

Dynamic Response of Supported Pipes Conveying Fluid

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Abstract— The effect of the applying extra supports on the dynamic response of a long pipe conveying fluid is studied. The ANSYS program is used to simulate of the polypropylene pipe under different boundary conditions. Some experiments are carried out for validation of finite element results obtained from ANSYS. The results show that using extra supports near the region of applied load is caused in reduction of sensitivity of the pipe to the load frequency and improving of dynamic behavior of pipe.

Keywords-Polypropylene Materials, Pipe Conveying fluid, Dynamic Load, and Extra Support.

I. INTRODUCTION

The first dynamic study of a pipe conveying fluid was made by Ashley and Havilland [1] for oil pipe line system in 1950. The finite element method of flowing fluid and moving pipe with the Eulerian approach and fictions concept in kinematic analysis was investigated by Zhang, Gorman and Rees[2]. They considered the effect of shear deformation and rotary inertia in their models and also Timoshenko analysis of beams after linearization the finite element formulation. Zhang et al. [3] studied the vibratory characteristics of a single-span liquid-filled and empty pipe for various initial axial tensions. They considered uniform velocity profile for fluid and a constant cross-sectional area for the pipe. Liu and Xuan [4] used precise integration method to analyze of Hamiltonian model of nonlinear flow induced dynamics of supported pipes. Galerkin's method was used for deduce of nonlinear equations to two-order ordinary differential equations. They tested their approach on pinned-pinned pipe conveying pulsating fluid. AL-Hilli Ntayeesh [5] analyzed the free vibration of elastically supported pipe conveying fluid. They calculated three eigenvalues of the Timoshenko beam for various value of stiffness. They resulted that natural frequency parameter was decreased with increasing values of mass ratio. A mathematical statement of clamped-pinned pipeline conveying fluid was presented by Valiente and Planas[6]. They used ANSYS

program for simulation of the dynamic system. They showed that the dynamics and stability of pipes conveying fluid not only depends on the boundary conditions but also to pipe materials and pressure produced by the fluid. Valiente and Planas [7] studied the mathematical modeling of clamped-pinned pipeline conveying fluid using means of linear Hamiltonian system. They introduced some specific materials as study case to compare the mathematical model with the results obtained from ANSYS program. The method for testing the effect of system parameters on the range of the instability areas and elevated levels of vibration was developed by Luczko and Czerwinski[8]. They showed that parametric vibration generated in a certain frequency range for flow velocities below the critical value. The principal and secondary resonance enveloped in the low frequency range. Parametric resonance associated with subsequent natural frequencies appeared in the higher frequency. Dagh and Sinir [9] modeled the dynamical behavior of the pipes using Euler-Bernoulli theory. They considered two set of classical boundary conditioned. They resulted that the value of natural frequencies was higher under tensile effect due to the immovable end conditioned. In the present paper finite element method model of a propylene pipe using ANSYS program was investigated. Predicted results were compared with data from experimental work. The effect of different supports on the dynamic response of a long pipe was studied.

II. FINITE ELEMENT MODELING

The ANSYS finite element program was used for transvers vibration analysis of propylene pipe. For this purpose, the key point was first created and then line segments were formed. The element type's pipe 289 and Elbow 290 were used for modeling of pipe and joints. Rate-dependent visco-plasticity Peirco model was used for simulation of propylene materials. The required data for material modeling were obtained from experimental work and shown in the Table (1). Two pipes of 2.15 and 1.12 m length were created horizontally and vertically

respectively. Then the pipe connected together with a joint part as shown in the figure (1). Modal and transient analysis was used in the simulation for different boundary conditions as discussed in part IV.

accelerometer, type 4507B with a frequency scope from 0.3 to 6000Hz. The module type 3560 Bruel and kajer with pulse program was used to vibration analysis of the pipe at different boundary conditions.

TABLE I. REQUIRED DATA FOR MATERIAL SIMULATION IN ANSYS

Parameter	Value
m (strain rate hardening parameter)	0.4958
γ (material viscosity parameter)	1.067
Sig0 (saturation stress)	17.6 MPa
R0 (slope of saturation stress)	5.79 MPa
Rinf (difference between saturation and initial yield stress)	5.10 MPa
b (hardening parameter)	2.19
EX (modulus of elasticity)	400 MPa
PRXY (poisson's ratio)	0.24
DENS (density)	900 kg/m ³

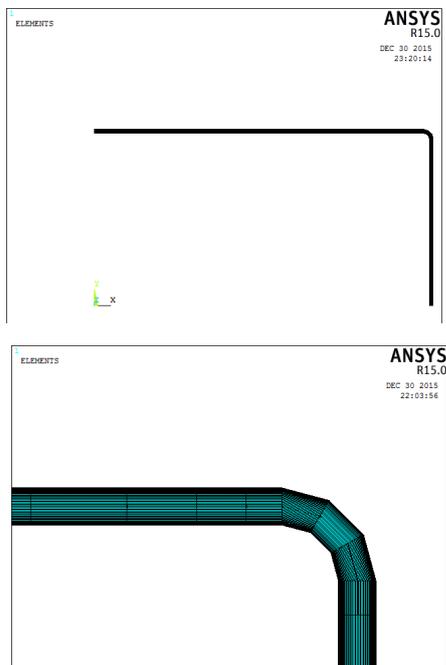


Figure 1. Finite Element Model of the Pipes in ANSYS

III. EXPERIMENTAL PROCEDURE

The tensile tests were carried out to find material properties needed for the ANSYS modeling of the pipes. The experimental setup of the vibration experiment on a polypropylene pipe is shown in the figure (2). The horizontal pipe had a length of 2.15 m and vertical pipe had 1.12 m length. The pipe excited by means of a force from Tira-vb exciter, and response measured by a light piezoelectric

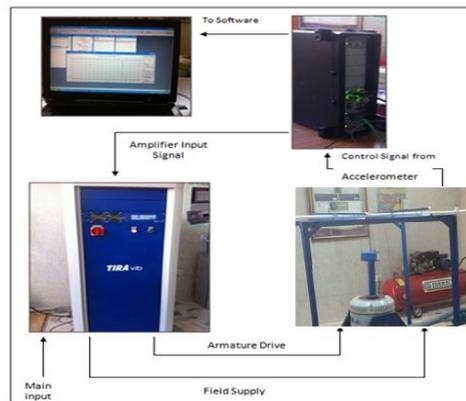


Figure 2. Finite Element Model of the Pipes in ANSYS

IV. RESULT AND DISCUSSIONS

The system which was studied in this paper consists of two polypropylene pipes joined together. The pipes were used to transfer the fluid (water) from the resource to a tank by means of a pump. The supports were used in the system for the pipes one on the pump and second on the tank. Figure (3) showed the results of finite element model of the pipe system for these boundary conditions of the supports. The validation for the finite element results done in the experiments works which were shown in the figures (4) and (5) for the case of $f= 10$ Hz and $f= 23$ Hz, respectively. Figure (3) showed a lot of peaks value in the modal analysis. Figure (6) showed the influence of the external load on the pipe some of peak value of $f= 23$ Hz. The pipe system showed a large deflection at each peak when exposed to an external dynamic load. Because of the existence of high number of peaks, pipe was being very sensitive to frequency and large deflection was occurred for small change in frequency value. An extra supports were used to improve long-pipe behavior under dynamic loads in the transferring of fluids. Figures (7) and (8) showed the effect of adding a pinned-pinned supports at joint point. There was no significant change in the results of modal analysis of the pipe in comparison with the case shown in figures (3) and (6). Pinned-pinned supports were used at each side of the horizontal pipe with the same distance from the external applied load. The results of using two pinned-pinned supports were shown in the figures (9) and (10) for the distance of 25cm and 15cm far from the position of applied load, respectively. There were a limited number of peaks with applying two supports which had a high effect on the behavior of the pipe under dynamic load. Figure (11) and (12) showed the experimental validation for the case of pinned-pinned supports at distance of 25cm. there was a good agreement between the finite element and experimental results. The transient analyses of the two pinned-pinned supports at ($x=25$ cm) far from the applied load were illustrated in the figures (13) and (14), the pipe behavior under dynamic load was less sensitive in comparison with the other boundary conditions. There was only two peaks for ($x=25$ cm), these effect of external load on the pipe was decreased when analysis done for

the same range of analysis of applying other supports. There was only one peak, with decreasing the distance of the supports to $x=15\text{cm}$ far from applied load as shown in the figure (15). This could be considering as the best case when had the most effect on the pipe behavior under dynamic load.

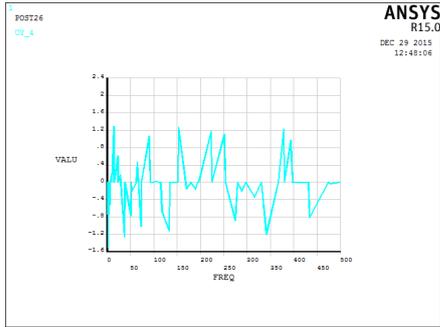


Figure 3. Finite Element Result of the Pipes

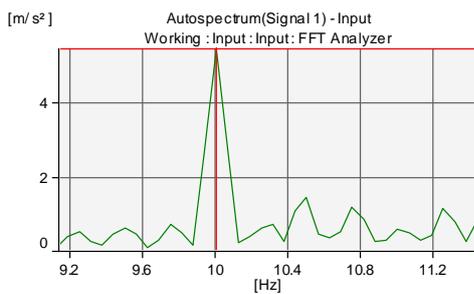


Figure 4. Experimental Results for validation of Finite Element Model of the Pipes for $f=10\text{ Hz}$.

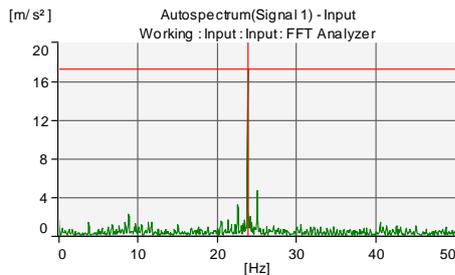


Figure 5. Experimental Results for validation of Finite Element Model of the Pipes for $f=23\text{ Hz}$

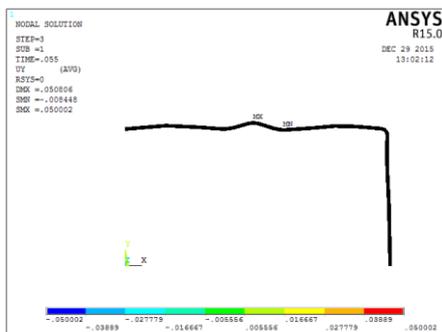


Figure 6. Finite Element Result of the Pipes at $f=23\text{ Hz}$

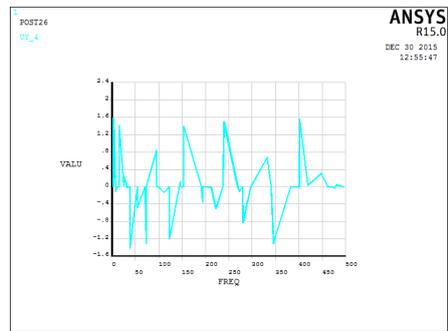


Figure 7. Finite Element Result of the Pipes for Extra Support at joint.

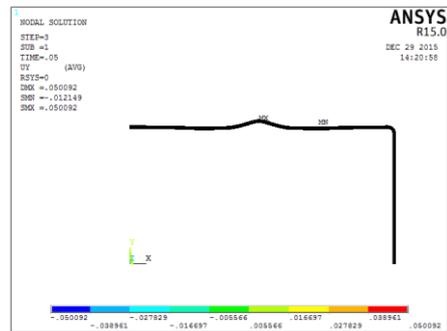


Figure 8. Finite Element Result of the Pipes for Extra Support at joint ($f=25\text{ Hz}$)

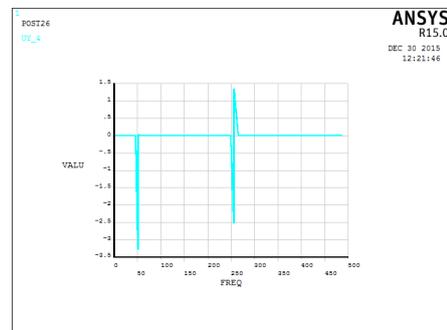


Figure 9. Finite Element Result of the Pipes for Extra Supports at 25 cm far from the applied load.

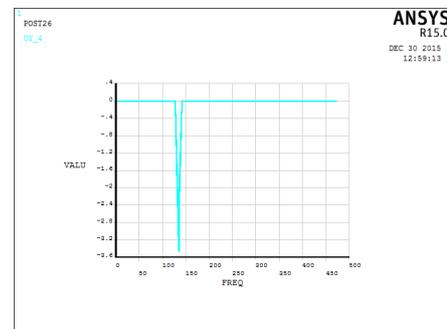


Figure 10. Finite Element Result of the Pipes for Extra Supports at 15 cm far from the applied load.

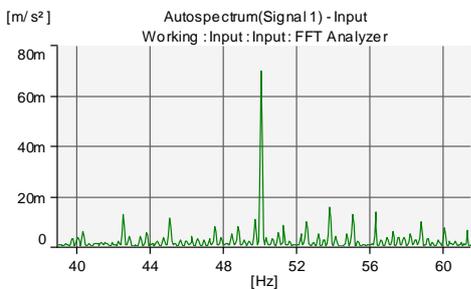


Figure 11. Experimental Results for validation of Finite Element Model of the Pipes for $f=50$ Hz.

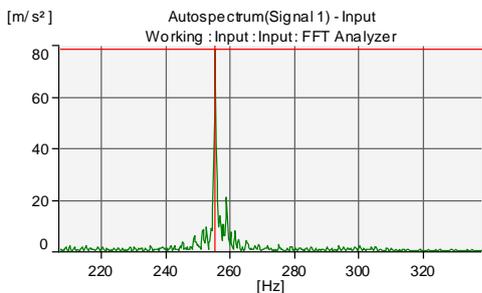


Figure 12. Experimental Results for validation of Finite Element Model of the Pipes for $f=255$ Hz.

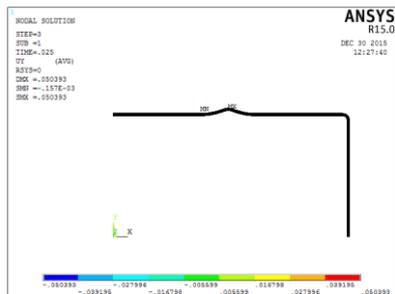


Figure 13. Finite Element Result of the Pipes for Extra Support at 25 cm far from Applied Load ($f=50$ Hz)

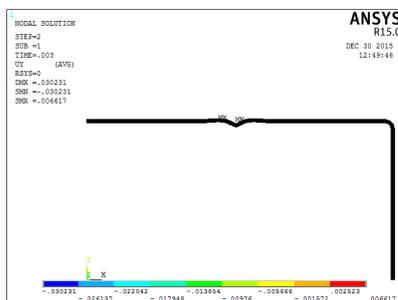


Figure 14. Finite Element Result of the Pipes for Extra Support at 25 cm far from Applied Load ($f=255$ Hz)

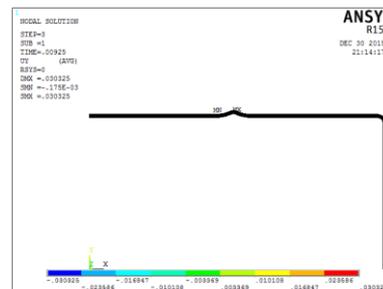


Figure 15. Finite Element Result of the Pipes for Extra Support at 25 cm far from Applied Load ($f=255$ Hz)

V. CONCLUSIONS

- 1- The long pipes conveying fluid was showed high sensitivity to the frequency of the dynamic applied load.
- 2- There was not significant effect using pinned-pinned supports.
- 3- The pipe sensitivity to the frequency of external load decreased by adding extra pinned-pinned supports at each side of the load.
- 4- The pipe sensitivity to the load frequency was varied with changing the distance of supported with respect to applied load.
- 5- The optimum distance was obtained for the case in this paper was $x= 15$ cm which gave one peak in a specified range of frequency used in this study.

REFERENCES

- [1] H. Ashley and G. Haviland, "Bending vibration of a pipe line containing flowing fluid," Journal of applied mechanics, 1950.
- [2] Y.L. Zhang, D. G. Gorman and J. M. Rees, "Analysis of the vibration of pipes conveying fluid," Journal of mechanical engineering science, vol. 213, 1992.
- [3] Y.L. Zhang, D. G. Gorman, J. M. Rees, and J. Horacek, "Observation on the vibration of axially tensioned elastomeric pipes conveying fluid," Journal of mechanical engineering science, vol. 214, 2000.
- [4] Long Liu and Fuzhen xuan, "Flow-Induced vibration analysis of supported pipes conveying pulsating fluid using precise integration method," Journal of mathematical problems in engineering, 2010.
- [5] Ali H. Al-Hilli and Thajer J. Ntayeesh, "Free vibration characteristics of elastically supported pipe conveying fluid," Nahrain University, college of engineering journal (NUCEJ), vol. 16, 2013.
- [6] Begona Mediano-Valiente and M. Isabel Gracia-Planas, "Modeling of a clamped-pinned pipeline conveying fluid for vibrational stability analysis," Cybernetic and physis, vol. 3, 2014.
- [7] B. Mediano-Valiente and M. I. Gracia-Planas, "Stability analysis of a clamped-pinned pipe line conveying fluid," Word scientific and engineering academy and society, vol. 13, 2014.
- [8] Jan Luczko and Andrzej czerwinski, "Parametric vibrations of pipe induced by Pulsating flow in Hudraulic system," Journal of theoretical and applied mechanics, vol. 52, 2014.
- [9] Begum Y. Dagh and B. Gultekin sinir, "Dynamics of transversely vibrating pipes under non-classical boundary conditions," Universal Journal of mechanical engineering, vol. 3, 2015.