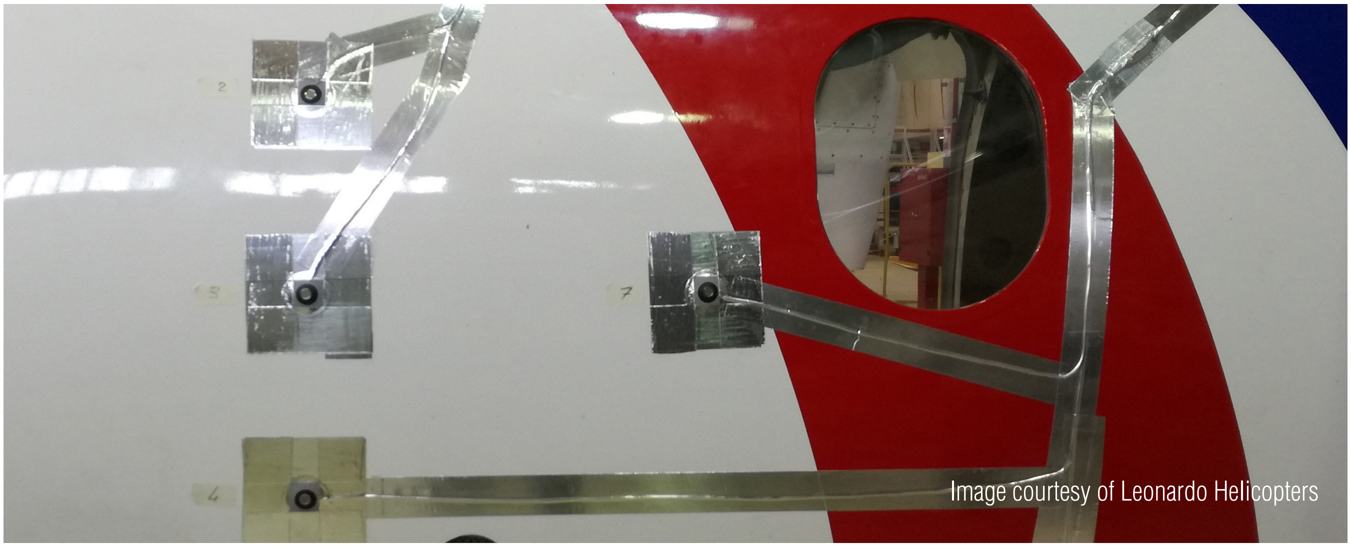

Tiltrotor Acoustic Data Acquisition through 130B40

ICP® Surface Microphones

Written By

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Introduction

The fluctuating pressures that act on the surfaces of flight vehicles due to propulsion systems and movable surface flows tend to induce oscillatory motions of the fuselage surfaces. These vibrations produce acoustic noise inside the aircraft. Too high a noise level can have adverse effects on the crew and passengers.
For such vehicles to be working successfully and commercially viable, the interior noise levels must be acceptable to civil passengers.
Structural-acoustic measurements were taken aboard an existing tiltrotor aircraft to better investigate the physical mechanisms that originate the interior noise in the tiltrotor. The transmission mechanism through the fuselage is responsible for the vibration and noise level which can be measured inside and for identifying potential solutions for their mitigation. The in-flight measurements have been first carried out on a flying Leonardo Helicopter tiltrotor, undergoing certification for use in the civil sphere. **All photos showing the tiltrotor are property of Leonardo Helicopters and provided as a courtesy**. For reasons of industrial confidentiality, sensitive data and graphs relating to measurements are masked. The sources that induce pressure loads on the external fuselage of the tiltrotor are essential of two types: a rotor noise due to the presence of the large rotors located at the wingtips and the boundary layer noise. Propeller engines generate a noise field that is highly tonal in frequency content and highly directional in spatial distribution. In high-speed flight, boundary layer noise can be a significant part of the noise perceived in the cabin. The obtained results are interesting and promising: these measurement procedures could also be addressed to more traditional airplanes and, possibly, to ground vehicles for characterizing, from this point of view, different transport systems.

Flight test set-up

Measurement and Analysis of noise is a powerful diagnostic tool in noise reduction for improving the quality of flights and to maximize passengers' comfort onboard. The interest of the tests was mainly focused on altitude, usual, and cruising speeds for this reason the conversion phase was not taken into consideration for the acquisition of the noise data. Noise data were acquired at the nine flight conditions indicated in Table 1. As you can see, these tests provided an opportunity to test the microphones at high airflow speeds.

Table 1 Flight test conditions

Flight condition	Speed (kt)	Altitude (ft)	RPM
I	150	20,000	478
II	155	20,000	478
III	160	20,000	478
IV	165	20,000	478
V	170	20,000	478
VI	175	20,000	478
VII	180	20,000	478
VIII	185	20,000	478
IX	190	20,000	478

The exterior spectrum levels were measured applying twelve 130B40 | ICP® surface pressure transducers with 13 mm diameter diaphragms and 3 mm height on the fuselage: eleven microphones on the port side of the tiltrotor and one surface microphone (no. 12) on the right side to verify the symmetry of the results. A drawing with the dimensions of the microphones is shown in Fig. 1.

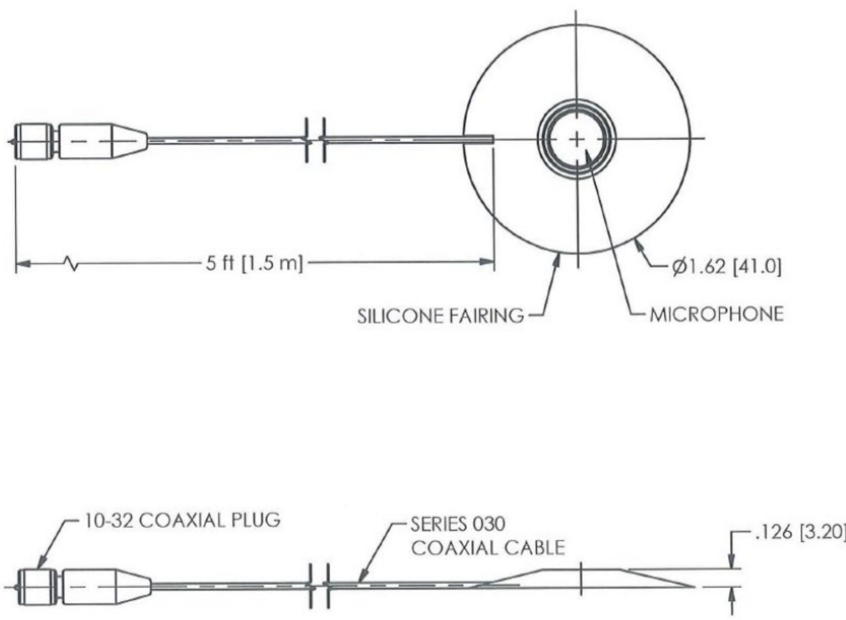

Figure 1 Surface microphone size

The exterior sensors installation scheme is shown in Fig. 2. Since the pressure loads are much higher near the plane of rotation of the propeller and rapidly decrease both forward and aft, most of the sensors have been installed to form a 'T' as close as possible to the propeller disk when the tiltrotor is in airplane configuration. This arrangement was able to take into consideration both longitudinal and transverse variations in the distribution of acoustic loads. Fig. 3 shows the surface pressure transducers locations. 30 sec of data were acquired.

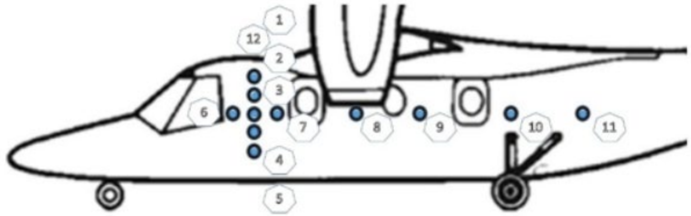

Figure 2 Layout diagram of external microphones

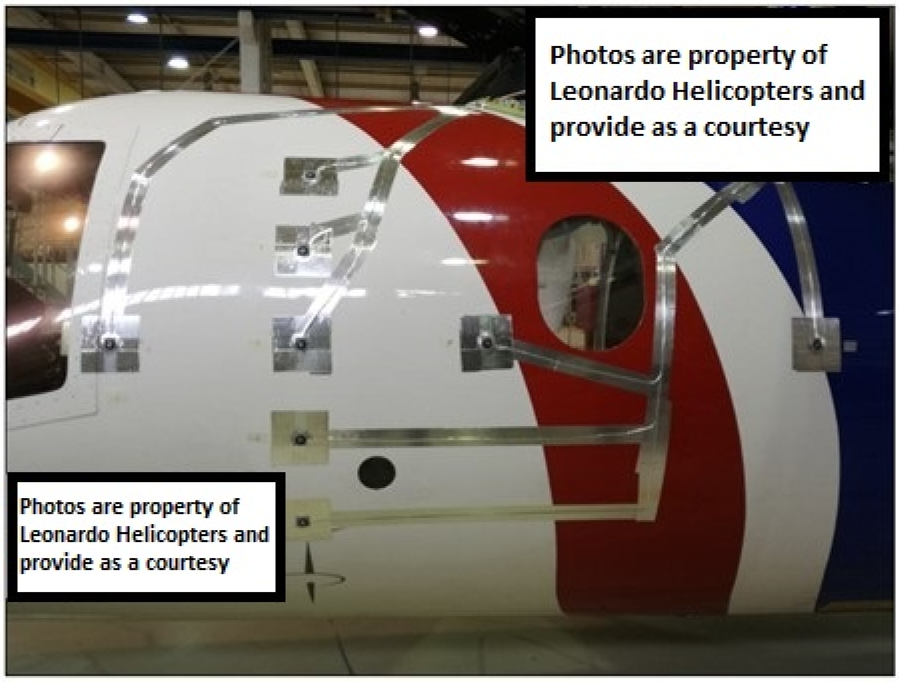

Figure 3 Photograph of Exterior Sensors Locations

Flight test main results

The main results deriving from the analysis of the acquired data are shown in this paragraph. For more details and insights, refer to references [1] and [2].
The measured pressure fluctuations and noise levels are quantified from a subjective point of view by means the Overall Sound Pressure Level (OASPL). Fig. 4 shows the OASPL plotted as a function of the flight speeds, with the twelve microphones indicated by different symbols. The OASPL is highest near the plane of rotation of the propeller and decreases rapidly in both forward and aft directions. As expected the overall level shows a linear trend with the speed. It significantly increases when the flight speed increases.

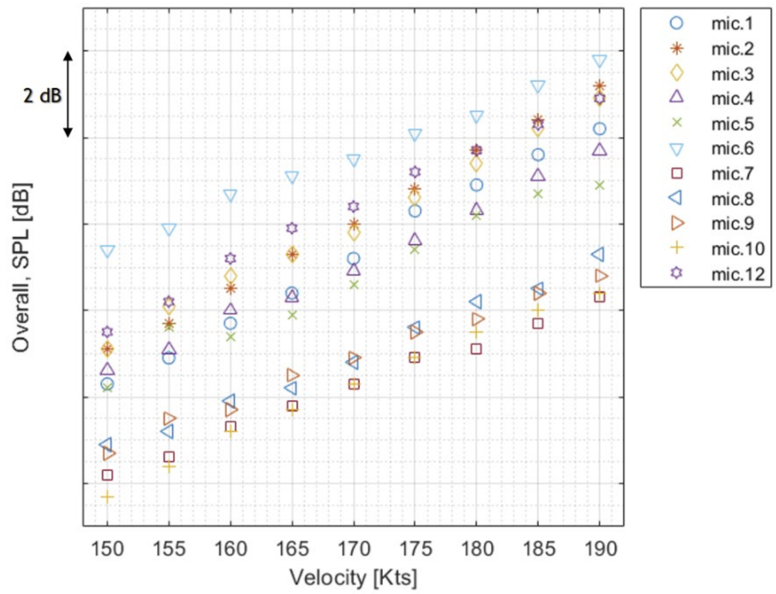

Figure 4 OASPL at different flight conditions

Sample time histories for the surface microphone no. 6 at the different flight speeds are shown in Fig. 5 in which the time period represents one rotation of the propeller. In each subplot, the thin line represents the instantaneous response whereas the heavy line denotes the time-averaged response. The time-averaged response closely follows the instantaneous response and you can appreciate that the magnitude of the response changes quite whereas the shape of the time history does not vary significantly as a function of the flight speed: the periodic trend linked to the passage of the propeller blades is very clear.

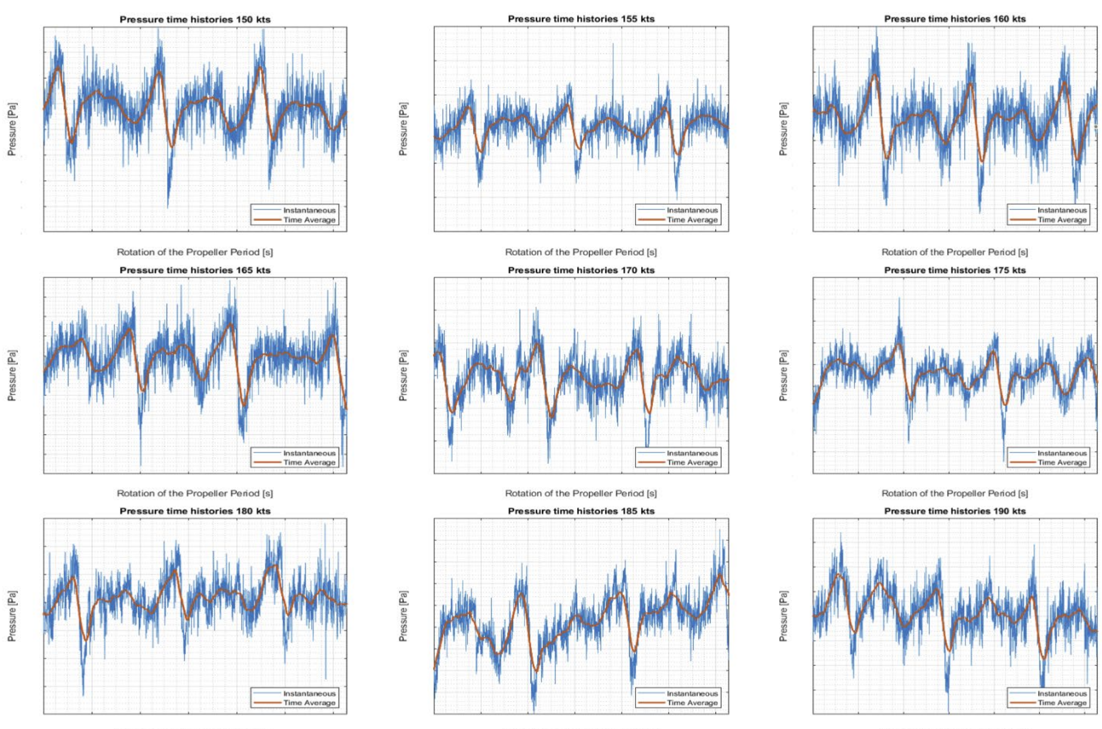

Figure 5 Acoustic pressures time histories

Fig. 6 shows the spectral shape for each microphone at the cruise speed of the tiltrotor. In general, the harmonic peaks of the exterior pressures due to the rotating propeller approaches the broadband noise floor between 300 and 400 Hz. By observing the data of the microphones 8, 9 and 10, located under the wing, we note that only the first three harmonics of the fundamental blade passage frequency are greater than the broadband noise. The presence of the wing considerably disrupts the flow and it probably increases the broadband level.

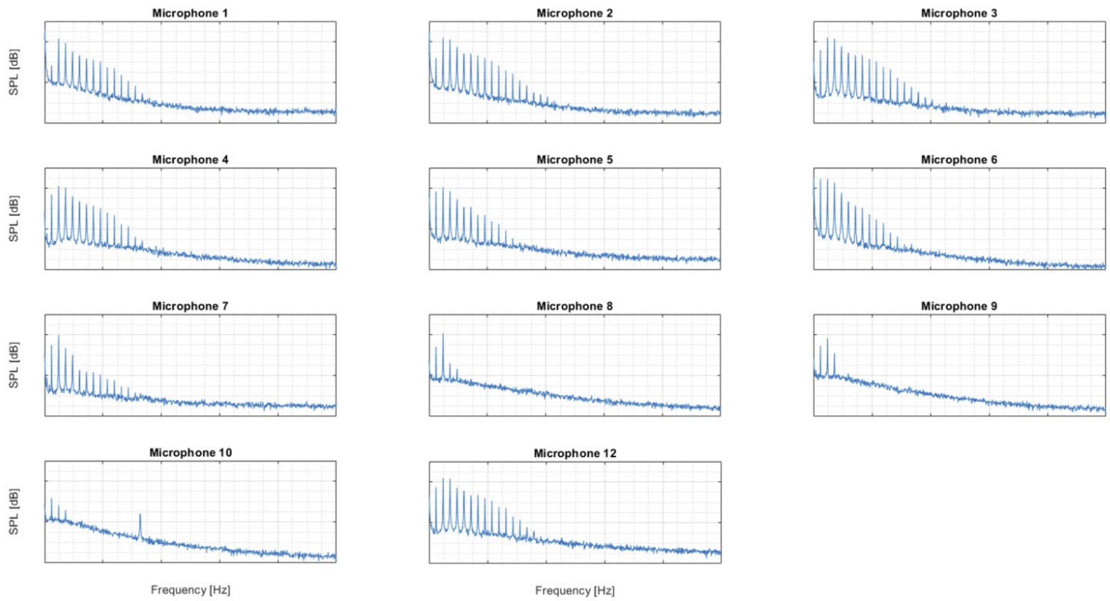

Figure 6 SPL Spectral shape for each external microphone, 175 kts

The data acquired during the whole acquisition time, referring to a time equal to the propeller rotation period (0.126 sec.), are shown in Fig. 7. This plot shows that with increasing speed there is a greater dispersion of the measurement: the data are less focused.

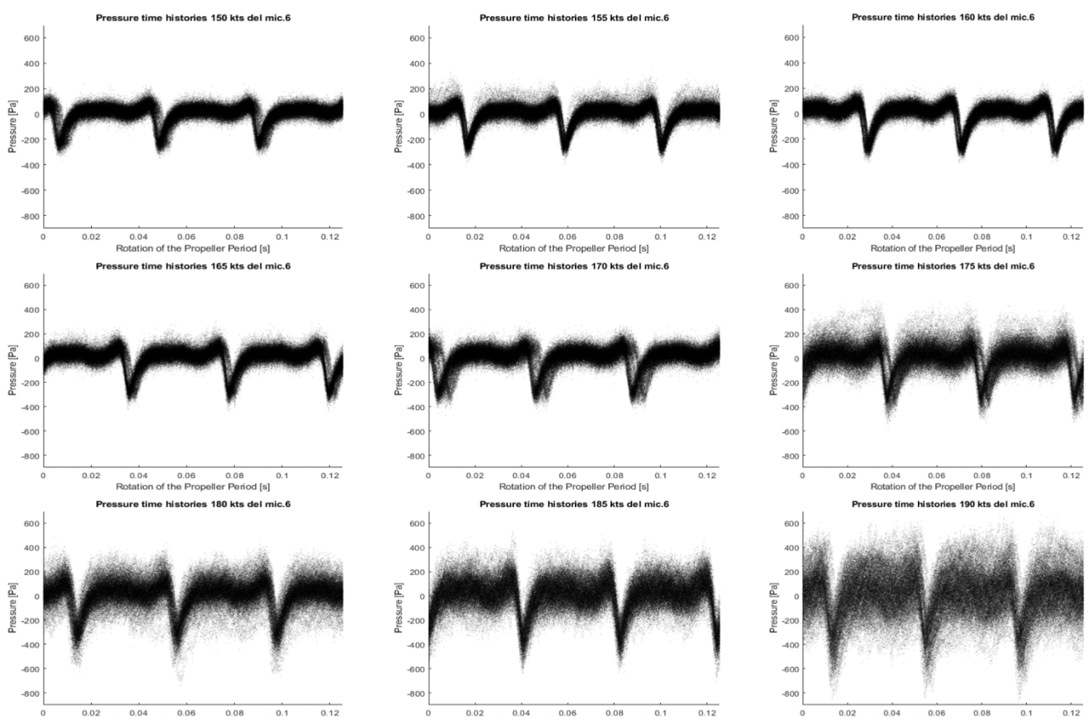

Figure 7 Pressure time history refer to propeller rotation period, mic. 6

References

[1] Marano, A. D., Polito, T., Guida, M., Barbarino, M., Belardo, M., Perazzolo, A., and Marulo, F., In-flight pressure load measurements and analysis. Proceedings of ISMA 2020 - International Conference on Noise and Vibration Engineering and USD 2020 - International Conference on Uncertainty in Structural Dynamics, 2020, pp. 341–352.

[2] Marano, A.D., Polito, T., Guida, M., Barbarino, M., Belardo, M., Perazzolo, A., and Marulo F., Tiltrotor Acoustic Data Acquisition and Analysis. Aerotec. Missili Spaz. 100, 111–122 (2021). https://doi.org/10.1007/s42496-021-00075-5

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