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Design and Analysis of Cold Pipe Line Structure with Compressed Air Flow

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ABSTRACT

The experimental pipelines used for research purposes must be structurally analyzed to meet the design requirements. The work carried out here focuses on the structural analysis of a thermal mixer pipeline. There is a cold compressed air flow in this pipeline at 8 bar pressure. Flow rate is to be varied based on mixing ratios; the supports in the pipe are designed to withstand maximum flow through the pipe. The pipeline is analyzed theoretically and by simulation using ANSYS APDL 16.0, finally the number of supports required to meet the design needs is concluded. Similarly in future, the whole experimental pipeline is to be studied individually and as a whole and the support structures are to be designed for the thermal mixer setup based on the analyzed data.

Keywords: *Structural; Thermal Mixer; Compressed Air; ANSYS APDL; Pipeline.*

1.0 Introduction

The long pipelines used in experimental setups must be supported to control the sagging due to concentrated loads and to limit the bending stresses within safety limit. The supports are designed based on the load in pipeline and the location of supports. Hangers , trusses , frames are usually used as pipeline supports .The deflection due to a concentrated load and bending stress can be controlled to a safety limit by increasing the supports in the span of pipeline. This paper discusses about determining number of supports for a pipeline to limit the deflection and bending stresses in the pipeline.

Kevin Koorey [1] carried out research on optimizing support span in geothermal pipelines and has developed design methods for support spacing in New Zealand geothermal projects. The sagging effect is taken as the parameter in deciding the optimum span in his research work.

Payal Sharma [2] carried out research in designing the piping support for process piping using a CAE package. The research work undergone provides the methods to ensure safe design in terms of stress and deflection results for applied loads in a pipeline.

A pipeline fixed between an elbow and a reducer is considered as a fixed beam and the pipeline is analyzed theoretically and in software ANSYS APDL 16.0. The methodology of determining number of supports by design criteria is discussed here. The pipeline discussed here is of a span 8 meter used in a thermal mixer test setup. The compressed cold air flowing through this is at room temperature and pressurized at 8 bar. It will mix with the hot air from another pipeline in thermal mixer. For ensuring the safety of the pipeline structurally, it is necessary to carry out structural analysis of pipeline. Fig 1 shows the actaul pipeline that for which analysis is carried out.

The pipeline highlighted in black in Fig 1. Shows the actual layout to be analysed structurally . The analyis is to be done for pipeline between the reducer and the elbow.

2.0 Theoretical Calculation of Maximum Deflection and Bending Stress in Pipeline

The pipeline fixed between two elbows be considered as a fixed beam. The self weight of pipeline and the weight of fluid in pipeline is assumed to act as point load at the center of pipeline

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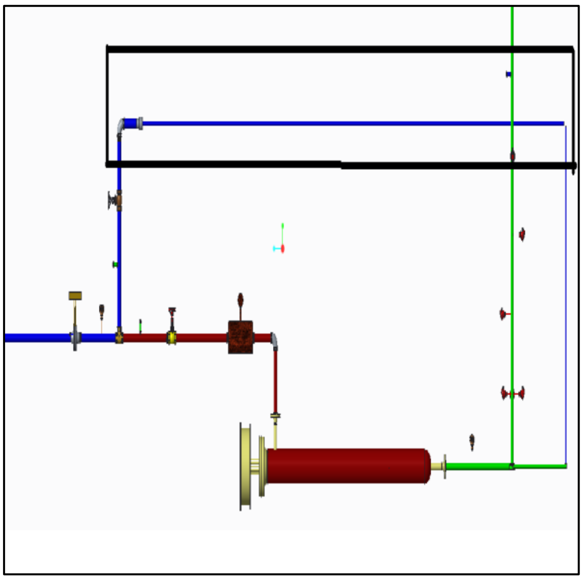
.The maximum deflection of the beam and the bending stress can be formulated from beam equations

Maximum deflection , $y = \frac{WL^3}{192EI}$ (1)

Maximum bending stress, $S_b = \frac{WL}{8Z}$ (2)

Where W is the weight of pipe and fluid concentrated at midpoint of pipeline in N. E is the Young's Modulus of stainless steel pipe in N/m^2

Fig 1: The Pipeline To Be Analysed



I is area moment of inertia of pipe in m^4

L is the span of pipe in m

Z is modulus of cross section of pipeline in m^3.

The pipeline is made of stainless steel grade SS304 40S . The span length L is 8 meter . The outer diameter of pipe D is 33.401 mm and inner diameter of pipe d is 26.6446 mm . The fluid inside pipeline is air at 8 bar pressure .

Weight of pipe and fluid ,W = 240.2 N

Young's modulus of stainless steel, E = 2 x 10^{11}N/m^2

Area moment of inertia of pipe ,I = 3.6354 x $10^{-8}m^4$

Section modulus of cross section of pipeline ,Z = 2.1768 x $10^{-6}m^3$

Maximum deflection value is found as 88.09 mm and maximum bending stress is 110.34 N/mm^2 . For safe design , L/600 (13.333 mm) is considered as safe deflection value andS_b=34.5N/mm^2(30% of allowable stress(115N/mm^2)) is considered as safe stress value .

3.0 CAE Analysis of Pipeline in ANSYS APDL 16.0

The pipeline discussed in previous section is modeled in ANSYS APDL 16.0 with two ends fixed and the weight of pipe and weight of fluid applied at the middle of the pipeline as shown in Fig.2

Fig 2: Pipeline Modeled with Weight Concentrated at Center

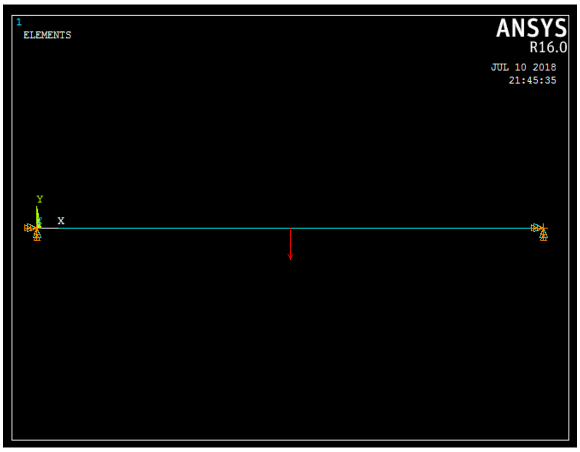


Fig 3: Deflection Results for Applied Loading Condition

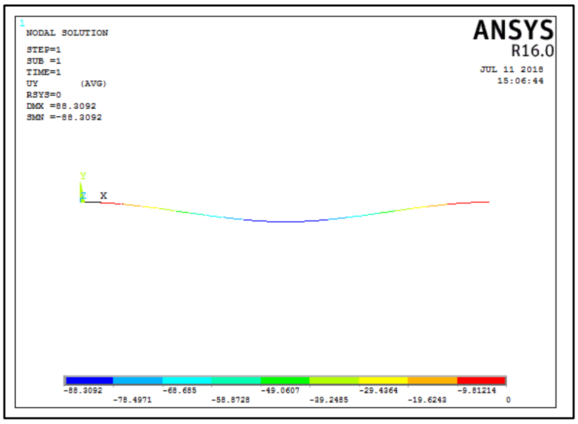
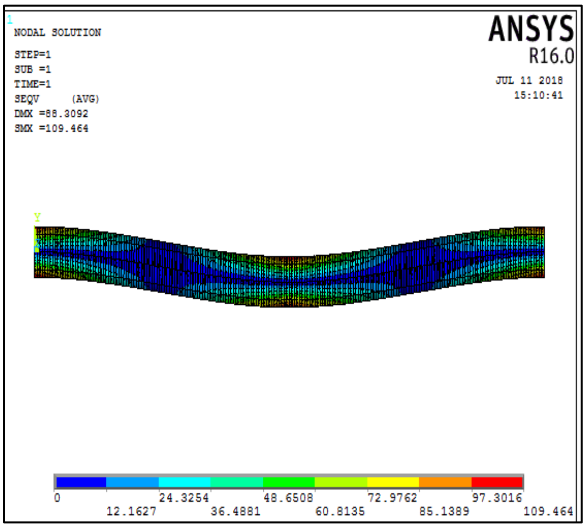


Fig 3 show the maximum deflection value to be 88.3092 mm . But this value of deflection is not in safety limit (L/600=13.333mm) . So more supports are to be provided to reduce deflection. First the supports are provided at 1000mm and 7000 mm as shown in Fig 4 and analyzed.

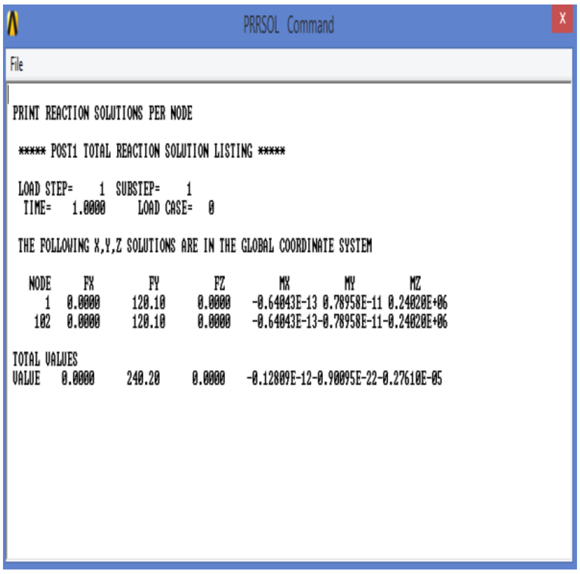
Fig 4: Bending Stress Results in Pipeline



From Fig 4. maximum bending stress value to be 109.464 N/mm^2 which is not in the safety limit of bending stress (34.5N/mm^2) .

The ANSYS APDL 16.0 analysis values of bending stress and maximum deflection for fixed beam case is varying by 0.2488 % and 0.7933 % respectively from the theoretically calculated value.

Fig 5: Reaction Results in Supports



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PRRSOL Command
File

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  TIME=    1.0000      LOAD CASE=   0

 THE FOLLOWING X,Y,Z SOLUTIONS ARE IN THE GLOBAL COORDINATE SYSTEM

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Figure 5 shows the support reactions for the applied load in two supports. From Figure 2 and figure 3 we can see that the deflection values and the bending stress values are not in the safety limits. Hence the more supports are provided at 1000 mm from the left support and 7000 mm from the left support and the deflection , bending stress , support reactions are to be analysed considering this beam as shown in figure 6.

Fig 6: Pipeline with Two Additional Supports

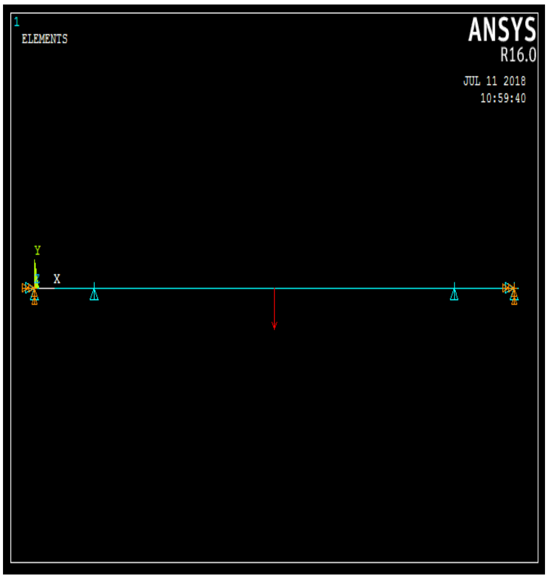
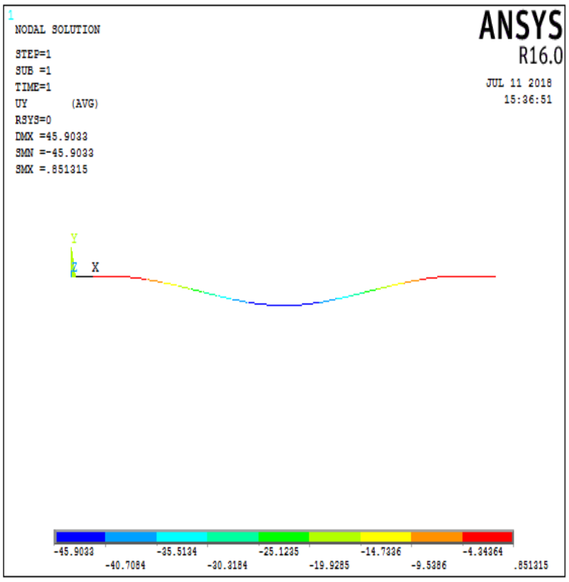


Fig 7: Deflection Plot for Two Added Supports Case



From Fig 7 we can see that maximum deflection value is 45.9022 mm. This is not within the safety limit (13.333 mm). From Fig 7 we can see that maximum bending stress is 81 N/mm^2 which is not within the safety stress value (35 N/mm^2)

Fig 8: Bending Stress Plot for Two Added Supports Case

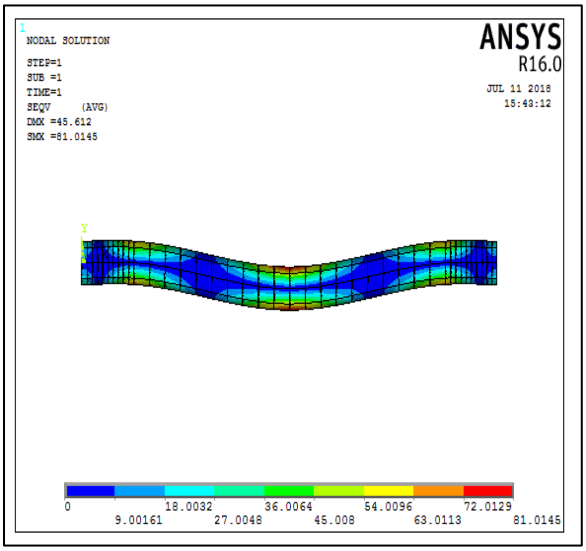


Fig 9: Reactions Results in Two Additional Support Case

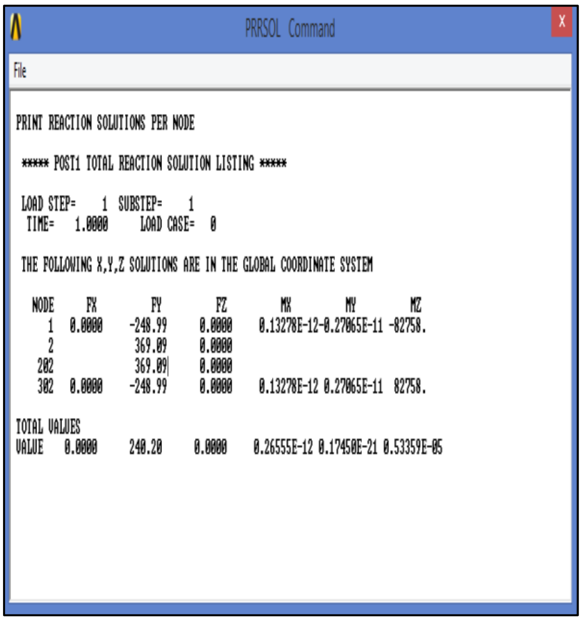


Fig 10: Pipeline with Four Added Supports

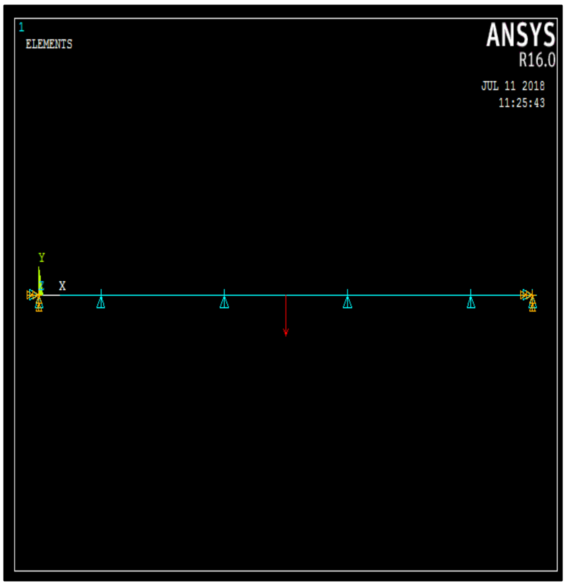


Fig 11: Deflection Plot for Four Added Supports Case

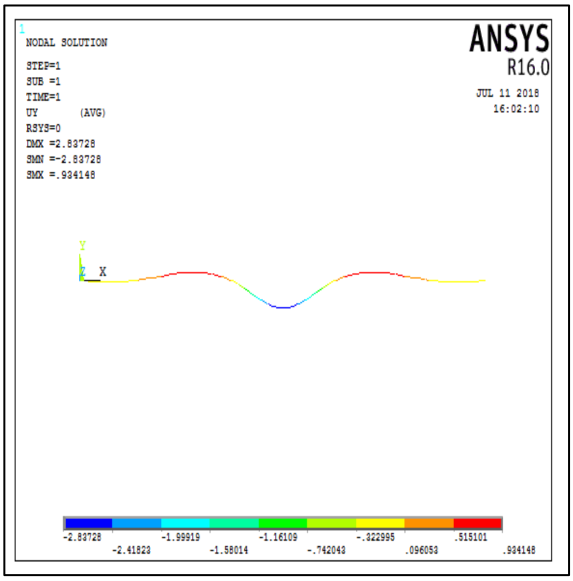


Figure 7 Shows the support reactions in all the four supports. From Figure 5 and figure 6 we can see that maximum deflection value is 45.9022 mm and maximum bending stress is 81 N/mm^2 .

Still the deflection and bending stress is not in safety limit hence two more supports added at 3000 mm and 5000 mm from elbow and pipeline is analyzed for deflection , bending stress and support reactions as shown in figure 10.

From Fig 11 we can see that the maximum deflection value is 2.83728 mm .We can see that deflection is within safety limit of L/600 (13.3333 mm). Fig. 12 Shows the maximum maximum bending stress results in pipeline for applied load . The maximum bending stress is 24.6162 N/mm^2which is within 30 percent of allowable stress .Fig. 13 shows the support reactions in all the four supports. The supports must be designed considering all these reactions at supports.

Fig 12: Bending Stress Results for Four Added Supports Case

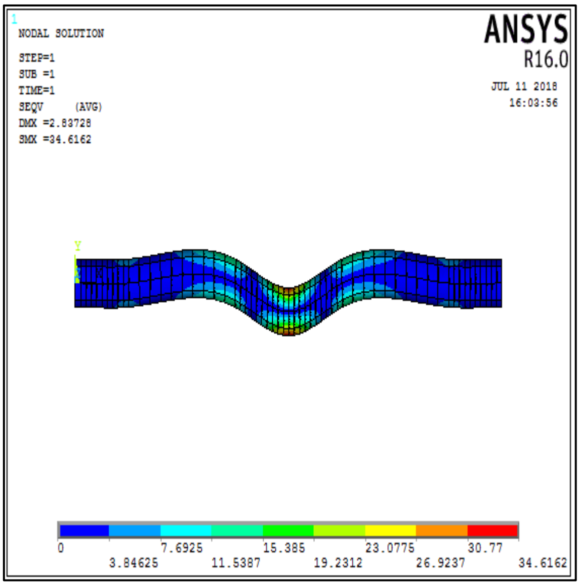
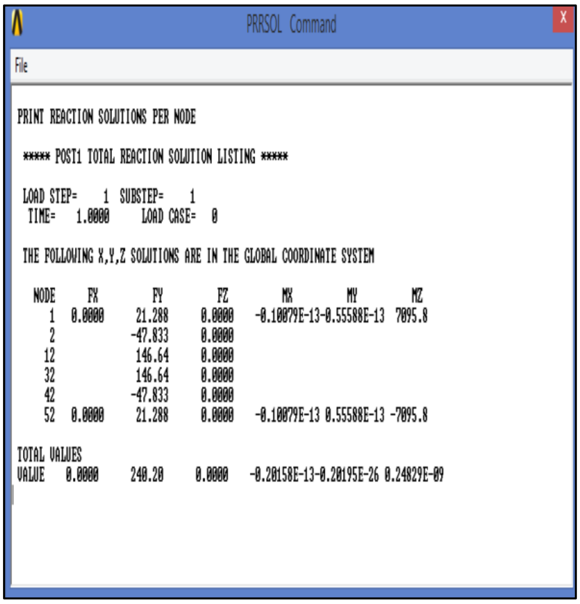


Fig 13: Support Reactions for Four Supports Case



PRRSOL Command

File

PRINT REACTION SOLUTIONS PER NODE

***** POST1 TOTAL REACTION SOLUTION LISTING *****

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TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN THE GLOBAL COORDINATE SYSTEM

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12		146.64	0.0000			
32		146.64	0.0000			
42		-47.833	0.0000			
52	0.0000	21.288	0.0000	-0.10079E-13	0.55588E-13	-7095.8

TOTAL VALUES

	FX	FY	FZ	MX	MY	MZ
VALUE	0.0000	240.20	0.0000	-0.20158E-13	-0.20195E-26	0.24829E-09

4.0 Conclusions

In this work, we reduced the deflection and bending stress to a safety limit by increasing number of supports. The deflection value is limited to L/600 which ensures safety. It is concluded that four additional supports at 1000 mm, 3000 mm , 5000 mm , 7000 mm are needed in addition to existing elbows at two fixed ends . The deflection value and bending stress value ensuring safety are 2.83728 mm and 34.6162 N/mm^2 respectively.

The ANSYS APDL 16.0 analysis values of bending stress and maximum deflection for fixed beam case is varying by 0.2488 % and 0.7933 % respectively from the theoretically calculated values . The accuracy of the software analyzed results can be appreciated .

The design of supports may also be affected by the vibrations in the pipeline which can be further analysed using modal analysis in case of drastically varying flow rates in pipeline.

References

[1] K Koorey. Determination of the optimal pipe support spans for geothermal pipelines. Proceedings World Geothermal Congress 2000 Kyushu - Tohoku, Japan

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