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ADAPTIVE ALGORITHM FOR IMPLEMENTING CONTINUOUS DESCENT OF THE AIRCRAFT

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In this article we describe the main aspects of continuous descent operations (CDO). Advantages of CDO application are discussing. CDO can enable several specific strategic objectives to be met and should therefore be considered for inclusion within any airspace concept or redesign. Considered also is the general adaptive algorithm of the forecast of continuous descent path and described influence of wind on the flight path

Key words: continuous descent operations, forecast of the flight path, full descent gradient, airspace configuration

Formulation of the problem

Continuous descent operations (CDO) is one of several tools available to aircraft operators to increase safety, flight predictability, and airspace capacity, while reducing noise, controller-pilot communications, fuel burn and emissions [1]. Over the years, different route models have been developed to facilitate CDO and several attempts have been made to strike a balance between the ideal fuel efficient and environmentally friendly procedures and the capacity requirements of a specific airport or airspace.

Future developments are expected to allow different means of realizing the performance potential of CDO without compromising the optimal airport arrival rate. The core CDO concept at the heart of this work will also apply to increasingly sophisticated methods of facilitating CDO.

CDO are enabled by airspace design, procedure design and facilitation by ATC, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix/final approach point. An optimum CDO starts from the top-of-descent (TOD) and uses descent profiles that reduce controller-pilot communications and segments of level flight. Furthermore it provides for a reduction in noise, fuel burn and emissions, while increasing the predictability of flight path to both controllers and pilots as well as flight stability.

Standardization of procedures is important for flight safety and need to be designed and presented in an unambiguous manner. For the procedure designer, it is important to understand the flight characteristics, limitations and capabilities of aircraft expected to perform CDO, as well as the characteristics of the airspace and routes where it will be used.

For airport operators and environmental entities, it is important to understand the extent and limitations of environmental benefits, aircraft performance, and airspace limitations when proposing to introduce CD operations. Considering the high cost of fuel and growing concerns about the environment and climate change, collaborating to facilitate CDO is an operational imperative where all stakeholders will benefit.

Analysis of last research and publications

Maintenance of safety during all phases of flight is impotent problem for the aviation community. Depending on the airspace concerned, and the method of CDO facilitation chosen, optimizing the benefits of CDO will be maximized by a review of the airspace configuration for CDO, taking into account separation and sequencing requirements. The design and operation of both strategic and tactical de-confliction measures should take into account the profile envelopes expected to be followed by the range of aircraft using the procedures, in order to facilitate CDO to the extent possible. The problem of the airspace configuration for CDO was description in studies [1, 2].

Purpose:

The purpose of this work is to describe the main aspects of continuous descent operations. The article describes an algorithm of the forecast of continuous descent path.

Advantages of CDO application

CDO offer the following advantages [1]:

- more efficient use of airspace and arrival route placement;
- more consistent flight paths and stabilized approach paths;
- reduction in both pilot and controller workload;
- reduction in the number of required radio transmissions;
- cost savings and environmental benefits through reduced fuel burn;
- reducing the incidence of controlled flight into terrain (CFIT); and
- operations authorized where noise limitations would result in operations being curtailed or restricted.

Depending on the airspace concerned, and the method of CDO facilitation chosen, optimizing the benefits of CDO will be maximized by a review of the airspace configuration for CDO, taking into account separation and sequencing requirements. The design and operation of both strategic and tactical de-confliction measures should take into account the profile envelopes expected to be followed by the range of aircraft using the procedures, in order to facilitate CDO to the extent possible. If ATC were to lose the flexibility to fully optimize sequencing and management of arrival flows, there could be a risk of reduced capacity and efficiency. Thus CDO should not be achieved at the expense of safety, capacity, flight efficiency or expedition and should be considered as being «the art of the possible» and, while «highly desirable» it is not to be achieved at any cost.

Early sequencing of aircraft can assist in increasing both the frequency and duration of CDO performed, especially during high traffic density level periods.

Adaptive algorithm for calculation of the continuous descent path

Forecast of the flight path is performed through the use of the full descent gradient (). The full gradient is a function of altitude, gross weight, outdoor temperature, engine mode and ratio of airspeed to stall speed.

Full descent gradient conveniently determined by nomograms presented in fig. 1. To solve assigned task it is necessary to have a number of nomograms covering the full range of engine modes.

Use the formula to calculate the change of the flight speed [3]:

$$\frac{dV}{dt} = g(n_X - \sin\theta).$$

where V – true airspeed;

n_X– longitudinal overload;

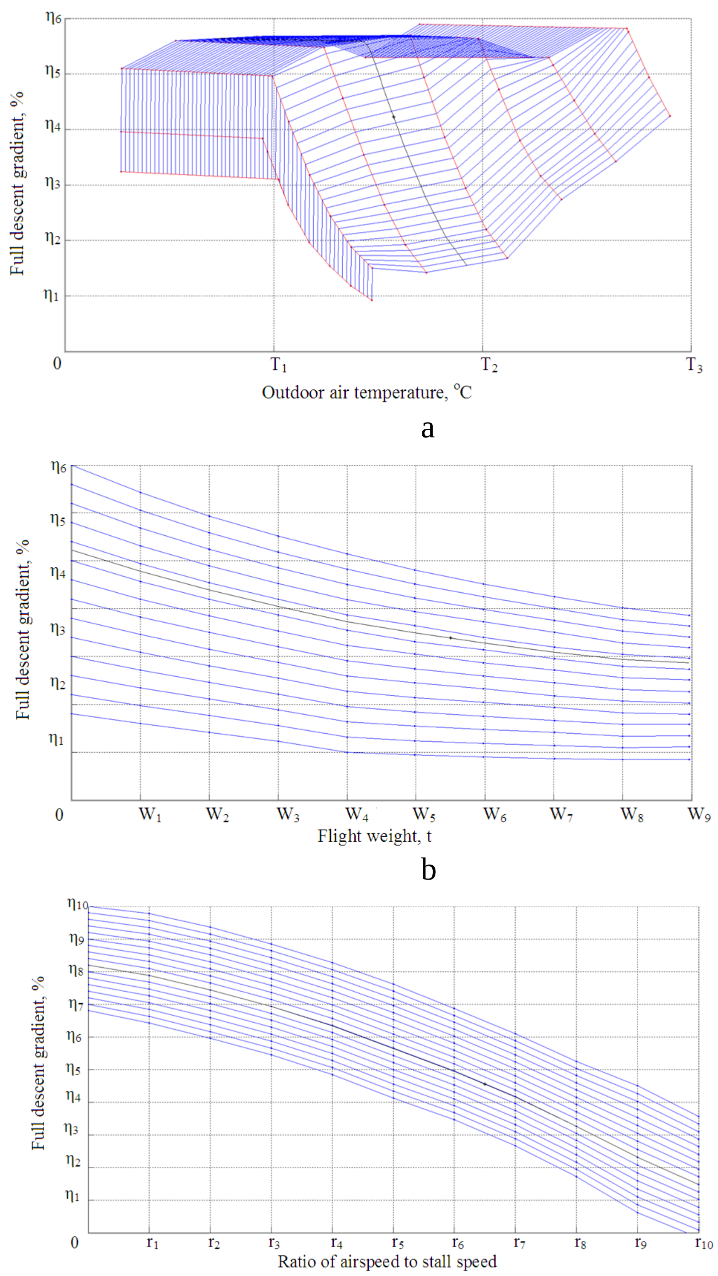
θ – given descent gradient.

Next, we obtain longitudinal overload:

$$n_X = \frac{dV}{gdt} - \sin\theta.$$

Taking into account that the longitudinal overload (n_x) in this case is stationed (full) descent gradient (η), we obtain the formula:

$$\eta = \frac{dV}{gdt} - \sin\theta.$$



a

b

c

Fig. 1. Nomograms for determination of full descent gradient (thrust at idle): a) function of outdoor temperature (T), b) function of gross weight (W), c) function of ratio of airspeed to stall speed (r)

On the basis of the obtained gradient determines the engine mode. Then determine the fuel consumption.

Change of location in vertical plane of the airspace depending on the flight time is given by

$$dL = \int_{t_0}^{t_C} V \cos\theta dt;$$

$$dH = \int_{t_0}^{t_C} V \sin\theta dt,$$

where t_C – time of the completion of mode;
t_0 – time of the beginning of mode;
dt– integration step.

The calculation should include adaptive algorithms to improve the accuracy of the forecast.

For the correction of the forecast of continuous descent path should be considered the present value of the equivalent wind in calculation. 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 [4] 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.

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 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. 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.

Conclusions

In this article we have presented a general algorithm of the forecast of continuous descent path and described influence of wind on the flight path.

In addition, we have described the main aspects of continuous descent operations. CDO can enable several specific strategic objectives to be met and should therefore be considered for inclusion within any airspace concept or redesign.

Literature

1. ICAO DOC. 9931 AN/476. Continuous Descent Operations (CDO) Manual. 2010. Montreal. - 57 p.

2. ICAO DOC. 8168 OPS/611. Aircraft Operations. Volume II. Construction of Visual and Instrument Flight Procedures. 2006. Montreal. - 700 p.

3. Byushgens G.S. 1984.Aerodynamics and flight dynamics haul aircraft. Textbook. Moscow. Publishing Department of TsAGI. - 772 p.

4. Mamaev V.Ya.; Sinyakov A.N.; Petrov K.K.; Gorbunov D.A. 2002. Airnavigation and elements of pilotage. Textbook. St. Peterburg. State University of Aerospace Instrumentation. - 256 p. (in Russian).

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