KnightHawk Engineering

Case Study: KnightHawk's Comprehensive Approach to Identifying Isolated Vortex Shedding Induced Deflections in Tall, Cylindrical Structures

Background; During a plant shutdown for a routine turnaround, the distillation towers in the unit were emptied and the trays were removed for maintenance. Two particular towers, nearly identical in height, diameter, and construction material, were situated side by side on the same foundation pad. Under standard wind conditions, one of the two towers suddenly started swaying significantly, while the other remained stationary. This novel phenomenon necessitated an investigation. Because the anchor bolts appeared intact and inspection showed no significant thinning of the vessel walls, the failure of the tower itself was eliminated as a potential cause of the swaying. A common cause of significant swaying in tall, cylindrical structures, such as these, is often the coupling of vortex shedding with the natural frequency of the structure. However, in this scenario, two nearly identical adjacent towers did not react in the same manner, creating uncertainty as to the exact root cause of this event.

Solution; KHE was asked to determine the root cause of the swaying. KHE first performed field services to assess the equipment and to determine what exactly occurred during the event. KHE also conducted a detailed analysis of the original design to assess its robustness and to rule out any potential design flaws.

In order to determine the natural frequency of the tower, KHE then utilized a combination of 3D FEA modal analysis and calculations in accordance with various national codes such as ASME STS-1 and Canadian National Building Codes. Next, the critical vortex shedding wind speed (the wind speed at which the frequency of vortex shedding will match the natural frequency of the tower) was calculated. Because the calculated critical wind speed was determined to be well within feasible sustained winds for the region, KHE then pulled weather records, as well as plant data, to determine the sustained wind speeds at the time of the tower swaying. The weather data and the calculated critical wind speed were a near match, which indicated that vortex shedding coupled with the natural frequency of the structure was a potential cause of the swaying seen. KHE then utilized further calculations in accordance with ASME STS-1 and the Canadian National Building Codes to determine the possible deflection due to vortex shedding coupling with the natural frequency of the structure under the conditions experienced during the time of the event. The deflections calculated by KHE explained the magnitude of tower swaying witnessed by personnel during the event. However, one question remained unanswered: Why weren't both towers swaying?

Fig damental Mode Shape and Frequency using 3D FEA Modal Analysis

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In order to answer this question, it became necessary to perform a comprehensive and detailed analysis of the actual conditions present that led to the one tower swaying so significantly. In this effort, KHE had to determine how the towers interacted from an aerodynamic perspective and what specific conditions existed that enabled one tower to sway, while the other did not. To do so, KHE performed 2D Computational Fluid Dynamics (CFD) simulations that recreated the location and orientation of the two towers relative to the wind direction and speed at the time of the isolated tower swaying. The results of the CFD simulation revealed that the direction of the wind relative to the towers resulted in the swaying tower damping out and interrupting the vortex shedding on the stationary tower. This led to a dramatic reduction in lift force from vortex shedding on the stationary tower, as well as prevention of the development of pronounced and powerful vortex shedding from the stationary tower.

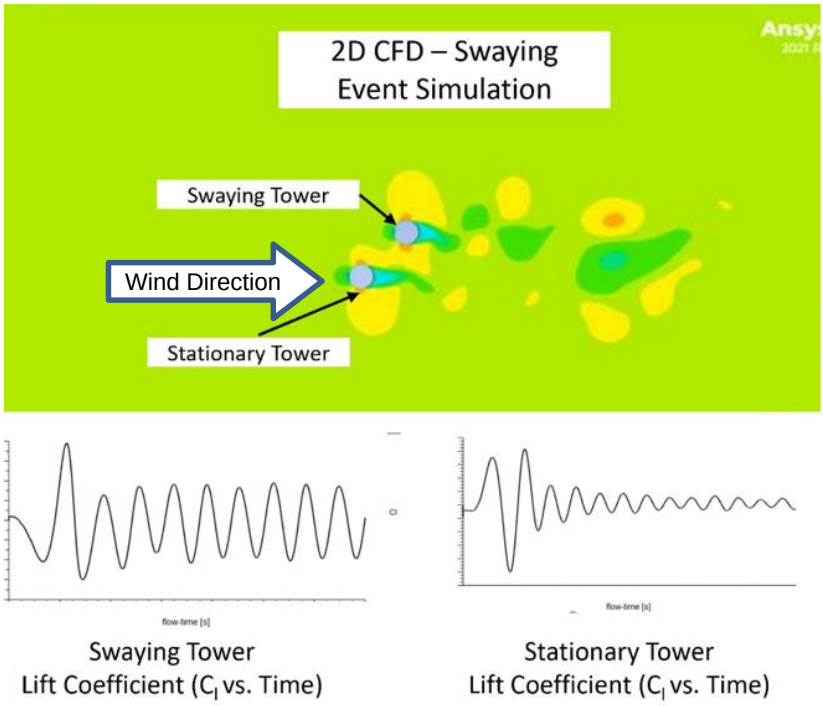

Figure 2: 2D CFD and Resulting Lift Coefficient vs. Time Plots

Takeaway When assessing the root cause of vortex shedding induced deflections, it is important to consider all environmental factors and interactions with the surroundings of the equipment. It is important to use a comprehensive approach to assess all possibilities. KHE has the personnel, experience, and tools needed to perform such assessment and to provide a comprehensive picture utilizing field assessments and knowledge of equipment design, process assessment, and mechanical and fluid analysis.

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