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DEVELOPMENT TRENDS OF AMPHIBIAN’S SHAPE.

Zdanevich Vitaly, Mazin Alexandr
Beriev Aircraft Company, Southern Federal University

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The hydroplanes appeared, in actual fact, contemporarily with the land-based aircraft out of necessity to design a flying vehicle capable of taking-off and landing on water. The economic and national objectives set to the designers a task to develop the most optimal structure for highly effective operation of seaplanes.
The intensive development of sea aviation in the middle of the 20th century resulted in a wide spectrum of created seaplanes in terms of the take-off mass and combat capabilities. Apart from the float- and boat- seaplanes, a development of one more type of seaplanes, i.e. amphibians, started, though with some delay. The predominant seaplane structure in that time was a flying boat. This type includes airplanes with the heaviest weight level.

The intensive operation of the seaplanes identified their real capabilities, both military and civil. As a result of the post-war (after the Second World War) world rearrangement, the areas of the sea aviation application were redefined according to the national interests. Some tasks were taken over by the ships and land-based aviation. Civil application of the flying boats was limited by the general aviation. The seaplanes whose technical level corresponded to that of the former war years did not satisfy the new demands. This predetermined the development of a new generation of seaplanes that demanded, in turn, adequate scientific and engineering resources, production facilities, allocation of time and money. Due to this fact, the first prototypes of seaplanes of new generation appeared in the 50th – 60th only. Whereas before the 50th the previously developed seaplane designs were generally duplicated, the second part of the century was distinguished by the search for conceptually new designs.

The seaplane designers still come across two key problems of seaplanes development.

The most important property of the amphibians is the capability of making water-landings which depends on their sea-worthiness. Balanced against these parameters is the flight performance. Because of providing the required seaworthiness, the seaplanes stay behind the land-based analogs in terms of flight performance. Still, according to the study of heavy flying boats, this lagging behind diminishes with the increase of size.

Thus, the key task of the seaplane designing is to find an optimal balance between the aircraft seaworthiness and the provision of required flight performance.

Having analyzed the operational experience and the area of sea aviation application, one can determine the main trends of amphibians design.

The developed till now seaplanes were mainly used as patrol aircraft and performed transportation tasks on a second priority basis. Correspondingly, their design was adapted to the main task. The seaplanes were provided with the side hatches intended for cargoes or passengers loading from the waterborne devices, which, at the sea disturbance, was associated with certain difficulties and extra loading time. The design of modern amphibians intended for cargo and passenger transportation as their primary function allows loading without additional waterborne devices, i.e. directly from the pier. Therefore the new pattern of the amphibians application without special water airports with ramps and shore parking aprons allows to significantly reduce the general operational costs and to raise the amphibians cost efficiency as a means of air transportation.

The latest years are remarkable for sharp ecological problems, which primarily demand forests fire-protection. The most effective means of the forest fire-fighting, as experience shows, is an amphibian. Forests fire-protection task is acute almost for any country. To solve this problem, an amphibian has a significant advantage as compared to the land-based airplanes owing to its capability to scoop water from the nearest water area during take-off. Within one fuel load a fire-fighting amphibian is capable of throwing on the fire area the amount of water that by an order exceeds the airplane take-off mass. The shape of fire-fighting amphibians implies a number of additional structural hull elements providing water scooping while skimming on the water surface and its drop over the fire area.

The tasks of providing national security at sea are acute for naval forces of many countries. The fleet solves not only the patrol tasks in adjacent economic zones, but tasks of reconnaissance and counteraction to the water-surface ships and submarines. It has to be noted that for a seaplane the mid-air refueling, aimed to extend the aircraft flight range, can be added by the possibility of fueling from ships and submarines when afloat.

Local military conflicts set a task of increasing the efficiency of transport operations, which can be solved by amphibians that are capable of delivering specialized troops using both land airfields and water areas.

The analysis of the seaplanes design reveals that among a great number of seaplanes there are only several key concepts that have successfully shown themselves in operation:

– with straight wing and high hull;

– with gull wing and average-height hull;

– with straight wing on a pylon and low hull.

The prevailing design is the one with straight wing and high hull. This is followed by the gull-wing and average-height hull design. And uncommon for the heavy airplanes is the design with low hull and wing mounted on one or two pylons. It should be mentioned that the last design suits the seaplanes with the average take-off mass (up to 25 t). Development, according to this design, of a seaplane with the take-off mass of several dozen tons implies some problems in terms of strength and rigidity of the airframe structure and combination of wing and hull.

The application of a gull wing, as experience in amphibians design shows, is also limited by the take-off mass of about 50 t, as far as the “gull” makes it problematic to develop a light-weight structure with significantly loaded center wing section.

For relatively heavy seaplanes the appropriate design is a straight wing and a hull of required height to protect the wing and the engines from the water jets during hydroplaning.

To date, the Beriev A-40 Albatros (NATO reporting name *Mermaid*), created back in the 1980s, has been the biggest and the most perfect of amphibians ever. The airplane, built as a traditional high-wing amphibian, opened an avenue for jet-propelled seaplanes with high take-off and landing speeds. The airplane was intended to demonstrate extremely high flight performance and seaworthiness: these requirements brought about use of high-aspect-ratio swept wing and take-off weight of 80 to 90 ton. The need to reach the required performance called for application of several innovative technical solutions. To improve aerodynamics, hull aspect ratio was increased to 13.4; the implemented reduction in the hull height resulted in bringing the wing (with high-lift devices extended) closer to water. Therefore, the designers made use of the hull hydrodynamic behavior at take-off, which consisted in up-floating followed by a considerable reduction of draught at speeds of $0.5V_{\text{take-off}}$ or higher. To benefit from such behavior, the airplane was designed to extend the flaps gradually in the course of taking off, with the distance from flaps to water at low speeds and at hydroplaning kept approximately uniform. Both on the Beriev A-40 and on the multipurpose amphibian Beriev Be-200 (into which the A-40 was later developed), main landing gear legs are not retracted into the hull; instead, they are stowed in special fairings, which are arranged directly under the wing. The solution allows keeping the landing gear away from the jet-affected area, thus contributing to a considerable increase in length of the landing gear legs.

It should be noted that take-off speed is reduced owing to efficient double-slotted wing high-lift devices with a relatively higher flap setting than on previous seaplanes, which were prevented from applying high flap settings due to flap proximity to water and the resulting greater hull height. The differential flap extension allows reducing the hull height by 20% on average, thus partially settling the issue of the 'high' main landing gear attachment fittings and reducing the distance to runway surface.

To protect engines from water, they are installed on pylons at an optimum location near wing trailing edge. In such configuration, the engines are protected against hull nose induced water jets by the forward-located wing; in addition, wing aerodynamics is improved due the engines being removed from their traditional location on the wing.

Along with take-off speed reduction, variable-deadrise hydrodynamic configuration of the bottom is used to reduce hydrodynamic loads.

The above-described seaplane features, which were successfully implemented in the design of the Beriev A-40, are stemming from the evolutionary changes in the traditional shape of an amphibian.

However, there is an alternative concept. Studies of new promising large-size airplanes resulted in developing a configuration of a low-wing airplane. For this configuration, the designers, rather than distancing the wing from water to the maximum extent possible, ensure direct contact of the wing with water. In large seaplanes, strength of the greater portion of the wing is provided for by panels, whose strength and rigidity are as good as those of hull bottom panels; therefore, landing with such wing would not require any major reinforcement. The capability to use a certain portion of the wing volume in water displacement and thus to reduce hull volume, and the use of surface effect at take-off and landing allows enhancing weight and aerodynamic performance of the airplane and considerably mitigating the problem of multi-wheel landing gear arrangement. A low-wing amphibian, whose wing, when afloat, is an additional water displacing volume, has a considerably smaller hull volume. Advantages of the low wing include the possibility to use low-mounted engines, reduced undesired negative pitching moment as may be caused by engine thrust at take-off, reduced landing gear height, greater comfort for the passengers, and better view from the cockpit.

At hydroplaning, the supporting hydrodynamic force occurs in the hull nose and at wing trailing edges. Thus, the hydroplaning airplane has a peculiar three-point supporting configuration. This hydroplaning pattern has no upper threshold for stability; however, it features higher hydrodynamic drag, which makes the take-off run somewhat longer. Such aerohydrodynamic configuration, in general, has several advantages in comparison to the traditional configuration; and, for a large-size airplane, such advantages have a potential for a considerable increase. In particular, this is the case with the surface effect at take-off (which is very important for a configuration without flaps), combined water-displacing functions of the wing and the hull, etc.

Thus, having analyzed seaplane configurations and designs, we can now summarize methods and alternative solutions relating to design of modern amphibians and improvement of their seaworthiness performance.

The hull, which is the principal component of an amphibian, may be designed to have an aspect ratio of 5-6 thru 13-14. Hull height is selected depending on payload location, equipment arrangement, and povisions for protecting the wing and the engines from water coming from the hull's water-jet area. Hull volume and size may be reduced by making use of a low-mounted water-displacing wing. The traditional hull may be replaced with a twin-hull configuration.

The airplane wing may be located on the hull deck, and have a high anhedral angle in order to keep the engines away from water; alternatively, the wing may be arranged on one or two pylons on the hull deck – in such a case, the hull will be lower. The wing may be provided with various high-lift devices and efficiency improvements for such high-lift devices. There are also amphibians with low-mounted water-displacing center wing with almost no or actually no high-lift devices.

Balance floats are arranged under wing tips. The floats may be of supporting or water-displacing type. Seaplanes with low load on water may utilize sponsons.

Engines may be arranged on hull sides, in wing leading edge (provided that the wing is sufficiently distanced from water), pylon-mounted on wing upper surface or on hull upper surface or above the wing at the trailing edge.

Main landing gear legs may be arranged, depending on internal layout and structural configuration of hull, on the hull sides, outside the hull or in hull or wing wells, in engine nacelles on the hull sides beyond the jet-affected area or fully in the wing (if the wing is a low-mounted one). In all cases, nose landing gear and tail gear are retracted into the hull.

Take-off and landing speeds may be reduced by improving the efficiency of wing high-lift devices, increasing the wing area or using special devices. Wing lifting capacity at take-off and landing may be enhanced by making use of the surface effect or creating an engine blast-induced dynamic ‘cushion’. The load relief effect may be achieved by using direct-lift engines.

Hydrodynamic loads may be reduced by enhancing the efficiency of the hull deadrise and aspect ratio, reducing the wave-caused sways by aerodynamic or hydrodynamic damping, and making use of hydro-ski and hydrofoils.

To change configuration of the water-jet area, designers may utilize hydrodynamic panels, reduce the load on water, increase deadrise or reduce displacement angles.

Thus, the most feasible means to reach the required seaworthiness performance and technical performance of an amphibian are presented above.

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