UDC 629.735.051-52:681.518.24 (045)

[1]**N. V. Korshunov,**
[2]**V. V. Pavlov,**
[3]**G. I. Rudyuk**

THE DATABASE OF AIRCRAFT PERFORMANCE CHARACTERISTICS

[1,3]Antonov Company
[2]Internetional Research and Training Center for Information technologies and Systems of the National Academy of Sciences (NAS) of Ukraine and Ministry of Education and Science (MES) of Ukraine
E-mails: [1]master512@ukr.net, [2]vpavlov@nau.edu.ua, [3]rudyuk@antonov.com

Abstract—*In this article we describe the main aspects of implementation of a database for flight control of the aircraft. Ways of increasing the accuracy of the initial data are describing there. We also describe a method of interpolation of aircraft performance characteristics. These performance characteristics are used to calculate the desired vertical flight path. In addition, the article describes an adaptive algorithm for the prediction of vertical flight path, which is based on the substitution of the parameters from the database.*

Index terms—Aircraft performance characteristics; database; flight control; optimum path; interpolation.

I. INTRODUCTION

Nowadays the system of flight control of the aircraft in the vertical plane must be able to construct a path to perform the following functions [1]:

− formation of the flight plan in the vertical plane;

− generation of control signals for performing piloting in the vertical plane in accordance with a predetermined flight plan at all stages: takeoff, climb, cruising, descent, approach to landing, missed approach;

− change in the flight plan in the vertical plane;

− select the recommended departure procedures;

− calculation of the remaining time and distance to the beginning of descent in the set point;

− calculation of the profile of the climb when you set the mode dial;

− calculation of the parameters of the flight plan;

− control and signaling deviations from the preselected spatial trajectory.

Consider the basic functional modules, solves the problem of forming and keeping the spatial trajectory.

This module consists of a set of procedures for performing the following functions:

− procedure for calculation of the parameters of vertical profile schemes SID / STAR / APPR for a given runway, given departure/landing aerodrome;

− procedure for calculation of the stage os climd / descent, locating points of the vertical profile of TOC (Top of climb), TOD (Top of descend) (the distance to the next nearest check point) in the total flight plan;

− procedure for calculation of the parameters of vertical path for the stage of climb / descent on the route;

− procedure for calculation of the parameters of the flight plan (latitude, longitude specified track angle, magnetic variation, given airspeed / Mach) points to the vertical profile of TOC, TOD;

− procedure for calculation of airspeed for each phase of flight, depending on the mode optimization.

All of these procedures in the calculation based on the information the navigation database and the database of performance characteristics.

II. PROBLEM STATEMENT

The task is the development of the database of aircraft performance characteristics.

Aircraft performance characteristics [2] aircraft are determined by the results of experiment in the wind tunnel and refined during flight testing and presented as nomograms. The typical form of a nomogram is shown in Fig. 1.

This nomogram is used to determine the maximum allowable flight gradient. This gradient is a function of altitude, outdoor temperature or a deviation from the standard atmosphere, gross weight, ratio of airspeed to stall speed (V / V_{S1}).

In the board computers these data form the electronic database of performance characteristics, which is containing nomograms in table form. The nomogram in table form is arrays points X_i ($i = 1 \dots n$) and Y_j ($j = 1 \dots m$), called nodes.

III. ANALYSIS OF LAST RESEARCH AND PUBLICATIONS

Determination of aircraft performance characteristics with high accuracy is impotent task.

It is necessary to create the database of the aircraft performance characteristics for performance-baced navigation (PBN) [3]. Currently, PBN aims to harmonise longitudinal and lateral performance requirements (i. e. 2D) for both RNAV and RNP specifications and in the future, a progression is expected to include 4D trajectory-based operations. Although PBN implementations will continue to be based on both RNAV and RNP specifications, future developments will focus on new RNP specifications. As more reliance is placed on GNSS, the development of airspace concepts will increasingly need to ensure the coherent integration of navigation, communication and ATS surveillance enablers.

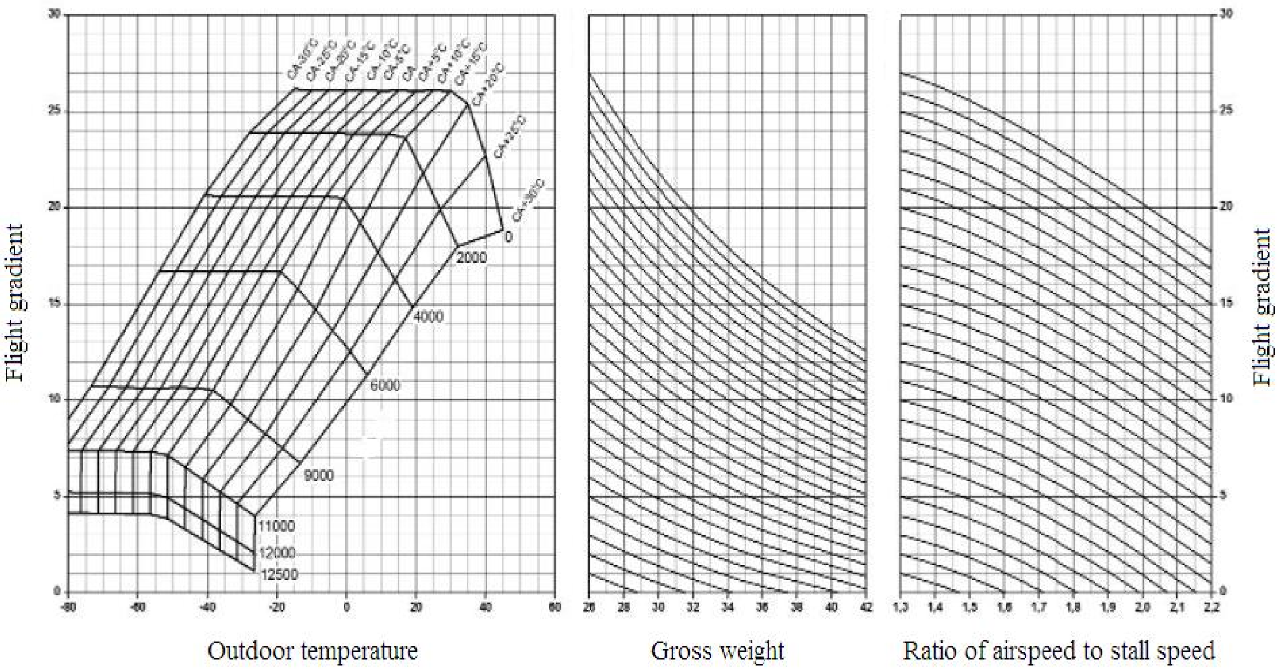

Fig. 1. The typical form of a nomogram for determination of aircraft performance characteristics

In the work [2], the authors raise a problem of choosing the optimal way to determine the takeoff and landing characteristics according to the nomograms, which are shown in the tabularform.

Purpose

The purpose of this work is to describe development of database of the aircraft performance characteristics.

IV. DEVELOPMENT OF DATABASE OF AIRCRAFT PERFORMANCE CHARACTERISTICS

In the [2] author carries out the comparative analysis of the existing methods of interpolation of aircraft performance characteristics from the calculation speed and accuracy point of view and grounds the rightness of selected method usage. All calculations are carried out on the basis of the data provided on Fig. 1. However the calculations which are carried out according to this nomogram are inexact. For increase of accuracy of definition of flight characteristics it is necessary to create a series of the nomograms for all expected flight altitude. The smaller the step altitude in a series of the nomograms, the greater the accuracy of the determination of performance. Consider a specific example of the definition of performance. For example, you must define the descent gradient of aircraft at altitude 12200m. Let's say in a database of flight technical characteristics there are nomograms of definition of descent gradient with a step on altitude 500 m: H = 12500, 1200, …, 0. In Fig. 2 are shown the nomogram for flight altitude 12500 m.

For a start we determine a decrease gradient for altitude 12500 m by this nomogram. As can be seen from Fig. 2 it is equal to –7.19 %.

Then we define a decrease gradient for height of 12000 m. As shown in Fig. 3 it is equal to –7.88 %.

For finding of a gradient of decrease on 12200 m it is applicable linear interpolation (Fig. 4).

$$\theta = \theta_0 + \frac{(H - H_0)}{(H_1 - H_0)}(\theta_1 - \theta_0),$$

where θ is the gradient at altitude equal 12200 m;

θ_0 is the gradient at altitude equal 12000 m;

θ_1 is the gradient at altitude equal 12500 m;

H is the altitude 12200 m;

H_0 is the 12000 m altitude;

H_1 is the 12500 m altitude.

Substitute numerical values and obtain:

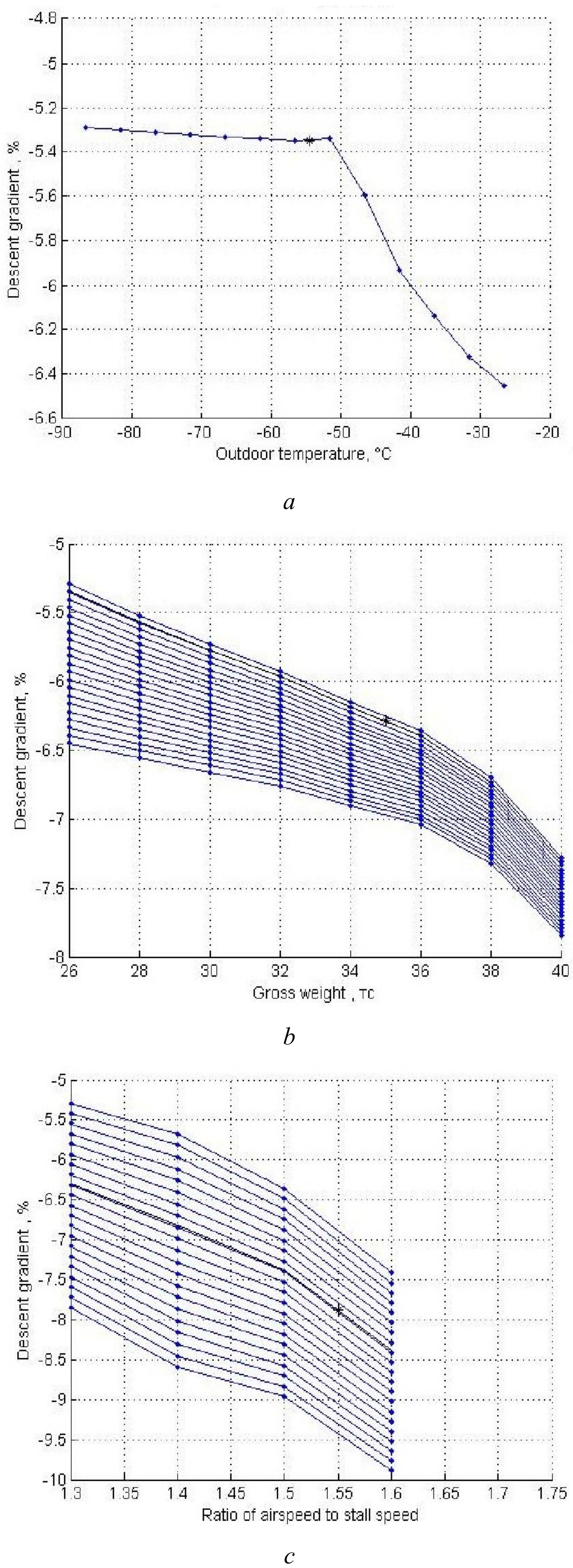

Fig. 2. The nomogram for determination of the descent gradient of aircraft at altitude 12000 *m*: *a* is the function of outdoor temperature (*T*): *b* is the function of gross weight (*W*); *c* is the function of ratio of airspeed to stall speed (*r*)

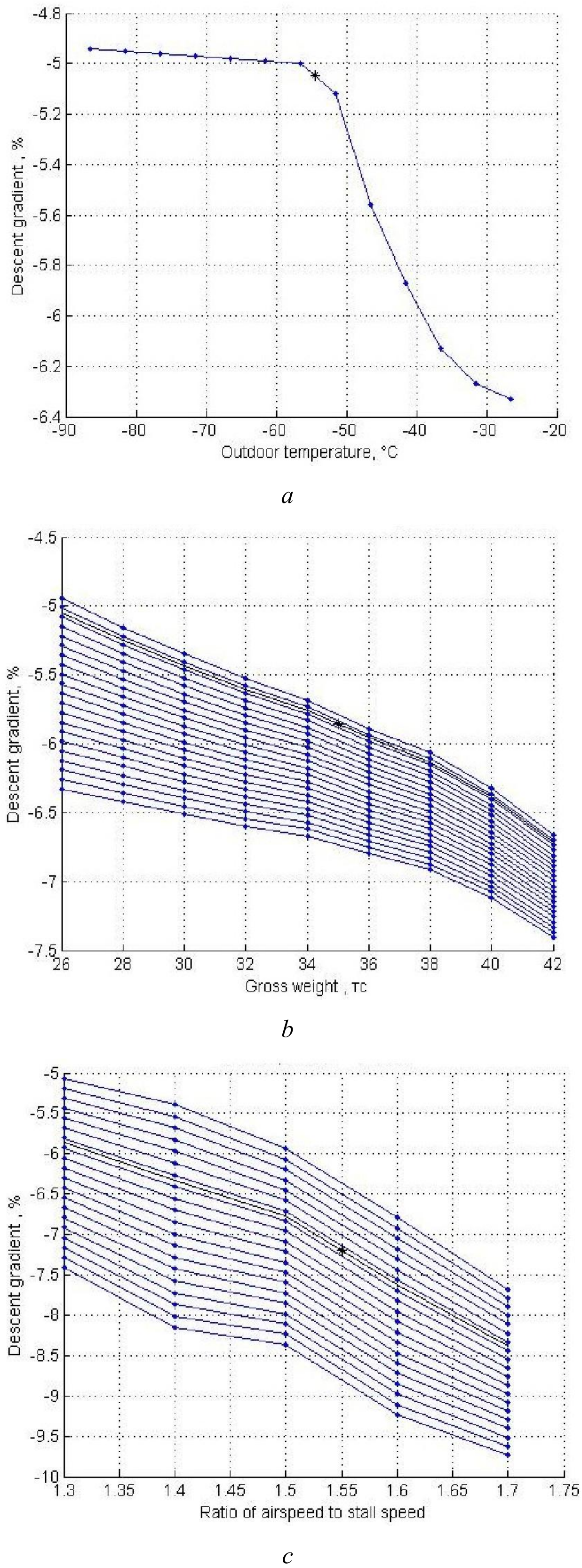

Fig. 3. The nomogram for determination of the descent gradient of aircraft at altitude 12500 *m*: *a* is the function of outdoor temperature (*T*); *b* is the function of gross weight (*W*); *c* is the function of ratio of airspeed to stall speed (*r*)

$$\theta = -7.19\% + \frac{(-12200m + 12000m)}{(-12500m + 12000m)}(-7.88\% + 7.19\%) = 7.47\%.$$

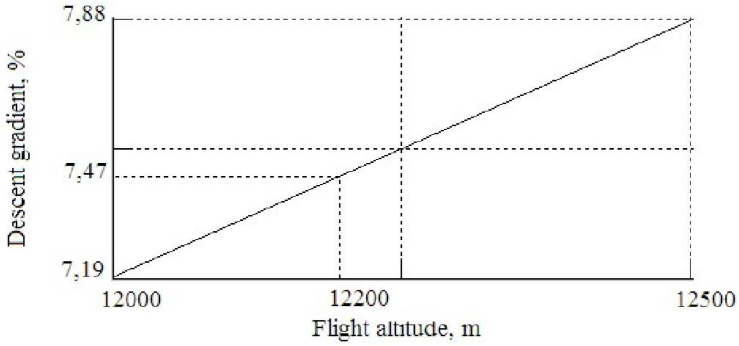

Fig. 4. The linear interpolation for determination of the descent gradient of aircraft at the desired flight altitude

CONCLUSIONS

In this article we have described the database of the aircraft performance characteristics.

The offered database allows to define aircraft performance characteristics with a high accuracy. The received characteristics are applied to formation of the operating signals (optimum vertical path angle) in the vertical plane. The optimum vertical path angle will vary depending on the type of aircraft, its actual weight, the wind, air temperature, atmospheric pressure, icing conditions, and other dynamic considerations [4]. However, the maximum benefit for an individual flight is achieved by keeping the aircraft as high as possible until it reaches the optimum descent point. This is most readily determined by the onboard FMS, which uses the above database.

REFERENCES

[1] Alkina, M. P.; Danilin, P. E.; Kalinina I. V. and Kuznetsov, A. G. (2011). "Special consideratios relating to the flight plan generation for the 3D trajectory implementing". *Journal Proceedings of the Moscow Institute of Electromechanics and Automatics*. Moscow, MIEA Publ., no. 4: 84–91 (in Russian).

[2] Alkina, M. P.; Dubova, I. V. and Kalinina, I. V. (2010). "Comparative analysis of non-linear functions interpolation methods of take-off and landing characteristics parametrization". *Journal "Proceedings of the Moscow Institute of Electromechanics and Automatics*. Moscow, MIEA Publ., no. 4: 84–91 (in Russian).

[3] ICAO DOC. 9613 AN/937. Performance-based navigation manual. Vol. I. Concept and implementation guidance. Vol. II. Implementing RNAV and RNP operations. Manual. 2013. 379 p.

[4] ICAO DOC. 9931 AN/476. Continuous Descent Operations (CDO) Manual. 2010. Montreal. 57 p.

Received 29 April 2015

Korshunov Nikolay. Postgraduate.
Antonov Company, Kyiv, Ukraine.
Education: National Aviation University, Kyiv, Ukraine (2011).
Research area: adaptive control, aircraft control systems, design of perspective aviation equipment.
Publications: 1.
E-mail: master512@ukr.net

Pavlov Vadim. Doctor of Engineering. Professor.
Research and Training Center for Information technologies and Systems of the National Academy of Sciences (NAS) of Ukraine and Ministry of Education and Science (MES) of Ukraine.
Education: Kyiv Polytechnic Institute, Kyiv, Ukraine (1956).
Research area: complex dynamic systems.
Publications: more than 300.
E-mail: vpavlov@nau.edu.ua

Rudyuk Gryhoriy. Ph. D. Chief Designer.
Antonov Company, Kyiv, Ukraine.
Education: Kiev Civil Aviation Engineers Institute, Kyiv, Ukraine (1981).
Research area: aircraft control systems, flight simulators, design of perspective aviation equipment.
Publications: 15.
E-mail: rudyuk@antonov.com

М. В. Коршунов, В. В. Павлов, Г. І. Рудюк. База даних льотно-технічних характеристик літака

Розглянуто основні аспекти реалізації бази даних для керування польотом літака. Обговорено способи підвищення точності розрахунків, що базуються вихідних даних. Описано методи інтерполяції льотно-технічних характеристик літака. Дані характеристики використовуються для розрахунку заданої вертикальної траєкторії польоту. Також описано адаптивний алгоритм прогнозу вертикальної траєкторії польоту, що базується на заміні параметрів з бази даних.

Ключові слова: льотно-технічні характеристики літака; база даних; керування польотом; оптимальна траєкторія, інтерполяція.

Коршунов Микола В'ячеславович. Аспірант. Конструктор.
ДП «Антонов», Київ, Україна.
Освіта: Національний авіаційний університет, Київ, Україна (2011).
Напрям наукової діяльності: адаптивне управління, системи управління літальними апаратами, конструювання перспективної авіаційної техніки.
Кількість публікацій: 1.
E-mail: master512@ukr.net

Павлов Вадим Володимирович. Доктор технічних наук. Професор.
Міжнародний науково-навчальний центр інформаційних технологій і систем НАН України та МОН України, Київ, Україна.
Освіта: Київський політехнічний інститут, Київ, Україна (1956).
Напрямок наукової діяльності: складні динамічні системи.
Кількість друкованих праць: понад 300.
E-mail: vpavlov@nau.edu.ua

Рудюк Григорій Іванович. Кандидат технічних наук. Головний конструктор.
ДП «Антонов», Київ, Україна.
Освіта: Київський інститут інженерів цивільної авіації, Київ, Україна (1981).
Напрям наукової діяльності: системи керування літальними апаратами, авіаційні тренажери, конструювання перспективної авіаційної техніки.
Кількість публікацій: 15.
E-mail: rudyuk@antonov.com

Н. В. Коршунов, В. В. Павлов, Г. И. Рудюк. База данных летно-технических характеристик самолета

Рассмотрены основные аспекты реализации базы данных для управления полетом самолета. Обсуждались способы повышения точности расчетов на основе исходных данных. Также описаны методы интерполяции летно-технических характеристик самолета. Данные характеристики применяются для расчета заданной вертикальной траектории полета. Кроме того, описан адаптивный алгоритм прогноза вертикальной траектории полета, основанный на подмене параметров из базы данных.

Ключевые слова: лётно-технические характеристики самолёта; база данных; управление полётом; оптимальная траектория; интерполяция.

Коршунов Николай Вячеславович. Аспирант. Конструктор.
ГП «Антонов», Киев, Украина.
Образование: Национальный авиационный университет, Киев, Украина (2011).
Направление научной дейтельности: адаптивное управление, системы управления летательными аппаратами, конструирование перспективной авиационной техники.
Количество публикаций: 1.
E-mail: master512@ukr.net

Павлов Вадим Владимирович. Доктор технических наук. Профессор.
Международный научно-учебный центр информационных технологий и систем НАН Украины и МОН Украины, Киев, Украина.
Образование: Киевский политехнический институт, Киев, Украина (1956).
Направление научной дейтельности: сложные динамические системы.
Количество публикаций: более 300.
E-mail: vpavlov@nau.edu.ua

Рудюк Григорій Іванович. Кандидат технических наук. Главный конструктор.
ГП «Антонов», Киев, Украина.
Образование: Киевский институт инженеров гражданской авиации, Київ, Україна (1981).
Напрям наукової діяльності: системы управления летательными аппаратами, авиационные тренажеры, конструирование перспективной авиационной техники.
Количество публикаций: 15.
E-mail: rudyuk@antonov.com