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Procedia Computer Science 103 (2017) 82 – 87

Procedia Computer Science

XIIth International Symposium «Intelligent Systems», INTELS'16, 5-7 October 2016, Moscow, Russia

Intelligent support for aircraft flight test data processing in problem of engine thrust estimation

O.N. Korsun[a],*, B.K. Poplavsky[b], S.Ju. Prihodko[c]

[a]*State Institute of Aviation Systems, 7 Viktorenko str., Moscow 125319, Russia*
[b]*Gromov Flight Research Institute, 2A Garnaeva str., Zhukovsky 140180, Russia*
[c]*Moscow Aviation Institute (National Research University), 4 Volokolamskoe shosse, Moscow 125310, Russia*

Abstract

The report deals with the design of the intelligent support for flight test data processing in the problem of separate estimation of aircraft thrust and drag forces in flight experiment. The thrust and drag identification belongs to the class of incorrect inverse problems, for which reason it is not to be solved by general system identification methods and their applications to aerodynamic parameter estimation from the flight data. The paper considers the specific aspects of the intelligent support for thrust and drag identification from the automatic estimation viewpoint of identification accuracy. The proposed algorithms are tested at the set of data generated using a modern aircraft simulation facility.

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Peer-review under responsibility of the scientific committee of the XIIth International Symposium "Intelligent Systems"

Keywords: aircraft; engine; flight test data; engine thrust estimation; estimation of aircraft drag forces; flight experiment; thrust identification; aircraft simulation facility.

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1. Introduction

In the problem of separate estimation of aircraft thrust and drag forces in flight experiment the thrust and drag identification belongs to the class of incorrect inverse problems[1], for which reason it is not to be solved by general system identification methods and their applications to aerodynamic parameter estimation from the flight data[2,3,4]. The report develops the approach proposed in[5]. The paper considers the specific aspects of the intelligent support for

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* Corresponding author.
E-mail address: marmotto@rambler.ru

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Peer-review under responsibility of the scientific committee of the XIIth International Symposium "Intelligent Systems"
doi:10.1016/j.procs.2017.01.017

thrust and drag identification from the viewpoint automatic estimation of identification accuracy. The proposed algorithms are tested at the set of data generated using a modern aircraft simulation facility.

2. Statement of the problem

The problem is formulated in the system of the coordinate axes related to the plane. As an example, let us consider the equation of forces acting on the aircraft along the x-axis associated with the aircraft:

$$P_x(t) = mgn_x(t) + C_x(t)qS \tag{1}$$

where $P_x(t)$ - the projection of thrust;

$n_x(t)$ - component of the vector overload;

$C_x(t)$ - coefficient of drag aerodynamic force;

$q(t) = 0,5\rho V^2$ - dynamic pressure;

m - aircraft weight;

S - wing area.

Let us substitute into equation (1) the results of measurements performed in flight, comprising measurement errors. The result:

$$P_x(t) = mgn_x(t) + C_x(t)q(t)S + \varepsilon(t) \tag{2}$$

where $\varepsilon(t)$ - equation discrepancy.

Let us assume measurement discretization interval being constant and denominate it as $\Delta t = h$. Then the discrete time moments for N successive measurements made on the processing interval are as follows: $t_i = hi, i = 0...N$.

To solve the problem let us define the sliding base interval containing $2m+1$ measurements of each parameter for the time moments $[t_{k-m} \cdots t_k \cdots t_{k+m}]$.

To simplify the calculations let us regard the mid-point of the sliding base interval as its zero point, believing $t_k = 0$.

Then for all the points of this sliding interval it's possible to form the system of equations

$$P_x(t_j) = mgn_x(t_j) + C(t_j)q(t_j)S + \varepsilon(t_j),\ (j = -m \ldots m) \tag{3}$$

To identify the separate estimates of thrust $P_x(0)$ and drag coefficients $C_x(0)$ at the midpoint of the sliding base interval it is necessary to make a number of assumptions about the nature of changes of the parameters of flight within a sliding base interval, that is for time $t \in [t_{-m} \cdots t_m]$.

Let's assume that

$$T \in \left[t_{-m} \cdots t_{j \cdots t_m}\right], \quad P_x(t_j) = const = P_x(0) ,$$

$$C_x(t_j) = C_x(0) + C_x^a(0)\Delta a(t_j), (j = -m...m),$$

where $P_x(0), C_x(0), C_x^\alpha(0), \alpha(0)$ parameter values at the midpoint of the sliding interval $[t_{-m \ldots} t_m]$, $\Delta\alpha(t_j) = \alpha(t_j) - \alpha(0)$.

Then

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