In Partnership With

Case Study

Acoustic Induced Vibration Study

Date Issued:	17/08/2021	
Tags:	Finite Element Analysis Acoustic Induced Vibration Modal and Harmonic Analysis	Ansys 2020 R2 Small Bore Connections ParaView 5.8.0

1 Background

Armech Solutions received a request for a proposal by a well-established Oil and Gas company that undertake Engineering Procurement and Construction (EPC) projects, predominantly within the middle east. The client was responsible for a project on the Recycle Gas Plant within Dukhan Oil Field, located approximately 80 Km west of Doha. The plant was commissioned in 1998 to produce 800 million standard cubic feet per day (MMSCFD) of gas from the Arab-D gas cap. The residue gas produced is reinjected into the same formation. The end client, Qatar Petroleum, aims to provide a means of establishing safe operation of the plant at an increased throughput of 880 MMSCFD; in turn, potential Acoustic Induced Vibration (AIV) issues require assessment. An additional objective is to extend the life of the plant through mitigation measures introduced through analysis.

A screening check is required to determine the likelihood of failure (LOF) associated with the acoustic induced vibration. The LOF for a chosen line within the plant can be established by following the methodology set out by the Energy Institute for the Avoidance of Vibration Induced Fatigue Failure Pipework (EIG) deriving from a sound power level at the source [1].

The UK Health and Safety Executive stated that 21% of all piping failures and hydrocarbon releases for the Offshore Industry are due to vibration-induced fatigue failures. Approximately 80% of these failures are related to small-bore connections (SBC). These can include small bore branches such as welded supports.

Acoustic Induced Vibrations result from a pressure drop in the system causing structural vibrations, which lead to potential fatigue failures. These failures are likely to occur at Relief Valves, Orifice Plates, Control Valves, or other system areas that experience a pressure drop. The change in pressure at these elements produces shock waves and turbulent mixing downstream, causing a high-frequency vibration within the range of 500Hz to 2000Hz. The LOF of the system increases through the excitation of the vibration modes of the shell. Thus, the LOF is directly related to the pressure drop and the flow rate of the area in question. Failure of the system through fatigue can be disastrous; these failures can occur without warning and within a matter of minutes of becoming induced.

2 Problem

The Gas Recycling Plant at Dukhan has multiple pipelines with relief valves, each introducing the potential for acoustic induced vibration damage. The EIG standard details the analyst's methodology to assess the operating conditions to find the LOF. The plant operates with a high flow rate and, therefore, is susceptible to damage when acting on safety-critical pressure relief valves; this poses the potential for a catastrophic failure. The technical field associated with AIV is specialist; therefore, the client required a consultancy with the necessary skills to highlight the areas of concern that may fail an in-depth analysis.

The project was on a tight timeframe, and therefore the client required the analysis to be undertaken without delay.

3 Solution

The oil and gas client contracted Armech Solutions to check the likelihood of failure associated with the acoustic induced vibration. The EIG, in section T2, details the methodology with the necessary calculations to deduce the LOF of the line. In addition, the client provided isometric drawings which specified the distances between the elements of interest. These elements include, but are not limited to, valves, weldolets and SBC.

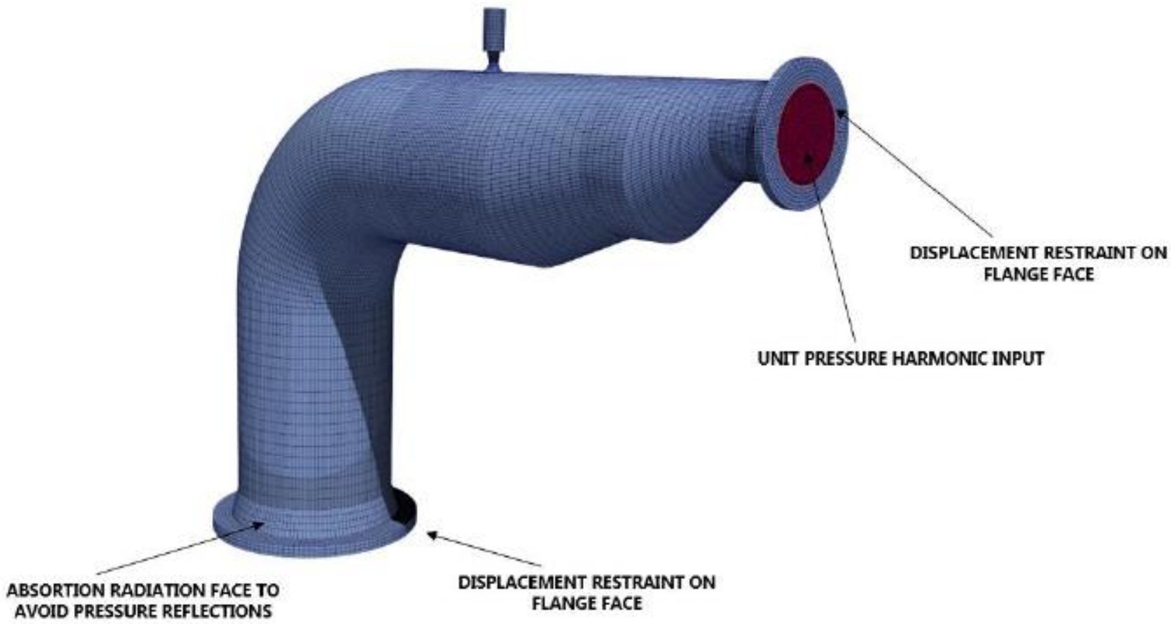
The EIG assessment of the lines found some that did not exceed the 0.29 LOF threshold, which is a safe region with no risk of AIV failure. However, most of the lines assessed resulted in a LOF above 0.29, indicating possible failure if no remedial actions or redesigns are implemented.

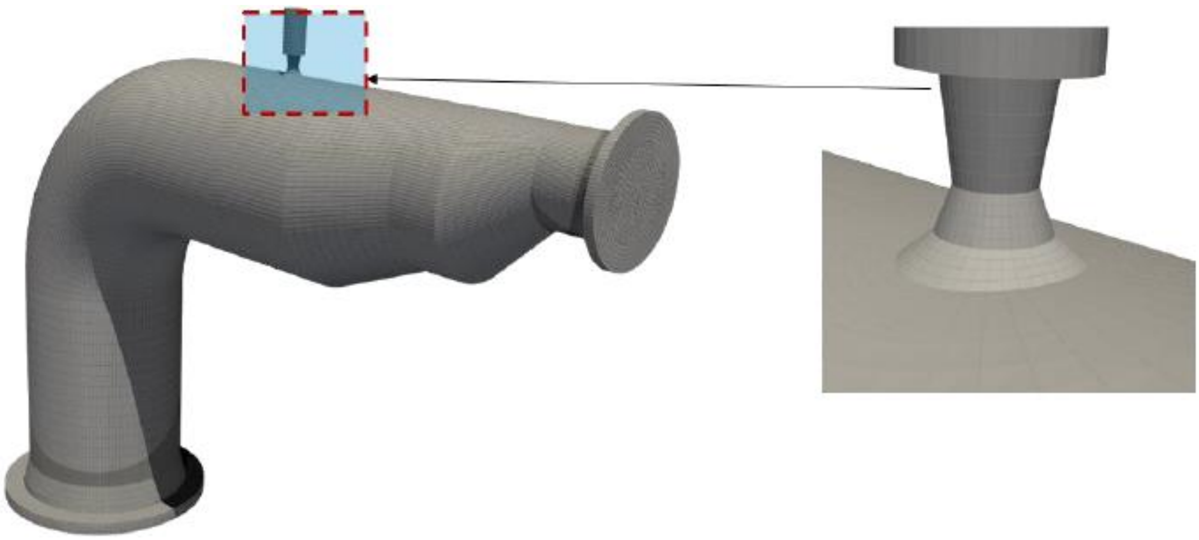
A baseline test case was carried out to illustrate the assessment process; the case included a weldolet and an elbow. The EIG assessment delivered a LOF of 2.09 and 2280 cycles to failure. At a frequency of 2000 Hz, the life until failure of the line would be 1.1 seconds.

The baseline test case highlighted the necessity for a detailed Finite Element Assessment which will return a more accurate fatigue life prediction due to conservatisms associated with the screening EIG method. The lines that exceeded the 0.29 threshold from the screening were recommended for FEA to determine their true fatigue life. A summary of the steps involved in calculating the LOF and the final fatigue failure time are included below:

- Calculating the sound pressure level according to EIG and spectral distribution according to IEC 60534 8-3 Industrial process control valves, Part 8-3: Noise Considerations - Control valve aerodynamic noise prediction is required to calculate the spectral distribution based on the Sound Pressure Level, providing the sound pressure level at a given frequency.
- FE modal analysis obtains the base frequencies for the harmonic acoustic analysis.
- Stress Spectral distribution on the region of interest, small-bore connections, are studied in detail to identify the worst frequencies.
- The hot spot method is applied, the results are compared with S-N curves to estimate final fatigue failure time.

Armech utilised ANSYS 2020 R2 to perform the modal and harmonic FEA, and ParaView 5.8.0 was used for the post process and enhancement of the contour image quality.





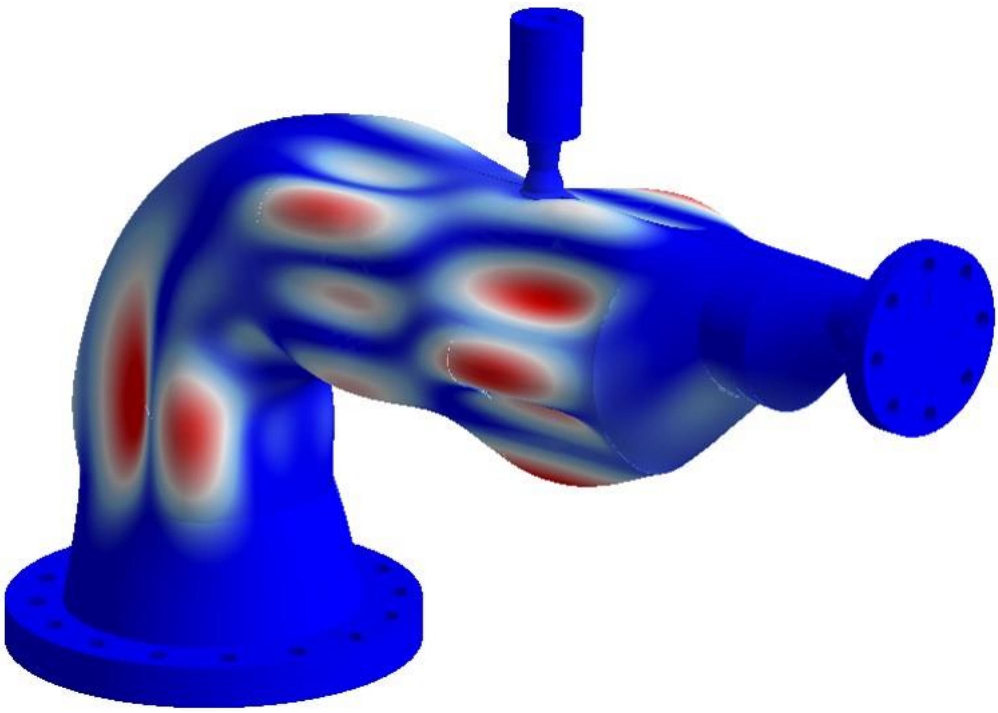
4 Results

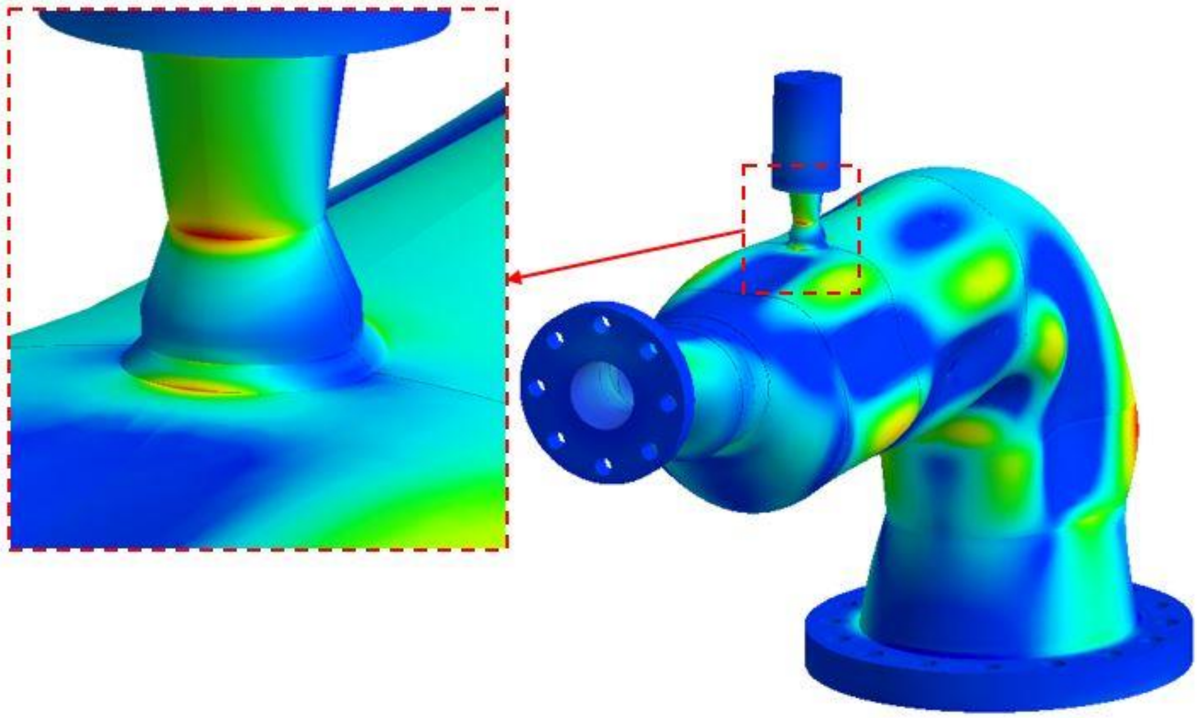
The FEA found areas of the system that required mitigation measures to prevent AIV and subsequent fatigue failure. These measures were delivered to Armech Solutions client and laterally to Qatar Petroleum for implementation.

The baseline case illustrated the importance of applying further analysis to the screening results. The table below details the results for three sound power levels considered.

PWL [dB]	MAX. STRESS RANGE VALUE [MPa]	NUMBER OF CYCLES	CRITICAL FREQUENCY VALUE [Hz]	MASS FLOW RATE [Kg/s]	FATIGUE LIFE [time]
184.3	88.07	612129	394	217.09	6.4 minutes
178	30.1	15.4e6	394	105.08	10.8 h
172	15.11	-	394	52.66	Beyond endurance limit

The most relevant analysis case to the project was 178 dB; this sound power level has a fatigue life of 10 hours, instead of the original 1.1 seconds found from the screening. A maximum flow rate of 217.1 Kg/s, corresponding to a sound power level (PWL) of 184.3 dB, predicted a weldolet failure in 6.4 minutes. These results were found prior to the mitigation measures being implemented.





5 What Next

The client was pleased with the work delivered and took forward the proposed mitigation measures for the line identified as a high risk of failure. Directly following the completion of the work, the client requested Armech submits a proposal for a crack propagation study. The client has expressed their positive experience with our methodologies and deliverables and look to continue sub-contracting to Armech in the future.

[1] "Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework" (AVIFF); 2nd Edition; Energy Institute 2008. ISBN 978 0 85293 463 0.