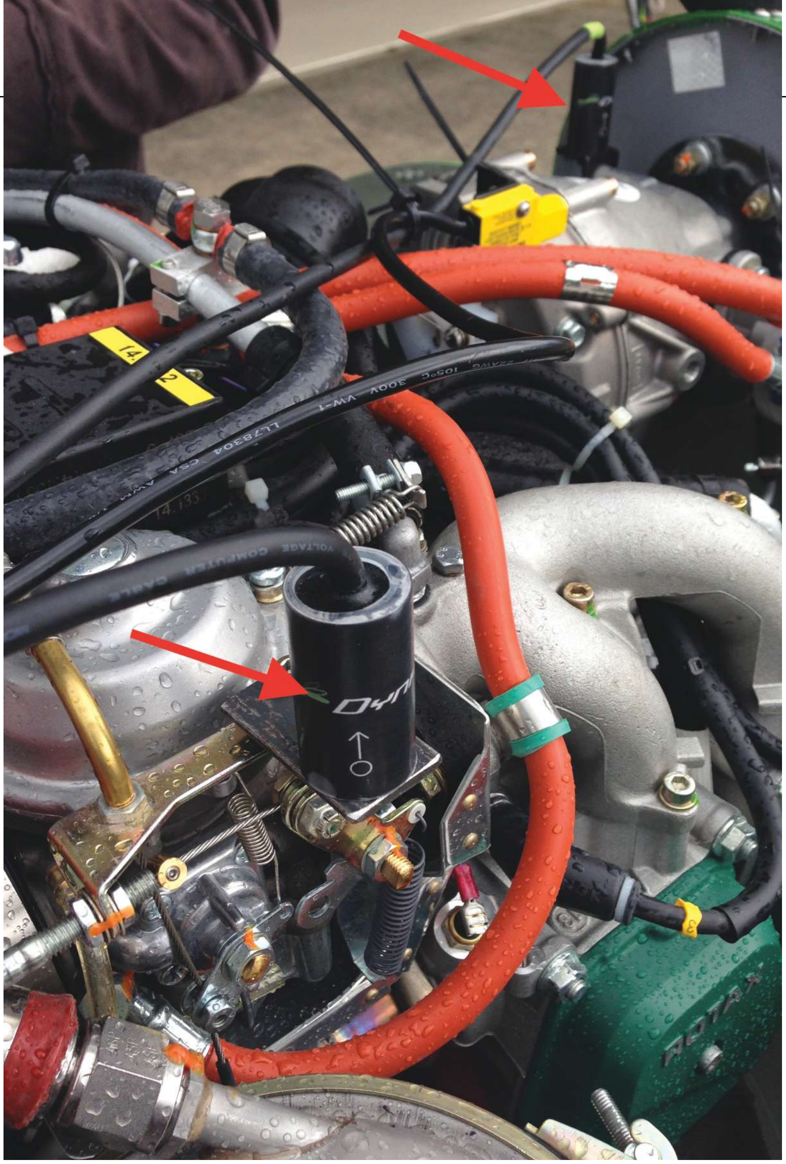

WHEN PROP Balancing ISN'T ENOUGH

Full-spectrum analysis helps isolate complex vibrations

BY MATTHEW DOCK

WHAT SHOULD YOU DO when a dynamic propeller balancing doesn't eliminate worrisome vibrations in an airplane? Full-spectrum vibration analysis is sometimes required to identify and correct complex vibrations. Left unresolved, high vibration levels affect the longevity of critical engine components, instruments, and the airframe, and in serious cases lead to premature failures. It's important to isolate and eliminate sources of vibration.

A recent example comes from an airplane powered by a Rotax 912 engine. A dynamic prop balancing eliminated the propeller as the vibration source, but a vibration problem persisted. Over the course of several months, mechanics had swapped out various engine components in an effort to isolate the vibration source. Experts had been consulted, including the engine manufacturer, all to no avail. Efforts to isolate this complex aircraft vibration issue and get to the root of the problem had so far been an exercise in futility.

Aircraft vibration has many potential causes; quite often it's due to a simple mass imbalance of the propeller assembly. Sometimes, however, correcting a propeller imbalance doesn't eliminate vibrations, because the source is in the engine. When this is the case, advanced frequency analysis is needed to examine the entire spectrum of vibration frequencies to determine the source. Performing a full-spectrum vibration analysis makes it possible to detect the difference between a propeller imbalance and a weak cylinder, propwash induced buffeting, alternator imbalance, or many other vibration sources.

Several challenges made isolating the source of the vibration on this particular Rotax 912 engine more difficult. One was the rpm range at which this vibration occurred. In this case, it wasn't constant, but only occurred at mid-range rpm levels, such as when the aircraft was turning base. A second challenge is that many vibrations manifest themselves somewhere other than the source, underscoring the importance of a diagnostic technique that considers all vibration spectra.

To troubleshoot this complex vibration problem, service personnel conducted a full vibration spectrum analysis using a DynaVibe GX2 from RPX Technologies. The process began with a visual examination of the engine. While it was running in the middle rpm range, gas was seen venting from the carburetors because of the severity of the vibration. Accelerometers were placed on the carburetors to determine the vibration magnitude, and it measured almost 1.5 inches per second (IPS). The right carburetor vibration was almost twice as severe as the left carburetor, perhaps due to its more forward position. To isolate the source of this vibration, the two accelerometers were repositioned to measure the vibration frequencies: one was mounted on the right carburetor, the location of the observed vibration, and a second was mounted above the crankshaft near the front of the engine, to measure propeller vibration. Readings were taken from both accelerometers. In the photo, the orange arrows point out where the accelerometers were mounted.

This mounting location was near the edge of the engine, at an ideal location to detect torsional vibration. With the accelerometers in place, data was collected while the engine was running and exhibiting the vibration.

The frequency analysis showed the presence of a "two-per" vibration, a vibration that occurs twice per prop rotation. This means that when the prop goes around once, there are two vibrations. When diagnosing machinery faults using vibration analysis, there are known industrial causes of a two-per vibration, such as a bent shaft, angular misalignment, parallel misalignment, misaligned bearing, or internal assembly looseness.

The two-per vibration of this engine measured almost 1.5 IPS. Ideally, there would be no vibration at all, but a vibration of 0.2 IPS or less is considered acceptable. In this testing, the vibration was so strong that it was venting gas out of the carburetor onto the exhaust manifold.

The presence of a two-per vibration links the vibration source to a component that rotates with the prop, and there are only two: the prop itself and the gearbox. Since the prop had already been dynamically balanced, and one accelerometer confirmed the prop was not the source of the vibration, attention fell on the gearbox. Testing the friction torque in the gearbox of the aircraft confirmed that the gearbox was the vibration source. The maximum allowed friction torque is 44 foot-pounds, but this engine tested at 66 foot-pounds, significantly out of specification. With this information, the owner can now work directly with the engine manufacturer to identify a permanent fix to the problem. No more expensive and time-consuming trial-and-error diagnosis is necessary, because there is now certainty about the source of the vibration.

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The gearbox wasn't the only issue, however: The analysis also revealed the existence of a second, more intense vibration, the one that manifested itself in the right carburetor. This was a 2.42 per vibration, essentially a variation in the torque of the engine that occurs with every other cylinder firing. There is a dramatic difference in intake lengths on the intake manifold of the Rotax 912 engine, with the front cylinder having a longer flow path than the back cylinder. This difference in front-back airflow causes a torsional vibration in the engine. This vibration goes away as rpm is increased into typical cruise rpm.

In this example, the location of the observed vibration was not the source of both vibrations, and this outcome illustrates the importance of the approach described here to troubleshoot vibration problems. The key to properly diagnosing the source of both vibrations were conducting a full-spectrum analysis using two accelerometers, and looking at all vibration spectra, including those caused by a propeller, weak cylinder, intake imbalance, and gearbox. The first step to reducing vibration should be a dynamic prop balancing, but when this doesn't take care of the problem, a full-spectrum analysis using the proper equipment will let you isolate the source(s) so you can eliminate them. EAA

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