On Some Recent Advances in Aeroacoustics

Luis Manuel Braga da Costa Campos

Instituto Supérior Técnico, Universidade Técnica de Lisboa, Av. Rovisco Pais, P-1049-001 Lisbon, Portugal

(Received 3 August 2005; accepted 22 August 2005)

A brief survey of the current status of aeroacoustics is used to identify eight aeronautical problems of concern needing attention: 1) acoustic fatigue of structural panels due to high-intensity noise (150 dB plus); 2) active cancellation of discrete tones in aircraft cabins; 3) estimation of the directivity and spectrum of jet noise; 4) noise radiation from a propellers; 5) influence of blade-vortex interaction on the noise of helicopter rotors; 6) noise due to the turbulent boundary layer over aircraft cabins; 7) sound attenuation in jet engine ducts by acoustical liners with non-uniform impedance; and 8) shielding of engine noise by aircraft structures, e.g. wings or fuselages. The motivation to study each problem is explained, followed by the formulation of a model, an outline of the solution and an illustration of results, often in comparison with experimental results from projects conducted in cooperation with the aeronautical industry. It is concluded that aeroacoustics has been, and is likely to remain an area of intensive research as air transport grows and environmental concerns give rise to an increasing impetus for new solutions to noise issues.

1. INTRODUCTION

This paper serves as a survey of current problems in aeroacoustics, which is far from comprehensive but describes some of the research studies relevant to aircraft noise reduction in three areas: linear and non-linear acoustics and aircraft operations.

1.1. Acoustic Fatigue

One aspect of non-linear acoustics that is of interest in the aerospace field is acoustic fatigue. The exhaust of large rocket engines used in satellite launchers can reach very high noise levels (150-170 dB); the water jets directed at the rocket engine exhausts near the launch pad serve both as cooling and sound absorption mechanisms. The exhausts of jet engines, and the turbulent wakes of flaps and other control and high-lift surfaces, also produce noise, which can cause fatigue of nearby structural panels.

The key problem in structural fatigue of aircraft and spacecraft is the determination of the correlation of the random pressures due to the sound radiation by the jet exhausts. The testing of satellites and other structures in reverberation chambers may not reach noise levels as high as in flight; the chambers also present a different acoustical environment, since acoustic fatigue in flight is dominated by propagating waves, while standing modes are dominant in a reverberation chamber, depending on its geometry. Testing for acoustic fatigue in a wind tunnel is an intermediate compromise between the relative simplicity of reverberation chambers and the complex reality of in-flight experiments.

1.2. Internal Noise

Internal noise concerns the comfort of the passengers in an aircraft or helicopter cabin and of the crew in the cockpit. Noise can be transmitted to the aircraft cabin via the air paths, e.g. propeller, rotor or jet noise transmitted through the cabin walls, or via structural vibration, e.g. gearbox noise in a helicopter. In some fighter aircraft with high performance and powerful engines, the noise in the cockpit can hinder conversation and cause ear damage, in spite of the use of helmets.

Focusing on commercial airliner or transport helicopter cabins, the use of passive methods (acoustical liners or Helmhotz resonators) is effective in reducing high-frequency noise. Low frequency noise requires active cancellation by anti-noise sources, which are more effective against discrete tones, such as propeller harmonics. Active cancellation of broadband noise is more challenging. Internal noise can also be affected by various aircraft systems (air conditioning, hydraulics, etc.).

1.3. External Noise

Apart from the sonic boom (see Section 1.5), which has effects over great distances, external noise concerns the area around airport runways. The main sources of external noise have historically been caused by the propulsion systems: the propellers of regional and general aviation aircraft, the rotors of helicopters, and the turbojet and turbofan engines of airliners. Turbojet and turbofan engines remain the main sources of external noise at takeoff. However, the progress in the reduction of turbofan engine noise means that with the engine at idle, on approach to land, airframe noise caused by the undercarriage, flaps and other control and high-lift surfaces, can be dominant.

Unlike internal noise, which is commercially sensitive, the external noise is subject to certification rules, which limit the flyover and sideline noise at takeoff and the approach noise at landing. Some airports apply stricter noise standards than the ICAO (International Civil Aviation Organization), including night curfews, reduced noise limits, additional measuring points, fines, etc. Over the last 20 years, a noise reduction of over 20 dB has been obtained by increasing the by-pass ratio of turbofan engines, which has also reduced fuel consumption. At present, the limit is being reached where further noise reduction is a compromise with fuel economy and pollutant emissions. In addition, further noise reduction requires tackling a multitude of engine and airframe related noise sources, since none of them is dominant for all flight regimes.