Application Note
#2
Identifying a Resonance

Finding the telltale signs of a resonance can be a little bit of a challenge for most people. With the aid of a speed map or waterfall display, the task becomes a lot easier. Examining these displays each and every time an engine is tested is probably not warranted either, as finding a resonance is not very common. Gas turbine engine designers and builders do their utmost to keep resonance's well out of the normal operating range of the engine. However, on occasion one will crop up with very serious consequences, and the ability to spot it early will greatly simplify your life.

There are many different kinds of resonant conditions and most are not damaging, just a little aggravating. The serious ones are structural and what is known as "criticals." Criticals are probably the ones you have heard about. But, again, most gas turbine engines never see a machine "critical" as the engines are designed to operate below the first machine critical. So the ones you are most likely to be confronted with are structural, and on top of that, they are only a problem when they provide the excitation forces that will create fatigue damage. You can readily see that this is a rare problem, but when confronted with one, the consequences can be very serious and costly. If you can properly identify a resonance and address the issue, you could save hundreds of thousands of dollars.

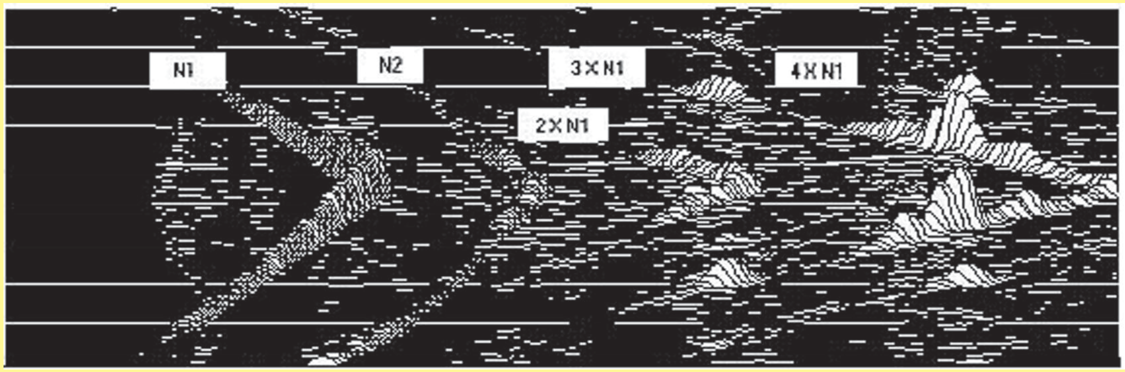


Figure 1. Speed Map

The first thing you must do is identify a rotational vibration component that acts as the exciting force or prime mover of the resonance. The next thing is identifying the region where the resonance and the prime mover are coincident. Finally, you must be able to logically separate the two and understand the interaction.

First, harmonics or speed "orders" (multiples of running speed) of the fundamental rotation are always present. Typically, with a low energy fundamental, the higher "orders" are not visible, or of any consequence. In this case however, the energy of the N1 signal is strong enough to provide higher than normal energy in it's harmonic content. You can plainly see in the speed map in Figure 1, above, that the out of balance condition of the N1 prime mover is providing the required excitation force in it's harmonic content which is exciting the resonances that are higher than either the N1 or N2 speed ranges. This area of the speed range needs closer examination.

Shown in Figure 2, on the next page, is an expanded view of the two resonant areas that are being excited by the second, third, and fourth orders of the N1 speed signal. Of course, as the engine increases in speed, the fourth order passes through *Resonant Region One* first, then *Resonant Region Two*. The second order never quite reaches *Resonant Region Two*. During the deceleration of the engine, the pattern is reversed. You can plainly see how the amplitude of the signal grows considerably when it is in the regions of resonance. Note also, once the resonance starts to grow, the resonant signal starts to take on it's own natural characteristics (See Note 1 in Figure 2.). This is evident by the erratic amplitude as the ordered signal passes through. What is happening is the two signals start to go in and out of phase with each other. When this starts to take place, the wild variations in amplitude are evident. It's not a smart idea to linger the engine while the resonances are being excited. In this case a balance session is definitely called for.

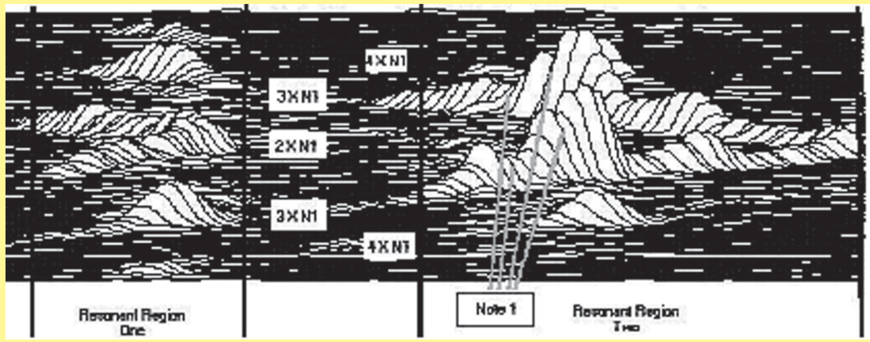


Figure 2. Expanded Speed Map

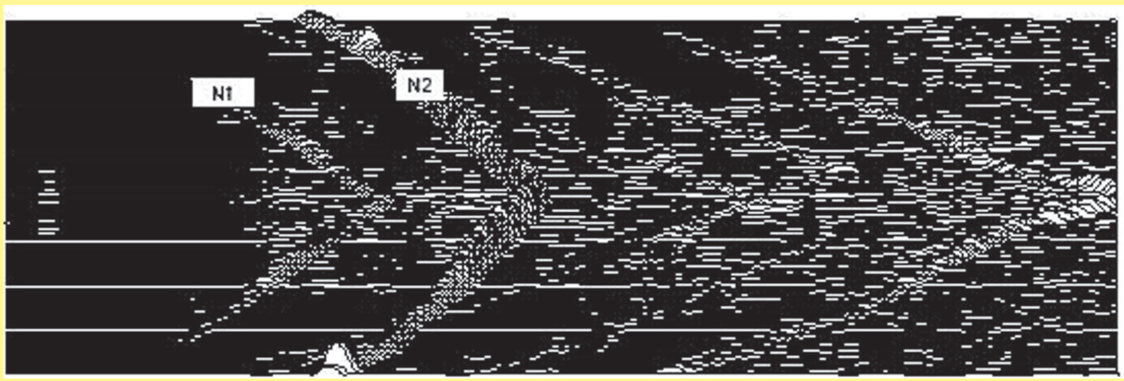
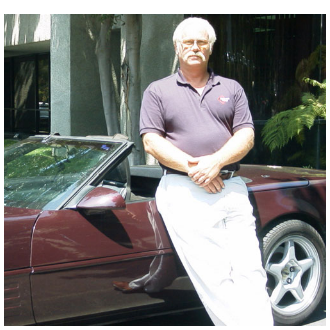


Figure 3. Speed Map After Balancing

Following the fan balance session, the amplitude of the N1 prime mover, as shown in Figure 3, is greatly reduced and is no longer providing the strong harmonic content (order amplitude) to stimulate the resonance. Are the resonances therefore gone? No. The resonant regions of the speed range are not gone; they are just not being amplified. Are they a problem? Probably not, unless it caused some accelerated fatigue damage to components modally sensitive during the time when they were being excited by the out of balance harmonics. The scale of the data was changed in the speed map, as shown in Figure 4, to see if there was any sign of excitation in the two regions of resonance, which explains the apparent increase in amplitude of N2.

Figure 4. Expanded Speed Map After Balancing



By
Pete Neild
pneild@cognitivevision.com

Cognitive Vision

7220 Trade Street, Suite 101
San Diego, CA 92121-2325 USA
Tel: 1.858.578.3778
Fax: 1.858.578.2778
instruments@cognitivevision.com
www.cognitivevision.com