UDC 629.733.015.3.07(045)

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PROBLEMS OF AIRPLANE UNSTEADY AERODYNAMICS

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Consider the question about influence of unsteady flight on the size of drag and lift coefficients. This influence can changes the trajectory of flight and important in case flight in turbulent atmosphere. Distinctive features of this investigation are obtaining data about aerodynamic drag changing aerodynamic in process unsteady flight. This question is not consider in many articles about influence unsteady forces on dynamic of flight plane.

Introduction

Scientific forecast shows that development of aerodynamics researches in XXI century will be directed on unsteady aerodynamics problems studying. It is assumed that researching in unsteady aerodynamics discovers new patterns and assists aircraft assembling replacement.

In unsteady aerodynamics there are many investigations made in field of estimated methods, based on discrete vortex methods in which liquid flow models are used.

In practice under unsteady motion of the wing, the flow structure changes it vortex scheme condition, depending on angles of attack and Struhal's numbers.

The change of pressure difference on the wing is a result of unsteady flow. In this case, aerodynamic coefficients depend as dynamic hysteretic on angle of attack.

Flight tests show, that it is necessary to improve mathematical models of flight in unsteady conditions.

Given analysis of aircraft flight tests under oscillation flight conditions show, that dynamic loops accompany change of lift and drag forces. The lift force within the angle of attack limits is designed by C_y^{α} denvative, drag dependence on dynamics of flight rangers deep research.

Drag depends from on the flow structure, from development of vortex features on the wing, fuselage and empennage. Under oscillation, vortices are interacting that change airplane aerodynamics characteristic.

The article illustrated with results of airplane flight tests.

Pay attention to the flight of the airplane with deflected flaps.

Airplane flow has been studied for many years, as an important real-world problem and as a fundamental aerodynamic problem.

Progress in unsteady aerodynamics determines improving wing profiles and automatic flight control system in aircraft structure.

In the field of aircraft exploitation it assists in increasing flight safety.

The flights under unsteady conditions of turbulent atmosphere cause air accidents in 62% causes as compared with other atmospherics influence (fig. 1).

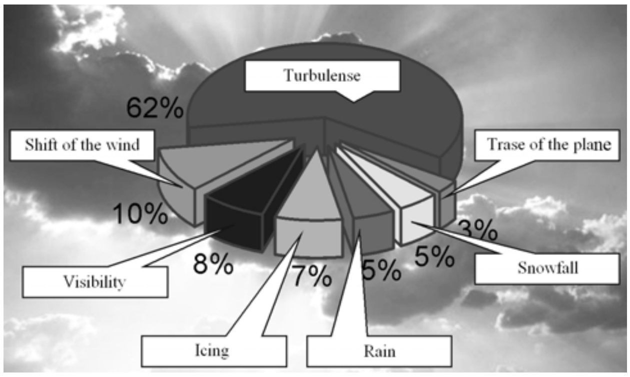


Fig. 1. Diagram wether conditions on air accidents

An unsteady flow about the wing leads to streamline structure rebuilding.

Aerodynamic characteristics under such rebuilding with increasing and decreasing angle of attack differ and make a dynamic loop at flight angles of attack, or hysteretic during returning from postcritical angle of attack leaving.

References analysis

First reason of ambiguous aerodynamic characteristics changes are viscous-non-viscous interaction [1] – interaction about boundary layer and created by it vortex-like flow of the wing [2]. Under pitch and yaw oscillatory motion condition, vortices are created at boundary layer of the wing. This vortices move from the leading edge to the trailing edge of the wing with the velocity equal to 0,3-0,5 of incident flow velocity.

This vortices change the pressure distribution along the wing and after its separation the unsteady flow process repeats with specified time intervals (fig. 2).

Shows the results of the pressure distribution calculation by profile NACA-0012, which has pitch oscillations by $\alpha = 5^0 \sin 0{,}4t$ for M=0,3; Re=10^6.

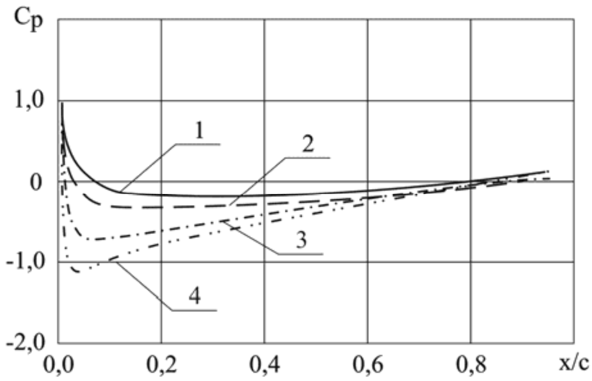
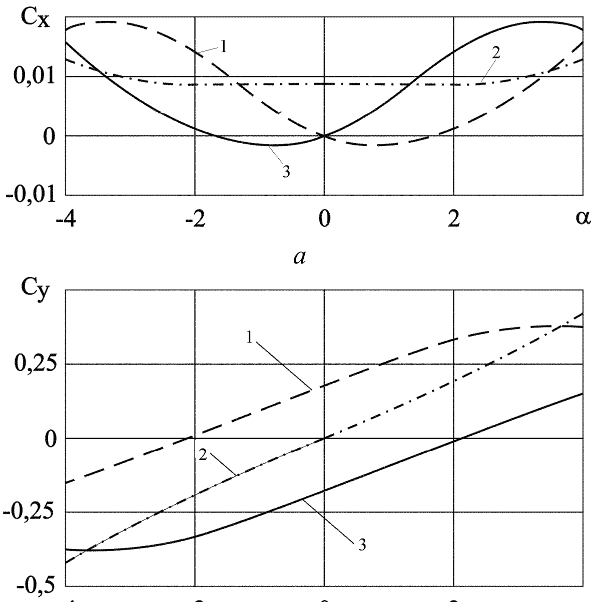


Fig. 2. Pressure coefficient on profile in subsonic flow on upper (*2*, *3*) and lower (*1*, *4*) surfaces when the profile oscillate ($\alpha = 4^o$)

The figure shows that pumping on the upper surface is greater at the decreasing angle of attack that increasing one.

Profile and airplane unsteady characteristics

Results show that aerodynamic characteristics – lift force, drag and longitudinal moment change by dynamic loop fig. 3.



b

Fig. 3. Loops in oscillating symmetrical profile drag (*a*) and lift (*b*) coefficients:
1 – decrease angle of attack; *2* – increase angle of attack;
3 – statically drag (*a*) and lift (*b*) coefficient significance

Development of unsteady flow about the wing profile depends on oscillation frequency, amplitude and airspeed.

Struchal's type modeling show: that lager oscillation frequency and smaller airspeed the influence of the unsteady flow on aerodynamics of the wing profile and airplane flight dynamic is greater.

Fig. 4 shows the results of cargo airplane flight tests with oscillated elevator and M=0,6, cruising regime and flaps deflected 20^o and 38^o, M=0,3 and M=0,27 is shown.

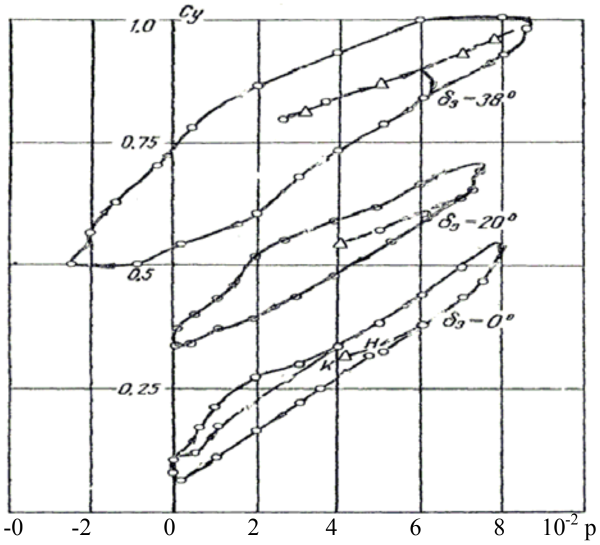


Fig. 4. Dynamic loop of the lift coefficient for flight without flaps ($\delta_з = 0$) and flaps 20° and 38°

As we see the flight with flaps make the dynamic wider. Developments of the vortex flow on the wing, most likely, result from vortex separation on the flaps.

The second case of the dynamic loop appearance in aerodynamic characteristics changes is the wing shock wave appearance.

The work [3; 4] show that during the wing profile oscillations the shock wave appears, depending on profile motion shifts along the wing chord changing the pressure distribution, as the result we have the dynamic loop, in of lift force, drag and moment changing.

Fig. 5 shows the results of the pressure distribution calculation by profile NACA-0012, which has pitch oscillations by

$$\alpha = 5^0 + 5^0 \sin 0{,}4t$$

for M=0,8; Re=10^6.

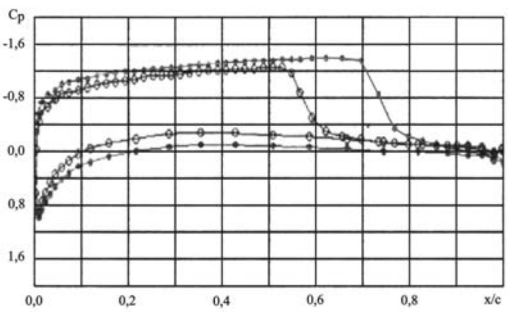


Fig. 5. Pressure coefficient changing on oscillating profile in transonic flow:
$\alpha = 5^o$ and move down; $\alpha = 5^o$ – and move upper

The figure shows that the pressure ratio on the upper surface essentially changes with increasing or decreasing angle of attack. The changing of the lift force and drag is shown in fig. 6.

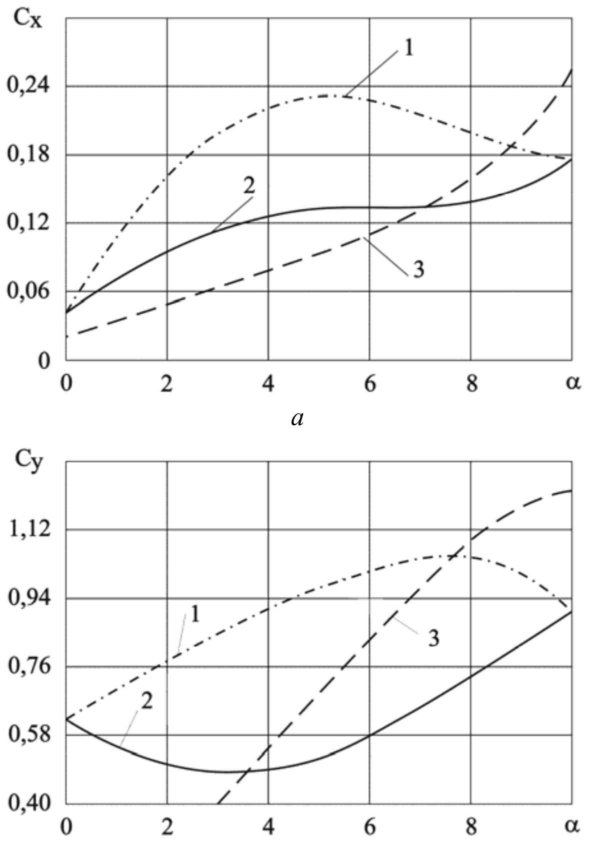


Fig. 6. Changing of drad (*a*) and lift (*b*) force coefficients by M = 0,8; Re = 10^6; α = 5 + 5 sin 0,4 *t*: *1* – decrease angle of attack; *2* – increase angle of attack; *3* – statically drag (*a*) and lift (*b*) coefficicut significance

Many scientists [5–8] have made reports on their investigation of unsteady flow of the wing. In general there is information about changing of the lift force and longitudinal moment, but there has been no consideration of aerodynamic drag changes so far.

Flight tests in disturbed atmosphere show there is an essential airplane altitude drop with constant thrust and oscillated motion within the limits of the flying angles of attack range change.

It could be explained as oscillation lift force or drag changing. In fig. 7 the results of the cargo airplane drag changing with pitch oscillations by elevator with different oscillation range and flaps deflected 20° and M=0,3 shown. The analysis shows profile and inductive drags changes in flight with flaps. Using flight tests data dependence $C_e^2 = f\left(C_x - C_p\right)$ fig. 8 was built. In this dependence an aerodynamic loop is saved.

Loop side up to intersection with $C_x - C_p$ axis gives us the change of profile drag with oscillations and ΔC_y^2 allows us to determine inductive drag. A change of drag coefficient is $-\Delta C_x = 0{,}006$ or 6,56% of nominal engine power.

Changes of lift force coefficient is $\Delta C_y = 0{,}1$. That correspond to inductive drag change $\Delta C_{xi} = 0{,}0006$ or 0,65% of nominal engine power. And full drag change with the flaps 20^0 is 7,21%.

Conclusion

Features of the unsteady aerodynamics will be important for the future aircraft design.

The research has shown that aerodynamic drug is being changed substantially under the unsteady flow about the wing. It is necessary to conduct special researches for the determination of the airplane drug change in the turbulent atmosphere.

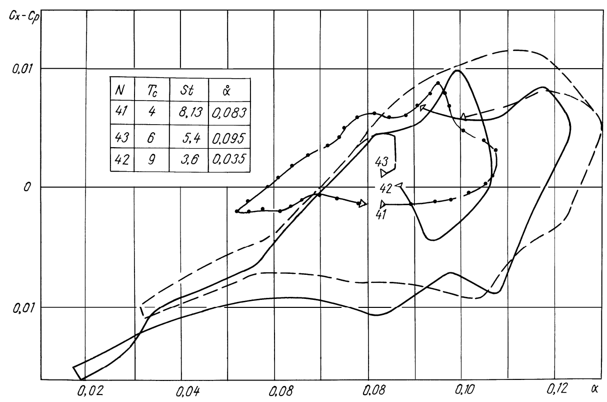


Fig. 7. Changing on the drag minus thrust coefficients, obtained in flight tests with oscillating plane by elevator (M = 0,29; δ = 20°)

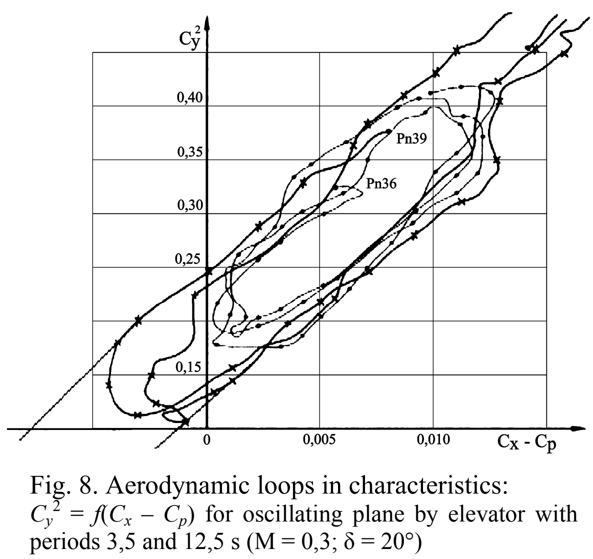


Fig. 8. Aerodynamic loops in characteristics: $C_y^2 = f(C_x - C_p)$ for oscillating plane by elevator with periods 3,5 and 12,5 s (M = 0,3; δ = 20°)

The research of the wing vortex structure and the active influence on them will permit to decrease the influence of unsteady impacts on the aircraft.

The increase of the profile drug under the wing profile oscillations in the transonic flow is more substantial than it was supposed. It is necessary to take into account substantial changes of aerodynamic characteristics of the airplane during the flight with flaps. The researches show that it is necessary to clarify the mathematical model of the airplane flight dynamics by introducing numbers, which take into account unsteady effects.

Acknowledgement

The author wants to thank the Science Department of National Aviation University for the research financing, teaching stuff of the Aerodynamics Department and students for their participation in unsteady aerodynamics studying.

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The editors received the article on 8 June 2005.

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Проблеми нестаціонарної аеродинаміки літаків

Розглянуто вплив нестаціонарного польоту літака на змінення коефіцієнтів опору та піднімальної сили. Показано, як цей вплив може змінювати траєторію польоту в турбулентній атмосфері. Отримані результати визначають зміни аеродинамічного опору в процесі нестаціонарного польоту. Це питання не розглядалось у багатьох роботах про вплив нестаціонарних сил на динаміку польоту літака.

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Проблемы нестационарной аэродинамики самолетов

Рассмотрено влияние нестационарного полета самолета на изменение коэффициента сопротивления и подъемной силы. Показано, как это влияние может изменять траекторию полета в турбулентной атмосфере. Полученные результаты определяют изменения аэродинамического сопротивления в процессе нестационарного полета. Этот вопрос не рассматривался во многих работах о влиянии нестационарных сил на динамику полета самолета.