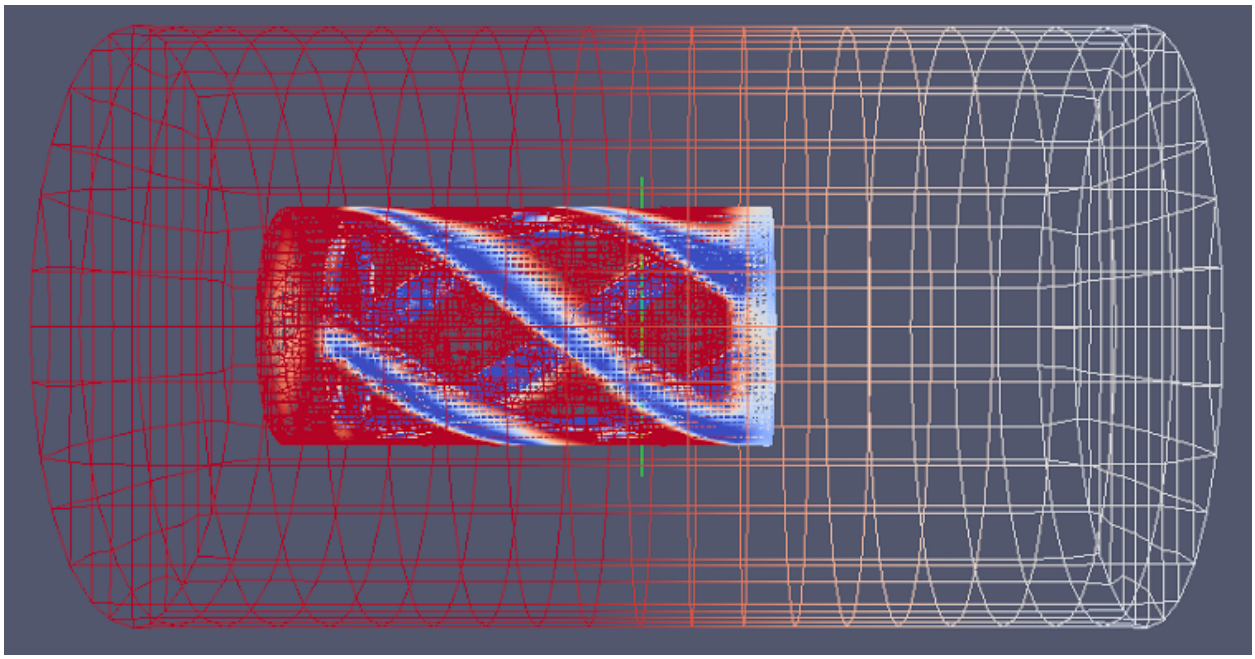
Computational Analysis and Study of the Vor-Prop Propeller System

Vor-Prop Modelling Summary

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1. Introduction

CFS performed a computational analysis of the proprietary Vor-Prop propulsion device for Vor-Prop LLC. This device has similar features to the Gorlov Helical Turbine device used to harvest energy from a flowing fluid.



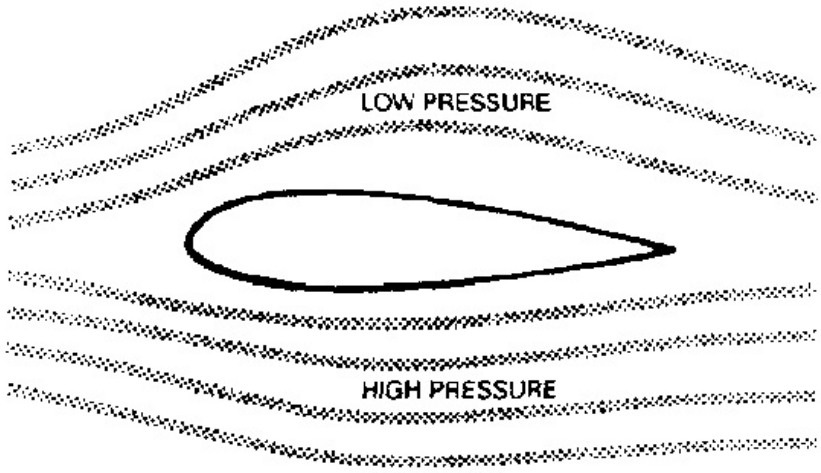
Figure 1: Gorlov Helical Turbines being installed in Cobscook Bay, Maine, US

The traditional Gorlov device has an axis perpendicular to the flow direction. The strategy behind the design is to "catch" the flowing fluid and spin, which rotates a shaft and can be transformed into usable power. The Vor-Prop device will have to operate in two fundamentally different manners. First, the process intended by the original Gorlov machine will be reversed, i.e. usable power will spin the device which will then displace fluid to generate propulsion. Secondly, the axis of the device needs to be parallel to the flow direction. The second difference will be more difficult to overcome than the first.

CFS created a model of the device in order to simulate performance under various conditions. At this stage, only a top-level analysis was performed. The main tool used in evaluation was a comparison to a standard propeller simulation operating under similar conditions.

2. Summary of Fluid Dynamics

Propellers create a forward propulsion because of an uneven pressure distribution on two opposing sides. This uneven pressure distribution is caused by differences in the velocity flow on the top and bottom of the propeller blades. A faster velocity will result in a lower pressure. This is confirmed in Bernoulli's principle.



3. Specific Simulation Data

3.1. Standard Propeller Analysis.

A standard propeller was modelled and inspected. The parameters of interest were velocity, pressure, and vorticity.

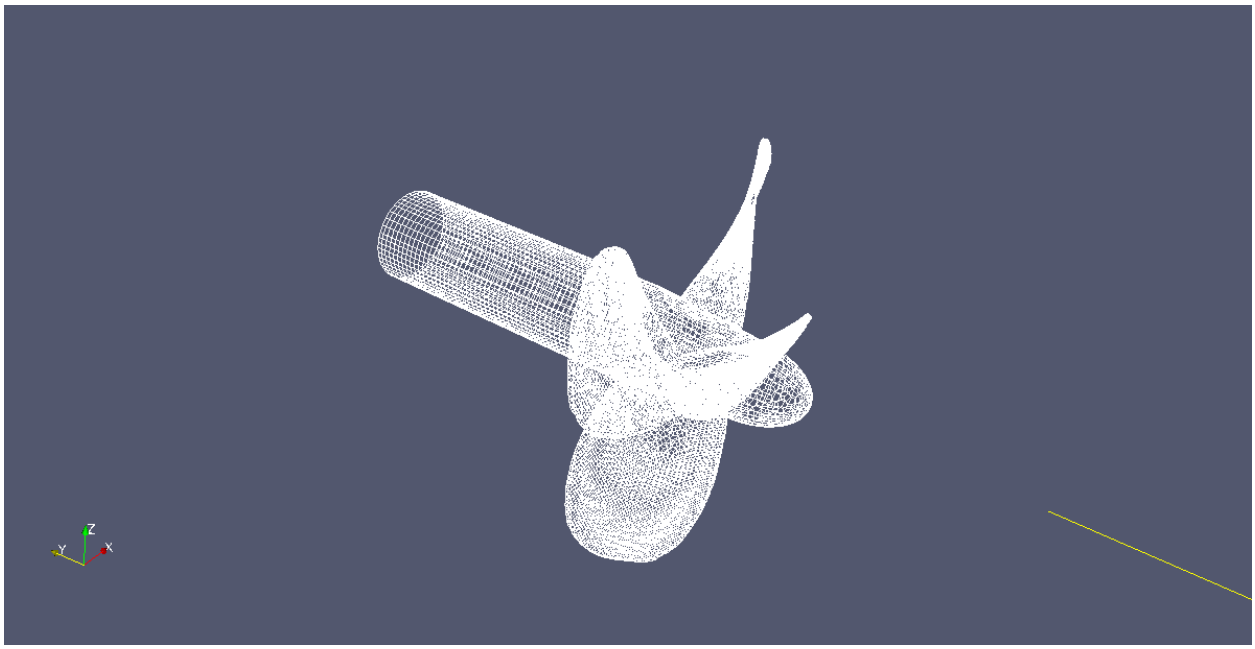


Figure 2: Standard Four Blade Propeller Mesh

Parameter	Value
Diameter (tip to tip)	400 mm (16”)
Ambient Flow (axial)	-5 m/s (left to right flow)
RPM	1500
Simulated Volume	600mm x 1020mm x 600mm

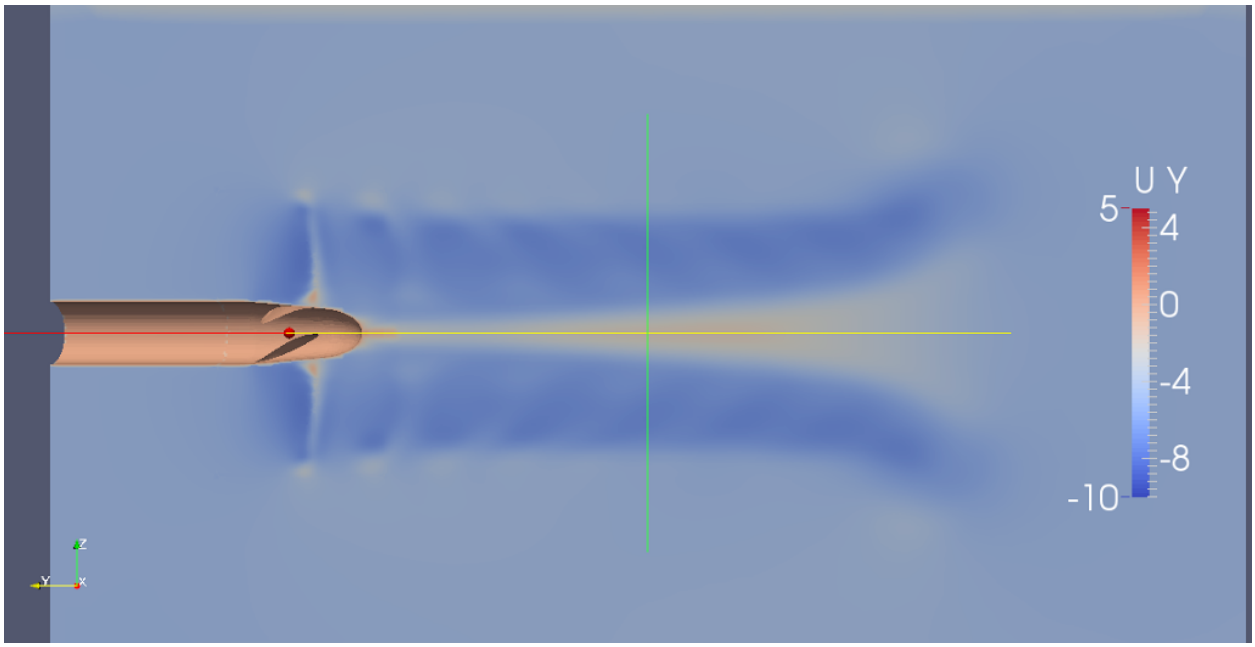


Figure 3: Standard Propeller Axial Velocity Profile

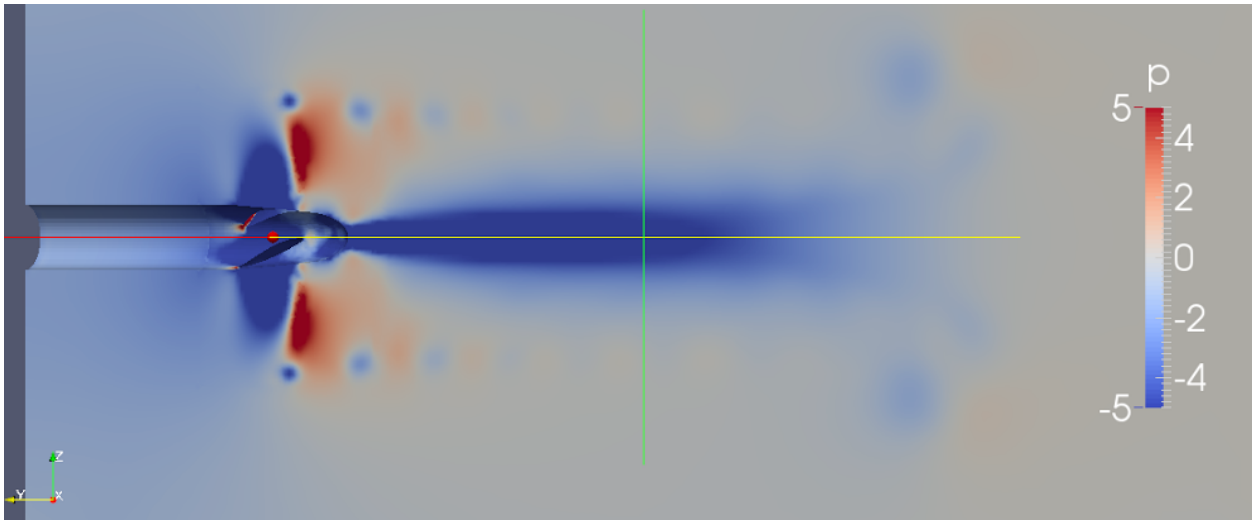


Figure 4: Standard Propeller Pressure Gradient

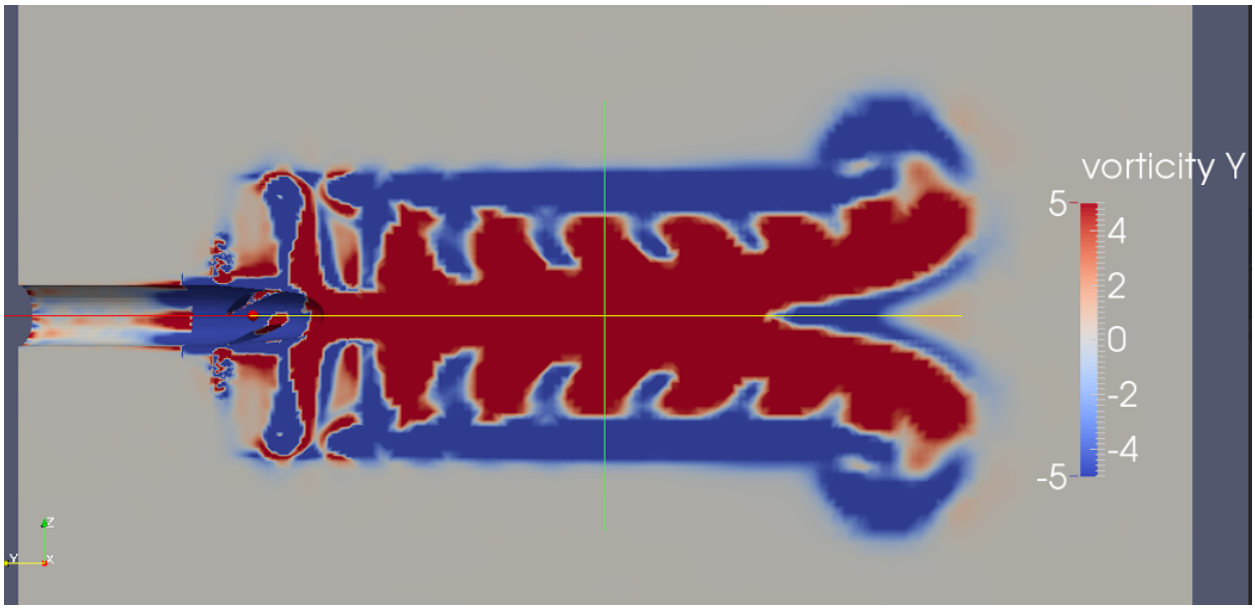


Figure 5: Standard Propeller Vorticity (indicates the flow spinning about the central axis)

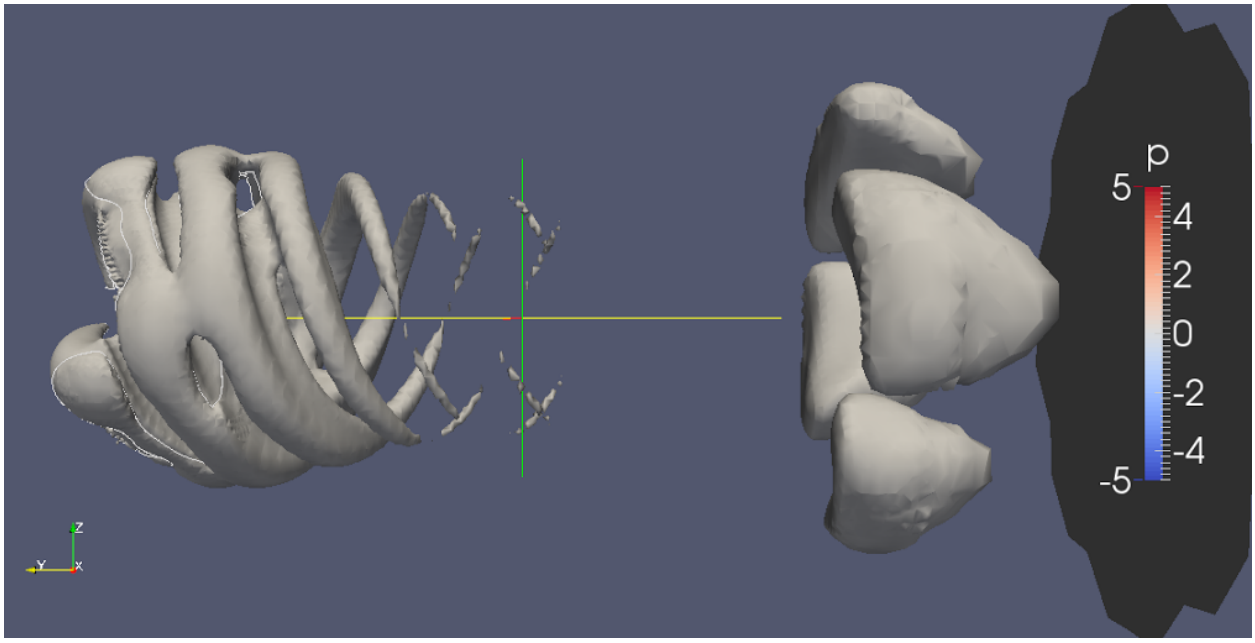


Figure 6: Standard Propeller Pressure Contour

The isocontour shown in Figure 6 is of the undisturbed flow. Think of this surface as the front of the disturbance from the rotating propeller. Note the strong indication of the spiral flow pattern. Each propeller blade can be accounted for by its own spiral pattern.

3.2. Vor-Prop Case Study 1

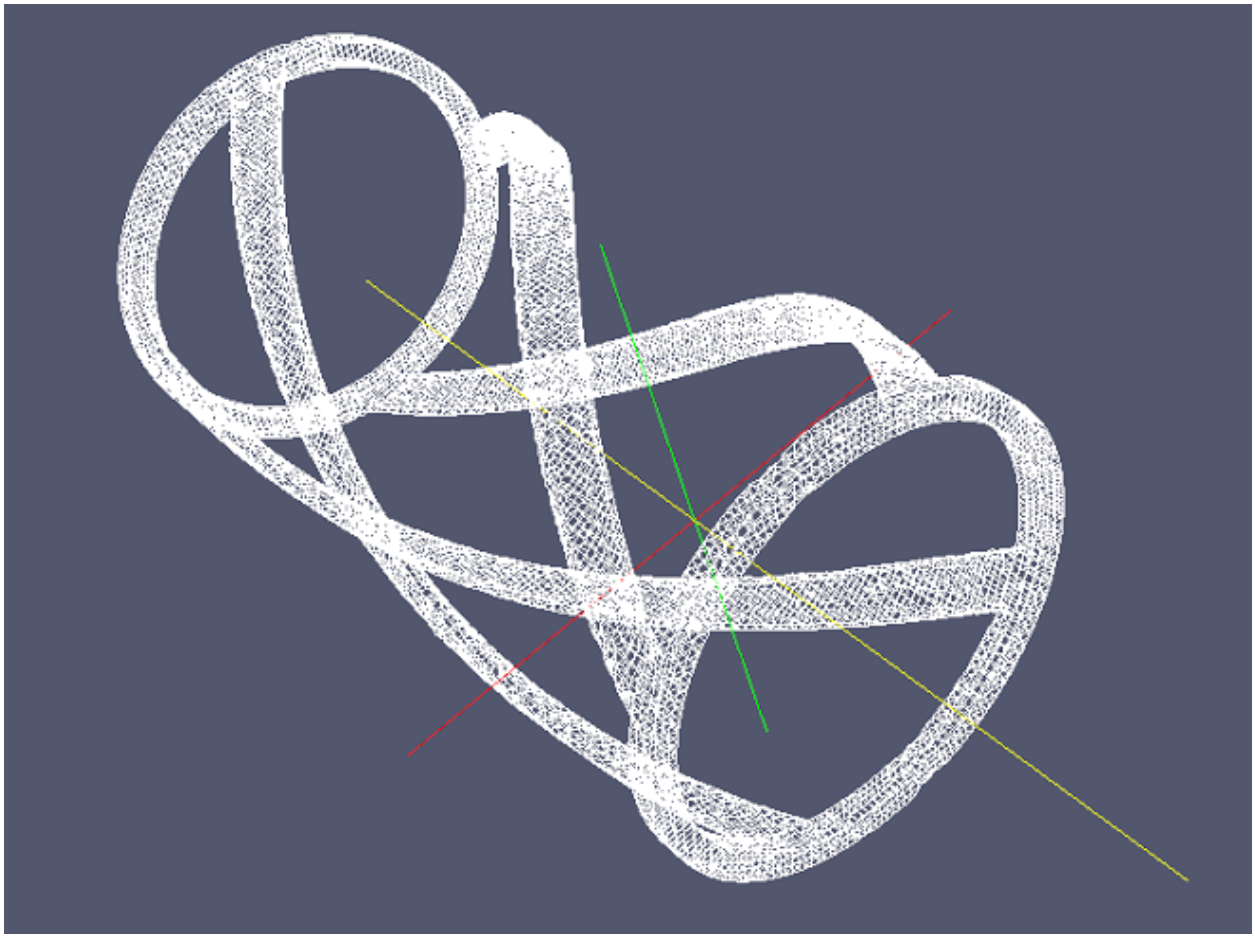


Figure 7: Vor-Prop Mesh

Parameter	Value
Diameter (tip to tip)	400 mm (16”)
Ambient Flow (axial)	-5 m/s (left to right flow)

RPM	1500
Simulated Volume	600mm x 1020mm x 600mm
Blade Thickness	31.4mm
Blade Height	12mm

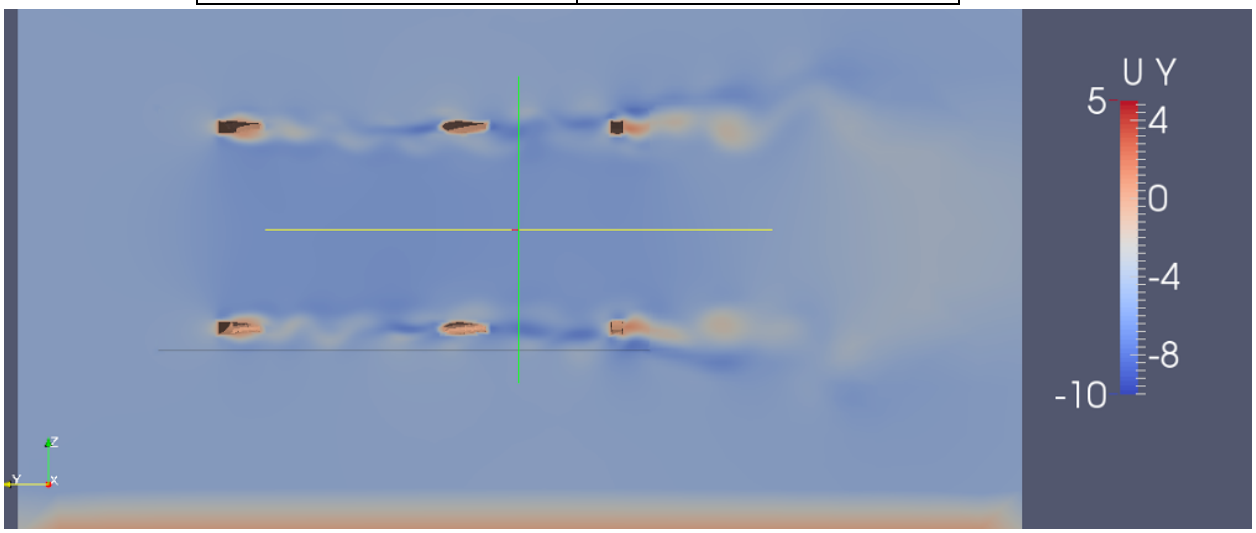


Figure 8: Vor-Prop Axial Velocity Profile

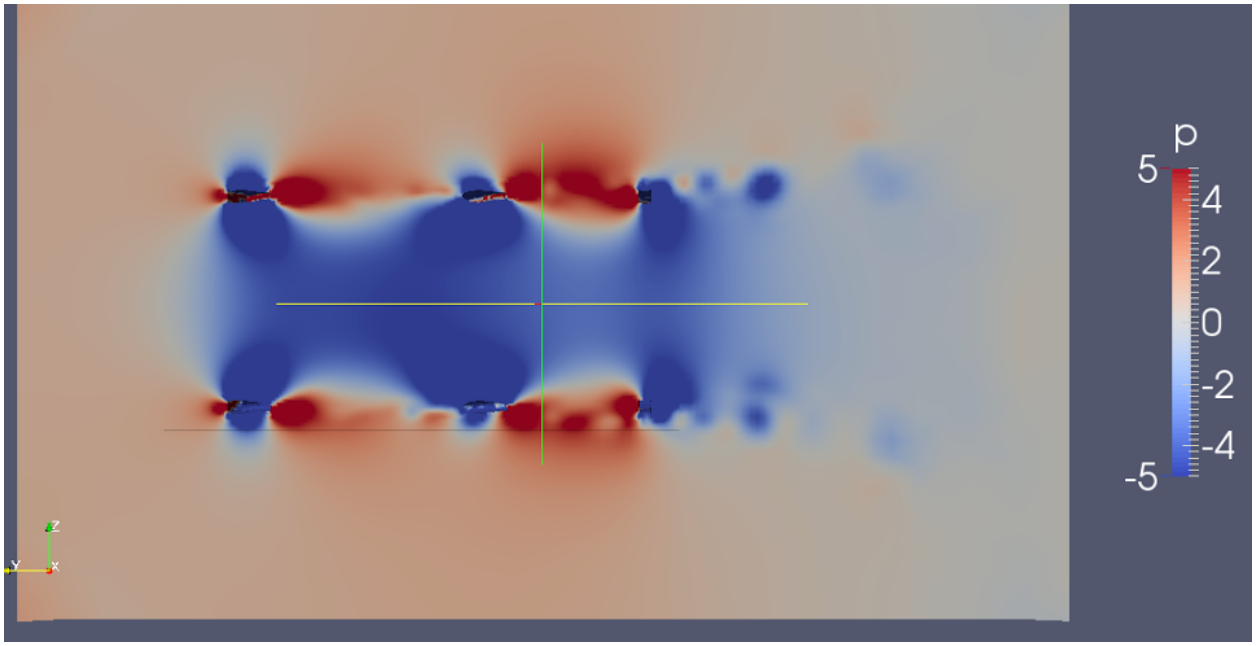


Figure 9: Vor-Prop Pressure Gradient

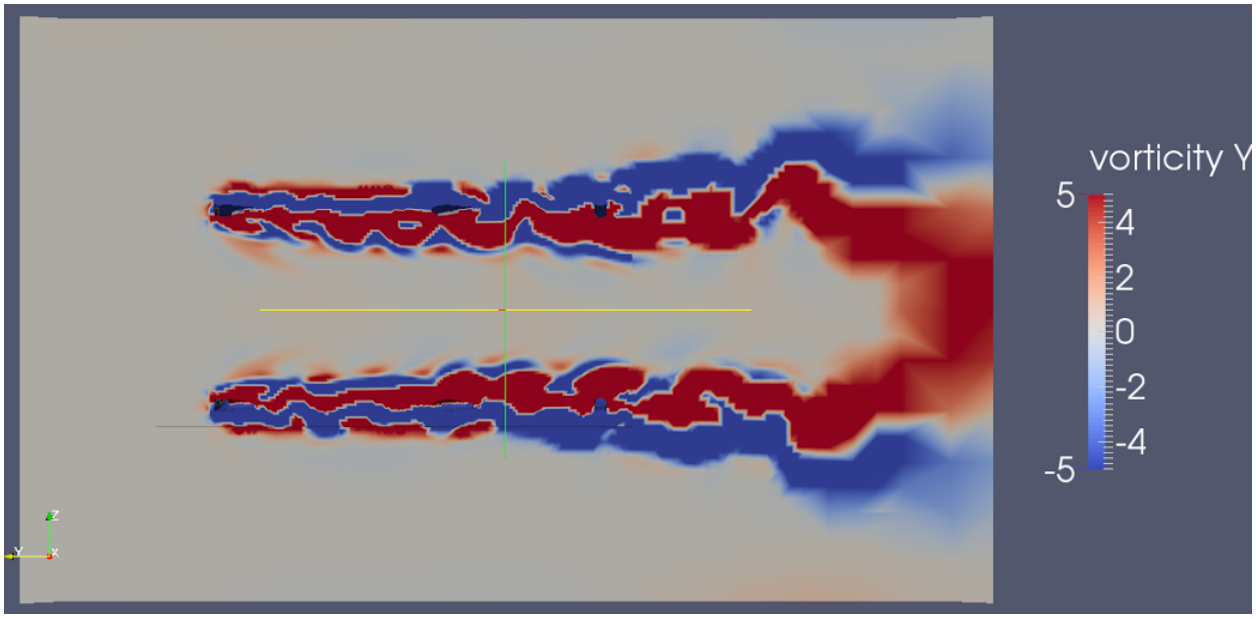


Figure 10: Vor-Prop Axial Vorticity Profile (indicates the flow spinning about the central axis)

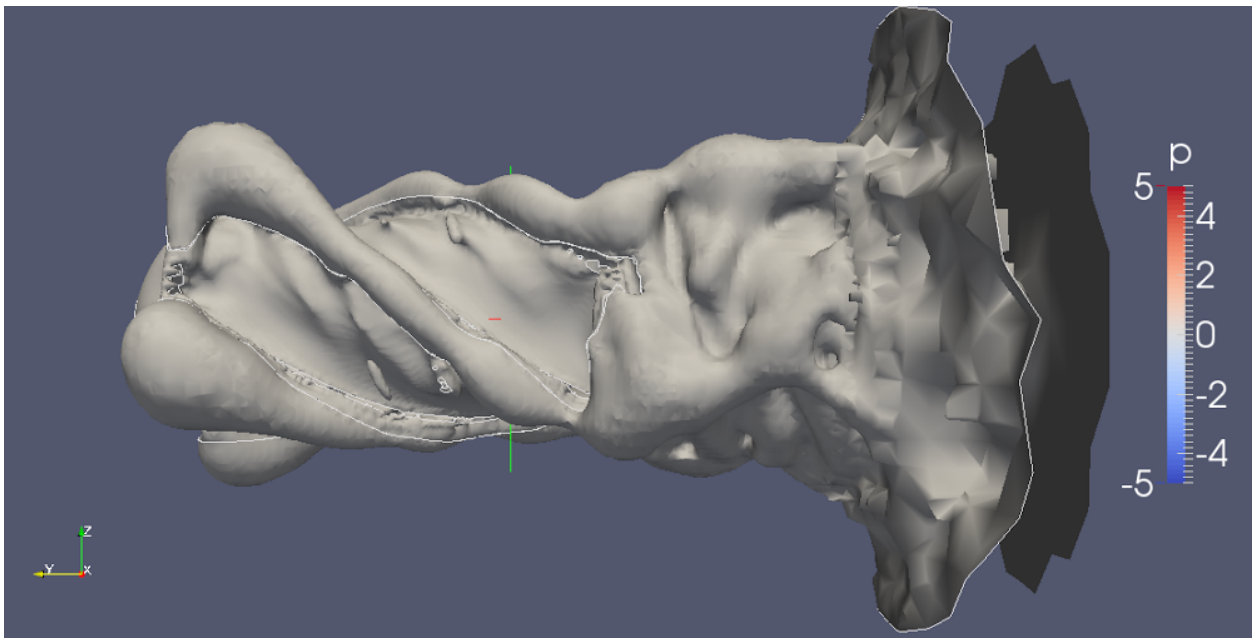


Figure 11: Vor-Prop Isocontour of Pressure

Again this is the contour of the undisturbed flow. Notice the spiral pattern beginning to develop, but the pattern is not as defined as the standard propeller.

3.3. Vor-Prop Case Study 2: Wide blades

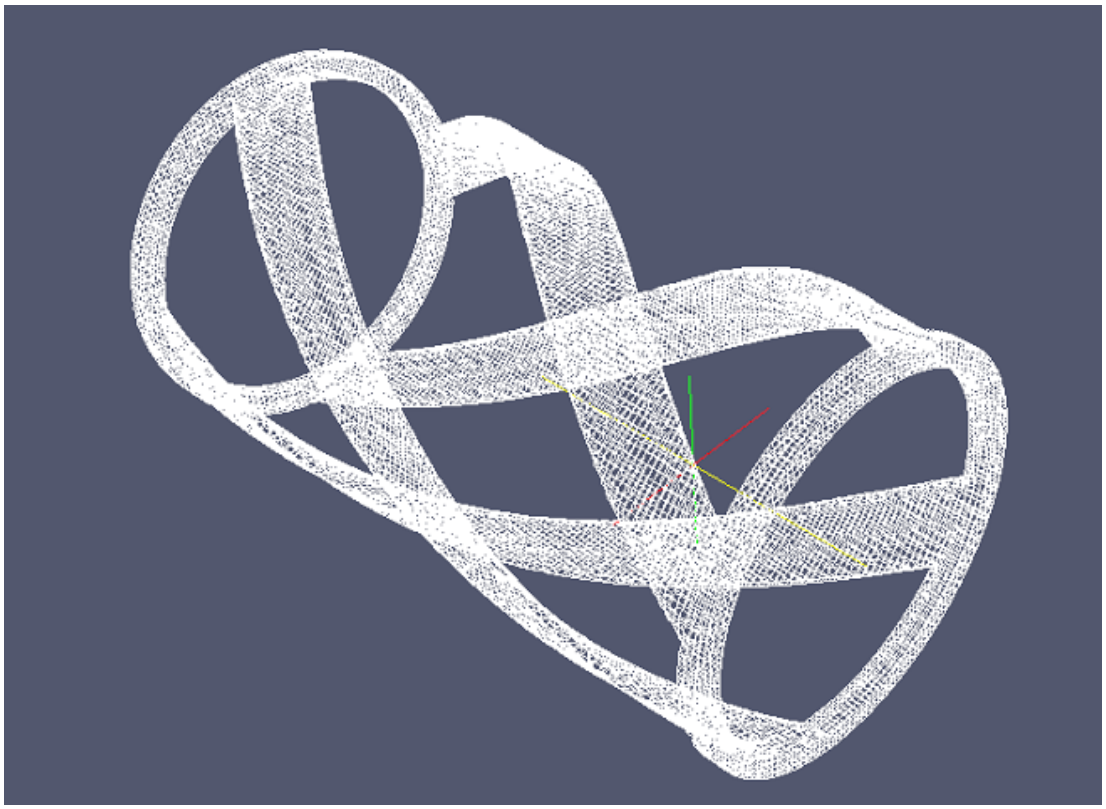


Figure 12: Vor-Prop (wide blade) Mesh

Parameter	Value
Diameter (tip to tip)	400 mm (16”)
Ambient Flow (axial)	-5 m/s (left to right flow)
RPM	1500

Simulated Volume	600mm x 1020mm x 600mm
Blade Thickness	50.0mm
Blade Height	12.5mm

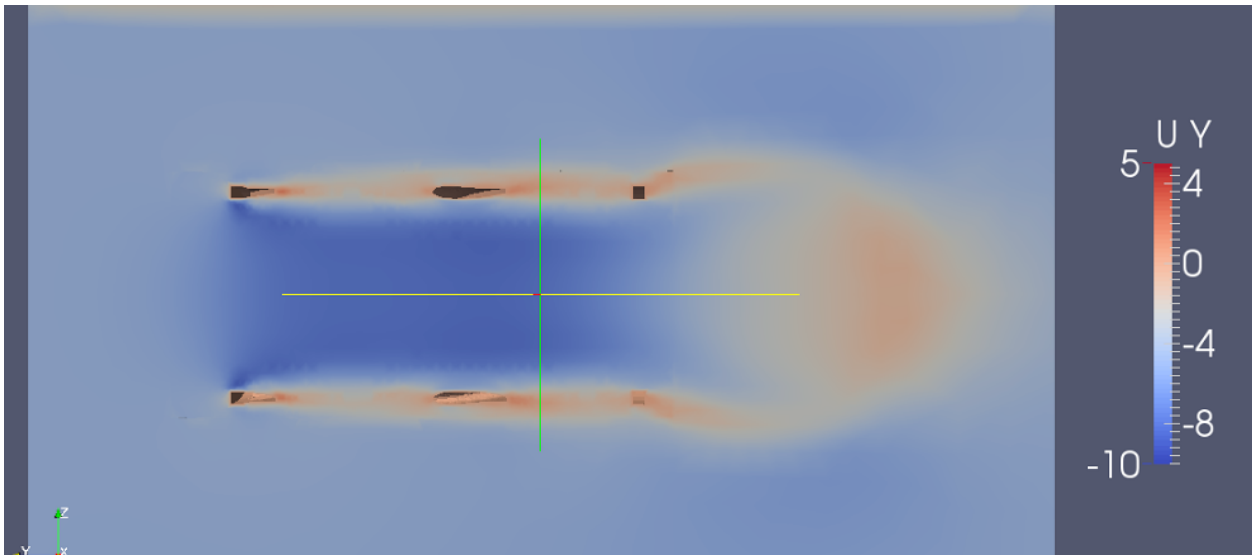


Figure 13: Vor-Prop (wide blade) Axial Velocity Profile

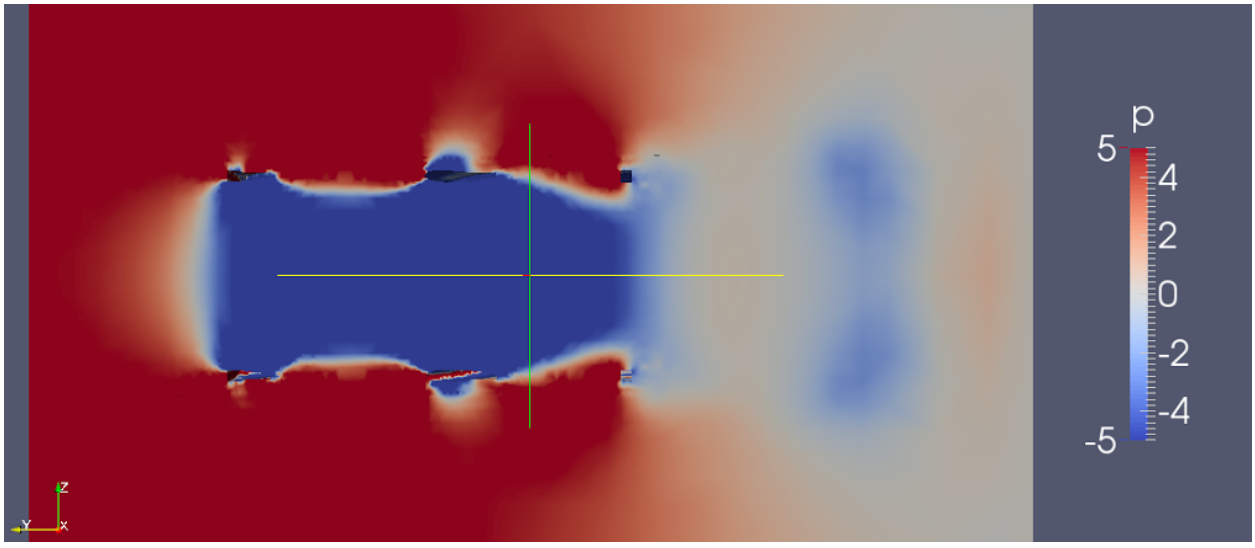


Figure 14: Vor-Prop (wide blade) Pressure Gradient

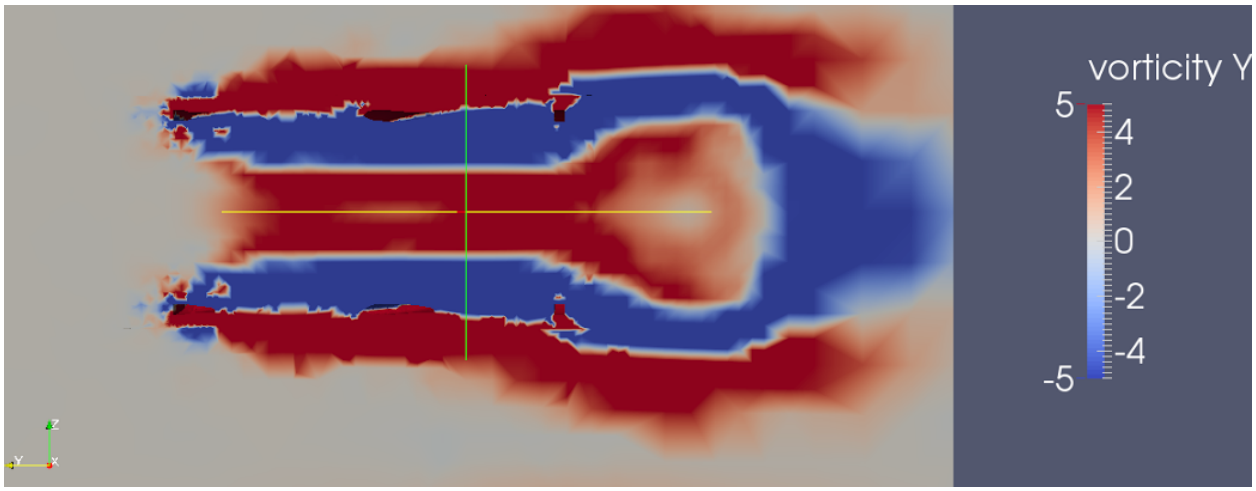


Figure 15: Vor-Prop Axial Vorticity

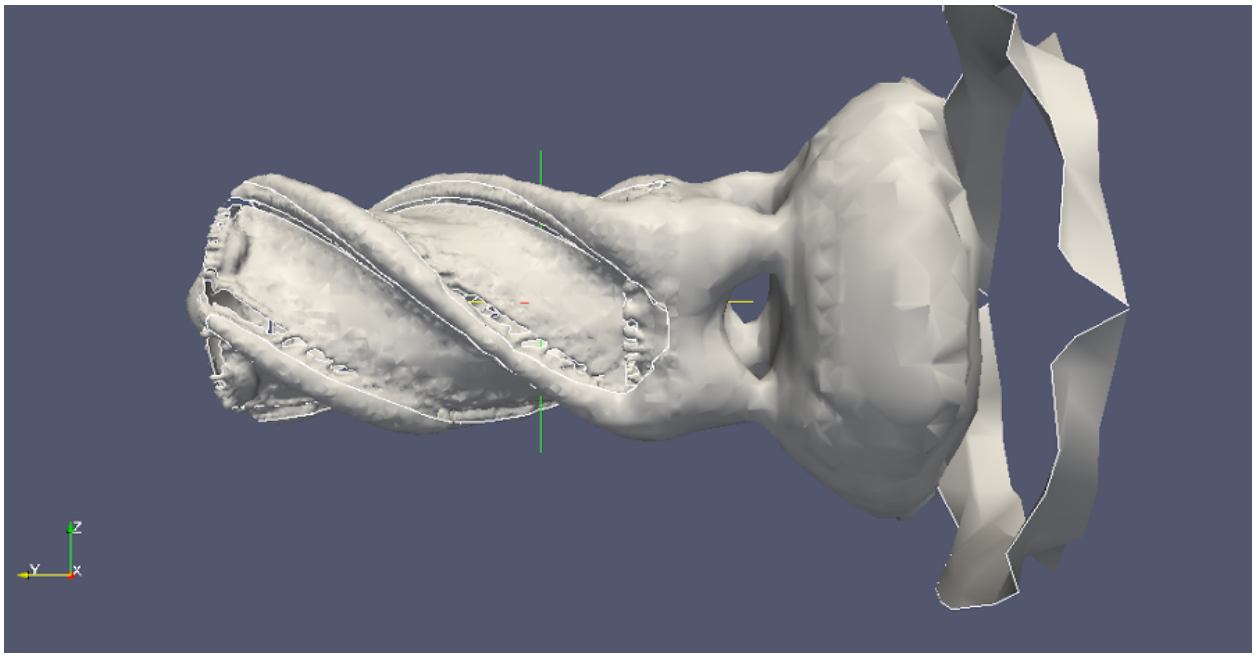


Figure 16: Vor-Prop (wide blade) Pressure Isocontour

Again this is the contour of the undisturbed flow. Here is the spiral pattern is more defined than the thinner blades but less than that of a standard propeller.

4. Discussion

In the Gorlov machine the blades are catching water flowing perpendicular to the axis of the propeller. The Vor-prop attempts to generate propulsion along the direction of the axis of the cylinder. For that reason, we would recommend not using comparisons to the Gorlov device as a tool for analysis. Rather, because the goal of this device is a net force in a specific direction, we believe that the momentum imparted on the water by the Vor-Prop should be our primary analytic tool.

Basically, a spinning device will impart some force on the medium in which it spins. By Newton's third law (for any force there is an equal and opposite reaction force) the spinning device will experience a force equal and opposite to the force imparted on the water. It is from this force that we get the propulsion of the system. With that in mind, the goal of the Vor-Prop should be to maximize the momentum we are imparting on the fluid in the axial direction. This is most clearly visible in the velocity profile plots.

In Summary:

1. Increasing the blade width added structure to the flow pattern and focused the velocity profile. See Figure 8 and 13. It may be beneficial to simulate the wide blade model further, as the pressure gradient (Figure 14) looks as though it is still developing. Widening the blade further and adding those results to the comparison may be helpful as well.
2. The velocity profile is a strong indicator of the effectiveness of the Vor-Prop. Conservation of momentum in this system requires that the forward momentum of any marine vessel be equal and opposite to the momentum of the water displaced by the Vor-Prop. Focusing this velocity profile (and therefore momentum) should be the goal when altering design parameters.
3. Another strong indicator is the pressure difference on the blades themselves. Notice in figure 4 the high pressure and low pressure regions on either side of the propeller blades. This is a very direct visualization of the net force which creates motion.

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5. References

Kundu, Pijush, and Cohen Ira. *Fluid Mechanics*. 4th ed. Print.

Gerr, Dave. *Propeller Handbook: The Complete Reference for Choosing, Installing, and Understanding Boat Propellers.* Camden Me.: International Marine Pub., 1989, Print.