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ASSESSMENT OF THE ACCEPTABLE RANGE OF AIRCRAFT LATERAL DEVIATIONS ON THE APPROACH PHASE

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The dependence of the acceptable range of aircraft lateral deviations from landing trajectory by appropriate aircraft approach category, at which it is possible its successful completion, is considered.

Keywords: correcting maneuver, landing, lateral deviations

Introduction

The analysis of aviation accidents in the global aviation indicates that during the approach and landing over 40 — 50% of accidents are happened. Approach takes 2 — 3% of an aircraft flight time and it indicates that probability of accidents at this stage of flight at 15 — 20 times more than an average during all flight time [2].

The set factor that affect on choice of landing system (weather conditions at the airport, the frequency of landings and take-off, the cost of landing and take-off) is determinative for decision height on which the pilot must decide to either continue the approach or to execute a missed approach if runway is not seen or aircraft stabilization on the landing trajectory is not achieved.

According to the International Civil Aviation Organization (ICAO), OCH/A is main parameter which takes into account during approach by adding a number of operational impacts factors. OCH/A is defined as the lowest altitude or height at which aircraft have to start landing or go-around to ensure compliance with appropriate obstacle clearance criteria through the application of minimum reserve height (fig.1) [5; 6].

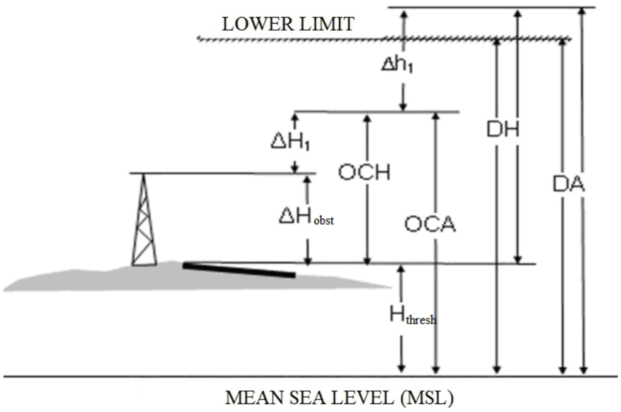

Fig. 1. Relation between OCA/H and DA/H when accuracy landing system use:
ΔH_{obst} — the highest height of obstacle zone approach or the equivalent of the highest obstacle in the area of missed approach;
ΔH_1 — altitude reserve.
Δh_1 — reserve height or lower limit.

Reserve altitude ΔH_1 depends on the landing speed of aircraft, drawdown during the go-around, and accuracy of height measurement and adjusts for steep glideslopes and airfields located at high altitudes, and the value of reserve height Δh_1 is based on operational considerations including:

- aircraft category;
- characteristics of ground/aircraft equipment;
- qualification of crew;
- aircraft performance;
- weather conditions;
- elevation of the aerodrome;

— relief of terrain in the case of radio altimeter use; pressure measurement error when using barometric altimeter.

Literature overview

As required by ICAO aircraft operation restriction in certain meteorological conditions is set to ensure the required level of safety [3]. Aerodrome operating minima is expressed in values of runway visual range (RVR) and minimum descend altitude / height (MDA/H) for inaccurate approach, or values of decision altitude/height (DA/H) for accurate approach and indicating the threshold visibility and runway visual range when vertical navigation (VNAV) is used.

Meteorological minimum (excluding skill level of crew) depends on two main factors:

— precision of flight on the appropriate trajectory, which provide navigation aids;

— flexibility of maneuver to eliminate an error during approach after establishment of eye contact with landmark and airfield runway [3].

The element of visibility is used to determine a task, which pilot has to perform at altitude of DA/H or MDA/H and below in order to complete landing.

Decision height (DH) is installed absolute or relative height at accurate approach at which should be initiated go-around if not installed a necessary visual contact with landmarks to continuation approach.

The required visual contact with landmarks means the visibility of a part visual facilities or approach zone during the time sufficient to assess a location of aircraft by pilot and rate of it change according nominal trajectory [1; 6].

Aircraft as usual has some deviation from landing trajectory at the moment of transition to visual flight; its heading is different from runway heading and it has deviation in height from a given glideslope. Thus, the deviation value from landing trajectory has been taking into account as it may be corrected during maneuvering after passing the point of minimum [3].

The goal of this paper is to assess maximum lateral deviations of aircraft from landing trajectory, under which it may be successfully complete.

Assessment of the allowable lateral deviations of aircraft

Successful landing depends on the range of allowable lateral deviations and accuracy of aircraft stabilization on the landing trajectory. At the point of transition to visual flight aircraft may have some deviation from the landing trajectory and there is a need in corrective maneuver to land in given place of runway. The point of transition to visual flight is characterized as beginning of corrective maneuver to complete an approach and it can be considered as an operation for the removal of aircraft in some sections of area M, which is a space of aircraft allowable lateral deviations.

$M = (\pm z_{max}, \pm H_{max})$.

Limits of area M is determined by allowable lateral deviations — z_{max} and deviations of height — H_{max} from a given trajectory of landing.

In the horizontal plane aircraft deviations from the landing trajectory is characterized by lateral deviations (concerning the course line) and angular deviations (deviation of aircraft ground speed vector from landing directly).

Lateral deviations of the aircraft from landing trajectory that require more time for corrective maneuver are of decisive importance than the deviation of height. Lateral maneuvering happens in the process of descending aircraft at a given glideslope and it completes up to reaching the minimum allowable height of go-around.

To correct lateral deviations from a given trajectory maneuver is performed, which consists of two connected additional turns. During the time of lateral deviation correction Z aircraft is running distance L with two additional turns an angle $\Delta\psi$ (fig. 2).

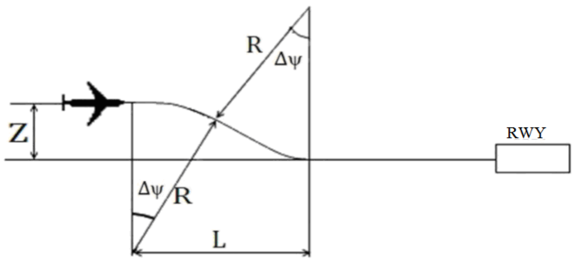

Fig. 2. Lateral deviation of aircraft from landing trajectory

Herewith

$Z = 2R(1 - \cos\Delta\psi)$;

$L = 2R\sin\Delta\psi \approx 2R\Delta\psi$, where R — radius of cornering in a coordinated turn:

$$R = \frac{V^2}{g\gamma}.$$

The value of angular deviation $\Delta\psi$ is

$$\Delta\psi = \frac{L}{2R}.$$

Then

$$Z = 2R\,(1\text{-}\cos\frac{L}{2R});$$

$$Z = \frac{2V^2}{g\gamma}\,(1 - \cos\frac{Lg\gamma}{2V^2}).$$

The main task is to determine a value of acceptable lateral deviations in minimum point which may be corrected before the moment of overfly a point of lateral maneuver completion. Obviously, in the worst case aircraft will have angular deviation and will be deviating from landing trajectory and increasing lateral deviation. In this case trajectory of aircraft flight can be submitted as area of turn to angle $\Delta\psi$ and additional turn (fig. 3).

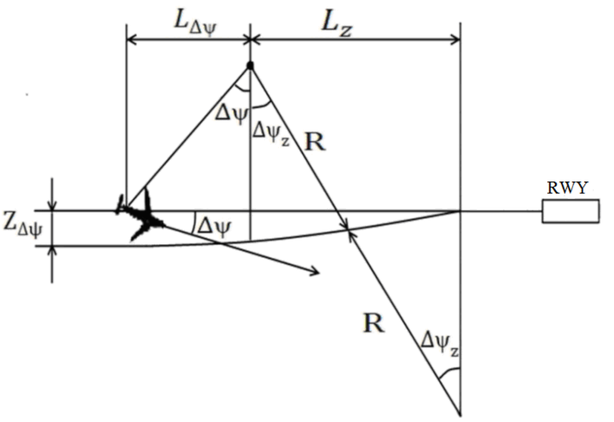

Fig.3. Angular deviation from a PC the landing trajectory

For calculation of aircraft allowable deviations from the landing trajectory assume that the lateral maneuvering happens in the process of aircraft descending at a given glideslope. Maneuver must be completed prior to overflying runway threshold.

At the point of lateral maneuver completion should not be deviations of ground speed vector from landing trajectory. For access to landing course where Δ = 0, Z = 0 aircraft should do maneuver, which consists of two parts: turn to angle $\Delta\psi$, after which $\Delta\psi = 0$, $Z = Z_{\Delta\psi}$ and dual additional turn. Aircraft will fly in direction of landing some distance L_{man}, which consists of two parts

$$L_{man} = L_{\Delta\psi} + L_z,$$

The distance of corrective maneuver with angular deviation $L_{\Delta\psi_0}$ is defined as

$$L_{\Delta\psi_0} = R \times \Delta\psi,$$

and L_z:

$$L_z = 2R \times \Delta\psi_Z.$$

Consequently, the distance of corrective maneuver for corner deviation correction

$$L_{man} = \frac{V^2}{g\gamma}\left[\Delta\psi + 2\arccos\left(\frac{1+\cos\Delta\psi}{2}\right)\right],$$

where V — average speed of the maneuvering area;

γ — average bank of maneuvering.

For most jet aircraft the maximum maneuver bank should not exceed 15°.

Aircraft deviation from given heading results to the same maneuvering as "pure" lateral is deviation where each angular deviation will meet lateral is deviation.

Distance in the direction of landing with the removal of the "pure" lateral deviation will determine

$$L_{man} = \frac{2V^2}{g\gamma}\left[\arccos\left(\frac{1-Zg\gamma}{2V^2}\right)\right].$$

Maximum allowable deviation of aircraft at the point of transition to visual flight at various $\Delta\psi$ will be determined by dependence $z = f(L, \Delta\psi)$:

$$Z_{max} = \frac{2V^2}{g\tan\gamma}\left[\frac{1+\cos\Delta\psi}{2} - \sqrt{1-\left(\frac{L_{man}g\tan\gamma}{2V^2} - \frac{\sin\Delta\psi}{2}\right)}\right] + z_0$$

ψ — angle between the direction of ground speed vector and the trajectory of landing;

z_0 — allowable lateral deviation of aircraft from the runway axis in time of landing.

After calculation

$Z_{max} = f(L_{man}, \Delta\psi)$,

we can plot the graph of allowable lateral deviations and symmetric to him, then select the area of allowable aircraft deviations (fig. 4).

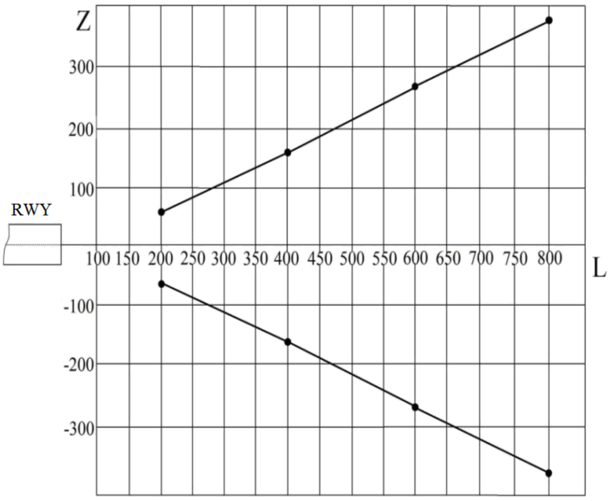

Fig. 4. The area of allowable aircraft deviations

In accordance with the standards of ICAO aircraft is divided into to 5 categories according to speed (fig. 5). Based on this distinction the landing minimums for aircraft and parameters of approach are defined (see table).

Classification of aircraft for approach procedures calculation

Aircraft category	Vat, km per hour	Speed		Maximum speed for visual maneuvering
		Initial phase	Final phase	
A	< 169	165/280	130/185	185
B	169/223	220/280	155/240	250
C	224/260	295/445	215/295	335
D	261/306	345/465	240/345	380
E	307/390	345/465	285/425	445

Note: Category E only for military aircraft

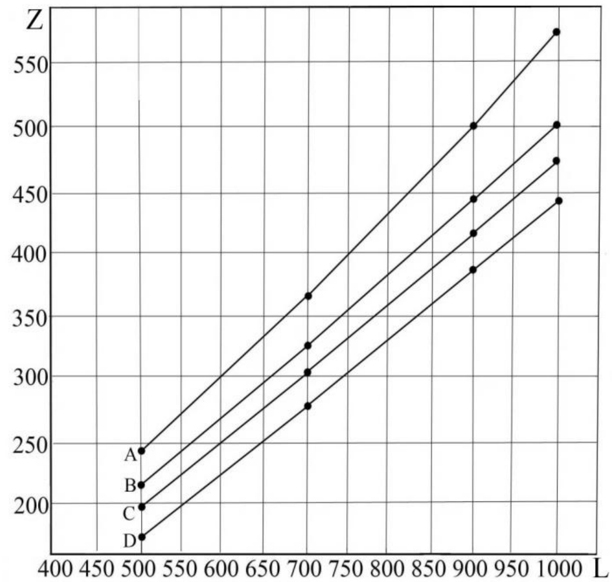

Fig. 5. Dependence between the maximum allowable lateral deviations of aircraft and speed at the point of minimum.

The lower speed has aircraft during approach, the more precise maneuverability, which means aircraft has smaller turning radius and in other equal conditions a lower acceptable meteorological minimum. Lower speed also ensures greater reserve of time for pilot after out of the clouds, which results a reduction of maneuver distance at which lateral deviations of aircraft may be eliminated.

Conclusions

Successful landing depends on the range of allowable lateral deviations of aircraft and the accuracy of the landing trajectory stabilization. For ensuring safety of operations under certain meteorological conditions should be taken into account the distance of corrective maneuver by maximum allowable deviation of aircraft from landing trajectory. The point of minimum depends on the distance of required corrective maneuver to adjust aircraft deviations from the landing trajectory. At this height pilot should begin corrective maneuver in case if deviation of aircraft does not exceed allowable limits or start go-around if deviation of aircraft exceed allowable value.

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