ADVANCE SEAPLANE CONCEPTUAL DESIGN ADAPTING TRIMARAN BOAT HULL CONCEPT

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Abstract

Early seaplane designs adapted the concept of adding a boat hull or either twin floats into an aircraft to convert it into a seaplane. The purpose of this paper is to adapt the best of using both ideas, a flying boat hull adapted with floats, i.e. a trimaran technology concept. The conceptual idea of the trimaran gives the seaplane an advantage over other type of design concepts. The hydrostatic stability, dynamic stability, wave handling and water performance are some of the advantages that trimaran resulted. One concern of the trimaran idea is the extra aerodynamic drag generated by the floats. The solution is to place the floats inside the boat hull, the same way landing gear is mounted undercarriage. The preliminary results showed that the trimaran concept gave an excellent hydrostatic stability, a greater water speed, and retracting the floats decreases the aerodynamic drag, hence better flight performance.

1 Introduction

Seaplanes are a type of fix wing aircraft adapted with a floating device (floats or boat hull) that is capable to land, takeoff and operate on water. With the creation of the world's first successful airplane done by the Wright Brothers in 1903, the idea for improving and exploring the world of aeronautics have been expanding rapidly throughout the 20th century. With the lack of suitable landplane infrastructure and the availability of vast motor boats, the idea of creating a seaplane could not be held. The first motor seaplane flight was conducted in 1910 by a French engineer Henry Fabre [1], and since then, much research on seaplane aviation was widely conducted.

Many experiments on seaplanes were conducted in order to design an efficient seaplane. However, in the mid-1950's, with the introduction to improve aircraft designs and the construction of suitable landplane infrastructure, the use of seaplane traffic and operations drastically drop [2]. No new experimental or theoretical approach has been done ever since. Most studies conducted today are by adapting existing aircraft with a floating device (floats) to convert a landplane to seaplane. Some of the advantages that seaplanes can afford today are the use air-sea rescue missions, fire bombers, tourism and can afford point to point connections to places inaccessible to other types of transportation [3]. Seaplanes can. Based on a research made by Cronin Millar Consulting Engineers to Harbour Air Ireland [4] and the US Army Corps of Engineers [5] seaplanes have a very low environmental impact.

The main problem with seaplanes today is compared to the case of the duck. I duck can fly, swim and move through land, but it cannot fly as fast as an eagle, swim like a penguin, or run like an ostrich. It is well known that air performance is compromised due to the increase of the water components added to the aircraft. But the main problem that seaplanes face today is the water performance due to the lack of efficient and economical floating ideas for a modern seaplane design [6].

In this paper, a new approach for an advance seaplane design will be analyzed. Manipulation of old empirical formulas with modern ideas will be adapted.

2 Conceptual Design Proposal

With the decrease in seaplane traffic and operations, modern seaplane designs stagnated. Most conceptual design ideas and theoretical approaches made for seaplanes are mainly used with early 1900's empirical equations and experimental testing. For this seaplane design, a new, modern and advance design would be approach in order to satisfy the needs of this futuristic idea.

2.1 Proposal Ideas

Based on the market research and the technological review, the creation of a new seaplane design will require time and costs in manufacturing, regulation, certification, and social acceptance. The most convenient solution for the near future will be to create an innovative seaplane design based on existing certified aircraft, i.e. converting an existing landplane into a seaplane by adding a floating device. The seaplane conversion will be cheap to repair due that it will share all the parts of its landplanes counterparts, except for the floating devices that will be used.

Many proposed ideas were analyzed for possible technical solutions that will aim to reduce costs on research, manufacturing and operation of an advance seaplane design. Some of the proposed ideas that were considered are the use of retractable floats, inflatable floats, advance navigation aids, hydrofoils, water thrusters, folded wings, advance composite materials, advance power plants, reversed thrusters, among many more ideas. After analyzing all of the proposed ideas, the complexity and high costs of some of these narrow the search for technical solutions that will meet the requirements of this seaplane.

First, it was decided to use trimaran boat hull technology that will increase hydrodynamic performance of the seaplane as shown in Fig. 1. One concern of using trimaran will be the exposed floats at flight. One solution is to retract the floats or either mount them inside the undercarriage, which in theory will reduce aerodynamic drag.

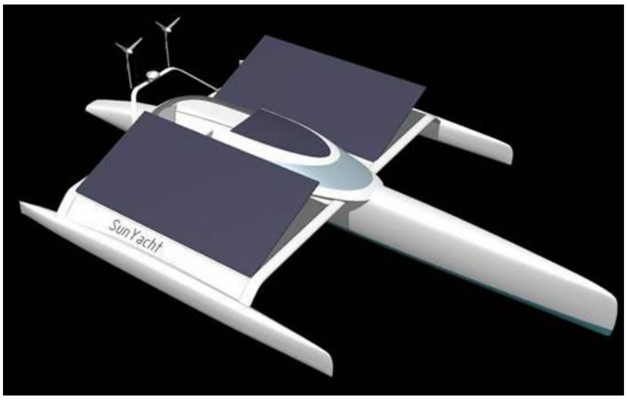

Fig. 1: Trimaran Example

2.2 Advance Design Ideas

The trimaran possesses some advantages over other types of boat hull designs [7].

- Low wave resistance at high speed due to its slender ship hulls
- Superior stability attributable to suitable layout of the side floats. A trimaran can keep a high speed under high sea conditions.
- The wave interference between the main hull and the outriggers can produce a beneficial wave interference optimizing the speed and engine power required correlation
- In case of an emergency the all float structure remains floating even when the hull or the outriggers are severely damaged.

Trimarans are superior in terms of stability because the arrangement of the hulls is such that individual centers of buoyancies have a righting moment about the centre of gravity that helps in stabilizing the vessel as shown in Fig. 2. This gives the boat or in this case the seaplane, more roll stability, better water maneuverability, and better water performance at docking and even at high waves.

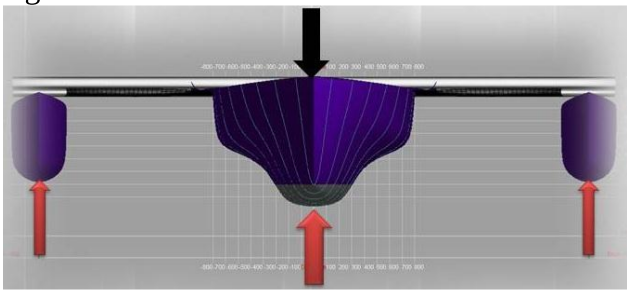

Fig. 2: Trimaran Stability-Beam Model

Another important aspect to analyze is wave performance. Seaplanes must have the ability to perform in any weather and water conditions. When a wave passes through a conventional float, it reaches the bow producing a lift force which pushes the stern down; as the wave passes through the body of the float, the center of buoyancy changes along with the wave. When the wave reaches the stern, the lift force pushes the bow; at high speeds, during rough water conditions, a dangerous pitch effect could cause the bow to be submerged and capsize violently. For the outriggers, when the peak of the wave moves towards stern, the lack of buoyancy on this section to the shape, negates the lift force which produces the pitching effect, therefore the outriggers are capable to operate in a wider range of rough water conditions than the conventional floats. Past studies conducted on trimaran shows that wave resistance of trimarans is significantly lower compared to an equivalent catamaran as shown in Fig. 3 [8]. For this instance, in theory, trimaran has superior seagoing performance.

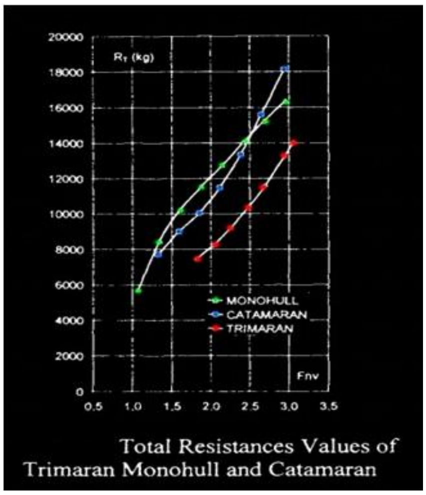

Fig. 3: Resistance comparison curves [8]

Since the trimaran concept will exposed the floats in the air when the seaplane is flying, this will generate extra aerodynamic drag that will compromise the air performance of the seaplane.

Tigerfish Aviation developed the use of retractable pontoons called **R**etractable **A**mphibious **P**ontoon **T**echnology (**RAPT**) [9]. Adapting the same concept idea, the floats will form a single component embodied to the hull and fuselage when retracted, as shown in Fig. 4. This will reduce the drag form interference factor added by the floats and boat hull [10], hence decreasing the aerodynamic drag.

Fig. 4: Retracting Float Concept [9]

However, retracting the floats into this position will not reduce entirely the aerodynamic drag caused by the floats. A final solution is to place the floats inside the boat hull, as shown in Fig. 5.

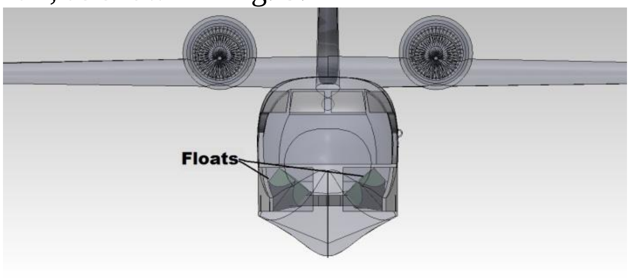

Fig. 5: Example CAD Model with undercarriage Floats

The floats will be retracted inside the boat hull, the same way the landing gear is retracted undercarriage. The only drawback will be the added structural support required, compromising an increase in weight of the strutting.

3 Conceptual Design and Theory

3.1 Conceptual Design

As stated, an existing landplane aircraft will be converted into a seaplane configuration. In that case, the proposed design equations will have to be manipulated in order to design the seaplane in this manner.

Many old seaplane design books approaches the seaplane design by first designing the floating device (i.e. the design of the boat hull or floats) and then designing the aircraft components (wings, fuselage, empennage, etc.) around the floating device [6],[11],[12]. However, since these design idea is to convert a landplane into a seaplane, a new theoretical approach will be conducted. The conventional equations shall be manipulated to arrange the design idea. Since the proposed idea of the seaplane is to adapt an advance trimaran concept, trimaran design theory and conventional flying boat theory will be blended together to obtain the most optimum trimaran design for this seaplane.

Finally, the main goals that should be attained to acquire the desire design will be focused on the following:

1. The seaplane should acquire an outstanding hydrostatic stability in order to excel during the water taxing operations, hence the trimaran concept.
2. The advance design will have the capability to operate in rough, high wave waters, giving the seaplane more water options in which to operate.
3. The increase in aerodynamic drag caused by the extra components should not compromise the flight performance of the seaplane, hence the retracting undercarriage floats.
4. Water Performance and Air Performance should be comparable to that of a speed boat and a speed aircraft, in order to attain the best of both designs.
5. Finally, all structural components would be analyzed thoroughly in order to meet all requirements.

3.2 Sizing Code Development

A sizing mathematical code developed in MATLAB was created in order to run specific theoretical calculations that will be necessary to size the optimum seaplane trimaran design. The sizing code is set up to work with a number of different aircraft configurations which would be converted into a seaplane configuration. The mathematical code will be elaborated in a fashion were the main inputs will focus the existing landplane parameters (Gross Weight, Wing Characteristics, Power plants, Aircraft Geometry). When given the known input parameters, the code outputs all major trimaran component geometries, hydrostatic estimation, component drag estimates, and mission water and air performance characteristics. The code is then put into a loop, where it compares the difference between the initial gross weight estimate and the gross weight calculated based on the trimaran geometry and performance characteristics. The sizing code will follow a series of calculations in order to meet the specify goals before it continues the loop iteration as shown in Fig. 6.

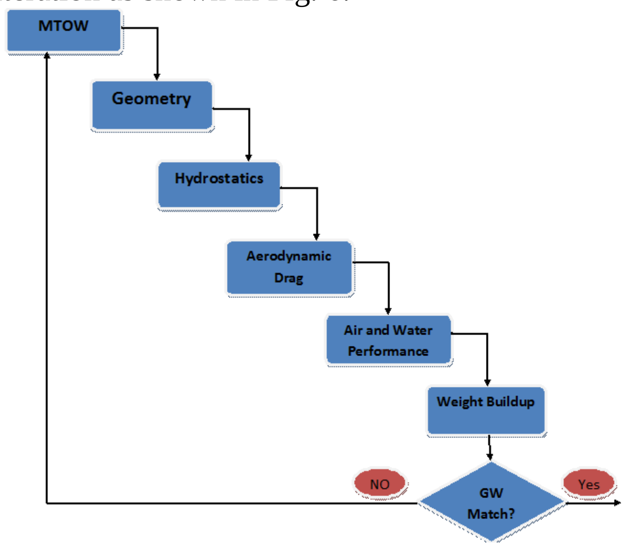

Fig. 6: Sizing Code Flowchart

With the aircraft sized, individual component weights are sent to functions which will calculate other components of the seaplane. Geometry and performance characteristics are then output and with this data obtained, a picture showing the basic geometry is drawn.

3.3 Theory

Based on the sizing code flow chart shown in Fig. 6, an analysis of the weight components of the trimaran will be conducted first. The sizing of the trimaran will be broken down into boat hull theory, and twin float theory. Calculations will be performed separately first and will then be merged together using trimaran theory. Using the initial Gross Weight (GW) of the aircraft, the weight of the boat hull and floats will be calculated using Langley's experimental testing. Calculation of Float Weight (W_f) was elaborated using a comparative curve of area and streamline forms [13], in which the following equation was derived:

$$W_f = GW0.0365 + 43.5 \qquad (1)$$

Langley calculates the weight of the boat hull based on statistics using materials from 1935; he calculated that the weight of the boat hull is around 12% the total gross weight of the aircraft.

The next step is to calculate the Trimaran Geometry. Based on Archimedes Principle, the volume (V) required for the seaplane to stay afloat on water will be calculated based on the displacement weight (Δ_0), as shown in eq. (2).

$$V = \frac{\Delta_0}{w} \qquad (2)$$

Where (w) is the density of the fluid. Calculation of the total volume of the trimaran should take into account an extra 90% of the total displacement, which represents the “reserve of buoyancy” [12]. Based on the literature review, generally the beam is established as the design reference parameter of seaplane floats and hull [14]. The beam is the widest section of the float as shown in Fig. 7.

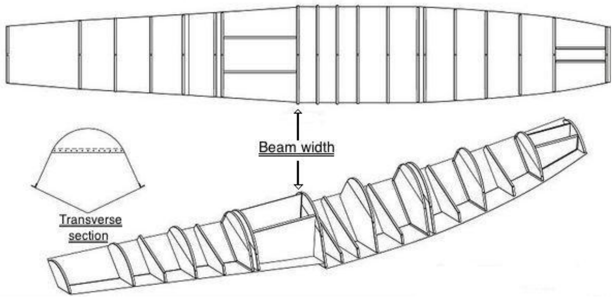

Fig. 7: Beam Width of a Conventional Float

From fluid dynamics, Tomaszewski came with an empirical formula on how to calculate the beam (b) of a hull [14]:

$$b = \sqrt{\frac{\Delta_0}{(C_{\Delta_0})w}} \qquad (3)$$

However, this empirical formula is well adapted to conventional floats and boat hulls, but not for a trimaran concept. A new approach must then be manipulated in order to find suitable formulas for the design process of the trimaran device. First, the outriggers of the trimaran must be assumed to function as twin floats. The key characteristic connection between floats and boat hulls is the slenderness ratio of a trimaran (SLR) shown in eq. (4).

$$SLR = \frac{L}{b} \qquad (4)$$

The slenderness ratio takes values depending upon the functional utility of the vessel in question. The standard values of slenderness ratio are shown in Fig. 8.

SLR	8-10: 1	For slow cruising vessels
	12-14: 1	For performance cruisers
	20: 1	For extreme racers

Fig. 8: Slenderness Ratio [17]

An important component of designing a hull or float is the forebody length. The size of the forebody represents compromising between flight requirements and seaworthiness at low speeds on water. If the length and the beam are too great, the structural weight and the aerodynamic drag limits the performance of the whole seaplane. On the other hand, if the length and the beam are too short, the spray characteristics become a limitation in gross weight and increase the hazards of operation in rough water [15]. The forebody length (l_f) in for a given beam load coefficient (C_{Δ_0}) is [14]:

$$l_f = b\sqrt{\frac{C_{\Delta_0}}{k}} \qquad (5)$$

From hydrodynamic point of view, the afterbody (l_a) assists getting over the hump and to provide buoyancy at rest. A relation between the length of the forebody and the afterbody is shown in eq. (6) [16]:

$$l_a = (110\% \; to \; 115\%) l_f \qquad (6)$$

Since the total length (L) of the hull or float is as follows:

$$L = l_f + l_a \qquad (7)$$

Rearranging eqs. (3) - (7), and choosing 111% of forebody to afterbody length, the following formulas are obtained:

$$\frac{l_f}{b} = \frac{SLR}{2.11} \qquad (8)$$

$$C_{\Delta_0} = k\left(\frac{l_f}{b}\right)^2 \qquad (9)$$

The only two unknown variables are spray coefficient (k) and slenderness ratio (SLR). Spray coefficient can be selected depending on the mission characteristics shown in Table 1.

k = 0.0525	Very Light Spray
k = 0.0675	Satisfactory Spray
k = 0.0825	Heavy but acceptable Spray
k = 0.0975	Excessive Spray

Table 1: Spray Coefficient Factors

Selecting the appropriate spray coefficient (k) and slenderness ratio (SLR), the beam of the hull (b) can be calculated from eq. (3). With the slenderness ratio (SLR) selected and the beam hull calculated, the total length of the boat hull (L) is calculated using eq. (4). However, there is a constraint in calculating the hull length. The hull length should not exceed the length of the landplane fuselage. With the beam hull other characteristics of the hull can be calculated (Bow Height, Forebody Deadrise Angle, Step Height, etc.). In order to maximize the efficiency of the trimaran concept, the outriggers (floats) should be half the length of the main hull [17]. Therefore, with the spray coefficient (k) and slenderness ratio (SLR) selected, the beam of the outriggers can be calculated from eq. (4). The same approach as the main hull will apply to calculate the rest of the float characteristics.

With the geometry of the trimaran calculated, another important aspect to consider is the hydrostatic stability. The metacentric height is a measurement of the static stability of a floating body. It is calculated as the distance between the centre of gravity of a vessel and its metacentre (GM) shown in Fig. 9. A larger metacentric height implies greater stability against overturning.

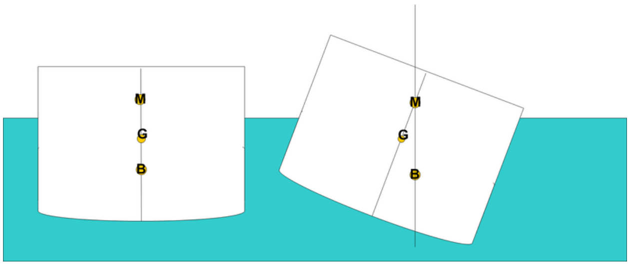

Fig. 9: Metacentric Height [18]

The derived formula for the reduction in metacentric height (BM) on water is [11]:

$$BM = \frac{I}{V} \tag{10}$$

Where (I) is the Moment of Inertia of the vessel. The metacentric height is an approximation of the vessel stability for small angle (0-15 degrees) of heel. Beyond that, the stability of the vessel is dominated by what is known as a righting moment (RM), eq. (11):

$$RM = \Delta_0 GM sin\theta \tag{11}$$

With the geometry of the trimaran calculated, calculations of the drag increase will be approached by calculating the parasite drag. A useful measure of the parasite drag is the equivalent flat plate-drag area (f). Therefore, the total parasite drag (D_P) is [10], [19]:

$$D_P = fq \tag{12}$$

where

$$q = \frac{1}{2}\rho Vel^2 \tag{13}$$

(f) is a drag component buildup, (ρ) is density of air, and (Vel) is the velocity of the seaplane. Each exterior component of the airplane is considered separately, and the total (f) of each component is finally sum together. The equivalent flat plate drag area can be computed from the following expression:

$$f_i = C_{f_i} F_i Q_i S_{wet_i} \tag{14}$$

Where (C_f) is coefficient of friction, (F) is form factor, (Q) is interference factor and (S_{wet}) is the wing area. With the increase in coefficient of aerodynamic drag (C_D), engine performance will decrease, as explained from the following:

$$T_R = \frac{C_D}{C_L} mg \tag{15}$$

(T_R) is thrust required, (C_L) is lift coefficient, (m) is mass, and (g) is gravitational constant.

4 Results

To obtained desire results, the use of typical data from an existing aircraft was researched. A series of common features were analyzed that are essential in order to conduct this advance seaplane design; a high wing configuration, engines with Short Takeoff or Landing (STOL) capability, and have cargo space. From the research conducted the input data of this typical aircraft is shown in Table 2.

Gross Weight [kg]	6,600
Empty Weight [kg]	3,960
Max Fuel [kg]	1,300
Max Payload [kg]	1,710
Fuselage Length [m]	14.47
Fuselage Diameter [m]	1.92
Wing Area [m^2]	34.86
C_{Lmax}	1.63

Table 2: Typical Aircraft Input Parameters

With the introduction of new materials such as composites, the weight parameters of the trimaran could be reduced. Most composite materials have a density of around 1.60 g/m^3, as compared to most aluminum alloys 2.8 g/m^3. It can be safely assumed that the weight of the material can be reduced by 50%. A comparison of the weight decrease between non composite materials and composites is shown in Table 3.

	Aircraft	*Aluminum*	*Composites*
Weights [kg]		*Seaplane*	*Seaplane*
MTOW	6,600	6,600	6,600
Boat Hull	0	745	370
Floats	0	540	270
Landing Gear	380	0	0
Empty Weight	3,960	4,865	4,220
Max Payload	1,710	1,710	1,710
Max Fuel	1,300	1,300	1,300
Fuel w/Max Pay	930	25	670
Pay w/Max Fuel	1,340	435	1,080

Table 3: Weight Component Breakdown

One of the main goals of this research is to create a modern seaplane that has improved water capabilities. In order to excel in its hydrodynamics, this seaplane must obtain the most suitable trimaran design both in strength and performance. As explained in the theory section and using eqs. (3) - (9), the following dimensions were obtained, shown in Table 4.

	Main Hull	**Outrigger**
Slenderness Ratio	7.13	12
Spray Coefficient	0.0974	0.08
Beam [m]	2.03	0.59
Length [m]	14.47	7.13
Forebody [m]	6.99	3.38
Afterbody [m]	7.48	3.75
Bow Height [m]	1.32	0.53
Step Height [m]	0.18	0.05
Forebody Angle	30^o	45^o
Afterbody Angle	22^o	40^o
Volume [m^3]	19.33	1.51

Table 4: Trimaran Dimensions

The next goal the sizing code must meet is the hydrostatic stability. Using the approach from eq. (10) in the theory section, the following hydrostatic results were obtained shown in Table 5.

Distance [m]	Hull	Float	Twin Float	Trimaran	Seaplane
Draft Line	0.47	0.44	0.44	0.46	0.46
Center of Buoyancy	0.26	0.24	0.24	0.25	0.25
Center of Gravity	0.85	0.37	0.42	0.83	1.84
Metacentre Transverse	0.45	0.04	6.99	1.83	1.83
Metacentre Longitudinal	22.92	5.98	12.93	20.82	20.82
Metacentric Height Transverse	-0.14	-0.09	6.82	1.26	**0.24**
Metacentric Height Long	22.33	5.85	12.75	20.25	**19.23**

Table 5: Hydrostatic Stability

To show the location of the metacentre (GM), the center of buoyancy (CB), and the centre of gravity (CG), a model of the trimaran seaplane was elaborated shown in Fig. 10.

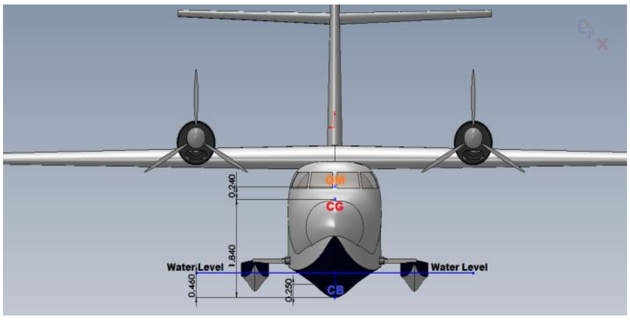

Fig. 10: CAD Model of Trimaran Seaplane at Transverse showing Metacentre, Centre of Gravity, and Buoyancy

Using eq. (11), the following graph was plotted with the data obtained from Table 5 and the required displacement of each component, Fig. 11; the graph show curves of the righting moment (RM) of each separate component (Boat Hull, Outrigger, Twin Float, Trimaran, and Seaplane) as a function of angle of inclination (θ). If the righting moment remains positive, the vessel is statically stable.

To compare the increase in aerodynamic drag caused by the boat hull, and outriggers of the seaplane, a flat plate drag breakdown is elaborated.

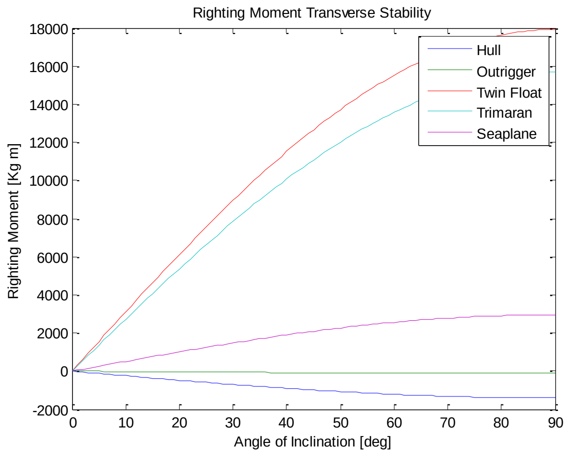

Fig. 11: Righting Moment for Transverse Stability

Using eqs.(12) - (14), the trimaran geometry from Table 4, and the aircraft inputs from Table 2, Table 6 was obtained.

Flat Plate Drag Area Breakdown [m^2]	***Aircraft***	***Seaplane [Extended]***	***Seaplane [Retracted]***	***Seaplane [No Floats]***
Fuselage	0.144	0.144	0.144	0.144
Wing	0.303	0.303	0.303	0.303
Horizontal Tail	0.074	0.074	0.074	0.074
Vertical Tail	0.052	0.052	0.052	0.052
Engines	0.095	0.095	0.095	0.095
Subtotal	1.109	1.109	1.109	1.109
Boat Hull	0.000	0.240	0.200	0.200
Floats	0.000	0.082	0.057	0.000
Total	1.109	1.440	1.368	1.310
C_d	0.0318	0.0413	0.0392	0.0376
C_d Increment	0	0.0095	0.0074	0.0058
Drag [N]	6850	8898	8448	8095
Drag Increase		**23.02%**	**18.92%**	**15.39%**

Table 6: Flat Plate Drag Area Breakdown Component

Table 6 shows the total drag that the landplane, the seaplane with extended floats, retracted floats, and with undercarriage floats at cruising speed of 380 km/hr and an altitude of 4,200 m. It is explained when an odd shape component is being calculated, an increase in drag form interference factor must be added to the actual value [10]. It is also explained: “The form factor is a measure of how “streamlined” the component is; it is a function of the component thickness-to-length ratio” [19]. In this case, the form interference factor (*F*) from eq. (14) of a flying boat hull must increase by a 50%, and for floats from 75%-300%, depending on the shape. It was then assumed that the interference factor for the boat hull had an increase of 10%, rather than 50% increased, due to the perfect aerodynamic shape mounted of the hull will be with respect to the fuselage.

Applying the increase in drag coefficient to eq. (15), and using typical engine data the following graph was obtained (Fig. 12).

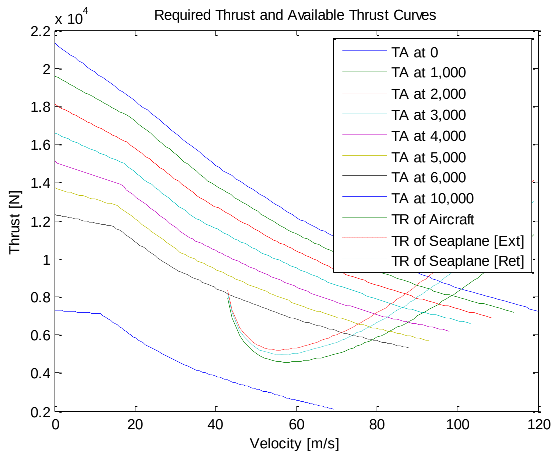

Fig. 12: Thrust Curves

The required thrust will increase if the coefficient of drag increases (C_D), hence compromising the entire flight performance of the seaplane. Table 7 shows the flight performance breakdown of the seaplane showing a comparison between the seaplane with the extended floats, and the retracted floats.

Endurance	Landplane	Seaplane [Ext]	Seaplane [Rect]
Takeoff [min]	0.33	0.32	0.32
Climb [min]	12.35	13.86	13.24
Cruising [hr]	2.46	1.90	2.09
Descent [min]	19.17	19.20	19.19
Landing [min]	0.39	3.61	3.62
Total [hr]	3.08	2.60	2.77
Range	Landplane	Seaplane [Ext]	Seaplane [Rect]
Takeoff [km]	0.56	0.55	0.55
Climb [km]	42.12	45.48	43.79
Cruising [km]	936.35	720.79	792.33
Descent [km]	95.94	95.94	95.94
Landing [km]	0.77	2.45	2.45
Total [km]	1075.74	865.20	935.05

Table 7: Endurance and Range of each Flight Segment

Since the thrust required increases due to the increase in aerodynamic drag, the rate of climb of the seaplane decreases. The seaplane with extended floats has a lower rate of climb, compared with the retracted floats. The seaplane takes longer and more distance to climb to desire altitude, i.e. the absolute and service ceilings decrease as shown from Fig. 13.

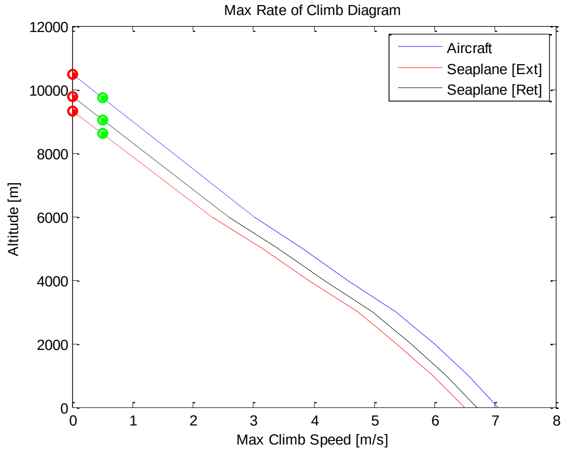

Fig. 13: Rate of Climb Diagram

With the weight parameters, endurance, and range, and data from Table 2, a payload range diagram was elaborated to compare the advantage of using both composite materials for this seaplane, as well as retracting the floats inside the boat hull, shown in Fig. 14.

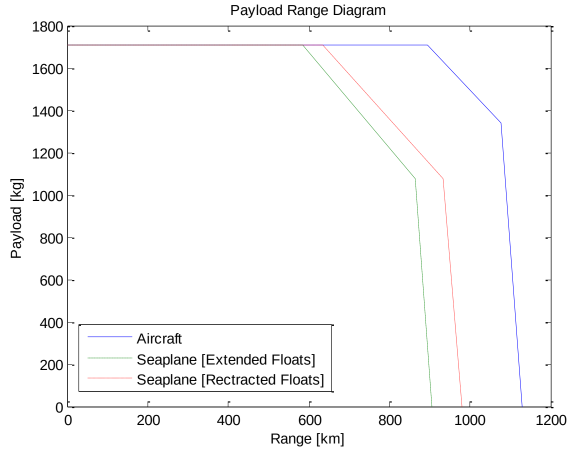

Fig. 14: Payload-Range Diagram

Finally, a water speed curve was elaborated to show the advantage of using a trimaran concept into this seaplane design, rather than using a simple boat hull, or twin floats. Fig. 15 shows Froude number as a function of speed. Higher the Froude number, the vessel has a higher resistance at high speeds, and higher performance at water operations.

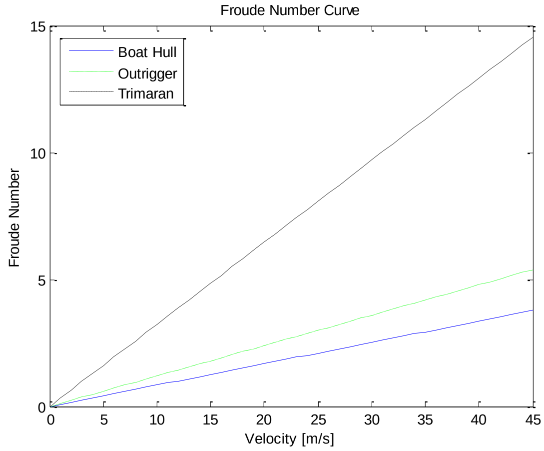

Fig. 15: Water Speed Curve

5 Conclusions

The preliminary results show some of the advantages of using the trimaran concept into a seaplane design, and the increase in flight performance when the floats are retracted. The design excels in hydrostatic stability as shown from Table 5 and Fig. 11. The metacentric height of this design has a positive value both in the transverse and longitudinal stability. The water speed that a trimaran shows is also significant, in which the amount of time and distance to takeoff is similar to that of the landplane when it takes off from land.

For the flight performance, mounting the floats inside the undercarriage decreases significantly the drag to around 10% as compared to an extended position. The flight performance of the seaplane increases the rate of climb, range, and endurance, shown in Fig. 13, Fig. 14, and Table 7.

The aim of this research is to design an "out of the box" idea that will stand out not only because of its improved performance, as well as its unique design idea. On a long term basis, a brand new seaplane can be design as well as suitable infrastructure (seaports) in order to increase seaplane market and operations.

Finally, with the aid of Computer Aided Design (CAD) software, SOLIDWORKS, a model was elaborated to show a futuristic picture of this advance trimaran seaplane design shown in Fig. 16, Fig. 17, and .

Fig. 16: Futuristic CAD Model of Seaplane at Takeoff from a Modern Sea Port

Fig. 17: Futuristic CAD Model of a Turboprop Seaplane

Fig. 18: Futuristic CAD Model Turbofan Seaplane with undercarriage floats at flight

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