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Research Paper

Modeling of piping system with dynamic vibration absorber using CAESAR II

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1. ABSTRACT

Vibrations exceeding the permissible limits in piping systems cause cyclic loads that lead to fatigue, damage, and fracture. The present study addresses vibration reduction in an actual piping system in a petroleum refinery. To reduce vibrations, we propose a cantilever beam with a lumped mass at the free end (named a “beam DVA” in this paper) as the vibration absorber. CAESAR II’s dynamic analysis results indicate that using an optimal beam DVA can lower pipe displacement by 73%. Next, the beam DVA is constructed and installed in the actual piping system to validate the modeling results. Experimental measurements show that installing the beam DVA reduces the vibration level of the pipe by 69%. Hence, a good agreement exists between the modeling and experimental results.

Keywords: Vibration, Piping system, CAESAR II, Vibration absorber.

2. INTRODUCTION

The most intuitive solution for controlling undesired vibrations in pipelines is eliminating or modifying the vibration source. However, removing the source of vibration in pipelines is not always feasible. Another method to control vibrations in pipelines is by designing appropriate supports at appropriate locations. Nevertheless, due to physical and spatial limits, and thermal displacements in pipes, supports sometimes cannot reduce vibrations to acceptable levels, also, one of the safest and most economical techniques is using vibration absorbers. As a result, they have attracted researchers’attention in recent years. Song et al. studied vibration control in an M-shaped piping system using the pounding tuned mass damper (PTMD). A PTMD consists of a cantilever beam with a lumped mass at the free end. The beam passes through a circular hole, the internal surface of which is coated with viscoelastic material. As the beam oscillates, it bends and collides with the viscoelastic material, and kinetic energy is damped in the process. Experimental results show that using PTMD has reduced the displacement and acceleration of the pipe by 86.6% and 83.6%, respectively [1]. Shemshadi et al. used experimental data from 1″, 2″, and 3″ pipes and the dimensional analysis method to present a mathematical model for reducing the displacement amplitude in the pipes. The absorber used in this study consists of a cantilever beam with a lumped mass at the free end [2].

3. PROBLEM DEFINITATION

In the bearing lubrication system of a 3 MW steam turbine generator in a petroleum refinery, the lubricant is pushed into the bearing chamber by a centrifugal pump through a piping system. As shown in Fig. 1, a 1-inch pipe passes over 2 supports and connects to the generator bearings at the end of the lubricant feeding path. Table 1 displays the specifications of the pipe and the lubricant feed pump.

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Figure 1. Lube oil piping configuration

Table 1. Specifications of the pipe and the lubricant feed pump

PUMP	Brand	Type	Discharge Pressure
	ALLWEILER	Centrifugal-Volute-Casing	9.9 barg
PIPE	Size (NPS)	SCH	Material
	1	160	ASTM A312 304L

Abnormal noise and high vibration amplitude were observed in the pipe section between the supports. In this study, vibration meter measurements showed that the displacements (zero to peak) in the horizontal and vertical planes are 0.72mm and 0.27mm at a frequency of 25 Hz. Thus, referring to the allowable vibration speed curves of VDI 3842:2004-6, the vibration is at a hazardous level [3].

4. SOLUTION

To reduce vibrations, we propose a cantilever beam with a lumped mass at the free end (named a "beam DVA" in this paper) as the vibration absorber (Fig.2). For obtaining the optimal absorber specifications, the piping system is modeled again with the beam DVA and the absorber is designed by changing the parameters of the beam DVA to reduce pipe displacement.

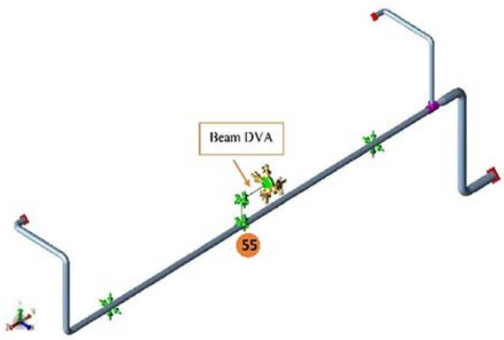
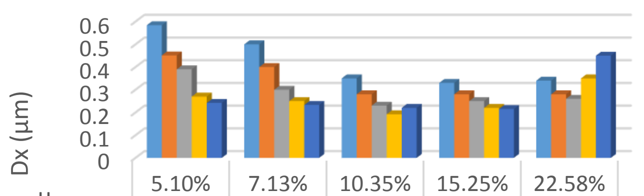


Figure 2. Model in CAESAR II - Lube oil piping with beam DVA



μ	5.10%	7.13%	10.35%	15.25%	22.58%
L/D=14.5	0.584	0.5	0.35	0.33	0.34
L/D=15.8	0.451	0.4	0.28	0.28	0.28
L/D=17	0.39	0.3	0.23	0.25	0.26
L/D=21.4	0.27	0.25	0.192	0.22	0.35
L/D=22.8	0.242	0.233	0.22	0.215	0.45

Figure 3. Displacement of node 55 for different L/D and different mass ratio

5. CONCLUSION

The software modeling results of the case study indicate that the absorber designed by the methodology presented here resulted in a 73% reduction in pipe displacement in an actual piping system. In addition, after the beam DVA was constructed and installed at the specified location, the horizontal pipe displacement was reduced to 69%. Therefore, There was a good macthing between the modeling and empirical results. (Figs. 4, 5)

Figure 4. Beam DVA installed on Lube oil piping

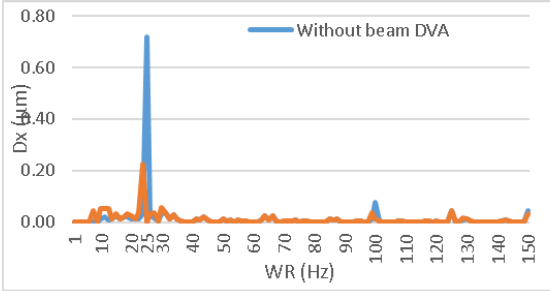


Figure 5. Experimental results of displacement versus frequency

6. REFERENCES

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