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AUTOMATED IDENTIFICATION SYSTEM BASEDS ON THE CHANGING OF THE TEMPERATURE FIELD OF AIRCRAFT ELEMENTS

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Abstract. *In this article, system of identification collisions (structural damage) in the air, based on the change of the temperature field was given. Identification system provides information about type and size of aircraft damage to all systems during recovering the controllability of the aircraft when an unexpected problem occurs during a flight is proposed.*

Keywords: identification system; aircraft; structural damage; reconfiguration; flight control system; loss of control in flight; stability and controllability.

I. INTRODUCTION

Bird collisions with aircraft is a global problem and is of interest for both civil and military aviation. Cases of collisions with birds and animals are reported during takeoff and landing by aircraft crews, air traffic controllers, ground services and airlines. Formal reports are made only in cases of injury, when you want to capture them as incidents. Total number of collisions, especially with small birds remains virtually unknown.

Having complete and accurate information about the time, place and degree of injury in a sudden flight will provide an opportunity to objectively evaluate the development of the emergency situation and take the necessary steps to prevent its development through the reorganization of the aircraft (aircraft) or changes in the flight profile.

Database compiled in a research organization of national and international communities do not contain complete data. The U.S. Air Force composed most large database SCB in 1974–1988 years. [1] Validity of information collected depends on the accuracy of the description of facts, methods and procedures for the registration in the databases. The system, mentioned in this article, is provided to help decreasing harmful influence of sudden damage and thus change of aerodynamic characteristics, which influences the aircraft control functionality.

II. MAIN PART

During the flight, the aircraft interaction with the airflow occurs heating the outer casing, which can be described by the following expressions:

$$\operatorname{div} \rho_T (k \nabla T) = Q - \frac{\partial T}{\partial t}; \quad (1)$$

$$\rho_T = -k \nabla T; \quad (2)$$

$$\frac{\partial U}{\partial t} = \frac{\partial (\rho C T)}{\partial t} = \rho C \frac{\partial T}{\partial t}, \quad (3)$$

where ρ_T is the density of thermal power; Q is volumetric power density of outside sources of heat; U is bulk density of the internal heat of the substance; k is thermal conductivity of the material; T the temperature; C is specific heat of the substance.

Expression (1) is the fundamental equation of the thermal field; (2) is equation describing heat-conducting properties of matter; (3) is an equation that describes the dynamic thermal properties of matter.

Substituting (2) and (3) in (1), we obtain the heat equation with respect to the temperature field :

$$\rho C \frac{\partial T}{\partial t} - \operatorname{div}(k \nabla T) = Q. \quad (4)$$

In case of damage to the outer covering of a typical aircraft, its aerodynamic characteristics change, that is accompanied by a temperature gradient plating:

$$\nabla t = \lim_{\Delta n \rightarrow 0} \left| \Delta t / \Delta n \right|_{\Delta n \rightarrow 0} = \frac{dt}{dn},$$

where ∇t is the vector directed along the normal (Δn) to isotherm surface towards the growth of the temperature and the many levels simultaneously derivative of the temperature in this area.

Figure 1 shows the location of thermal imaging cameras. These cameras are averaged shell flashing beacon that capture the changing thermal field of aircraft external outline and its engines in flight.

For digital thermal imaging cameras analog-digital convertor is not a necessary block. All information processing can be done in the digital form, combining thermal imaging camera and an image processing unit primary one unified element (It receives the image, compares it with a reference one, conveys information about the object control, by command shows a picture from the camera needed to the monitor in cockpit).

The system given here provides possibility of connection between elements of the system in a digital form (reducing the mass of hardware and cable connections as well as the convenience of adapting the system to a different number of channels of control). Automated diagnosis obtained by the heat change determines the location, time and type of damage, and takes the appropriate sound signal to the boar crew. If it is necessary, the crew has the ability to display images from any camera.

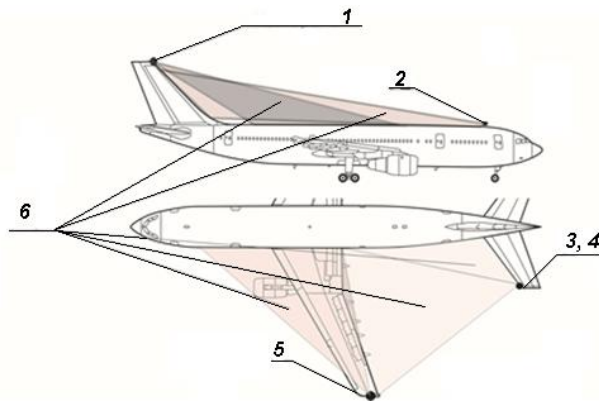


Fig. 1. Location of thermal imaging cameras: 1-5 are thermal imaging cameras; 6 is areas covered by cameras

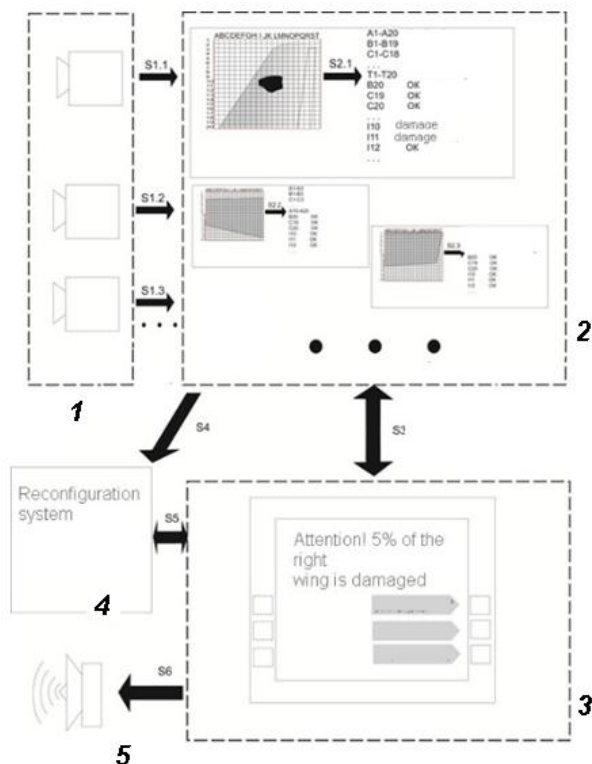


Fig. 2. Block diagram of the automatic identification system of an emergency aircraft in flight:

1 is thermal imaging cameras that transmit information about heat to the image processing block; 2 is current information processing unit; 3 is reconfiguration system; 4 is the display; 5 is sound notification system

Not every thermal imaging camera provides needed image quality. It is correct to use cameras with such characteristics (Table).

The characteristics of cameras

Type of detector	Uncooled microbolometer matrix of 640×480, 384×288 and 160×120 elements.
Spectral range	8-14 microns.
Cell Size	25×25 microns.
Sensor	of 0,06 ° C.
Optics	Lenses with a focal length of 8 mm to 150 mm with manual and remote focus.
Manual control of brightness / contrast	Manually adjust the brightness and contrast to improve the image quality based on the specific environmental conditions.
Automatic control of brightness / contrast	Auto contrast and brightness for better perception of the human eye image.
Electronic zoom	Gives you the opportunity to improve the performance picture.
Video Output	Composite . Chance LVDC.
Remote control	RS232
Operating temperature	-30 °C – +60 °C (optional -40 °C)
Storage temperature	-40 °C – +70 °C.

III. MATHEMATICAL MODEL “AIRCRAFT-EMERGENCY SITUATION”

In operational practice there may be some deviation of the quality of the systems operation of the aircraft which do not lead to the loss of their ability to work, i.e. permissible changes occur in a whole aircraft state. These deviations assign change the aerodynamic conditions of the external contours of the aircraft in flight. Permissible changes in the state of the external contours of the aircraft form a subset of states $\{N_i\}$, in which the aircraft is operational. In the future change of aerodynamic and technical condition of the aircraft shall be regarded as a change in the degree of disability or the stock of aircraft performance. In addition, if these changes do not exceed prescribed limits, $N_i \in N_0$, where N_0 is the stock performance object. If the change in the degree of disability beyond the permissible $N_i \notin N_0$, then the object loses its efficiency, i.e. brings a state of failure. It is obvious that the stock performance of the object is determined by the conditions under which the $\{N_i\}$, does not go beyond N_0 .

Aerodynamic surface of the aircraft will submit the three main components: the carrier surface (aerodynamic wing surface), the fuselage (the aerodynamic surface of the fuselage), tail surfaces (aerodynamic surface of the tail).

Wing is the basic element that creates lift aircraft. But with the lifting force of the wing is always a source of resistance and the longitudinal moment.

Evaluation of changes to the aerodynamic conditions of an airplane wing in flight provides the definition of storage conditions, stock performance, the choice set of variables, allowing to check the status of an airplane wing in flight, the identification of methods for measuring and monitoring these values and the search for methods of determining the extent and time of occurrence of an injury. It is known that any damage to the external contour of the aircraft leads to the instantaneous change in the aerodynamic forces and moments acting on it. Therefore, to monitor in-flight condition of the aircraft aerodynamic surface and determine its damage, which occurred suddenly need a check number, in general, interrelated parameters that characterize these changes.

For control the aerodynamic surfaces condition of aircraft in-flight of and determine the place of injury is needed testing a number of generally interdependent parameters:

$$Z_0 = [n_x, n_{x0}, n_y, n_{y0}, n_z, n_{z0}, \omega_x, \omega_{x0}, \omega_y, \omega_{y0}, \omega_z, \omega_{z0}]^T,$$

nominal value of each of which is ensured by a certain subset Ω_i . Each parameter is evaluated by testing the reaction in pre-selected points on the surfaces of a mechanical or electro-dynamic forcing.

$$\begin{aligned} C_y &= C_{y0} + (\Delta C_y)_{\alpha=0} + \Delta(C_y^\alpha)\alpha + C_y^{\bar{\alpha}} \left(\frac{\dot{\alpha} b a}{V} \right) + C_y^{\bar{\omega}_z} \left(\frac{\bar{\omega}_z b a}{V} \right) + \Delta(C_y^{n_y}) n_y \\ &\quad + \Delta C_{y\ st} + \Delta C_{y\ el} + \Delta C_{y\ sp} + \Delta C_{y\ br} + \Delta C_{y\ unbal} + \Delta C_{y\ dmg}; \\ C_x &= k(C_{x0} + \Delta C_{x\ st} + \Delta C_{x\ el}) + (1-k)C_{x\ m}(M) + \Delta C_{x\ sp} + \Delta C_{x\ ail} \\ &\quad + \Delta C_{x\ br} + \Delta C_x^\beta + \Delta C_{x\ r} + \Delta C_{x\ unbal} + \Delta C_{x\ ind} + \Delta C_{x\ dmg}; \\ C_z &= C_z(\beta) + \Delta C_{z\ r} + \Delta C_{z\ unbal} + \Delta C_{z\ dmg}; \\ m_z &= m_{z0} + (\Delta m_z)_{\alpha=0} + \Delta(m_z^\alpha)\alpha + C_y(\bar{X}_T - 0, 25) + m_z^{\dot{\alpha}} \left(\frac{\dot{\alpha} b a}{V} \right) + m_z^{\bar{\omega}_z} \left(\frac{\bar{\omega}_z b a}{V} \right) + \Delta(m_z^{n_y}) n_y \\ &\quad + \Delta m_{z\ st} + \Delta m_{z\ el} + \Delta m_{z\ sp} + \Delta m_{z\ br} + \Delta m_z^\beta + \Delta m_{z\ r} + \Delta m_{z\ unbal} + \Delta m_{z\ ind} + \Delta m_{z\ dmg}; \\ m_x &= m_x(\beta) + m_x^{\bar{\omega}_x} \left(\frac{\omega_x l}{2V} \right) + m_x^{\bar{\omega}_y} \left(\frac{\omega_y l}{2V} \right) + \Delta m_{x\ ail} + \Delta m_{x\ sp} + \Delta m_{x\ r} + \Delta m_{x\ unbal} + \Delta m_{x\ ind} + \Delta m_{x\ dmg}; \\ m_y &= m_y(\beta) + m_y^{\bar{\omega}_y} \left(\frac{\omega_y l}{2V} \right) + m_y^{\bar{\omega}_x} \left(\frac{\omega_x l}{2V} \right) + \Delta m_{y\ ail} + \Delta m_{y\ sp} + C_z(\bar{X}_T - 0, 25) \frac{b a}{l} \\ &\quad + \Delta m_{y\ r} + \Delta m_{y\ unbal} + \Delta m_{y\ ind} + \Delta m_{y\ dmg}; \end{aligned} \quad (4)$$

We denote a test that checks the status of a subset of surfaces Ω_i , $i=1, m$. As a result of each test can only be two outcomes: “no damage” if:

$$\begin{cases} \hat{e}(k/k) = Z(k) - \hat{Z}(k) = 0; \\ \tilde{e}(k/k) = Z(k) - \tilde{Z}(k) = 0, \end{cases} \quad (1)$$

where $e(k/k)$ is the discrepancy, which appear due to violation of an aerodynamic surface $\hat{Z}(k)$ is estimate $Z(k)$ which includes measurements on the k th step, $\tilde{Z}(k)$ is estimate to measure on k th step – “damage”, if appeared damaged at least one point belonging to the aerodynamic surface Ω_i :

$$\begin{cases} \hat{e}(k/k) = Z(k) - \hat{Z}(k) \neq 0; \\ \tilde{e}(k/k) = Z(k) - \tilde{Z}(k) = 0. \end{cases} \quad (2)$$

Estimate vector $\hat{Z}(k)$, the satisfying requirements (1) and (2) is the conditional mean

$$\hat{Z}(k/k) = M\{Z(k)/Y_1^k\}. \quad (3)$$

Changes in the aerodynamic forces and moments acting on aircraft in flight, are due to changes in local aerodynamic forces and moments of change in their coefficients. Dimensionless aerodynamic coefficients of forces and moments in the case of sudden damage to the external contours of the aircraft is a function not only of angles of attack and slip, the Mach number, altitude, alignment, proximity to land, deviations of control and configuration of the aircraft, but also the functions of the damage location and nature.

where C_{y0}, C_{x0}, m_{z0} is the main coefficients of lift, drag force and the longitudinal moment of a rigid aircraft in this configuration with retracted landing gear while centering the 25 % of the MAH and the neutral position of control;

$(\Delta C_y)_{\alpha=0}, (\Delta m_z)_{\alpha=0}$ is a change the basic lift coefficient and coefficient of longitudinal moment at the $\alpha=0$ in aeroelasticity effect;

$\Delta(C_y^\alpha)_\alpha, \Delta(m_z^\alpha)_\alpha$ is a changing the basic lift coefficient and the coefficient of the longitudinal moment of impact aeroelasticity on the slope of the main factor (in the linear region);

$C_y^{\dot{\alpha}} \left(\frac{\dot{\alpha} b_a}{V} \right)$ is a change the basic lift coefficient due to the rate of change of angle of attack;

$C_y^{\bar{\omega}_z} \left(\frac{\bar{\omega}_z b_a}{V} \right)$ is a changing the basic lift coefficient due to the rate of change of speed pitch;

$\Delta(C_y^{n_y})_{n_y}$ is a change the basic lift aeroelasticity coefficient due to normal overload;

$\Delta C_{y\ st}, \Delta C_{y\ el}, \Delta C_{y\ sp}, \Delta C_{y\ br}$ are change the basic lift coefficient due to deflection of the stabilizer, elevator, spoilers, and sections of brake flaps from the neutral position;

$\Delta C_{x\ unbal}, \Delta C_{z\ unbal}, \Delta m_{z\ unbal}, \Delta m_{x\ unbal}, \Delta m_{y\ unbal}, \Delta C_{y\ unbal}$ are changes in the main coefficients of lift, drag lateral force, longitudinal moment of roll and yaw moment due to the unbalanced position of the flaps and slats;

$\Delta C_{x\ st}, \Delta C_{x\ el}, \Delta C_{x\ sp}, \Delta C_{x\ ail}, \Delta C_{x\ br}, \Delta C_{x\ r}$ are change the basic coefficient of drag force due to deflection of the stabilizer, elevator, sections spoilers, ailerons, sections of brake flaps and rudder from the neutral position;

C_x^β is a change the basic coefficient of drag force caused by the slip;

$C_{x\ m}(M)$ is the coefficient of force drag for a given Mach number;

$\Delta C_{x\ ind}, \Delta m_{z\ ind}, \Delta m_{y\ ind}, \Delta m_{x\ ind}$ are change the main drag coefficient, the longitudinal moment, yaw moment of heel due to the manifestation of the individual characteristics of a particular aircraft;

k is a coefficient taking into account the influence of Mach number;

$G_z(\beta), m_x(\beta), m_y(\beta)$ are the coefficient of lateral force, longitudinal moment of roll and yaw due to

slip; $\Delta C_{z\ r}$ is a change of lateral force due to deflection of the rudder;

$C_y(\bar{X}_T - 0,25)$ is the main changes in the coefficient of longitudinal moment due to displacement of the center of mass of the position of 25 % of the MAH;

$m_z^{\dot{\alpha}} \left(\frac{\dot{\alpha} b_a}{V} \right)$ is a change the basic factor of the longitudinal moment due to the rate of angle attack change;

$m_z^{\bar{\omega}_z} \left(\frac{\bar{\omega}_z b_a}{V} \right)$ is a changing the main factor of the longitudinal moment, due to the rate of change of speed pitch;

$\Delta(m_z^{n_y})_{n_y}$ is a change the basic factor of the longitudinal moment due to the normal congestion;

$\Delta m_{z\ st}, \Delta m_{z\ el}, \Delta m_{z\ sp}, \Delta m_{z\ br}, \Delta m_{z\ r}$ are the change the basic factor of the longitudinal moment due to deflection of the stabilizer, elevator, spoilers, and sections of brake flaps and rudder from the neutral position;

Δm_z^β is a change the main longitudinal moment coefficient due to sliding;

$m_x^{\bar{\omega}_x} \left(\frac{\bar{\omega}_x l}{2V} \right), m_y^{\bar{\omega}_x} \left(\frac{\bar{\omega}_x l}{2V} \right)$ are change the torque coefficient roll and yaw due to roll rate for this configuration the aircraft;

$m_x^{\bar{\omega}_y} \left(\frac{\bar{\omega}_y l}{2V} \right), m_y^{\bar{\omega}_y} \left(\frac{\bar{\omega}_y l}{2V} \right)$ are changing the coefficients of roll and yaw moment due to yaw rate for this configuration the aircraft;

$\Delta m_{x\ ail}, \Delta m_{x\ sp}, \Delta m_{x\ r}$ are changing the coefficient of rolling moment due to aileron, spoilers section and rudder from the neutral position;

$\Delta m_{y\ ail}, \Delta m_{y\ sp}, \Delta m_{y\ r}$ are changing the yaw moment coefficient for by aileron, spoilers, and sections of the rudder;

$\Delta C_{y\ dmg}, \Delta C_{x\ dmg}, \Delta C_{z\ dmg}$ are the main changes of the coefficients of lift, drag force and lateral force due to the appearance of wind damage;

$\Delta m_{z\ dmg}, \Delta m_{x\ dmg}, \Delta m_{y\ dmg}$ are changes in the basic factors of the longitudinal moment, roll and yaw moments due to the appearance of lesions of the external contours of the aircraft in flight.

IV. CONCLUSION

Structural damage can change aerodynamic characteristics of an aircraft. Reconfiguration can

help pilots in recovering control, but it is almost useless without structural damage identification system. In this article such a system, based on the change of the temperature field is given. The organization of monitoring the state of aerodynamic aircraft in flight was reviewed by the example of the wing as the main element of aircraft, which creates lift aircraft, in this research. Defined the differences

between the forces acting on the undamaged wing and when it is damaged by foreign objects.

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Д. О. Шевчук. Автоматична система ідентифікації пошкоджень зовнішніх обводів літака на основі зміни температурного поля

Наведено структурну схему автоматичної система ідентифікації типових пошкоджень зовнішнього обводу в результаті зіткнення з механічними, електричними об'єктами, яка заснована на вимірюві зміни температурного поля. Запропонована автоматична система ідентифікації фіксує момент, місце і ступінь типових пошкоджень для системи реконфігурації управління польотом.

Ключові слова: особлива ситуація; пошкодження зовнішніх обводів; стійкість і керованість; літак.

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Напрямок наукової діяльності: методи відновлення керованості літака в умовах виникнення особливих ситуацій у польоті.

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Д. О. Шевчук. Автоматическая система идентификации поврежденных внешних обводов самолета на основе изменения температурного поля

Приведена структурная схема автоматической система идентификации типовых поврежденных внешнего обвода в результате столкновения с механическими, электрическими объектами основанная на изменении температурного поля. Предложенная автоматическая система идентификации фиксирует момент, место и степень типовых повреждений для системы реконфигурации управления полетом.

Ключевые слова: особая ситуация; повреждение внешних обводов; устойчивость и управляемость; самолет.

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Направление научной деятельности: методы восстановления управляемости самолетом в условиях возникновения особой ситуации в полете.

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