



VAN HORN AVIATION, L.L.C.
Tempe, Arizona

FLIGHT TEST REPORT No. 206L-MR-FTR-306

**RISK ASSESSMENT OF LIGHTWEIGHT, HIGH-SPEED,
VERTICAL VIBRATION**

MAIN ROTOR BLADE ASSEMBLY 20633000-101

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Revision: N/C

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REFERENCES

1. SB33000-6 Lightweight, High Speed Vertical Vibration Recovery and Mitigation.
2. BHT-206L4-MM-6 Maintenance Manual.
3. 206L-MR-FTR-301 Flight Strain Survey Flight Test Report, Revision C.

LIST OF SYMBOLS

C.G. – Center of Gravity
 g – Gravitational constant
 G.W. – Gross Weight
 H_D – Density Altitude
 Hz – Hertz
 In-lbf – Inch-Pounds
 IPS – Inches Per Second
 MCP – Maximum Continuous Power
 N_r – Main Rotor Speed
 OEM – Original Equipment Manufacturer
 RPM – Rotations per minute
 SB – Service Bulletin
 TOGW – Takeoff Gross Weight
 VHA – Van Horn Aviation
 V_{NE} – Velocity, Never Exceed

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1. SCOPE

The following report assesses the flight safety risk to the aircraft in the event that a lightweight, high-speed, vertical vibration is encountered during operation. This draws on VHA flight test data as well as documented operator reports of in-service vibrations.

2. BACKGROUND

Bell 206L LongRanger aircraft equipped with VHA main rotor blades 20633000-101 are known to potentially experience vertical vibrations in high-speed flight when operating in lightweight configurations. This phenomenon has been documented in Reference 1. A total of 26 occurrences have been reported on 15 different aircraft out of a fleet of approximately 300. While some aircraft have had multiple occurrences, in many cases it is not readily repeatable. Furthermore most aircraft have never experienced the vibration despite several that are known to operate within the weight-speed regime where it is known to occur.

Numerous maintenance actions have been identified which can significantly reduce the likelihood and severity of the vertical vibration. In addition, a proven, reliable recovery method has been identified which causes the vibration to cease almost immediately by reducing airspeed and loading the rotor.

This report addresses the question, if a pilot performs the correct recovery, what if any impact is there to continued operational safety of the aircraft after experiencing this vibration?

3. FLIGHT TEST DATA

To date, VHA has performed 35 hours of flight testing on 4 aircraft to investigate and gather data related to the vertical vibration. The amount and nature of testing performed on each aircraft is highly varied, due in large part to availability. The somewhat rare and sporadic nature of the vibration means that simply testing any 206L is not sufficient; some aircraft do not experience the vibration.

It is necessary to test aircraft which have experienced the vibration and attempt to reproduce it. Unfortunately, even aircraft which have reported the vibration do not repeat this phenomenon reliably. This means that most often, the vibration must be deliberately initiated with pilot inputs. VHA has found that abruptly reducing collective or shaking the collective stick can instigate the vibration when the aircraft is at sufficiently high speed and low weight.

For the purposes of this report, however, these artificially initiated vibrations are likely not representative of real-world vibrations since the intensity is often related to the intensity of the input. Nonetheless, in a few instances, vertical vibrations did initiate on their own during testing and this allowed the measurement of vibration levels. In all cases, the pilot was not expecting the vibration to occur, but was aware of the appropriate recovery technique and to

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not reduce collective. The resulting data are therefore considered representative of the onset and expected recovery for real-world vertical vibration occurrences. Cabin vibration was measured using a Shear ICP Accelerometer mounted vertical on the center console. Data acquisition was accomplished using a DEWESoft SIRIUS-R4RT or DEWESoft Krypton 4xACC data acquisition systems at a sample rate of 5000Hz. Due to significant high-frequency signal noise even during level flight, a 100 Hz, Butterworth, low-pass filter was applied to the data to more clearly show the 5Hz frequency content. Figure 1 and Figure 2 show plots of the worst vertical accelerations measured on aircraft N62HP & N393S both of which had previously reported severe vibrations. On N62HP the recovery took about 1.5 seconds for acceleration levels to resume baseline levels, on N393S it took approximately 3 seconds. In both cases, the max G levels only occur for a single cycle with diminishing values immediately before and after. When VHA received N393S for testing, it was configured with nearly 12 pts of forward sweep. No forward sweep is permitted per section 62 of the maintenance manual (Reference 2). The sweep was a result of improper procedure used in string alignment of the rotor head during install. In this forward swept condition, the aircraft was much more prone to the vertical vibration. The minimum and maximum acceleration levels were .41 G and 1.97 G, resulting in a cyclic G level of ± 0.78 G. The 5Hz cycles are approximately ± 0.5 G. This represents the worst-case configuration with a ship well out of published maintenance limits.			

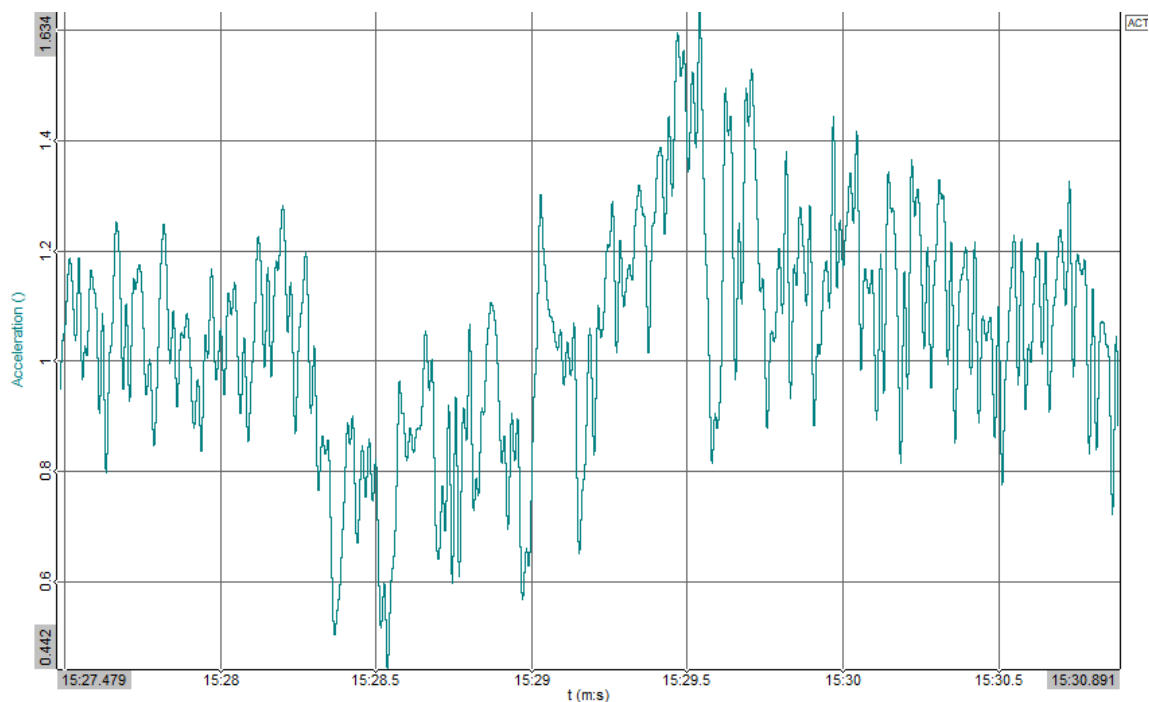


Figure 1: Unprovoked vertical vibration on N62HP

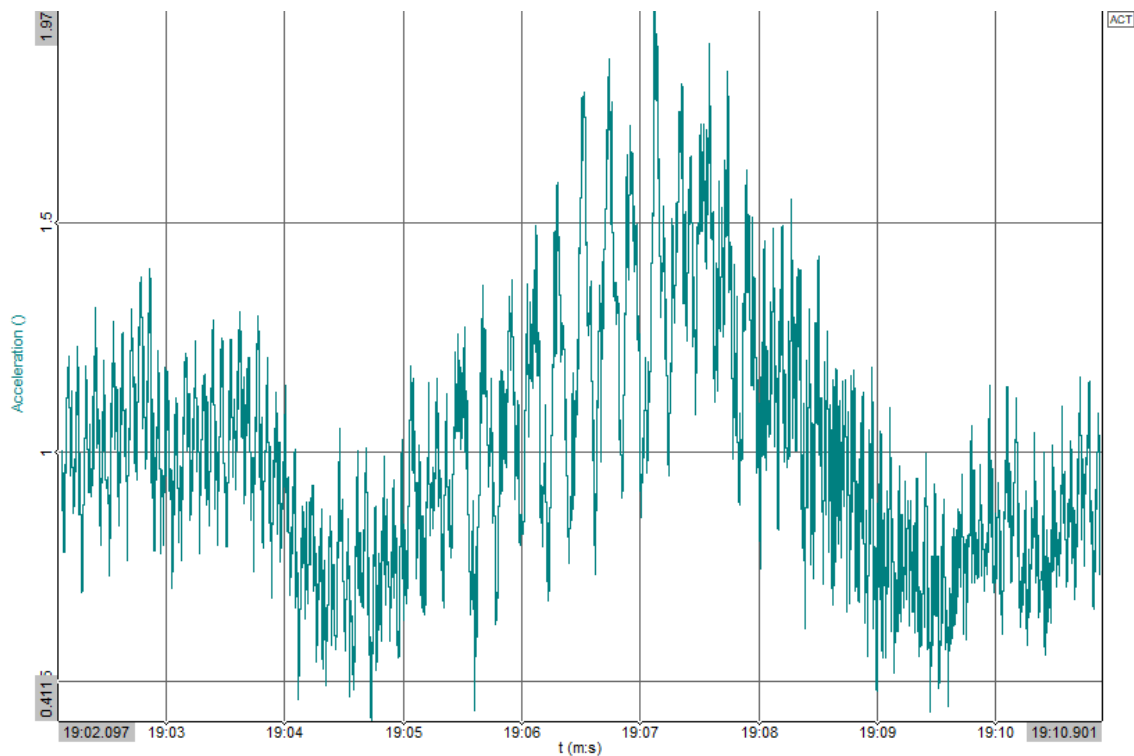


Figure 2: Unprovoked vertical vibration on N393S

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4. FIELD EXPERIENCE

All evidence from available field reports supports the measured flight test data. In all known cases where severe vibrations were reported, pilots reduced collective in order to descend for a precautionary or emergency landing. Conversely, all instances where the pilots have performed the appropriate recovery, vibrations have been reported as mild or moderate and it has been noted that the vibration does not reach a severe level. This indicates that the vertical vibrations are not inherently severe but rather become so after collective is significantly reduced. This coincides with testing experience where abrupt collective reductions are used to deliberately initiate the hop, as described in Section 3.

While pilot reports are very informative, they are also unfortunately subjective and varied in their level of detail, etc. However, in two instances, vertical vibrations in the field were captured on in-cockpit video. These provide objective insight into the behavior of the aircraft.

Cockpit video from Papillon aircraft N20316 captured what was only the 2nd reported occurrence of the vibration. In the video, the aircraft is initially in level, cruise flight at 7,000 ft, 115 KIAS, and a torque setting of 76-79%. At 32 seconds into the video a gust or wind shear abruptly causes the airspeed to increase to over 120 kts and a vertical vibration is seen to start. It is noteworthy, that while the outside air temperature is not factually known, it is likely at this altitude that the Vne was 120 kts. It is therefore possible that the vertical vibration was initiated by the onset of retreating blade stall. In any case, approximately 1.5 seconds after the vibration starts the torque setting suddenly decreases to 40%, indicating the pilot reduced collective to descend; this is corroborated by decreasing altitude. As soon as this is done the vibration gets significantly more intense; the pilot’s ipad is seen to jump off of his lap, for example. This indicates that the decrease in collective made the vibration worse and is consistent with proven recovery technique which includes raising collective. Torque is then decreased to 0% to enter an autorotation and speed gradually decreases. At approximately 100 KIAS the vibration appears to have been eliminated. This further substantiates testing indications that the vibrations will cease below a certain airspeed, which can vary from aircraft-to-aircraft. The second incident in the same video mirrors this behavior. The hop initiates as airspeed climbs to over 120 KIAS, gets significantly worse after power is reduced, and ceases below 100 KIAS.

Lastly, cockpit video from Omni Executive aircraft VH-NPI shows a steady, but much less severe vibration. The gages are not visible in this video, but the operator indicates it was taken in level flight at 100 KIAS, 80% torque, and 1400 ft. What is most noteworthy about this video is the pilot is obviously aware of the vibration and the recovery as he is not surprised or alarmed by its onset. Instead, for the purposes of the video, he allows the vibration to continue for nearly 14 seconds before recovering. For the duration, the vibration is never nearly as severe as either of the Papillon videos. This again agrees with test flights which indicate that as long as collective is not reduced, the vibration remains mild or moderate providing ample time to recover without risk to flight safety. At approximately 43 seconds he appears to initiate a left turn and reduces collective, which immediately makes the vibration more severe. He then slows down as indicated by aft cyclic motion and the vibration subsides.

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5. CONCLUSIONS

Certification testing for the 20633000-101 main rotor blade (reference 3) documented acceleration levels ranging from 0.4 during a simulated power failure to 2.5 G's during a cyclic pull-up (Figure 3). The worst-case acceleration level measured during a vertical vibration event in which the pilot performed the appropriate recovery method was 1.97 G's. Since the airframe certification testing would have required the demonstration of structural capability and life limits beyond these G levels, there is no impact to the structural integrity of the aircraft. Furthermore, the measured G values are conservative since they were measured on an aircraft with grossly out-of-tolerance maintenance conditions.

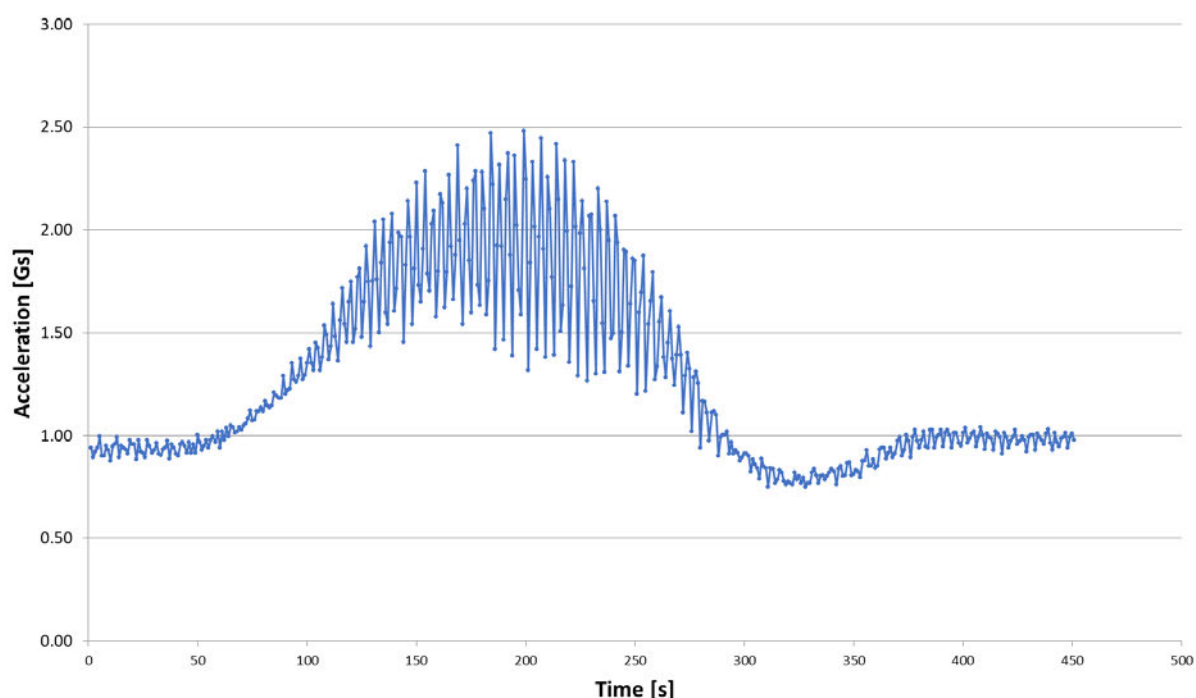


Figure 3: Measured acceleration during a Max G, Cyclic Pull-up

Flight testing performed by VHA has confirmed that unprovoked vertical vibrations discussed in this report do not contribute to G loading in excess of what was simulated in certification structural testing. Additionally, customer reports and feedback ensure that with proper knowledge of the phenomenon and the recovery, the vibration is easily detectable and can be recovered without becoming a safety of flight concern.