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PREDICTING THE FLIGHT PATH OF THE AIRCRAFT DURING ENGINELESS APPROACH

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Abstract. *In this article we describe the influence of wind on the path of the aircraft during engineless landing and discuss methods of approach path. In addition, the paper considers the general algorithm accounting influence of wind on the approach path.*

Keywords: approach path; flight management system; graphic VNAV display; equivalent wind; non-directional beacon

1. Introduction

Ensuring of a high level of safety during approach is a priority area of research for aviation. Approach with complete failure of all engines is a very complicated procedure.

Today automation of this procedure is a very important task. Leading aviation design bureau develop algorithms for flight management computer, which are ensuring the implementation of this procedure.

In domestic navigation systems have not engines out mode for approach. It is necessary to develop algorithms of the prediction of the flight path for this mode. Particular attention should be paid to influence of wind.

2. Analysis of last research and publications

Improving of piloting accuracy in the terminal area is impotent problem for the aviation community The theme of high-precision navigation automatic flight was description in many studies [1, 2, 3].

Methods of indicating when approaching landing path were described in [4, 5].

The accounting of influence of wind was described in [6].

3. Purpose of work

Main Purpose:

– Description of influence of wind on the flight path during engineless landing;

– Development of a general algorithm accounting influence of wind on the approach path;

– Description of methods of approach path indication.

4. Methods of indication of approach path

Aircraft vertical navigation (VNAV) systems provide vertical guidance to a specified waypoint at a particular altitude, often along a path defined by a line joining two waypoints at specified altitudes [4]. Alternatively, the path may be defined by a vertical angle from a given waypoint or be a fuel-use-optimized curved path between waypoints [5]. Most flight management system (FMS) equipped aircraft and some area navigation (RNAV) equipped aircraft have VNAV capability. VNAV displays allow the pilot to plan and check a VNAV route, monitor VNAV function when the autopilot or FMS is flying the aircraft, or manually fly the computed approach path. Graphic VNAV displays probably enhance vertical situation awareness. VNAV systems that incorporate some form of flight-path predictor display have been popular among pilots. VNAV capability and map displays are planned for the next generation of GPS Wide Area Augmentation System navigation receivers [5] to make it easier for pilots to fly complex FMS arrivals and approaches within the required narrow navigation performance envelopes.

The basic component of a VNAV display is a vertical course deviation indicator (CDI), analogous to an instrument landing system glideslope needle, which shows vertical path error. Many displays also include some form of flight-path prediction information to offset the workload increase associated with manually flying a glideslope needle through an entire departure or arrival. Perhaps the simplest method is to numerically display a recommended vertical speed that will keep the aircraft converging with the desired path. On some VNAV equipment, this is shown in numeric form. Alternatively, it is sometimes presented as a symbol on a moving map display used for lateral navigation (LNAV). For example, on Boeing–Honeywell FMS displays, a moving green altitude range arc continuously shows where the aircraft will reach the preselected altitude. Pilots adjust vertical speed to keep the altitude range arc on the display superimposed over the next waypoint.

Many altitude deviation incidents have been attributed to the lack of explicit vertical situation information in the cockpit. Because moving map displays do not depict the aircraft's vertical situation explicitly, some manufacturers have experimented with supplemental profile displays that graphically depict altitude versus distance en route in a manner analogous to the profile (elevation) view on a paper instrument approach plate. One model includes a flight-path predictor vector. Typically, the profile view has been located in a narrow area beneath the moving map display, so altitude resolution has been a concern.

5. Influence of wind on the flight path

It is necessary to bring the airplane to Non-Directional Beacon on a certain height. This height is significantly dependent of wind direction and strength (see. Fig. 1).

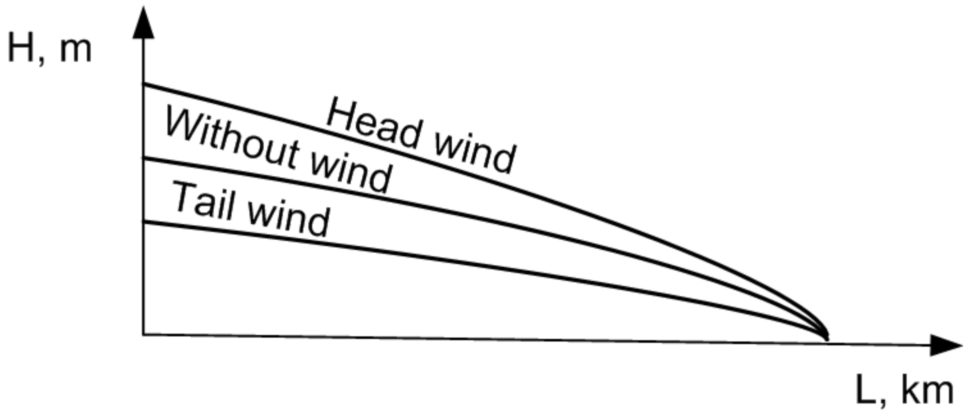

Fig. 1. Influence of wind on the approach path

Approach time is determined by numerical integration of the following expression:

$$t = \int_{H_0}^{H_c} \frac{dH}{V_y},$$

where t – time of flight;

Hc – height of the completion of mode;

H_0 – the height of the beginning of mode.

dH– integration step;

Vy – vertical speed.

The range of the approach is determined by numerical integration of the following expression:

$$L = \int_{H_0}^{H_c} \frac{V_x dH}{V_y},$$

where L – range;

H_c – height of the completion of treatment;

H_0 – height of the beginning of the regime.

dH – integration step;

Vy – vertical speed;

Vx – horizontal component of the true air speed.

Influence of wind is taken into account at each step of the integration:

$$\Delta L = (V_x + U_e)\, \Delta t,$$

where ΔL – the change of distance per one step of integration;

Δt – change of time per one step of integration;

U_e – equivalent wind;

Now consider in detail the calculation of equivalent wind.

When solving navigation tasks can estimate influence of wind on the ground speed, if we use the equivalent wind entered the international Civil Aviation Organization (ICAO). Conditional wind is called the equivalent wind (U_e), if its direction coincides with the desired course, and the value of its speed at a given path flight mode produces the same ground speed, as well as the actual wind speed [6] is the difference between the ground speed and the true airspeed at a given point of the route of flight:

$$U_e = W - V,$$

where U_e – equivalent wind;
W – ground speed;
V – true airspeed.

Thus, the equivalent wind can only be favourable (positive) or contrary (negative) (see fig. 2).

Equivalent Wind speed is determined by the parameters of the actual wind (ground speed):

$$W = V\cos(DA) + U\cos(WTA).$$

where DA – drift angle;
WTA – wind track angle.

From the equation

$$\frac{\sin(DA)}{U} = \frac{\sin(WTA)}{V} = \frac{\sin(DA+WTA)}{W},$$

follows that

$$\sin(DA) = \frac{U\sin(WTA)}{V},$$

from where

$$\cos(DA) = \sqrt{1-\left(\frac{U\sin(WTA)}{V}\right)^2},$$

and ground speed can be represented as

$$W = U\cos(WTA) + V\sqrt{1-\left(\frac{U\sin(WTA)}{V}\right)^2},$$

In view of this relationship can be written:

$$U_e = U\cos(WTA) + V\sqrt{1-\left(\frac{U\sin(WTA)}{V}\right)^2} - V.$$

Equivalent wind (see. Fig. 2) is approximately equal to

$$U_e \approx \Delta U = U\cos(WTA).$$

The concept of equivalent wind associated with a specific actual wind and the direction of flight. It is valid only for a limited area and time.

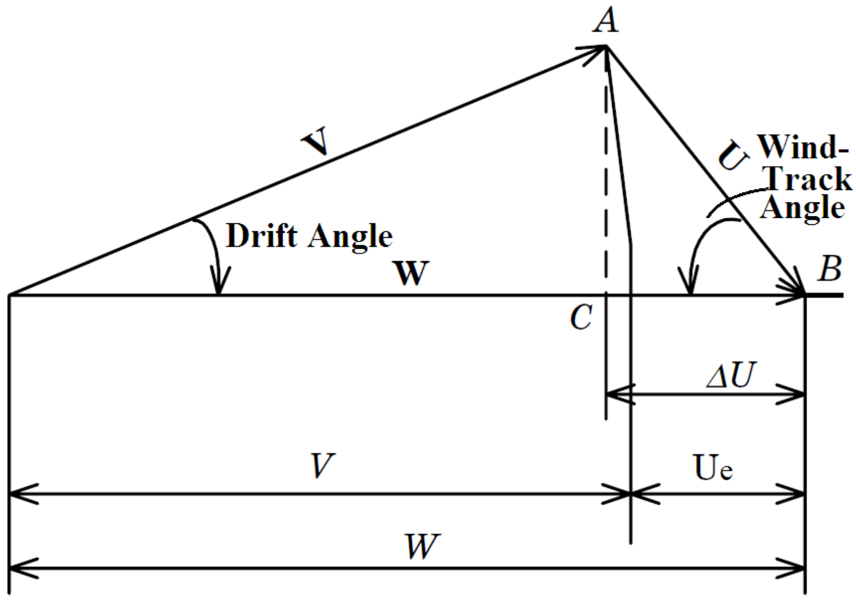

Fig. 2. Equivalent wind Equivalent wind is especially useful in cases where it is necessary to consider the influence of the wind around the flight route or a certain part of it

6. Conclusions

In this article we describe influence of wind on the trajectory of the aircraft during engineless landing. Methods of approach path indication are also discussing in this work.

In addition, we have developed a general algorithm accounting influence of wind on the approach path.

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М.В. Коршунов. Прогнозування траєкторії польоту літака під час безмоторного заходу на посадку

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У статті описано вплив вітру на траєкторію польоту літака протягом безмоторного заходу на посадку. Для розрахунку пройденого шляху використовується поняття еквівалентного вітру. Поняття про еквівалентний вітер пов’язано з конкретним значенням фактичного вітру й напрямком польоту. Еквівалентний вітер особливо зручно використовувати у тих випадках, коли необхідно врахувати вплив вітру на маршруті або на окремих його частинах. Обговорюються різні способи індикації траєкторії посадки. Також розглянуто загальний алгоритм урахування впливу вітру на траєкторію польоту літака.

Ключові слова: графічний дисплей вертикальної навігації; еквівалентний вітер; навігаційний обчислювач; приводний радіомаяк; траєкторія посадки

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В статье описывается влияние ветра на траекторию полёта самолета во время безмоторного захода на посадку. Для учета пройденного пути применяется понятие эквивалентного ветра. Понятие об эквивалентном ветре связано с конкретным значением фактического ветра и направлением полета. Эквивалентный ветер особенно удобно использовать в тех случаях, когда надо учитывать влияние ветра по всему маршруту полета или на его определенной части. Обсуждаются способы индикации посадочной траектории. Также рассмотрен общий алгоритм учета влияния ветра на траекторию полета самолета при посадке.

Ключевые слова: графический дисплей вертикальной навигации; навигационный вычислитель; приводной радиомаяк; траектория посадки; эквивалентный ветер

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