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VIDEO STUDY

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A. ACCIDENT

Location: St. Mary's, Alaska
Date: September 12, 2023
Time: 2047 Alaska daylight time
Aircraft: Piper PA-18-150

B. SUMMARY

B.1. The accident

On September 12, 2023, about 2047 Alaska daylight time, a Piper PA-18-150, N109T, sustained substantial damage when it was involved in an accident near St. Mary's, Alaska. The pilot was fatally injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 135 on-demand flight.

B.2. Objective and scope of the Video Study

The objective of this Video Study was the estimation of the airplane engine speed and the estimation of the maximum pitch angle and the maximum bank angle that occurred during a transient shortly after takeoff. Analysis was based on the sound and visual information in a video recorded with a hand-held phone by an observer on the ground.

C. DETAILS OF THE INVESTIGATION

The analyzed video was recorded with a hand-held iPhone 12 Pro Max. It had 1920x1080 resolution and frame rate of 30 fps (frames per second). The video lasted about 15.4 seconds. The camera recorded sound at the rate of 44,100 samples per second. The airplane started its takeoff roll before the video started. At video time 5.3 seconds, the airplane was in front of the camera. It rotated at about video time 12 seconds and became airborne at about time 12.5 seconds. Right after liftoff, the airplane experienced a pitch and bank transient that lasted until about time 14.2 seconds. During the transient, the nose-up pitch angle and the right-wing-down bank angle peaked at about video time 13 seconds. The airplane impacted the ground shortly after the video ended.

C.1. Estimation of engine speed

Engine speed was estimated via sound spectrum analysis. The spectrum of the sound stream in the video was computed with the Fast Fourier Transform (FFT) algorithm. The transform used 65,536-point windows, resulting in windows that were 1.4861 seconds wide and in a frequency resolution of 40 cpm (cycles per minute).

Spectra were computed in 12 windows with starting times ranging from 3 seconds to 14 seconds. The last window ended approximately at the end of the video.

Figure 1 shows the computed sound spectra. Table 1 lists the frequencies of some of the spectral peaks seen in Figure 1. The airplane propeller had two blades so that the propeller blade passage frequency (BPF) of 5046 cpm indicates an engine speed of $5046/2=2523$ rpm. In a four-stroke engine, each cylinder fires once per two engine revolutions. At an engine speed of 2523 rpm, the cylinder firing frequency and its harmonics are $N \times 2523/2 = N \times 1261.5$ where N is the number of a harmonic. For example, the 3rd harmonic frequency is $3 \times 1261.5 = 3784.5$ cpm. This frequency agrees well with the frequency listed in Table 1, considering that the frequency resolution of the FFT algorithm was 40 cpm.

Table 1. Sound spectrum peaks

Spectral Peak	Frequency (cpm)	Comment
A	3795	3 × cylinder firing frequency
B	5046	propeller BPF
C	6337	5 × cylinder firing frequency
D	7590	6 × cylinder firing frequency
E	8882	7 × cylinder firing frequency
F	10134	2 × propeller BPF
G	11386	9 × cylinder firing frequency

Figure 1 shows a slight decrease of the propeller BPF as time advances. It is due to the Doppler effect caused by the increasing speed of the airplane away from the camera as it was taking off. Past time 13 seconds, the characteristics of the sound spectrum change, however the spectra show that the engine speed remained at about 2500 rpm. The spectrum in the window starting at time 13 seconds includes the propeller BPF frequency just under 5000 cpm. The spectrum in the window starting at time 14 seconds includes the peak at 3 × cylinder firing frequency near 3795 cpm.

Since the video ended at about the time when the window starting at time 14 seconds ended, there are only about 2.5 seconds of the signal that had different spectral characteristics. Consequently, the changed characteristics could not be investigated any further. It is possible that the higher-frequency spectral content past time 13 seconds was due to a wind gust and the higher frequency was not emitted by the airplane. It is also possible that the spectral characteristics changed because the distance of the airplane from the camera was increasing.

There was a video available from a previous takeoff of the accident airplane from the same location. The spectrum of the sound stream in that video indicated that the engine speed when the airplane was taking off was about 2500 rpm, as it was during the accident flight.

C.2. Estimation of airplane pitch and bank angles during a transient

Shortly after liftoff, the airplane underwent a pitch and bank transient that peaked at about video time 13 seconds. Figure 2 shows the airplane at that time. It was desirable to estimate the maximum nose-up pitch angle of the airplane to determine whether the angle was large enough to cause the cargo in a cargo pod to shift toward the tail of the airplane and change the dynamic characteristics of the airplane.

The usual method for estimating of the pitch and bank angles and the speed of an airplane is the use of a mathematical model of the camera optics. This method was not possible in this case because the accident area did not include any man-made references that could be used for calibration of the camera optics model. This was also the reason why estimation of the speed of the accident airplane was not possible based on the video.

The estimation of the pitch and bank angles of the airplane was possible even without a calibrated camera model because their estimation was only marginally dependent on the unknown location of the airplane. The estimation involved the development of a wireframe model of the Piper-18-150. The model consisted of points on the airplane nose, wings, horizontal stabilizer, and tires.

The wireframe model was superimposed on the video frame shown in Figure 2 and then scaled and rotated until it optimally aligned with the image of the airplane in the video frame. The pitch and roll angles of the wireframe model when it was optimally aligned were the optimal estimates of the angles of the accident airplane at the time when the video frame was recorded.

For the purpose of the analysis, the pitch angle of the airplane was defined as zero when the bottom of the wing airfoil was horizontal. The estimated airplane nose-up pitch angle was 16.2° . The estimated right-wing-down bank angle was 16.6° . The bottom of the cargo pod that was mounted under the fuselage sloped up by 13° toward the tail of the airplane when the airplane pitch angle was zero. Consequently, at time 13 seconds, when the airplane nose-up pitch angle was 16.2° , the bottom of the cargo pod sloped down toward the tail by $16.2^\circ - 13^\circ = 3.2^\circ$. If the uncertainty of the estimation is accounted for, the estimated slope can be specified as $3^\circ \pm 1.5^\circ$.

D. CONCLUSIONS

A video recorded with a hand-held phone was used for estimating the speed of the engine of an airplane during takeoff and the slope of the bottom of a cargo pod installed on the airplane. The estimated airplane engine speed was about 2500 rpm and the maximum slope of the bottom of the cargo pod during a short transient was estimated as $3^\circ \pm 1.5^\circ$. Also estimated were the maximum pitch angle and the maximum bank angle that occurred during a transient shortly after takeoff.

FIGURES

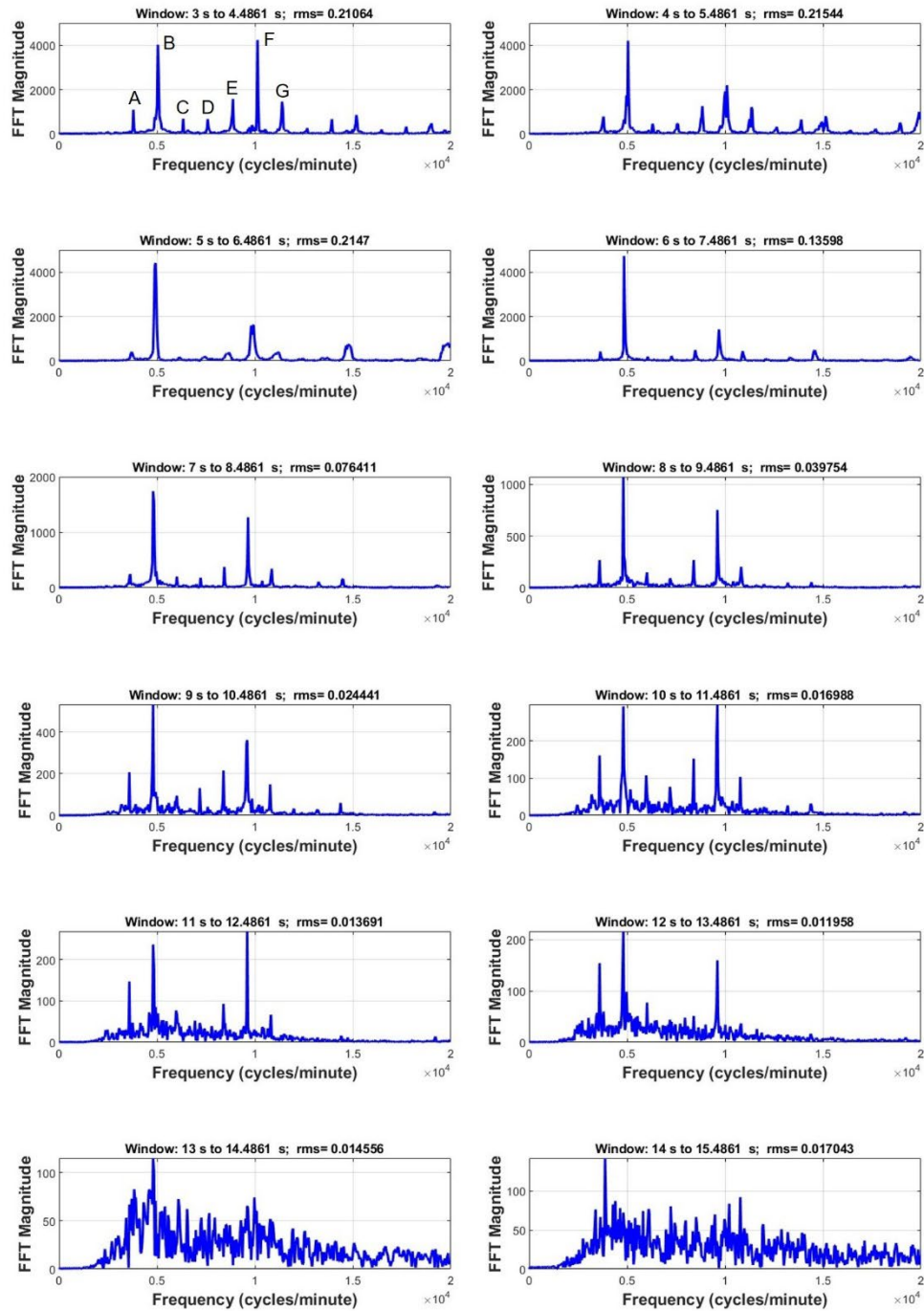


Figure 1. Sound spectra in windows with starting times from 3 through 14 seconds



Figure 2. Airplane at video time 13 seconds