International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:7, No:5, 2013

Study of Aerodynamic Characteristics of the Unmanned Aircraft in the Wake

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***Abstract*—**The methodology of numerical simulation and calculation of aerodynamic characteristics of aircraft taking into account impact of wake on it has been developed. The results of numerical experiment in comparison with the data obtained in the wind tunnel are presented. Efficiency of methodology of calculation and the reliability of the results is shown.

***Keywords*—**Unmanned aircraft, vortex wake, aerodynamic characteristics.

I. Introduction

THE coefficients of the aerodynamic forces and moments, generated on the model of the unmanned aircraft in the wake from the aircraft wings are calculated by the discrete vortex method (DVM). Comparison of the results with experimental data was carried out. The vortex trail generated by wings, represent long "living" formations which fade for a long time. Entry of the aircraft in the vortex trail can cause catastrophic consequences for it. Study of vortex traces during take-off and landing is very important. The study of vortex traces particularly important for airline hubs where there is a large number of takeoffs and landings for small intervals of time and the possibility of aircraft entry in the vortex trail in the area of the runway is a cause of airports capacity restriction.

II. Numerical Experiment

Study of aerodynamic characteristics of unmanned aircraft model, located in the wake from aircraft wings were carried out according to the technique based on DVM [1]. The calculation results are compared with the data of experimental studies [2]. Numerical study of the vortex trails are conducted in a leading aviation countries, for example, there are the results of the research presented in [3, 4, 5].

Model of the swept wing $\chi_{L.E} = 30°$ with angle of dihedral wing $\psi = 5°$ was used as the former of wake. Wing span of model was $l_{former} = 1.3\,m$. Attack angle of model wing was $\alpha = 10°$.

Schematic model, which has a thin axisymmetric fuselage and straight wing with span $l_{mod\,el} = 0.6\,m$ and horizontal and vertical tail was used as a model of the unmanned aircraft located in the wake of the former. The overall look and basic geometrical dimensions of unmanned aircraft model presented in Fig. 1.

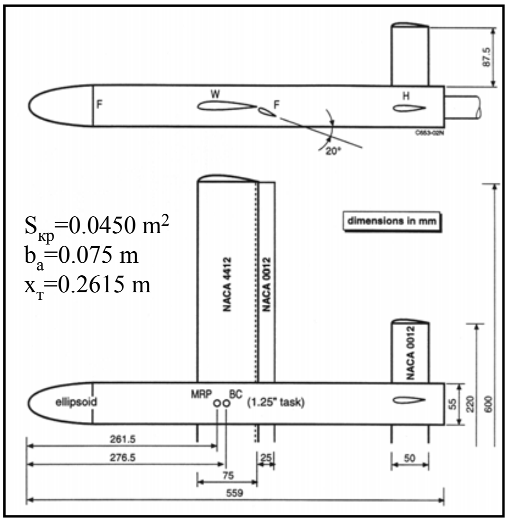

Fig. 1 Model of the unmanned aircraft

At the initial stage of the experiment [2] dependencies $c_{ya}(\alpha)$ have been determined in an undisturbed flow for the studied model of the unmanned aircraft without trailing-edge controls of the wing and with extended flap. Then studies of aerodynamic characteristics of the unmanned aircraft model in the wake of the former were carried out. Attack angle of the studied model of the unmanned aircraft in these experiments was $\alpha_{mod\,el} = 0°$. The distance between the former of wake and studied model of the unmanned aircraft during experiment was $D = 15\,m$.

Fig. 2 shows field of perturbed velocity obtained in wind tunnel, as well as coordinate system that defines the position of the studied model in the perturbed velocity field [2].

Vortex calculation diagrams of the wake former and studied model are presented in Fig. 3 and 4.

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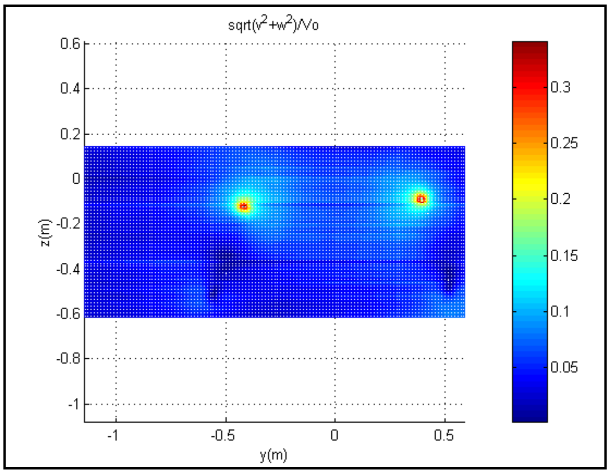

Fig. 2 Field of perturbed velocity of the wake former

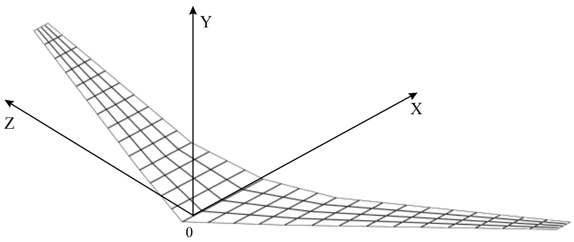

Fig. 3 Vortex diagram of the wake former

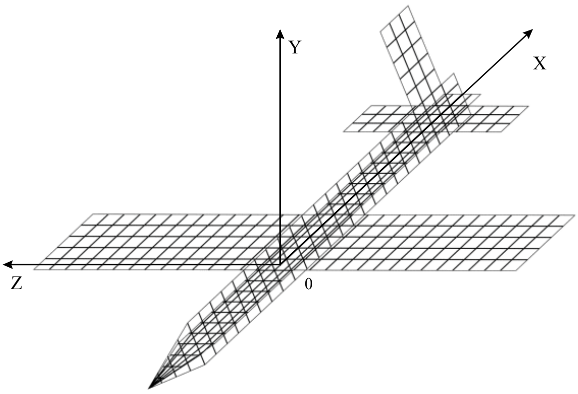

Fig. 4 Vortex diagram of the studied model

Fig. 5 shows the vortex sheet, calculated at unsteady flow of the wake former at an attack angle $\alpha = 10°$.

Field of perturbed velocity calculated at distance $D = 15\,m$ from the former presented in Fig. 6. Comparison with the perturbed velocity field obtained in [2] (Fig. 2) leads to the conclusion of satisfactory compliance between experimental and calculated data.

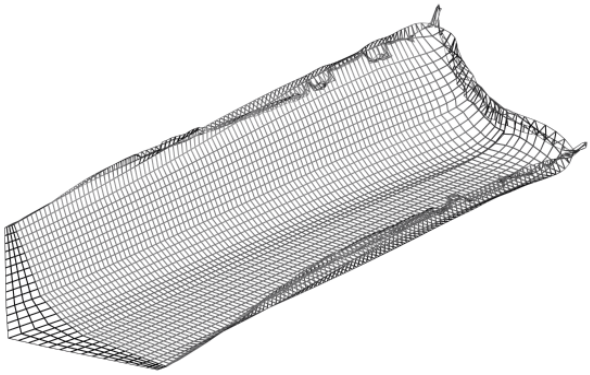

Fig. 5 Vortex sheet behind the wake former

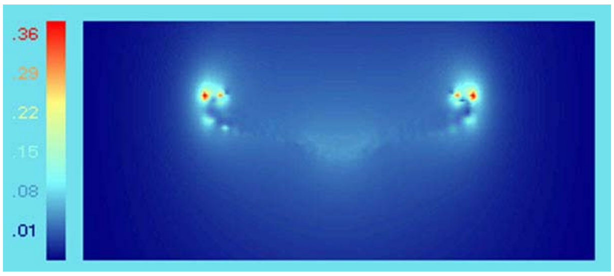

Fig. 6 Calculation velocity field behind the wake former

Calculation of aerodynamic characteristics is carried out at various positions of studied unmanned aircraft model in the wake, consistent with available experimental data and grouped in 2 positions. Fig. 7 presents position of the unmanned aircraft model along the axis $0Y$ at $Z = -0.3\,m$. The results of the calculations are shown in fig. 8-11. The coordinate system used in the development of dependencies, is shown in Fig. 2.

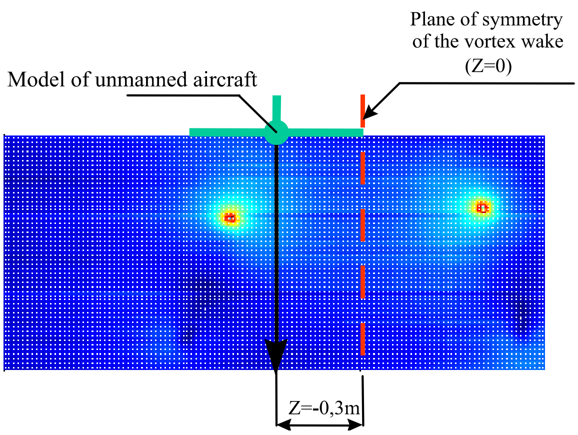

Fig. 7 Vertical position of aircraft model

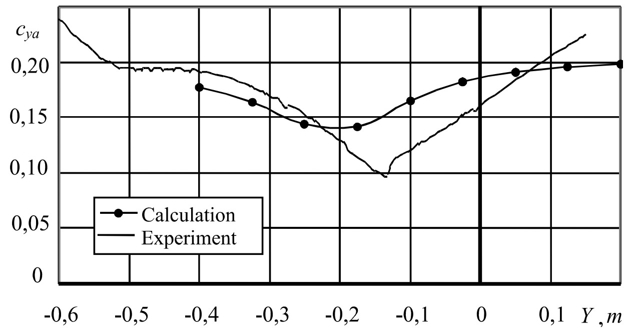

Fig. 8 Dependence $c_{ya}(Y)$, $Z=-0.3\,m$

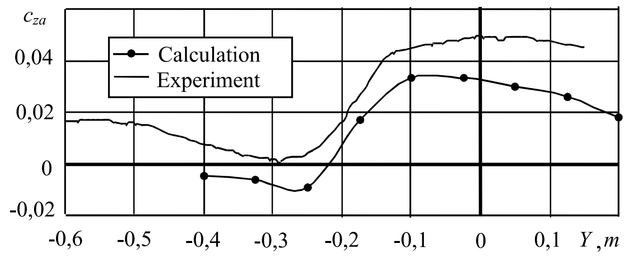

Fig. 9 Dependence $c_{za}(Y)$, $Z=-0.3\,m$

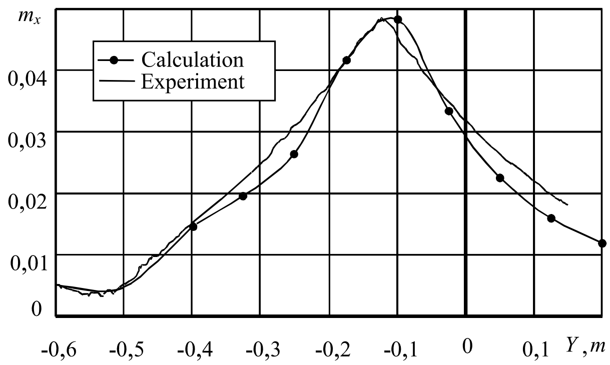

Fig. 10 Dependence $m_x(Y)$, $Z=-0.3\,m$

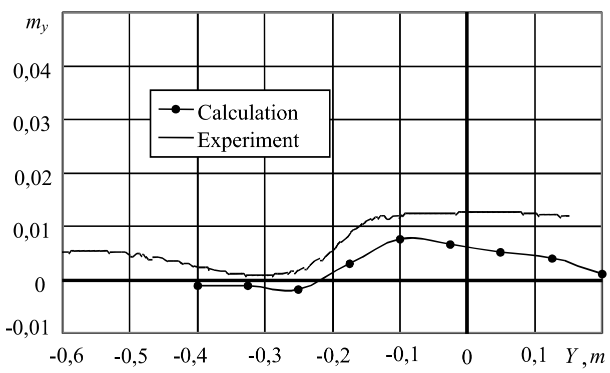

Fig. 11 Dependence $m_y(Y)$, $Z=-0.3\,m$

Qualitative and quantitative compliance of experimental and calculated data is observed in dependence $m_x(Y)$. In dependencies $c_{ya}(Y)$, $c_{za}(Y)$, $m_y(Y)$ only qualitative compliance of results is observed. There are two reasons for this.

Firstly, the calculation of the wake was carried out for the model, located in an unbounded space, rather than in a limited wind tunnel walls, as in [2].

Secondly, the fuselage of the studied model was simulated by two flat panels (Fig. 4), placed perpendicularly to each other, which led to an incomplete recording of forces and moments arising on the fuselage.

Fig. 12 presents position of the studied unmanned aircraft model along the axis $0Z$ at $Y=-0.1\,m$. The results of the calculations at this position are shown in Fig. 13-17.

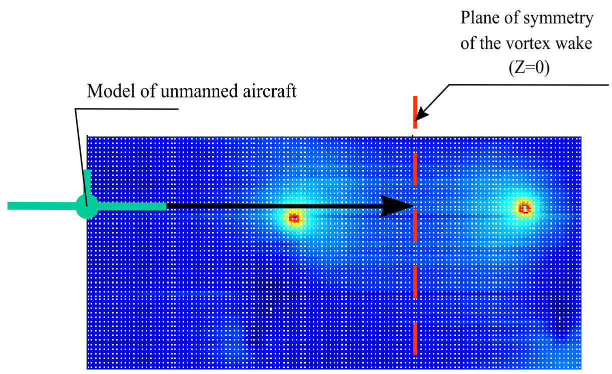

Fig. 12 Horizontal position trajectory of aircraft model

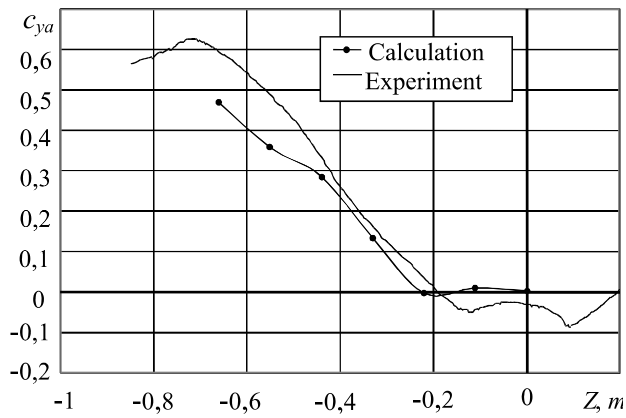

Fig. 13 Dependence $c_{ya}(Z)$, $Y=-0.1\,m$

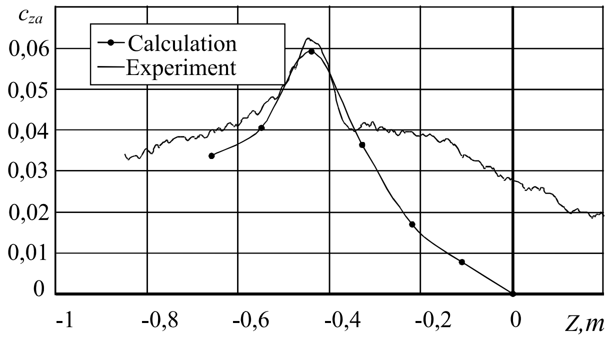

Fig. 14 Dependence $c_{za}(Z)$, $Y = -0.1\,m$

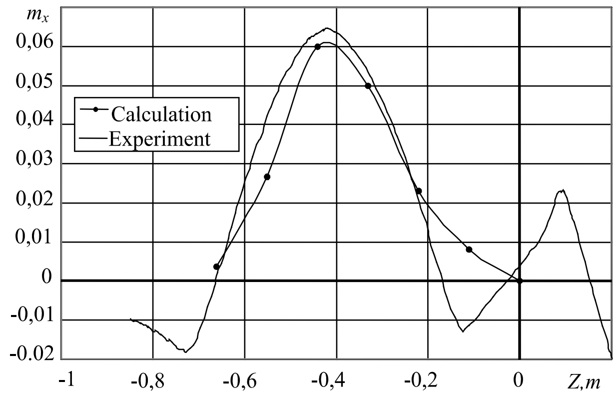

Fig. 15 Dependence $m_x(Z)$, $Y = -0.1\,m$

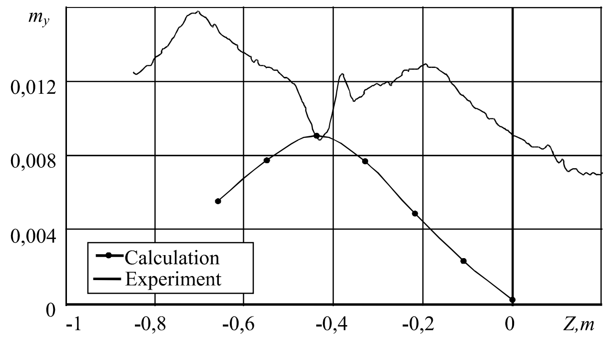

Fig. 16 Dependence $m_y(Z)$, $Y = -0.1\,m$

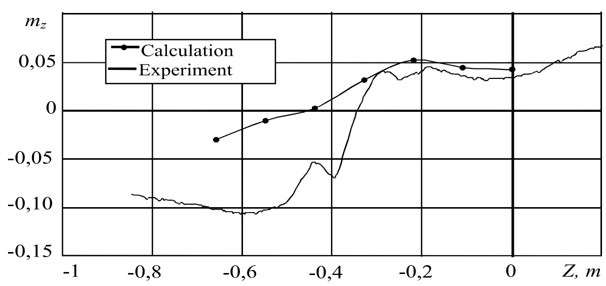

Fig. 17 Dependence $m_z(Z)$, $Y = -0.1\,m$

Analysis of the obtained dependencies shows that satisfactory compliance of the results of calculation and experimental data [2] is observed at the area of tip vortex ($Z \approx -0.45\,m$). Qualitative and quantitative compliance of results is obtained in dependencies $c_{ya}(Z)$, $c_{za}(Z)$, $m_x(Z)$. The mismatch between the calculated and experimental data in dependencies $m_y(Z)$ and $m_z(Z)$ are explained by the two stated reasons.

III. Conclusion

The developed methodology of calculation allows obtaining of aerodynamic characteristics of an aircraft, located in the wake with a sufficiently high accuracy of the results obtained.

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