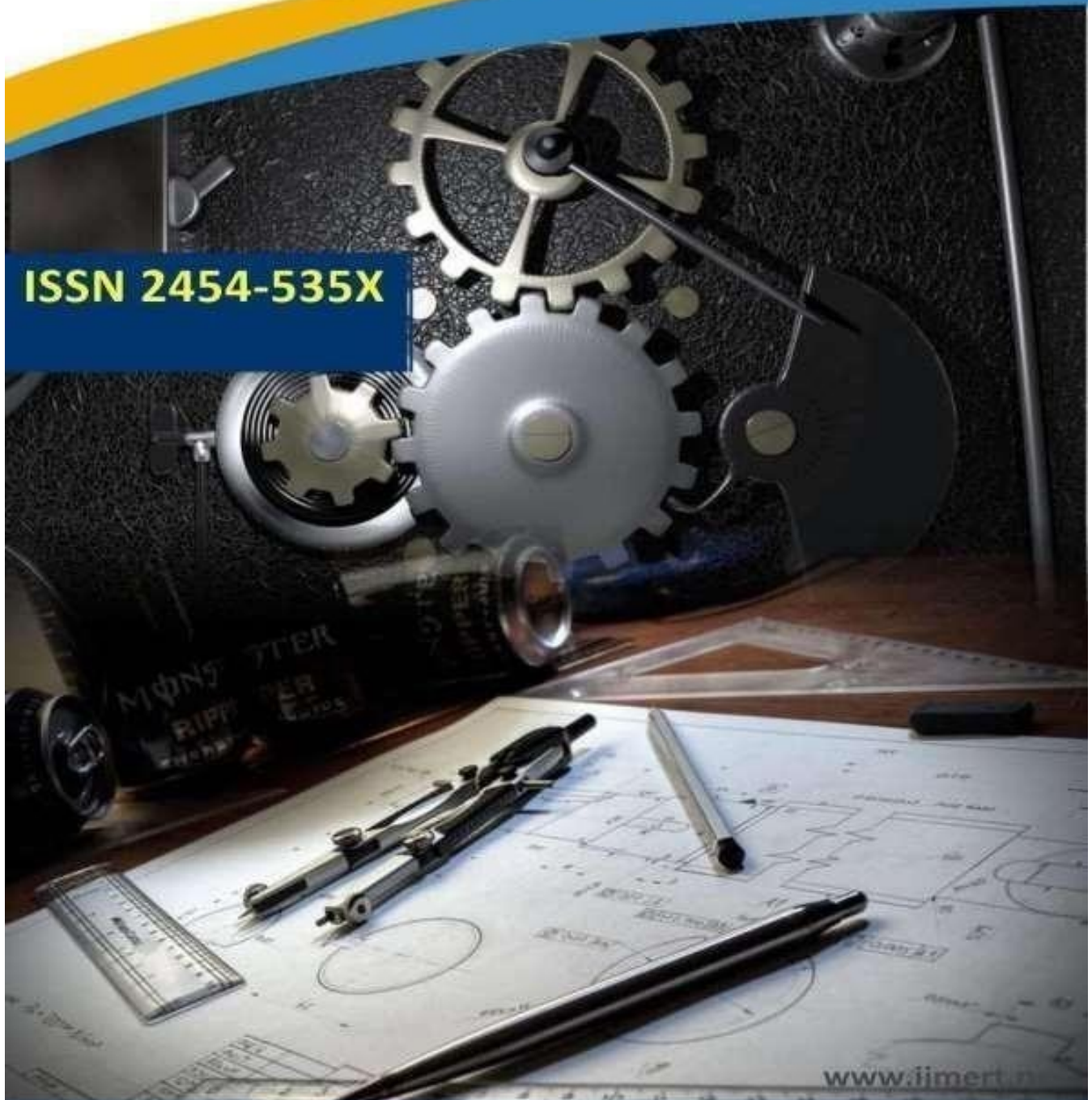




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Aerodynamic Characteristics of the Design of Liam Propeller Blades: An Investigation

¹ M. Pravalika, ² K. Praveen kumar

¹Department of Aeronautical Engineering, Sathyabama Institute of Science and Technology,
Semmencheri, Chennai 600119, India.

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ABSTRACT

By looking at new design changes, this study examines how well Low-Induction Axial Momentum (LIAM) propeller blades function aerodynamically. By comparing blade designs that include airfoil geometries and wave patterns along the edges, the research hopes to boost UAV performance and assist humanitarian operations. Results on lift, drag, and total efficiency under different operating circumstances may be gleaned using ANSYS simulations. This design adjustment has a considerable influence on aerodynamic performance, according to early-stage studies. It provides a platform for additional optimization and refining. Aerodynamics, Unmanned Aerial Vehicle Propellers, LIAM Blades, ANSYS Models, Airfoil Templates, Wave Formations



1. Introduction

The ever-increasing use of unmanned aerial vehicles (UAVs) in fields ranging from defense to aid has prompted calls for enhanced aerodynamic performance. Propeller blades are one of the most important parts of a UAV, and new designs may cut energy consumption and increase lift-to-drag ratios. Optimizing aerodynamic features with a focus on decreased energy losses during operation has been made possible by the idea of Low-Induction Axial Momentum (LIAM) blades. Researchers have investigated several blade design tactics, such as using sophisticated airfoils and modifying the edges, to achieve these aims [1] [2]. By comparing various design approaches, this research aims to analyze the aerodynamic properties of LIAM propeller blades. The effect on performance measures including lift, drag, and efficiency of two main changes—the incorporation of an airfoil and the introduction of wave-patterned edges—are studied. This inquiry is built upon computational simulations utilizing ANSYS software, which provide accurate insights into flow behavior and performance consequences.

2. Research Methodology

The research methodology is structured around the computational analysis of propeller blade designs using ANSYS software. The following steps outline the approach:

2.1 Baseline Design

The baseline propeller blade geometry was selected from existing LIAM blade models with proven performance characteristics. This design serves as a reference for comparison with modified geometries.

2.2 Design Modifications

Three innovative concepts were introduced to the baseline blade: Airfoil profiles were integrated along the blade span to improve lift characteristics. NACA 0008 airfoil sections were chosen due to their low drag and high structural stability [3] [4]. 2 different wave patterns were added to the blade edges, inspired by natural structures such as humpback whale fins. These patterns aim to reduce flow separation and enhance aerodynamic stability [5] [6].

2.3 Simulation Setup

Computational analysis was conducted using ANSYS Fluent, employing steady-state conditions to evaluate the aerodynamic performance. Boundary conditions like standard atmospheric pressure, temperature of 30 degree celcius, velocity, variable flow parameters, mesh



configurations, and solver settings were standardized for consistency across all of the designs subjected to the simulation.

3. Experimental/Numerical work

3.1 Blade Design in CATIA

The initial geometries for the LIAM propeller blades were developed using CATIA software, a leading tool for parametric 3D modelling [7] [8]. The baseline design was first modeled, adhering to standard dimensions suited for UAV applications. Subsequently, modified blade designs incorporating airfoil sections and wave-patterned edges were created for comparative analysis [5] [6]. All designs maintained consistent chord lengths and blade spans to isolate the effects of the geometric variations on aerodynamic performance [9].

3.2 Simulation Setup in ANSYS

The aerodynamic analysis was conducted in ANSYS Fluent, employing steady-state flow conditions to evaluate the performance metrics across all blade configurations [7] [10].

3.2.1 Boundary Conditions

The following boundary conditions were applied uniformly across all simulations [7] [8]:

Table 1.1: Boundary conditions for the ANSYS Simulation

Inlet Velocity	Outlet Pressure	Temperature	Wall Conditions
70-90 km/h at 6000 rpm	Standard Atmospheric Pressure (101325 Pa)	30°C - 35°C	No-slip conditions were enforced.

3.2.2 Mesh Generation

A high-quality mesh was generated using ANSYS Mesher [8] [9]. The mesh combined structured hexahedral elements in the vicinity of the blade's surface and unstructured tetrahedral elements for the surrounding flow field. Fine refinements were introduced along the leading and trailing edges to accurately resolve boundary layer behavior. The grid independence study ensured that the results were unaffected by further mesh refinement [10] [11]

3.2.3 Solver Settings



The pressure-based solver was employed, with the k-omega SST turbulence model selected to balance computational efficiency and accuracy in capturing near-wall effects [9]. Convergence criteria for the simulations were set at residuals below 10^{-5} for continuity, momentum, and energy equations [11].

3.3 Performance Metrics Analyzed

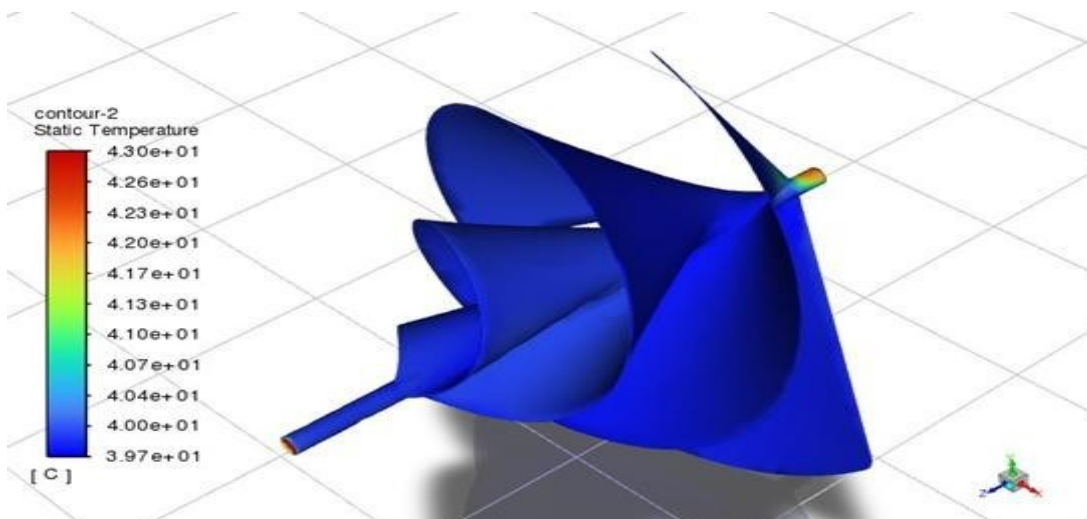
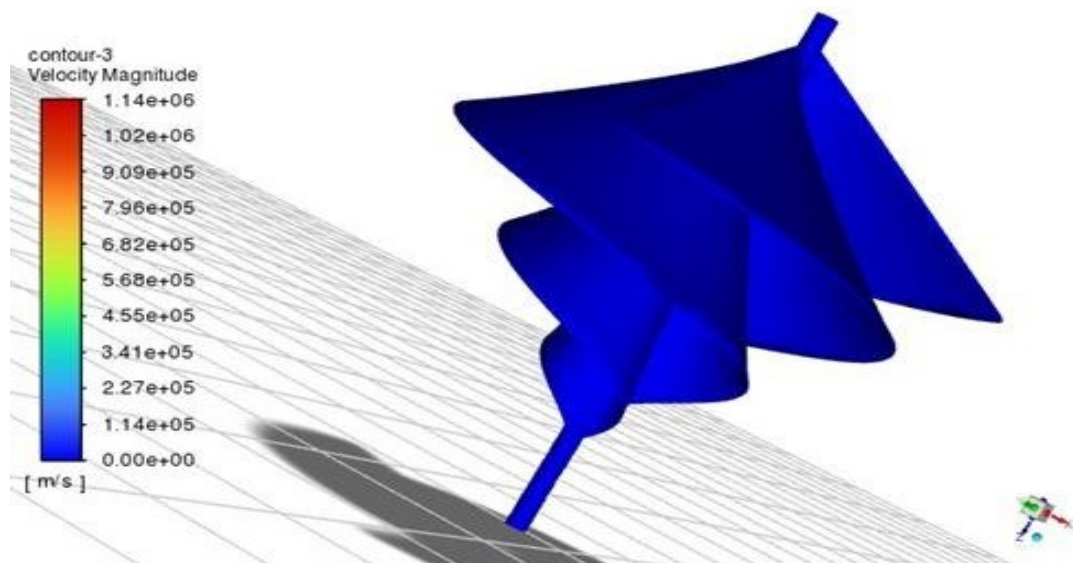
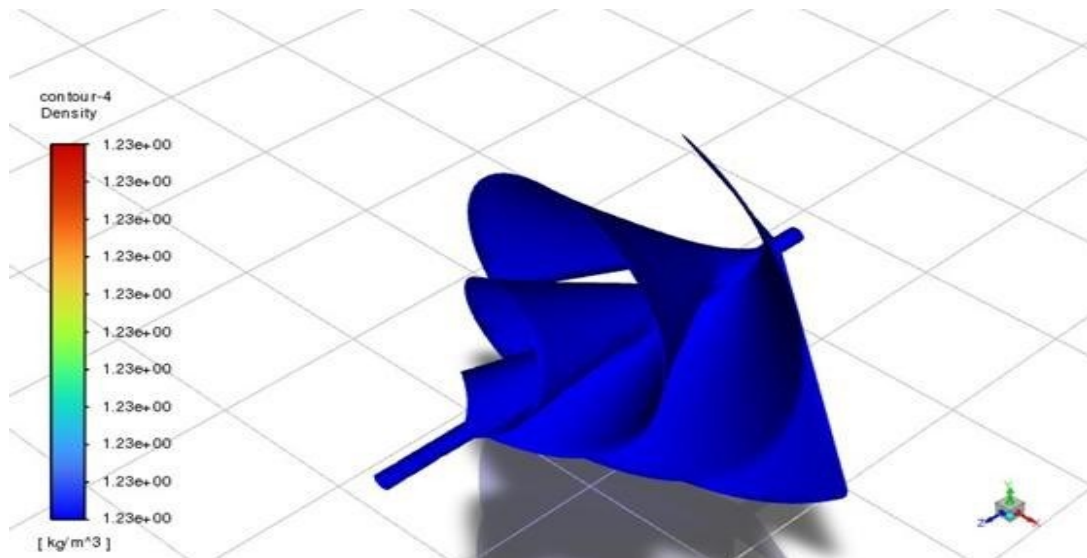
The simulations provided detailed insights into the impact of design variations on key aerodynamic parameters, including [10] [12]. **Pressure Distribution:** Variations across the blade surface were analyzed to assess lift generation. **Density Variations:** Localized density changes due to airflow interaction were observed, highlighting regions of high aerodynamic efficiency. **Velocity Profiles:** The flow behavior around the blade, particularly at the leading edge and trailing edge, was examined for indications of flow separation or turbulence. **Temperature Effects:** Surface temperature distributions were monitored to evaluate thermal influences on aerodynamic performance. The consistent boundary conditions ensured a fair comparison of results across the different blade configurations [9] [10]. Early findings suggest significant variations in these parameters based on the implemented design modifications, providing a strong basis for further exploration and optimization [5] [6].

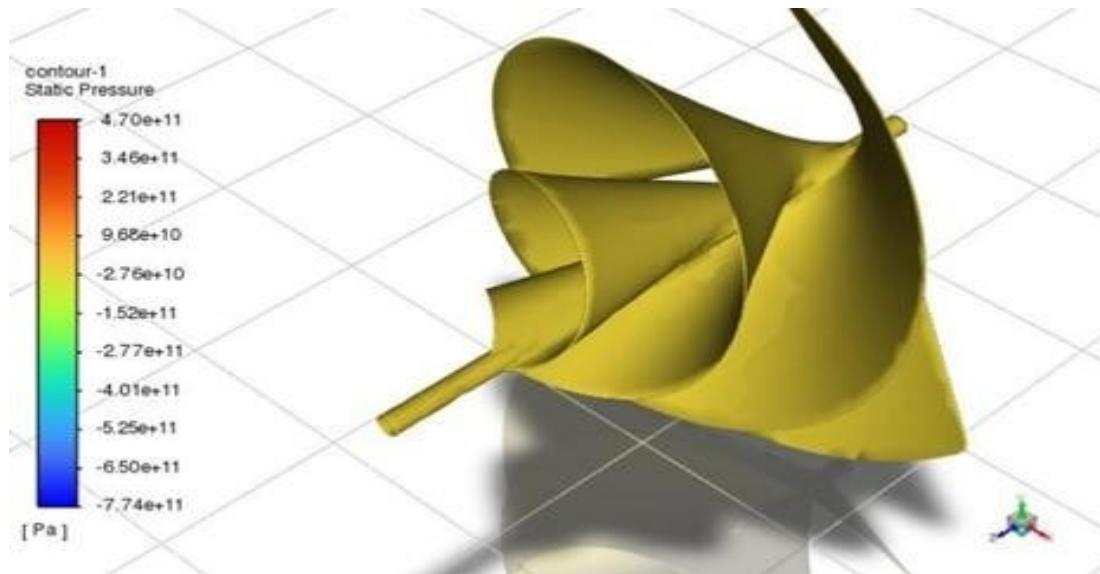
4. Results and discussion

4.1 Original Design Result Parameters

The Original design of the LIAM Propeller design is simulated for result comparison with respect to the other designs on parameters like density, velocity, static temperature and pressure. The Density is 1.23kg/m^3 , velocity is from 0 to $1.14\text{e}+06\text{ m/s}$, temperature varies from 39.7 to 43 degree celcius and pressure is from -7.74 to $4.7\text{e}+11\text{Pa}$.

Density	Velocity	Temperature	Pressure
1.23kg/m^3	0 to $1.14\text{e}+06\text{ m/s}$	39.7 to 43 degree celcius	-7.74 to $4.7\text{e}+11\text{Pa}$

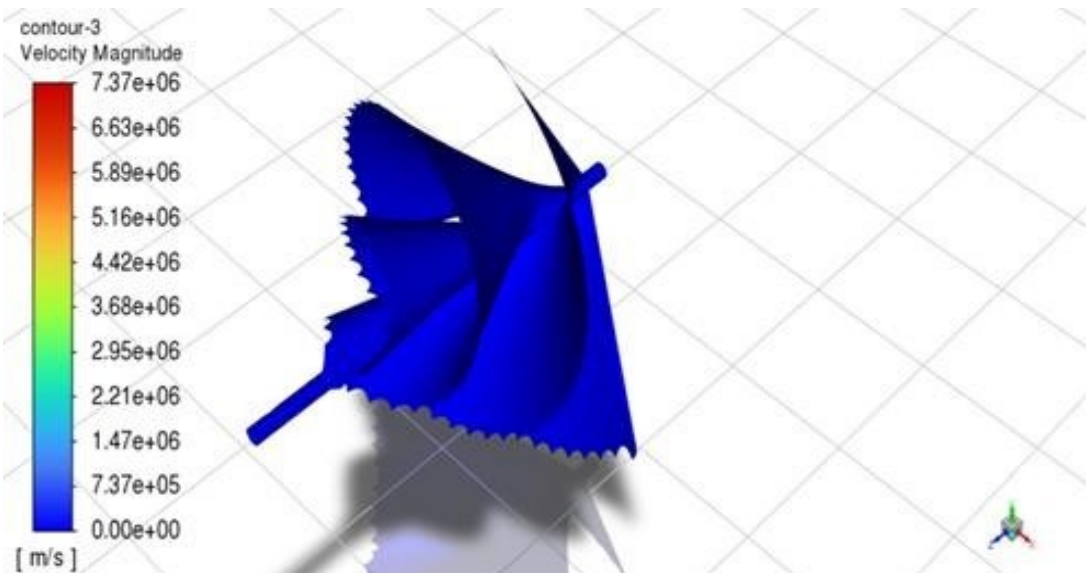
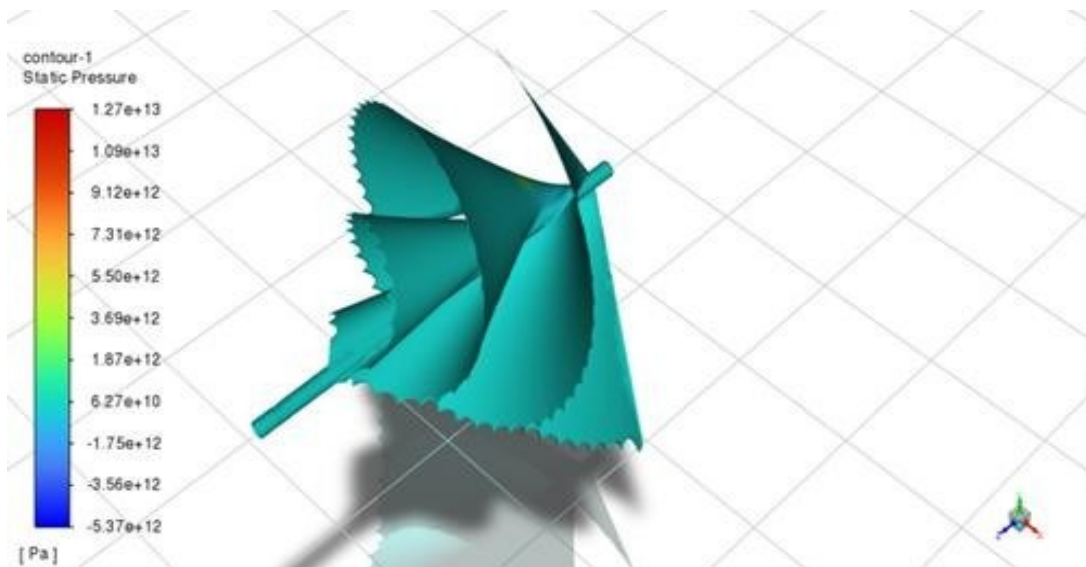
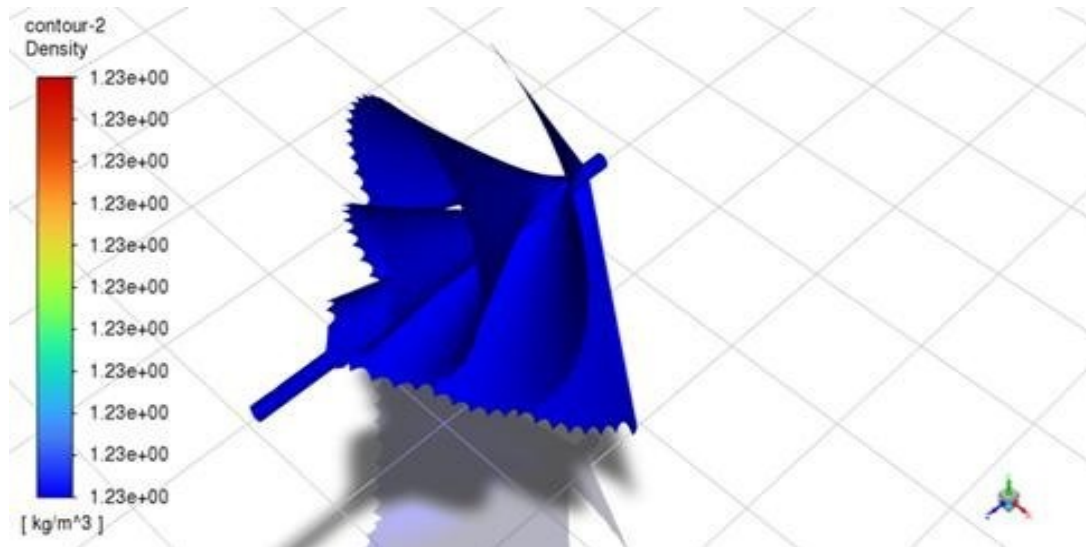


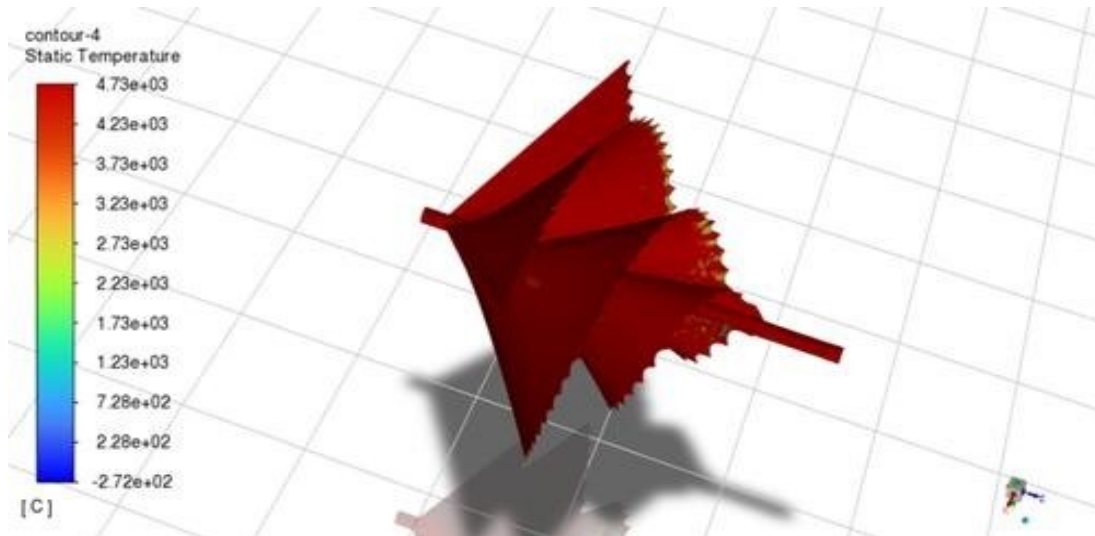


4.2 1st Wave Pattern Result Parameters

The Result parameters of the 1st wave pattern design is taken into consideration as given below. The Density remains at 1.23kg/m³, the temperature varies from -272 to 4730 degree celcius, velocity varies from 0 to 7.37e+06m/s, and pressure varies from -5.37e+12 to 1.27e+13 Pa, were the results obtained.

Density	Temperature	Velocity	Pressure
1.23kg/m ³	-272 to 4730 degree celcius	0 to 7.37e+06 m/s	-5.37+12 to 1.27+13 Pa

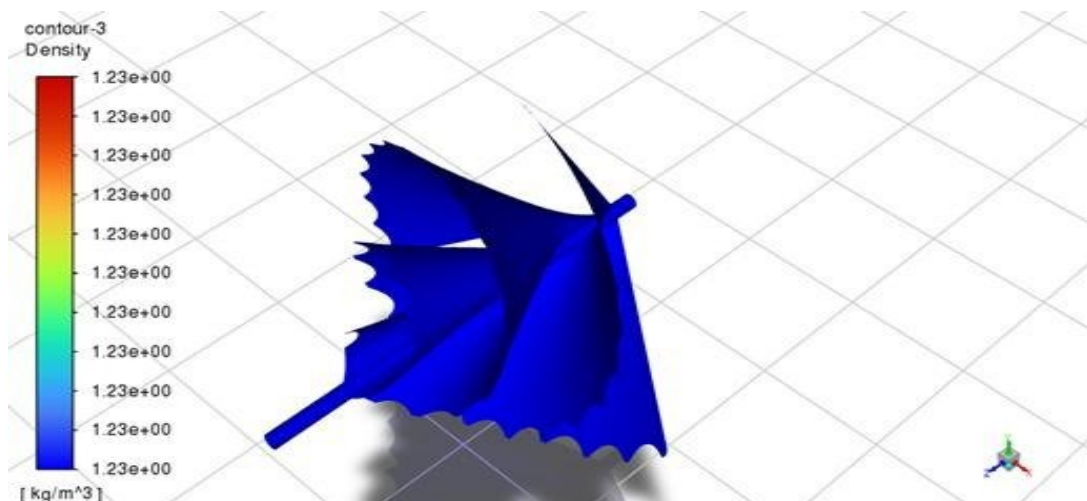


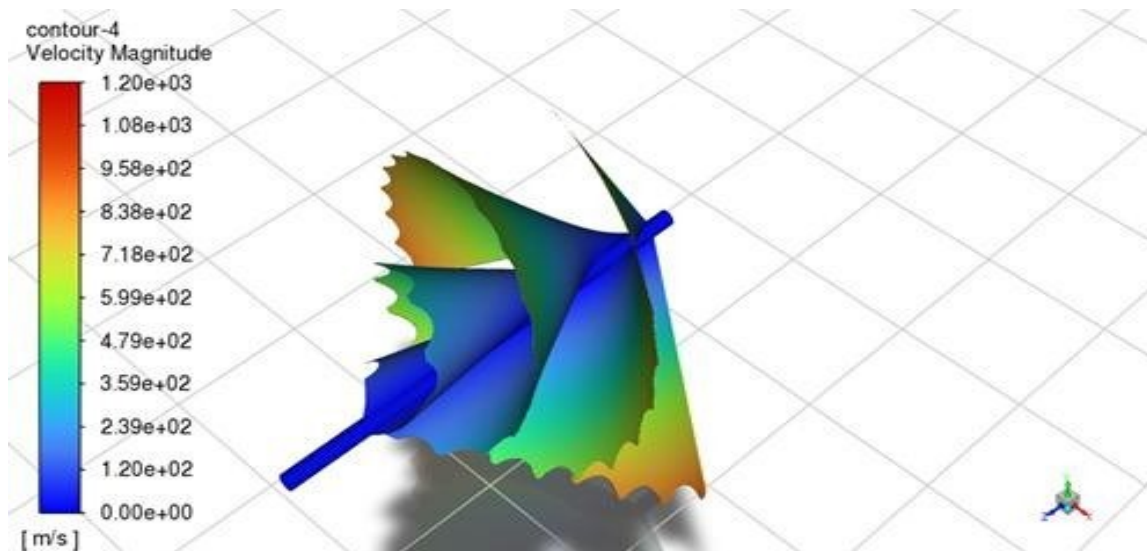
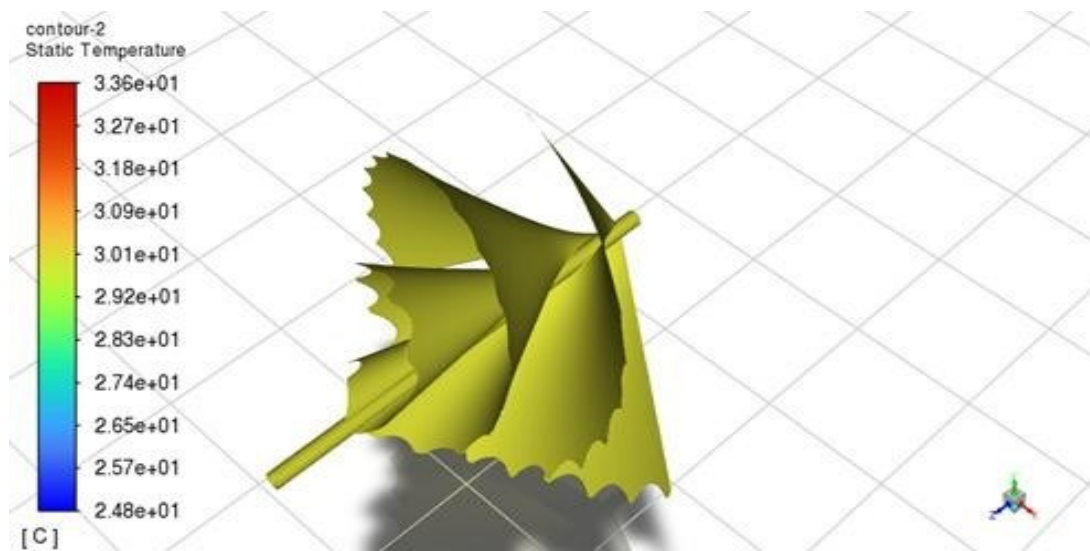
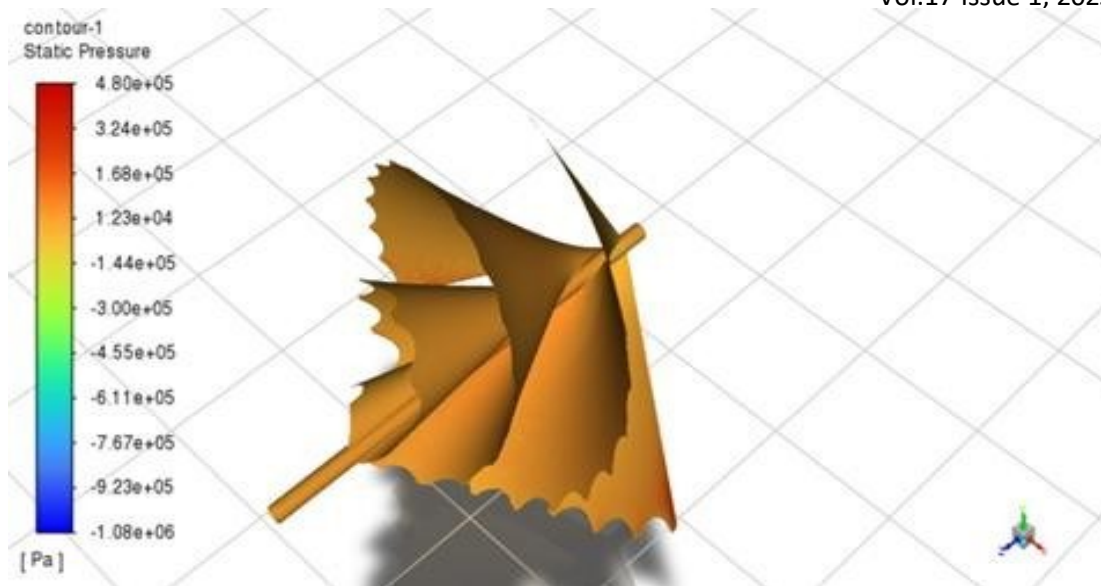


4.3 2nd Wave Pattern Result Parameters

The Result parameters of the 2nd wave pattern design is taken into consideration as given below. The Density remained at 1.23 kg/m³, pressure varies from -1.08e+06 to 4.8e+05 Pa, temperature varies from 24.8 to 33.6 degree celcius and velocity varies from 0 to 1200 m/s.

Density	Pressure	Temperature	Velocity
1.23 kg/m ³	-1.08e+06 to 4.8e+05 Pa	24.8 to 33.6 degree celcius	0 to 1200 m/s

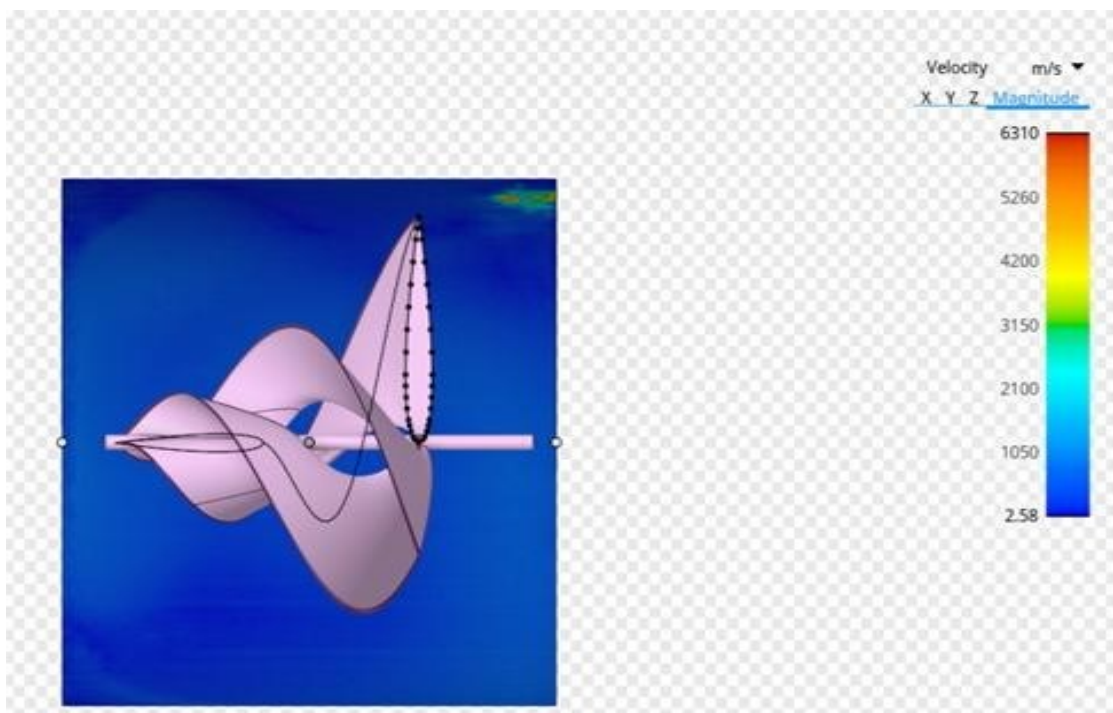


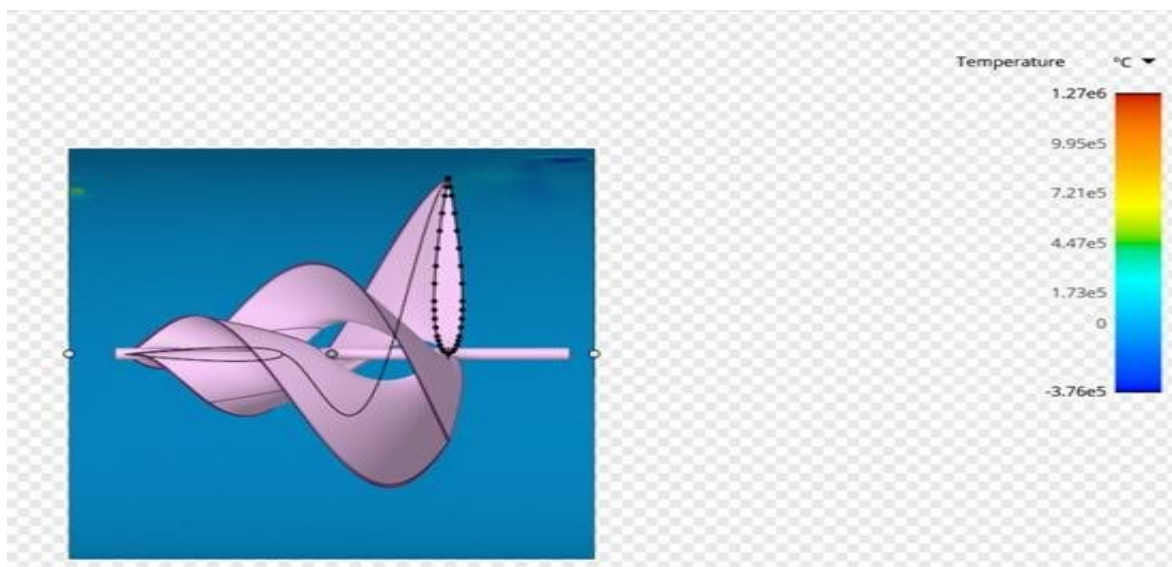
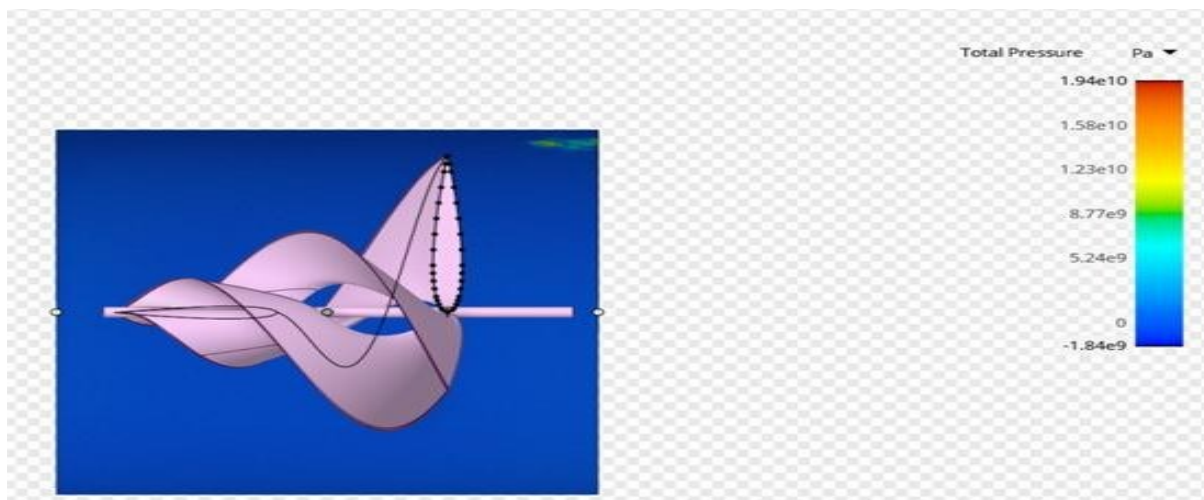
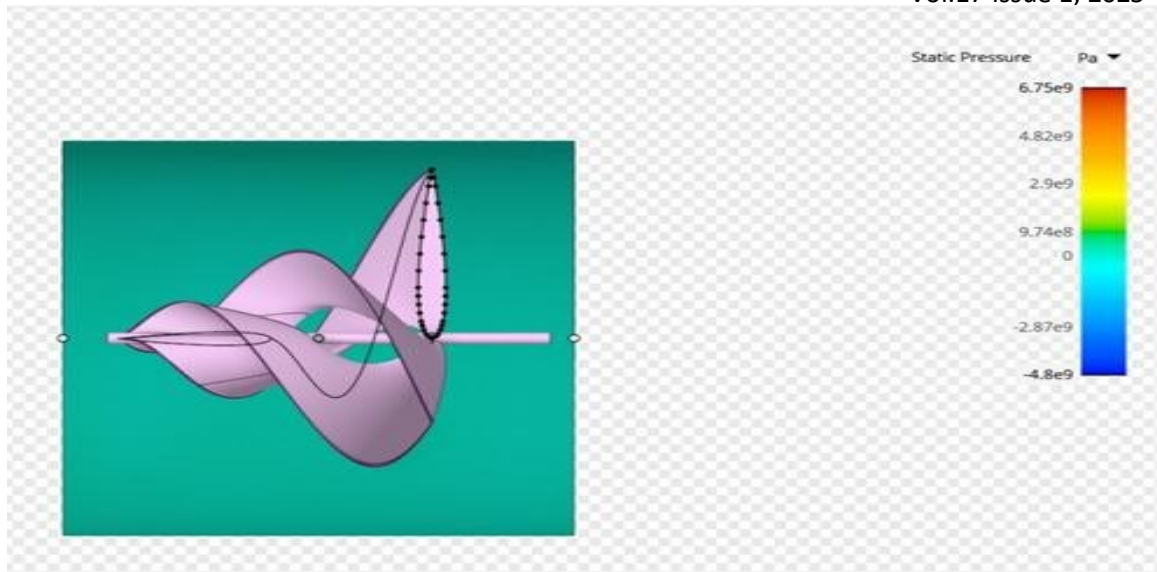


4.3 NACA Airfoil induced Results

The result parameters of the NACA Airfoil induced design is taken into account as given below. The velocity ranges from 2.58 to 6310 m/s, the temperature ranges from -3.76×10^5 to 1.27×10^6 degree celcius, static pressure ranges from -4.8×10^9 to 6.75×10^9 , and total pressure is from -1.84×10^9 to 1.94×10^{10} Pa.

Velocity	Temperature	Static pressure	Total Pressure
2.58 to 6310 m/s	3.76×10^5 to 1.27×10^6 degree celcius	-4.8×10^9 to 6.75×10^9 Pa	-1.84×10^9 to 1.94×10^{10} Pa.







5. Conclusion

Based on the results of the aforementioned Ansys simulations, it can be inferred that the first and second wave pattern designs are more suitable for capturing energy from incoming air because of their favorable properties, such as nominal temperature and pressure. Designing and Ansys simulations for the aforementioned Designs Patterns were finished by Tushant.S and A.Prasanna, the second and third writers, respectively. Mr. S. Venkatesh, the first author, is guiding us through this project, and he also conferred with Mr. Venkatesana and Mr. G. Madhankumar, the fourth and fifth writers, respectively. This research paper would not have been possible without the combined efforts of all five writers. To delve into the developments and improvements of wind turbines for effective wind energy collecting is the rationale for selecting this subject for the research paper. The funding for this research is split evenly between the third and second authors. This study work would not have been feasible without my co-authors, and I am grateful to them all.

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