


Ministry Of Higher Education and Scientific Research

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College of Engineering

Aviation Engineering Department

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Chapter 1
Lecture: 3

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Characteristics of a standard takeoff and landing cycle

Stage	Relative thrust	Duration, min2.
1. Idling and taxiing before takeoff	**0,07**	**15**
2. Takeoff	**1**	**0,7**
3. climb up to 900 m	**0,85**	**2,2**
4. landing approach from 900 m	**0,3**	**4**
5. taxiing and idling after landing	**0,07**	**7**

Table. 1

As can be seen from Table. 1, ground stages 1 and 5 are characterized on average by the same relative thrust. Therefore, when calculating the pollution of the airport zone, they can be combined into one ground stage with a relative thrust of 0.07 (idling and taxiing before takeoff and after landing) with a total duration of 22 minutes.

Carbon monoxide emission indices CO, hydrocarbons C_nH_m and nitrogen oxides NOx at various stages of the takeoff and landing cycle

Stage	Relative thrust	Emission index, g/kg		
		CO	C_nH_m	NOx
1. Idling and taxiing before takeoff	**0,07**	50	18	2
2. Takeoff	**1**	0	0	35
3. Climb up to 900 m	**0,85**	0	0	30
4. Landing approach from 900 m	**0,3**	10	3	10
5. Taxiing and idling after landing	**0,07**	50	18	2

Table. 2

For more accurate assessments of the pollution of the airport area by aircraft of various types, it is necessary to use specific data on the emission indices of aircraft engines installed on aircraft of each type. These data are determined experimentally on the basis of certification tests of aircraft engines.

Aircraft fuel consumption per unit of time at each stage of the takeoff and landing cycle Q_i depends on the type of aircraft, on the number and type of engines installed on it, on their power and efficiency.

Data on fuel consumption at various stages of the takeoff and landing cycle by aircraft of different types are presented in the Flight Manual (RLA). As an example, in Table. 3 shows data on the fuel consumption of the IL-86 aircraft with NK-86 engines.

Fuel consumption of the IL-86 aircraft at various stages takeoff and landing cycle

Stage	Relative thrust	Fuel consumption, kg/min
1. Idling and taxiing before takeoff	**0,07**	**20**
2. Takeoff	**1**	**180**
3. climb up to 900 m	**0,85**	**160**
4. landing approach from 900 m	**0,3**	**40**
5. taxiing and idling after landing	**0,07**	**20**

Using the table. 1-3 data, it is not difficult to calculate the release of each of the pollutants by the IL-86 aircraft in the airport area.

So, in accordance with formula (4), the total CO emission for the entire takeoff and landing cycle is:

$$M = \sum_i El_i . Q_i . t_i$$

M (CO)= 50 $g/kg\,.\,20\,kg/min.\,15\,min + 0\,g/kg\,.\,180\,kg/min\,.\,0{,}7min$
$+ 0\,g/kg.\,160\,kg/min\,.\,2{,}2min + 10\,g/kg\,.\,60\,kg/min\,.\,4\,min + 50\,g/kg.\,20\,kg/min.\,7\,min$

Total:

M (CO)=(15000+0+0+2400+7000) g=24400 g=24,4 Kg

The total surge C_nH_m is:

C_nH_m= 18 $g/kg\,.\,20\,kg/min.\,15\,min + 0\,g/kg\,.\,180\,kg/min\,.\,0{,}7min$
$+ 0\,g/kg.\,160\,kg/min\,.\,2{,}2min + 3\,g/kg\,.\,60\,kg/min\,.\,4\,min + 18\,g/kg.\,20\,kg/min.\,7\,min$

Total:

C_nH_m=(5400+0+0+720+2520) g=86400 g=8,64 Kg

The total surge NOx is:

$$NOx = 2\ g/kg\,.\,20\ kg/min.\,15\ min + 35\ g/kg\,.\,180\ kg/min\,.\,0{,}7min + 30\ g/kg.\,160\ kg/min\,.\,2{,}2min + 10\ g/kg\,.\,60\ kg/min\,.\,4\ min + 2\ g/kg.\,20\ kg/min.\,7\ min$$

The total surge NOx is

NOx=(600+4410+10560+2400+280) g=18250 g=18,25 Kg

In the given example, the values of emission indices averaged over different types of aircraft were used in the calculations. More accurate estimates of airport area pollution by an aircraft of the type under consideration can be obtain, using in the calculations more accurate values of the emission indices characteristic of a given aircraft.

In table. Table 4 presents the results of calculations of CO, C_nH_m and NOx emissions for a takeoff and landing cycle for several types of aircraft.

As can be seen from Table 4, the values of emissions for the takeoff and landing cycle of the same substances polluting the airport area by aircraft of various types can differ significantly from each other.

CO, C_nH_m and NOx emissions per takeoff and landing cycle aircraft of various types

aircraft type	Emission value, kg		
	CO	C_nH_m	NOx
1. IL-86	61	9	25
2. IL-62M	90	16	18
3. TU-154	109	34	18
4. Yak-42	10	3	11
5. AN-2	3,3	1	0,1

This is partly due to the difference in the emission indices of engines installed on different types of aircraft. However, the main reason is the difference in the amount of fuel consumed by aircraft of different types.

Flying heavier and faster aircraft requires the use of more powerful engines. Accordingly, the greater the power of aircraft engines, the more fuel they consume in unit of time and the more harmful substances enter the atmosphere during the takeoff and landing cycle.

Data on emissions of harmful substances for the takeoff and landing cycle by aircraft of various types (see Table.4) are used to calculate the gross emission of each of the pollutants in the airport area per day, per month, per year.

Gross emission per day M_c of each pollutant will be respectively equal to:

$$M_c = n_1 M_1 + n_2 M_2 + \cdots + n_k M_K \qquad 5$$

where M_K is the release of the substance under consideration by aircraft of type k during one takeoff and landing cycle.

The summation in formula 5 is made for all types of aircraft that take off and land at the airport.

For example, let 5 IL-62M, 10 TU-154, 15 Yak-42 and 20 AN-2 aircraft take off and land at the airport during the day.

Then, according to the data from Table. 4, the gross emission per day in the airport area of each of the considered pollutants (CO, C_nH_m and NOx) will be equal, respectively:

$$M_D(CO) = (5.90 + 10.109 + 15.10 + 20.3,3)\ kg = (450 + 1090 + 150 + 66) kg = 1756\ kg$$

$$M_D(C_nH_m) = (5.16 + 10.34 + 15.3 + 20.1)\ kg = (80 + 340 + 45 + 20) kg = 485\ kg$$

$$M_D(NO_X) = (5.18 + 10.18 + 15.11 + 20.0,1)\ kg = (90 + 180 + 165 + 2) kg = 437\ kg$$

To obtain the gross emissions of pollutants for the month *Mm*, it is necessary to sum up the gross emissions for each day of the month under consideration.

If the intensity of aircraft traffic did not change during the month, then the monthly gross emission can be obtained by multiplying the daily gross emission by the number of days in the month under consideration.

So, if the number of days in a month was 30, and the daily gross emissions of pollutants during the month were the same as in the previous example, then the gross emissions of (CO, C_nH_m and NOx) for the month are, respectively:

$$M_M(CO) = 30.1756\, kg = 52680 = 52{,}68 \text{ т},$$

$$M_M C_n H_m = 30.485\, kg = 14550 = 14{,}55 \text{ т},$$

$$M_M NOx = 30.437\, kg = 13110 = 13{,}11 \text{ т},$$

If the gross emissions per month change little during the year, then the gross emissions per pollutant per year Mg can be obtained by multiplying the monthly gross emissions by the number of months in a year.

So, in this case, in the given example, gross emissions of (CO, C_nH_m and NOx) for the year will be equal, respectively:

$$M_Y(CO) = 12.52{,}68 \text{ т} = 632{,}16 \text{ т},$$

$$M_Y(C_nH_m) = 12.14{,}55 \text{ т} = 174{,}60 \text{ т},$$

$$M_Y(NOx) = 12.13{,}11 \text{ т} = 157{,}32 \text{ т},$$

However, usually the intensity of aircraft flights at airports varies significantly throughout the year. As a rule, in the summer months it is higher, and in the winter months it is lower than the average annual flight intensity.

Therefore, it is necessary to calculate gross emissions of pollutants separately for each calendar month. The calculation results can be presented in the form of a graph that will characterize the annual course pollution of the airport area by aircraft engines.

By summing the gross emissions for all calendar months, one can obtain the gross emissions of pollutants for the year. These values - the annual gross emissions in the airport area of each of the pollutants - are recorded in the airport's environmental passport.

Question

1. Aircraft fuel consumption per unit time at each stage of the takeoff and landing cycle Qi depends?

2. Write a formula to calculate the emission of each of the pollutants by an aircraft in an airport area?

3. For example, if the fuel consumption of an aircraft is 20 kg/min, the emission index is (CO=50 $C_nH_m = 18$, NOx=2) g/kg, the duration, min is 15 minutes, and the relative thrust is 0.07, calculate the emission of pollutants by the aircraft in the airport area?

4. Why is there a difference in the emission indices of aircraft engines?

5. How does the intensity of aircraft flights at airports change during the year?