UDK 532.512.:629.735.35

A.A. Rasstrygin, Cand. of Sc. (Eng.)

METHODOLOGICAL FUNDAMENTALS FOR INCREASE OF EFFECTIVENESS DESIGNING BOTH SAFETY OF OPERATION OF SEAPLANES AND AMPHIBIANS

Armed Forces of Ukraine Central Scientific and Research Institute

On the basis of earlier developed methodology of estimation of local and general hydrodynamics of amphibious and water-landing aircrafts, some outcomes of numerical researches of hydrodynamic parameters and their analysis for a mild multi-purpose amphibian are adduced at different versions of interplay with water surface on take-off and landing modes.

Introduction

The problem of maintenance of reliability of creation and safety of exploitation of flight vehicles (FV) of water and amphibious basing (seaplanes, amphibians, wingships – hereinafter FV) is one of major.

The experience of usage of similar FV on occasion has shown the indisputable superiority of their application as contrasted to FV of the conventional schemes [1].

Thus the circle of possible solved problems of such FV is rather significant – from general up to specific.

At the same time a number of complexities takes place at creation of such FV with the purpose of maintenance of reliability of a design during the subsequent exploitation, that is connected, first of all, to features of loading of bodies boats at interplay with water surface (WS) on take-off and landing modes (TLM), to what availability of a non-uniformity of distribution of hydrodynamic loads on the wetted back end of a boat, the values can essentially exceed which one the conforming values at flight in atmosphere, can be by the cause of plastic deformations or structural failure of FV during a contact to WS on TLM, to what the experience of creation of FV of last decades testifies.

The necessity of knowledge of the in-depth information about nature of loading of members of FV is necessary already at the stage of preliminary designing with the purpose of maintenance of sufficient strength and reliability of created design.

However, the definition of hydrodynamic parameters (HP) on TLM is complicated problem, that is connected to availability of demarcations of mediums, the characteristics of FV at interplay of a body of a boat with WS are non-linear.

Two approaches now will traditionally be used at definition HP at a stage of creation prototypes of FV with the purpose of acceptance of the design solutions: idealized and experimental.

The final operational development of prototypes of FV implements during flight-sea tests.

Today, a numerical modeling is considered as the most perspective, which one if there is adequate mathematical models allows effectively enough, with accuracy, reasonable to practice, to receive the indispensable information.

The idealized activities in a direction of similar researches in different statements of problems are known [1–5].

However, as the experience of designing of FV and analysis of known idealized surveys in the given direction testifies, for today is present of very poorly idealized outcomes satisfying practice [6].

Solution of a problem

For increase of efficiency of hydrodynamic designing, with the purpose of creation of reliable FV, the writers offer a methodology of an estimation HP FV on TLM [5], in which one for the basis the mathematical model of hydrodynamics for a body crossing a free surface of an ideal incompressible heavy fluid in non-linear non-steady statement is taken [4].

The assumption about model of medium is generally accepted for a similar kind of problems [1–5], the count of forces of tenacious interplay thus is designed by the known approaches [1].

Particular cases of numerical implementation of mathematical model [4] by a method of discrete vortexes for the flat and spatial schemes have shown sufficient reliability of the obtained outcomes [5].

However, sufficient experience of usage of mathematical model [4] for the different individual appendices has resulted in a conclusion about expediency of its usage for research, first of all, of problems of local hydrodynamics, that is connected to complexity of numerical implementation of spatial mathematical model in model of dynamics, specially at simulation of motion on agitated WS, including cross sea.

Numerical implementation of a complex of individual techniques of mathematical model [4] allows to determine: distributions of pressure on a wetted surface of the flying-boat in an incipient state of landing (landing impact and gliding), including with kinematical parameters invoking an asymmetry of flow (availability of bank angles, slip, their derivative and others) with the purpose of the analysis of local strength; issues of an input information for its calculations; definitions of operating limits of kinematical parameters and mining's of the proposals on a piloting technique on TLM, and also other problems.

The research FV dynamics behavior of on quiet and agitated WS, including cross sea, in concerns of problems of motion stability, definition of the balance characteristics, general strength, optimization of aerohydrodynamic layout and other writers is made on the basis of synthesis of different methods (flat cross sections [1; 2] and discrete vortexes [5]) in [7] and guesses the solution conforming system of differential equations [8] with the purpose of the count of change of kinematical parameters during a gliding of FV.

In a general methodology of researches these problems is referred to the unit of problems of general hydrodynamics.

As against known activities [1; 2], where the strip method flat cross sections, in [7] the hydrodynamics of sections on different phases of immersing a contour of arbitrary geometry in a liquid are determined by means of implementation of non-linear mathematical model [4], that allows as contrasted to by known analytical theory [1; 2] essentially to expand capabilities at researches HP FV.

Aerodynamic properties in right members motion equations [8] are determined on the basis of synthesis of linear and non-linear mathematical models of aerodynamics, which one realized by a method of discrete vortexes [5] and allow for influencing a screen (demarcation of mediums) and sprays from power plants at motion of FV on water surface on TLM.

For the count of friction drags the known approaches in theory of ship utilized and aerodynamics [1], and at simulation of a condition of WS – widely applicable in theory swinging of the ship a Neuman spectrum. For the count of the form of a track behind a main planing step of FV on it HP the known generalization of an experimental stuff on the given problem will be used [9].

Numerical examples of calculation and their analysis

As an example of implementation offered methodology some outcomes of numerical researches of local and general hydrodynamics of a mild multi-purpose amphibian "Lutama", located on a closing stage of construction (fig. 1) are adduced below.

In a fig. 2 the attitude of a maximum design pressure to set norms is adduced [10] for different values of a vertical velocity of landing V_y and angle of trim φ on landing on a smooth water h_w = 0 ("impact in a planing step") up to wash of bilge's (disregarding of margin of safety *f*).

The FV law motion in calculations was considered known, the changes of kinematics parameters were leave accounted.

As it is visible from a fig. 2 at separate modes of landing (speed key of kinematics parameters φ, V_y) the output for limitations of set norms local pressure takes place, that at exploitation can become the cause of destruction, plastic deformation of a design and by that decrease of a flight safety and exploitation as a whole

The availability of an agitated surface (h_w > 0) results in padding increase of load. For an example in a fig. 3 the computational distribution of factors of pressure is adduced at a longitudinal gliding (V_y=0) on declines of a regular surge of a swell with an angle of trim $\varphi = 5{,}5^o$ at a wave height h_w = 0,25 m for two lengths of surges λ_w = 15 m and λ_w = 35 m accordingly.

The outcomes of calculations are adduced only for a dextral half of back end in the field of a planing step on cross-sections *x*=const, where $\bar{z} = z/B$, *B* – width of the back end of a boat.

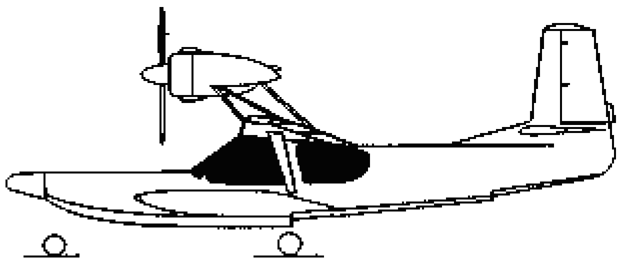

Fig. 1. A multi-purpose amphibian "Lutama"

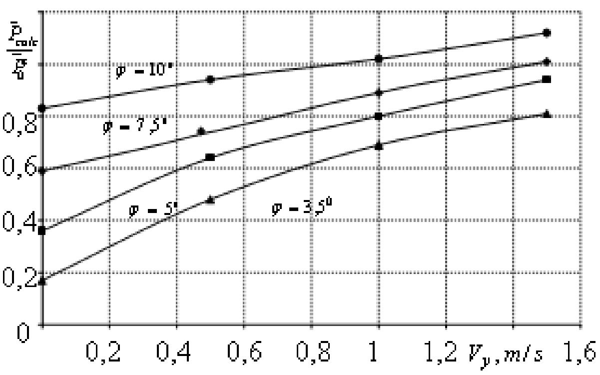

Fig. 2. A maximum design pressure during impact in a planing step

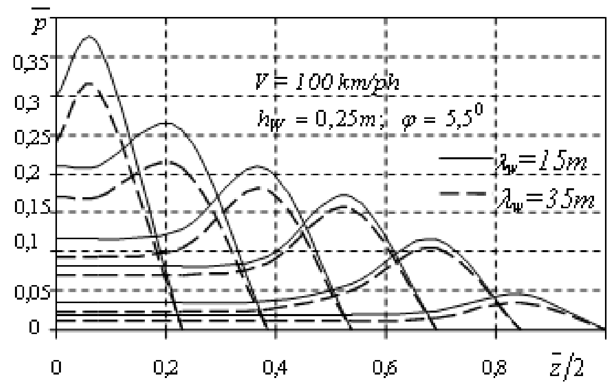

Fig. 3. Pressure distribution at a longitudinal gliding

The reduced outcomes of calculations demonstrate, that the range of possible implementations (speed key of kinematics parameters φ, V_y) secure landings (fig. 2) will be narrowed down.

The obtained data of numerical researches after their processing and analysis have allowed to formulate the guidelines on a piloting technique of FV on landing modes from a condition cross out for limits of set norms local pressure.

The similar information on a weight distribution on the flying – boat of designed FV is relevant in strength calculations and selection of a primary structure of boats.

As an example of implementation of a methodology on research of general hydrodynamics in a fig. 4 the counted balance characteristics (h_w = 0 m) – trim angle of a trim difference φ_{bal} and return lift-drag ratio ε in a function of a Froude number Fr_Δ are adduced for mean X_T position center-gravity of FV.

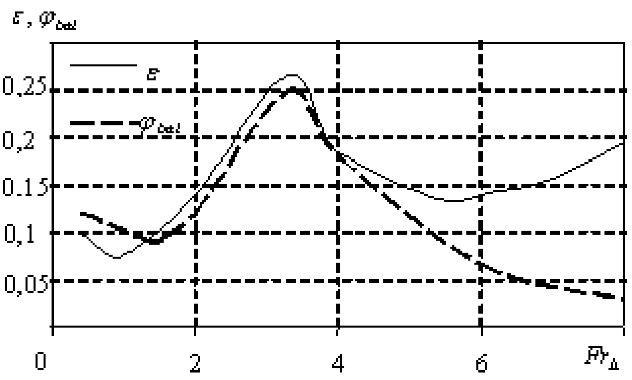

Fig. 4. Balance characteristics

In a fig. 5 the value, obtained in calculations, of normal overload in a cabin of FV during take-off from WS of regular sea by an altitude h_w = 0,45 m is adduced.

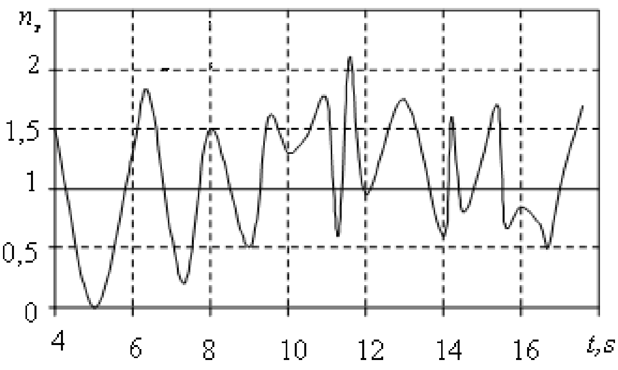

Fig. 5. Normal overload in a cabin of amphibian

The obtained data testify to necessity of their count at designing and exploitation of considered phylum's of FV.

Conclusion

The analysis of similar and other information obtained with usage of a designed methodology, allows to correct if necessary aerohydrodynamic layout, previously to evaluate:

– local strength;

– fracturing behaviors of studied object at a different condition of water surface;

– power demand of a power plant;

– to determine take-off (landing) ranges;

– possible overloads in interesting cross-sections of FV;

– to form limitations on kinematics parameters and guidelines on engineering of a secure piloting on TLM and many other, as a whole to increase efficiency of hydrodynamic designing and safety of exploitation of FV, contacting with WS.

References

1.*Косоуров К.Ф.* Теоретические основы гидроавиации (гидромеханика гидросамолета). – М.: Воениздат, 1961. – 600 с.

2.*Логвинович Г.В.* Гидродинамика течений со свободными границами. – К.: Наук. думка, 1973. – 247 с.

3.*Vorus W.* A flat cylinder theory for vessel impact and steady planing resistance// Journal of Ship Research. – 1996. – Vol. 40, № 2. – P. 89–106.

4. *Майборода А.Н.* Математическая модель гидродинамики для тела, пересекающего свободную поверхность идеальной весомой жидкости // Докл. АН УССР. – 1991. – Сер. А, № 5. – С. 50–53.

5.*Майборода А.Н., Расстрыгин А.А.* Математические модели гидродинамики тел, пересекающих свободную поверхность жидкости // Наука и оборона. – К. – 1994. – № 4. – С. 95–110.

6.*Dathe I., De Leo M.* Hydrodynamics characteristics of seaplanes as attected by hull shape parameters // Intersoc. Adv. Mar. Veh. Conf., Arlington, June 5–7, 1989. Collect. Tech. Pap. – Washington (D. C.), 1989. – P. 275 – 284.

7.*Расстрыгин А.А., Майборода А.Н., Михалочкин Н.А.* Методологические основы синтеза методов в задаче определения гидродинамических характеристик летательных аппаратов водного и амфибийного базирования для оценки их мореходности при продольном движении по водной поверхности // Матеріали VI міжнар. наук.-техн. конф. «Авіа-2004», 26–28 квіт. 2004 р. – К.: НАУ, 2004. – Т. 3. – С. 33.72–33.75.

8.*Расстрыгин А.А.* Некоторые аспекты методологического подхода к повышению эффективности гидродинамического проектирования летательных аппаратов водного и амфибийного базирования // Сб. науч. тр. IV междунар. науч.-техн. конф. «Гиротехнологии, навигация, управление движением и конструирование авиационно-космической техники», 21 – 23 апр. 2003 г. – К.: НТУ «КПИ», 2003. – Т.2. – С. 173 – 183.

9.*Korvin-Kroukovsky B.V., Savitsky D., Lehman W.F.* Wave countours in the wake of a 30^o deadrise planing surfact // Stev. Inst. of Technol. – 1949. – Rep. № 229. – 50 p.

10. *Четвериков И.В.* Конструкция гидросамолетов. – Л.: ЛКВВИА, 1953. – 230 с.

Стаття надійшла до редакції 30.09.05.

О.О. Расстригін

Методологічні основи підвищення ефективності проектування та безпеки експлуатації гідролітаків і літаків-амфібій

На основі реалізації розробленої методології оцінки локальної та загальної гідродинаміки літальних апаратів водного й амфібійного базування досліджено гідродинамічні характеристики легкого багатоцільового літака-амфібії при різних варіантах взаємодії з водною поверхнею на злітно-посадкових режимах. Наведено деякі результати та їх аналіз.

А.А. Расстрыгин

Методологические основы повышения эффективности проектирования и безопасности эксплуатации гидросамолетов и самолетов-амфибий

На основе реализации разработанной методологии оценки локальной и общей гидродинамики летательных аппаратов водного и амфибийного базирования исследованы гидродинамические характеристики легкого многоцелевого самолета-амфибии при различных вариантах взаимодействия с водной поверхностью на взлетно-посадочных режимах. Приведены некоторые результаты и их анализ.