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SELECTED ASPECTS OF THE MODERN FIGHTERS EVALUATION

INTRODUCTION

In available literature on military aircraft evaluations including multirole aircraft, the considered type of aviation is analysed by means of design survey, development trends of selected parameters in some period of time. Some relevant conclusions can be drawn from these evaluations, particularly referring to the present status and development trends of the considered class of the aircraft. Anyway, it is impossible to accomplish a conclusion regarding aircraft assessment, especially from the point of view of their combat capabilities, dominance areas etc. In this paper, a concept of a comprehensive method aircraft evaluation is presented. The method was adapted to the needs of assessment of aircraft combat capabilities using a matrix calculus technique.

EVALUATION TECHNIGUE

In general, military aircraft are designed to carry out various types of air operations. So, some areas, called the areas of comparison, which are important from the point of view of the task realisation, can be determined. For the contemporary fighters these areas are weapon system, avionics and navigation systems, manoeuvrability, dynamics, service flexibility etc. The mentioned areas as representative of some class, type of fighters should be carefully evaluated through the identification of the relevant parameters representing the investigated area and then some comparison analysis should be carried out.

It can be assumed that n – is the number of the same class aircraft e.g. fighters, bombers, attacks or trainers, which can be evaluated, m – is the number of assessed areas determined for these aircraft. Within every selected area some parameters or measurements can be specified and defined. In this way for the i area parameters: a_{i1}, a_{i2} ,..., a_{ik}, were specified (k-is the number of the defined parameter). It means that a considered aircraft is depicted by m areas and every area is represented by k parameters, So **A-**designated aircraft, can be shown as a mxk matrix. To put it briefly, an aircraft was described by m areas, and every area by k parameters so, in this way for next aircraft similar matrices **– B, C, D,..., Z** could be created. As it mentioned earlier, every area is depicted by k dimensional or non-dimensional parameters. What is more, the impact of a parameter on the area must be determined; of course, it could be advantaging or disadvantaging.

$$\mathbf{A} = \begin{bmatrix} a_{11}, & a_{22}, & \ldots, & a_{1k} \\ a_{21}, & a_{22}, & \ldots, & a_{2k} \\ \ldots, & \ldots, & \ldots, & \ldots, \\ a_{m1}, & a_{m2}, & \ldots, & a_{mk} \end{bmatrix} \tag{1}$$

After that, for all the considered aircraft, proper areas should be compared. In this case, the matrix representing the considered area comprising all the investigated aircraft is built. We can create m such type matrices, i.e. as many as the specified areas. For the first area, the matrix is:

$$\boldsymbol{S_1} = \begin{bmatrix} a_{11}, & a_{12}, & ..., & a_{1k} \\ b_{11}, & b_{12}, & ..., & b_{1k} \\ ..., & ..., & ..., & ..., \\ z_{11}, & z_{12}, & ..., & z_{1k} \end{bmatrix} \tag{2}$$

Such composed matrix (2) representing the evaluation areas, which comprises (each of them) all the considered aircraft, should be normalised in a proper way. In a similar way the matrices $\mathbf{S}_1$, $\mathbf{S}_2$,...,$\mathbf{S}_\mathrm{m}$, for subsequent areas could be created. Such matrices must be normalised in a proper way. The matrix components are a value from 0 to 1, and at least one of them equals 1. Using the above presented procedure, for the other aircraft areas, m aircraft matrices can be created. Such created matrices should be used for designing of separate matrices regarding every aircraft and comprises all the specified areas. So, for the first aircraft the **A** matrix has the following form:

$$\overline{A} = \begin{bmatrix} \overline{a}_{11}, & \overline{a}_{12}, & ..., & \overline{a}_{1k} \\ \overline{a}_{21}, & \overline{a}_{22}, & ..., & \overline{a}_{2k} \\ ..., & ..., & ..., & ..., \\ \overline{a}_{m1}, & \overline{a}_{m2}, & ..., & \overline{a}_{mk} \end{bmatrix} \tag{3}$$

Similar to the matrix (1) but with non-dimensional components. The number of the matrices (3) is determined by the number of the evaluated aircraft. These matrices are the essential base for the final evaluations. Using the matrices (3), an analysis of selected aircraft areas as well as the final aircraft ranking can be made. In cases, (area, aircraft) the final score is the result of aggregation of the fraction scores. For an area the result is the sum of the component values of the proper matrix rows line of the **A, B, C,..., Z** matrices, which be can written as:

$$\begin{aligned} L_{iA} &= \overline{a_{i1}} + \overline{a_{i2}} + \ldots + \overline{a_{ik}} = \sum_{j=1}^{k} \overline{a_{ij}} \\ L_{iZ} &= \overline{z_{i1}} + \overline{z_{i2}} + \ldots + \overline{z_{ik}} = \sum_{j=1}^{k} \overline{z_{ij}} \end{aligned} \qquad (4)$$

for i=1,2,3,..., m areas
An aircraft holds superiority within the i area, when the following formula is met:

$$L_{i,\max} = \max(L_{iA}, L_{iB}, \ldots, L_{iZ}) \qquad (5)$$

for i=1,2,3,..., m areas
Implementing a similar procedure for the aircraft i.e. aggregating values of all the considered areas according to (5) we can obtain the values of the consecutive aircraft taken into consideration. An aircraft is superior when reach its maximum:

$$L_{\max} = \max(L_A, L_B, \ldots, L_Z) \qquad (6)$$

Numerical values obtained from formulas (5) and (6) we can use as the base for the other areas and the aircraft as well. In this way we can fix a value from 0 to 1 for all the areas and aircraft, and also the areas and aircraft can be made up. Moreover, the aircraft with the best capabilities within the specified areas can be identified e.g. area of combat capabilities, survivability area etc. What is more, some relations between the evaluated aircraft, from the point of investigated areas can be given.

SAMPLE OF FIGHTERS EVALUATION

Combat capability means the ability to destroy aerial and surface targets by an aircraft with proper technical and tactical features. In this work, considerations were limited to the air-to-air operation. A group of selected modern multirole fighters were the object of analysis, while the goal was the comparison some features, that are essential for combat capabilities. According to the method requirements some significant areas should be determined for these class aircraft. The areas are manoeuvrability, aircraft dynamic properties, weapon system, avionics, service flexibility etc. In the paper, presented comparison samples are limited to two selected areas, i.e. manoeuvrability and dynamic properties.

Manoeuvrability

This feature is a key factor in a close-in dogfight where a manoeuvrability and fire at short distance are essential. Manoeuvrability is understood as the ability to rapid change the aircraft location, i.e. speed, altitude and flight direction.

Seven parameters were employed for evaluation of this area. Their values for evaluated aircraft are presented in Table 1. They are significant and relevant for this class of aircraft. However, some comments to these parameters is required; normal take off mass is taken as an aircraft mass, in the case of an aircraft with lifting fuselage, the fuselage was added to a general aircraft surface. The inertial moment I_y is given as non-dimensional and refers to the MiG-29(9-12) I_y moment. It was assumed that I_y =1 for the MiG-29. The data from table 1 are essential for evaluation of considered area. According to the technique presented in paragraph 2, all the dimensional parameters were normalised in proper way to non-dimensional form. As a consequence, the evaluated fighters can be ranked following the manoeuvrability, see Fig.1.

Dynamic properties

In available literature there is a lack information about dynamic characteristics, especially important from point of view of acceleration and deceleration times, rate of climb, scramble time etc. For estimation of dynamic properties, some factors may be used, which could be determined generally on the basis of the reliable resources. These factors can presented in the form of e.g. thrust to lifting surface ratio, see Fig.2. Russian aircraft from Suchoy and Mikoyan design bureaus have advantage over the others. It is the result of their huge power; thrust surplus, especially with afterburner (e.g. the MiG-21bis) and very precisely designed aerodynamic shape of the aircraft (e.g. the MiG-29, Su-27). It should be pointed out, that the top scored aircraft in this area, is superior to the others in view of acceleration and energy as well. It allows among the other things for determination how the aircraft is capable to change altitude, speed, and so on.

CONCLUSING REMARKS

In a short form, a comprehensive method of aircraft assessment was presented and its utilisation to combat capabilities. In this case, only two sample areas were determined from the point of view of examined features. Selected areas were defined by representative factors, which were used for the aircraft evaluation, on the assumption that all the factors were equivalent in hierarchy. Then, the areas scores were cumulated in the form of the final ranking. The combat capability assessment was done for an equivalent scale of the examined areas. In practise, for a much more comprehensive analysis, all the fighter areas should be examined (only two in this paper) with variable, differ scales.

Manoeuvrability ranking Table 1.

	Aircraft, type	n_e 1	n_k daN/kg	n_{kd} daN/kg	$V_{ląd}$ km/h	w m/s	I_y 1	p kg/m²
1	**F-4 *Phantom***	7	0.52	0.84	280	152	1.44	382
2	**MiG-21 bis**	8	0.46	1.12	280	225	0.50	379
3	**MiG-29 (9.12)**	9	0.63	1.04	235	330	1.00	249
4	**F-16C**	9	0.62	1.07	235	300	0.61	270
5	**Su-22M4**	7	0.47	0.67	285	220	1.25	475
6	**F/A-18C**	8	0.58	0.94	240	300	1.04	258
7	**JAS 39**	9	0.68	1.01	235	300	0.37	200
8	**Su-27**	9	0.58	1.07	235	250	2.46	213
9	**MiG-29M**	9	0.59	1.02	235	334	1.08	270
10	**Mirage 2000-5**	9	0.59	0.90	220	284	0.51	217

List of abbreviations:

- n_e – max service load;
- n_k – normal thrust ratio (dry);
- n_{kd} – max trust ratio (with afterburner);
- $V_{ląd}$ – landing speed;
- W – climbing speed;
- I_y – inertial moment about the side axis to the moment of the MiG-29 9.12 variant;
- P – surface load.

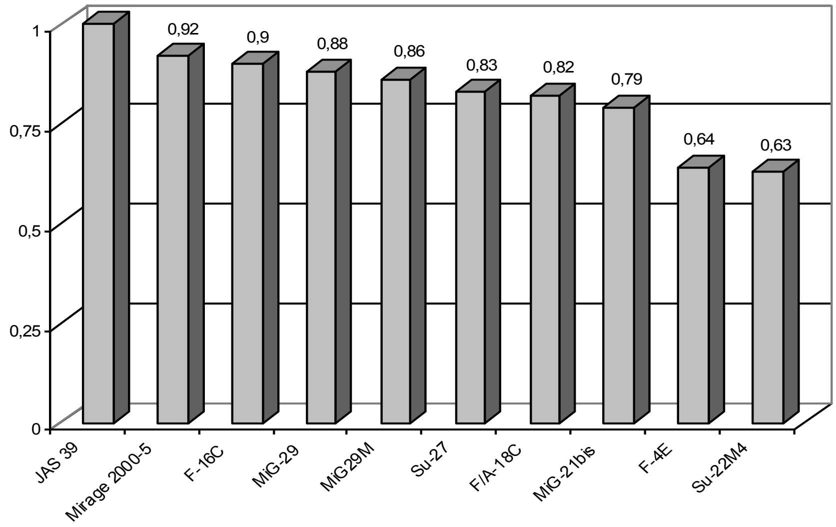

Fig.1. Manoeuvrability ranking

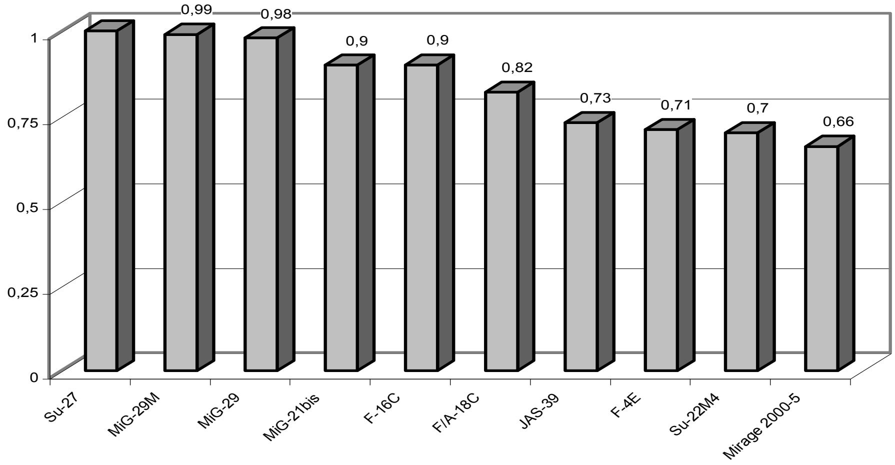

Fig. 2. Ranking of the dynamic properties

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