Research on Testing Technology for Noise Certification of Civil Aircraft

Chunzhuang Zhao(✉), Jiaxin Gao, Lei Wang, and Tengyuan Liu

Harbin Aircraft Industry Group Co., Ltd., Harbin 150066, China
zhaochunzhuang@126.com

Abstract. Aiming at the actual demand for noise certification of civil aircraft, the noise certification testing technology of propeller small aircraft and helicopters is mainly studied. Civil aircraft noise certification is mainly carried out in accordance with the provisions of CCAR-36, including two aspects of test system architecture and test flight method design. The qualification criteria in the noise certification test are mainly two points, one is that the noise data meets the restriction requirements of CCAR-36, and the other is that the measured track meets the method requirements of CCAR-36. An equivalent procedure for noise certification of small propeller aircraft is provided, and two specific implementation methods for determining the measured track are provided, which provide some effective references for noise certification of other types of aircraft.

Keywords: Small propeller plane · Helicopter · Noise · Airworthiness

1 Introduction

Due to the requirements of environmental protection, the outside noise generated by civil aircraft during flight needs to be limited within a certain range. The International Civil Aviation Organization has detailed regulations on civil aircraft noise in Annex 16, including four aspects: test flight methods, measurement system requirements, data processing methods and noise data limits. With reference to ICAO Annex 16 and FAR-36, the Civil Aviation Administration of my country has formulated the "Noise Regulations for Aircraft Type and Airworthiness Certification" (CCAR-36) [1, 2]. All civil aircraft must complete the noise by the test flight method specified in CCAR-36. Therefore, there are two main assessment points for the validity of the noise certification test, one is that the flight trajectory of the aircraft in the test must meet the requirements, and the other is that the measurement system that obtains noise data in the above flight trajectory must meet the requirements. This paper mainly studies the noise certification test technology of propeller small aircraft and helicopter.

2 Noise Measurement System Architecture

2.1 The Architecture of Noise Measurement System for Small Propeller Aircraft

The noise measurement system of propeller small aircraft consists of metal disc, microphone (amplifier), calibrator, data acquisition recorder, GPS system and cable assembly.

Chinese Society of Aeronautics and Astronautics: CASTYSF 2022, LNEE 972, pp. 68–74, 2023.
https://doi.org/10.1007/978-981-19-7652-0_8

Among them, the microphone must be 12.7 mm in diameter, with a protective fence; the surface of the metal disc is painted with white paint [3], 40 cm in diameter, and not less than 2.5 mm in thickness. The noise measurement system is located on the ground projection line of the flight trajectory of the small propeller aircraft, and the distance from the brake release point of the aircraft is 2500 m.

The microphone is installed upside down on the metal disc, the film is parallel to the surface of the disc, the axis is perpendicular to the surface of the disc, the projection point of the axis on the surface of the disc is located at three quarters of the radius and the line connecting with the center of the circle is perpendicular to the flight trajectory on the disc. Projection of the surface. The microphone is connected to the data acquisition recorder through a cable assembly, and the calibrator is used for on-site acoustic calibration before and after each experiment. The GPS system provides GPS time to the data acquisition logger.

2.2 Helicopter Noise Measurement System Architecture

The noise measurement system of the helicopter consists of a microphone (amplifier), a calibrator, a data acquisition recorder, a windshield, a tripod, a time synchronization device, a GPS system and a cable assembly. The noise measurement system includes three ground noise measurement stations, which are one flight trajectory noise measurement station and two sideline noise measurement stations. The flight trajectory noise measurement stations are located on the ground projection line of the helicopter's flight trajectory, and the distance from the helicopter is not less than 500 m; Two sideline noise measurement stations are located 150 m on both sides of the flight trajectory noise measurement station, and the line connecting the two is perpendicular to the ground projection line of the helicopter flight trajectory.

Each noise measurement station includes a microphone (amplifier), a windshield, a tripod, a data acquisition recorder and several cable assemblies. The microphone is mounted on a tripod, and the distance between the tripod and the ground is 1.2 m and the axis is adjusted by adjusting the tripod. It is perpendicular to the incident direction of helicopter noise. The GPS system is installed at the flight trajectory noise measurement station, and provides GPS time to the data acquisition recorder. The time synchronization device is connected to three ground noise measurement stations at the same time, and realizes the time synchronization of the three ground noise measurement stations by means of synchronizing marks.

3 Method of Flight Test

3.1 Method of Propeller Small Aircraft Flight Test

General Procedure. The propeller plane is adjusted to the maximum take-off weight (the weight needs to be re-adjusted after the flight time exceeds one hour), take off from the brake release point (point A) with the take-off power, and pass the height of 15 m above the runway (point C) after leaving the ground (point B). After adjusting to the optimum rate of climb speed (point D), continue to climb, and record the air position and noise data of the aircraft when it passes right above the noise measurement point (point O) (point E). Figure 1 shows a schematic diagram of the general procedure for the noise certification test for small propeller aircraft.

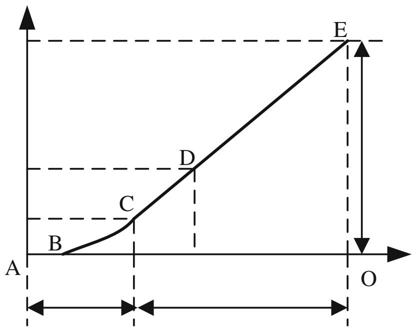

Fig. 1. Schematic diagram of the general procedure for noise certification test of propeller small aircraft.

Equivalent Procedure CCAR-36 stipulates that the effective number of flights in the noise certification test is not less than 6 times, so the number of cycles of the general procedure is not less than 6 times noise. In order to save the cost of airworthiness certification and reduce the impact of noise on the surrounding environment of the airport, the equivalent procedure can be used instead of the general procedure.

The equivalent procedure is realized by the method of track cut-in [4, 5]. After the propeller aircraft completes the first noise test according to the general procedure, it performs level flight at the level at which the best rate of climb speed is achieved in the first flight, and continues level flight to the height position (point A1) just above the original braking point., after reaching the position (point D) where the best rate of climb speed is reached in the first flight, turn to the climbing state, keep the power and speed unchanged, and record the air position and noisy data. The sequential method repeats subsequent noise tests. Figure 2 shows a schematic diagram of the equivalent procedure for noise certification of propeller small aircraft.

3.2 Method of Helicopter Flight Test

The helicopter noise certification test includes three sub-tests, namely take-off, fly-over, and approach noise tests, and the noise measurement results of the three sub-tests are in the 10 dB drop range [6, 7].

In the take-off noise test, the helicopter climbs from the starting point (point A) at a height of 20 m from the ground and 500 m from the flight path noise measurement station (point O) with the maximum take-off power, the best rate of climb, and the best rate of climb speed. Just above the flight path noise measurement station (point B), continue to climb until the end point (point C) of the take-off noise test is passed. Figure 3 shows the schematic diagram of the flight path of the take-off noise for helicopter noise certification.

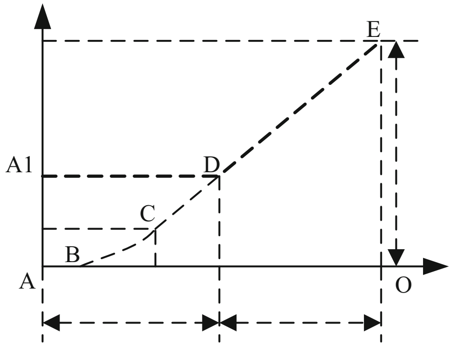

Fig. 2. Schematic diagram of the equivalent procedure for noise certification of propeller small aircraft.

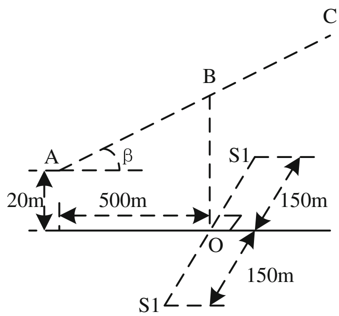

Fig. 3. Schematic diagram of the flight path of take-off noise for helicopter noise certification

In the flyover noise test, the helicopter flies level from the starting point (point D) at a height of 150 m from the ground and passes directly above the flight path noise measurement station (point O) (point E) and continues level flight until it passes the end point of the flyover noise test (point F). The level flight speed selects the minimum value of 0.9VH, 0.9VNE, 0.45VH+120 km/h, 0.45VNE+120 km/h, VH is generally referred to as the maximum level flight speed, and VNE is generally referred to as the unsurpassable speed. Obtain the flight manual. Figure 4 shows a schematic diagram of the flight path of the helicopter noise certification flyover noise.

In the approach noise test, the helicopter continues the approach from the starting point (point G) of the approach noise test, at an approach angle of 6°, after passing 120 m (point H) directly above the flight path noise measurement station (point O), until Pass the endpoint of the approach noise test (point I). Figure 5 shows a schematic diagram of the approach noise flight trajectory for helicopter noise certification.

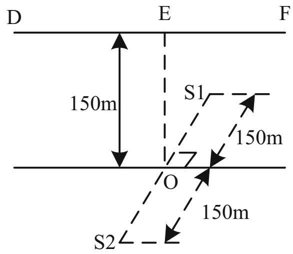

Fig. 4. Schematic diagram of flight path of helicopter noise certification flyover noise

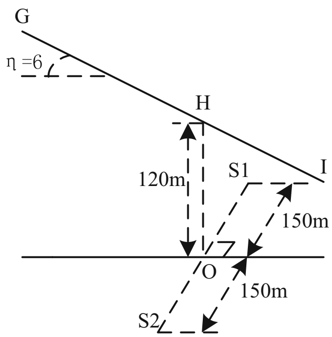

Fig. 5. Schematic diagram of flight path of helicopter noise certification approach noise

4 Method of Track Measurement

4.1 Method of Photographic Ratio

The photographic ratio method is a method of determining the position of the aircraft in the air by using the trigonometric function relationship and the imaging principle. When using it, it is necessary to select the significant structure on the aircraft as the reference benchmark. The propeller usually selects the wing of the small aircraft, and the helicopter generally selects the rotor. The photographic scale method is implemented based on the photographic scale system. The schematic diagram of the photographic scale system is shown in Fig. 6. The number is adjusted according to the different test objects. The propeller small aircraft only needs to use one photographic scale system, and the helicopter needs to use three sets of photographic scale systems. The starting point of each test, the point just above the flight path and the end point, the connection of the three is regarded as the flight path of the helicopter.

A photo-scale system consists of a rectangular frame (square frame), a stand, and a camera. The rectangular frame is divided into 10 equal parts by inelastic strings, and the height of the rectangular frame is supported by adjustable brackets. When the aircraft passes over the camera scale system, take a picture, apply the imaging principle and trigonometric function relationship to obtain the measured track height to judge the altitude deviation, and use the aircraft position on the photo to judge the heading

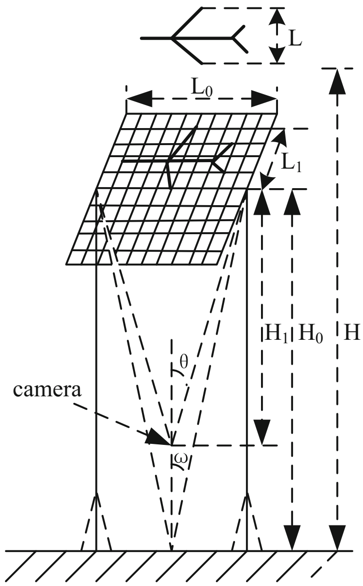

Fig. 6. Photographic scale system

deviation. The calculation formula of the measured track height is as follows:

$$H = \left(\frac{10 * L * L3}{L0 * L2} - 1\right) * \frac{L0}{2 * \tan\theta} + H0$$

Among them, ω is the angle between the edge of the rectangular frame and the vertical direction of the ground, θ is the angle between the edge of the rectangular frame and the vertical direction of the camera lens (the larger value of the corresponding angle of yaw 10° and 20 m), H is the measured track height, H0 is the vertical distance from the grid plane to the ground, H1 is the vertical distance from the camera lens to the grid plane, L0 is the side length of the rectangle, L is the length of the (wing) rotor diameter, and L1 is the wing (rotor) diameter at The length on the rectangular frame, L2 is the length of the diameter of the wing (rotor) in the photo, and L3 is the grid width of the rectangular frame in the photo.

4.2 Method of DGPS

A GPS system is placed at a point with a known precise location, an aircraft and a noise measurement station. Among them, one point with a known precise position is used as the base station, and the two points of the aircraft and the noise measurement station are used as the mobile station. The DGPS coordinates of any point on the measured track and the DGPS coordinates of noise measurement station A are obtained from the GPS system. Take point A as the calculation origin, take the aircraft heading as the X-axis direction, take the direction perpendicular to the ground as the Z-axis, and determine the Y-axis from the right-hand coordinate system. The allowable range of deviation under the GPS coordinate system is obtained from the allowable range of deviation between the measured track and the reference track [8]. Software such as matlab can be used to draw all the measured track points and the area in the same three-dimensional map. If a point is located inside the area, then It indicates that the measured track conforms to the reference track deviation, and vice versa.

5 Conclusion

Through the research on civil aircraft noise certification test technology, the following conclusions are drawn:

(1) All civil aircraft must meet the noise requirements of CCAR-36, and must use the prescribed test flight methods and measurement methods to obtain noise data.
(2) For propeller small aircraft and helicopter, a specific construction method of noise measurement system is provided respectively.
(3) The method of Photographic Ratio and the method of DGPS are designed to determine the measured track, and a specific implementation method is provided.
(4) For the propeller small aircraft, an equivalent procedure of the test flight method is introduced, which can reduce the number of take-off, landing and adjustment of the aircraft and improve the test flight efficiency.

References

1. CCAR-36-R2: Aircraft Model and Flight Qualification Verification Noise Regulations (2017)
2. AC-36-AA-2008-04: Consultation notice of Aircraft Model and Flight Qualification Verfication Noise Regulations (2008)
3. Haojun, X.: Introduction to the Airworthiness. Northwestern Practice University Press, Xi'an (2012)
4. Chen Dejun, W., Zhigang, W.K.: Design and application of helicopter noise airworthy test system. Comput. Measur. Control. **06**, 368–284 (2018)
5. Fang, W., Ning, Y., Long, Z.: Research on the development of civil aircraft noise. Air Stand. Qual. (01), 45 (2019)
6. Guohua, Y., Jie, L.: Application of the equivalent flight paths in airworthiness certification of civil aircraft noise. Acoust. Technol. (02), 163 (2018)
7. Guochi, G., Jingze, Q., Li, D. et al.: Airworthiness certification technology for the kakeoff noise concurrent flight testing of the Y12F aircraft. Civ. Aircraft Des. Res. (02), 57 (2019)
8. Enhui, Z., Jinying, Y., Shuren, X.: Noise and Vibration Control, vol. 47. Metallurgical Industry Press, Beijing (2012)