FREQUENCY RESPONSE – An Option to Consider for Detecting Complex Structural Defects

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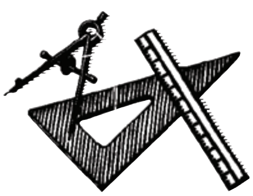
Once again there is a crack found in the inlet tubesheet in your high-pressure high temperature heat exchanger. As head of the maintenance engineering effort, you know that plant management will ask you if it can run safely and reliability until the next scheduled shutdown. In the daily production meeting the issue comes up and you recommend that a fitness for service (FFS) analysis be performed. Non-destructive techniques are reviewed and there is too much resulting uncertainty over the reliability of the characterization of the crack work. Without the proper characterization of the crack it is unlikely that a FFS could be performed and the unit would have to be shutdown and repaired during a non-scheduled outage. In the back of your mind you remember an application where frequency response testing was done on compressor blades to assess the effects of microcracks that were difficult to characterize in depth due to location of the fur tree.



The situation described is not uncommon. Every facility has a goal to run safely and reliably. Some situations just do not fit the traditional approach due to lack of available technology for the task at hand.

Every structure, especially when placed under load, has a natural frequency and mode shape for every frequency. Examples of these loads can be normal operational, some percentage in excess of that, hydrotests, etc. In the compressor blade scenario a baseline was determined based on a good blade under normal loads. The blades with microcracks were checked with acoustic frequencies and mode shapes characterized. Most of the proposed replacement blades had the same frequency response and mode shape as measured by accelerometers as non-damaged blades. In addition non-destructive testing that could be done found nothing indicating problems. The blades could be run. Several of the blades however had a very distinct and different response so those particular blades could not be used. The blades were tested in the machine for the best and most realistic response.

For the situation involving the heat exchanger inlet tubesheet the situation is more complex. A "cluster" of accelerometers tied into a data acquisition system would need to evaluate the response around each tube section. In such a system one is looking for/at the variance from the established norm for that situation. For both of the situations described it is best to have acoustic sensors attached to the equipment as well to assist in the overall evaluation.

A general methodology that would apply to both static and rotating equipment is as follows:

Exhaust all standard non-destructive techniques (NDT) and follow standard applicable Code procedures. If a positive conclusion cannot be reached with standard NDT then the following may be considered as applicable.

1. Develop a test protocol for the testing. This will typically consist of both acoustic sensors and accelerometers.
2. Instrument a "good" specimen or area that is known to have no structural defects.
3. Establish frequency and mode shape.
4. Perform the same procedure for the equipment believed to be defective.
5. Review the data and establish a norm that compares to the baseline.
6. Develop acceptance criteria based on the above.

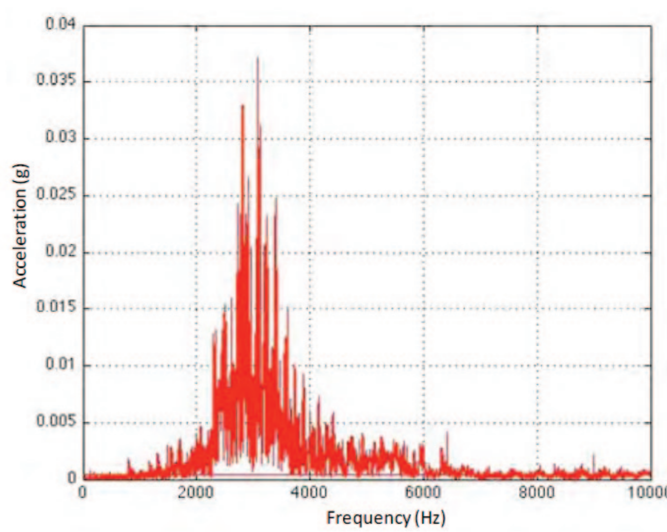


Figure 1: Typical Frequency Response of Tubesheet

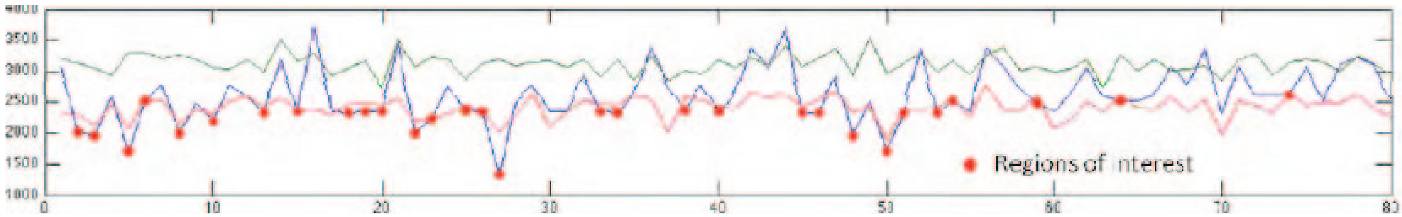


Figure 3: Evaluation of each measurement comparing upper and lower bound

Figure 1 shows a typical response of a tubesheet. The response can be taken of each tube in question and compare against the acceptance criteria or established baseline. Figure 3 shows a comparison of upper and lower bound analysis to establish acceptance criteria. Essentially the "bad" reading is one that is far outside the baseline that is established. Figure 5 shows a technician installing the transducers for frequency response.

In general this testing is highly specialized and requires technicians and engineers familiar with the complete scenario, dynamics, operating practices and consequences. In no case should the results of this testing replace or supersede standard any NDT work governed by applicable Codes and Standards. The test should only be conducted in addition to or when other methods simply will not work, where the risks are acceptable, and where the scatter in the answers and their potential ramifications are clearly understood. All work should be directed and supervised by a professional engineer that is qualified for this type work.

Figure 5: Example of connection of transducers for frequency response on heat exchanger

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Cliff is President and co-founder of KnightHawk Engineering, Incorporated since 1991. He is a Professional Engineer with 31 years of experience. Besides his corporate responsibilities as President of KnightHawk, Cliff is also Chief Engineer and Supervising Professional for the Engineering Consulting Group. As Chief Engineer, Cliff serves as the lead technical professional for major multidiscipline investigations into industrial static and rotating equipment failures. Cliff holds five US Patents and is a registered Professional Engineer. Cliff has a BSME from Louisiana State University 1980.

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