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Airplane Landing by the Curvilinear Glide Paths in Limits of the Border Trajectories Modelling Method

Рассмотрен новый метод посадки самолетов, который будет соответствовать современным требованиям гражданской авиации и обеспечит повышение уровня экологичности и экономичности полетов. Изучено моделирование метода генерации виртуальной криволинейной глиссады посадочного снижения самолета в рамках предельных траекторий с поддержанием индивидуального, оптимального, вертикального профиля снижения с эшелона полета до начала взлетно-посадочной полосы.

Ключевые слова: посадка самолетов, криволинейные глиссады, предельные траектории, моделирование, авиационная безопасность.

Розглянуто новий метод посадки літаків, який відповідатиме сучасним вимогам цивільної авіації та забезпечить підвищення рівня екологічності та економічності польотів. Досліджено моделювання роботи методу генерації віртуальної криволінійної глісади посадкового зниження літака в межах граничних траєкторій з підтриманням індивідуального, оптимального, вертикального профілю зниження з ешелону польоту до початку злітно-посадкової смуги.

Ключові слова: посадка літаків, криволінійні глісади, граничні траєкторії, моделювання, авіаційна безпека.

A new airplane landing method, that would correspond to the modern civil aviation requirements and assured ecological and economical level enhancement is considered. We present the generation method (calculation and construction) development and modeling of the virtual curvilinear airplane landing descending glide path in the limits of the border trajectories with sustaining of own individual, optimal vertical landing descending profile from flight level to the runway threshold.

Keywords: airplane landing, curvilinear glide paths, border trajectories, modeling, aviation safety.

Introduction. Modern development status in domain of the new landing approach assurance methods of the airborne vehicles (AV) are characterized by the diversity of lead ups to the improvement of air traffic control (ATC) and AV procedures, by the way of the air traffic control specialists operations automatization and the AV crew.

Today, the civil aviation flight quantity is growing constantly, that leads to increasing of the aviation noises level, atmosphere pollution and flight control devices overweighting. Because of the strict international legislation regulation of the ecological safety rules, some limits of aircraft exploitation in airports appeared correspondingly.

For these problems solving, the mission of aviation industry system is to create the correspondingly sets, that would allow:

- elevating the ecological and economical level of flights quantitatively and qualitatively in aviation in general;
- essential elevation of the safety flight level;
- unloading of holding area in the airport area;
- solving the airport overloading problem, that is appearing afterwards rising of air traffic intensiveness;
- elevating the effectiveness of the aviation vehicles, etc.

Modern development analyzes and problem setting

After analyze of literature sources [1–8] further conclusions could be done – one of the efficiency improvement methods is an airplane landing by border (vacant) trajectories. For example, such is the principle of the “flexible” trajectories [4]. Principle of the “flexible” trajectories implements a control programme strategy and it is in realization of “flexible”, updating (frequently recalculating) with prescribed period, programme air traffic trajectory, that provides accomplishing of the control during the “real conditions”. Principle resides in refusal of the navigating airborne traffic matching to preplanned (nominal) trajectory and formation (if necessary) much more profitable traffic trajectories, correspondingly to current situation, on the assumption of the factual conditions of the airplane motion.

Basic difficulties in navigation by the “flexible” trajectories problem solving are stipulated by its doublepoint border character. Quite effective concept of its solving bases on usage of, so called, method of inverse dynamic problems. A characteristic feature of which lies in the fact that, at first, programme motion of AV is designated (that fulfills prescribed border conditions) and then navigation that realizes these motion is determined. However, such concept is unfit for general class of non linear navigational objects.

That’s why a new airplane landing method development, that would, at least fractionally solve the problem of air traffic accordance to the modern aviation regulatory requirements and that would allow assuring of the airborne vehicles exploitation in conditions of the dramatic increasing of air traffic intensiveness – is an actual problem. So, in basis of the work, a new airplane landing method problem is being set, and this method would be directed to correspondence to current civil aviation requirements and enhancement of ecological level and flight economical efficiency [9].

The aim of the work is development of the generation method (calculation and construction) of virtual curvilinear glide path of airplane landing approach in limits of border trajectories with support its own individual, optimal vertical descending profile from flight level to the runway threshold.

Method of airplane landing by curvilinear glide path in limits of the border trajectories

An airplane landing by curvilinear glide paths is the method that provides descending of the airborne vehicles. It tends to reduce fuel consumption level and level of noises in comparison to the other traditional descending methods. Airplane landing by the border curvilinear trajectories provides the fluent airplane descending from a flight level with constant angle for landing on the runway.

An airplane landing by curvilinear glide paths in limits of border trajectories procedure begins from the highest point of the descending start, in other words, on the cruise flight altitude and it allows an airplane to support its own individual optimal vertical profile until the runway threshold.

The aim of landing by the border curvilinear trajectories is reducing of the aviation noises and emissions of gaseous substances in airports and reducing of fuel consumption without an influence on the flights safety.

An optimal vertical profile takes a profile of an uninterruptedly recessive trajectory with the minimal segments of a straight-line motion of AV, that appearing under the necessity of aircraft deceleration. Slope angle of airplane trajectory, usually, is not recorded, but it determinates by the airborne vehicle factual productivity and atmospheric conditions.

Airplane landing by border curvilinear trajectories could be done with or without support of vertical trajectory of flight that is generated by computer (function of vertical navigation in flight control computer). Using of vertical track, that was generated by computer would lead to maximum profits and exploitation simplicity. Optimal slope angle of the trajectory would variate in dependency of the aircraft type, its factual weight, wind, air temperature, atmospheric pressure and frosting conditions and another dynamical data.

Comparison of the current airplane landing method with a new landing method by curvilinear glide paths in the limits of border trajectories

Calculation of landing distance during an ordinary descending from flight level in accordance with utilizable aircraft landing scheme is adduced.

Descending conditions:

- Slope angle of the trajectory – 10 deg;
- Latitudes – [1, 2, …, 10] km;
- Descending start speed 520 km/h (indicated airspeed);
- Speed of landing 270 km/h.

By the modeling results (fig. 1) it is evidently, that for the landing by standard trajectory process accomplishment a long distance descending is necessary. From the 10 km latitude for descending to the ground is necessary to pass 150 kilometers distance. Moreover, the airplane is descending with full power of the engines that increases fuel consumption and emission of the harmful substances into the environment.

Calculation of the developing method of landing by curvilinear glide paths in limits of border trajectories landing distance result is given. The proposed method is based on the use of all aerodynamic and functional abilities of the aircraft to control the lift, speed and drag during the process of descending. It is expected, that all engines are in the "flight-idle" mode from the moment of descending from the flight level.

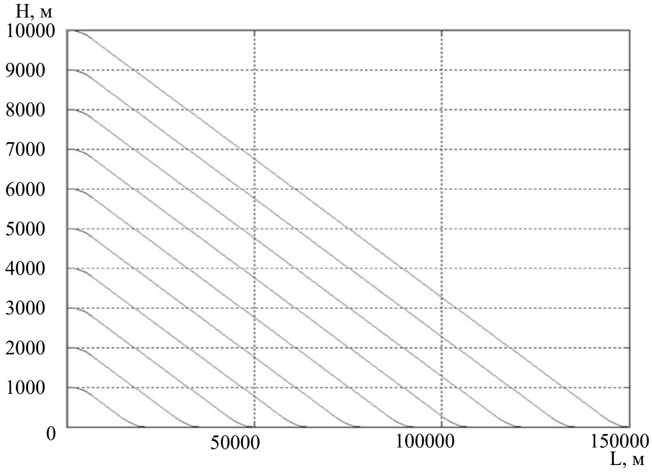

Fig. 1. The airplane landing trajectory graph by standard technology for the different latitudes

Conditions of descending:

- Slope angle of the trajectory – 10 deg;
- Latitudes – [1, 2, …, 10] km;
- Descending start speed 520 km/h (indicated airspeed);
- Speed of landing 270 km/h.

By the results of modeling (fig. 2), it is evidently that over the initial conditions (speed and slope angle of the trajectory) that are equal to standard landing method the difference of landing distance approach in new method is appearing. For the 10 km latitude, distance of landing reduces from 150 km to 60 km. It demonstrates an essential advantage in dependence to the standard technology as a result of more than 55% reducing of the distance.

The new landing method provides sustained flight on the preset flight level and assures 2–2.5 times more effective fuel economy in comparison with the traditional landing technology. As a result, the time of descending and landing approach is reduced from 30–40 minutes from the 10 km latitude to 20–25 minutes, the level of noises and harmful emissions in the airport zone reduces at average by 600–800 kg of carbonium dioxide (CO_2) as well.

The results of accomplished modeling for the turn radius definition during landing by curvilinear border trajectories in horizontal surface during the accomplishment of the turning maneuver before the approaching to the runway with different roll angles [5, 6, …, 10 deg] is shown on fig. 3.

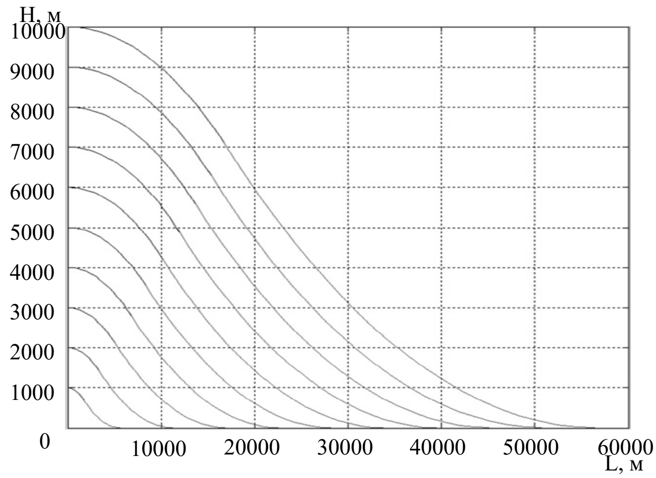

Fig. 2. New method of airplane landing for different latitudes trajectory graph

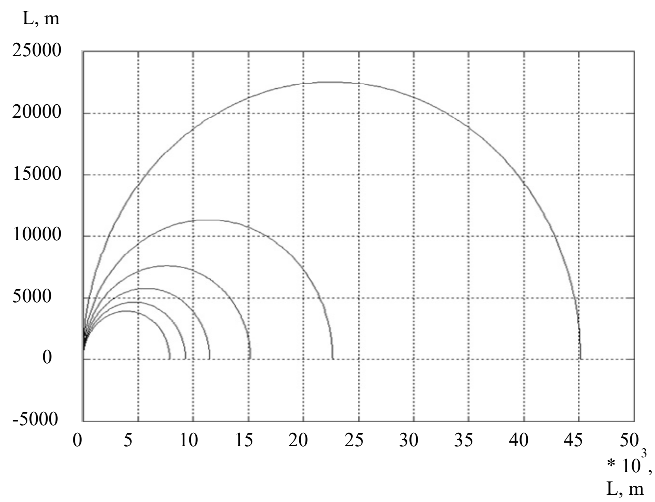

Fig. 3. Turn radius in horizontal surface during the turning maneuver accomplishment before approaching to the runway with the different roll angles

The conditions of descending:

- Slope angle of the trajectory – 10 deg;
- Descending start speed 520 km/h (indicated airspeed);
- Speed of landing 270 km/h.

Landing with horizontal turn maneuver accomplishing allows to approach the runway threshold under the flight by heading that is not allowed during performing the straight approaching to the runway initially.

On the fig. 4 are given the results of landing distance modeling of the new landing method by the curvilinear border trajectories with different initial speed conditions (speed at the beginning of descending [480÷520 km/h] and the speed of landing [240÷270 km/h]), over the same slope angle of the trajectory.

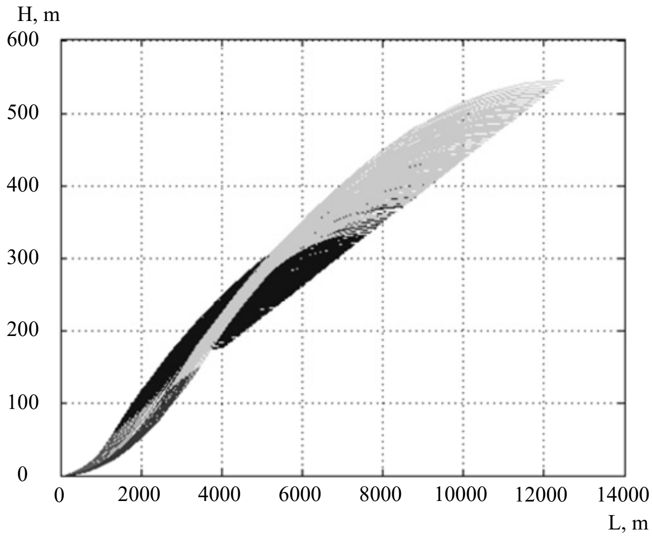

Fig. 4. Landing distance for the new landing method by curvilinear border trajectories with the different initial conditions of speed and with the same slope angle of the trajectory

Such modeling shows the border trajectories for landing procedure accomplishing by curvilinear glide paths. On the graph 2 variants of landing accomplishing are introduced. The first variant is constructed with the condition of hardly fixed overload during the process of landing but with different speeds at the initial point of descending [480÷520 km/h] and in the end of trajectory of descending [240÷270 km/h]. The second variant is constructed under the condition of the hardly fixed speeds at the initial point of descending 520 km/h and at the end of the landing trajectory 260 km/h and different overloads [0,95÷1,15g].

On the fig. 5, the areas at the beginning of the landing descending by the curvilinear border trajectories maneuver accomplishing are adduced in the dependency on distance with the runway [15 – 50 km], the latitude from the descending maneuver could be accomplished [0.5 – 5 km], and slope angles of the trajectory [5–10 deg] with which the procedure of descending is conducted independently to the runway latitude and distance.

Descending could be accomplished by two ways. The first – with constant latitude parameter. The second – with constant slope angle of the trajectory. Consequently, trajectories would be differentiated by the distance and slope angle of the trajectory in the first case and by the distance and latitude of the initial point of descending.

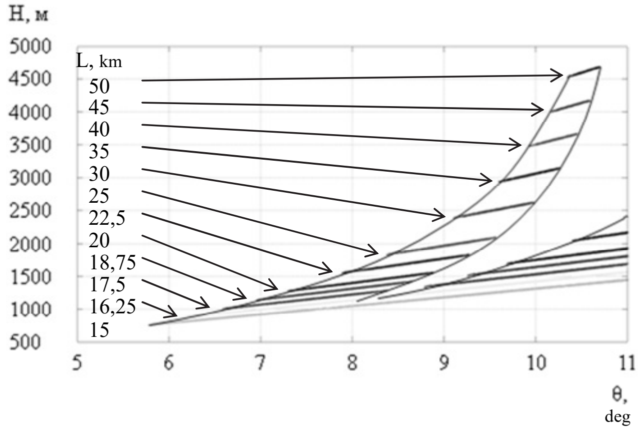

Fig. 5. Areas of the beginning of the landing descending process

On the fig. 6 is given the area of possible landing trajectories by curvilinear glide paths that were constructed with following initial conditions:

- Latitude – 500 meters;
- Slope angle of the trajectory – 10 deg;
- Descending accomplishment start speed – 500 km/h;
- Speed of landing – 270 km/h.

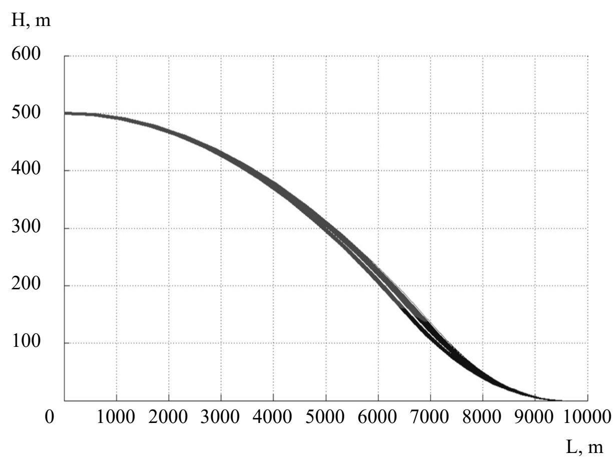

Fig. 6. Zone of possible landing trajectories

The variety of the trajectories gives an image about the trajectory selection strategy during the accomplishment of the descending, because of the possibility to change one method to another during the process of descending (fig. 7).

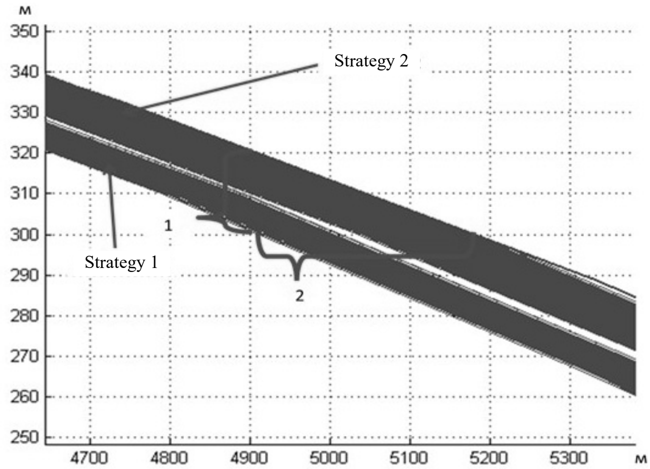

Fig. 7. Zone of possible landing trajectories during the enlargement of a little section from the fig. 6

On the figure 7 enlarged area of the figure 6 is adduced, as an example of selection and transition between the strategies of landing by curvilinear glide paths. As could be seen from the figure, possible airplane landing trajectories by the two curvilinear glide paths strategies are calculated (first strategy – hardly fixed overload with different speeds at the initial point of descending [480÷520 km/h] and at the end of the descending trajectory [240÷ 270 km/h]; second strategy – hardly fixed speeds at the initial point of descending 520 km/h and at the end of the trajectory 260 km/h with the different overloads [0,95÷1,15g]). Also, areas 1 and 2 could be seen on the graph. The first area represents margin of latitudes in which transition between the strategies is allowed at the prescribed distance after the start of descending (at the 4900 m distance, an airplane has a 20 m margin of latitude in which it could make a transition from trajectory of the first strategy to the second). The second area represents the margin of the flight distance, in which transition between strategies and trajectories of these strategies is possible (on the 300 meters latitude an airplane has a 300 meters margin of the distance).

The variety of the airplane landing curvilinear glide paths that were modeled with hardly fixed initial conditions: the speed at the beginning of descending – 500 km/h, the speed of descending – 270 km/h are shown at the figure 8. Variety of the airplane landing curvilinear glide paths that was modeled with hardly fixed initial conditions: the speed at the beginning of descending – 500 km/h, speed of landing – 270 km/h are shown on fig. 8. This variety of trajectories is received as a result of slope angle of the trajectory changing, due to what the calculation must be done. Several airplanes from different flight levels could begin the procedure of landing approach on one runway simultaneously. The difference in time (20–60 sec depending on the latitude difference of airplanes that are accomplishing landing procedure) of landing by their trajectories allows increasing of air traffic intensity at the airports.

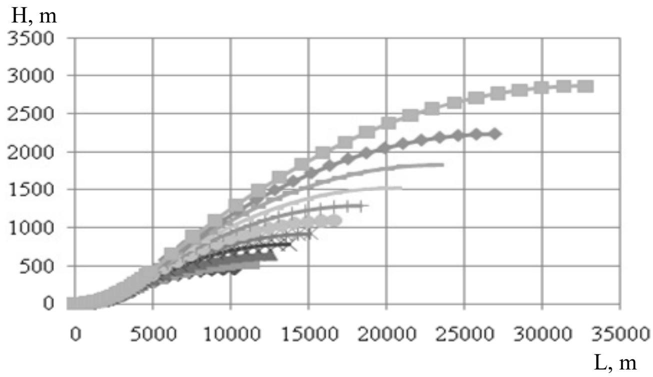

Fig. 8. Complex of curvilinear airplane landing glide paths of an aircraft with the fixed basic conditions

Conclusions

So far as the quantity of flights is constantly increasing, an influence of aviation noise and emission in atmosphere could lead to restrictions at the airfields and increasing of the exploitation expenses.

In order to solve these problems, we presented airplanes landing by curvilinear glide paths offering the flexible descending and flight trajectory during the process of landing approach that assures basic ecologic and economic profits, including reducing of the fuel consumption, the level of gaseous emission and noises without any harmful influence on safety.

The airplane landing by curvilinear glide paths reduce the level of the fuel consumption, noises and emissions in the following way:

1) minimal thrust installed during the descending;

2) minimal aerodynamic drag;

3) increased latitude of the flight trajectory.

Landing by curvilinear glide paths principle is in refuse of the navigating airborne traffic matching to preplanned (nominal) trajectory and formation (if necessary) of much more profitable traffic trajectories, correspondingly to the current situation, on the assumption of factual conditions of the object motion.

Total energy margin of the airborne vehicle on the high latitudes could be used in the most efficient way during the descending with minimal thrust and aerodynamic drag.

It is expected that landing approach by the curvilinear glide paths would allow to increased the airport capacity by 30–40%. In the airport total number of takeoffs and landings from one runway could be increased from 30 to 45 per hour.

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