ACOUSTIC CERTIFICATION OF HELICOPTER Ka-32A

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Abstract

The results of flight acoustical tests of co-axial type helicopter Ka-32A at take-off, forward flight and approach regimes are presented. Tests, measurements and processing of the experimental data are made according to the requirements of ICAO Standard (Annex 16, v1, Chapter 8) and of Aviation Register of Russia (Part AR-36) to certification of acoustical tests of helicopters.

It is established that for helicopters Ka-32A of given configuration of rotor blades the community noise levels are lower of acceptable limiting values at take-off and approach regimes by 6.9 EPN dB and 4.6 EPN dB, respectively, and they do not exceed the reglamentation requirements at forward flight. The main community noise source of helicopter is pulse acoustic radiation generated at aerodynamical interaction between the lower propeller blades and the tip vortices formed in the wake of the upper rotor blades.

Helicopter

Helicopter Ka-32A is realized according to a coaxial scheme (Fig.1). The helicopter rotor system consists of two coaxial 3-bladed rotors of 15,9 m in diameter, which rotate in opposite directions. The power plant includes 2 gas-turbine engines of TB3-117 type, each of 2200 h. p. in power.

The acoustical characteristics in this work were determined for the helicopter with the following parameters under reference certification conditions (ISA+10^0):

- normal take-off mass – 11000 kg;
- take-off trajectory:
  - trajectory slope angle – 230;
  - flight velocity – 125 km/h;
  - flight altitude over the noise measurement point – 230 m;
- forward flight:
  - altitude – 150 m;
  - velocity – 230 km/h;
- approach:
  - glide slope angle – 6^0;
  - flight velocity – 125 km/h;
- relative revolutions of main rotors:
  - at take-off – 89%;
  - flyover and approach – 91%.

Test procedure

According to the requirements of Standards [1,2], the community noise measurements were made at three regimes of helicopter flight – take-off, forward flight and approach (Fig.2). The noise measurement points were situated on a line normal to the flight trajectory projection on the ground surface with an interval of 150 m. The tests were realized with the use of the equivalent procedure [3]. Take-off and take-off simulations were made with a course angle of 248^0, approaches and approach simulations – with a course angle of 68^0 and forward flights - with course angles of 248^0 and 68^0 in turn. All the flight regimes were realizes continuously, one after another. Helicopter landing was made only with the purpose of fueling so that the flight mass value was within the acceptable limits of 90%-103% of the certification value.

Three systems of parameter measurements were used in the tests:

- board system for measurement and registration of helicopter flight parameters and engine and rotor operation regimes;
- ground system of flight trajectory registration with the use of photo-scale method
- ground system of helicopter community noise level measurement and registration.

For work synchronization of all the systems two signals were used: a signal of unified time which was generated on the helicopter board with a given frequency (1sec) and was recorded on the board and ground recording systems for flight and acoustical data and a signal of momental operation of the photo-camera shutter; this signal was recorded on a magnetic tape of acoustical data recorder. The moment of helicopter flyover above the central microphone was marked by the board data recorder as well as by the ground acoustic data recorder.

Processing of the measurement results for helicopter flight trajectory parameters showed that the flight altitudes determined with the use of photo-scale method and with the use of usual altitude radio meter placed on the helicopter board were practically identical. RMS-value of the difference between the data measured at the flight altitudes up to 300 m was not more than 2m.

Atmosphere parameters (temperature, pressure, air humidity, wind speed and direction) were measured at two places: at the stationary meteostation of the airport away from the place of realization the tests at a distance up to 1000 m and directly close to the place of the central measuring microphone position.

System of measuring and processing of acoustical data

Noise level measurements were realized with the use of 3 microphones, type 4134 "B&K". Signals from the microphones were supplied to three sound meters, type 00023 “RFT” after passing through pre-amplifiers and were recorded using a 4-channel magnetic tape recorder of “Sony”. The measurement complex had a linear amplitude-frequency characteristic in the frequency range of 20-10000 Hz.

Analysis of noise recording made on the magnetic tape was realized with the use of analog and digital methods based on special program for processing the magnetic recording of flyover noise with the use of a specialized computer, type HP-9826 and of 1/3-octave band analyzer of real time type “B&K”. In the process of realizing the computation program for each helicopter flight regime, first a matrix of 1/3-octave sound pressure spectra was determined, which corresponded to the consequence of helicopter positions on the flight trajectory at a step of 0.5 sec for the whole period of time corresponding to the time period of upper 10 TPN dB noise sounding.

Then for each 1/3-octave sound pressure spectrum the following values are computed: perceived noise level (PNL), a correction for the spectrum non-uniformity (C) and weighted overall sound pressure level of the standard sound meter (dBA). The maximum value of the perceived noise level (PNLTM) is determined for each flight regime and the value of effective perceived noise level is computed.

The measurement results are reduced to the reference certification conditions according to the following relation [1,2]:

$$EPNL_r = EPNL + \Delta 1 + \Delta 2 + \Delta 3;$$

where Δ1 is the correction accounting for the effect of the difference between the sound absorption coefficient in the atmosphere under test conditions and its value under reference certification conditions; Δ2 is the correction accounting for the effect of flight altitude and velocity variations during the tests in comparison with the reference certification conditions; Δ3 is the correction accounting for the effect of variations of helicopter flight mass during the tests on EPNL.

The statistical evaluation of helicopter noise levels consisted in determining for each flight regime the conditions of the average value of EPNL and of the confidence interval for the conditional average at a given value of confidence probability equal to 90%.

Evaluation of flight regime conditionality

The requirements of Standards related to conditionality of flight tests can be conditionally divided into the following groups:

- limits with respect to meteoconditions and acoustical background;
- limits determining the stability of maintaining the helicopter flight regime;
- limits related to the flight trajectory geometry;
- limits related to permissible variations of helicopter flight mass;
- limits related to the correcting values used for the predicted EPNL which account for the flight parameter deviations within the limits permitted by the Standards.

In addition to the above limits, the Standards include also the limits related to the common atmosphere state according to which the sound absorption value at the frequency of 8 kHz must not exceed the value of 12 dB/100m.

Under conditions of quiet atmosphere, i.e. in the absence of atmospheric fronts in the region of tests, which lead to a strong air turbulization in the near-ground layer, the limit related to the absorption coefficient value is never exceeded, if the air humidity and temperature, wind speed and its transversal component are within the range of permitted values.

The common parameters of atmosphere state which took place during the tests of helicopter Ka-32A were within the limits prescribed by the Standards [1,2].

According to the data obtained at the stationary meteostation during the acoustical tests, the mean temperature of air was ~15,5^{0}C, pressure was 758 mm of r.c., humidity was 90%. As a whole the atmosphere state was unstable. The mean wind speed at the place of noise measurements varied within the limits of 3-5 m/sec at the course wind angle of 220^0. In principle, the atmosphere conditions corresponded to the limits formulated in the standards [1,2].

The tests were carried out in the airport Sheremeteyvo (29.09.1994) during a specially chosen time interval, when there were no air liner flights.

The acoustical background spectrum measurements at the place of tests showed that the useful signal level in 1/3-octave frequency bands in the range of 500-2000 Hz, in which the radiation intensity determines the perceived noise level of helicopter, exceeded the acoustical background level by the value up to 30 dB.

Stability of helicopter trajectory flight regime is evaluated by the value of deviation of the mean air velocity and mean relative revolutions of the main rotors from their reference values:

$$\Delta\overline{V} = \left|\overline{V_a} - V_r\right| \le 9 km/h;$$
$$\Delta\overline{n_f} = \left|\overline{n_f} - n_r\right| \le 1\%;$$

According to given parameters, two take-offs (out of 8 measured ones) two forward flights and one approach appeared to be not conditional.

The limits related to flight trajectory geometry were set in the following form: the permitted value of side deviation of the helicopter flight trajectory from the vertical plane passing through the central measurement community point, the permitted value of approach glide slope angle deviation from the reference value of 6^0 and the permitted value of the helicopter flight mass deviation

$$|\beta| \le 10^0$$
$$|\Delta Q_{app}| \le 0.5^0$$
$$m = (0.9 \div 1.05) \cdot m_{max}$$

It was found from the test results that the side helicopter deviation (β) at take-offs did not exceed 5^0 and at forward flights and approaches it did not exceed 10^0. The helicopter flight mass value varied during the tests in t he following limits: at take-offs – 100-102 percent, at flyovers - 98.1÷102,1 percent, at approaches – 99.9÷102.3 percent. The approach glide slope angle deviations in the interval of (PNLTM-PNLTi)≤10 TPN dB did not exceed 0.5^0.

Helicopter noise levels

It is found experimentally [4] that one of the principal community noise sources of helicopter of coaxial scheme is the pulse acoustical radiation generated at the aerodynamical interaction between advanced blades of the lower main rotor and the tip vortices formed in the wake of retreating blades of the upper rotor. The pulse radiation is characterized by harmonic spectrum of sound pressure. The effective method of reducing this noise intensity is variation of the tip vortex intensity formed at the retreating blade of the upper rotor. Selection of a special form for the blade tip part and of its position in space permitted obtaining a considerable (up to 5 EPN dB reduction of helicopter noise level in the range of cruise velocities.

The noise levels of helicopter Ka-32A measured at take-off are presented in Table 1. There are also presented the predicted values of corrections Δ1, Δ2, Δ3 and the overall value of all the corrections Δ_Σ and a part of correction Δ_2 (Δ_2'=-7.5lg(H/H_r) for the values of which the limits are set in the standards:

$$|\Delta_\Sigma| \le 4\text{EPNdB};$$
$$|\Delta_2'| \le 2\text{EPNdB}.$$

The statistical treatment of EPNL values reduced to the reference conditions for take-offs gives the following values for the mean EPNL value and for the confidential interval limits at 90 percent of the evaluation reliability level:

EPNL=93.5±1.5 EPN dB

The permissible limiting noise level values for the helicopter with mass of 11000 kg at take-0ffs is 100.4 EPN dB [1,2]. The helicopter noise level corresponds to the requirements of chapter 8, ICAO Standard with a margin of 6.9 EPN dB.

Similar data for the forward flight regime are presented in Table 2. The sum of all the corrections to EPNL (Δ_Σ)must not exceed 2 EPNL dB for this regime. Regime N27 does not satisfy this condition. Therefore the statistical evaluation of EPNL was realized using the first eight flyovers. It is found that

EPNL=94.4±0.44 EPN dB

EPNL value permitted by the reglamentation is 94.4 EPNL dB, i.e. the helicopter noise level at forward flight regime agrees with the reglamentation.

Helicopter noise levels at approach are presented in Table 3.

The mean noise level of the helicopter at approach and the confidential interval limits at the evaluation reliability equal to 90 percent are as follows:

EPNL=96.8±0.3 EPN dB

The helicopter noise level equal to 96.8 EPN dB corresponds to the reglamentation requirements with a margin of 4.6 dB.

Reference

1. International Standards and recommended practice. Environmental protection. Annex 16 to Convention on International Civil Aviation. Volume 1. Aviation Noise. ICAO, 1993.
2. Aviation Rules. Part 36. Community Noise Certification of Air Vehicles. Aviaregister, 1995.
3. Environmental Technical Manual on the Use of Procedures in the Noise Certification of Aircraft. ICAO, 1995.
4. V.F.Samokhin, B.N.Burtsev. On the Nature of Pulse Acoustic Radiation of Coaxial Rotors. 26 ERF, Proceedings, v1,2000, pp 53-1÷53-5.

Table 1

N regime	$EPNL_m$			$\overline{EPNL_m}$	Δ1	Δ2	Δ3	$Δ_Σ$	$Δ_Σ'$	$\overline{EPNL_r}$
	N1	N2	N3							
1	93.3	95.1	93.1	93.9	-2.1	0.7	-2.1	-3.5	0.4	90.4
9	93.2	94.9	91.9	93.3	2.0	-0.2	-1.1	0.7	-0.3	94.0
11	92.3	94.3	90.6	92.4	2.0	-0.3	-0.8	0.9	-0.3	93.3
13	93.2	95.1	91.6	93.3	2.0	-0.1	-0.6	1.3	-0.3	94.5
15	92.7	94.5	91.2	92.8	3.3	-0.2	-0.2	2.9	-0.5	95.7
17	93.6	96.7	91.8	93.7	-1.7	0.7	0	-1.0	0.3	92.7

Table 2

N regime	$EPNL_m$			$\overline{EPNL_m}$	Δ1	Δ2	Δ3	$Δ_Σ$	$\overline{EPNL_r}$
	N1	N2	N3						
3	99.5	103.6	99.4	100.8	-2.6	1	0.1	-1.5	99.3
4	102.6	104	97.9	101.5	-3.1	1.1	0.2	-1.8	99.7
19	101.9	103.4	99	101.4	-2.3	0.9	-0.6	-2.0	99.4
20	103.5	102.2	98.6	101.4	-2.1	0.8	-0.7	-2.0	99.4
23	102.5	102.5	100.7	101.9	-0.7	0.2	-1.3	-1.8	100.1
24	101.1	101.2	98.5	100.3	-1.0	0.4	-1.4	-2.0	98.3
25	101.8	102.4	101.4	101.9	0.2	-0.1	-1.8	-1.7	100.2
26	100.6	99.6	97.0	99.1	1.2	0.4	-2.1	-0.5	98.6
27	101.5	102.3	103.7	102.5	-0.5	0.2	-2.4	-2.7	99.8

Table 3

N regime	$EPNL_m$			$\overline{EPNL_m}$	Δ1	Δ2	Δ3	$Δ_Σ$	$\overline{EPNL_r}$
	N1	N2	N3						
6	96.8	102.4	97.4	98.9	-1.2	0.7	-1.4	-1.9	97.0
8	97.3	102.8	96.5	98.9	-2.5	1	-0.8	-2.3	96.6
10	97.7	102.9	96.7	99.1	-2.3	0.7	-0.6	-2.2	96.9
14	96.6	102.8	95.7	98.4	-2.3	0.7	-0.3	-1.9	96.5
16	97.8	101.6	95.0	98.1	-2.3	0.9	-0.1	-1.5	96.6
18	97.6	101.9	95.2	98.2	-1.6	0.6	0.1	-0.9	97.3

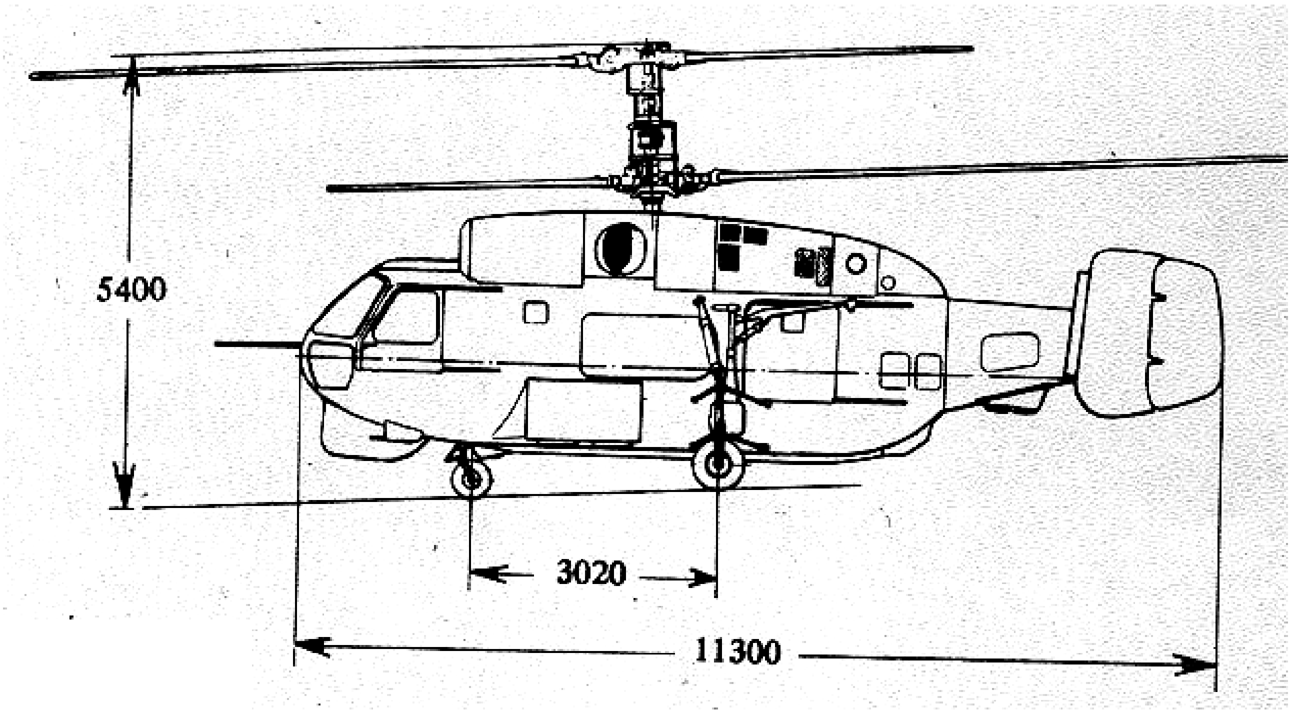
5400
3020
11300

Fig.1

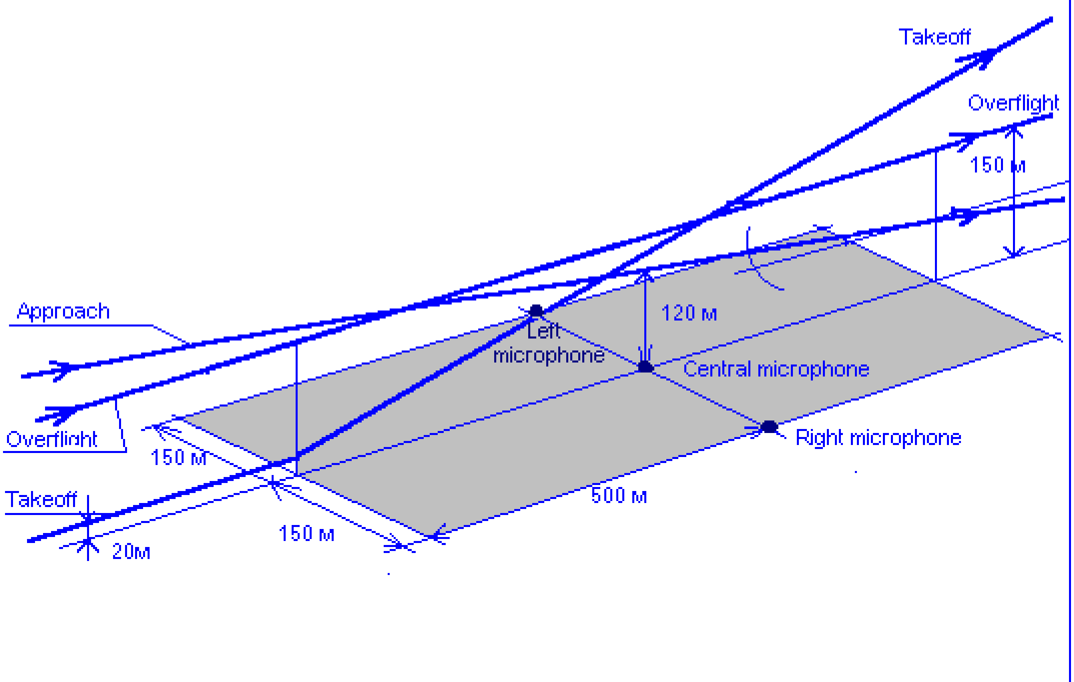
Takeoff
Overflight
150 м
120 м
Approach
Left
microphone
Central microphone
Overflight
Right microphone
150 м
Takeoff
150 м
500 м
20м

Fig. 2