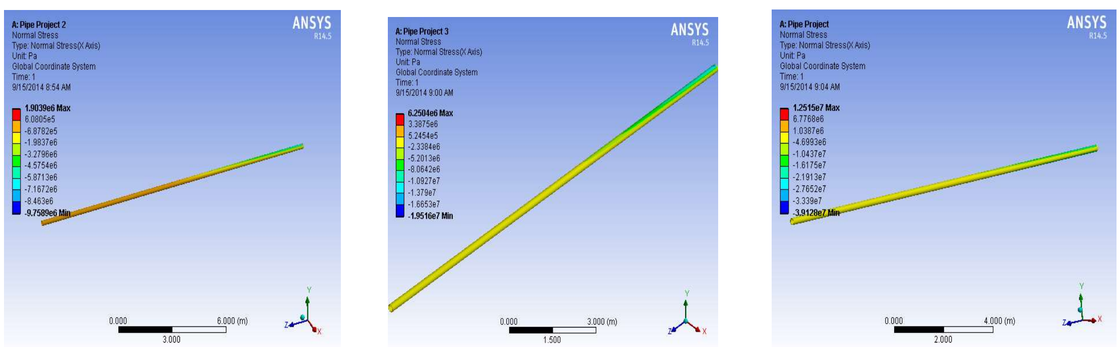


(a) (b)



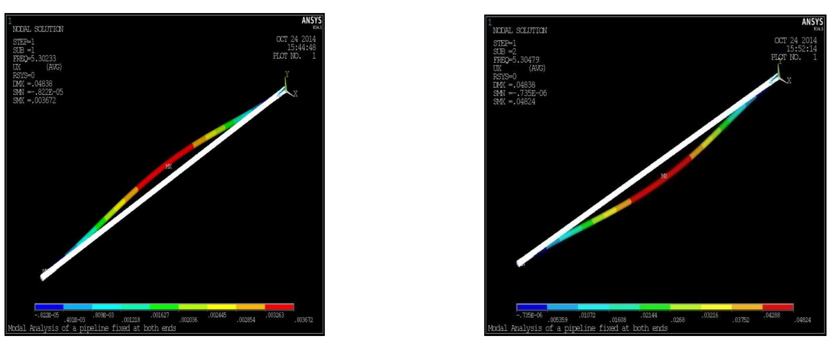
(c) d)

Figure 8: Normal Stress Behavior of the Pipe when subjected to (a) empty self load (b) 0m/s (c) 38.1m/s and (d) 76.2m/s in a Crude Oil Static Structure.



(a) (b) (c)

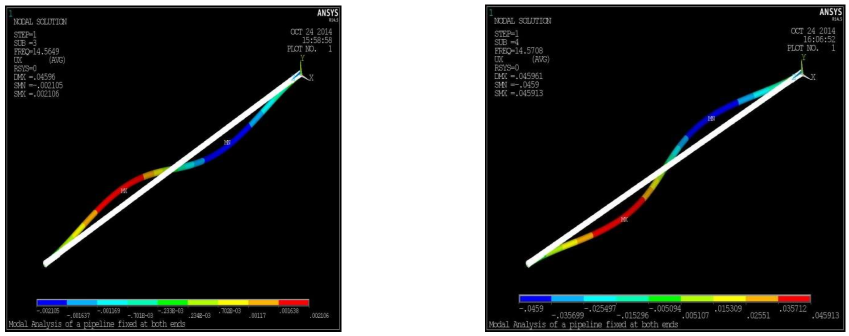
Figure 9: Normal Stress Behavior of the Pipe when subjected to (a) 152.4m/m (b) 304.8m/s (c) 609.6m/s in a Crude Oil Static Structure.



(a) (b)

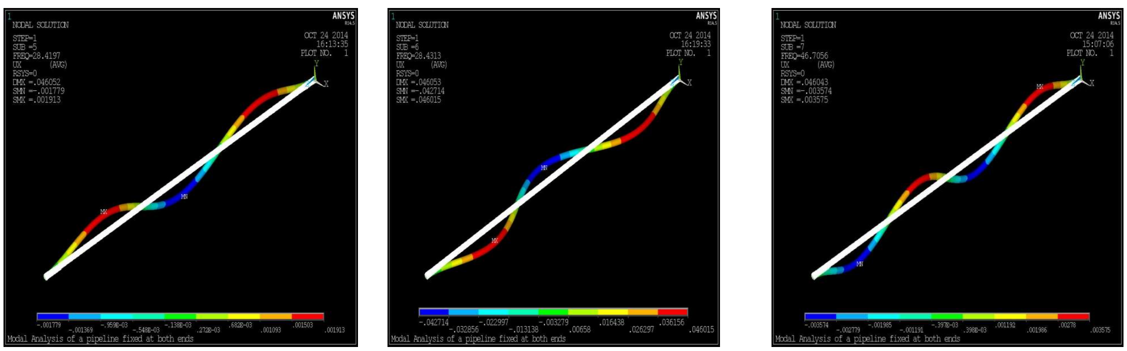
Figure 10: Total Deformation Behavior of the Pipe in various mode (a) Mode 1, (b) Mode 2 in a Crude Oil Modal Analysis.

Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal
Volume 8, No 1, March 2022 Series



(a) (b)

Figure 11: Total Deformation Behavior of the Pipe in various mode (a) Mode 3, (b) Mode 4 in a Crude Oil Modal Analysis.

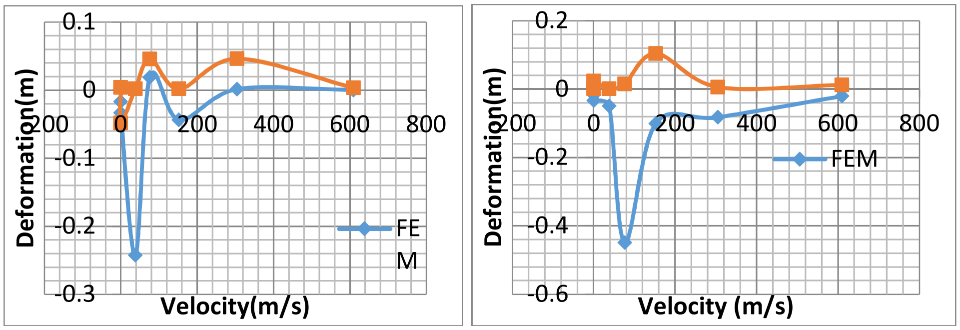


(a) (b) (c)

. Figure 12: Total Deformation Behavior of the Pipe in various modes (a) Mode 5, (b) Mode 6 and (c) Mode 7 in a Crude Oil Modal Analysis.

Figure 13 (b) shows a combination of the graph of deformation against velocity for ANSYS static structure analysis and Finite Element Method when coriolis force effect was not enabled and this graph clearly shows how closely related both graphs are. With this comparison, the deformation behavior of the ANSYS modal analysis in which the coriolis force effect was enabled validates the deformation behavior obtained from the Finite Element Method (FEM), although the slight difference in Figure 13(a) could be as a result of the two element chosen for the finite element analysis.

If a higher number of element was chosen in the finite element method, a better and more accurate result would have been obtained as stated by Sayer (2004). The twist in the deformation behavior as obtained in Figure 10(a), Figure 11 and Figure 12 clearly show the effect of coriolis force as compared to non twist in the deformation behavior as obtained in Figure 5, Figure 6, Figure 7 and Figure 7(c) where there is no coriolis force effect.



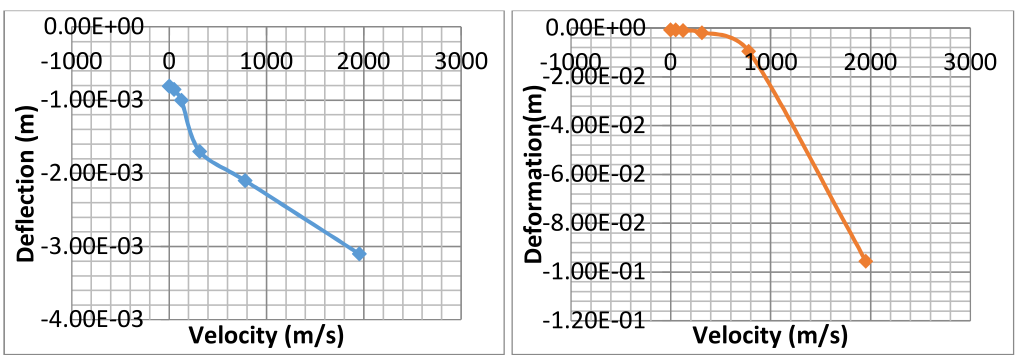
(a) (b)

Figure 13: (a) Deformation against Velocity with coriolis effect for crude oil. (b) Deformation against Velocity without coriolis effect for crude oil.

3.2 Results for Natural Gas Analysis

3.2.1 Results from Finite Element Method for Natural Gas Analysis

The results for natural gas analysis obtained from the finite element method when coriolis force was present as plotted in figure 13(a) so as to compare the behavior of the pipe using Finite Element Method with that from the ANSYS analysis. Also the results obtained from the finite element method when coriolis force was not enabled was also plotted as shown in Figure 14(b).



(a) (b)

Figure 14: (a) Graph of Deformation against Velocity from FEM with coriolis force for Natural Gas. (b) Graph of Deformation against Velocity from FEM without coriolis force for Natural Gas

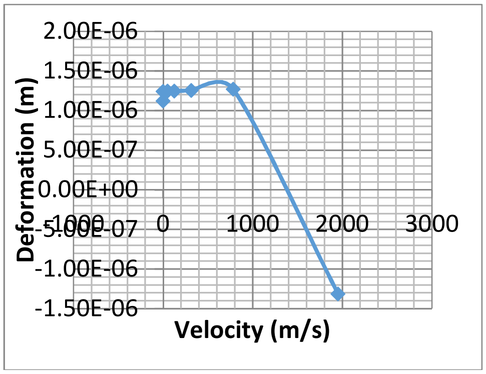
3.2.2 Results from ANSYS Software for Natural Gas Analysis

The results obtained from the ANSYS analysis were plotted as shown in Figure 14(b) when the coriolis force was not enabled (Static Structure Analysis) and in Figure 15(a) when the coriolis force was enabled (Modal Analysis). The values analyzed were the deformation values against the velocity in the static structure analysis and the modal analysis.

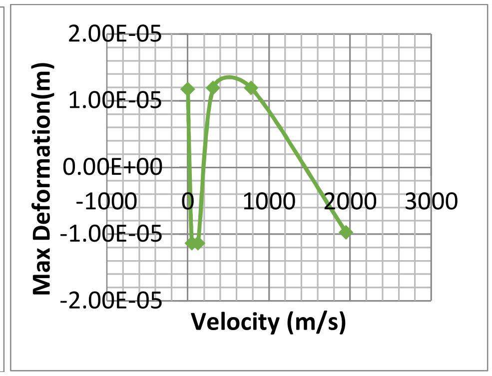
3.2.3 Static Structure Analysis

In the static structure ANSYS analysis, the results of the deformation behavior were analyzed as shown in Figure (16), (17) and Figure (18) below.

Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal
Volume 8, No 1, March 2022 Series

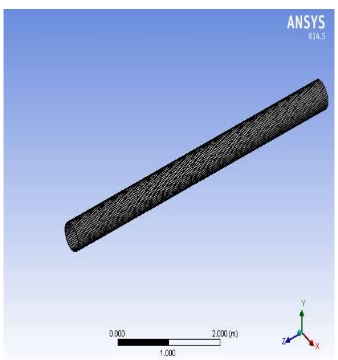


(a)

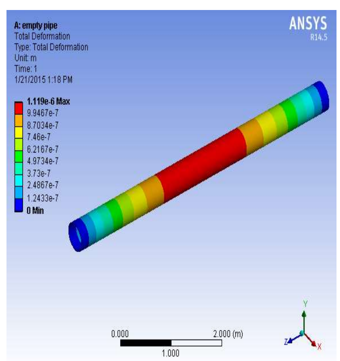


(b)

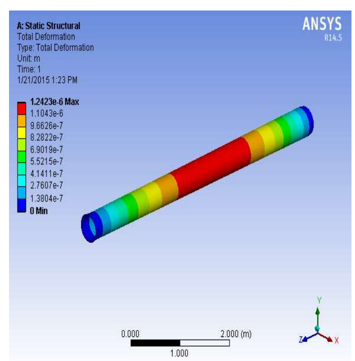
Figure 15: (a) Deformation against Velocity from for Static Structure without Coriolis Force for Natural Gas. (b) Deformation against Velocity from Modal Analysis with Coriolis Force for Natural Gas



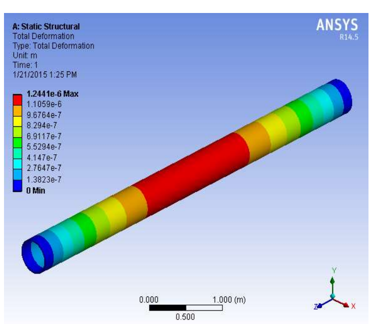
(a)



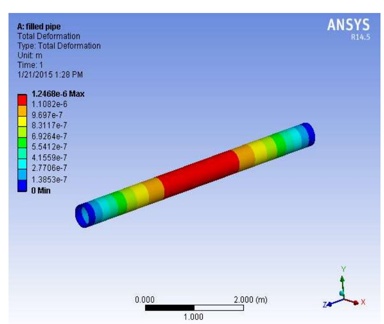
(b)



(c)



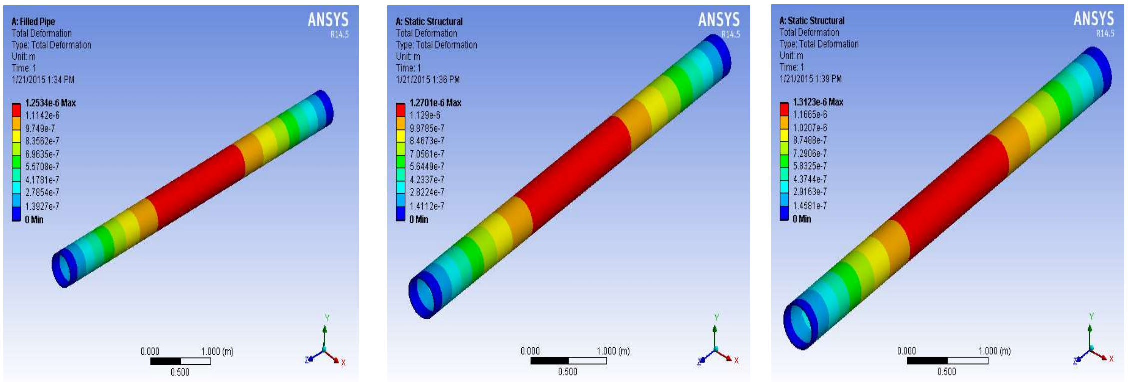
(d)



(e)

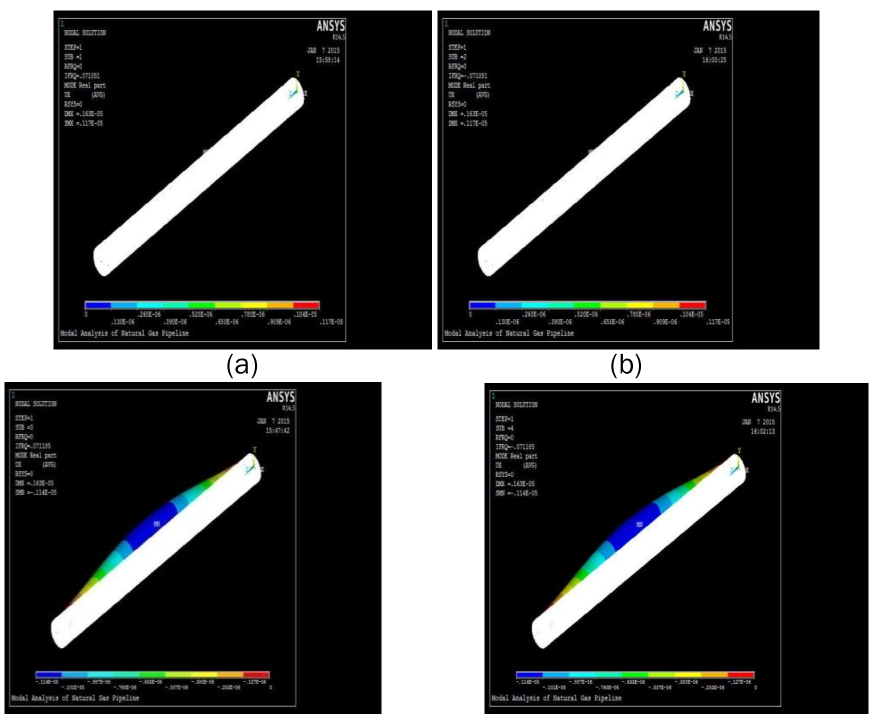
Figure 16: (a) Pipe meshed with a Solid Brick 8 Node 185 in a Natural Gas static structure Analysis. Total Deformation behavior of the pipe when subjected to (b) Pipe Self Load (c) Pipe and Fluid weight (d) v = 50m/s (e) v = 125m/s in a Natural Gas static structure Analysis

Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal
Volume 8, No 1, March 2022 Series



(a) (b) (c)

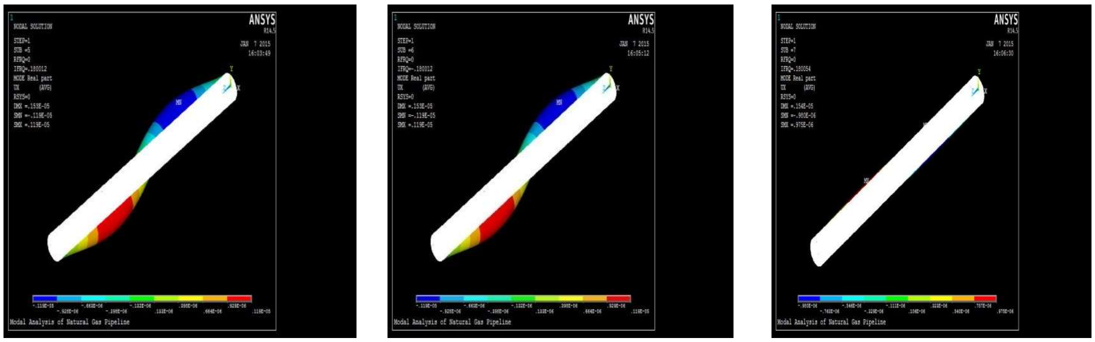
Figure 17: Total Deformation behavior of the pipe when subjected to (a) v = 313m/s (b) v = 781m/s (c) v = 1953m/s in a Natural Gas static structure Analysis.



(a) (b)

(c) (d)

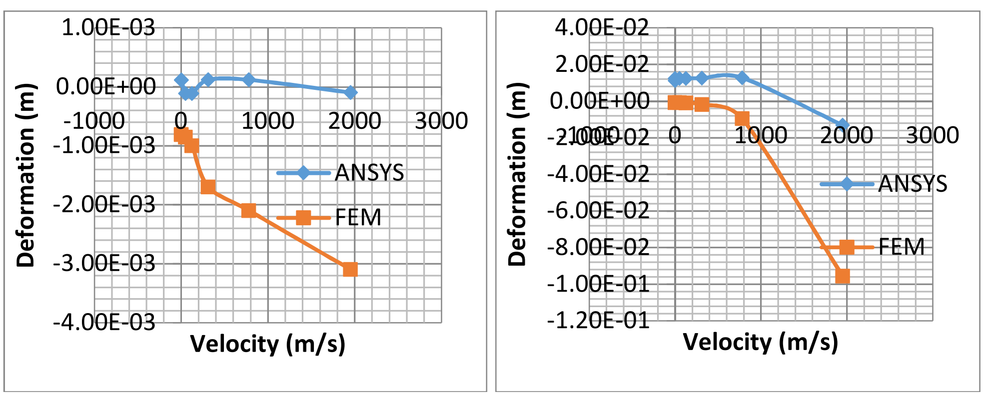
Figure 18: Total Deformation Behavior of the Pipe in various mode (a) Mode 1, (b) Mode 2, (c) Mode 3, (d) Modal 4 in a Natural Gas Modal Analysis.



(a) (b) (c)

Figure 19: Total Deformation Behavior of the Pipe in various mode (a) Mode 5, (b) Mode 6, (c) Mode 7 in a Natural Gas Modal Analysis.

When the calculated values from the finite element method and the values from the ANSYS modal analysis were compared, It was noted that there is no much difference in the deformation behavior of the pipe in both methods as the flow velocity of the fluid increases. Both methods showed similar deformation behavior both in the case when coriolis force was enabled and when coriolis force was not enabled. This can be seen in Figure 20(a) and (b) which shows the combination of Figure 15(b) and Figure 14(a) and Figure 15(a) and 14(b) respectively.



(a) (b)

Figure 20: (a) Maximum Deformation against Velocity with coriolis effect for Natural Gas(b) Maximum Deformation against Velocity without coriolis effect for Natural Gas

4. CONCLUSION

Effect of Coriolis force on a vibrating pipeline carrying crude oil and also natural gas had been investigated in this study, with both Finite Element Method and ANSYS software simulations for validation purposes. The study shows that coriolis force effect influences the deformation behavior of pipelines which results to an irregular wave behavior which is referred to as pipe flutter for when carrying both crude oil and natural gas. The deformation behavior obtained from the finite element method also agrees to an extent with the ANSYS simulation result as the velocity increases.

However, a slight variation observed of the results especially from the finite element method was due to insufficient number of elements used. Model was created and this enabled obtaining more details about the natural frequency and mode shape of the pipeline, through the ANSYS simulations.

REFERENCES

[1] Durrani. J.N (2001). Dynamics of Pipeline with a finite element method, pp 120-121.
[2] Gong, W., Zhang, G., Yuan, L., Zhang, H., & Zhu, L. (2021). Effect of the Coriolis force on salt dynamics in convergent partially mixed estuaries. *Journal of Geophysical Research: Oceans*, *126*, e2021JC017391. https://doi. org/10.1029/2021JC017391
[3] Housner G.W (1952). Bending vibration of a pipeline containing flowing fluid, Applied Mechanics Journal, Vol. 19, pp 205-208.
[4] Koriko, O. K., Adegbie, K. S., Oke, A. S. and Animasaun, I. L. (2020). Corrigendum: Exploration of Coriolis force on motion of air over the upper horizontal surface of a paraboloid of revolution, Phys. Scr., Vol. 95, 035210.
[5] Lee, S., Ryi, S.-K. and Lim, H. (2017). Solutions of Navier-Stokes equation with Coriolis force, Advances in Mathematical Physics, 7042686.
[6] Liang, X. and Chan, J. C. (2005). The effects of the full Coriolis force on the structure and motion of a tropical cyclone. Part I: Effects due to vertical motion, American Meteorological Society, Vol. 62, pp. 3825 - 3830.
[7] Naguleswaran. S and Williams .C.J (1968). Lateral Vibration of a Pipe conveying flow, mechanical Engineering Science Journal, Vol. 10, pp 228-238
[8] Oke, Abayomi S. and Mutuku, Winifred N. (2021). Significance of Coriolis Force on Eyring-Powell Flow Over A Rotating Non-uniform Surface, Applications and Applied Mathematics: An International Journal (AAM), Vol. 16, Iss. 1, Article 36.
[9] Olunloyo, V.O.S., Oyediran, A. A., Adewale, A., Adelaja, A.O., and Osheko,C.A.,(2007). Concerning the Transverse and Longitudinal Vibrations of a Fluid conveying Beam and the pipe walking phenomenon, 26th International Conference on off-shore mechanics and Arctic Engineering - OMAE, San Diego, CA, vol. 3, pp 285 - 298.
[10] Persson, A. (1998). Bulletin of American Meteorological Society, Vol. 79. *Bulletin of American Meteorological Society, Vol. 79* , pp1374.
[11] Sayer, R. J. (2004). Sound and Vibration. *Finite Element Analysis - A Numerical Tool for Machinery Vibration Analysis* , pp 18.