

Vibration analysis and control of a screw compressor outlet piping system

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Abstract

The severe vibration of a screw compressor outlet piping system caused the premature failures of some thermowells and the unplanned shut down of the compressor system. The root causes of the vibration problem were investigated by numerical simulations. An acoustic model was established to predict the pressure pulsation of the gas inside the pipelines, and two finite element models were built to study the vibration characteristics of the overall piping system and of the thermowells. The numerical results indicated that the vibration problem may be attributed to the excessive pressure nonuniformity of the gas inside the pipelines, low overall stiffness of the piping system and the first-order structural resonance occurred on the thermowells. A pulsation attenuator was added and the pipelines were rearranged to reduce the pressure pulsation, some pipe supports were added to improve the overall stiffness of the piping system, and the thermowells were reinforced to avoid the first-order structural resonance. After the modifications, the field measurement data showed that the vibration of the piping system decreased significantly, and the modified piping system has been operating normally for nearly two years.

Keywords

Piping system, vibration, gas pulsation, structural resonance, compressor

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Introduction

Compressors are widely used to pressurize the gas in petrochemical industries. The vibration issue is a potential threat to the integrity of the compressor system. Excessive vibrations induced by the gas pulsation or structural resonance may lead to premature failure of the pipelines, gas leakage and other safety problems. For example, abnormal vibration of the outlet piping system of a screw butadiene compressor used in a chemical plant caused the unplanned shut down of the compressor system. The screw compressor has four male rotors and six female rotors. The rated speed, rated motor power and rated flow rate of the compressor are 2950 r/min, 1500 kW, and 15,277 m³/h, respectively. The inlet pressure and temperature of the compressor are 159 kPa and 318 K, respectively, and the outlet pressure and temperature are 530 kPa and 374 K, respectively. During the operation, the vertical vibration velocity at the first elbow after the outlet muffler was 28.8 mm/s, which far exceeded the allowable value of 16 mm/s.¹ Moreover, the fatigue fractures occurred on the root of some thermowells, as shown in Figure 1. To control the vibration and ensure the production, the temporary measure of changing the elastic support near the outlet muffler

to the guide support was adopted; nevertheless, severe vibrations still occurred in the main pipelines and thermowells. As a result, vibration analysis and corresponding control measures were urgently needed to ensure the safety and reliability of the compressor system.

The gas pulsation and mechanical vibration of the piping systems have drawn much attention in the past few decades. Some researchers are devoted to improving the accuracy of theoretical analyses and numerical simulations of the gas pulsation and piping vibration. Koai and Soedel^{2,3} and Wu et al.⁴ developed acoustic models to evaluate the gas pulsations in the screw compressors. Papas et al.⁵ developed a mathematical model to predict the pressure pulsation in a screw expander inlet pipe. Xu et al.,⁶ Ghanbariannaseni and Ghazanfarihashemi,⁷ and Zhan and Duan⁸ developed

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