

# Investigating the effect of various initial conditions on flow around the propeller

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## 1 Introduction

The aim of the project was about making a comparison of conditions of the flow behind the propeller which was set in the velocity field with laminar air flow in front of it. The initial conditions, which were the temperature and density of the flow and rotational speed of the propeller, have been being changed.

## 2 Model

The model used in the project is based on the report titled 'Simplified flow around the propeller', written by Gonzalo Montero [1]. The propeller itself is a 3-bladed propeller with NACA 0012 airfoil differently angled along its radius. Aerodynamic characteristics (lift and drag coefficients) of the propeller has been implemented using xfoil prepared file. The extent of the blades is also limited on either side, which is visible in the layouts of velocity behind the propeller. The setting of the propeller is represented with cylindrical out-take of the laminar air flow. Mesh of the cylinder is being shown below on Figures 1 and 2:

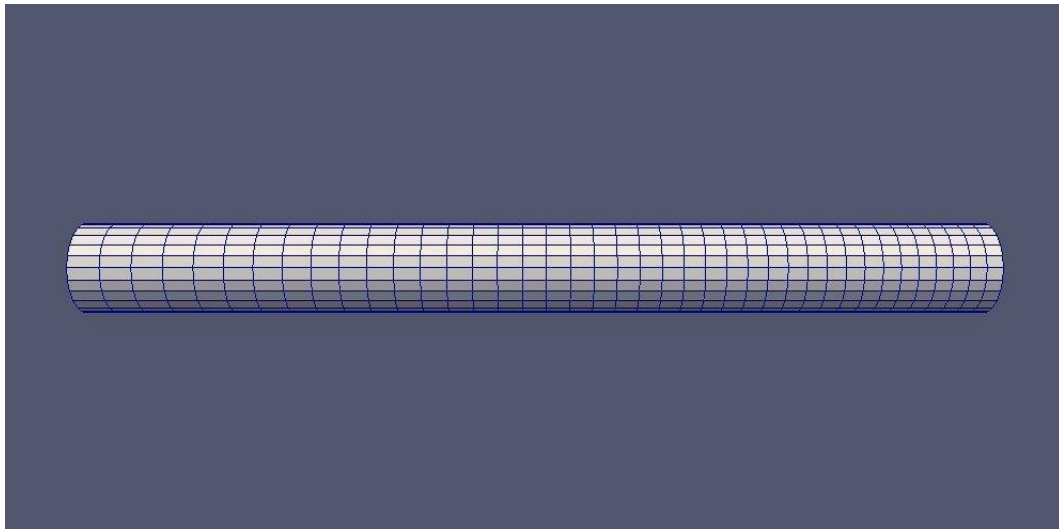


Figure 1: Mesh used in cases - picture 1

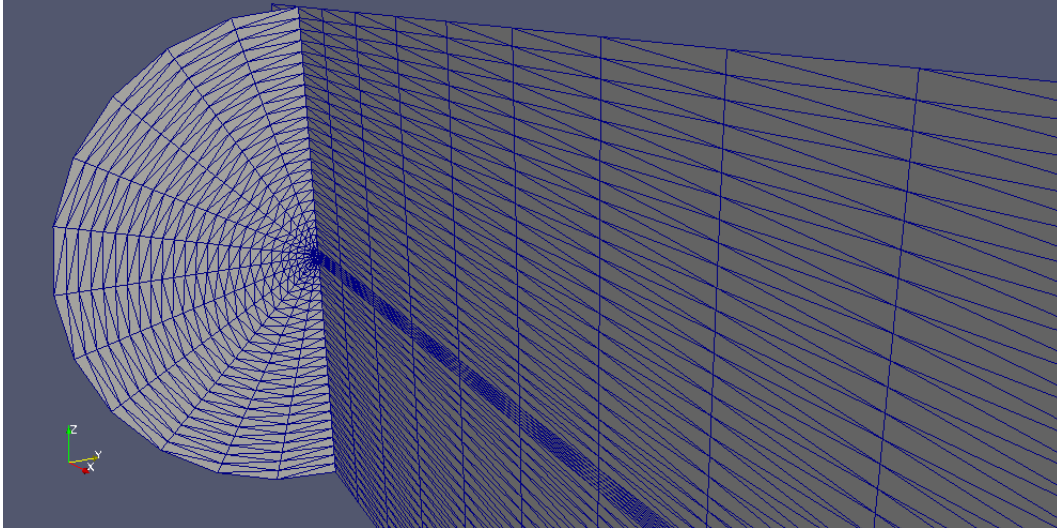


Figure 2: Mesh used in cases - picture 2

As it has been shown in the figures above there is no propeller mesh model. The propeller is implemented using two-dimensional disk with smooth change of the flow parameters in its surroundings. The value of change of parameters depends on characteristics of the flow and the propeller.

### 3 Cases

In the project twelve cases were studied. Differences between particular cases were various height of the flight and rotational speed of the propeller. The height has been implemented with temperature and density which were based on ISA calculations. The cases were:

1. 0 km; 500 rpm;
2. 0 km; 1000 rpm;
3. 0 km; 1500 rpm;
4. 4 km; 500 rpm;
5. 4 km; 1000 rpm;
6. 4 km; 1500 rpm;
7. 8 km; 500 rpm;
8. 8 km; 1000 rpm;
9. 8 km; 1500 rpm;
10. 11 km; 500 rpm;
11. 11 km; 1000 rpm;
12. 11 km; 1500 rpm;

## 4 Results

For each case 3 figures have been taken: pressure, velocity and streamlines behind the propeller. It is crucial to know that the value of pressure calculated by OpenFOAM and shown in the results is related to initial pressure, which is equal to 0 for each case. That means that what is being shown in the figures is a difference in pressure between surroundings and the flow effected with the rotating propeller. Also, the layouts on the figures are represented with 2 cross-sections of the calculated cylinder. All of the cases are being presented below with proper description.

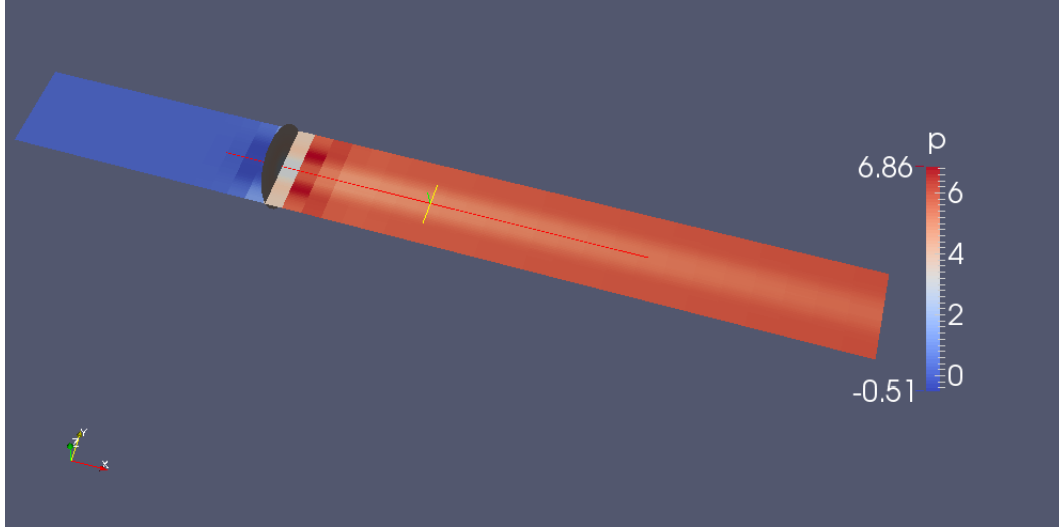


Figure 3: Plot of pressure with rotational speed 500 rpm at 0 kilometers

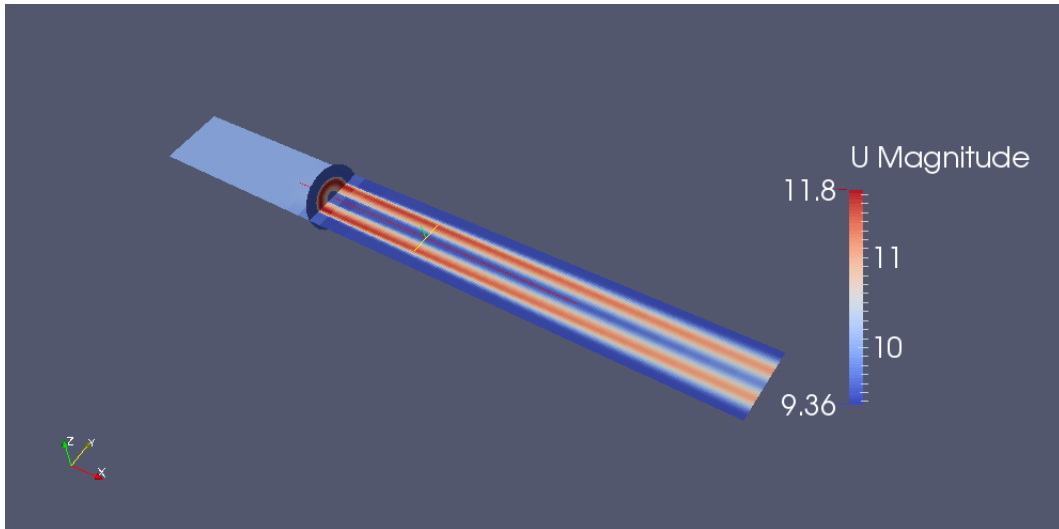


Figure 4: Plot of velocity with rotational speed 500 rpm at 0 kilometers

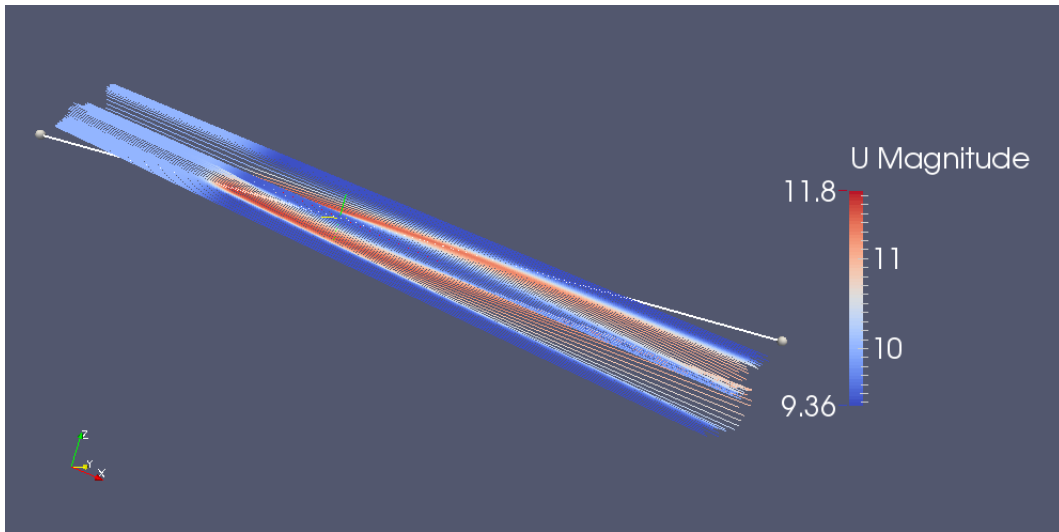


Figure 5: Rotation plot with rotational speed 500 rpm at 0 kilometers

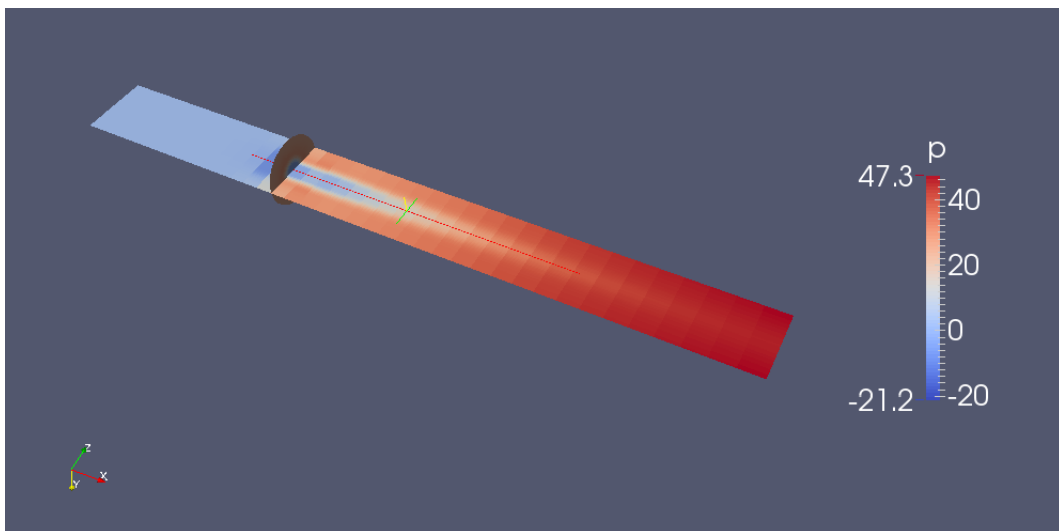


Figure 6: Plot of pressure with rotational speed 1000 rpm at 0 kilometers

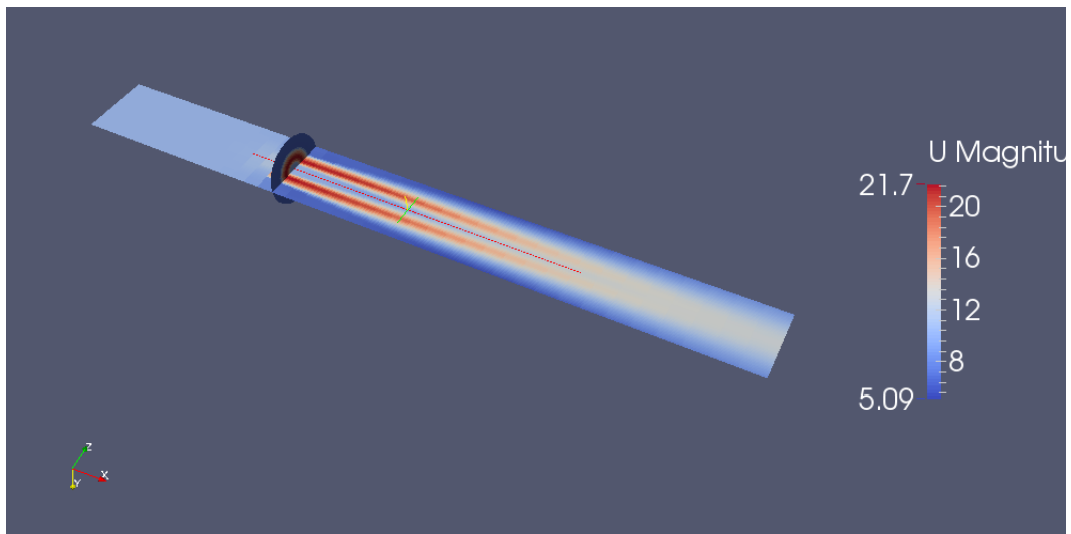


Figure 7: Plot of velocity with rotational speed 1000 rpm at 0 kilometers

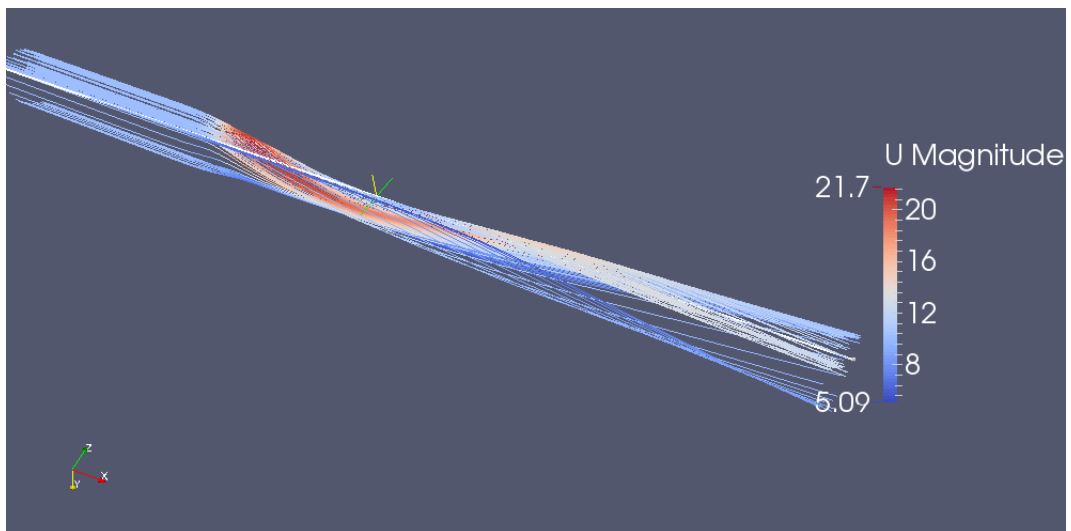


Figure 8: Streamline plot with rotational speed 1000 rpm at 0 kilometers

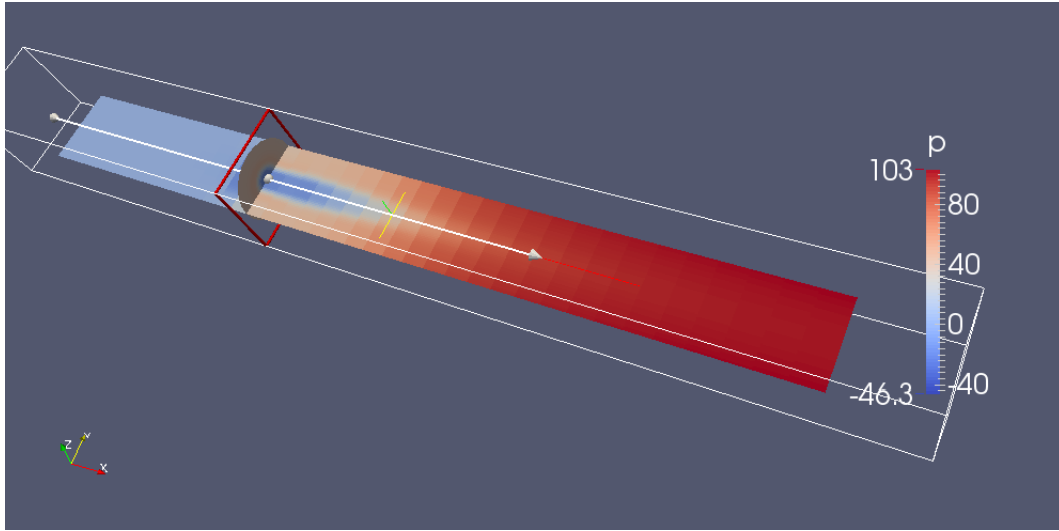


Figure 9: Plot of pressure with rotational speed 1500 rpm at 0 kilometers

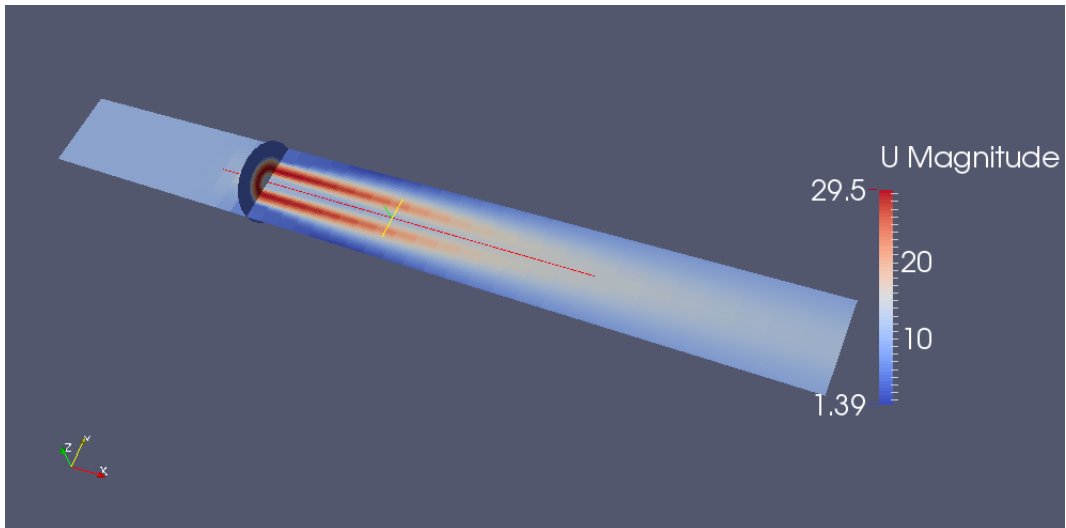


Figure 10: Plot of velocity with rotational speed 1500 rpm at 0 kilometers

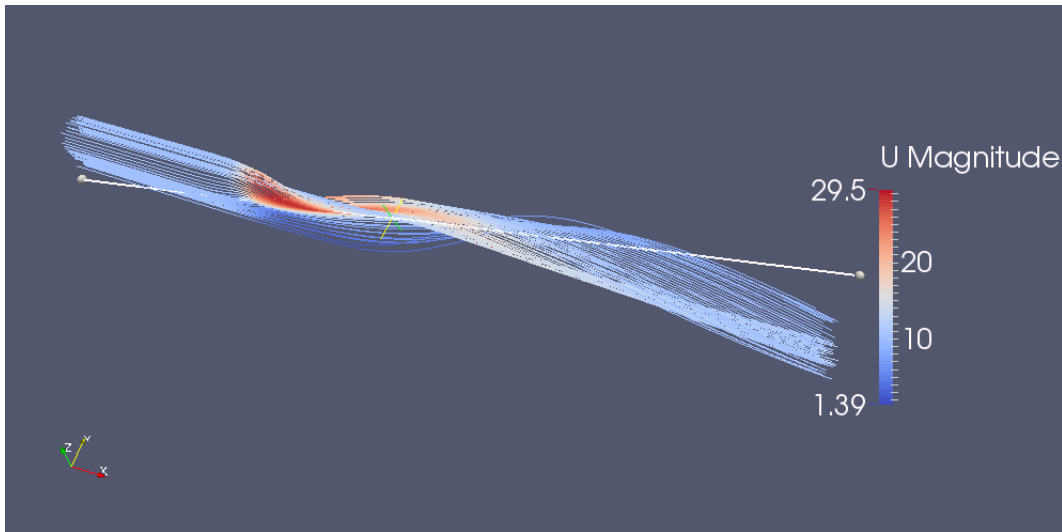


Figure 11: Streamline plot with rotational speed 1500 rpm at 0 kilometers

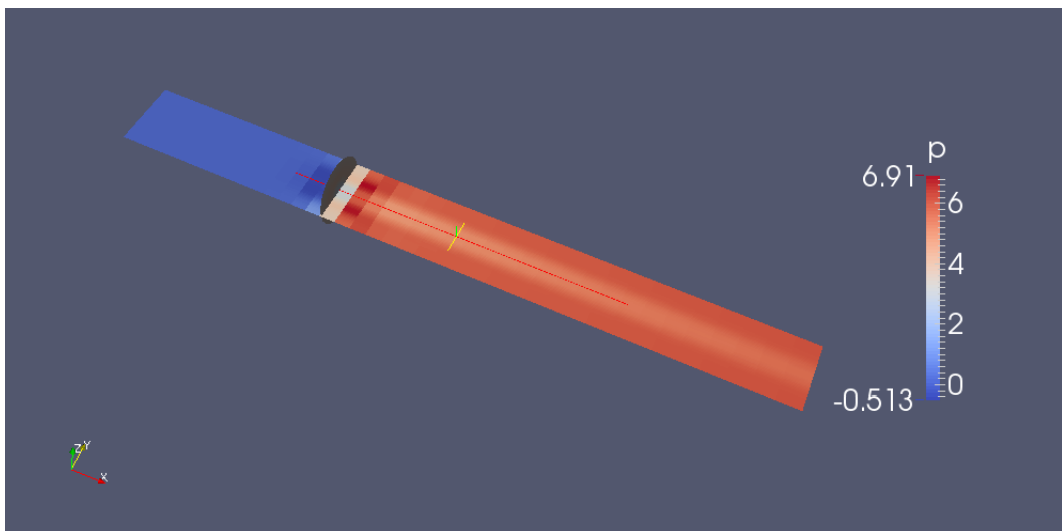


Figure 12: Plot of pressure with rotational speed 500 rpm at 4 kilometers

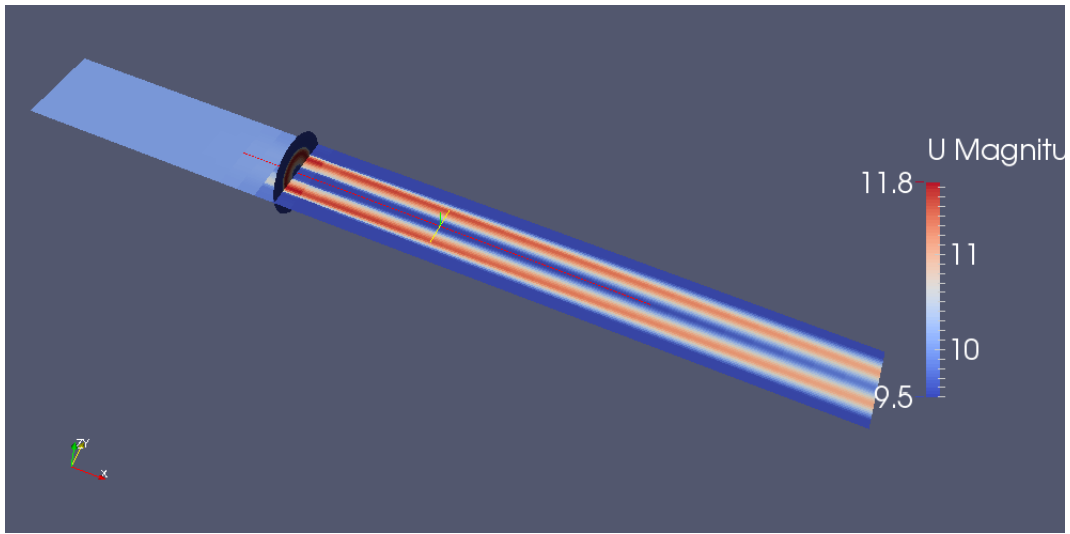


Figure 13: Plot of velocity with rotational speed 500 rpm at 4 kilometers

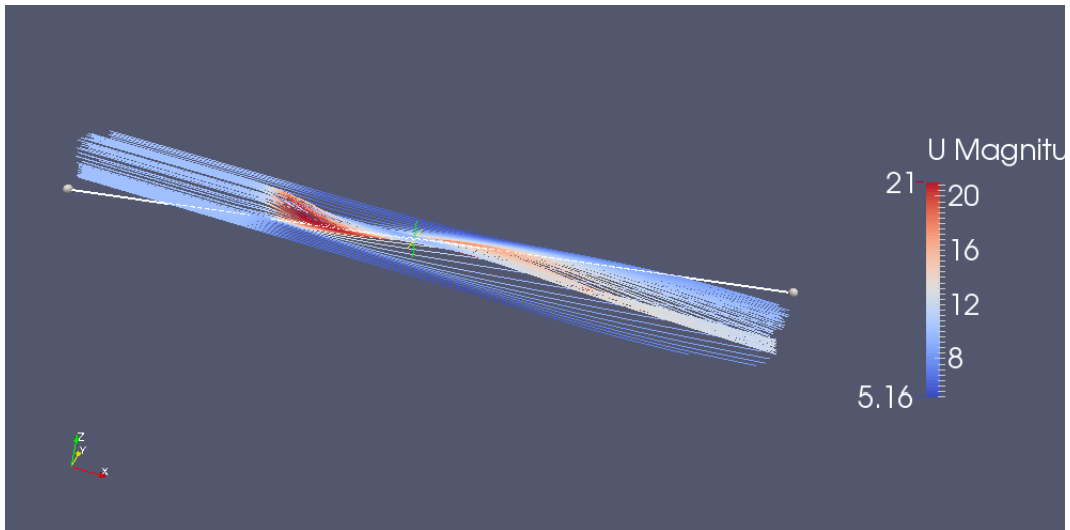


Figure 14: Streamline plot with rotational speed 500 rpm at 4 kilometers



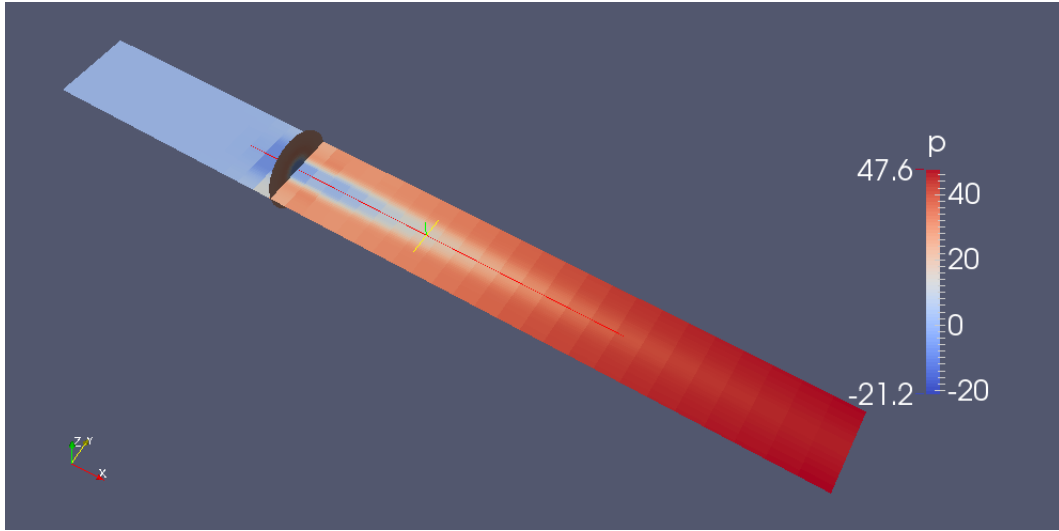


Figure 15: Plot of pressure with rotational speed 1000 rpm at 4 kilometers

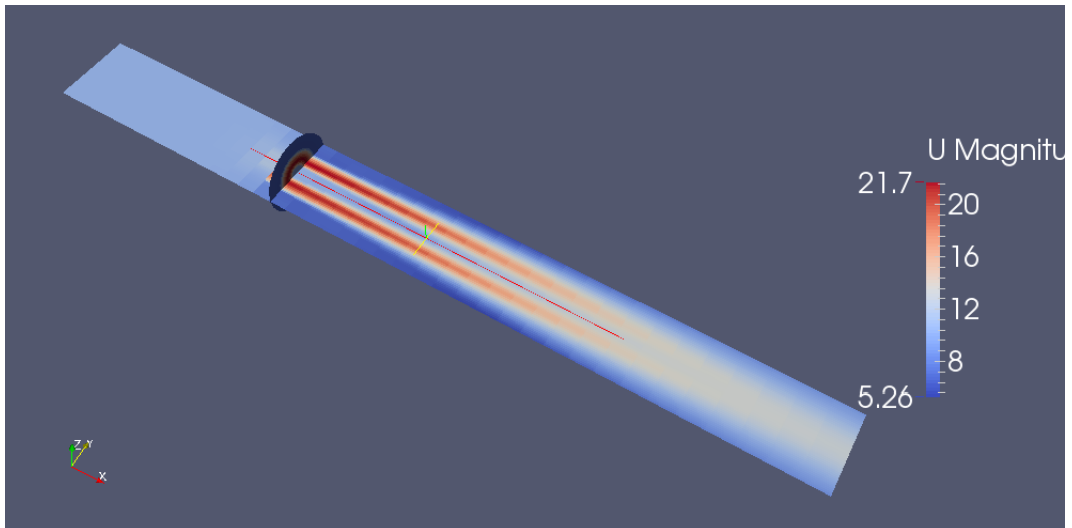


Figure 16: Plot of velocity with rotational speed 1000 rpm at 4 kilometers

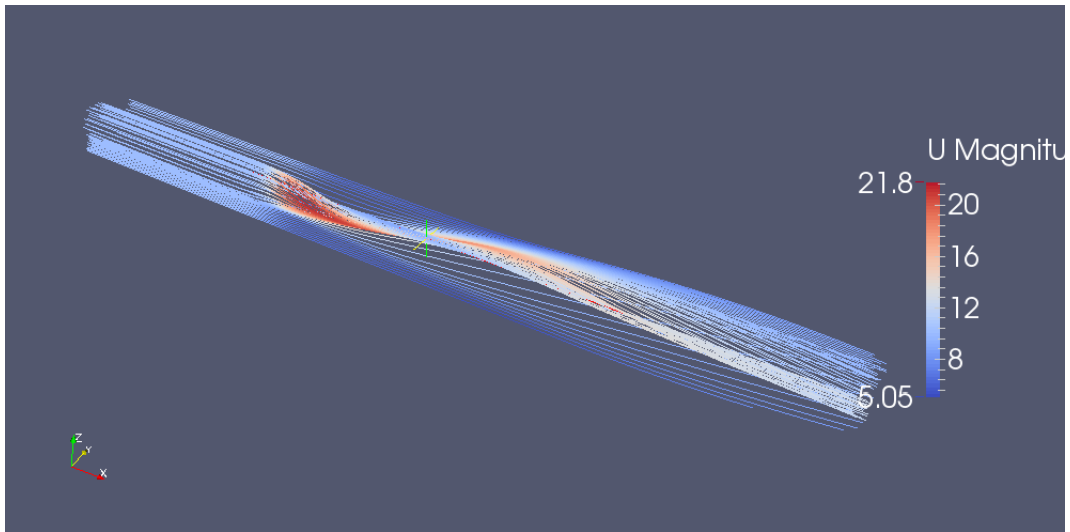


Figure 17: Streamline plot with rotational speed 1000 rpm at 4 kilometers

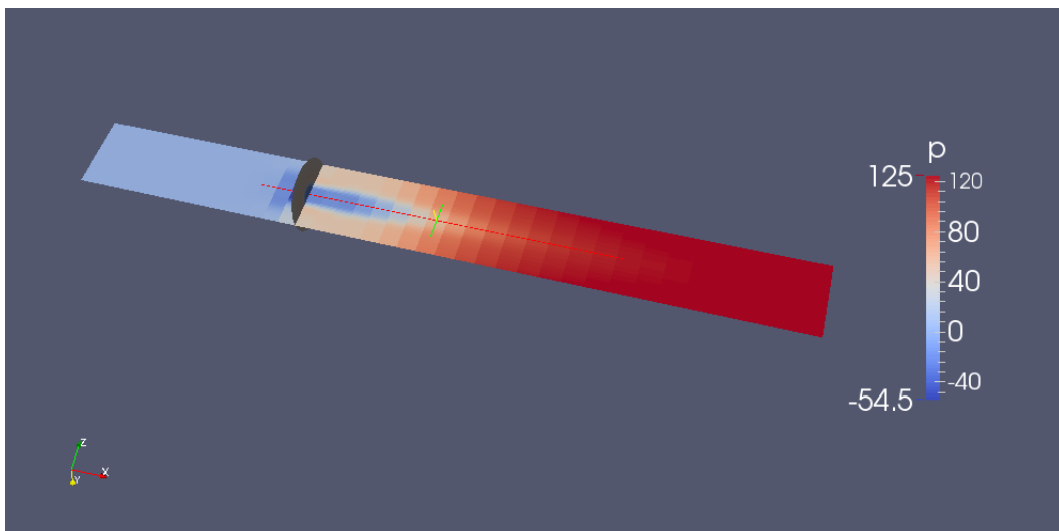


Figure 18: Plot of pressure with rotational speed 1500 rpm at 4 kilometers

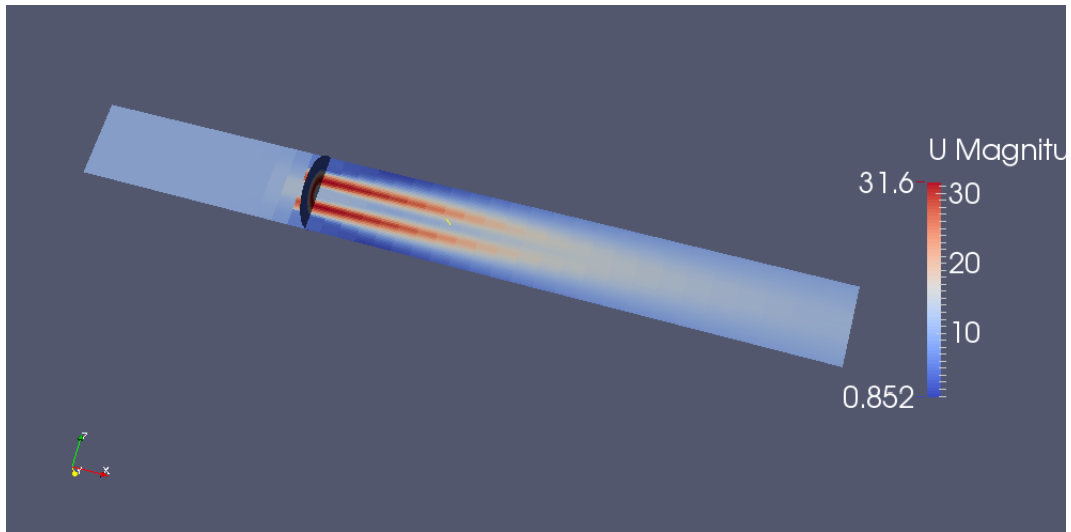


Figure 19: Plot of velocity with rotational speed 1500 rpm at 4 kilometers

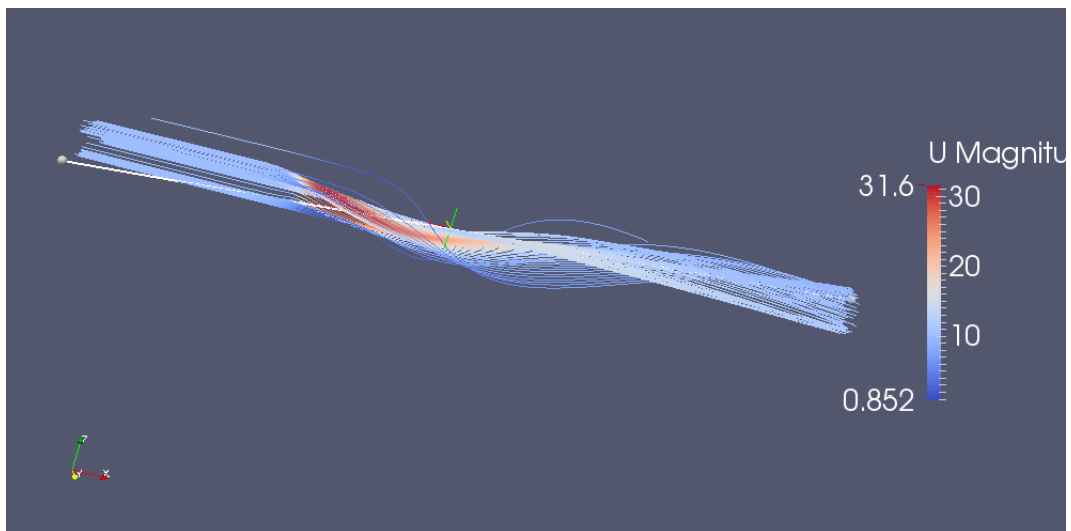


Figure 20: Streamline plot with rotational speed 1500 rpm at 4 kilometers

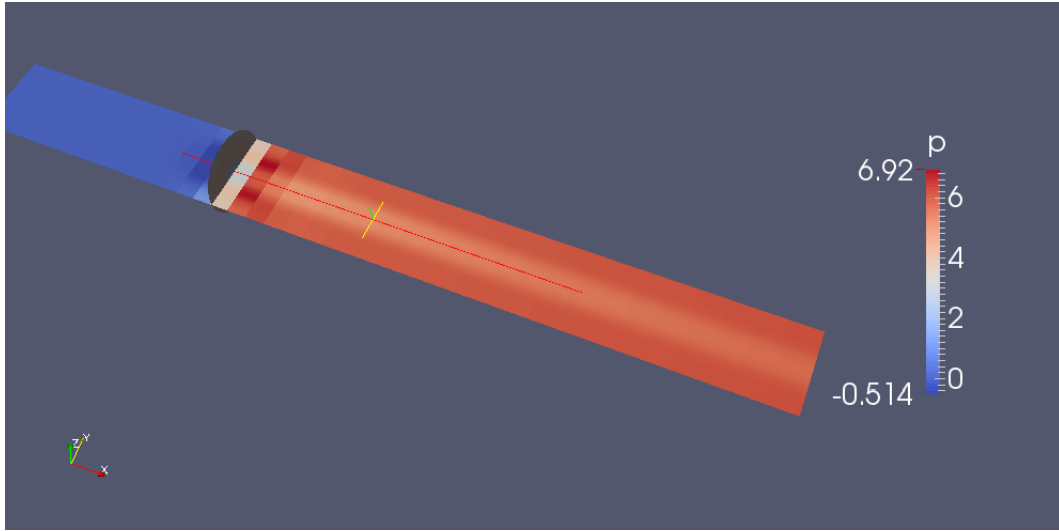


Figure 21: Plot of pressure with rotational speed 500 rpm at 8 kilometers

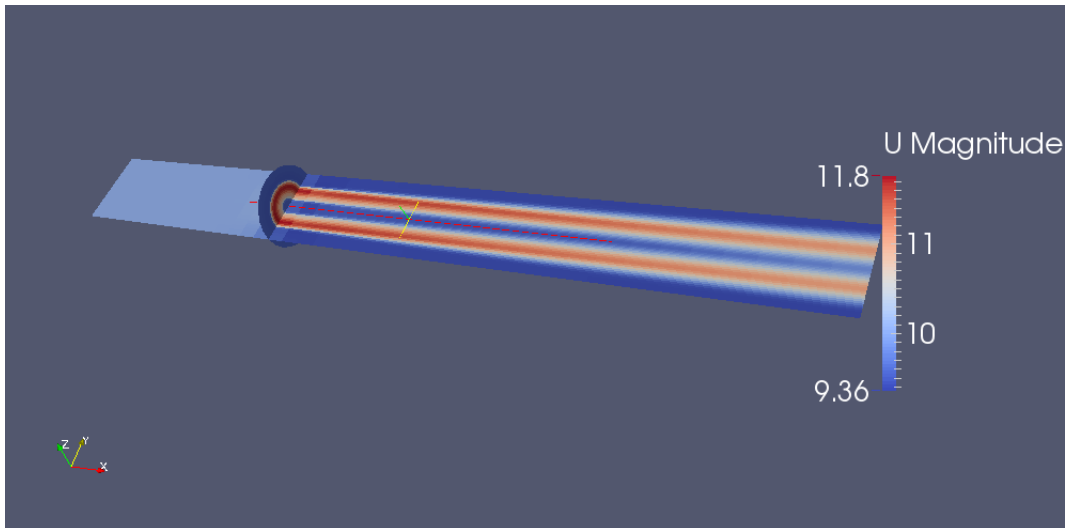


Figure 22: Plot of velocity with rotational speed 500 rpm at 8 kilometers

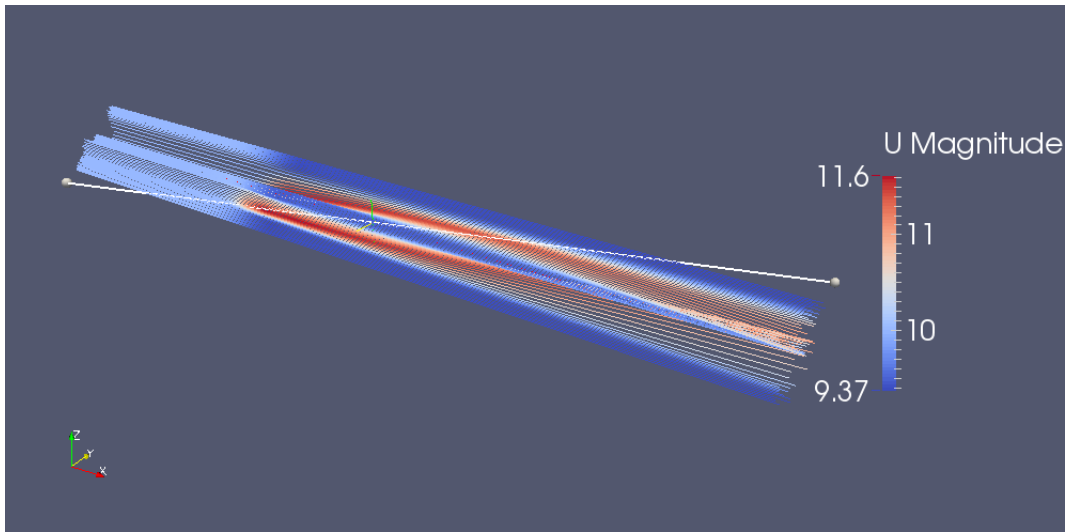


Figure 23: Streamline plot with rotational speed 500 rpm at 8 kilometers

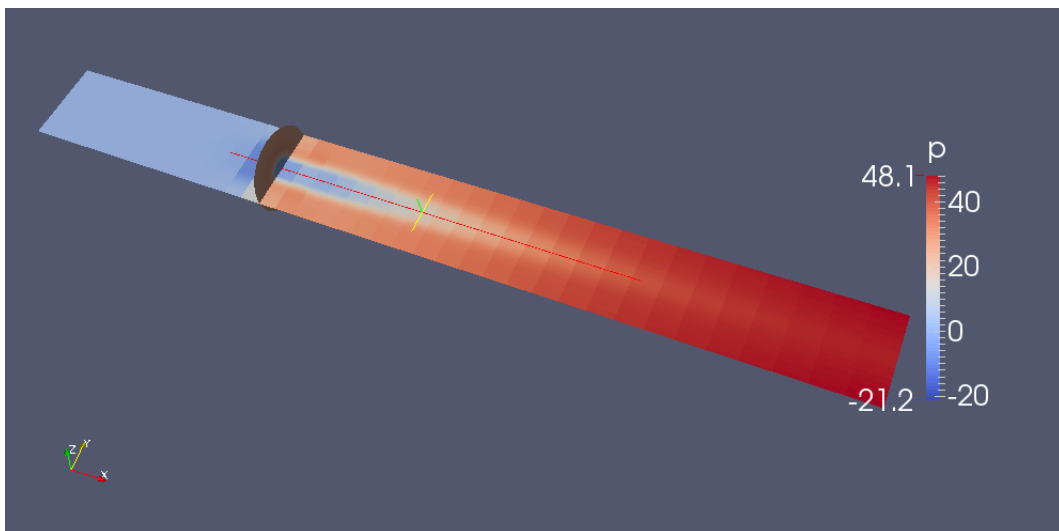


Figure 24: Plot of pressure with rotational speed 1000 rpm at 8 kilometers

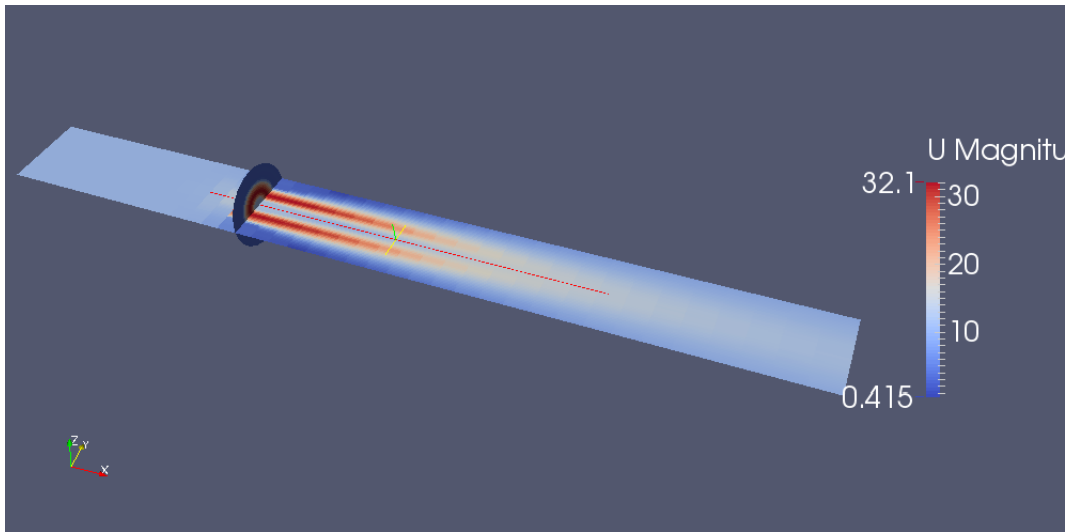


Figure 25: Plot of velocity with rotational speed 1000 rpm at 8 kilometers

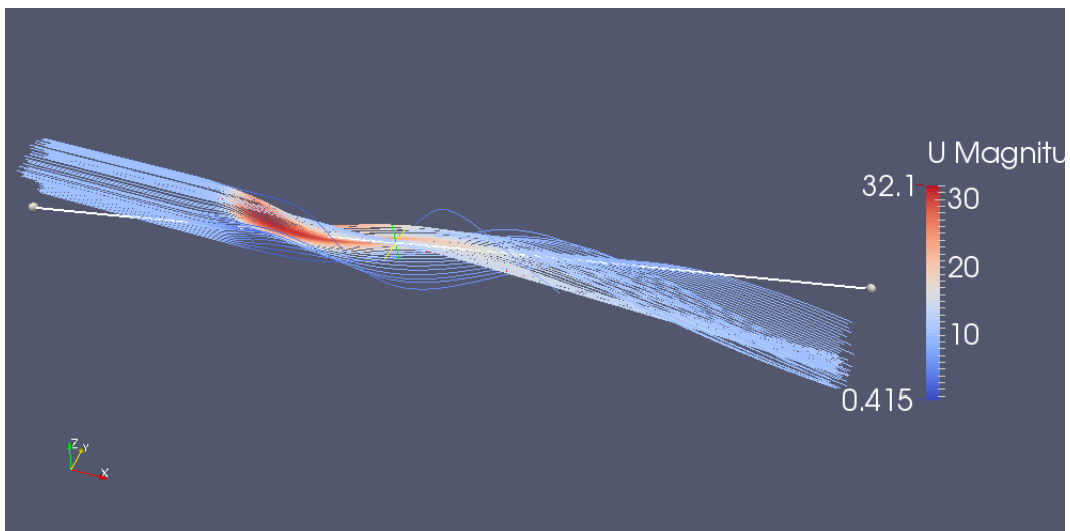


Figure 26: Streamline plot with rotational speed 1000 rpm at 8 kilometers

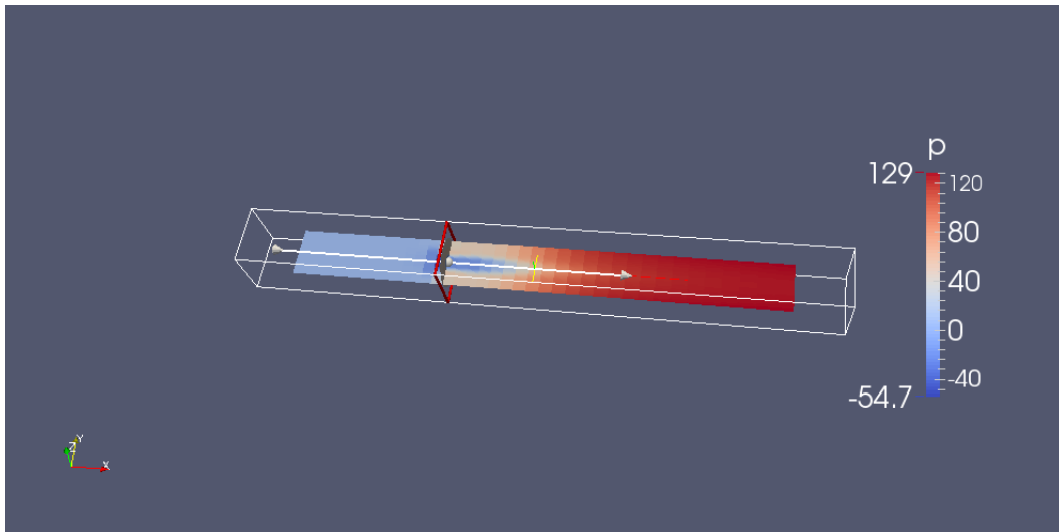


Figure 27: Plot of pressure with rotational speed 1500 rpm at 8 kilometers

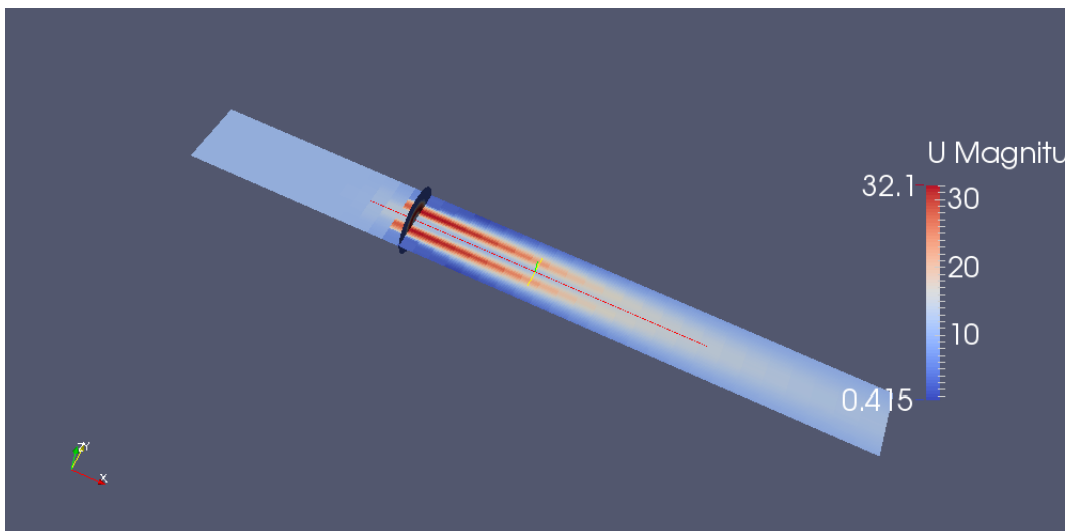


Figure 28: Plot of velocity with rotational speed 1500 rpm at 8 kilometers

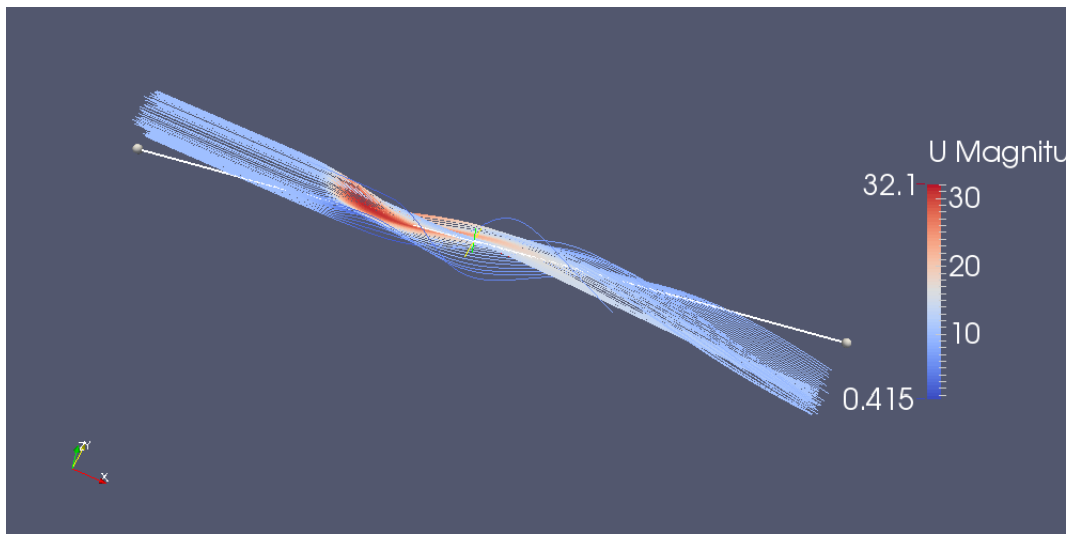


Figure 29: Streamline plot with rotational speed 1500 rpm at 8 kilometers

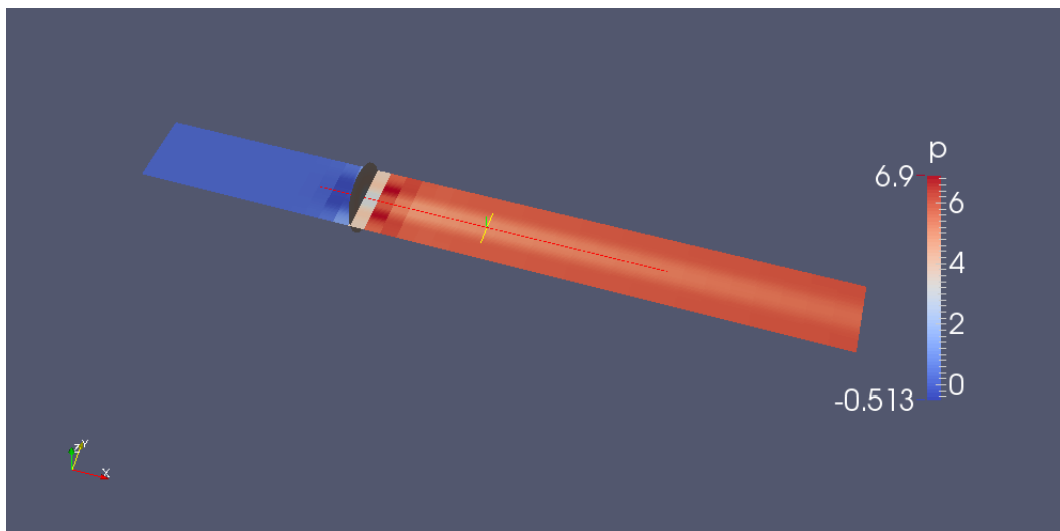


Figure 30: Plot of pressure with rotational speed 500 rpm at 11 kilometers



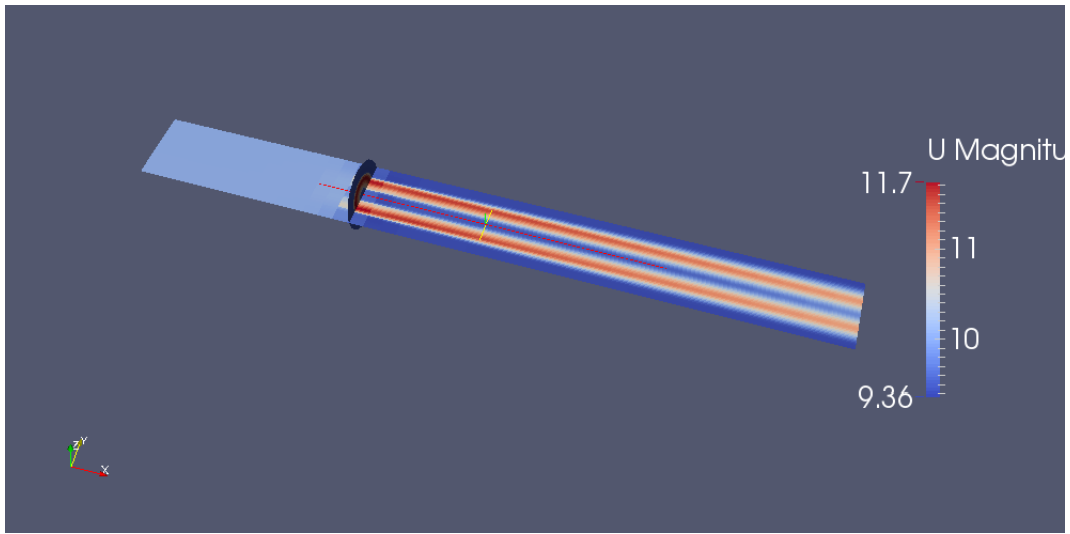


Figure 31: Plot of velocity with rotational speed 500 rpm at 11 kilometers

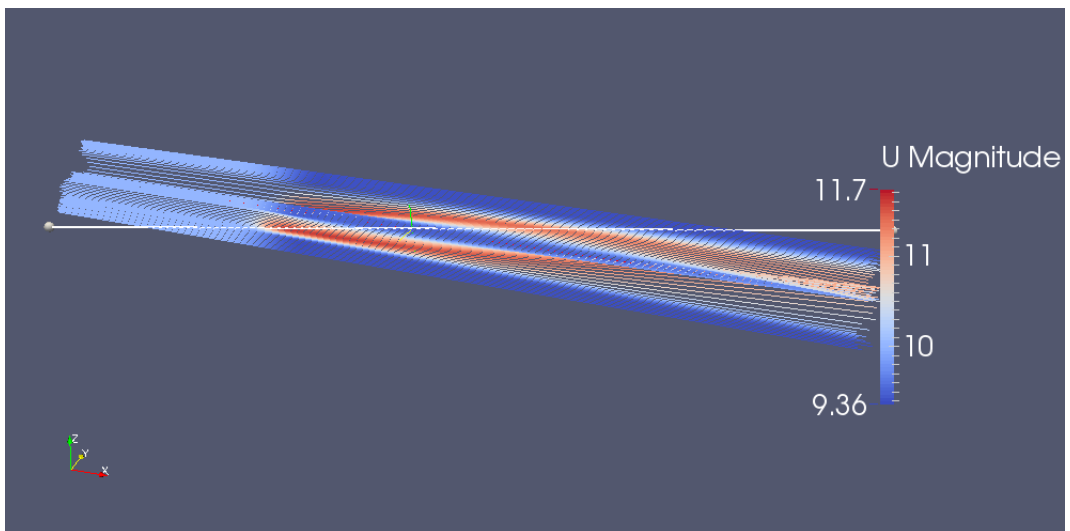


Figure 32: Streamline plot with rotational speed 500 rpm at 11 kilometers

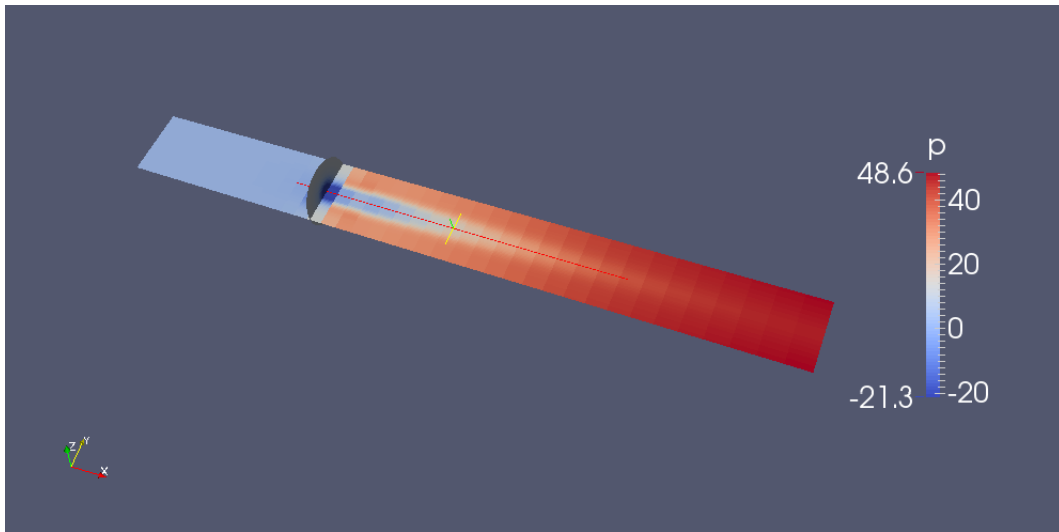


Figure 33: Plot of pressure with rotational speed 1000 rpm at 11 kilometers

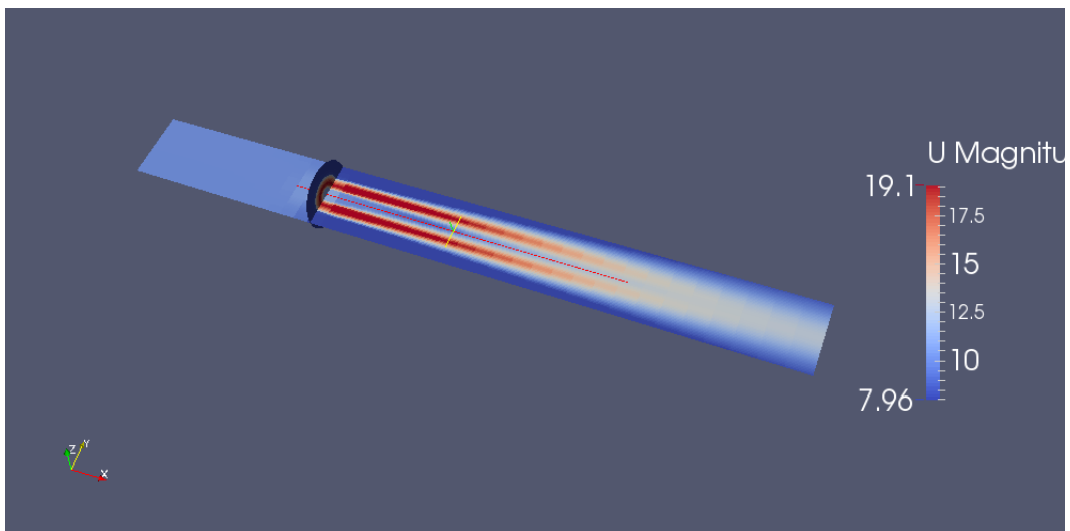


Figure 34: Plot of velocity with rotational speed 1000 rpm at 11 kilometers

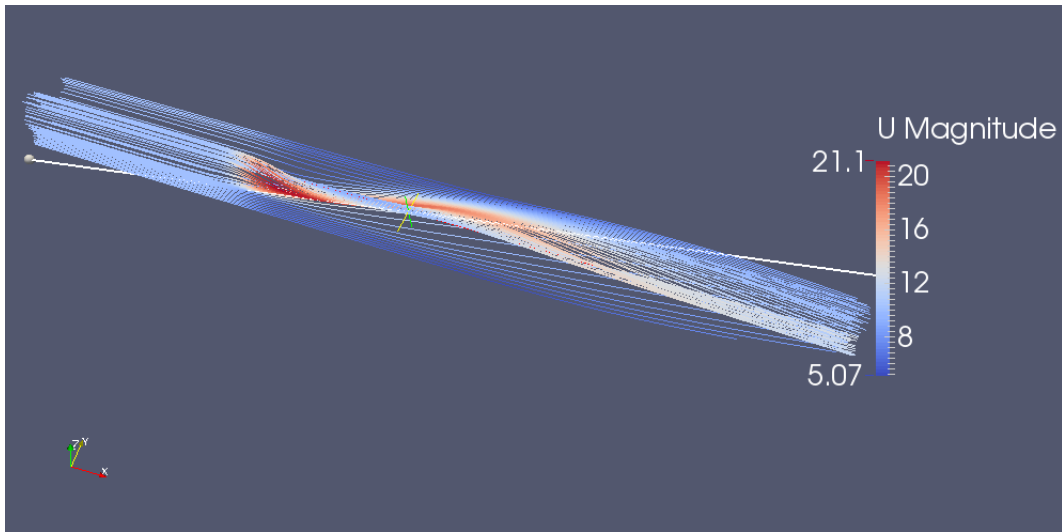


Figure 35: Streamline plot with rotational speed 1000 rpm at 11 kilometers

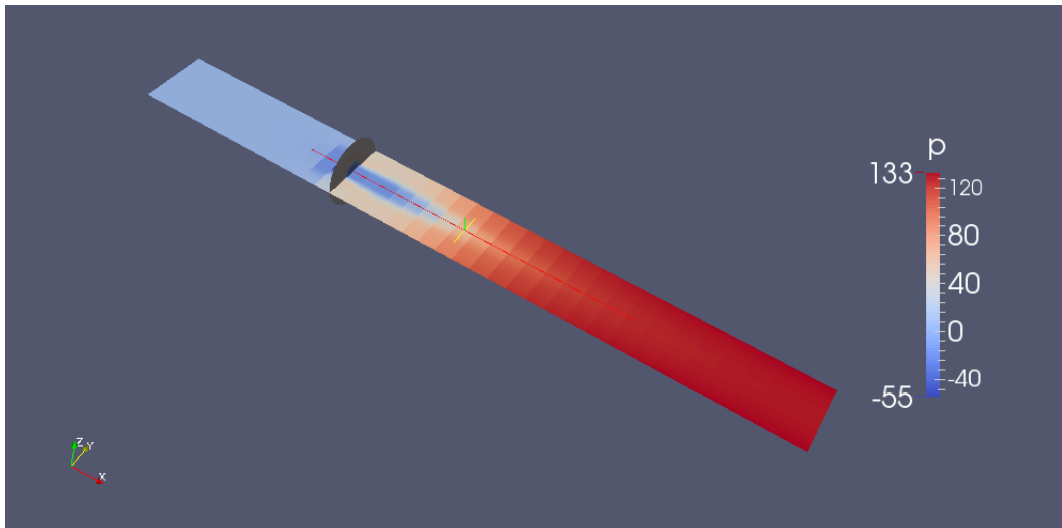


Figure 36: Plot of pressure with rotational speed 1500 rpm at 11 kilometers

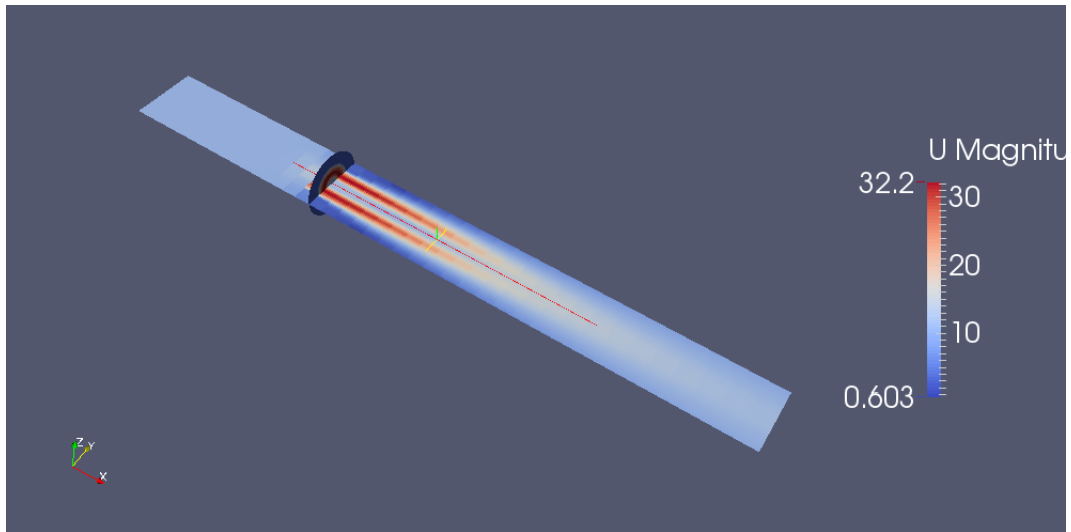


Figure 37: Plot of velocity with rotational speed 1500 rpm at 11 kilometers

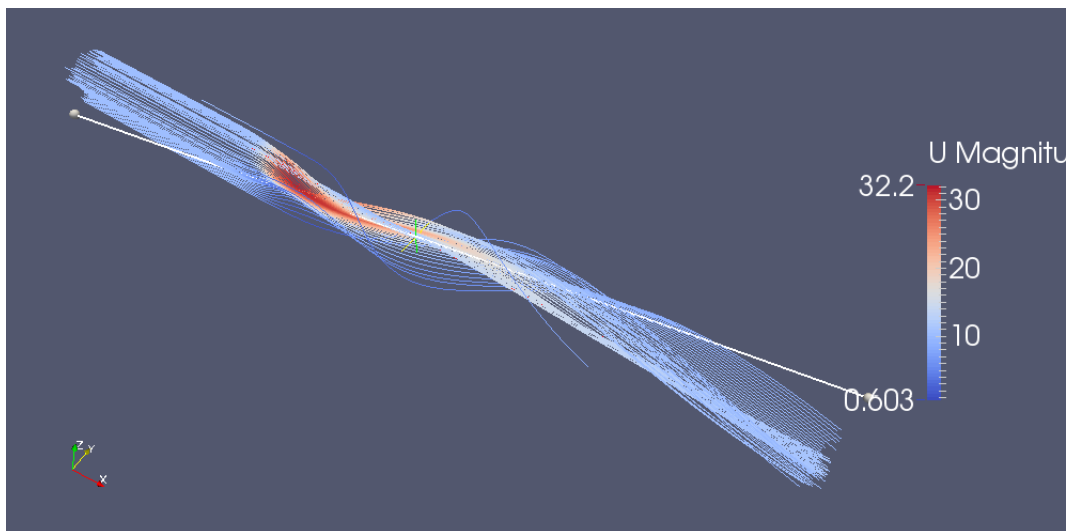


Figure 38: Streamline plot with rotational speed 1500 rpm at 11 kilometers

## 5 Conclusion

As it is being seen in the results there are differences between cases, while the height of the flow increases, the pressure difference increase, as well for each rotational speed of the propeller. It is also greater for bigger values of rotational speed. There is also increase of the magnitude velocity of the flow with growth of height of the flow and rotational velocity. Both of those increases are related to lower density of air flowing through the propeller and the greater volume of air is being flowed according to higher value of rotational speed. Increase of rotational speed is also the reason of more coiled flow behind the propeller. For more accurate results, especially in cases with lower rotational speed, better mesh should be considered. The problem with the one, which has been used, is most visible in pressure layouts for low flow velocity.

## References

1. <http://www.tfd.chalmers.se/~hani/kurser/OS-CFD-2015/GonzaloMonteroVillar/reportGonzaloMontero.pdf>
2. <http://www.tfd.chalmers.se/~hani/kurser/OS-CFD-2015/GonzaloMonteroVillar/presentationGonzaloMontero.pdf>
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5. Svenning, E. 'Implementation of an actuator disk in OpenFOAM', 2010
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