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Method for Determinating the ISO-Noise Levels by Simulated Aircraft Flight Operations.

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The purpose of the model outlined below is to give a possibility for evaluating the perceived aircraft noise level in the function of aircraft position and time. But perceived aircraft noise level changes simultaneously with time and pos. as the noise source, in this case the aeroplane, is moving on the ground or in the air. The change of the perceived noise level can be calculated using the noise attenuation equation.

$$L_{PN}=L_{PN_0}-20\log\frac{D}{D_0}-B(D-D_0)$$

where D is the distance from the noise source;

D_o is the referance distance;

L_{PN_o} is the perceived noise level at D_o distance; and

B is the coefficient of air noise attenuation.

The coefficient B depends on air temperature, on its relative humidity and, naturally, on the noise frequency. The timely difference of the perceived noise level arises actually from the time functioned change of distance D measured between the source of noise and the observer.

The situation is rendered more complicated by the Doppler effect which may not be neglected because, at the characteristic speed of, say, 170 metres per sec, the frequency shift induced by it can be as much as minus two thirds of, or plus one full octave.

Noise abatment regulations use the quantity of "noise energy content" as this will bring into the correlation theeffect harmful to human health. Thus, ISO recommends to use the integral of the perceived and time functioned noise belonging to the noise attenuation rate of minus 10 dB and divided by the highest noise level, as expressed by the equation

$$L_{eq}=k\,\frac{1}{T}\int_{t_1}^{t_2}10^{\frac{1}{k}L_{PN}(t)}\,dt$$

where t_1 and t_2 are the instants belonging to the noise attenuation value of minus 10 dB as compared to the highest perceived noise.

In an attempt to take into account the above effects, the 0-point of the engine noise emittance coordinates was taken as being permanently fixed to the center of gravity of the aircraft and the change of characteristics was calculated as the function of engine power level and of the spectrum of Doppler effect and, additionally, of the momentary distance between the aircraft and the observer.

To evaluate the perceivable noise level at some given observation point in any instant the knowledge of the coordinates where the aircraft would be in any given instant, of its vector velocity, of its pitch angle and of its engine power levels is needed.

According to the above, two submodels have been developed. First, the movement of the plane at, and in the vicinity, of the airport during its take off, climbout and descend for landing was simulated. The aircraft movement is determined by the equations

$$\frac{dv_{1x}}{dt}=\omega_{1z}v_{1y}-\omega_{1y}v_{1z}+\frac{1}{m}(X_1-P)-g\sin\gamma$$

$$\frac{dv_{1y}}{dt}=\omega_{1x}v_{1z}-\omega_{1z}v_{1x}+\frac{1}{m}Y_1-g\cos\vartheta\cos\gamma$$

$$\frac{dv_{1z}}{dt}=\omega_{1x}v_{1y}-\omega_{1y}v_{1x}+\frac{1}{m}Z_1-g\cos\vartheta\sin\gamma$$

$$\frac{d\omega_{1x}}{dt}=\frac{1}{J_x}\left[M_{1x}+\omega_{1y}\omega_{1z}(J_y-J_z)\right]$$

$$\frac{d\omega_{1y}}{dt}=\frac{1}{J_y}\left[M_{1y}+\omega_{1z}\omega_{1x}(J_z-J_x)\right]$$

$$\frac{d\omega_{1z}}{dt}=\frac{1}{J_z}\left[M_{1z}+\omega_{1x}\omega_{1y}(J_x-J_y)\right]$$

where v_{1x}, v_{1y} and v_{1z} are the velocities;

ω_{1x}, ω_{1y} and ω_{1z} are angular velocities of the aircraft;

x_1, y_1 and Z_1 are aerodynamic forces; and

M_{1x}, M_{1y}, and M_{1z} are components of momentum in the coordinate system the O-point of which follows continuously the aircraft's center of gravity;

P is the momentary thrust level;

J_x, J_y, and J_z are main inertia moments of the plane. The other inertia tensor elements have the value of zero;

ϑ and γ are the pitch and roll angles.

The correlation between aerodynamical forces and moments and velocities is non-linear but their linear approach gives adequate precicion:

$$X_1 - X_1 + \frac{\partial X_1}{\partial v_{1x}} dv_{1x} + \frac{\partial X_1}{\partial v_{1y}} dv_{1y}$$

$$Y_1 = Y_1 + \frac{\partial Y_1}{\partial v_{1x}} dv_{1x} + \frac{\partial Y_1}{\partial v_{1y}} dv_{1y}$$

$$Z_1 = Z_1 + \frac{\partial Z_1}{\partial v_{1z}}$$

$$M_{1x} = M_{1x} + \frac{\partial M_{1x}}{\partial v_{1z}} dv_{1z} + \frac{\partial M_{1x}}{\partial \omega_{1x}} d\omega_{1x} + \frac{\partial M_{1x}}{\partial \omega_{1y}} d\omega_{1y}$$

$$M_{1y} = M_{1y} + \frac{\partial M_{1y}}{\partial v_{1z}} dv_{1z} + \frac{\partial M_{1y}}{\partial \omega_{1x}} d\omega_{1x} + \frac{\partial M_{1y}}{\partial \omega_{1y}} d\omega_{1y}$$

$$M_{1z} = M_{1z} + \frac{\partial M_{1z}}{\partial \dot{v}_{1z}} d\dot{v}_{1y} + \frac{\partial M_{1z}}{\partial v_{1y}} dv_{1y} + \frac{\partial M_{1z}}{\partial \omega_{1z}} d\omega_{1z}$$

The partial differential coefficients are themselves variables. They are, therefore, dependant by the highest degree upon the velocity, the air density, its humidity, etc. what is expressed by the equations, for example:

$$\frac{\partial X_1}{\partial v_{1x}} = -C_x \varrho F V$$

$$\frac{\partial Y_1}{\partial v_{1y}} = -\frac{1}{2}\left(\frac{dc_y}{d\alpha} + C_x\right) \varrho F V$$

The total trastment needs the consideration of some 40 parameters which are defined by the structure of a given aircraft type or by its aerodynamic characteristics.

The second submodel will be the acoustic one. By knowledge of the noise emittance characteristics of a given aircraft and of the meteorological conditions the perceived noise at any coordinate point /position/ on the ground can be calculated by the method outlined earlier in this treetment.

The equivalent noise can be summarized by the equation:

$$L_{eq} = k \log \frac{1}{T} \sum_i 10^{\frac{1}{k} L_{PNi}} \Delta t$$

To consider the influence of other specified and scheduled flights with different flight pathes the value E is to be calculated by the equation:

$$E = \sum_i 10^{\frac{1}{k} L_{PNi}} \Delta t$$

and the equivalent noise level for all the possible flight pathes will be:

$$L_{eq} - k \log \sum_j \frac{n_j E_j}{T}$$

where n_j is the number of flight operations on the path j within the actual duration of T.

Some results of adaptation of these models to the vicinity of the International Aerodrome Budapest-Ferihegy are given schematically below.

MAXIMUM NOISE LEVEL OF A SIMULATED TAKE-OFF
(Izofon curves in PN dB.)