

Validated Computational Solutions for Pipe Vibrations and Design Analysis

By: Jens Conzen, Manager, Structural Services & Vibration, Fauske & Associates, LLC,
 Pascal Veber, PhD, CEO, Onsala Ingenjörbyrå AB and Erik Bernesson, Co-owner, BerDiz Consulting AB

Steam Line Vibration

Extended Power Uprates or “EPUs” for power plants typically result in an increase of steam flow velocity and component replacements (e.g. valves) in the main steam system. A subsequent increase in steam line vibration has been observed as a result of that. Unacceptable amplitudes of vibration may force the power plant to operate at reduced power. The worst consequence would be damage to plant components or failure of the main steam lines. It is, therefore, of great importance to identify the root cause and fix the problem so that the plant can continue to operate safely and at full power. Hence, a root cause analysis (RCA) is often time critical and not always straight forward. The most common mechanisms for steam line vibration in a power plant are mechanically induced or flow/acoustically induced vibration. A way to check if the vibrations are flow induced vibrations is to perform an acoustic analysis of the component where the vibrations have been detected. This can be done analytically, numerically and empirically.

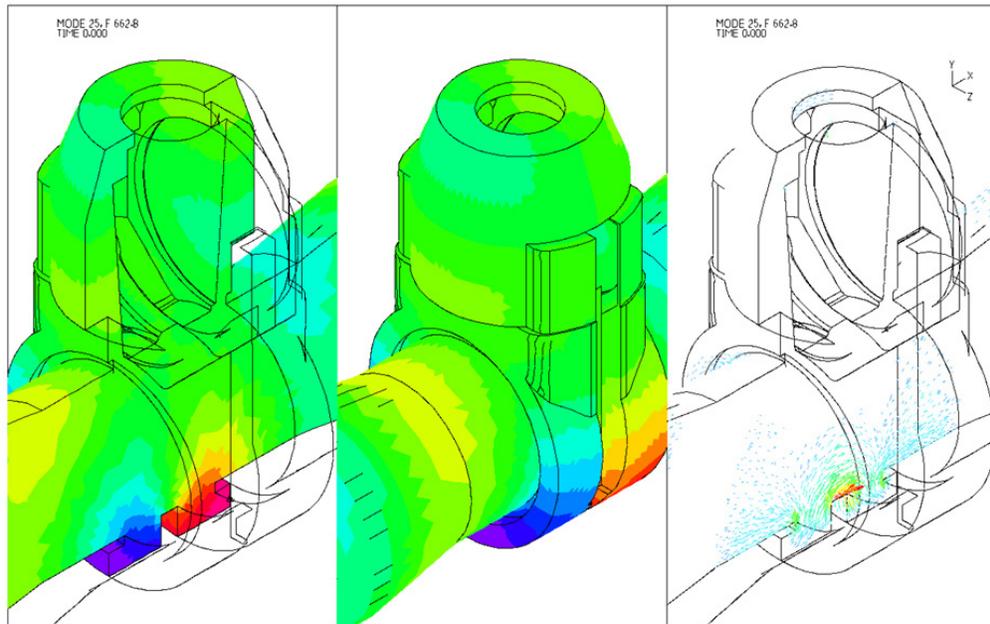


Figure 1

Figures 1 and 2 are examples of numerical acoustic analyses performed by Onsala on a valve as well as a main steam system. The simulation is used to determine the acoustic modes for the frequencies of the peak vibrations, which can be compared to the eigenfrequencies of the pipe. If there is a match between the acoustic frequencies and eigenfrequencies, there is a strong indication that the vibrations are flow induced.

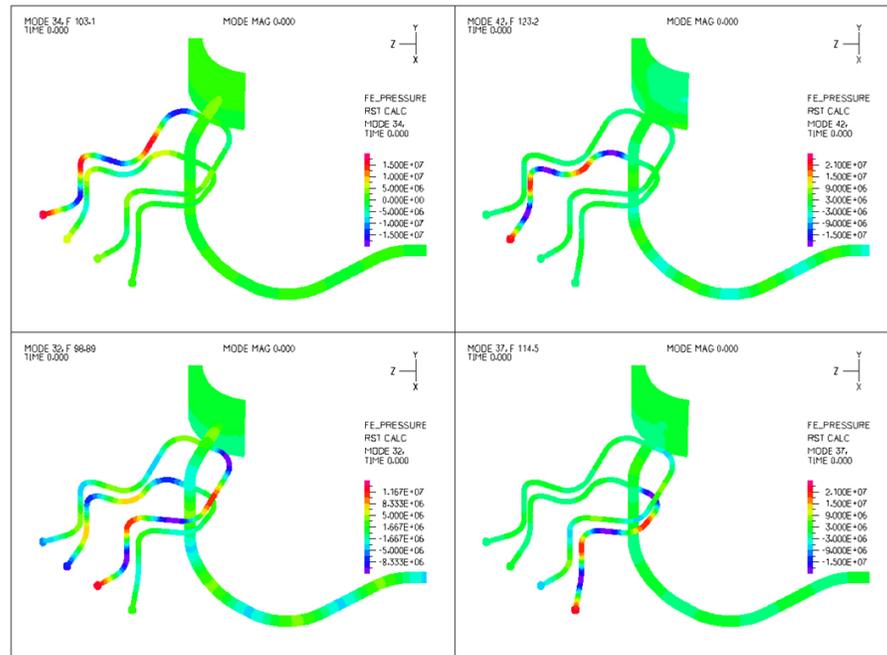


Figure 2

If a match is identified, a computational fluid dynamics (CFD) calculation (Figure 3) can be performed to determine the source of excitation of the acoustic modes. This may be a vortex shed at a T-junction e.g. stand pipe, drain stub, side branch. If the vortex shedding frequency is close to an acoustic frequency, the acoustic mode is excited resulting in pressure pulsations that could then excite the pipe eigenfrequencies and cause pipe vibrations.

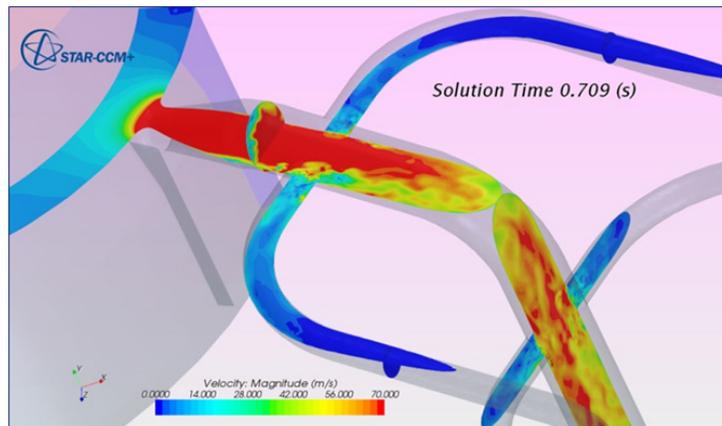


Figure 3

In figure 3, the velocity field in the steam line shows a high level of fluctuations in the small bore branch lines. The vortex shedding frequency depends on the steam flow velocity or the plant power. If the shedding frequency is close to the acoustic eigenfrequency of the side branch a “lock-in effect” with the acoustic mode could occur. The lock-in could potentially result in damaging vibration amplitudes. The pressure fluctuations from the CFD calculations can be mapped in a structural model of the pipe to obtain the velocity magnitude of the vibrations that can be compared to field data. Likewise, the computed frequency of vibration can be compared against test data to provide validation to the model. Figure 4 shows a photograph of a test model of the valve that is shown in Figure 1. FAI performed laboratory scale (1:5) acoustic testing to provide validation to the calculations that helped solve the vibration problem at the power plant.



Figure 4

Analysis of Piping Systems with Cut Boundary Technique

Analyses are often performed by cut-boundary technique, where loads are taken from a global model and applied on a more detailed sub-model. This allows to start with a more general approach to save complexity and time/cost as most parts of the piping system (including components) are usually qualified with the ordinary linear Pipestress analyses and corresponding linear analysis of the supports. However, certain spots or components could be in need for more sophisticated analyses to get qualified. These parts are singled out and detailed sub-models are evaluated using boundary from its adjacent environment.

An example of the cut-boundary technique is presented in Figure 5 below where an entire piping system from a nuclear power plant reactor was analyzed by BerDiz.

The loads on the piping systems, coming from CFD- or RELAP5 calculations, can be transformed and applied in Pipestress or ANSYS finite element models. By following this approach, the piping system, corresponding supports, T-junctions, thermal mixers, anchoring on walls etc. can be analyzed and evaluated in accordance to the ASME codes or any other applicable code. Analyses include dynamic transients, thermal transients, vibrations, plastic analyses, limit loads, buckling analyses and fatigue as well as ordinary static and non-linear analyses.

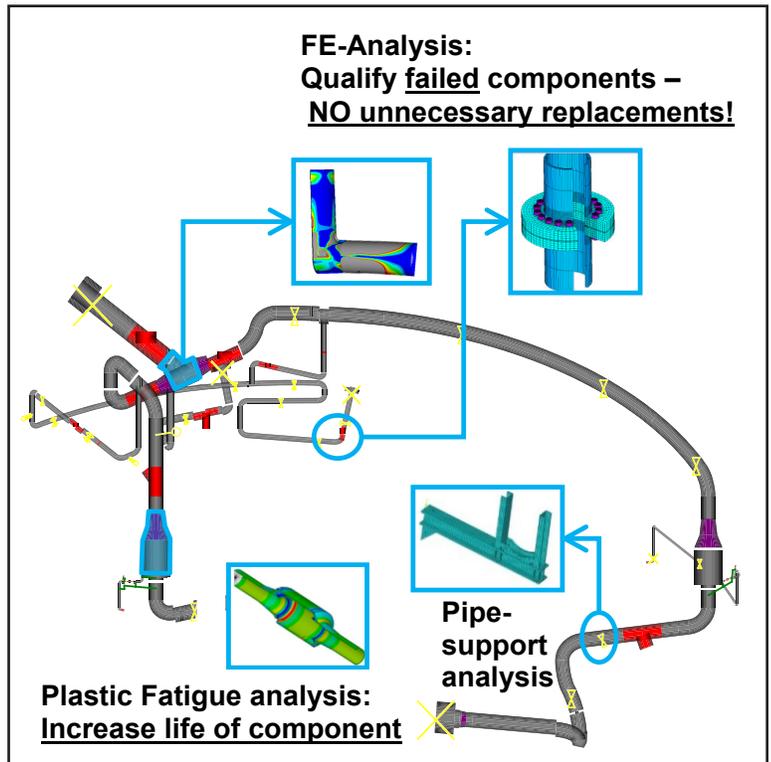


Figure 5

Design Verification of Emergency Relief Systems (ERSs)

Pressure vessels must be equipped with an adequate pressure relief device to avoid catastrophic failure when an overpressure scenario occurs. Chemical production reactors, for example, are therefore equipped with an emergency relief system (ERS). The ERS often consists of a rupture disk, relief piping and a catch tank. The overpressure risk is typically identified during a process hazard analysis (PHA) and may occur due to a loss of cooling. FAI performs chemical testing to characterize the reaction. Calculations are performed with the test data to adequately size the relief device and associated piping. As the internal pressure reaches the burst pressure of the rupture disk a rapid depressurization transient will occur that will cause the relief piping to experience dynamic loads. FAI evaluates the dynamic loads with the RELAP5 software. BerDiz performs the structural design verification to assure that the piping design meets industry standards such as ASME B31.3. This joint effort has been discussed in detail in a previous Technical Bulletin (TB). For more information, please refer to TB N-15-04 on www.fauske.com.

Fauske and Associates, LLC (FAI) has completed a variety of projects with Onsala Ingenjörbyrå AB (Onsala) and BerDiz Consulting AB (BerDiz). Onsala and BerDiz are both located in Sweden and serve the Scandinavian and European engineering industry. Onsala specializes in advanced computational methods such as finite element analysis (FEA) and CFD. BerDiz specializes in the solution of applied engineering problems and also provides staffing support. The synergy results in high end computational solutions in conjunction with laboratory testing and applied engineering. FAI, Onsala and BerDiz provide engineers with advanced degrees and fluency in a variety of languages such as English, Swedish, German, French and Spanish.



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Onsala Ingenjörbyrå AB
Advanced solid and fluid mechanics

www.onsala-ing.se

BerDiz
Consulting AB

www.berdiz.se

For more information, contact:

Jens Conzen
Manager,
Structural Services & Vibration
(630) 323-8750
conzen@fauske.com

Fauske & Associates, LLC
16W070 83rd Street
Burr Ridge, IL 60527



www.Fauske.com