Distributed Electric Propulsion

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ABSTRACT

This investigation focused on predicting aerodynamic improvements obtained when air is blown over a wing by six propellers distributed equally along the wing's span. The purpose was to validate a method to implement Distributed Electric Propulsion and quantify its impact during conceptual aircraft design. PUPR's 2017 SAE Regular Class Aircraft with DEP had previously been designed as part of a capstone project. The original methodology was to be validate or improved through this research.

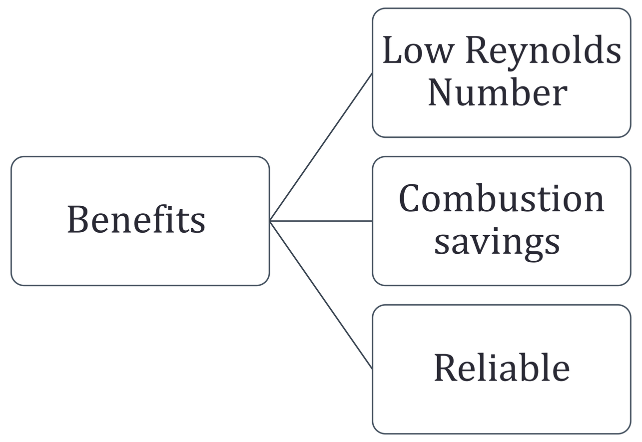
Using vortex theory and ANSYS Fluent we quantify lift and drag coefficients of the wing S1223 at low Reynold number in order to assess how DEP on the wing advantages over regular airfoil geometry at same ambient conditions. Although we frequented limitation in the study, results with DEP does shows an improvement over regular wings, but not as expected.

INTRODUCTION

Combustion engines govern the sky nowadays, however as electric motor technology improves, the new, low power-to-weight and efficient motors have led designers to re-visit distributed propulsion technology. Distributed Electric Propulsion is a design feature that significantly improves aircraft performance by coupling propulsion and air dynamics, through the distribution of properly designed propellers along a lifting surface. Furthermore, aircraft flying at very low Reynolds number are expected to realize larger relative improvements in aerodynamic performance than aircraft flying at Reynolds numbers in the order of millions.

PUPR's SAE team designed an electric aircraft as part of their Capstone project. At that time, predictions showed that lift could increase as much as 400%. This meant that an aircraft that featured DEP would need much less total propulsive power to fly the same mission.

This research is aimed at understanding DEP at low Reynolds numbers and to produce a valid method to predict the resulting effects.



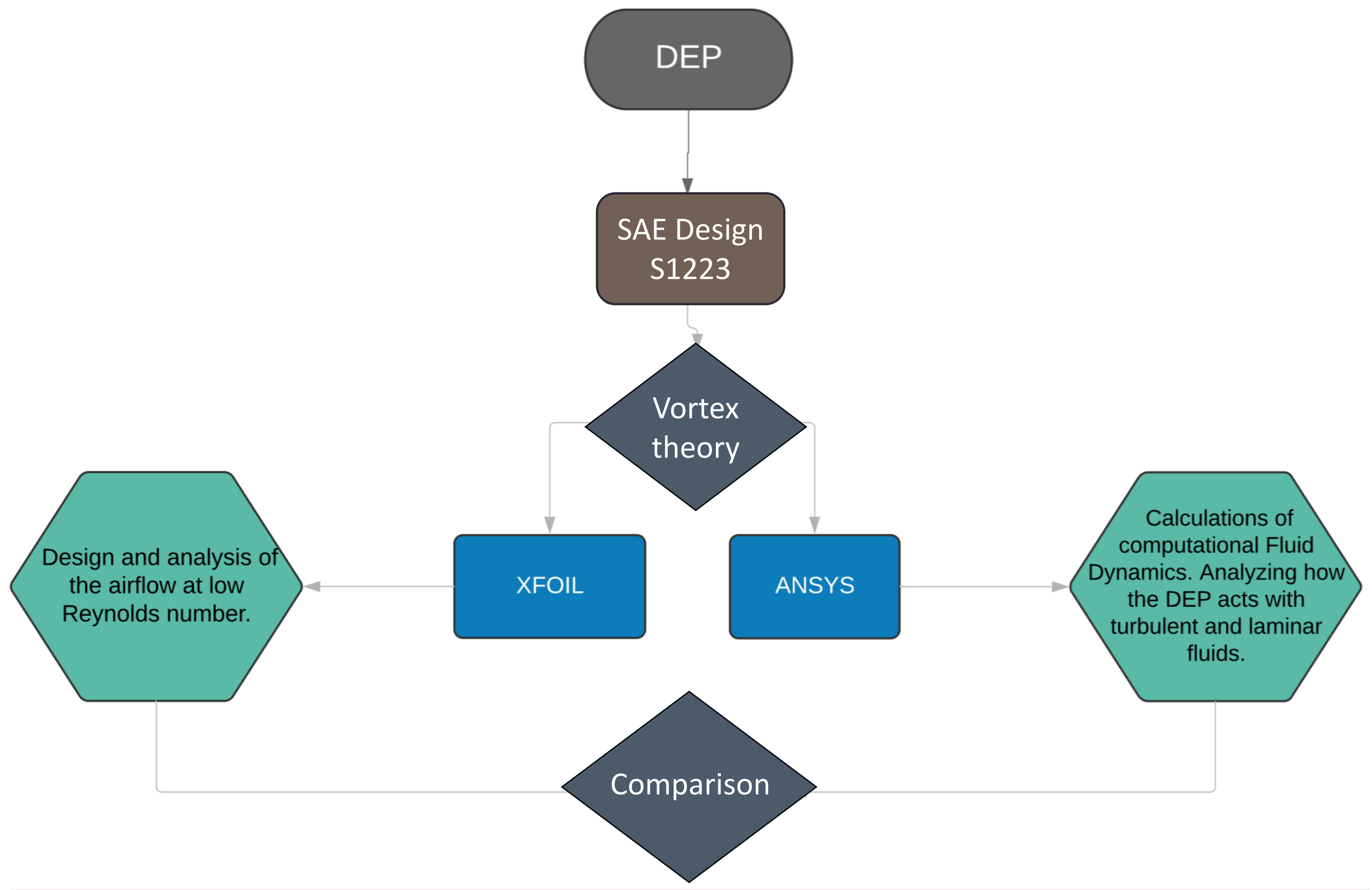
OBJECTIVES

The report will be focus on studying the 2017 SAE Aerodesign wing design that features a S1223 airfoil. The analysis will be conducted at standard sea level conditionsand speeds of 10, 20, and 30 fps.

3D flow simulations will be conducted as well as mathematical models using Vortex theory.

Results will be used to compare between these methodologies and with previously predicted aerodynamics based solely on momentum theory.

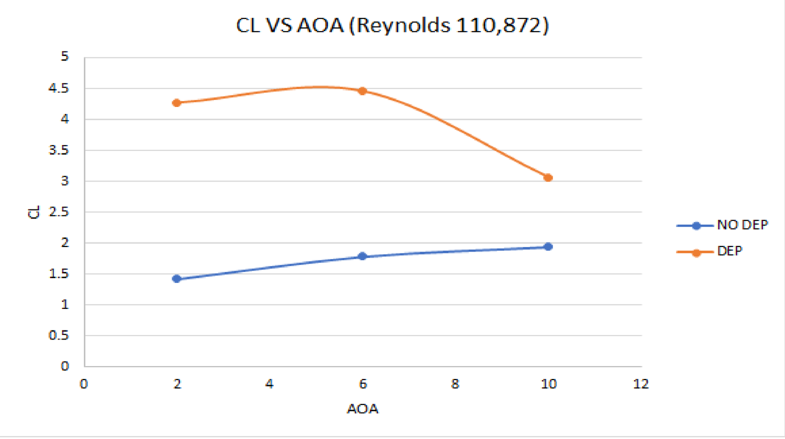
METHODOLOGY

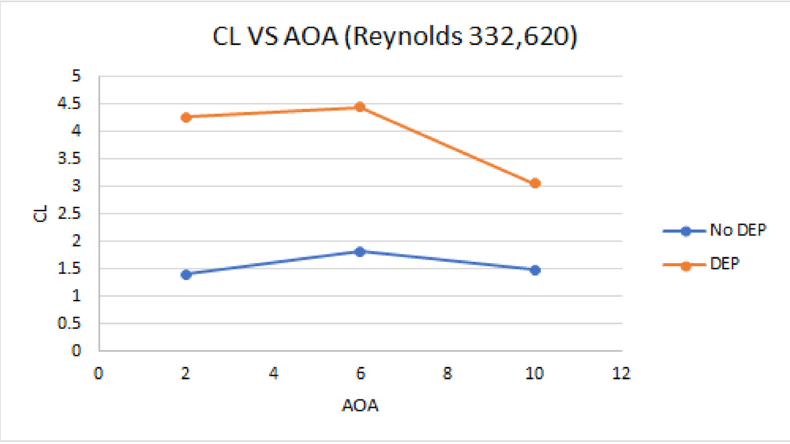


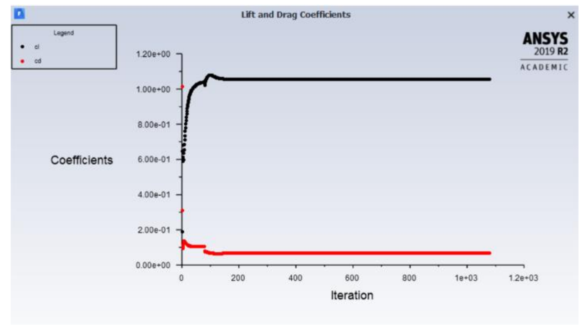
DATA

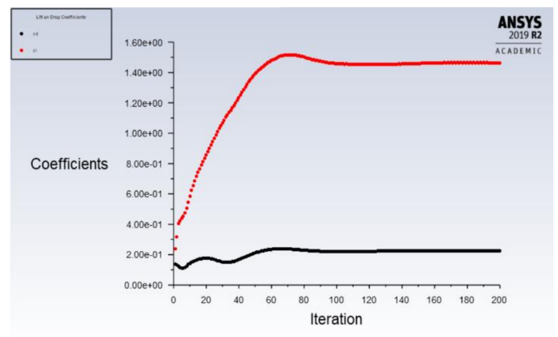
Vortex theory

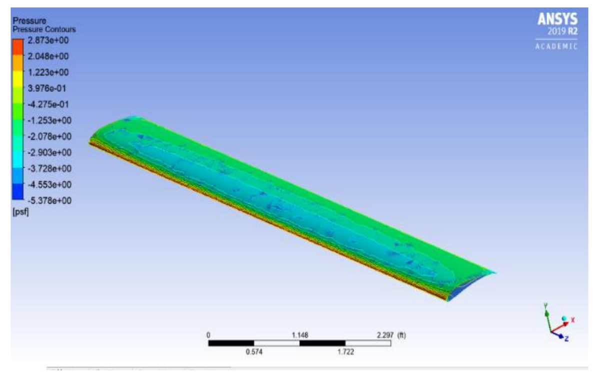
3D simulation Fluent

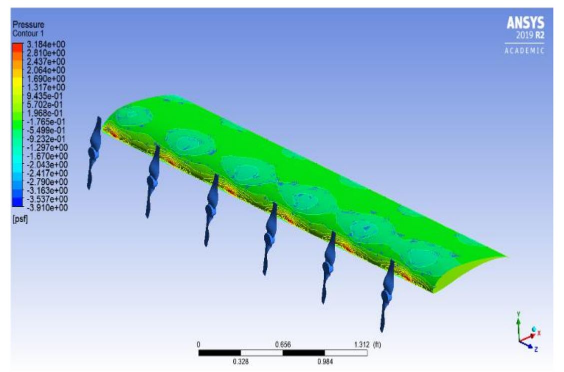


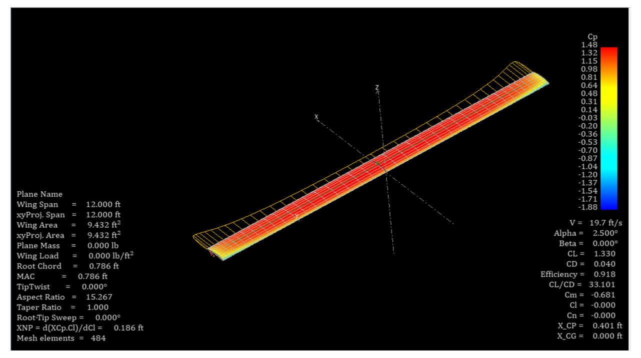


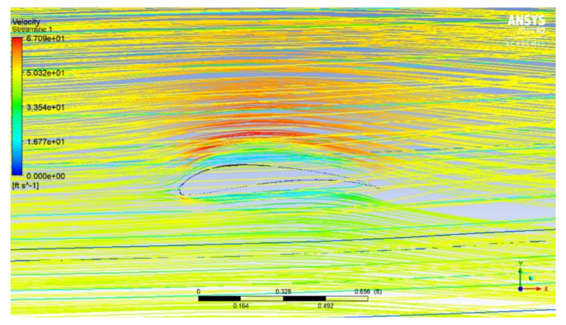


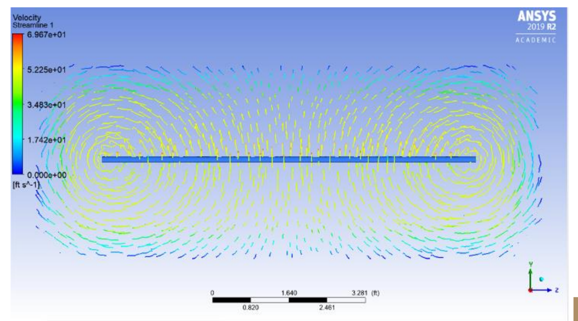


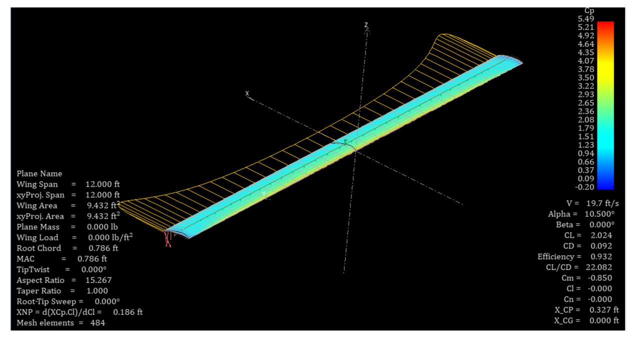


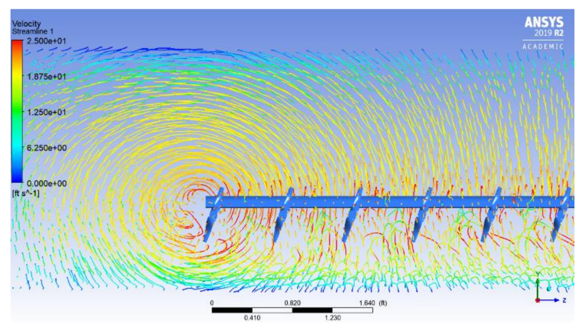


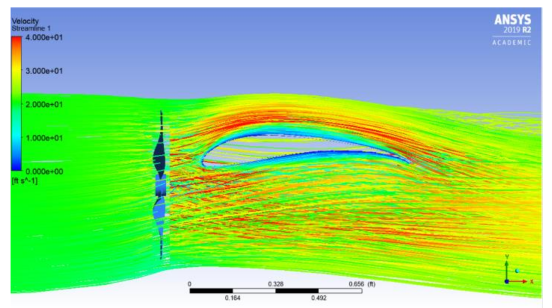












ANALYSIS AND RESULTS

DEP showed an improvement vs no DEP in lift coefficient using vortex theory at very low angles of attack. At an angle of attack of zero degrees, CL increased from 1.0 to 4.00. CL improved also at higher angles of attack but to a lesser extent.

At the same angle of attack, computational fluid dynamics analysis showed a much smaller improvement. CL increased from 1.05 to 1.47 at an angle of attack of zero degrees.

Rey =110872			
NO DEP		DEP	
AOA	CL	AOA	CL
0	1.17631	0	2.02946
2	1.10121	2	2.52055
6	1.78225	6	3.04063
10	1.93917	10	2.52036

Rey=332571			
NO DEP		DEP	
AOA	CL	AOA	CL
0	1.1608	0	2.00282
2	1.41161	2	2.43014
6	2.12448	6	2.82971
10	1.8279	10	1.23152

CONCLUSION

In conclusion, vortex theory shows a larger advantage due to using DEP than computational fluid dynamics. It is believed that further research should focus on validating the predictions of propeller-induced velocities, as these are central to the analysis.

Other effects to be studied are propeller blade shape the placement of the propeller disk with respect to the wing.

Results did show an overall improvement in lift due to DEP that increased at slower aircraft velocities, as predicted before.

CFD analysis with Ansys Fluent should be re-visited after a research license that permits and unlimited problem size is obtained. The current license was limited to a mesh size of 512,000 elements. An appropriate mesh should have a number of elements in the millions.

FUTURE WORK

We were limited to further expand our study in 3D simulation due to the ANSYS student version restrictions in mesh size, faces, and number of bodies forcing us to study half the wing apply symmetry on one end. Also the mesh elements size could not be refine in order to reduce residual making the study not as precise as desire.

Contacting ANSYS to acquire an unlimited version of Fluent in order to have a more accurate study of flow simulation of the wing. Place the propeller in different arrangement in front of the wing in order to maximize the induce velocity of the propeller but only to the upperpart of the wing. We are certain that results are going to be breathtaking.

To continue studying more profound DEP with Vortex theory and compare the 3D results of CP, CL with the results obtained from the CFD analysis.

ACKNOWLEDGEMENTS

This project is dedicated to our mentor José R. Pertierra and to the Undergraduate Research Program for PUPR Honor Students, for expanding our knowledge in the aerospace branch and preparing us professionally in our lives as future mechanical engineers.