INTERFERENCE DIAGRAM REFRESHER

By Christopher Sykora

This article is a refresher summary of previous articles about the interference diagram and its use in understanding vibration of packeted blade systems like steam turbine blades and centrifugal impellers. The objective of the interference diagram is the same as the widely known Campbell diagram used for individual rotor blades, which is to determine the risk of exciting resonant vibration in the operating speed range. Since the full background of the interference diagram required a series of seven previous articles, I would encourage you to reference those for more details after absorbing this summary. You can find old newsletters on the RMS website and you can find the “Interference Diagram Series” by using the newsletter index at the top of the webpage.

There are five basic elements to the diagram shown in Figure 1. The first two elements are the axes. The Y-axis is the frequency in Hz just like a Campbell diagram. The X-axis is the nodal diameters (ND).

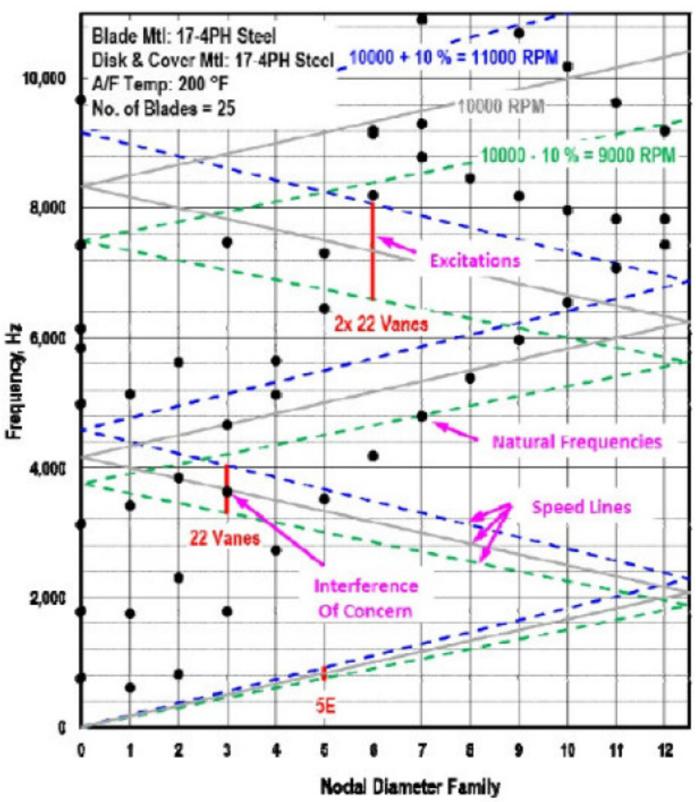

Figure 1: Example Impeller Interference Diagram

The ND are patterns that the vibration modeshapes of a cyclic symmetric structure like an impeller will form when excited at their natural frequency. Some examples of two different patterns are shown below in Figure 2. Plot A is a 2 ND pattern, while Plot B is a 3 ND pattern. You can count the diameters by counting the number of zero displacement lines that cross the pattern (marked in black in the figure). Fortunately it is not necessary to manually count each analytical result on a complex structure like an impeller because FEA software like ANSYS counts them automatically during its modal solution. As a rule it is only possible to have nodal diameters up to ½ the number of blades due to the aliasing effect. Aliasing is the phenomenon commonly seen in digital signal processing where higher frequencies are interpreted lower because the space between blades is too great to resolve the true, higher frequency. Understanding aliasing is key to the construction of the interference diagram, but this summary will help you read the diagram for concerning spots even if you do not.

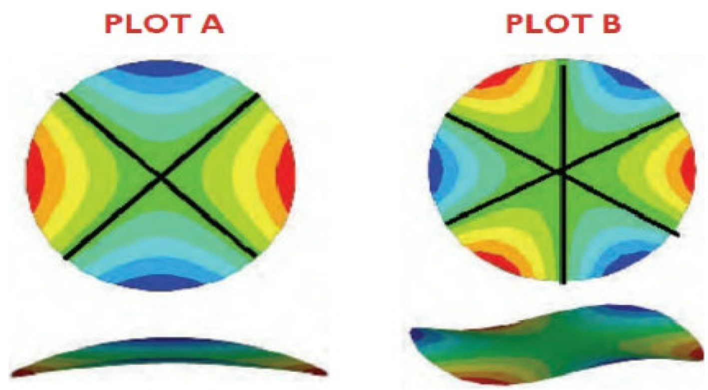

Figure 2: Examples of Two Different Patterns

The black dots on the diagram are the natural frequencies of the impeller, usually found with FEA and plotted versus the corresponding nodal diameter on the X-axis. The diagonal lines on the diagram are the operating speed lines and they bounce back and forth on the edges of the diagram also due to the aliasing effect. The rotor speed in RPM is converted to frequency for the diagram using the short formula.

The central diagonal line is the actual operating speed, while the adjacent two lines include the required separation margin. The final element of the interference diagram is the red vertical lines which represent the sources of excitation (usually from upstream or downstream vane wakes). Just as in a Campbell diagram, if the excitation forces correspond with the natural frequencies of the rotating structure, there could be damaging resonance. The excitation lines are located on the diagram by counting up along the speed diagonal lines with increasing nodal diameter as if they are staircases. Therefore, a source from 22 vanes is placed "on the 22nd step" of the speed lines.

Then it is simple to look for interferences that might result in resonant vibration. An interference is when the natural frequency (black dot) intersects an excitation source (vertical red line) between the operating speed range + margin. An example is noted in Figure 1. All of the other natural frequencies are not intersecting any of the excitation sources, so these should not be issues. In general the most concerning interferences to avoid are those where a lower frequency modeshape is crossed with an excitation source from a vane wake that is closely coupled with the rotor blades. This is because there are stronger forces from the wake closer to where it originated and the lower frequency modeshapes result in larger vibration amplitudes which create higher stresses when excited.

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