Methods and Algorithms of Turbojet Engines Thrust Parameters Control Unerroric

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Abstract. This report shows a real way for solving the problem of turbojet engine thrust parameters control in flight. The purpose of the research is the formalization of the digital methods and its algorithms for turbojet engines thrust parameters control unerroric. The methods of deductive digital signal processing and combined method of system analysis and approximate synthesis are used for such research. It is described the digital algorithms of unerroric methods which are based on rotor speed control for turbojet engines of twin-engine airliner by its power plant control system. There are given the calculation formulas for those algorithms.

1. Introduction
The turbojet engines thrust parameters control unerroric is the best way to solve a problem of flight safety for airliner with two turbojet engines [1].

The concept of "unerroric" (from the Latin "errare") means the combined application of methods and procedures to reduce the error of methods and algorithms for processing information [2].

The unerroric for turbojet engines thrust parameters control is the combination of software and hardware for reducing the margin of such control in the conditions of turbojet engines mass production and during operation turbojet engines in the power plant of twin-engine airliner.

Possible solutions to this problem are reflected in a number of scientific reports and articles [1,3-4].

The proposed methods and algorithms can be successfully implemented on the basis of the element base of modern microelectronics [5-10].

2. Purpose and methods of research
The purpose of the research is the formalization of the digital methods and its algorithms for turbojet engines thrust parameters control unerroric.

The methods of deductive digital signal processing and combined method of system analysis and approximate synthesis are used for such research.

3. Theoretical fundament
The theoretical fundament for any methods and algorithms of turbojet engines thrust parameters control unerroric is a software for system analyzing of turbojet engines thrust parameters [1].

This system analyzing is based on the digital methods of the turbojet engines thrust parameters deep testing in the conditions of turbojet engines mass production [3].
That approximate synthesing software is based on the recurrent algorithms for the deductive digital signal processing of the control signals from the turbojet engines rotors speed sensors [11-15].

4. Research result

The research results prove the possibility of using twin-engine airliner turbojet engines thrust parameters control unerroric methods and algorithms for solving some problems of the safety for twin-engine airliner flight with thrust asymmetry of airliner turbojet engines.

Its thrust asymmetry can be minimized or compensated by digital methods and algorithms of step-by-step system analysis and approximate synthesis for the control values of two turbojet engines thrust parameters in flight [1].

These methods and algorithms are realized by formulas (1) - (4) on every $i$-th step if $i=1,2,3\ldots I_{\text{max}}-1$ and such parameters are the digital signals from the airliner turbojet engine rotor speed sensors [1,4]:

\[
(n_{1}^{LE})_{i+1} = \begin{cases} 
(n_{1}^{LE})_{i} & \text{if } 0 < n_{1}^{MIN} < (n_{1}^{LE})_{i} + C_{1}^{LE} \left( \frac{dn_{1}^{RE}}{dt} \right)_{i} \leq n_{1}^{MAX}; \\
(n_{1}^{LE})_{i} + \left[ (n_{1}^{RE})_{i} - (n_{1}^{LE})_{i} + C_{1}^{LE} \left( \frac{dn_{1}^{RE}}{dt} \right)_{i} \right] & \text{if } 0 < n_{1}^{MIN} < (n_{1}^{LE})_{i} + C_{1}^{LE} \left( \frac{dn_{1}^{RE}}{dt} \right)_{i} \leq (n_{1}^{RE})_{i} \leq n_{1}^{MAX}; \\
(n_{1}^{LE})_{i} + \left[ n_{1}^{MIN} - (n_{1}^{RE})_{i} + C_{1}^{RE} \left( \frac{dn_{1}^{RE}}{dt} \right)_{i} \right] & \text{if } 0 < (n_{1}^{RE})_{i} + C_{1}^{RE} \left( \frac{dn_{1}^{RE}}{dt} \right)_{i} \leq n_{1}^{MIN} < (n_{1}^{LE})_{i} + C_{1}^{RE} \left( \frac{dn_{1}^{RE}}{dt} \right)_{i} \leq n_{1}^{MAX}; 
\end{cases}
\]

\[
(n_{2}^{LE})_{i+1} = \begin{cases} 
(n_{2}^{LE})_{i} & \text{if } 0 < n_{2}^{MIN} < (n_{2}^{LE})_{i} + C_{2}^{LE} \left( \frac{dn_{2}^{RE}}{dt} \right)_{i} \leq n_{2}^{MAX}; \\
(n_{2}^{LE})_{i} + \left[ (n_{2}^{RE})_{i} - (n_{2}^{LE})_{i} + C_{2}^{LE} \left( \frac{dn_{2}^{RE}}{dt} \right)_{i} \right] & \text{if } 0 < n_{2}^{MIN} < (n_{2}^{LE})_{i} + C_{2}^{LE} \left( \frac{dn_{2}^{RE}}{dt} \right)_{i} \leq (n_{2}^{RE})_{i} \leq n_{2}^{MAX}; \\
(n_{2}^{LE})_{i} + \left[ n_{2}^{MIN} - (n_{2}^{RE})_{i} + C_{2}^{RE} \left( \frac{dn_{2}^{RE}}{dt} \right)_{i} \right] & \text{if } 0 < (n_{2}^{RE})_{i} + C_{2}^{RE} \left( \frac{dn_{2}^{RE}}{dt} \right)_{i} \leq n_{2}^{MIN} < (n_{2}^{LE})_{i} + C_{2}^{RE} \left( \frac{dn_{2}^{RE}}{dt} \right)_{i} \leq n_{2}^{MAX}; 
\end{cases}
\]
The values \((n_{1}^{LE})_{i+1}\) and \((n_{2}^{LE})_{i+1}\) are the control values for the low-pressure compressor rotor speed and the high-pressure compressor rotor speed of the left turbojet engine in power plant of twin-engine airliner for every \((i+1)\)-th step of the step-by-step analyzing and synthesing, \(i=1,2,3\ldots I_{\text{max}}-1\).

These methods and algorithms are realized by formulas (1) - (4) the values \((n_{1}^{RE})_{i+1}\) and \((n_{2}^{RE})_{i+1}\) are the control values for the low-pressure compressor rotor speed and the high-pressure compressor rotor speed of the right turbojet engine in power plant of twin-engine airliner for every \((i+1)\)-th step of the step-by-step analyzing and synthesing, \(i=1,2,3\ldots I_{\text{max}}-1\).

The values of their first derivatives are calculated by the hardware and the software of the control system such power plant. The values of the coefficients \(C_{1}^{LE}\) and \(C_{1}^{RE}\) for the left turbojet engine rotors and \(C_{2}^{RE}\) for the right turbojet engine rotors are set depending on the dynamic properties of these rotors. The specified values \(n_{1 \text{min}}^{min}\) and \(n_{2 \text{min}}^{min}\) are the minimum allowed values of the low-pressure compressor rotor speed and the high-pressure compressor rotor speed of the left turbojet engine and the right turbojet engine.

The specified values \(n_{1 \text{max}}^{max}\) and \(n_{2 \text{max}}^{max}\) are the maximum allowed values of the low-pressure compressor rotor speed and the high-pressure compressor rotor speed of the left turbojet engine and the right turbojet engine.

The reliability of the research results is confirmed by their compliance with the results of known developments [4,16-17].
5. Conclusions
The digital methods and algorithms of turbojet engines thrust parameters control unerroric allow to solve some problems of the safety for the twin-engine airliner flight with thrust asymmetry of two airliner turbojet engines.

The novelty of those methods and algorithms consists in using the turbojet engine thrust parameters for controlling and minimizing or compensating the thrust asymmetry of two airliner turbojet engines in flight.

Development of such methods and algorithms by this report author is the practical realization of his idea for twin-engine airliner turbojet engines thrust asymmetry control unerroric in flight.

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