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Safety and Airworthiness Design of Ultra-Light and Very Light Amphibious Aircrafts

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Abstract

Ultra-light and very light amphibious aircrafts are the special kinds of low-speed general aircrafts. They are low weighted and small sized but can takeoff and land either on land or water without changing the structure of any parts. These characteristics result in the distinctive configuration and structure design, and meanwhile bring about significant features of safety and airworthiness design. These problems are investigated by developing the ultra-light amphibious aircraft "Frigate bird" and analyzing the other aircrafts' design. This paper mainly discusses the preliminary design about structure, aerodynamics, power effect, flying qualities, dynamics and statics on water. Some analysis methodologies and design parameters which are different from the conventional general aircrafts' are also represented.

Keywords: Ultra-light; Very light; Amphibious; General aircraft; Safety; Airworthiness; Preliminary design;

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1. Introduction

The amphibious aircrafts can takeoff and land either on land or water without changing the structure of any parts so they are suitable for some special missions over wetland and sea. Since the early 1930s, the seaplanes and amphibious aircrafts have had their golden age because the land-based aircrafts without air refueling ability and reliable engines can't accomplish the missions with long distance over ocean.

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However, nowadays the seaplanes are no longer the main force of air vehicles but the amphibious aircrafts still play the important roles in some special fields such as private flying, fire fighting, search and rescue. Among famous large ones there are Canadian CL-215/415, Japanese US-1, Russian Be-200, and some general aircrafts such as "Seawind", LA-250, Be-103 are also popular because of their wide applicability in different environments [1]-[2].

An amphibious aircraft has retractable landing gear and special hull or floats which must endure the water impact loads and ensure the stability when landing or planing on water. In addition, it should have anti-spray configuration for power system, anti-rust structure and enough reserve buoyancy to avoid sinking or upsetting if it's damaged or encountering extreme weather and wave. All of above make the safety and airworthiness design of the amphibious aircrafts much more complex than the conventional design. And it's especially significant and difficult for an ultra-light and very light amphibious aircraft with extremely limited empty weight to satisfy the requirements of airworthiness certificates and corresponding design standards.

"Frigate bird" (figure 1 and table 1) is an ultra-light amphibious aircraft developed to lower the costs of the flight missions for flood monitoring, reservoir patrol and geography exploration in wetland. The flight tests and users' experience show that the aircrafts in this category have many features of aerodynamics, flying qualities, dynamics and statics on water. Aerodynamic and structure design are always the compromise between performance and reliability.

Fig. 1 "Frigate bird" during flight tests and trials on water

Table 1 Performance and technical data of "Frigate bird"

Wingspan (m, include wingtip)	10.6
Length (m)	6.4
Wing area (m2)	15.2
Maximum takeoff weight (kg)	352
Empty weight (kg)	190
Stalling speed (km/h)	40
Cruise speed (km/h)	70-85
Top speed (km/h)	100
Engine power (hp)	49
Standard fuel capacity (liter)	20

2. Definition and Airworthiness Standards

The most typical standard airworthiness standards for general aircrafts in commercial operations is FAR part 23 [3] which always brings about extensive costs and period of testing to prove the aircraft's airworthiness. Therefore many countries issue the special airworthiness certificates for the low-speed kit-built, amateur-built, research, sport and experimental light aircrafts in order to lower the costs of developing and using small general aircrafts. These corresponding special airworthiness standards and design standards [4]-[12] are usually applicable to the ultra-light and very light aircrafts with a single engine which carry no more than 2-3 persons. Their classification is mainly defined by the upper limits of maximum takeoff weight and stalling speed which are somewhat different in countries (figure 2). The two physical parameters indirectly limit the geometrical size and flight performance of the aircrafts.

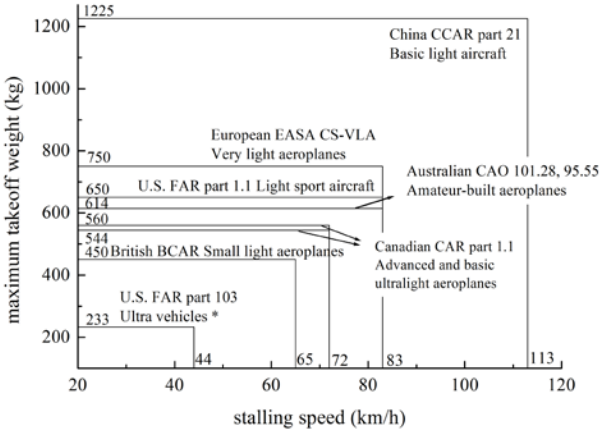

Fig. 2 Different classification standards of small light amphibious aircrafts

(* Empty weight and fuel capacity restricted in reference [12] plus the weight of pilot (80kg), hull (14kg) and wingtip floats (9kg) [13])

The airframe of a seaplane is surely heavier than the land based aircraft with the same gross weight. Therefore, it should be noticed that many standards in figure 2 allow the additional empty weight of the retractable landing gear, special hull and floats for a seaplane or an amphibious aircraft. Figure 3 shows the useful load of some typical ultra-light and very light amphibious aircrafts and indicates that their average useful load percentage is only about 41%.

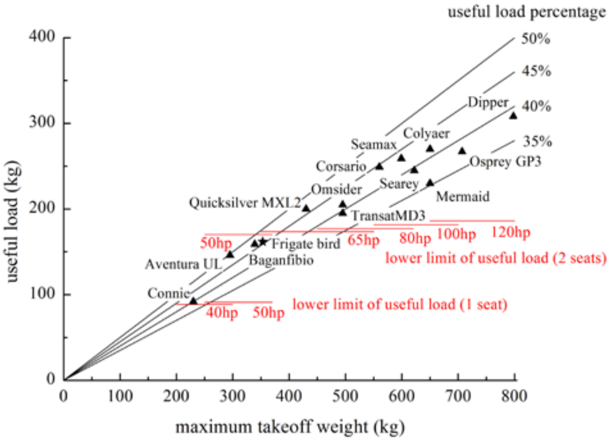

Fig. 3 Useful load of some small light amphibious aircrafts

In fact, the useful load of an amphibious aircraft is usually 15%-20% less than the land-based one with the same performance and gross weight. And this drawback of insufficient useful load is especially obvious with regard to the ultra-light aircraft with rated engine power lower than 50hp. Reference [8] and [10] require the minimum useful load in figure 3 as equation (1):

$$W_{min}=80S+0.22P \text{ (kg)} \qquad (1)$$

S is the number of seats and P is the rated engine power (hp). This requirement is only related to the practicability of an aircraft but not safety. As shown in figure 3, "Aventura-UL", "Frigate bird" and "Baganfibio" with rated engine power between 40hp to 50hp are not very competent to operate as the typical two seats aircrafts. Although the larger wing area can increase the useful load capacity, this design may worsen the cruise performance and more gross weight easily causes the difficulty on getting away from water. Therefore, they are more suitable to be the single seat aircrafts. Their empty weights inevitably exceed the upper limit of reference [12] and [13] considering some unnecessary airborne equipment and comparably streamlined and clean configuration are helpful for practical operation.

In general, aerodynamic and structure design requirements of these special airworthiness standards follow or simplify the corresponding requirements of FAR part 23 [3], and the systems of control, powerplant and airborne equipment are also properly simplified. These special airworthiness standards are usually seen as the design standards of ultra-light and very light aircrafts worldwide. Therefore, "Frigate bird" is designed mainly according to the European certification specifications for very light aeroplanes [5] and Canadian design standards for advanced ultra-light aeroplanes [10] which are popular for applying the special airworthiness certificates in different countries.

3. Aerodynamics Design and Flying Qualities

3.1. Longitudinal Characteristics

The aircraft must be longitudinally stable under reference [3]. This basic requirement always leads to the medium or larger horizontal tail volume ratio V_h (0.5-0.65) for the conventional general aircrafts. But ultra-light "Aventura-UL" and "Frigate bird" both show the obviously short tail arm and small horizontal tail in figure 4. In fact, V_h of the "hang-glider" configuration with high wing and inverted pusher engine even can be lower than 0.42 and still supplies enough longitudinal stability. This design feature results from the "pendulum stability" [14] of high wing and power effects of propeller.

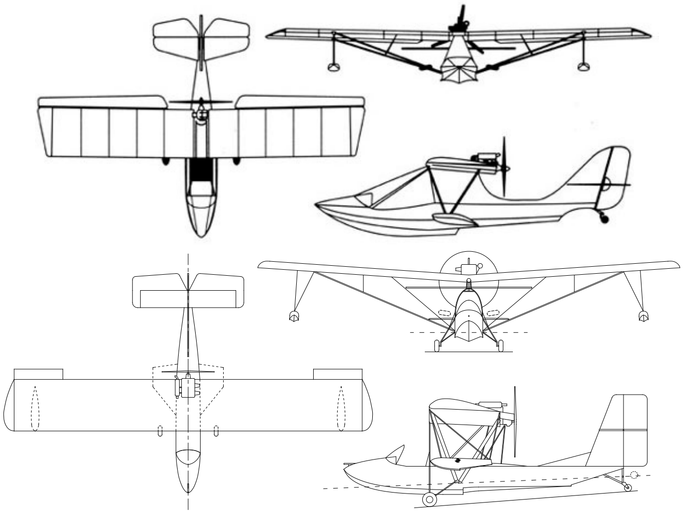

Fig. 4 Three-view drawings of "Aventura-UL" (up) and "Frigate bird" (low)

Figure 5 shows the wind tunnel test results of wing's pitching moment coefficient C_{mw} about center of gravity (CG) at different positions. Nondimensional $\overline{X}_G$ and $\overline{Y}_G$ are the longitudinal and vertical distances from CG to leading edge of wing's root chord which are divided by the mean aerodynamic chord of wing.

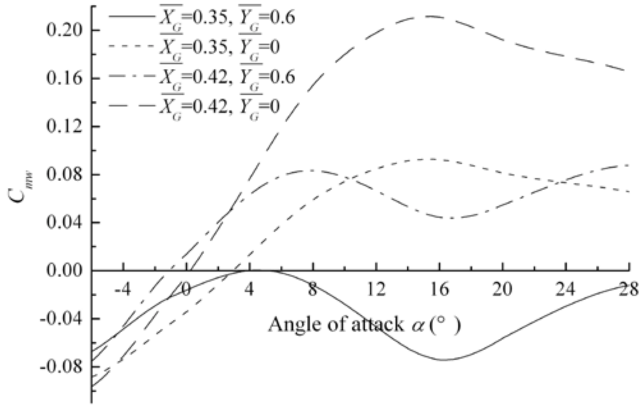

Fig. 5 Pitching moment coefficient of wing versus angle of attack

The position of CG significantly affects C_{mw}. The wing even produces noseup moment if CG moves rearward, therefore the horizontal tail may produces positive lift to trim when nosedown moment of engine thrust is insufficient. This trimming characteristic is somewhat identical to the aircraft with static instability design. And the large vertical distance $\overline{Y}_G$ especially decreases the curves' slope before stalling. This effect means that the high wing configuration produces additional longitudinal static stability (figure 6).

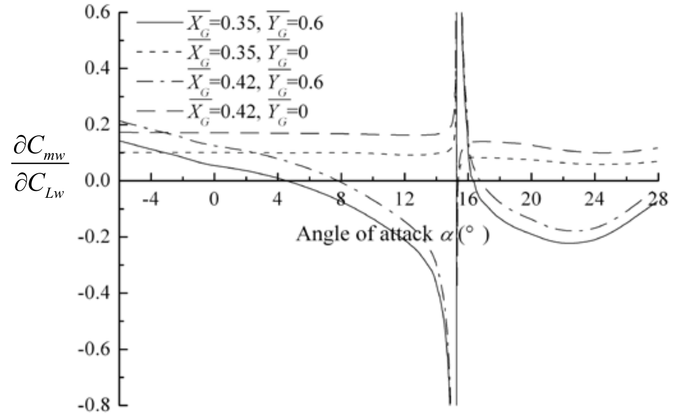

Fig. 6 High wing's contribution to longitudinal static stability

$\partial C_{mw} / \partial C_{Lw}$ is the partial derivative of wing's C_{mw} with respect to its lift coefficient, and the opposite number of this value can be seen as the wing's contribution to static margin. According to the figure 6, high wing of "Frigate bird" supplies additional static margin of about 9%-25% at smaller angle of attack, even the aircraft could be stable ($\partial C_{mw} / \partial C_{Lw} < 0$) without horizontal tail at medium angle of attack before stalling. The singularity at stalling angle is due to that C_{Lw}-α curve slope equals to zero when wing reaches the point of maximum lift.

The designer of light amphibious aircraft always adopts an inverted pusher engine mounted above wing to avoid the water spray. This design causes the resultant power effects of propeller on longitudinal stability.

The normal force of propeller after CG with variable α_T produces longitudinal static stability. This effect can be calculated according to the blade element theory of propeller with small α_T [15] or estimated according to reference [16].

Average induced velocity v_1 at propeller disk based on momentum theory can be calculated as equation (2) [17].

$$v_1^4 + 2v_1^3 V_0 \cos(\alpha_T - \varepsilon) + v_1^2 V_0^2 - \left(\frac{2T}{\rho\pi D^2}\right)^2 = 0 \tag{2}$$

V_0 is the airspeed. T is propeller thrust. α_T is the angle of attack of thrust line and ε is the downwash angle of wing. Contraction and acceleration of slipstream will cause the additional dynamic pressure Δq and angle of attack $\Delta\alpha_h$ of horizontal tail as equation (3) and (4).

$$\Delta q = \rho[k_d^2 v_1^2 + 2k_d v_1 V_0 \cos(\alpha_T - \varepsilon)]/2 \tag{3}$$

$$\Delta\alpha_h = -\varepsilon - \arcsin\left[\frac{k_d v_1 \sin(\alpha_T - \varepsilon)}{\sqrt{k_d^2 v_1^2 + V_0^2 + 2k_d v_1 V_0 \cos(\alpha_T - \varepsilon)}}\right] \tag{4}$$

k_d is the development factor of v_1 [17]. Table 2 shows the power effect on typical derivatives of horizontal tail.

Table 2 Typical derivatives of horizontal tail in different conditions

Trimmed condition	C_L =1.0 Engine on	C_L=1.0 Engine off	C_L=1.5 Engine on	C_L=1.5 Engine off
$C_{m\alpha h}$	-1.25	-0.64	-1.22	-0.64
C_{mqh}	-8.66	-4.90	-8.54	-4.91
$C_{m\dot{\alpha}h}$	-3.76	-1.84	-3.65	-1.82

It is concluded that the propeller slipstream actually has the equivalent effect of enlarging nearly 90% of horizontal tail's area. All the power effects mentioned above nearly produce additional 4.5% static margin and obviously change the short period characteristics of "Frigate bird" as table 3.

Table 3 Short period characteristics in different conditions

Trimmed condition	C_L =1.0 Engine on	C_L=1.0 Engine off	C_L=1.5 Engine on	C_L=1.5 Engine off
ω_{nshort}	4.14rad/s	3.02rad/s	3.31rad/s	2.62rad/s
t_{short}	3.98s	9.81s	2.79s	3.23s
t_{half}	0.18s	0.23s	0.29s	0.40s
ζ_{short}	0.92	0.98	0.73	0.67

The power effects strengthen the "pitching stiffness" by increasing the undamped natural frequency ω_{nshort} (or decreasing time of short period t_{short}), and meanwhile the convergence of pitching oscillation is accelerated by decreasing time to half t_{half}. The larger damping ratio ζ_{short} of C_L=1.0 is due to the higher airspeed.

Flight tests finally prove that "Frigate bird" with much lower horizontal tail volume ratio (V_h=0.4) still shows enough stability with CG located at normal longitudinal position of conventional design ($\overline{X}_G$=0.3-0.4). However, large elevator is always necessary for this configuration to ensure sufficient maneuverability in power-off condition, even the stabilator is adopted for some aircrafts such as "Connie", "Transat-MD3" and "Seamax".

3.2. Lateral-Directional Characteristics

Different airworthiness standards all give the specific requirements about flying quality of dutch roll mode, for example, this mode must be damped to 1/10 amplitude in 7 cycles with the primary controls under FAR part 23. In contrast, spiral mode is always neglected but it's more significant for the low-speed aircraft with larger wingspan like a powered sailplane, and this is just the common design for amphibious aircrafts to ensure takeoff performance on water. Table 4 compares the typical lateral-directional derivatives of "Frigate bird" with other general aircrafts' [18].

Table 4 Typical lateral-directional derivatives of different aircrafts

	Frigate bird	Frigate bird	Cessna-182	King Air
	Cruise	Approach	Cruise	Approach
C_L	1.0	1.5	0.35	1.15
$C_{y\beta}$	-0.49	-0.49	-0.31	-0.59
$C_{n\beta}$	0.092	0.102	0.065	0.12
$C_{l\beta}$	-0.162	-0.183	-0.089	-0.13
C_{lr}	0.279	0.414	0.096	0.06
C_{lp}	-0.60	-0.61	-0.47	-0.50

$\left| C_{n\beta}/C_{l\beta} \right|$ of "Frigate bird" is comparably small and this probably brings about unsatisfactory dutch roll mode. However, flight tests show that the lateral-directional flying qualities are basically satisfactory and there is not any unacceptable oscillation. This characteristic is partly due to the sufficient damping ratio ζ_d of dutch roll mode which results from the larger damping derivatives such as $C_{y\beta}$ and C_{lp} matched with smaller gross weight and moment of inertia. Another important reason is the special effect of "static stability of bank angle" which is indicated in the eigenvector diagrams of dutch roll mode (figure 7).

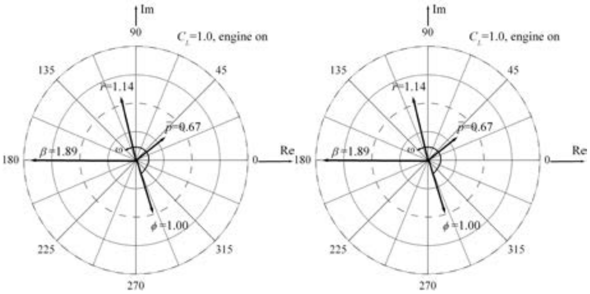

Fig. 7 Eigenvector diagrams of "Frigate bird" dutch roll mode

The large coupling derivative C_{lr} of “Frigate bird” is caused by its high lift coefficient and large wingspan. Figure 7 shows that the phase difference between bank angle ϕ and yaw rate r is about 180°. Hence the C_{lr} and r with comparably large amplitude will produce large lateral righting moment during lateral-directional oscillation.

Table 5 gives the lateral-directional characteristics of “Frigate bird” with different dihedral angle of wing which has great effect on flying qualities. The symbols below are defined in reference [19].

Table 5 Lateral-directional characteristics of “Frigate bird” with different dihedral angle of wing

C_L =1.5 Engine off	Dihedral angle of wing		
	2°	4°	6°
$\lvert C_{n\beta}/C_{l\beta}\rvert$	1.06	0.55	0.39
t_R	0.14s	0.14s	0.13s
t_2	5.69s	8.57s	17.08s
ζ_d	0.50	0.42	0.36
ω_{nd}	2.15rad/s	2.27rad/s	2.40rad/s
$\omega_{nd}\zeta_d$	1.08rad/s	0.96rad/s	0.87rad/s

The data in table 5 and pilot’s evaluation both prove that dutch roll mode of “Frigate bird” can easily satisfy the level-1 of reference [19]. However, Flight tests indicate that the disturbed aircraft tends to increase bank angle and gets into steep turn. This divergent phenomenon will be more serious if dihedral angle is decreased. This is due to the divergent spiral mode whose the time to double t_2 only satisfies the level-2 of reference [19] with 4° dihedral angle of original wing design. The simplified criterion for convergence of spiral mode [20] is:

$$\lvert C_{n\beta}/C_{l\beta}\rvert < \lvert C_{nr}/C_{lr}\rvert \tag{5}$$

In fact it’s difficult for designers to satisfy inequality (5) by normal techniques because the large C_{lr} is inherent for this low-speed configuration. Increasing $\lvert C_{l\beta}\rvert$ by adopting large dihedral angle of wing is advisable to modify spiral mode. Large $\lvert C_{l\beta}\rvert$ also benefits roll control (figure 8), and it’s especially significant for ultra-light aircrafts without enough control power of ailerons. Even the wing with medium sweepback angle may be adopted such as “Searey” (figure 9) to get the similar “dihedral effect”.

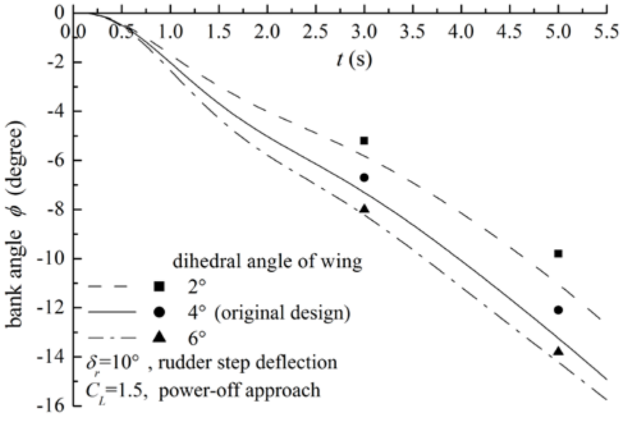

Fig. 8 Response of bank angle to rudder step deflection

Many ultra-light and very light aircrafts adopt the flexible wing with the skin made of dacron or nylon fabric, therefore the structure without wing box limits the control power of ailerons. In figure 8, the flight test data and calculated curves of linear model of "Frigate bird" both show that the large dihedral angle enhances the rudder's ability to control bank angle. And the result is also partly due to the large C_{lr} which brings about the divergent spiral mode. However, it's suggested that the control derivative of rudder $C_{n\delta r}<-0.04$ should be ensured.

Ultra-light "Quicksilver MXL-2" (figure 9) and "Frigate bird" both adopt the configuration of large rudder matched with "superabundant dihedral effect". The pilots can always use the combination of controls to satisfy the requirements about rate of roll in the airworthiness standards [3] [5].

Fig. 9 Very light "Searey" (left) and ultra-light "Quicksilver MXL-2" (right)

4. Hull and Wingtip Floats Design

4.1. Hull Design

In order to achieve higher performance, an amphibious aircraft is always designed to be a flying boat which consists of a hull as fuselage and two wingtip floats. The structure and form of the hull for small amphibious aircrafts are not essentially different from the large ones', however there exists some design features with regard to the ultra-light and very light classifications.

An amphibious aircraft may not have dangerous or uncontrollable porpoising characteristics during operating on water [3]. However, there has not been a systematic theory for analyzing the hydrodynamics of hull in planing regime. Therefore, the water handling characteristics are always investigated through tank tests of scaled model and trials on water of the real plane.

The afterbody of the hull of an ultra-light and very light amphibious aircraft is always comparably short and thin, and this is caused by the structure and aerodynamic design. Short tail arm and thin afterbody easily bring about insufficient afterbody buoyancy and unacceptable water resistance hump at resultant large trim angle. To solve this problem, "Frigate bird" adopts the smaller sternpost angle to increase the displacement volume of afterbody, and this design also decreases the parasite drag of hull during flight. However, the smaller sternpost angle lowers the upper limit of trim angle for stable planing [21], and as a result "Frigate bird" with original step design shows the divergent porpoising at larger trim angle. This problem has been finally solved by changing the position and shape of the original transverse step as shown in figure 10. The *b* in figure 10 is the width of hull.

When get into planing, the hydrodynamic loads result in the main force and moment instead of aerodynamic loads. The aircraft tends to increase the trim angle to move afterwards the hydrodynamic pressure center at forebody bottom, and then to setup a balanced condition. However, the small sternpost angle seriously limits the trim angle. Then the large noseup moment caused by forebody bottom and the nosedown moment caused by sternpost become the alternate loads and lead to the divergent porpoising. The hydrodynamic pressure center of the thin hull with tandem seats is especially at the adverse forward position and worsens the divergent porpoising.

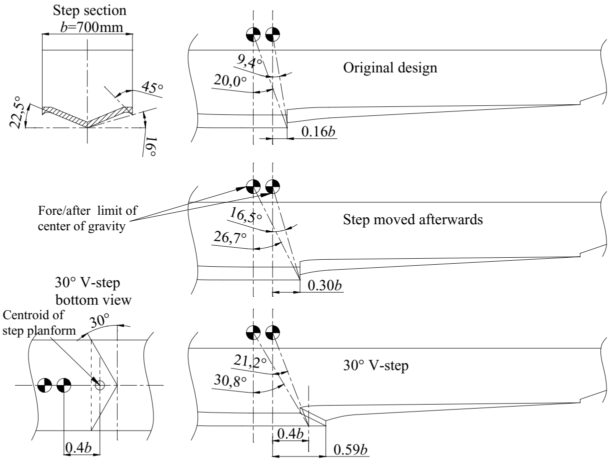

Fig. 10 Original step of “Frigate bird” and its two modified shapes

The longitudinal distance between CG and step is the most important factor determining the stability of planing. The CG is usually 0.15*b*-0.3*b* forward of step for the conventional seaplanes and the angles shown in figure 10 concerning CG and keel point of step is usually 10°-25°[22]. But trials show that these ranges are not very suitable for “Frigate bird” with small sternpost angle when CG is at after limit. Finally, 0.3*b* is thought to be the lower limit of the longitudinal distance from CG to step for stable planing of “Frigate bird”, and 0.4*b* makes the safe range of trim angle wide enough for short takeoff. The V-step can lead to the mild transition from displacement regime to planing regime and decrease the low-speed water resistance and air drag of hull. Figure 11 shows that the hull step of “Colyaer” with the thinner afterbody and smaller sternpost angle obviously is also at a comparably afterward position.

Fig. 11 Comparing the longitudinal position of hull step of “Colyaer” (left) and “Aventura-2” (right)

Considering the low weight and simple structure of ultra-light and very light amphibious aircrafts, the watertight compartments are not the necessary design for the aircrafts with maximum weight lower than 680kg in reference [3]. However, the watertight compartments are still significant for the safety of practical operation. “Frigate bird” has the strengthened hull bottom and the two main watertight compartments at bow and stern (figure 12) where is most probably damaged by underwater obstacle and other vessels. If these two watertight compartments are filled with water, the hull with more than 150% reserve buoyancy can still support the aircraft. The hull of all-metal “Mermaid" even has five watertight compartments, and this design far exceeds the design standard in reference [3].

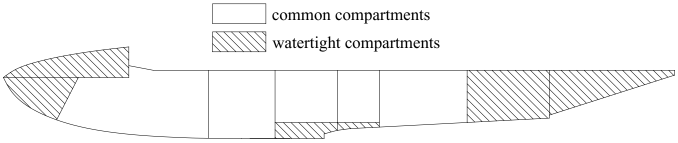

Fig. 12 Watertight compartments distribution of “Frigate bird”

During taxiing on water, large seaplanes may control direction in displacement regime by making the engines on wing produce asymmetric thrust. However, this control method is not applicable for an ultra-light and very light design with restricted single engine [5] [10]. Some very light ones such as "Seamax", "Searey" and "Colyaer" adopt a water rudder after sternpost, and it is always retractable to avoid damage during takeoff and landing on land (figure 13). However, this design seems to be somewhat complex and unnecessary for an ultra-light design with inverted pusher propeller. The area of water rudder is commonly 1.8%-2.8% of the product of draft and wetted length. This value is 2.5% for the original design of "Frigate bird", and the control moment of water rudder can be estimated according to reference [23].

Fig. 13 Retractable water rudder of "Seamax"

The performance of propeller in axial flow can be calculated accurately by strip theory [24] and then the control moment of air rudder can be estimated as equation (6) [16]:

$$N_r = 0.5\rho[(V_0 + k_d v_1)^2 S_v' + V_0^2 (S_v - S_v')] C_{n\delta_r} \delta_r \tag{6}$$

The induced velocity v_1 and development factor k_d can be calculated based on momentum theory as mentioned above [17]. S_v is the area of vertical tail, and S'_v is the area of its part submerged in propeller slipstream.

Figure 14 compares the control moment of water rudder and air rudder with the same deflection angle of 30° .

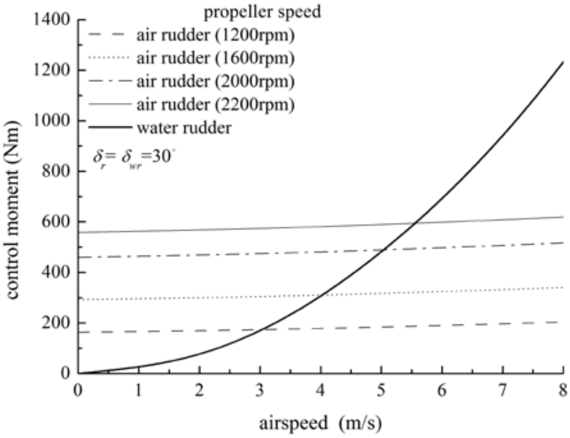

Fig. 14 Comparing the control moment of water rudder at sternpost and air rudder in propeller slipstream

The displacement regime of "Frigate bird" is less than 7m/s and the air rudder can supply considerable control moment especially at low speed less than 5m/s. Trials on water only using air rudder prove that even the lower propeller speed below 1600rpm is competent to produce enough control moment of air rudder by which the aircraft can make a turn within the radius smaller than its wingspan. The water wake after the hull in figure 15 indirectly shows this performance.

Fig 15 Turning on water within small radius only using air rudder in propeller slipstream

4.2. Volume of Wingtip Floats

The form of wingtip floats is not the key factor for hydrodynamic characteristics but their volume is the most important parameter for the safety on water. It is difficult for a hull with common form design to have CG below its transverse metacenter, therefore enough volume of wingtip floats is necessary to supply righting moment when the airframe is tilted (figure 16).

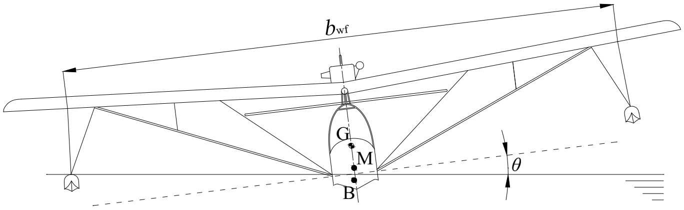

Fig. 16 Tilted attitude with a wingtip float submerged in water

Volume of wingtip floats V_{wf} is always estimated by equation (6) and (7)[22] [25] :

$$V_{wf} = (1+n)\frac{2W_0\overline{MG}\tan\theta}{\rho_{water}b_{wf}} \tag{6}$$

$$\overline{MG}=\overline{BG}-I_x/V \tag{7}$$

As shown in figure 16, θ is the angle of inclination when a wingtip float is completely submerged in water. $\overline{MG}$ is the vertical distance from transverse metacenter (M) of hull to CG (G). $\overline{BG}$ is the vertical distance from center of buoyancy (B) to CG, and it is assumed to be a constant value since θ is always a small angle (θ=6.5° for "Frigate bird"). It should be noticed that the buoyancy of hull will not produce any moment about transverse metacenter (M) in the theory of ship statics [26]. W_0 is the gross weight of aircraft. I_x is the moment of inertia of hull's waterplane and V is the hull's displacement volume.

The most important parameter in equation (6) is the reserve buoyancy coefficient n which is a safety factor considering the possible damage of float and additional upsetting moment caused by crosswind and wave height. The value of n is suggested to be 2-3 [22] [25].

When n is assumed to be zero, V_{wf} to balance the upsetting moment of tilted "Frigate bird" on smooth water is only 0.0032m^3 through equation (6). However, the V_{wf} of "Frigate bird" is finally designed to be 0.0125m^3 which has about 290% reserve buoyancy (n=2.9). Trials on water prove that adopting n=0.5 in airworthiness standards [3] and [5] as the lower limit of reserve buoyancy is not feasible because the centrifugal force produces quite large upsetting moment when “Frigate bird” is making a steep turn on water. Sometimes this factor even consumes most of the reserve buoyancy according to the experience from trials of “Frigate bird”. This paper gives another semi-empirical equation (8) to determine the V_{wf}:

$$V_{\mathrm{wf}} = \frac{2W_0\overline{MG}(1.5\tan\theta + a_{n\max}/g)}{\rho_{water} b_{\mathrm{wf}}} \tag{8}$$

$a_{n\max}/g$ is the design value of maximum normal load factor when the amphibious aircraft is turning on water. This value for an ultra-light or very light design is between 0.25-0.32.

Decreasing the parasite drag caused by wingtip floats with considerable V_{wf} is significant for an ultra-light and very light amphibious aircraft. Enhancing the transverse stability of hull by decreasing the distance $\overline{\mathrm{MG}}$ is the only method to decrease the required V_{wf}. This object always leads to the cabin with seats side by side and resultant large width of hull. However, the aircraft with tandem seats and thin hull such as “Baganfibio” and “Omsider” (figure 17) may adopt two auxiliary floats at midship to increase the height of hull’s transverse metacenter (M) and this design brings the additional advantage of higher hydrodynamic lift during planing.

Fig. 17 “Omsider” with auxiliary floats at midship

5. Conclusions

Ultra-light and very light amphibious aircrafts have many features about their safety and airworthiness design. There are many classification standards under the airworthiness standards of different countries.

The characteristics of amphibious aircrafts’ structure design bring about the drawback of insufficient useful load, therefore the ultra-light one with engine power lower than 50hp is more suitable to be a one-seat design.

High wing and power effects caused by inverted pusher propeller produce enough longitudinal stability for the design with much lower horizontal tail volume ratio than the conventional design value.

The low-speed and high-lift configuration like a powered sailplane usually has the outstanding flying qualities of dutch roll mode but the spiral mode is divergent. Enhancing the “dihedral effect” can modify the spiral mode and bring the advantage of roll control.

The longitudinal distance between CG and step of a hull with thinner afterbody and smaller sternpost angle should be larger than conventional design value.

Watertight compartments seem to be still necessary for the safety of ultra-light and very light amphibious aircrafts. However, the water rudder may be unnecessary for the design with vertical tail submerged in propeller slipstream.

The volume of wingtip floats is not only determined by static balance in water, but the upsetting moment caused by inertia force during turning on water should be considered as the most important factor.

The hull with large width or auxiliary floats at midship is the helpful design to enhance its transverse stability and to decrease the required volume of wingtip floats which causes large air drag.

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