FLIGHT SAFETY FOUNDATION

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The Cockpit-to-Shop Communications Link

Flight safety can be enhanced through close coordination between flight and maintenance personnel. Here is how one pilot dealt with a vibration problem.

by
Michael Charland
President
Anavibe Services Inc.

Place yourself in a single-engine helicopter flying straight and level at cruise speed, everything going normally. Then, with no indications of trouble, a strange lateral shudder is felt for about one second; and then it disappears. As a conscientious pilot, after you return from the flight you write up the incident as an intermittent lateral vibration.

That evening, the maintenance crew goes out with you to duplicate the vibration you experienced earlier. Nothing unusual happens, but since the vibration troubleshooting kit is on the aircraft, the technicians proceed to make minor blade track and balance adjustments.

The helicopter is placed back in service. However, the intermittent lateral vibration continues to occur two to three times a week; each time it lasts a second or two then disappears. This pattern continues for two months.

As a pilot, you dutifully report each event to the maintenance crew. Each time the maintenance technician is aboard the helicopter trying to experience the vibration, it cannot be duplicated. By now, everyone involved in the operation is aware of the "gremlins" in this aircraft. Your confidence as a pilot is shaken and you start to wonder if your mind is playing tricks on you or worse yet, whether you could be the one inducing the mysterious vibration.

In the case at hand, the communications exchange requires an accurate description of unusual vibrations experienced during flight. Specifically, the emphasis should be on the one-on-one exchange between the pilot and the maintenance person. To illustrate this point, out of several case histories, the following one was chosen from the available data base. This case history pertains to an incident on a rotary wing aircraft, the type being irrelevant.

A Plan Was Made — and Followed

This is what the pilot in this scenario did. He obtained an empty log book in which he documented the time, date, flight profile, power setting, elevation, air temperature, and other parameters for each occurrence of the strange vibration. He was determined to get to the bottom of the problem. For the next month, he plotted all the operating parameters on a graph, still insisting to the maintenance crew that there was something wrong. He continued to be the only person who suspected a problem.

After three months, the pilot got his first break. The president of the company was present during an occurrence of the unusual lateral vibration. During previous casual conversation with the president, the pilot had discussed these irregular vibrations and assured him that every inspection revealed everything to be all right. However, after having the president aboard during a vibration episode, the pilot began to feel increasingly uneasy about the situation. With the company president as a witness to what then had become a legitimate problem, he contacted the aircraft manufacturer's field engineer.

A thorough inspection of dynamic components from the planetary gears to the main rotor blades was carried out and nothing unusual was found. The field engineer reported his findings to his supervisor. The supervisor then requested assistance from the manufacturer's chief vibration engineer and a vibration diagnostic firm as a consultant. During the time this was occurring, the manufacturer's field engineer received a second request for assistance — another aircraft had experienced a similar, unidentified vibration problem.

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The vibration consultants instrumented the airframe, transmission, and powerplant with real-time analyzers to monitor vibration frequencies from 0.3 Hz to 100 Hz. Although the vibration had been experienced the day before the test equipment installation by the pilot, the vibration could not be duplicated in the presence of the vibration consultants. Nevertheless, a modal analysis was carried out. (This diagnostic procedure is performed to establish the resultant deflected shape of a rotor or structure as the result of an externally applied variable frequency excitation force such as a vibrator. It results in a three-dimensional presentation of the lateral deflection along the rotor or structure shaft axis.)

Tracing the Illusive Cause

The aircraft was suspended from its main rotor head using a mobile crane. Modal responses were taken on the airframe, blades, mounts, skids, etc. and were compared to the consultant's database of historic responses for this aircraft type. The only abnormality that surfaced was that one engine mount deviated from the baseline. As a precautionary step, the engine mount was replaced.

The lateral vibration disappeared completely, only to return two weeks later. The pilot had studied all of the inflight parameters that had been monitored. He now claimed to be able to duplicate and induce the vibration at will. The aircraft was then instrumented with accelerometers mounted to the airframe, engine, transmission and skid crosstube. A test flight strategy was planned with two of the aircraft manufacturer's representatives and the vibration consultants present, in addition to the pilot.

Step-by-step requirements were discussed to enable the gathering of the necessary data. A contingency plan was incorporated in the event of a flight control system failure during the test flight.

The pilot was true to his word. As planned, the vibration was induced as the helicopter approached the heliport. At this point, things unexpectedly began to go wrong. The mild lateral vibration continually built up in intensity and, within three seconds, the passengers in the helicopter cabin experienced the sensation of a falling leaf, swinging laterally side-to-side at approximately a one hertz frequency. According to the contingency plan, the pilot reduced the collective pitch control and reduced power, simulating an autorotation. The aircraft flight profile recovered instantly, and the pilot added power and made a standard approach and landing with no further incident.

The entire event was captured in real-time on the instruments that had been installed for that purpose. What remained to be discovered was an explanation of what had occurred. The 12.5 seconds of digitized data revealed a 4 Hz modulation of the 6.56 Hz main rotor rotation. The 4 Hz frequency coincided with the rotor head and mass assembly first resonance, which had been determined during the modal analysis conducted two weeks previously. Each time these two frequencies would be in phase, or in sympathetic vibration, the gyroscopic effect of the rotor would force the airframe side to side.

The Mystery Deepens

The 4 Hz damped natural frequency of the rotor head mass assembly was a normal characteristic of this aircraft. The remaining question was, what was the exciting force that caused the rotor assembly to go into resonance?

After careful analysis of responses imposed by excitation forces, it was concluded that nothing inherent in the design of the airframe, or powerplant, could be the source of excitation.

Something had to be causing this series of events to occur. Reviewing the vibration data, it could be seen that the aircraft instantly recovered upon lowering the collective pitch control and reducing the engine throttle.

The attention of the vibration consultants was then focused on the theory that the fuel to the combustion chamber might be modulated at a frequency of 4 Hz. Further testing was therefore indicated.

The aircraft owner was provided with a courtesy aircraft from the manufacturer to use for transportation until a solution to the problem was found and the consultants began to analyze the client's helicopter that had the vibration problem. The simplest way to prove the theory was to try out the major fuel handling components one at a time on a different aircraft, and another helicopter was used as a test aircraft. The first component tried out was the governor. The effect when the governor, removed from the problem helicopter, was installed on the test aircraft was dramatic. As the skids left the ground during takeoff, the rotor head mast assembly went into resonance that required an immediate landing by the test pilot. This proved that the severity of the problem was variable from one aircraft to the next.

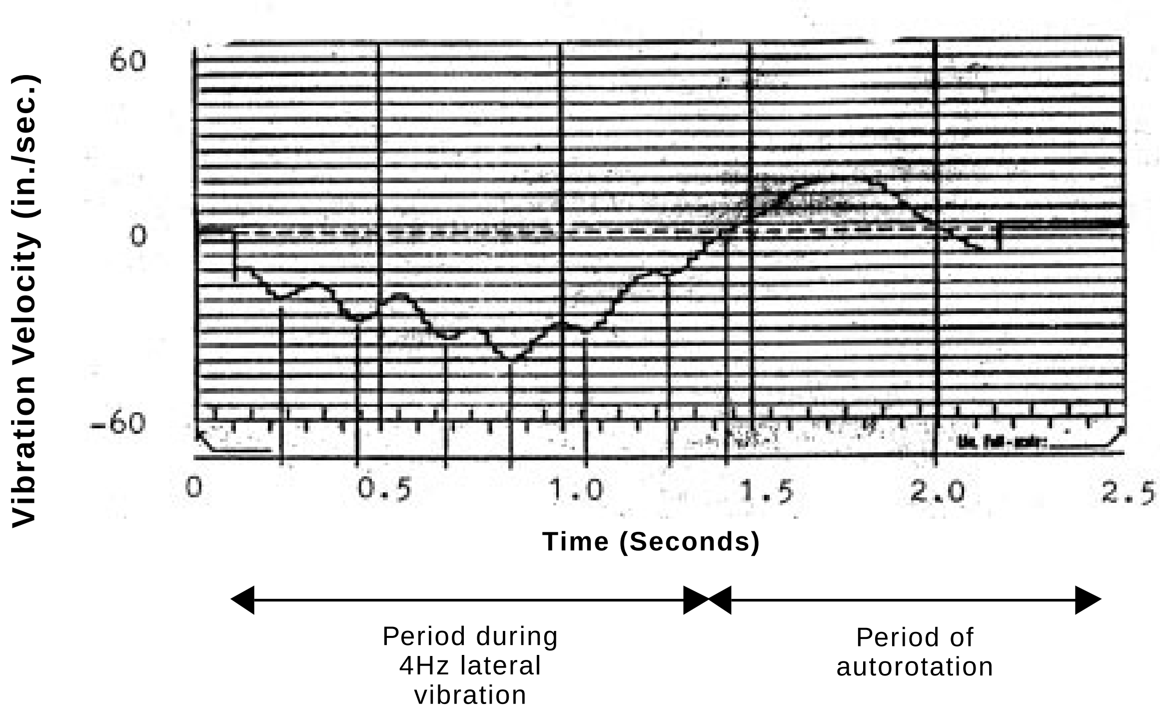
The governor originally installed on the test aircraft was then installed on the client's aircraft. The 4 Hz problem was gone without a trace.

Test bench data from the suspect governor originally on the client's aircraft, showed that under very specific series of circumstances the fuel pressure would modulate at a 4 Hz frequency. Hence the pulsating fuel delivery was converted to a pulsating torque which excited the main rotor and mass assembly at that same frequency.

After the problem had finally been resolved, some questions still remained to be answered. Why did it take three months before the problem was brought to the attention of the manufacturer? Was it the responsibility of the flight crew or the maintenance personnel to advise the manufacturer of this problem?

Consider why so much time passed before the manufacturer was contacted.

In-flight Disturbance



An example of a recorded trace produced by a vibration episode similar to that described in the text. A normal zero-vibration condition would have produced a level trace (dotted horizontal line), but the vibration episode produced the variable pattern that was brought back to the original zero-vibration line only after the aircraft was put into the autorotation flight mode.

First, the circumstances of the vibration events did not permit duplications at will; maintenance personnel were unaware of the analytical tools available to them for measurement of vibrations of short duration (transients); the potential consequences of the situation at hand were unknown to both the flight and maintenance personnel; the aircrew said, "There is something not right about this aircraft; do whatever is necessary, but fix it"; and the maintenance crew said, "If there is something wrong, we can't find it."

Three months later, the manufacturer was called in to help solve the problem, but only after all of the available in-house expertise was exhausted. Although the pilot and maintenance crew communicated daily, they were unable to get to the root of the problem.

Scheduling downtime for a serviceable aircraft had appeared impractical to both flight and maintenance personnel. Because of this, the problem went unresolved. The importance of solving a vibration problem became clear to the maintenance facility management only when the aircraft was no longer available for service and a courtesy aircraft was needed. It was then evident to the maintenance manager that the structure of the work planning system needed reevaluation. Vibration problems require better assessment capabilities than were available at the operator's location.

The Barn Door Is Closed

Improvements were made at the operator's facility to prevent the recurrence of long delays before problems were solved. A flagging system for work orders was introduced to indicate priorities. A time limit was introduced to minimize time spent on vibration problems: a two-week maximum time period was granted to the shop personnel before outside help was to be called. ♦

About the Author

Mike Charland has been president of Anavibe Services Inc., a vibration monitoring and diagnostic service in Hawkesbury, Ontario, Canada, since 1986. Formerly a subsidiary of Kidd Creek Mines Ltd., Anavibe is now a privately owned corporation.

Charland joined Texas Gulf Mines Ltd. (later known as Kidd Creek Mines), located in Timmins, Ontario, Canada, in 1975. As a material specialist, he was responsible for quality control of three mines and two metallurgical plants; design, development and implementation of working procedures used by maintenance personnel on rotating machinery and reactors. His duties also included machinery design and testing of turbine discs, bearing supports and rotors used in industrial and aircraft applications.

Charland previously worked with Canadian Liquid Air Research and Development Laboratories after graduating in 1974 with a degree in Welding Engineering Technology from Northern College AAT in Kirkland Lake, Ontario, Canada.

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