Global Journal of Engineering and Technology [GJET]
ISSN: 2583-3359 (Online)
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journal-gjet-home/

THE PRIORITY INFORMATION DISPLAY ON THE SCREEN IN THE COURSE OF STATICAL TOUGHNESS TESTING OF AIRPLANES

BY

Vuong Anh Trung[1*], Cu Thanh Phong[2], Nguyen Van Thinh[3], Nguyen Quang Trung[4]

[1]Faculty of Aviation Technical, Air defense-Air Force Academy, 100000 Hanoi, Vietnam 0000-0002-4602-3975
[2,3]Faculty of Aviation Technical, Air defense-Air Force Academy, Hanoi, Vietnam
[4] Naval Technical Institute, Hai Phong, Vietnam

Article History

Received: 07/04/2023
Accepted: 12/04/2023
Published: 14/04/2023

Vol – 2 Issue – 4

PP: - 08-12

Abstract:
The problem task of priority presentation information on the screen about a structure's action while toughness testing is considered. The dynamical priorities' dedication has been formulated, and neural network procedure of control by supervision page display at weighting is suggested. When carrying out strength tests of such complex structures as airplanes, along with the organization of the loading field and the installation of strain gauges that measure the strength of the state of the product, there is the problem of choosing a piece of information about the test progress that is primarily needed by the operator. In accordance with the procedure accepted in practice for presenting the results to a human operator on the screen of the display system, it is necessary to show on display one of several pages consisting of a given number of lines. In this case, each line contains information about the level of tension of the structure in a different place and the number of the loading step, and each page carries information about the state of the strength of the corresponding structural unit. After the next increase in the static load, the operator has the opportunity to view one of several pages on the screen alternately. The operator can view one page at a given time and identify significant changes in parameters, and then move on to view another page. However, with a sequential search of pages, a situation may arise when new messages about the occurrence of dangerous violations of the structure's strength appear in some lines of the pages not shown and stored in the computer memory, which will lead to an accident. Therefore, to improve the characteristics of the system for displaying information on the screen, it is advisable to determine the procedure for optimal presentation of pages by assigning dynamic priorities.

Keywords: *priority presentation information; neural network; procedure for optimal presentation of pages*

1. Introduction

Consider the solution to the problem of displaying information under the following conditions. The object of strength tests is a complex technical system consisting of a given number of structural units; each of its nodes is controlled by strain gauges, which is equal.

In static strength tests, the input action is the loading forces $P = [P_1,...,P_r]$ that simulate the load for various flight modes - takeoff, landing, maneuvers, etc. The output signals are readings of strain gauges (Figure 1), highlighted by bold dots.

As can be seen from this figure, individual parts of the aircraft structure (wing, fuselage, tail section, etc.) are controlled by their groups of strain gauges, transmitting signals to measuring data collection systems, the widely used K-732 systems [1]. When the structure is loaded from above, the upper part of the aircraft skin is stretched, and the lower one is compressed. Therefore, some of the sensors have signals of one sign, the rest - of another sign. According to Hooke's law, if the structure has sufficient strength, it is in the elastic deformation zone at any loading step. Otherwise, the deviation from the deformation zone leads to a violation of the law. As a rule, these violations occur in a particular place of the structure, and strain gauges installed in this place record a strength failure.

With additional loading, new sensors fall into a failure state, and the number of failures begins to grow steadily. The process of increasing the number of detected failures during testing carries essential information about the expediency of their continuation since the timely provision of this information to the operator and the termination of loading will prevent the aircraft structure from destruction.

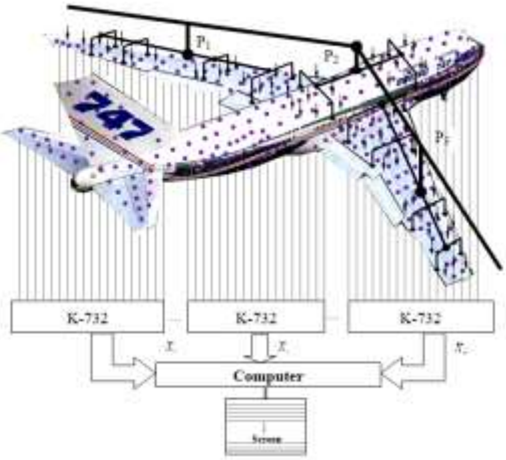

Figure 1. Scheme of carrying out static strength tests

Experimental studies have shown that, based on the mathematical model of the increase in the number of failures during testing of a particular structural unit, the dynamics of the development of strength failure can be described using the differential equation:

$$\frac{dx_j}{d\tau} = a_j + b_j x_j \qquad (1)$$

τ -the current test time with a sequential increase in the load;

a_j -the coefficient characterizing the degree of strength;

b_j - coefficient that determines the rate of development of the violation.

It must be said that Eq. (1) corresponds to an unstable aperiodic link with a time constant $T_j = \frac{1}{b_j}$ and describing an irreversible increase in the number of sensors that did not fall into the elastic deformation zone.

The characteristics of the increase in the number of failures are shown in Fig. 2, from which it can be seen that some structural elements can fail earlier (curve 1) and others later (curve 2, $a_2 < a_1$), and the rate of development of the violation may not be the same (curve 3, $b_3 > b_2$).

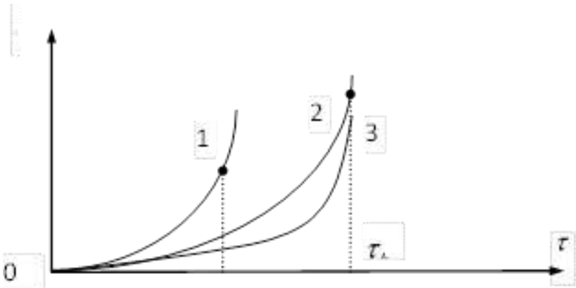

Figure. 2. Processes of increasing the number of design failures with increasing load

The difference in the coefficients a_j, b_j of the adopted model represents the reference information and corresponds to the elements' unequal safety factor, and the most unreliable of them must be identified first. The current information about the "i-st" structural unit's behavior contains the page, which is characterized, respectively, by the number x_i of failure messages not presented to the operator and the delay time t_i in their display.

Considering the difference in the rate of change in the phase coordinates of the presented *j* page and those not presented at *i*- *x* pages, the dynamics of changes in these parameters can be described as follows.

$$\dot{x}_i = \begin{cases} a_i + b_i x_i \\ 0 \end{cases} \qquad (2)$$

Expression (2) shows that if *j*- page did not hit the screen, i.e. $i \neq j$, then the number of undelivered messages grows in proportion to the given speed $(a_i + b_i x_i)$, and if it is displayed on the screen during the time $\Delta\tau$, then the speed of undelivered messages $\dot{x}_j$ becomes zero, since the next time the structural elements damaged by them will remain the same. The meaning of the expression for the rate of change of the delay time can be explained in a similar way t_i

$$\dot{t}_i = \begin{cases} 1 \\ -\frac{t_j}{\Delta\tau} \end{cases} \qquad (3)$$

$\Delta\tau$ -set time for the operator to read the shown page;

This means that when the page is displayed, the delay time is reset to zero; otherwise, it grows in proportion to the real-time.

Under the formulated conditions, it is required to minimize the time of presentation of failure readings of load cells, primarily in the most dangerous (including unforeseen) places of the structure.

Considering the above, as a criterion for the optimality of the display mode, the condition of the minimum total number of messages can be taken for all pages, "lost" due to delays in their presentation to the operator during the test [2]

$$J = \min\left\{\int_0^{\tau_k} f_0(X_n, t_n, \tau)d\tau\right\}$$

Where $f_0(X_n, t_n, \tau)$- the average rate of messages lost at the current test step;

There are various estimates of information loss due to its aging due to a time delay, among which an exponential model may be acceptable [3]

$$f_{oi} = x_i\left(1 - e^{-\frac{t_i}{T_i}}\right)$$

f_{oi} - the average rate of loss of messages on the *i-st* unannounced page; T_i - a time constant close in value to the half-age period adopted in information theory, after which the

*Corresponding Author: Vuong Anh Trung

number of unlost messages is halved; The expression indicates the possibility of complete loss of messages x_i when $i \to \infty$. Considering the average number f_0 of all messages lost per unit of time equal to the additive sum of losses on each unannounced page and expanding the expression into a limited Taylor series,

taking into account the smallness of the ratio $\frac{t_i}{T_i}$ we obtain for $T_i = \frac{1}{t_i}$

$$J = \sum_{i \neq j}^{n} x_i(\tau) t_i(\tau) d\tau \to min \qquad (4)$$

where – j the number of the i page displayed at the moment

Formula (4) corresponds to the condition of the minimum total delay time in the presentation of rejected messages on the screen. With the selected criterion, you need to find the procedure for priority display of pages on the screen.

2. Derivation of Formula for Assigning Dynamic Priorities to Page Presentation

The posed problem of optimal assignment of dynamic priorities in the presentation of information can be solved based on dynamic programming. For this, in the case, according to [4], the Bellman equation is used:

$$-\frac{\partial \varepsilon}{\partial \tau} = \min_j \left\{ \sum_{i=1}^{n} D_i t_i x_i + \sum_{i \neq j}^{n} \frac{\partial \varepsilon}{\partial x_i} \dot{x}_i{}_{i \neq j} + \frac{\partial \varepsilon}{\partial x_j} \dot{x}_j + \sum_{i \neq j}^{n} \frac{\partial \varepsilon}{\partial \tau_i} \dot{t}_i{}_{i \neq j} + \frac{\partial \varepsilon}{\partial \tau_j} \dot{t}_j \right\} = \min_j F_j(X_n, t_n)$$

(5)

ε - the Bellman function;

F_j - the minimized risk function on the right side of the equation.

It is possible to use an approach based on the representation of the Bellman functionin the form of a power seriesto obtain an approximate analytical solution, in particular, a second-order power polynomial [5], which makes it possible to obtain a solution in quadratures for control and monitoring problems:

$$\varepsilon \cong \alpha + \sum_{i=1}^{n} \left(\beta_{1i} x_i + \gamma_{1i} \frac{x^2{}_i}{2} \right) + \sum_{i=1}^{n} \left(\beta_{2i} t_i + \gamma_{2i} \frac{t^2{}_i}{2} \right) + \sum_{i=1}^{n} \psi_i x_i t_i + ...$$

or $$\varepsilon = \alpha + \sum_{j=1}^{n} \left(\beta_{1i} x_i + \gamma_{1i} \frac{x^2{}_i}{2} + \beta_{2i} t_i + \gamma_{2i} \frac{t_i^2}{2} + \psi_i x_i t_i \right)$$

$\beta_{1,} \psi_1, \quad \gamma_1, \beta_{2j,} \gamma_{2j}, \frac{\partial \varepsilon}{\partial x_i}, \frac{\partial \varepsilon}{\partial \tau_i}$ – required approximation coefficients

In this case, it can be assumed that due to the increase in the risk function depending on and, all derivatives and are positive

$$\frac{\partial \varepsilon}{\partial x_i} = \beta_{1i} + \gamma_{1i} x_i + \psi_i t_i \,; \qquad \frac{\partial \varepsilon}{\partial \tau_i} = \beta_{2i} + \gamma_{2i} t_i + \psi_i t_i$$

(6)

Substituting (2-6) into Bellman's equation (5) and neglecting the terms of the second-order of smallness, obtains for D=1 the following optimality condition

$$-\frac{\partial \varepsilon}{\partial t} = \min_j \left\{ \begin{array}{l} \sum_{i \neq j}^{n} [x_i t_i + (\beta_{1i} + \gamma_{1i} x_i + \psi_i t_i)(a_i + b_i x_i) + \beta_{2i} + \gamma_{2i} t_i + \psi_i x_i] + \\ + x_j t_j - (\beta_{2j} + \gamma_{2j} t_j + \gamma_j x_j) \frac{t_j}{\Delta \tau} \end{array} \right\}$$ or

$$-\frac{\partial \varepsilon}{\partial t} = \min_j \left\{ \sum_{i=1}^{n} F_i^* - (\beta_{1j} + \gamma_{1j} x_i + \psi_j t_j)(a_j + b_j x_j) - (\beta_{2j} + \gamma_{2j} t_j + \psi_j x_j) \frac{t_j + 1}{\Delta \tau} \right\}$$

Thus $$-\frac{\partial \varepsilon}{\partial t} = \min_j \left\{ \sum_{i=1}^{n} F_i^* - \Pi(x_j, t_j) \right\} \quad (7)$$

From expression (7), it can be seen that the minimum of the risk function will be when the terms in curly brackets with a minus sign reach their maximum. Hence, they determine the maximum page priority Π_j.

It is necessary to write down a system of corresponding equations to find the desired approximation coefficients, for which the page priority Π_j should be represented as follows:

$$\Pi_j = \max \left\{ \psi_{1j} \left(b_j + \frac{1}{\Delta \tau} \right) x_j t_j + (\psi_{1j} a_j + \beta_{1j} b_j) x_j + \left(a_j \psi_{1j} + \psi_{1j} + \frac{\beta_{2j}}{\Delta \tau} \right) t_j + \right.$$
$$\left. + \gamma_{1j} b_j x_j^2 + \frac{\gamma_{2j}}{\Delta \tau} t_j^2 + (\beta_{1j} a_j + \beta_{2j}) \right\} \qquad (8)$$

$\beta_{1j}; \; \psi_{1j}; \; \gamma_{1j}; \; \beta_{2j}; \; \gamma_{2j}$ which corresponds to the need to determine the desired approximation coefficients

These coefficients of approximation can be found according to the well-known method of the operating point are determined from the condition of equality of the ordinates C_i of the risk taken in the vicinity of [2,6] from the condition of equality to take the ordinates of the risk in its vicinity C_i, for the individual situations considered below

$$C_0 = C_{1l}^{-} = C_{1l}^{+} = C_{il}^{++} = C_{2l}^{\ominus} = C_{2l}^{\oplus},$$

Where the minus sign means a deviation to the left of the working point by an amount Δx for coordinates x_i, or by an amount Δt for coordinates t_i; the + sign means the corresponding deviation right; the index $1l$ corresponds to the coordinate number x_l; the index $2l$ - to the coordinate number t_l.

Calculating the required coefficients. By the working point ε with the coordinates of vectors x_n, t_n in $2n$- dimensional space, means such a combination of the number of messages not shown on each page and the time of their delay in presentation, at which no page preference can be given, and the risk functions $F_i(x_{pn}, t_{pn})$ will be the same. Therefore, the ordinate C_0 at the operating point can be equal to any risk function $F_i^*(x,t)$ that will be acceptable for calculation or equal to their average value, which is used in this work:

*Corresponding Author: Vuong Anh Trung

$$C_0 = \frac{1}{n}\sum_{i=1}^{n} F_i(X_n, t_n) = n\Delta t\Delta x + \frac{n-1}{n}\sum_{i=1} F_i - \frac{1}{n}\sum_{i=1}^{n}(\beta_{2l} + \gamma_{2l}\Delta t + \psi_l \Delta x) \quad (9)$$

Now considers the case when one of the pages does not contain new messages and is not of interest, and the other pages are equal. Thus obtains the equation as follows:

$$C_{1l}^{-} = \frac{1}{n-1}\sum_{i\neq l}^{n-1} F(X_n - \Delta x_l, t_n) = \quad (10)$$

$$\frac{n-2}{n-1}\sum_{i\neq l}^{n} F_i - \frac{1}{n-1}\sum_{i\neq l}(\beta_{2l} + \psi_l + \gamma_{2l}\Delta t) + (n-1)\Delta x \Delta t$$

Formulas (9) and (10) allow to compose the first equation:

$$0 = C_0 - C_{1l}^{-} = \Delta t\Delta x + \frac{1}{n(n-1)}\sum_{i\neq l}^{n}(\beta_{2l} + \gamma_{2l}\Delta t + \psi_l\Delta x) - \frac{1}{n}(\beta_{2l} + \gamma_{2l}\Delta t + \psi_l \Delta x) -$$

$$- F_l(x_l = 0) + \frac{n-1}{n}\{(a_l + b_l\Delta x)(\beta_{1l} + \gamma_{1l}\Delta x + \psi_l\Delta t)(\beta_{2l} + \gamma_{2l}\Delta t + \psi_l\Delta x)\} \quad (11)$$

The other case will be considered when one of the pages has just been shown $(t_l = 0)$, as in the previous case, it is also not of interest. Then he gets

$$C_{2l}^{\ominus} = \frac{1}{n-1}\sum_{i=1}^{n-1} F(X_n, t_n - \Delta t_l) =$$

$$\left\{(n-1)\Delta x\Delta t + \frac{n-2}{n-1}\sum_{n-1}^{n-2} F_i + F_l(t_l = 0) - \frac{1}{n-1}\sum_{i\neq l}(\beta_{2l} + \gamma_{2l}\Delta t + \psi_l\Delta x)\right.$$

This allows the researcher to write the second equation

$$0 = \beta_{1l} b_l \Delta x + \gamma_{1l}\Delta x(a_l + b_l\Delta x) - \gamma_{2l}\Delta t + \psi_l(\Delta x - a_l\Delta t)$$

(12)

Consider the opposite situation to the previous cases, when one of the pages is preferable to the other. For example, suppose there are twice as many new messages on one of the pages than others. Then could receive the answer that the minimum risk function will be when this page is presented in the first place, e.t.c

$$\underset{x_j = 2\Delta x}{C_{1l}^{+}} = F_l(X_n + \Delta x_n, t_n) = (n-1)\Delta x\Delta t + 2\Delta x\Delta t + \sum_{i\neq l}^{n} F_i - \beta_{2l} - \gamma_{2l}\Delta t - 2\psi_{2l}\Delta x$$

Figure3. Flowchart of priority presentation of pages on the screen information display systems

Similar reasoning can be applied if all pages are equal, but one of them was presented earlier than the others by twice the delay time interval. Therefore, it would be worth showing this page in the first place:

$$\underset{t_j = 2\Delta t}{C_{2l}^{\oplus}} = F_l(X_n, t_n + \Delta t_l) = (n-1)\Delta x\Delta t + 2\Delta x\Delta t + \sum_{i\neq l}^{n} F_i - 2\beta_{2l} - \gamma_{2l} 4\Delta t - 2\psi_{2l}\Delta x$$

The calculated values of the ordinates of risk C_{1l}^{+} and $C_{2l}^{\oplus}$ are sufficient to form the next equations:

$$C_{1l}^{+} - C_{2l}^{\oplus} = 0: \quad \beta_{2l} + 3\Delta t\gamma_{2l} = 0; \quad C_0 - C_{1l}^{-} + \frac{C_{1l}^{-} - C_{1l}^{+}}{n} = 0 \quad (13)$$

$$\frac{n-2}{n}\Delta t\Delta x + \beta_{1l}\left(-\frac{a_l}{n} + \frac{n-1}{n} b_l\Delta x\right) \quad (14)$$

$$+\gamma_{1l}\Delta x(a_l + b_l\Delta x)\frac{n-1}{n} + \psi_l\left(\Delta x + b_l\Delta x\Delta t\frac{n-1}{n}\right) = 0$$

Finally, let imagine a situation of more than the apparent preference for the page with the newest posts $(x_j = 2\Delta x)$ and the most latency in their display $(t_j = 2\Delta t)$. Then the researcher obtain the estimate

$$\underset{\substack{x_j = 2\Delta x \\ t_j = 2\Delta t}}{C_{il}^{++}} = 4\Delta t\Delta x + (n-1)\Delta t\Delta x + \sum_{i\neq e}^{n} F_i - 2\beta_{2l} - 4\Delta t\gamma_{2l} - 4\psi_l\Delta x$$

And compose the last equation

$$C_{il}^{++} - C_{1l}^{+} = 0 = -2\Delta x\Delta t + \beta_{2l} + 3\gamma_{2l}\Delta t + 2\psi_l\Delta x \quad (15)$$

Equations (11-15) are sufficient to calculate the required approximation coefficients β_{1l}, β_{2l}, γ_{1l}, γ_{2l}, ψ_l.

Approximate calculations give the answer

$$\gamma_{2l} = \frac{-\beta_{2l}}{3\Delta t}; \psi_l = \Delta t; \beta_{2l} = 3\Delta t^2 a_l;$$

$$\beta_{1l} = \frac{\Delta x\Delta t(n-1)(1 + b_l\Delta t)}{a_l}; \gamma_{1l} \cong -\frac{(n-1)b_l\Delta x\Delta t}{a_l(a_l + b_l\Delta x)};$$

Knowing all the approximation coefficients allows returning to the priority assignment formula (8), which can be simplified as a multiplicative convolution of two factors:

$\Pi_j \cong C(X_j + A_j)(t_j + B_j)$

A_j, B_j, C_j where are easily determined using the known parameters of the system a_j, b_j, and the found coefficients β_{1j}, β_{2j}, γ_{1j}, γ_{2j}, ψ_{ji}. If $\Delta X = a_j T_j = m_j$ $\Delta t = \Delta\tau$ is accepted then the equation can be rewritten as follows

$$\Pi_j = (x_j + 3m_j)(t_j + 2\Delta\tau)\frac{\Delta t}{\Delta\tau + T_j} = C_j(x_j + 3m_j)(t_j + 2\Delta\tau) \quad (16)$$

C_j -the coefficient of relative importance.

The obtained approximate answer can be explained as follows. The greater the expected intensity of violation of a structural unit over its controlled area, and the higher the rate of crack development (the shorter the time constant Tj=1/bj), the higher the priority of the hazard and the need to observe this place, along with the importance of the current number of new changes and the delay time tj of their non-display. The implementation of the priority page presentation mode on the screen is possible using the test monitoring control scheme shown in Fig. 3. One of the forms of implementation of the observation procedure can be an artificial neural network, which is also trained using theoretical and practical examples. Besides, with the neural network approach, it is possible to reuse the same neurons of the network trained for the

*Corresponding Author: Vuong Anh Trung

subsequent secondary analysis of the stress diagrams of structural elements to identify the place of failure.

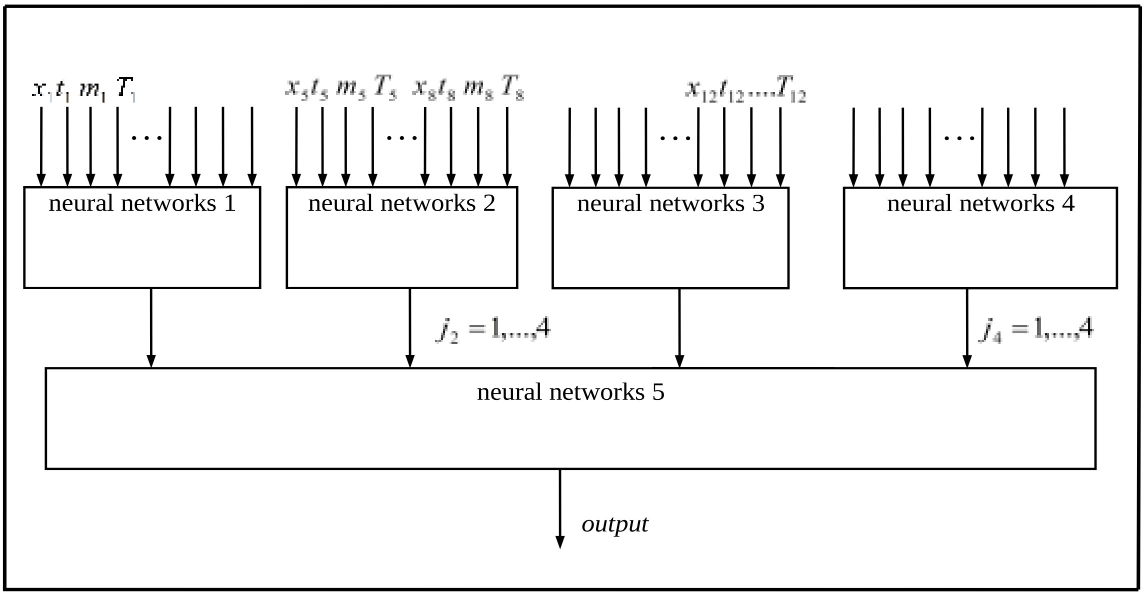

Figure.4. Feedforward network for alternate page selection

3 Conclusion

Thus, found the dependence of the dynamic priorities of each page on its relative importance, that is, on the number of new dangerous changes in the stress state, on the delay time in the presentation of the page on the screen, as well as on the expected degree of reliability of a structural element, or an a priori estimate of its safety margin.

The resulting dependence can be used to form examples of training a neural network that controls displaying pages during tests. The same network can be trained to recognize the stress plots of elements and diagnose failures during strength tests.

References

1. Z.W. Thu, “Design and Optimization of Aircraft Configuration for Minimum Drag” International Journal of Aviation, Aeronautics, and Aerospace, Vol. 5 [2018], Iss. 5, Art, 2018.

2. John D. Anderson, “Aircraft Performance and design”, McGraw-Hill. pp. 382–386. ISBN 0-07-001971-1, 1999.

3. T.H.G Megson. “*Aircraft Structures*” Elsevier Ltd. p. 353. ISBN 978-1-85617-932-4, 2010.

4. Zuo, Y., & Chen, P, “Advanced aero structural optimization techniques for aircraft design”, Hindawi Publishing Corporation, Mathematical Problems in Engineering, Article ID 753042. http://dx.doi.org/10.1155/2015/753042, 2015.

5. Lloyd R. Jenkinson; Paul Simpkin; Darren Rhodes, "Aircraft Market". Civil Jet Aircraft Design. Great Britain: Arnold Publishers. p. 10. ISBN 0-340-74152-X, 1999.

6. McGeer, T, Wing design for minimum drag with practical constraints. Journal of Aircraft, 21(11), 879-886. doi:10.2514/3.45058, 1984.

7. Cavus, N, “Aircraft design optimization with artificial intelligence” AIAA SciTech Forum, In the proceedings of the 54th AIAA Aerospace Sciences Meeting, San Diego, CA, 4-8. doi:10.2514/6.2016-2001, 2016.

*Corresponding Author: Vuong Anh Trung