DESIGN SIMULATION AND FABRICATION OF HYDROFOIL ON WATERCRAFT

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ABSTRACT:

Hydrofoil is similar to the Aero foil but difference is application at different medium and usage. The main reason for implementing the hydrofoil on watercraft is to reduce the surface contact area with the water surface when the vehicle is travelling at higher velocities. The coefficient of the hydrodynamic drag of the vehicle will decrease. The main purpose of the hydrofoil is to generate the enough lift force to move a watercraft. By the application of the hydrofoil performance and efficiency of the watercraft will be improved, Fuel consumption of the watercraft also minimize. In this project an effective hydrofoil will be designed according to the constraints, simulated by using the analysis software like ANSYS and fabrication procedure will be explained step by step process.

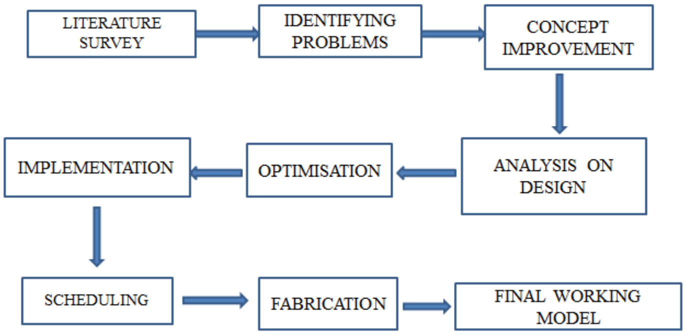
Keyword: *- excellent material to reinforce, hydrofoil is used to reduce a friction between surface and increase the velocity*

1.0 INTRODUCTION:

A hydrofoil is a lifting surface, or foil, that operates in water. They are similar in appearance and purpose to aero foils used by aero planes. Boats that use hydrofoil technology are also simply termed hydrofoils. As a hydrofoil craft gains speed, the hydrofoils lift the boat's hull out of the water, decreasing drag and allowing greater speeds. The hydrofoil usually consists of a wing like structure mounted on struts below the hull, or across the keels of a catamaran in a variety of boats (see illustration). As a hydrofoil equipped watercraft increases in speed, the hydrofoil elements below the hull(s) develop enough lift to raise the hull out of the water, which greatly reduces hull drag. This provides a corresponding increase in speed and fuel efficiency. Wider adoption of hydrofoils is prevented by the increased complexity of building and maintaining them. Hydrofoils are generally prohibitively more expensive than conventional watercraft. However, the design is simple enough that there are many human-powered hydrofoil designs. Amateur experimentation and development of the concept is popular. Italian inventor Enrico Foramina began work on hydrofoils in 1898 and used a "ladder" foil system. Foramina obtained patents in Britain and the United States for his ideas and designs. Between 1899 and 1901, British boat designer John Thorneycroft worked on a series of models with a stepped hull and single bow foil. In 1909 his company built the full scale 22-foot (6.7 m) long boat, Miranda III. Driven by a 60 hp (45 kW) engine, it rode on a bow foil and flat stern. The subsequent Miranda IV was credited with a speed of 35 km (65 km/h; 40 mph).In Canada during World War II, Baldwin worked on an experimental smoke laying hydrofoil (later called the Como Torpedo) that was later superseded by other smoke-laying technology and an experimental target-towing hydrofoil. The forward two foil assemblies of what is believed to be the latter hydrofoil were salvaged in the mid-1960s from a derelict hulk in Bad deck, Nova Scotia by Colin Macgregor Stevens. These were donated to the

Maritime Museum in Halifax, Nova Scotia. The Canadian Armed Forces built and tested a number of hydrofoils (e.g., Bad deck and two vessels named Bras d'Or), which culminated in the high-speed anti-submarine hydrofoil HMCS Bras d'Or in the late 1960s. However, the program was cancelled in the early 1970s due to a shift away from anti-submarine warfare by the Canadian military. The Bras d'Or was a surface-piercing type that performed well during her trials, reaching a maximum speed of 63 knots (117 km/h).

2.0 PROJECT FLOW CHART:

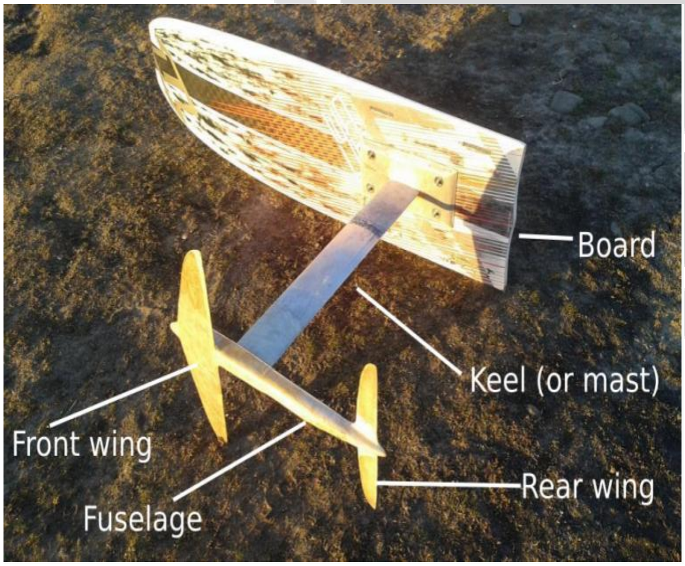


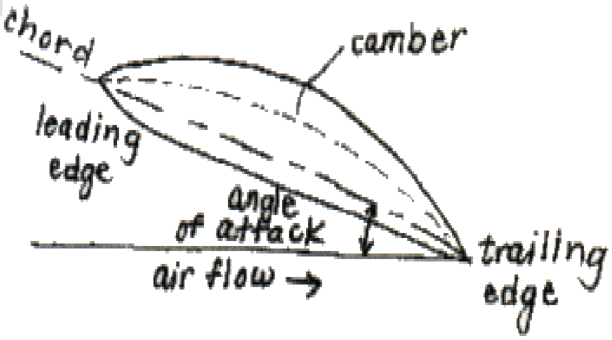
3.0 DESIGN:

Making a hydrofoil is even more difficult than learning to ride one, but certainly possible. Here are some guidelines to help you tackle a difficult but very rewarding adventure.

PARTS OF A HYDROFOIL:

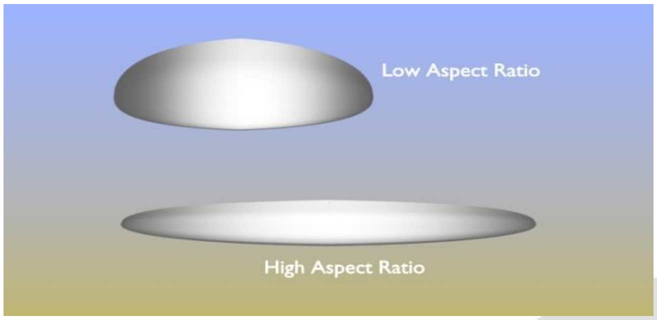
Here is a picture of the first hydrofoil that I made (and I could only ride it 20m far by the time it broke and sank to the bottom of the dam). It shows the main parts of a hydrofoil





3.1 ASPECT RATIO:

Aspect ratio is the ratio of the wingspan to the area of a wing. A wing with a short chord and long wingspan has a very high aspect ratio and vice versa



3.2 THE KEEL:

The keel (or sometimes called mast or strut) is the part between the board and the fuselage of the hydrofoil. It needs to be very low drag since it is not used for lift, but it needs to be as stiff as possible

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3.3 KEEL LENGTH:

The keel is normally between 800mm and 1m long. The longer it is the stiffer it needs to be, but the more range it allows you while riding. A longer keel is very nice to have in large chop conditions and a must have for faster hydrofoils. If you ride slowly, then you can easily ride over chop that is more than 1m high with an 800mm keel since the chop (or wave) pushes you up and down as you ride over it. But as you go faster, or if the chop gets less spaced out, a longer keel is much more useful. I personally would not want to go back to anything less than 900mm anymore. Some people claim that learning on a shorter keel is easier, but I am not so convinced. A longer keel gives you much more room for error before hitting the board on the water or allowing the wing to come out the water, and this gives you more time to react

3.4 CHORD LENGTH:

The chord length is the length from front to back. It is generally 100mm. A wider chord means that you need more material (typically carbon fiber) and I think that a too wide chord will start affecting the turning and handling slightly. A narrower chord distorts the profile if the thickness of the keel is quite thick, and this can have horrible effects when it comes to ventilation problems

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3.5 THICKNESS:

The keel needs to be as thin as possible. It is normally between 10 and 20mm thick. Anything less than 12mm will require extremely stiff materials and will most likely require a high modulus carbon fiber composite with a very good layup, or it will have to be steel. A clean profile that is 20mm thick will not add excessive drag and will make the stiffness required more easily achievable. But a thicker profile will need a wider chord to keep the profile undistorted.

I have made two keels made of G10 fiberglass. This is probably the best grade fiberglass you can get, with stiffness (Young's modulus) of 25GPa. I found that the 16mm thick one of G10 was not stiff enough, and more importantly, it did not have enough torsional stiffness. One would have to go very thick on the keel if you are not using carbon fiber or metal for the keel

3.5 PROFILE:

The profile (shape, or aero profile or hydro profile) should be a symmetrical profile for laminar flow. As a starting point, I think any symmetrical hydrofoil profile should work. I think the accuracy of the end product (how well it is manufactured) is probably more important than the exact profile itself. I think the pepper 836 should work just fine for a hydrofoil keel (a picture is available here

Most hydrofoils have a straight keel. I think fancies tend to require more stiffness and add more weight without adding much benefit, but I could be wrong. Some keels are tilted/curved with the top near the board more forward than the bottom part. I think this might help to decrease the amount of spray that is kicked up behind the foil. I think a cleaner profile will likely have a better effect than tilting the mast. The other reason might simply be to keep the mounting on the board further forward while moving the fuselage further back. An example of this is the Moses hydrofoil

3.6 THE FUSELAGE:

The fuselage is the part that holds everything together at the bottom. It allows for attaching a front wing, a rear wing and connects onto the keel. Most hydrofoils have the keel and fuselage as one piece, which allows a lighter or stronger hydrofoil than making it removable.

3.7 LENGTH:

The length of the fuselage varies depending on the design. The average is probably around 750mm. Most are only long enough to hold the front and rear wings a set distance apart, but some extend beyond the wings to allow a more streamlined design.

A longer fuselage will obviously give you more pitch stability (up and down angle). However, it is not always a given that a much longer fuselage will be much easier to learn on. Controlling the height of a hydrofoil required fast rider response and making the fuselage longer might not slow down the foil enough to make much of a difference (but I could be wrong). Once you have learned to control the height by muscle reflex, the speed at which a hydrofoil pitches up or down is does not feel so fast any more, and is not the most difficult part of staying balanced on the hydrofoil. At high speeds, smaller changes in angle makes a larger response of the foil, making height control difficult at speeds above the optimum speed that the foil was designed for. But at higher speeds, the hydrofoil also resists pitch changes more, and a shorter keel might even work better for high speed foils than a longer one. If you compare two of the fastest hydrofoils (the Spots and Taro) you will notice that the wings look rather close together. Other designs like the Zero and Alpine seem to have a much longer distance between the wings and are promoted as being fast but still beginner friendly.

A shorter fuselage will give you more maneuverability and allow you to change your height faster. This is very useful in the waves, where you need to go over waves much higher than the height of your mast. When going out in big waves you'll need to pitch up over the face of the face and then pitch back down very quickly on the other side so as not to ramp right out of the back of the wave.

3.8 SHAPE:

The fuselage shape is normally driven by design elements of where you want the wings to be positioned. It needs to have as little drag as possible (minimum frontal area), needs to be strong enough and needs to allow the wings to get connected to it.

The widths are normally just wide enough to comfortably hold screw holes for the wings to screw into and allow some surface area for the wings to press against when fastened onto the fuselage. I had a fuselage that was only 12mm wide and was made of solid aluminium. It worked well until it got washed out in big waves and broke. Currently I use a 16mm thick solid aluminium keel which is proving to be an excellent thickness to keep weight low and still give a very solid fuselage. The height of the fuselage is normally driven by the loads that it needs to carry. The loads between the bottom of the keel and the middle of the front wing can be much more than most people initially assume. Under dynamics loads, the main wing might have to carry twice your body weight, and the further the main wing is in front of the keel the more stress has to be sustained by the fuselage. My second home made foil was about 20mm high fiberglass and the loads were too much for it and it broke the first time I tried to ride it. My next one was 25mm aluminium and that seems to be strong enough. It is important that the fuselage does not bend when loaded since this will change the wing's angle of attack and make it impossible to ride. A smart way to add more stiffness and strength to the fuselage is to add a web, which practically stops any bending without added much weight or frontal area. The MHL Lift has a nice web underneath to make the fuselage rock solid: A web like this might add certain yaw dynamics to the play, which might be useful or could make the handling worst depending on the design

3.9 THE WINGSOPERATION:

The front wing of the foil takes all your weight (and any pull resistance from the kite) while the rear wing is only a stabilizer to help you keep the angle of attack stable. The rear wing should have either no lift, or a little bit of lift force downwards causing the nose of the board to want to pitch upwards. If the rear wing has a lot of lift upwards, then your center of lift of the foil will move back, causing your center of mass to have to move backwards as well and making the foil less stable. The most important thing about the relative angles of the wings is that the foil will stay pitched the same no matter what speed you are doing. It must not require you to balance on the back of the board for slow speeds, and then have to move forward as you speed up. Ideally you want to stay centered on the board for the full speed range. With only the front wing making lift, the rear wing would be unnecessary if we could control the foil angle. But controlling the pitch angle with only one small wing is probably too difficult, although I would guess not impossible. Normal aerodynamic (or hydrodynamic) profiles are unstable in pitch, making them want to pitch away from the straight and level angle. Hang gliders overcome this problem with techniques such as reflex to make the whole wing pitch stable. This makes the wing return to its normal angle of attach after the pitch was changed. I think a hydrofoil need much more aggressive pitch stabilization which is why we need a small wing about 70cm behind the main wing. This adds a lot of pitch stability, but for anyone learning it probably feels like it does not add nearly enough.

3.10 SIZE:

The front wing is normally about 600 square centimeters (cm2). Faster foils will have a less area and will need more speed before they can hold your weight up. Larger foils will normally be easier to learn on since you can stay up at a slower speed. The size of the wing makes a very big difference on how fast a foil will be, and how much glide feeling it will have. I have found that larger wings on the same low drag keel and fuselage can make a foil feel very slow and almost make it feel stuck. But getting used to a fast foil takes time and I definitely would suggest anyone learning to ride a foil board to start on a slower, larger wing.The rear wing is normally about 2.5 to 3 times smaller than the front wing. The further the wings are apart, the smaller the rear wing can be.

3.11 OUTLINE:

The shape or outlines of the wings are normally delta shape. A delta shape acts like a tapering wing that has a little bit of sweep back. Sweep back is normally used to give a wing yaw stability. When the wing yaws slightly to the one side, say left of the direction of travel, there will be more surface area and hence drag on the right hand side thus forcing the wing to face directly forward again. This is why hang gliders are delta shaped and it would be impossible to control yaw on a hang glider without a delta type wing sweep back. But on a hydrofoil, the rear wing is so far behind the front wing that any bit of drag there will create a lot more yaw stability than the wing shape can hope to achieve, unless the wingspan is very large compared to the fuselage length. A much more efficient way to add yaw stability (if needed) would be to put a small vertical fin/rudder near the rear wing and this will do much more for yaw stability than a delta wing shape I believe.

Some foils are more of an elliptical shape. This shape minimizes induced drag, so makes the foil as efficient as possible for a given aspect ratio. The drawback of this shape is that the stall happens across the whole wing at once, which is why aircraft do not have elliptical wings anymore. But for a hydrofoil, I have not found elliptical wings to cause sudden stalls any more than other wing shapes I tested. We can change our angle of attach and add pull from the kite quickly to get out of a stall, and even if we shall we just hit the board on top of the water and take off again. I have found that the stiffness of the keel and fuselage is a far more important factor in determining whether a foil would cause unforeseen stalls than the wing outline shape.

Wings that gradually get narrower towards the sides seems to be standard for hydrofoils. This makes sense in that the loading on the wing decreases from the middle towards the sides and the wing can be narrower towards the sides. (If the profile is kept constant, the wing thickness should become narrower as the length/chord of the wing gets narrower). A narrower wing tip also means less mass at the outsides of the wing, decreasing its moment of inertial (making it more maneuverable) and less likely to vibrate.

Another consideration in wing shape is that there are no sharp corners so that it is at least a bit safer when you do fall off. But a foil is dangerous already, so this is probably not really important

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3.12 ANHEDRAL:

Anhedral is the curve of the wing downwards. Dihedral is a curve in the opposite direction (upwards) and is normally found on aircraft such as gliders to give them roll stability. With dihedral, if the wing rolls left, there will be more wing area on the left, causing more lift on the left and causing the wing to want to roll back upright. One would think that this is what a hydrofoil should have- roll stability to help keep it upright. Yet, if you look at hydrofoils, almost all of them have anhedral making them even more unstable!

This seemingly contradiction has made me think quite a bit as to why? The amount of roll stability that dihedral would give is quite small compared to the length of the keel with most of the mass so far above. Dihedral would probably not add any noticeable roll stability, and neither would anhedral take away any noticeable roll stability. I used to think that is was mainly for the handling dynamics of roll/yaw interaction, but after making a couple of different wings I think the main reasons for anhedral are:

To allow more room before the wingtips break the water surface when riding upwind (with the board riding at an angle)

and to add vertical wing area to stabilize the yaw axis. I had a foil board which had a keel of 800mm and a flat wing of close to 600mm. It was very irritating when the wing tip exited the water. It was not much fun to ride in chop conditions. If the wing could have had a bit of anhedral so that the wing tip is 100mm lower, it would have given the same controlling range as having a 100mm longer keel. The shorter a keel can be, the less stiffness it needs so using anhedral as a way of increasing one's control range is a smart idea. This does not mean that flat wings are much inferior, since a shorter flat wing with a longer keel can also give a very nice control range to the rider. When the foil becomes more streamlined, some vertical wing components are required to give the foil yaw stability and help it stay gliding in a straight line. Using anhedral, especially a sharp curve near the tip of the main wing effectively adds a vertical component of the wing near the front of the foil. But more importantly I think low drag foils also need a vertical wing component near the rear, which can either be incorporated onto the rear wing or consist of a vertical fin in the rear.

3.13 VERTICAL FINS:

On slower foils, especially ones that are not very streamlined, a vertical fin does not seem to be needed. But as the foils get more streamlined, some vertical wing component, either incorporated in the wings, or as a separate vertical fin, makes a big difference to *the handling of a foil board. Most0 foils seem to add large vertical winglets to the rear wing to add a vertical wing component at the rear of the foil to give it yaw stability. With flatter wing, a small vertical fin near the rear of the foil can give the same effect.*

A second vertical fin further forward is normally not needed, since the keel acts like a massive vertical fin. But most foils have quite a lot of downward curve on the tips of the main wing (or simply a lot of anhedral) which would act as a vertical fin near the front of the wing. Others have a fin as part of the keel structure near the front like the previous MHL Lift, which then doubles up as a structural element and also protects the wing from taking impacts if the rider hits the sand when coming in.

3.14 THE BOARD:

One would think that a board that simply floats in the air most of the time can be just about any shape. However, when tacking and jibing (and even when just cruising and losing your control now and then) the design of the board can make a big difference. Especially when learning, a good board can help you master the foil board a lot faster.

Size. The larger the board, the easier it is to learn with and the easier tacks and jibes will be. A lot of early foil boards were very short, which makes it less likely to break and makes traveling easier. I have long been riding with a board of 170cm long, which is longer than most and made learning to ride and jibe very easy. My current favourite board is 160cm long, which to me is an excellent length. A lot of boards, even ones made for light wind conditions with extra float, are down to 150cm long. I personally find a slightly longer board nice to have, since one needs to see the end of your board in your peripheral vision in order to keep the height of the foil just right. I find a too short board requires me to look down on the water more to see how high I am, whereas I can look out at the horizon and see the tip of my board on my longer 160cm board. Since hydrofoils can go out and stay upwind is such ridiculously light winds, it is often nice to have a wider board to assist take off when very underpowered, or simply for extra flotation if the wind dies off totally. A lot of boards are in the 50cm wide range. Going much wider than this will cause the rails of the board to touch the water too soon when riding upwind and the foil is angles a lot. Going much more narrow will make take offs and slow jibes more difficult, especially in very light winds. The thickness of the board is a compromise between total mass and flotation. A thicker board should help when taking off is very light winds, or for self-rescue. A thinner board would be lighter weight, and would will also have less wind drag in strong wind conditions. I made a very thick, very wide board and the first time I tested it was in very strong winds. While riding the foil felt like it was slow and like I had grass stuck on my foil. It could not be bored drag on the water, since the board is cleanly above the water while riding. When I put my old board back, I realized just how much wind drag the big bulky board had! And that was on a rather slow foil, so we will probably start seeing more aerodynamically smaller boards for racing in strong wind conditions in the future. I find that a 6 to 7cm thick board is an excellent compromise between low wind drag, and good flotation for light wind.

3.15 OUTLINE:

A rounded surfboard outline is excellent for making jibes easy. A very square board with straight rails still works decently and adds extra area for light winds without the board becoming too wide or long. I have found that a shape between a rounded surfboard shape and a square shape to be the best of both worlds, offering easy jibes, soft touch downs that do not pull you off balance, and enough area to make take offs in light wind easy without the board having to be too wide

3.16 ROCKER:

Having quite a bit of rocker in the front of the foil board is very useful. One often crashes down onto the water from a bit of a height when on the foil, and enough rockers in the front can help the board recover without nose-diving into the water. It does not need to be excessive however, and normal surfboard nose rocker lines seem to work well. Rocker in the rear is not really needed on a foil board. Most foils mount so that they want a flat rocker at the rear, and the nose of the board would be riding too high if the foil is mounted on a boar with rocker at the rear. A flat rear section allows earlier planning, improving light wind performance. Since the board is mostly in the air, one does not need rocker there for manoeuvring around a wave like you do on surfboards.

3.17 RAILS:

The ideal shape of the rails on a foil board are quite different to normal board rail shapes since the board has quite a different function to normal boards that need to use its edge to go upwind. That said, normal surfboard rails can be used for a foil boards, but a dedicated foil board rail shape will provide a number of advantages.

The rear 1/4 to 1/3 of the board should have a flat bottom and sharp rails to assist the board getting up to speed in light conditions. Almost all boards have these types of rails at the rear of the board. The mid parts of the board should have quite the opposite shape rails. Here the rails should be a cut out or rounded shape to avoid the board edging well. When the board touches the water, you do not want to board to edge against the kite since so that the forces resisting the kite pull can stay on the foil only. This way your *balance position with the board on the water and the board in the air will be quite similar, and you would have minimal disturbance when the board hits the water. The front part of the board is a compromise between how much volume you want to flotation versus extra wind drag area. I find that if the nose section is too thin with too thin rails, that the noise can dig into the water quite easily, especially when you are learning to jibe and the front of the board hits down onto the water when you put the board down to make a turn.*

4.0 Properties of Materials

4.1 STRENGTH/STIFFNESS/MATERIALS:

The forces on a foil board are obviously quite a bit more than on a surfboard. All the forces are concentrated in one section. Every time you crash down from height onto the water the board needs to survive quite an impact. Even just washing out in massive shore break with the long lever arm of the foil acting on the board puts quite a bit of stress on the board.

On the other hand, the board does not need to be as stiff as normal directional surfboards, since you are not using the board edge at all and simply need it as a magic carpet to stand on. Choosing materials that have more flex can make for a more impact resistant board that would flex on impact before breaking. For that reason, I prefer to make my boards out of polyurethane foam and polyester fiberglass. I find that polyurethane foam blanks are much stronger and shares the load with fiberglass much better than polystyrene foam. The polyester resin also allows the skin to flex a bit more than epoxy boards would normally allow. Fiberglass also flexes a lot more than carbon fibre would before breaking, making it probably one of the best materials one can use for a hydrofoil board.

My current board of 162cm long and 48cm wide weighs 4kg (without the foil), and I find that this mass range allows it to have enough fiberglass on it that I do not have to worry about ever breaking the board. I used about 1kg of dry fiberglass fabric on the board, which is much more than any other boards I know of. I personally think that it is not worth trying to make the foil boards too light and risk making it too fragile and potentially losing an expensive foil.

4.2 TORSIONAL STIFFNESS:

Obviously the keels need to be as stiff as possible for flex along its axis. It is important also that it has a lot of torsional stiffness (i.e. that it does not twist too easily). An easy mistake to take is to assume one only needs carbon fibres in one direction, and unidirectional carbon fibre is definitely the most needed part to give it enough stiffness. But it requires some 45 degree fibres as well to take out twist. Aluminium and stainless steel keels have excellent torsional stiffness, but composite keels require some care to get the torsional stiffness corrected. For metal foils, even if the keel has very high torsional stiffness, it could possibly still resonate. Any vibration on a hydrofoil is an instant efficiency and speed killer. So far I have found that vibrations are normally caused by hydrofoils that are not streamlined nicely. Rough edges, especially along the fuselage such as screw heads and poorly finished parts can be a cause of vibrations.

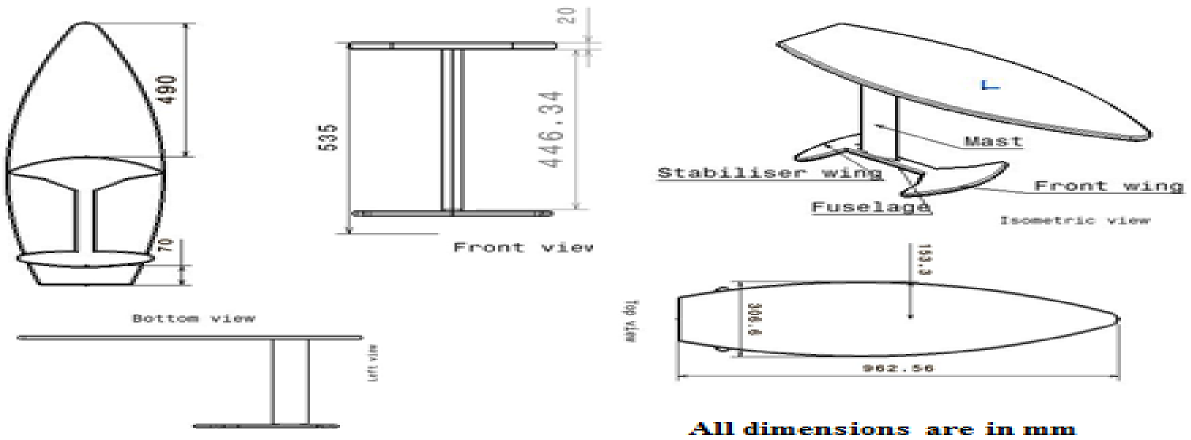
4.3 MATERIALS:

So far the only materials I know that has worked successfully for the keels are aluminium and carbon fibre. Aluminium has a modulus of around 70 GPA. A solid aluminium keel of 13 to 14mm works very well, and gives the best combination of longitudinal and torsional stiffness that I have been able to achieve. It is almost double the weight of carbon fibre though, and not very strong despite being very stiff.Carbon fibre is the obvious choice for most foils. It is very versatile and has fantastic properties, but it is a bit of an art to get a good carbon fibre foil, since there are so many factors that will affect the end product.

For carbon fibre, if you use normal modulus fabric, you will unlikely be able to get the longitudinal and torsional stiffness as good as aluminium for the same thickness of keel. If you do a good layup (using a combination of unidirectional fabric and beaux fabric at 45/45), then a thickness of around 15 or 16mm should allow you to get a good stiffness. A higher modulus fabric should give much more stiffness, but can be difficult to obtain and becomes very expensive. If you use normal woven carbon fibre and are not experienced with carbon fibre, going for an even thicker profile is probably a safer option. You will also need to get a lot of carbon fibre into the keel. A skin thickness of 2mm is probably the minimum, and then you will still need a very good (non compressible core). My current carbon fibre T-bar that works well is 15mm thick and is solid carbon fibre.

5.0 Drafting of hydro foil on surfboard (Water Craft)

DRAFTING OF HYDRO FOIL ON SURFBOARD (WATER CRAFT)



6.0 FLUID DYNAMICS ON THE HYDROFOIL

6.1 BERNOULLI’S EQUATION STREAMLINE:

Curvature Effect

Bernoulli’s Equation: $Po = P_1 + \frac{1}{2}rv_1^2 + rgy_1 = P_2 + \frac{1}{2}rv_2^2 + rgy_2$

VARIABLES UNITS:

Po	*Stagnation Pressure*	*[Pa] or [lbf/ft^2]*
P	*Pressure*	*[Pa] or [lbf/ft^2]*
R	*Density*	*[kg/m^3] or [lbf/ft^3]*
V	*Velocity*	*[m/s] or [ft/s]*
G	*Gravitational Constant*	*[m/s^2] or [ft/s^2]*
y	*Height*	*[m] or [ft]*

The fluid that moves over the upper surface of the foil moves faster than the fluid on the bottom. This is due in part to viscous effects which lead to formation of vertices at the end of the foil

6.2 EULER’S EQUATION:

Euler’s Equation: $d(p+rgy)/dn = rv^2/R$

VARIABLES UNITS:

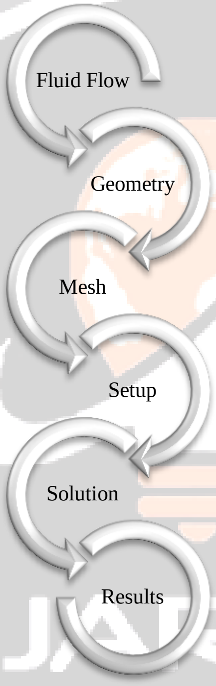
P	*Pressure*	*[Pa] or [lbf/ft^2]*
r	*Density*	*[kg/m^3] or [lbf/ft^3]*
V	*Velocity*	*[m/s] or [ft/s]*
g	*Gravitational Constant*	*[m/s^2] or [ft/s^2]*
y	*Height*	*[m] or [ft]*
n	*Vector in Radial Direction*	---
R	*Radius of Curvature of Streamline*	*[m] or [ft]*

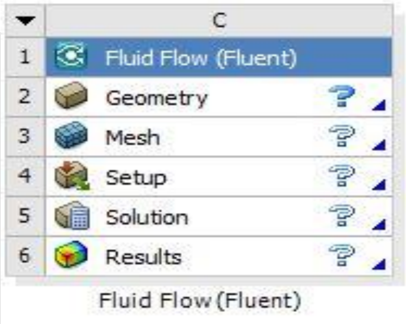
If the velocity of a particle with an initial momentum is increased, then there is a reactant momentum equal in magnitude and opposite in direction to the difference of the momentums

7.0 FLUENT FLOW (FLUENT) MODULE USED FOR ANALYSIS:

ANSYS Fluent is a state-of-the-art computer program for modeling fluid flow, heat transfer, and chemical reactions in complex geometries.
ANSYS Fluent uses a client/server architecture, which enables it to run as separate simultaneous processes on client desktop workstations and powerful computer servers. This architecture allows for efficient execution, interactive control, and complete flexibility between different types of machines or operating systems.
ANSYS Fluent provides complete mesh flexibility, including the ability to solve your flow problems using unstructured meshes that can be generated about complex geometries with relative ease. Supported mesh types include 2D triangular/quadrilateral, 3D tetrahedral/hexahedral/pyramid/wedge/polyhedral, and mixed (hybrid) meshes. ANSYS Fluent also enables you to refine or coarsen your mesh based on the flow solution.

7.1 PROCESS SETUP FOR FLUENT:

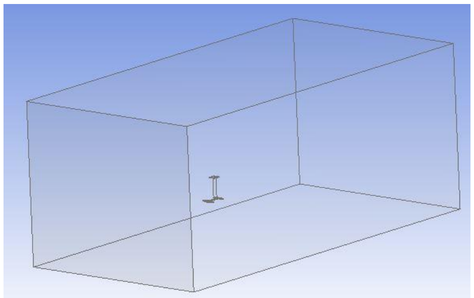


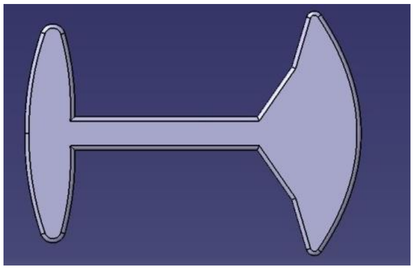


	C
1	Fluid Flow (Fluent)
2	Geometry
3	Mesh
4	Setup
5	Solution
6	Results

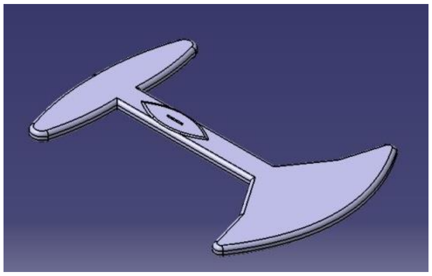
Fluid Flow (Fluent)

7.2 GEOMETRY OPERATIONS

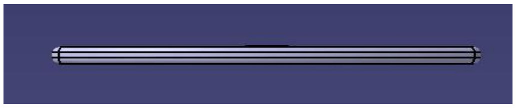




Top view

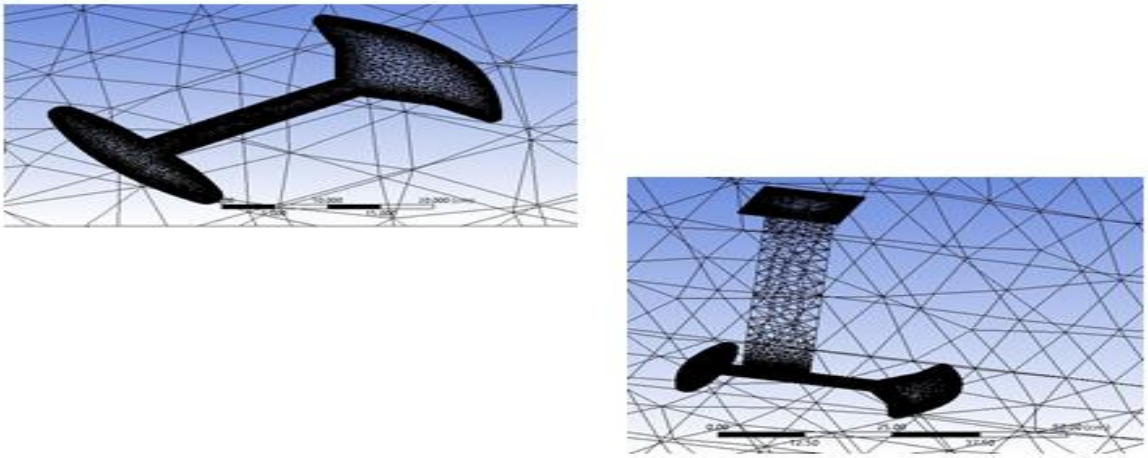


Isometric view

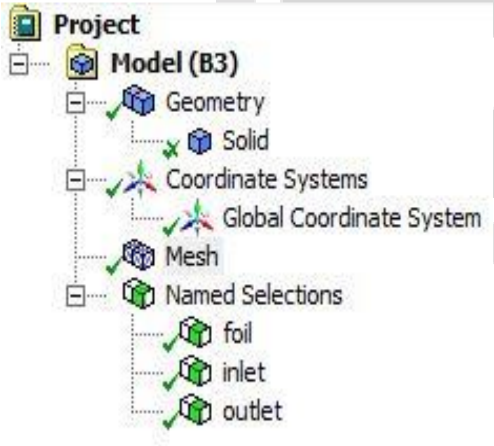


Front view

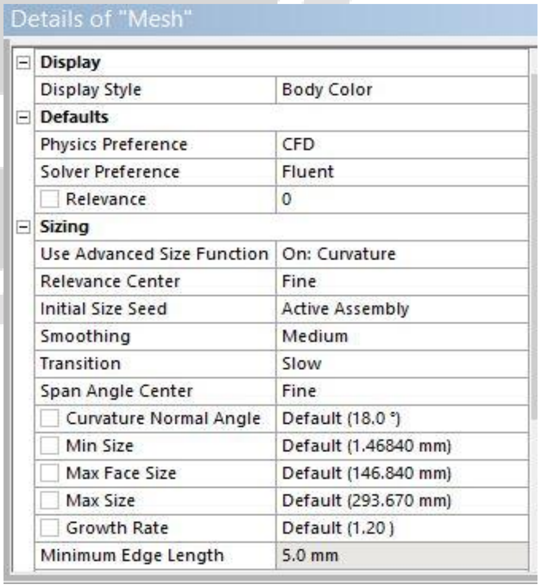
7.2 MESHING PROCEDURE



Tetrahedral meshing on hydro foil



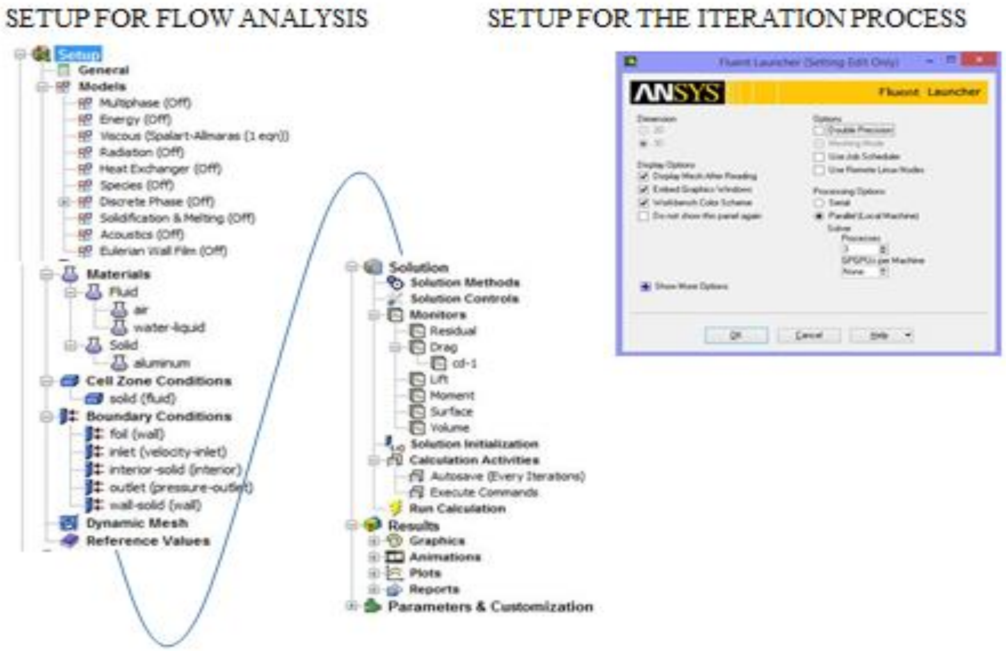
- **Project**
  - **Model (B3)**
    - Geometry
      - Solid
    - Coordinate Systems
      - Global Coordinate System
    - Mesh
    - Named Selections
      - foil
      - inlet
      - outlet



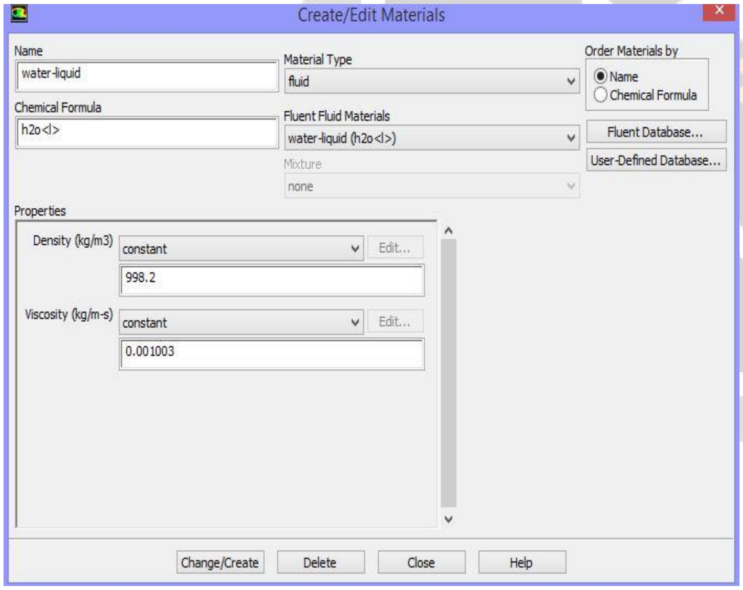
Details of "Mesh"

Display	
Display Style	Body Color
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
☐ Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Fine
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
☐ Curvature Normal Angle	Default (18.0 °)
☐ Min Size	Default (1.46840 mm)
☐ Max Face Size	Default (146.840 mm)
☐ Max Size	Default (293.670 mm)
☐ Growth Rate	Default (1.20)
Minimum Edge Length	5.0 mm

7.3 SET UP FLOW



7.3.1 FLUID PROPERTIES **7.3.2 INLET VELOCTY**



Name: water-liquid

Chemical Formula: h2o<l>

Material Type: fluid

Fluent Fluid Materials: water-liquid (h2o<l>)

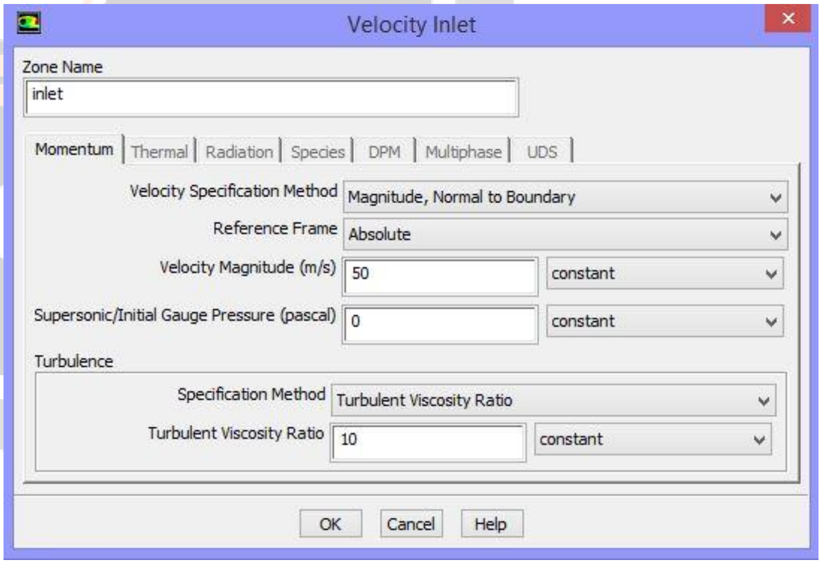
Mixture: none

Order Materials by: ● Name ○ Chemical Formula

Properties

Density (kg/m3): constant, 998.2

Viscosity (kg/m-s): constant, 0.001003



Zone Name: inlet

Velocity Specification Method: Magnitude, Normal to Boundary

Reference Frame: Absolute

Velocity Magnitude (m/s): 50, constant

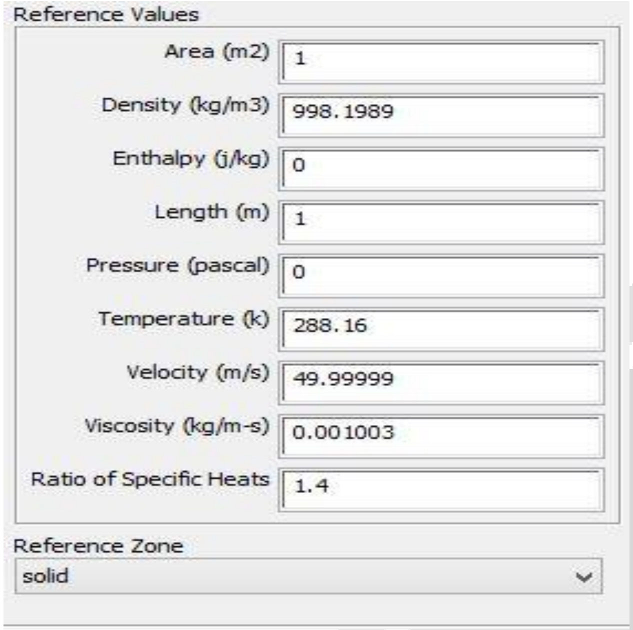
Supersonic/Initial Gauge Pressure (pascal): 0, constant

Turbulence

Specification Method: Turbulent Viscosity Ratio

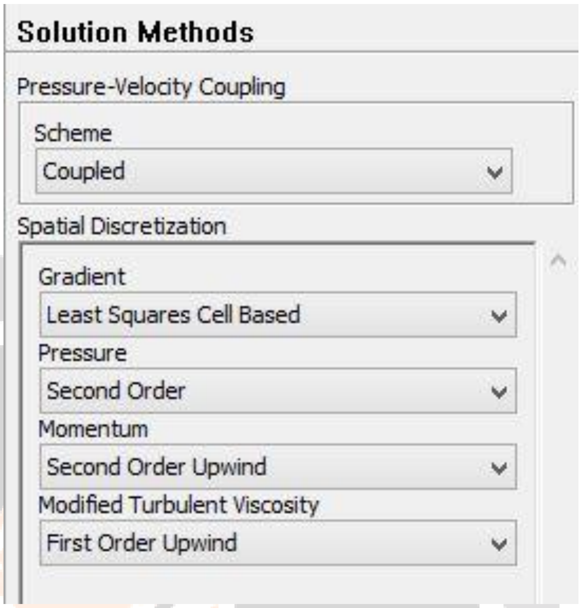
Turbulent Viscosity Ratio: 10, constant

7.3.3 REFERENCE VALUES



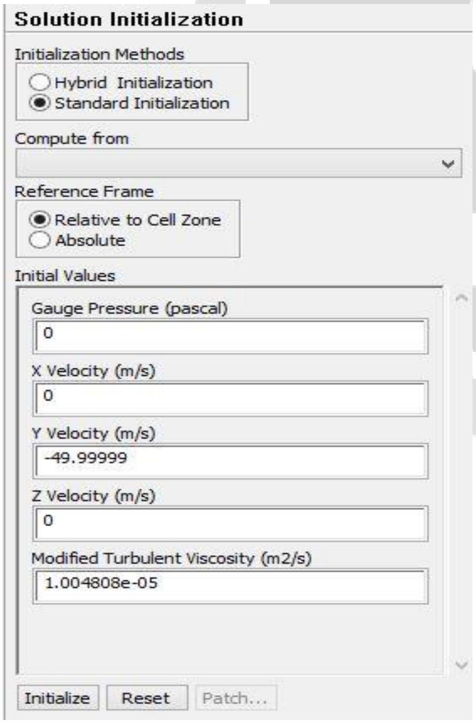
Reference Values
Area (m2): 1
Density (kg/m3): 998.1989
Enthalpy (j/kg): 0
Length (m): 1
Pressure (pascal): 0
Temperature (k): 288.16
Velocity (m/s): 49.99999
Viscosity (kg/m-s): 0.001003
Ratio of Specific Heats: 1.4
Reference Zone: solid

7.3.4 SOLUTION METHODS



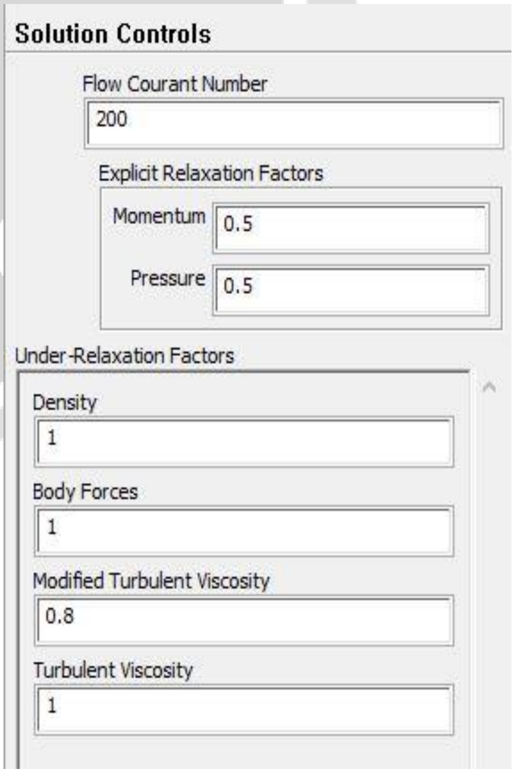
Solution Methods
Pressure-Velocity Coupling
Scheme: Coupled
Spatial Discretization
Gradient: Least Squares Cell Based
Pressure: Second Order
Momentum: Second Order Upwind
Modified Turbulent Viscosity: First Order Upwind

7.3.5 SOLUTION INITIALIZATION



Solution Initialization
Initialization Methods
○ Hybrid Initialization
● Standard Initialization
Compute from:
Reference Frame
● Relative to Cell Zone
○ Absolute
Initial Values
Gauge Pressure (pascal): 0
X Velocity (m/s): 0
Y Velocity (m/s): -49.99999
Z Velocity (m/s): 0
Modified Turbulent Viscosity (m2/s): 1.004808e-05

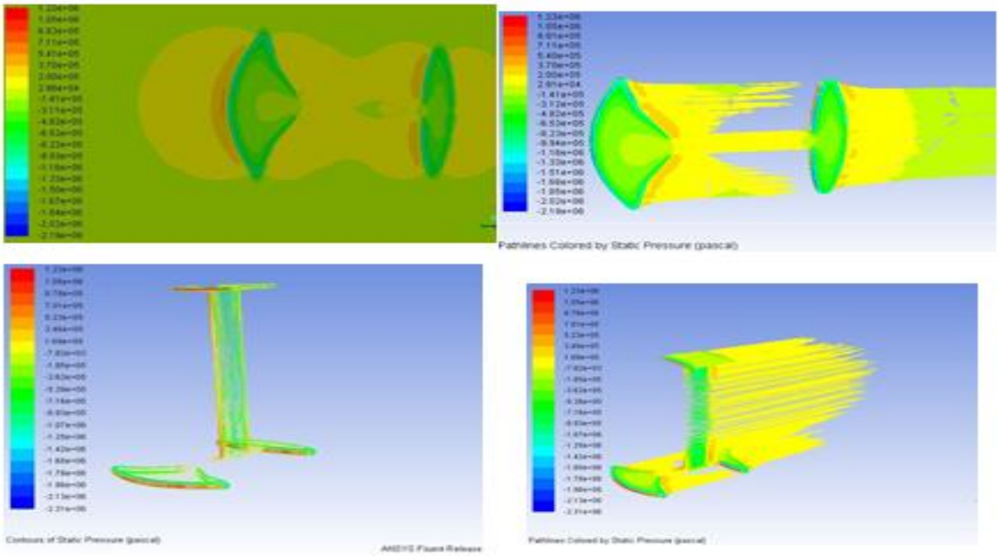
7.3.6 SOLUTION CONTROLS



Solution Controls
Flow Courant Number: 200
Explicit Relaxation Factors
Momentum: 0.5
Pressure: 0.5
Under-Relaxation Factors
Density: 1
Body Forces: 1
Modified Turbulent Viscosity: 0.8
Turbulent Viscosity: 1

7.4 SOLUTION

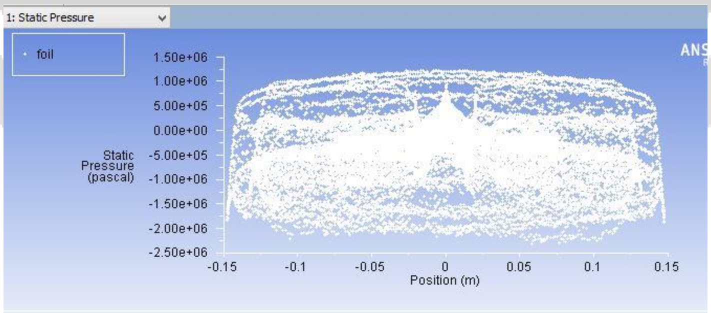
Static pressure build on the foil at 1 m/s velocity is 1.23 MPa



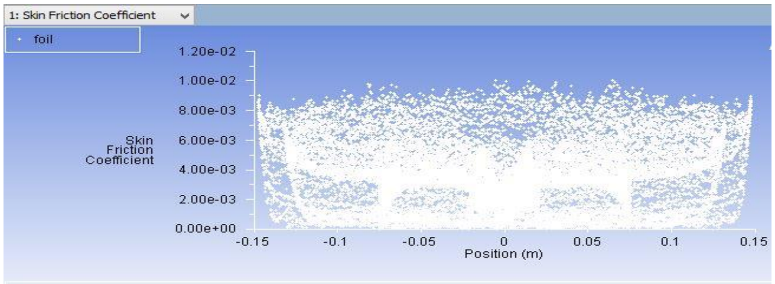
7.5 RESULT

Velocity around the hydrofoil at 1m/s velocity drag is 0.092

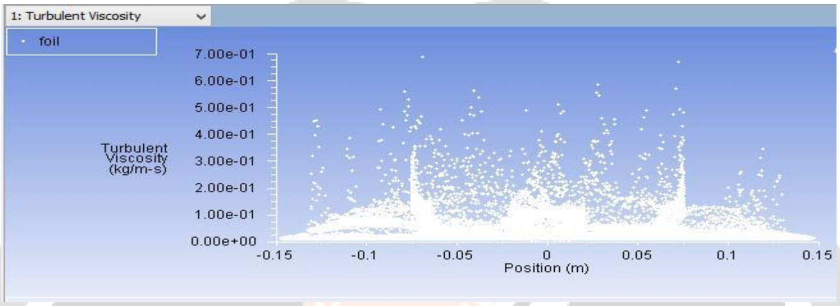
STATIC PRESSURE AND POSITION PLOT



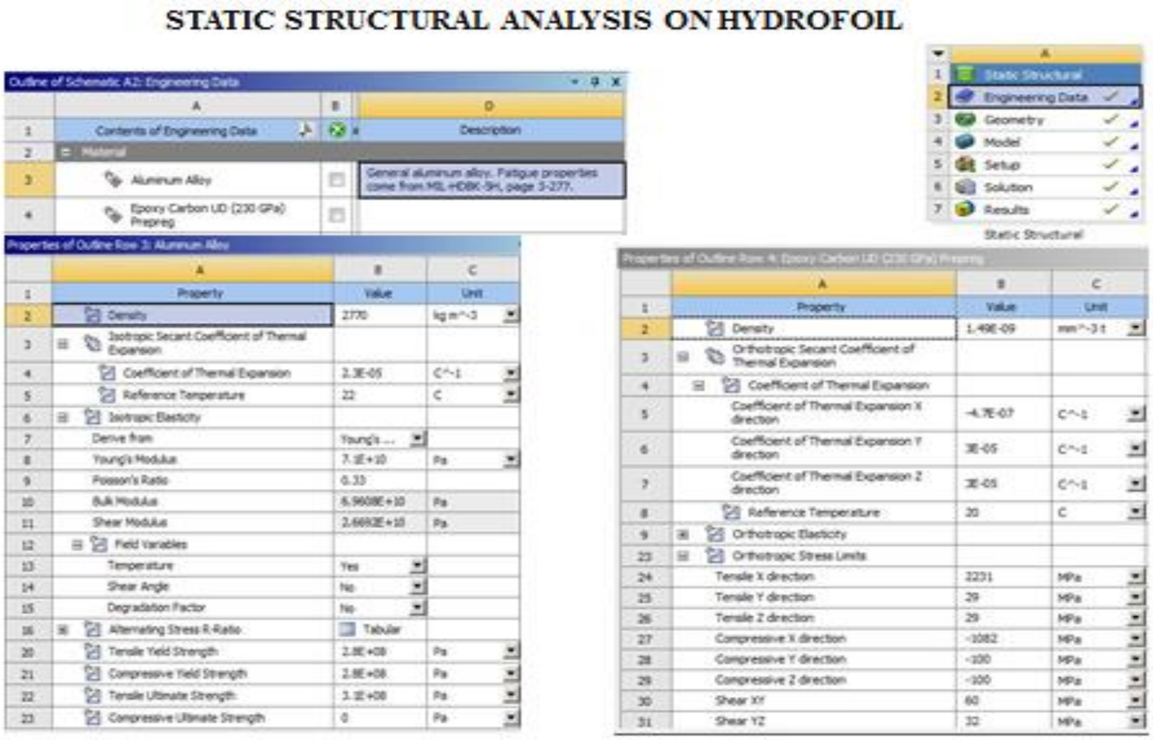
SKIN FRICATION COEFFICIENT AND POSITION PLOT



TURBULENT VISCOSITY AND POSITION PLOT



8.0 STATIC STRUCTURAL ANALYSIS ON HYDROFOIL



STATIC STRUCTURAL ANALYSIS ON HYDROFOIL

Outline of Schematic A2: Engineering Data

	A	B	D
1	Contents of Engineering Data		Description
2	Material		
3	Aluminum Alloy	☐	General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.
4	Epoxy Carbon UD (230 GPa) Prepreg	☐	

Properties of Outline Row 3: Aluminum Alloy

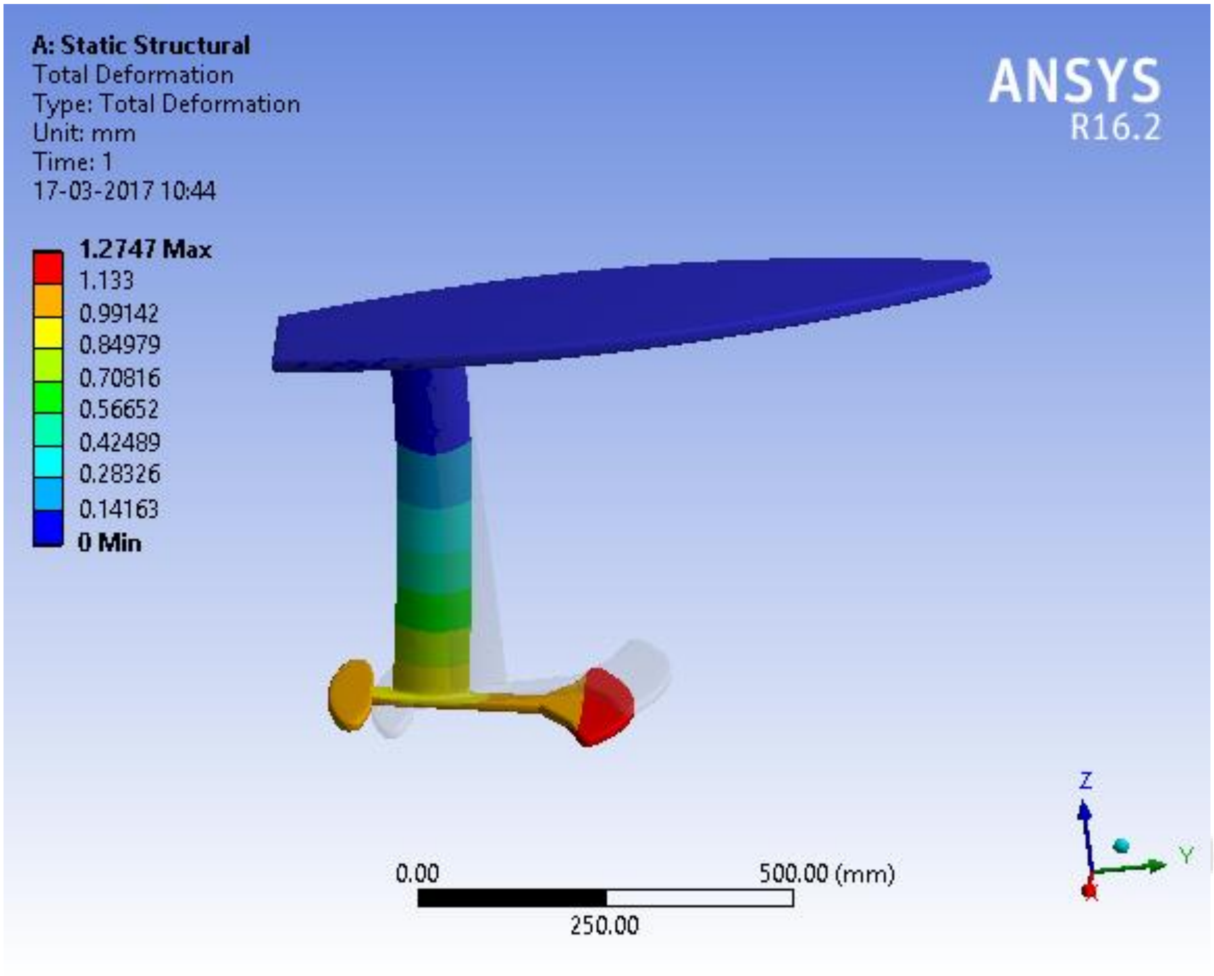
	A	B	C
1	Property	Value	Unit
2	Density	2770	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	2.3E-05	C^-1
5	Reference Temperature	22	C
6	Isotropic Elasticity		
7	Derive from	Young's ...	
8	Young's Modulus	7.1E+10	Pa
9	Poisson's Ratio	0.33	
10	Bulk Modulus	6.9608E+10	Pa
11	Shear Modulus	2.6692E+10	Pa
12	Field Variables		
13	Temperature	Yes	
14	Shear Angle	No	
15	Degradation Factor	No	
16	Alternating Stress R-Ratio	Tabular	
20	Tensile Yield Strength	2.8E+08	Pa
21	Compressive Yield Strength	2.8E+08	Pa
22	Tensile Ultimate Strength	3.1E+08	Pa
23	Compressive Ultimate Strength	0	Pa

	A
1	Static Structural
2	Engineering Data ✓
3	Geometry ✓
4	Model ✓
5	Setup ✓
6	Solution ✓
7	Results ✓

Static Structural

Properties of Outline Row 4: Epoxy Carbon UD (230 GPa) Prepreg

	A	B	C
1	Property	Value	Unit
2	Density	1.49E-09	mm^-3 t
3	Orthotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion X direction	-4.7E-07	C^-1
6	Coefficient of Thermal Expansion Y direction	3E-05	C^-1
7	Coefficient of Thermal Expansion Z direction	3E-05	C^-1
8	Reference Temperature	20	C
9	Orthotropic Elasticity		
23	Orthotropic Stress Limits		
24	Tensile X direction	2231	MPa
25	Tensile Y direction	29	MPa
26	Tensile Z direction	29	MPa
27	Compressive X direction	-1082	MPa
28	Compressive Y direction	-100	MPa
29	Compressive Z direction	-100	MPa
30	Shear XY	60	MPa
31	Shear YZ	32	MPa



Total deformation of 1.2mm on surfboard
at 1.1Mpa, Aluminium alloy material

9.0 CONCLUSION:

Hydrofoil on watercraft is designed and analysed by using CATIA and fluent tool in ANSYS software. Optimum results were obtained. Various fabrication processes have been studied. By implementing this type of hydrofoil we can improve performance of watercraft by reducing drag and static pressure values. By developing this technique we can implement in heavy water vehicles.

10.0 REFERENCES:

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[3] Neil Bose'. B. Sc. "DESIGN OF, A WIND PROPELLED FLYING TRIMARAN" Submitted as a Thesis for the Degree of Doctor of Philosophy Department of Naval Architecture and Ocean Engineering University of Glasgow April 1982.

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[7] D. H. Fruman, P. Cerrutti, T. Pichon and P. Dupont *"Effect of Hydrofoil Planform on Tip Vortex Roll-Up and Cavitation" doi:10.1115/1.2816806.*

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