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Lawrence W. Lay, DO, PhD
21317 SW Purity Springs Rd
Douglass, Kansas 67039-8590

Grand Sea Planes
Steve Robinson, Owner

SURFACE AREA ON SEAPLANES

INTRODUCTION

I am the designated pilot examiner, DPE for Grand Seaplanes that operates on Grand Lake in Oklahoma. Over the years I have noticed that in the oral evaluations students seem to have a poor understanding of some of the principles that dictate the handling characteristics of seaplanes both hull and float. Whether you train in a hull or float seaplane I believe an understanding of some basic principles are essential especially to commercial pilots with Flight Instructor certificates, CFI. The importance of this is to recognize that these pilots can instruct in seaplanes after they obtain their commercial license. In this presentation I will use basic stick type drawings to illustrate my points that a CFI could draw for students to illustrate his points. Much of the information is strictly my opinions and even though they may not be technical correct they give logical explanations as to the characteristics of seaplanes.

FORCES

Most of the unusual characteristics of sea planes can be explained by forces developed by forward flight or the wind acting on the surface area of exposed surfaces of the seaplane. Let's try and understand how this force is created. Forward motion or the wind creates a dynamic pressure. The value can be calculated by taking 0.5 times the air density times the true airspeed or speed of wind squared. For some comparisons I have calculated a few dynamic pressures for different wind speeds and true airspeeds at sea level in a standard atmosphere and they are listed below.

Wind speed or TAS in knots	Dynamic pressure pound/ft^2
5	0.085
10	0.339
15	0.762
20	1.355
80	21.666
100	33.855

To get a force from a dynamic pressure you multiply the pressure times the exposed surface area in square feet. Just to get an idea of the forces that can be created lets use a fuselage length of 10 feet by 4 feet. The table below shows the potential forces generated by the above dynamic pressures.

Wind speed or TAS in knots	Force created on 40 square feet - pounds
5	3.4
10	13.56
15	30.48
20	54.2
80	866.64
100	1354.2

The above concept is just an analytical expression of putting your hand out the window of the car and noting a force on it. The faster you go the more force you feel. The same thing happens with a seaplane.

The above is sufficient to explain many concepts however we must also remember forces are created by an object getting an angle of attack, AOA. We generally associate this with airfoils either symmetric or cambered but even a flat plat exposed to a moving airflow with an angle of attack develops lift and drag, both aerodynamic forces. The associated aerodynamic forces are also a function of the true airspeed squared just as dynamic pressure is. The simple figure 1 show two different shapes and illustrates this concept.

Figure 1 shows that an angle of attack, AOA is developed when we have a relative wind over a flat plat or the cross section of a float. The lift and drag forces are shown close to the quarter chord point just as with an airfoil to minimize pitching moment changes with AOA changes. The pitching moment is not shown that should also be developed.

We have now shown the two ways we can visualize how aerodynamic forces are created on surfaces of the seaplane be on the fuselage, control surfaces or floats.

CENTER OF GRAVITY AND CENTER OF BUOYANCY

These two concepts are often confused by applicants testing for the seaplane rating. The center of gravity, CG is the point of an aircraft where the forces of gravity act causing no rotation of the body. This is the balance point that the aircraft could be suspended from and not rotate. This is the center of gravity we always use in weight and balance calculations. For sea plane discussions this is the point we are concerned with as soon as the aircraft leaves the water. As soon as the aircraft leaves the water this is the important point to discuss and the center of buoyancy, CB has no meaning for us.

An important point to remember is CG in flight and CB on the water. When an applicant answers questions related to flight they are referenced to the CG and when the aircraft is on the water the answers are related to the CB.

The CB in a sea plane is only applicable when the aircraft is in the water. The CB is the center of gravity of the water we displace. The two points are not the same. We can for simplicity purposes consider this is the point where the buoyancy force of the water acts on the hull or float of a seaplane. In the aircraft we really have a CB of the air but this is negligible. The CB is below the CG and located in the aircraft structure. The magnitude of this force is the weight of water displaced by Archimedes principle.

SAILING

When we sail a seaplane we pivot about the CB. It takes a very little force to rotate us about the CB. With controls are neutral the aircraft will point into the wind. This is because there is more surface area behind the CB and so the wind rotates the aircraft into the wind. The wind acting on this area forces the nose of the aircraft into the wind. See figure 2. I find the best way to visualize how controls have to be placed is to decide which way you want the tail to point. If you apply left rudder a force is created on tail to right. This rotates the tail to the right. This means the left wing has to go aft. This means right aileron will cause left aileron to go down. This creates more lift on the left side with more drag and the left wing rotates counterclockwise or aft. This is simply adverse yaw we all learn about in private training. The water rudder must be up because it causes a turning tendency in the other direction. Again think about surface areas. Put the flaps down to increase the speed aft. Another way to help the tail turn to the left is open right door. To increase speed, open both doors. This simply gives more surface area for the wind to act on.

PLOW TAXI

So how does a plow taxi turn us downwind? We generally have the water rudder down that helps but what we really do is move the CB aft. This is done with full back elevator and power thus raising the nose of the aircraft out of the water and we now have more surface area ahead of the CB and the wind by the above mechanisms rotates the aircraft downwind. We now have more surface area ahead of the CB and the dynamic pressure acting against this area turns the aircraft downwind. See figure 3.

STEP TURNS

Turns on the step are more dangerous into the wind than turning downwind since the centrifugal force and wind act in the same direction tending to roll the aircraft to the outside of the turn. Sea planes tend to “DIG IN” if the turn is made too sharp. Surface area again comes into play because with the aircraft on the step more area is aft of the CB and thus the wind tends to turn the aircraft into the wind abruptly due to the large aerodynamic forces on the fuselage. See figure 4. We generally don't think about the dynamic pressure acting on the surface area in this maneuver.

LONGITUDINAL STABILITY

This applies when the aircraft is flying and so we are talking about the CG. If you look at most float plane data the aft CG limit is moved forward due to decrease in longitudinal stability. This is because floats are destabilizing. This again is a function of surface area and possible some aerodynamic forces because we have so much surface area ahead of the CG. This causes a pitch up or down when there is an angle of attack on the floats. Thus we have created forces that tend to destabilize the longitudinal stability. See figure 5. Drag and pitching moment are not shown.

DIRECTIONAL STABILITY

If you will look at float planes there is additional vertical area added to the elevator or fuselage that increase the directional stability. This is again due to surface area of the floats ahead of the CG and when the aircraft develops a yaw the dynamic pressure against this surface area tends to cause a force that tends to yaw the aircraft more and this is destabilizing. See figure 6.

LATERAL STABILITY

This should not be destabilized because any increase in surface area on sponsons or wing floats should create forces to return the wing to level once rolling is started and thus is stabilizing.

SUMMARY

As we can see many characteristics a sea plane, boat or float can be explained by the surface area either ahead or behind the CG in flight or the CB when on the water. Hopefully instructors can use the stick type drawings to help communicate this information to students and hopefully the distinction between the CG and CB will be more apparent. In summary floats or hulls are destabilizing and require extra surface area aft to compensate for this and special care with certain maneuvers. Like all things there are good and bad. The good uses of surface area are to turn the aircraft downwind and slow down in a water taxi and to sail the aircraft.

Sea Planes are just plain fun and I believe an understanding of what is happening increases the enjoyment and hopefully will make it safer.

FIGURE 1

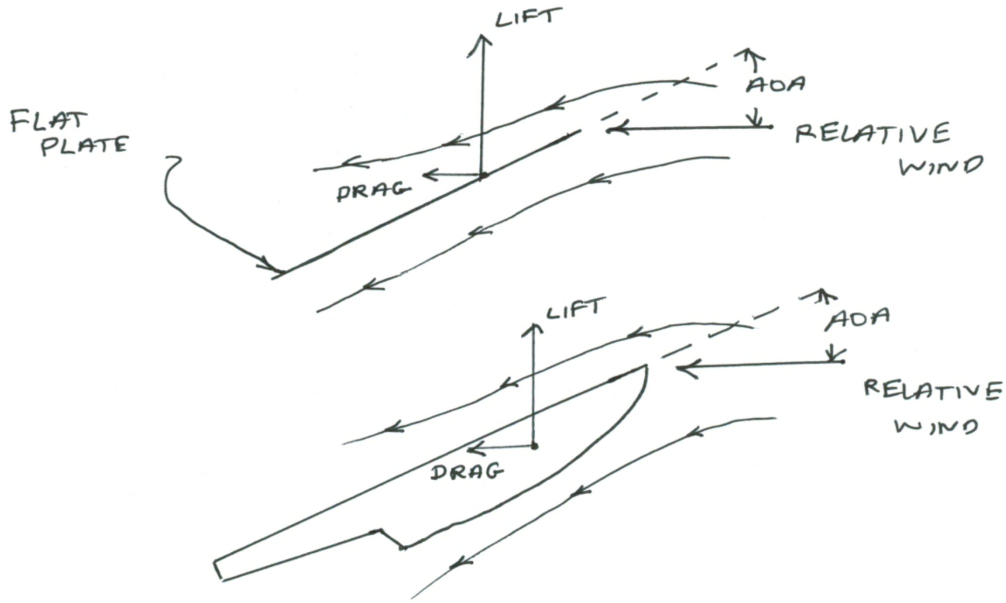
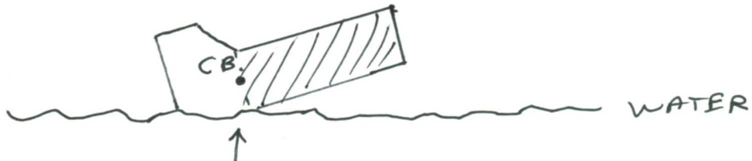


FIGURE 2

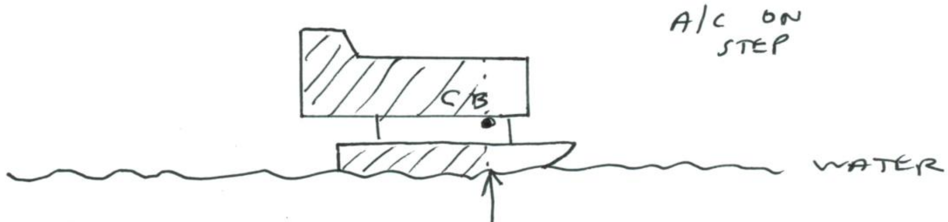
AREA AFT CB, TURNS A/C INTO WIND

FIGURE 3



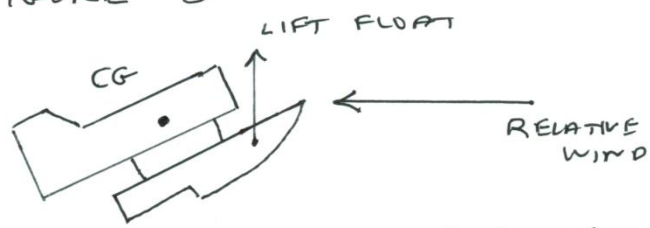
AREA FWD CB, TURNS AIRCRAFT DOWNWIND

FIGURE 4



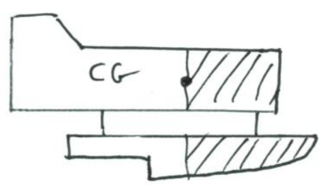
AIRCRAFT TENDS TO DIG INTO WATER

FIGURE 5



LIFTING FORCE FROM DYNAMIC PRESSURE ACTING ON BOTTOM FLOATS AND AERODYNAMIC FORCE SINCE FLOAT HAS AOA

FIGURE 6



FLOAT CROSS SECTION AREA CAUSES INCREASE FORCES IN YAW WITH SIDESLIP DESTABILIZING AIRCRAFT