IN-FLIGHT ACOUSTIC LOADS MEASUREMENTS ON AN ENGINE FLYING TEST BED

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Abstract

During one of the earliest flights of CFM's newly –developed LEAP engine, surface microphones were mounted on the fuselage of a Boeing 747 engine flight test bed. The main purpose of this parallel test was to measure acoustic loads in flight conditions with real engine operating for the first time in a new aircraft development program. The test planning and set-up will be first introduced in the paper. Acoustic signatures of the new engine are investigated across different combinations of flight and operating conditions. Engine noise and turbulent boundary layer noise are separated using coherence techniques at chosen conditions, and compared with previous predictions models. Scaling methodologies at different altitudes and flight Mach number for engine and turbulent boundary layer noises are also reported.

1 General Introduction

Aircraft interior noise level is one of the most influential indicators of the overall cabin comfort, and a quitter cabin is more and more considered as a competitive advantage for a new aircraft development program [1]. To have an optimized balance between weight and performance for the acoustic insulation system, cabin acoustic modelling, its verification and validation are iteratively carried out. Acoustic loads on the fuselage during flight, mainly excited by the turbulent boundary layer and the engine, are critical for the whole modeling process.

Engine installed on the flying test bed (FTB) is one major milestone during new engine development. A very intense test campaign is performed to investigate the engine in-flight performance. A "piggy-back" acoustic test is performed by COMAC for the purpose of measuring acoustic loads, as the engine FTB would provide COMAC opportunities to verify and improve the acoustic loads prediction discussed in [2].

2 Test Set-up

The acoustic test was carried out in 2014 with GE's Boeing 747-100 flying test bed in Victorville, California. Engine No. 2 (the left inboard engine, closest to the fuselage) of the Boeing 747-100 was replaced with the new LEAP-1C engine. The microphone installation proposal was accepted after adjustments considering structural constrains and safety assessment on site (Fig.1).

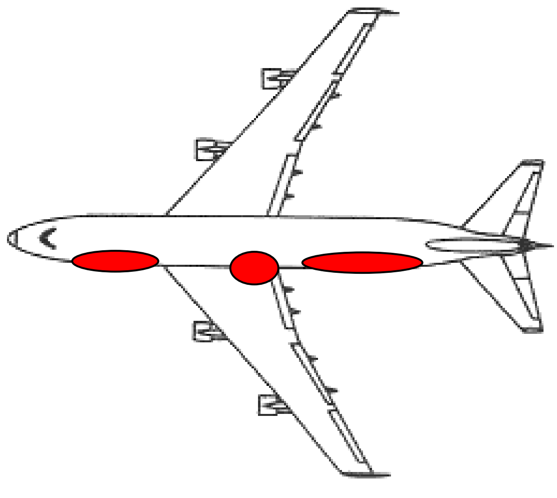

Fig. 1 Proposed microphone location on a B747 fuselage

Brüel&Kjær type 4948 surface microphone was used in this test campaign. The microphone was held with its associated polymer mounting pad, and was fixed onto the fuselage using aluminum tape. Mounting system was specially designed and manufacturing by B&K for this test according COMAC's specification.

Fig. 2 Microphone Mounting on the Fuselage

Microphone cables were bunched into groups and then passed through a special-designed dummy window to connect with the acquisition system inside the cabin.

Fig. 3 Cables passing through the dummy window

In total thirty-four B&K 4948 surface microphones were finally installed on the fuselage of the flying test bed. COMAC flight test engineers installing microphones onto the forward fuselage with the help of a lifting platform (Fig. 4). The final microphone set-up on the aft fuselage is shown in Fig. 5.

Fig. 4 Install microphones on a lift platform

Fig. 5 Surface microphones on the aft fuselage

3 Test outcomes

Acoustic loading data were acquired during one performance test. About forty test points were achieved at different flight attitude, Mach number and engine power settings. As a piggy-back test, data post-processing and analysis has to be performed by carefully selecting data sets and comparing across measurement conditions. Brief introduction about the measurement data and associated analysis are introduced in this section.

As a quick check, Fig. 6 shows spectrums from microphones on the forward fuselage at low and high engine power settings. Some acoustic signatures of the new engine can also be identified from the spectrums.

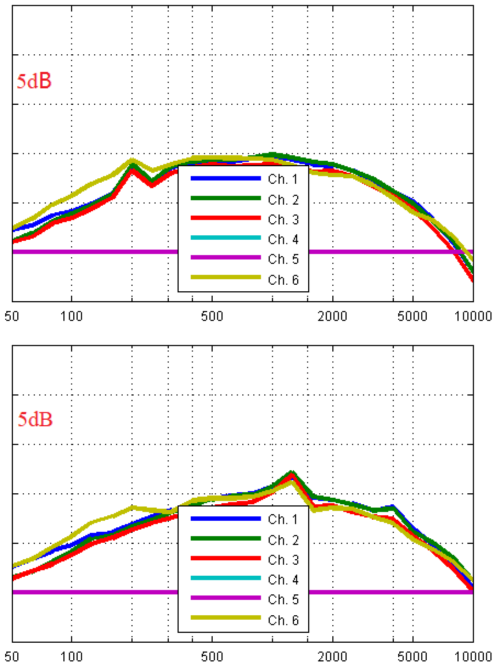

Fig. 6 Spectrums from microphones on the forward fuselage at low(top) and high(bottom) power settings

Coherence techniques [3] are applied on a group of 3 neighboring microphones to separate engine noise and turbulent boundary noise. This methodology was only applied to tonal noise, however in this study, engine noise is considered coherent for broadband and tonal noise. Also the separation method depends on the noise level of TBL relatively to the engine noise. Fig.7 shows the results of three microphones on the forward fuselage.

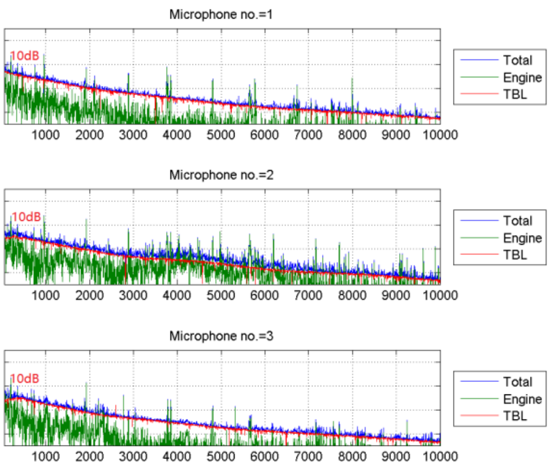

Fig. 7 Separation engine noise from TBL

Fig. 8 shows the engine noise spectrum of microphone no.1, where the main contribution is assumed to be engine inlet noise, at three different flight conditions. It is found that they can be well scaled by the inlet prediction model proposed by Rice [4], which projects static test data to flight conditions. The original model was developed for low speed flight condition, especially for community noise. Its application to high speed up to Mach number 0.78 was never reported before. Figure 5 shows that the scaling of engine noise, mainly inlet noise with Rice model provide satisfactory outcomes.

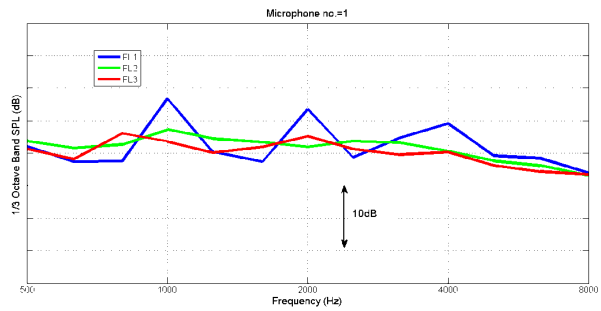

Fig. 8 Scaling engine inlet noise at three flight conditions

TBL noise was also studied after this test campaign. Several available empirical TBL noise prediction models [5] are calculated and compared with flight test data. Robertson model [6] is found to match the measurements best from this study.

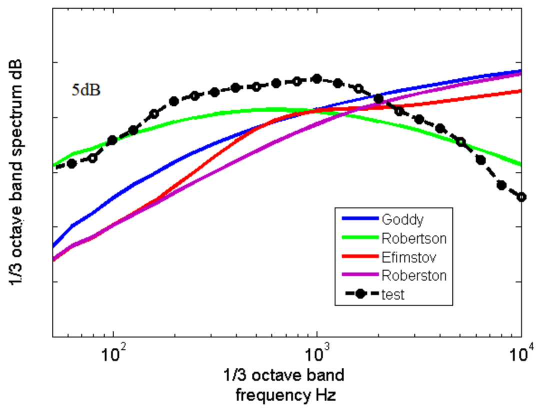

Fig. 9 Comparisons of measurement and prediction results for TBL

4 Summary

An in-flight acoustic loads measurement was for the first time conducted by COMAC on an engine flying test bed. In this paper, the test set-up introduced, and outcomes about measurement data and associated analysis are reported. COMAC engineers gained hands-on experiences from this test campaign, which will be beneficial for future acoustic test of this category.

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