SSG Case Study Template - Vibration Mitigation in Oil and Gas Plant Booster Gas Station

Author: Abdelrahman Mohamed Hosni Abdelghaffar Abdelrahman

Company represented: NA

Role: Asset Integrity Engineer

Sector: Oil & Gas

Asset owner: Leading Oil and Gas Company in North Africa

Introduction

Description of assets in study

Unit D of the Oil and Gas Plant Booster Gas Station, specifically the 1st stage Air Cooler inlet and recirculation lines, affecting the 1st stage anti-surge valve (FV-711) and 1st stage recirculation valve (HV-011).

When was the activity carried out?

- Test and Measurement Campaign: February 2020

- Acoustic Model Development: March to April 2020

- Solution Implementation: April to June 2020

Why was the activity carried out?

Excessive vibrations were detected in Unit D, impacting operational stability and potentially leading to equipment damage. These vibrations posed operational and safety risks, necessitating immediate intervention. This aligns with the **Asset Management Policy** and **Asset Management System** by demonstrating a commitment to safety and operational standards.

Terminology

- FIV: Flow-Induced Vibrations

- RMS: Root Mean Square (a measure of vibration amplitude)

- pk-pk: Peak-to-Peak (a measure of pressure pulsation amplitude)

- Acoustic Resonance: A phenomenon where a system vibrates with increased amplitude at specific frequencies due to external excitation.

Description of activity

Integration with Broader Asset Management: The project aimed at extending asset life by reducing wear and tear from vibrations, optimizing performance, and minimizing unplanned downtime.

Methodology

A multi-stage approach was employed, reflecting the **Planning** stage of the **Asset Management Strategy and Objectives**:

1. Vibration Survey: Conducted a steady-state vibration survey to identify the location and magnitude of vibrations. The highest vibrations were recorded at the 1st stage recirculation lines and air cooler inlet manifold.
2. Pressure Pulsation Measurement: Measured pressure pulsations at key points to identify potential sources of excitation, revealing significant pressure pulsations downstream of the recirculation valve.
3. Valve Travel Analysis: Investigated the effect of valve opening on vibration levels to understand the relationship between flow and vibration, discovering that opening the anti-surge and recirculation valves at a specific percentage could mitigate vibration.
4. Acoustic Modeling: Developed and validated an acoustic model to simulate the system's behavior using test and measurement campaign data to confirm the FIV hypothesis.
5. Solution Development:
    - Piping Modification: Implemented Modification to reduce dead branch length and prevent acoustic resonance. This involved:
        - Junction of anti-surge and recycle lines into a Y connection.
        - Reorientation of the recycle valve to increase the first acoustic mode frequency.
    - Structural Supports: Added new and modified existing supports to stiffen the piping system and mitigate vibrations.
    - Execution Plan: A detailed methodology was established for dismantling and erecting new piping, ensuring safety and operational standards compliance. This demonstrates the importance of **Maintenance Delivery** within the **Life Cycle Delivery** framework.

References

- API 618: Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services

- VDI 3842 Vibrations in Piping System

- ISO 10816 – Mechanical Vibration

- ASME B31.3 – Process Piping Code

- ISO 55000 – Asset Management

- The Orange Book Management of Risk – Principles and Concepts

Risk Types

- Operational Risk: Risk of equipment failure and downtime due to excessive vibrations.

- Safety Risk: Potential for injury to personnel due to vibrating equipment.

Risk Management Process

The risk assessment was integrated with the overall project **Risk** management process. Identified risks were evaluated based on their likelihood and potential impact. Safety protocols were strictly enforced, including the use of Personal Protective Equipment (PPE), exclusion zones, and comprehensive HSE risk assessments for each phase of the modification process. This demonstrates a commitment to **Leadership & Governance** through effective risk management.

Risk Assessment: Identified risks through a vibration survey and pressure pulsation tests, revealing excessive vibration due to FIV.

1. Risk Prioritization: Prioritized based on impact on operational stability and safety.
2. Mitigation Impact: Implemented modifications to reduce the identified risks.

Integration with Corporate Risk Register: Incorporated the findings into the corporate risk register to ensure tracking and mitigation.

Tools Used

- Vibration measurement equipment: Accelerometers, Velocity Sensors, Displacement Sensors, Vibration Analyzers, data acquisition system

- Pressure transducers

- Acoustic modeling software

- Finite Element Analysis (FEA) software: Caesar

- Method Statement and Work Schedule: To ensure systematic and safe execution of modifications

Costing

The project's financial considerations encompassed several key aspects. Firstly, procurement involved the acquisition of essential materials and equipment needed for the piping modifications. This process was carefully planned to ensure alignment with budgetary constraints, emphasizing cost-effectiveness and timely delivery. The modification phase involved detailed planning and execution, with expenses covering labor, equipment usage, and safety measures. Additionally, resources were allocated for the installation of new supports, welding, and quality control activities. This comprehensive approach to budgeting ensured that the project remained within financial parameters while achieving the desired outcomes in vibration mitigation.

People

- Vibration Specialist/Engineer

- Engineering Contractor

- Operations Personnel

- HSE Coordinator and HSE Officer

- Asset Integrity Engineer

This project involved a team with diverse **Competence Management** skills, highlighting the importance of specialized knowledge in asset management.

Evaluation

What was the main output of the activity?

- Documented vibration levels and pressure pulsations.

- Identification of the root cause of vibrations (FIV).

- Development and implementation of a solution to mitigate vibrations, specifically Modification involving piping configuration changes and additional supports.

• **Operational Efficiency**: Significant reduction in vibration levels, leading to enhanced stability of Unit D.
• **Safety**: Mitigated risks of equipment failure and potential harm to personnel.
• **Cost Savings:** Reduction in maintenance costs due to fewer equipment failures and less downtime.

Results and Findings

1. **Test and Measurement Campaign:**

    - **Steady-State Vibration Survey**: Indicated highest vibration levels on the 1st stage recirculation lines and air cooler inlet manifold.

- **Pressure Pulsation Measurement**: Identified significant pressure pulsations downstream of the recirculation valve, confirming FIV.

2. **Proposed Solution - Modification**:

    - Junction of anti-surge and recycle lines into a Y connection.
    - Reorientation of the recycle valve to reduce dead branch length.
    - Acoustic and structural modeling validated the solution's effectiveness.

Continuous Improvement

- **Monitoring:** Post-modification vibration monitoring confirmed a significant reduction in vibration levels.
- **Ongoing Analysis:** The solution allows for continuous evaluation and optimization, contributing to the broader asset management strategy.

Sustainability Considerations

- **Environmental Impact:** Reduction in vibrations minimizes the risk of leaks or equipment failure, contributing to environmental safety.
- **Resource Efficiency:** Optimization of performance leads to better resource utilization and reduced waste.

Validation

- Post-modification vibration measurements: Confirmed a significant reduction in vibration levels.

- Acoustic and structural models: Validated the effectiveness of the solution.

- Compliance with Method Statement: Ensured adherence to safety and operational standards throughout the modification process.

Outcome

- Successful: The activity successfully mitigated the excessive vibrations in Unit D.

- Improved Operational Stability: The solution improved the operational stability of the compression unit.

- Reduced Risk: The risk of equipment failure and downtime was significantly reduced.

Lessons Learned

- Early Detection and Diagnosis: Early detection and diagnosis of FIV are crucial for preventing equipment damage.

- Multi-Disciplinary Approach: The involvement of vibration specialists, engineers, and operations personnel is essential for effective FIV mitigation.

- Acoustic Modeling and FEA: Valuable tools for understanding and solving FIV problems.

- Comprehensive Risk Management: Ensuring a structured approach to safety and operational risk management is vital for successful execution.

This project demonstrates the importance of **Continuous Improvement** through ongoing **Monitoring** and learning.