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Transient CFD — Establishing the real picture for assessment

It is another day at the plant and, as usual, your boss calls and says there is a meeting in the conference room that he wants you to attend regarding a compressor failure. That is all you know, but from experience, you know it must be something major since all the "brass" will be in attendance.

The meeting starts with an overview from the production folks on what happened and their plan to put a spare into service that has not been refurbished and that has already failed once before. The bottom line is to get the plant running safely, as the margins are good at this time. The vendor is on a plane and crossing the "big pond" as the conference goes on.

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As it turns out, the compressor has experienced another blade failure. However, this time it was clear that the inlet guide vane also failed. Once again, the vendor confirmed that this problem has not been experienced before, and it is unlikely that the issue is a problem with the compressor. At the meeting, all kinds of plots from finite element analysis to computational fluid dynamics suggest no problems. Also, SAFE diagrams suggest there can be no interaction between the inlet guide vanes and the compressor blades. Surge is suggested, but the compressor was operating far away from surge. Yes, here is another case where everything points to no problems, but you are not about to tell your production manager this news, as you don't want to be booted out. So what is the problem?

Metallurgical and mechanical analysis suggests fatigue, but the flow is steady state and within all design parameters. You ask, "Is the flow and pressure field really steady state?" Good question, because it really is not for any compressor.

Most compressor designs consider steady state effects. The so-called "SAFE" analysis and steady state computational approaches do not consider all the physics involved with the compressor design. Several shortcomings involve:

➢ Cavity acoustics — This involves the pressure pulsation generated inside the compressor cavity that is coincident and couples with mechanical natural frequencies.

➢ Secondary wake effects — Secondary effects due to wake interaction can set up a pulsation that can excite the compressor blades.

➢ Pressure fluctuation — These are effects due to poor volute, piping and/or diaphragm design.

When experiencing problems such as the "phenomena" compressor failure, a good approach to troubleshooting the problem is as follows:

1. Reverse mechanical finite element analysis — If it is known that the failure is fatigue, then this analysis will determine the magnitude of the driving forces and the blade mode failure.

2. Acoustical analysis — The cavity acoustics should be evaluated.

3. Metallurgical analysis of the physical evidence of the failure. Evaluate the failure and look at the failure striations with a scanning electron microscope (SEM).

4. Field services — There are two tests that can be conducted:

➢ Field data acquisition. This involves looking at strain, vibration and dynamic pressures. It is also a good idea to look at a spare impeller to evaluate blade modes and shape. Remember, this will not include stress stiffening.

➢ Laser scanning of failed geometry to verify design.

5. Computational fluid dynamics (CFD) — A transient CFD model should be done of the inlet piping through the impeller to the discharge volute. This will pick up any driving forces for the flow field.

6. Compressor performance/process/controls analysis.

7. Root cause failure analysis.

A compressor wreck can be quite involved when all of the physics is properly looked at. The amount of work involved to walk away from the problem is quite cheap when compared to safety, production loss and possible environmental issues. A professional engineer who is competent in this type of work should evaluate all work.

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