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# INVESTIGATION ON AERODYNAMIC CHARACTERISTICS OF LIAM PROPELLER BLADES DESIGN

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**ABSTRACT**

*This research investigates the aerodynamic performance of Low-Induction Axial Momentum (LIAM) propeller blades by exploring innovative design modifications. The study aims to enhance UAV performance and support humanitarian missions by comparing blade designs incorporating airfoil geometries and wave patterns along the edges. Simulations conducted using ANSYS software provide insight into lift, drag, and overall efficiency under varying operational conditions. Early-stage findings suggest these design modifications significantly impact aerodynamic performance, offering a foundation for further refinement and optimization.*

**Keywords:** Aerodynamics, UAV Propellers, LIAM Blades, ANSYS Simulations, Airfoil Designs, Wave Patterns

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## 1. Introduction

Unmanned Aerial Vehicles (UAVs) have become indispensable in various sectors, from military operations to humanitarian missions, necessitating continuous improvements in their aerodynamic performance. Among the key components affecting UAV efficiency are propeller blades, where advanced designs can significantly enhance lift-to-drag ratios and reduce energy consumption. The concept of Low-Induction Axial Momentum (LIAM) blades has emerged as a promising approach to optimizing aerodynamic characteristics, emphasizing reduced energy losses during operation. To address these objectives, researchers have explored a range of blade design strategies, including the incorporation of advanced airfoils and edge modifications [1] [2]. In this study, we aim to evaluate the aerodynamic characteristics of LIAM propeller blades by comparing different design concepts. Two primary modifications—airfoil implementation and wave-patterned edges—are analyzed for their impact on performance metrics such as lift, drag, and efficiency. Computational simulations using ANSYS software form the backbone of this investigation, offering precise insights into flow behavior and performance outcomes.

## 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℃ - 35℃ | 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

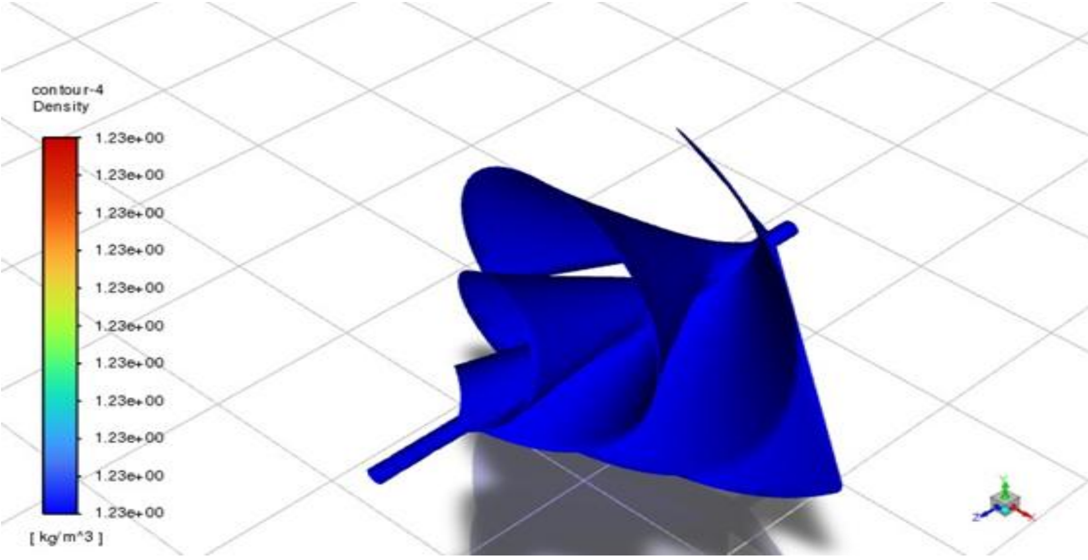
The simulations provided detailed insights into the impact of design variations on key aerodynamic parameters, including [10] [12]. Pressure Distribution: Variations across the blade surface were analyzed to assess lift generation. Density Variations: Localized density changes due to airflow interaction 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].

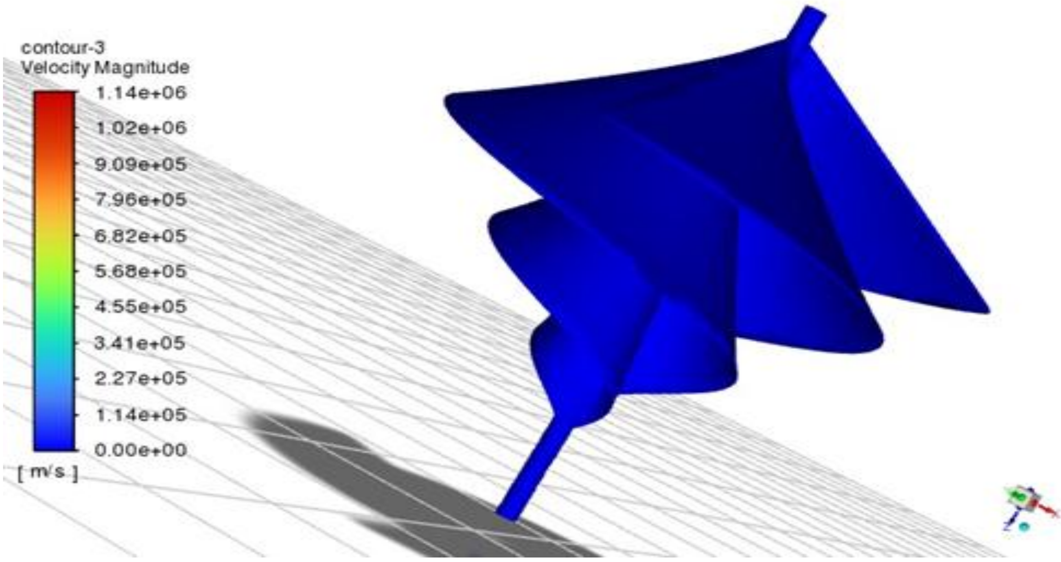
## 4. Results and discussion

### 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/m3,velocity is from 0 to 1.14e+06 m/s,temperature varies from 39.7 to 43 degree celcius and pressure is from -7.74 to 4.7e+11Pa.

| **Density** | **Velocity** | **Temperature** | **Pressure** |
|---|---|---|---|
| 1.23kg/m3 | 0 to 1.14e+06 m/s | 39.7 to 43 degree celcius | -7.74 to 4.7e+11Pa |


contour-4
Density
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
[ kg/m^3 ]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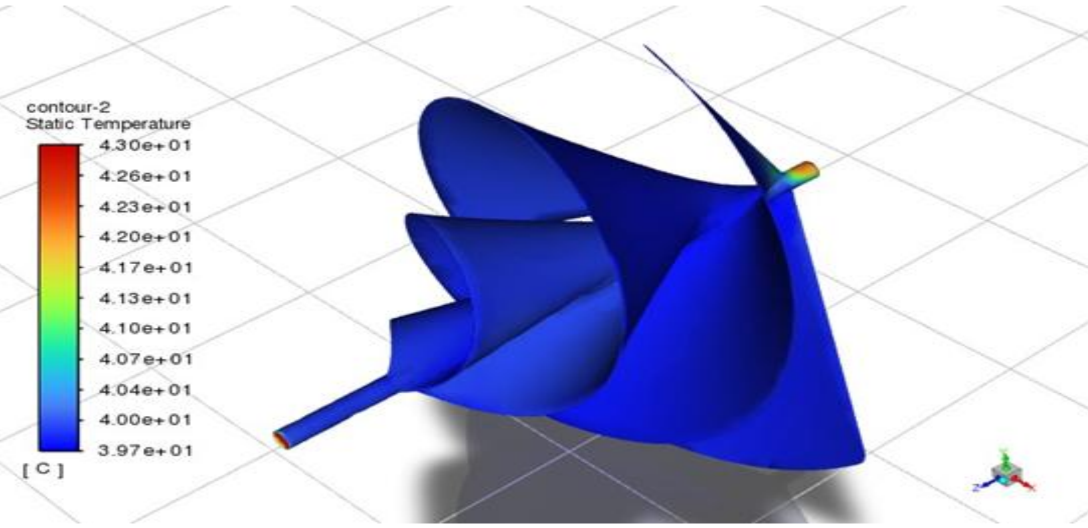
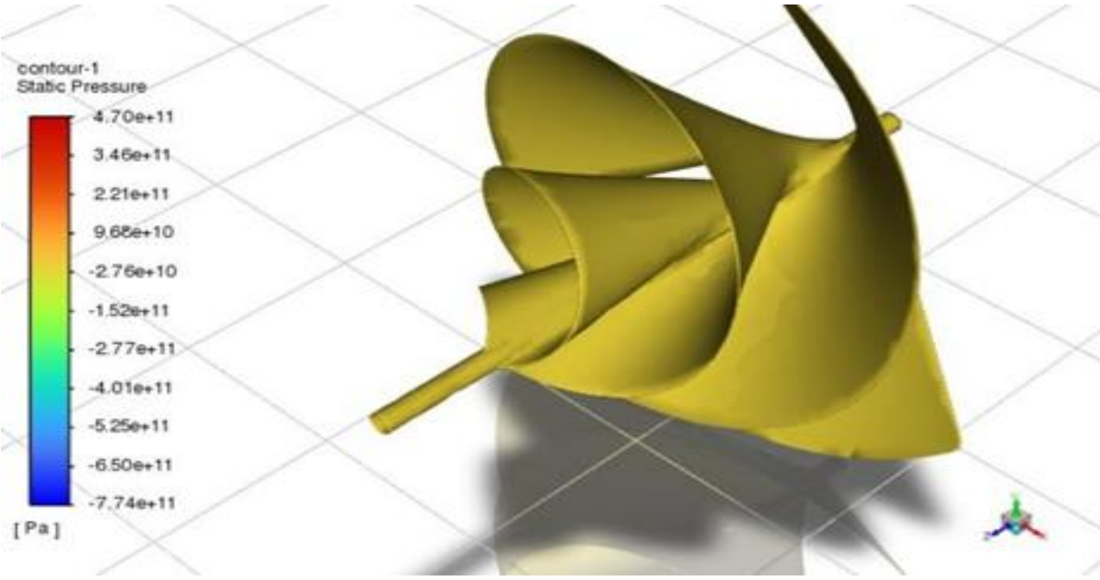
Velocity Magnitude
1.14e+06
1.02e+06
9.09e+05
7.96e+05
6.82e+05
5.68e+05
4.55e+05
3.41e+05
2.27e+05
1.14e+05
0.00e+00
[ m/s ]

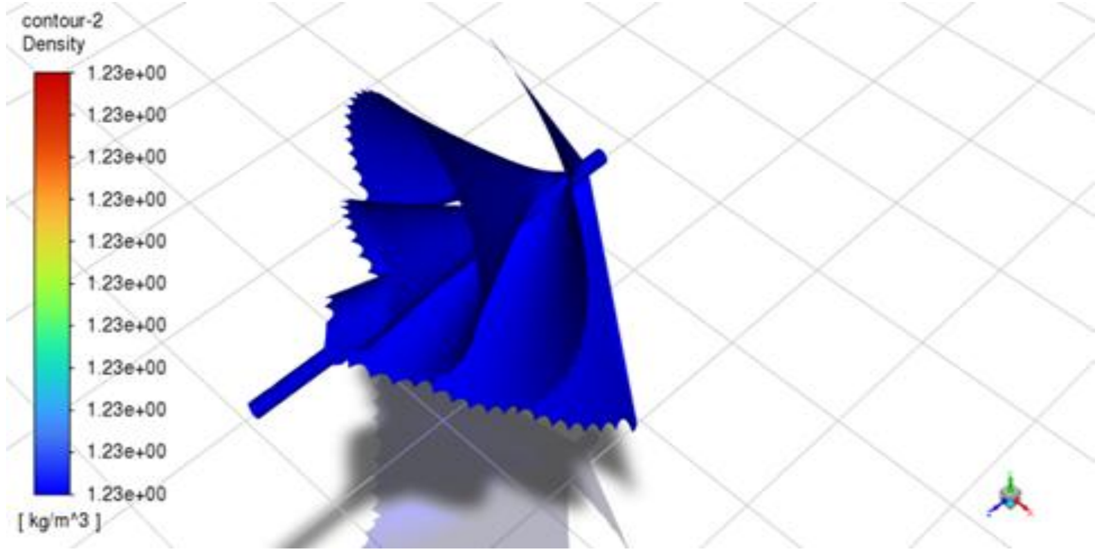

contour-2
Static Temperature
4.30e+01
4.26e+01
4.23e+01
4.20e+01
4.17e+01
4.13e+01
4.10e+01
4.07e+01
4.04e+01
4.00e+01
3.97e+01
[ C ]

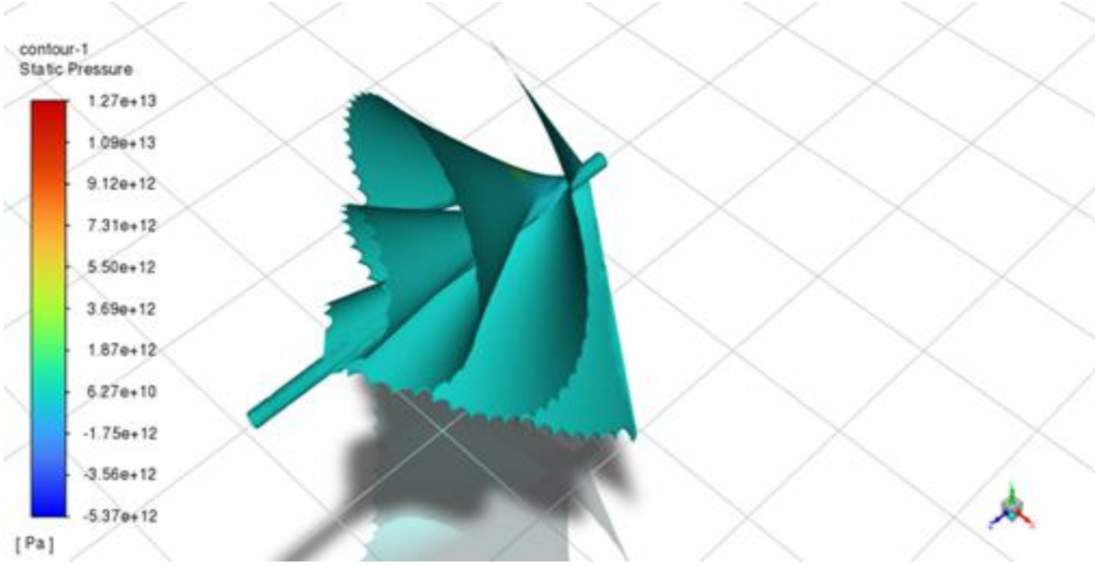


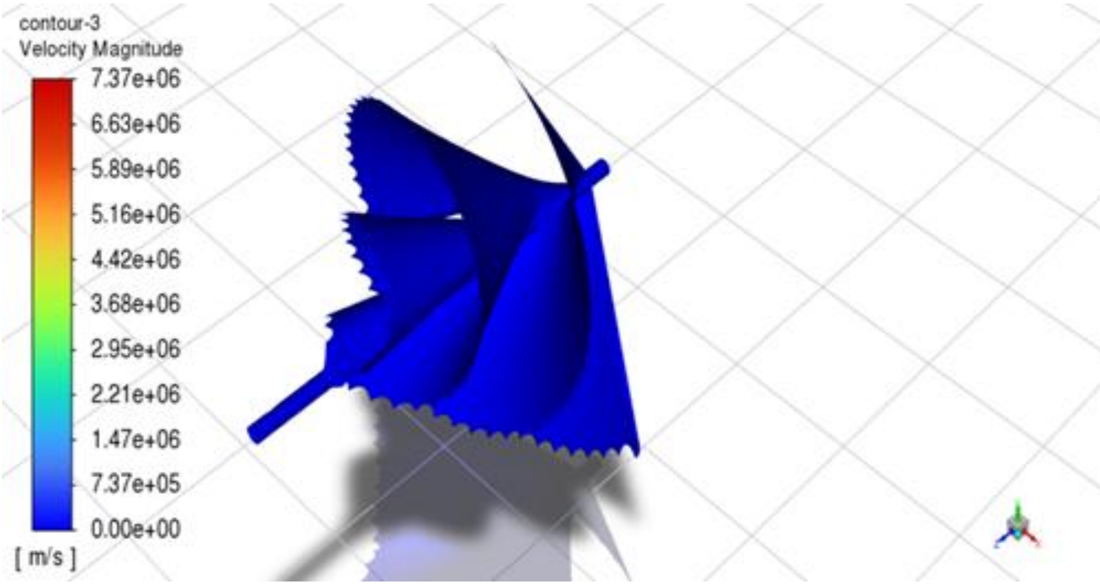

## 4.2 1st Wave Pattern Result Parameters

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/m3 | -272 to 4730 degree celcius | 0 to 7.37e+06 m/s | -5.37+12 to 1.27+13 Pa |


contour-2
Density
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
1.23e+00
[ kg/m^3 ]


contour-1
Static Pressure
1.27e+13
1.09e+13
9.12e+12
7.31e+12
5.50e+12
3.69e+12
1.87e+12
6.27e+10
-1.75e+12
-3.56e+12
-5.37e+12
[ Pa ]


contour-3
Velocity Magnitude
7.37e+06
6.63e+06
5.89e+06
5.16e+06
4.42e+06
3.68e+06
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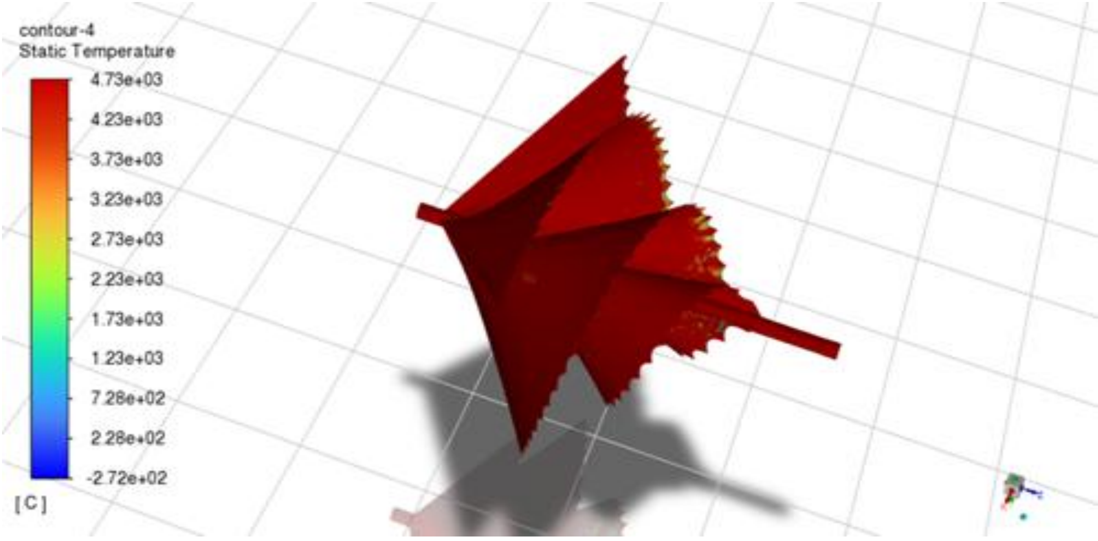
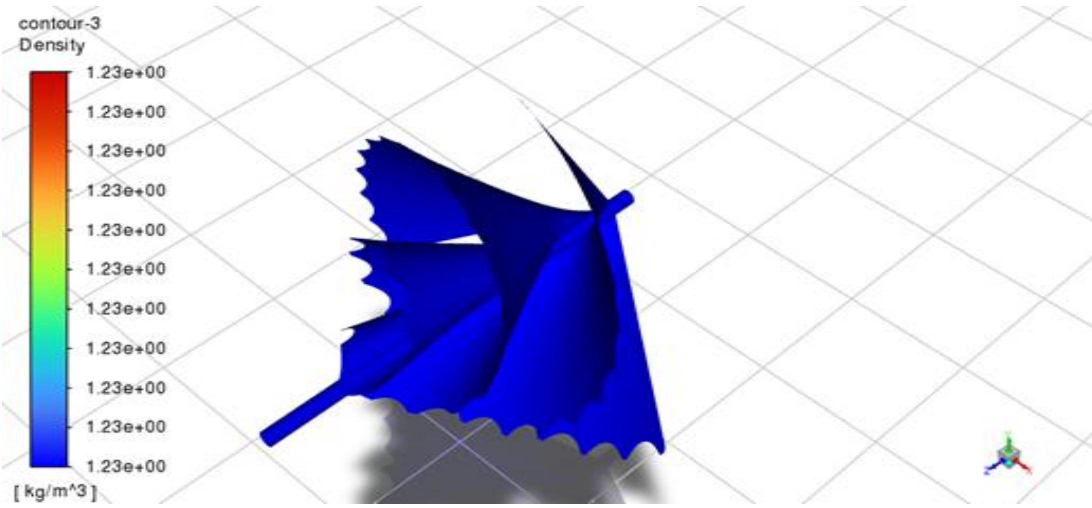
2.21e+06
1.47e+06
7.37e+05
0.00e+00
[ m/s ]

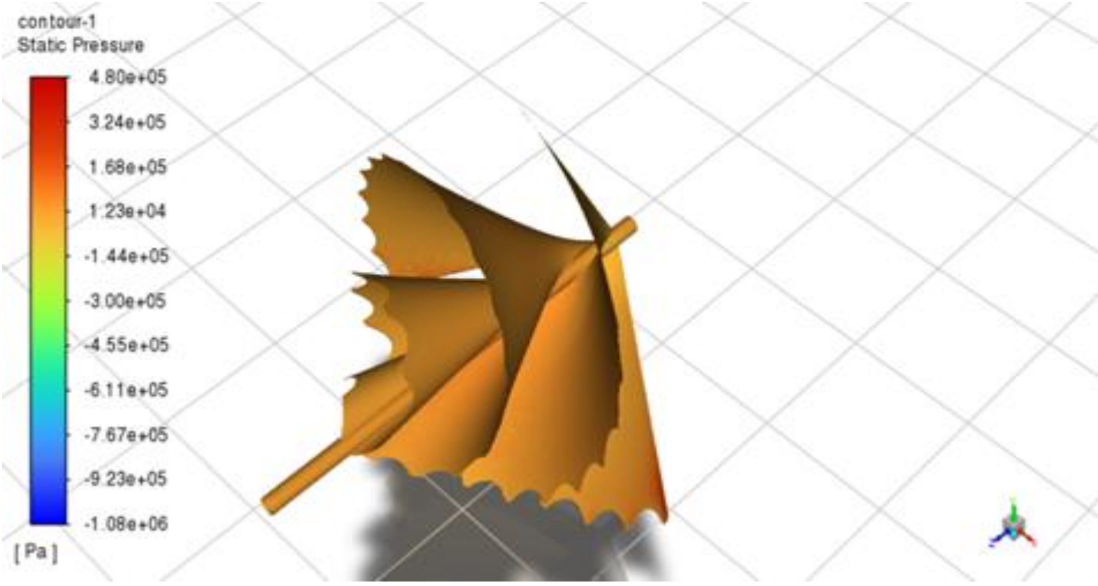



### 4.3 2nd Wave Pattern Result Parameters

The Result parameters of the 2nd wave pattern design is taken into consideration as given below.The Density remained at1.23kg/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 1200m/s.

| **Density** | **Pressure** | **Temperature** | **Velocity** |
|---|---|---|---|
| 1.23kg/m3 | -1.08e+06 to 4.8e+05 Pa | 24.8 to 33.6 degree celcius | 0 to 1200 m/s |




contour-1
Static Pressure
4.80e+05
3.24e+05
1.68e+05
1.23e+04
-1.44e+05
-3.00e+05
-4.55e+05
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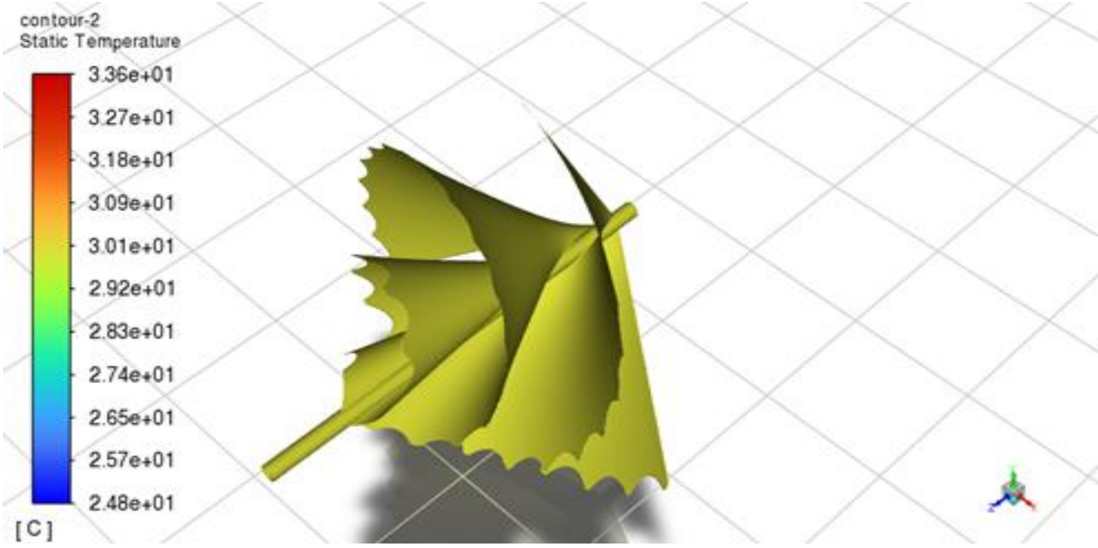
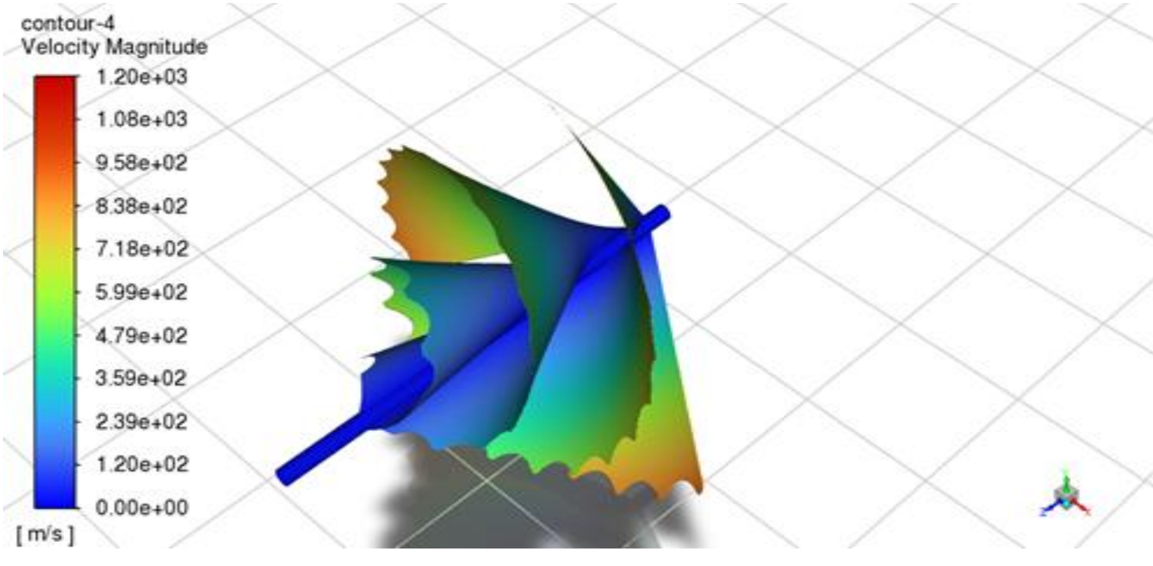
-7.67e+05
-9.23e+05
-1.08e+06
[ Pa ]

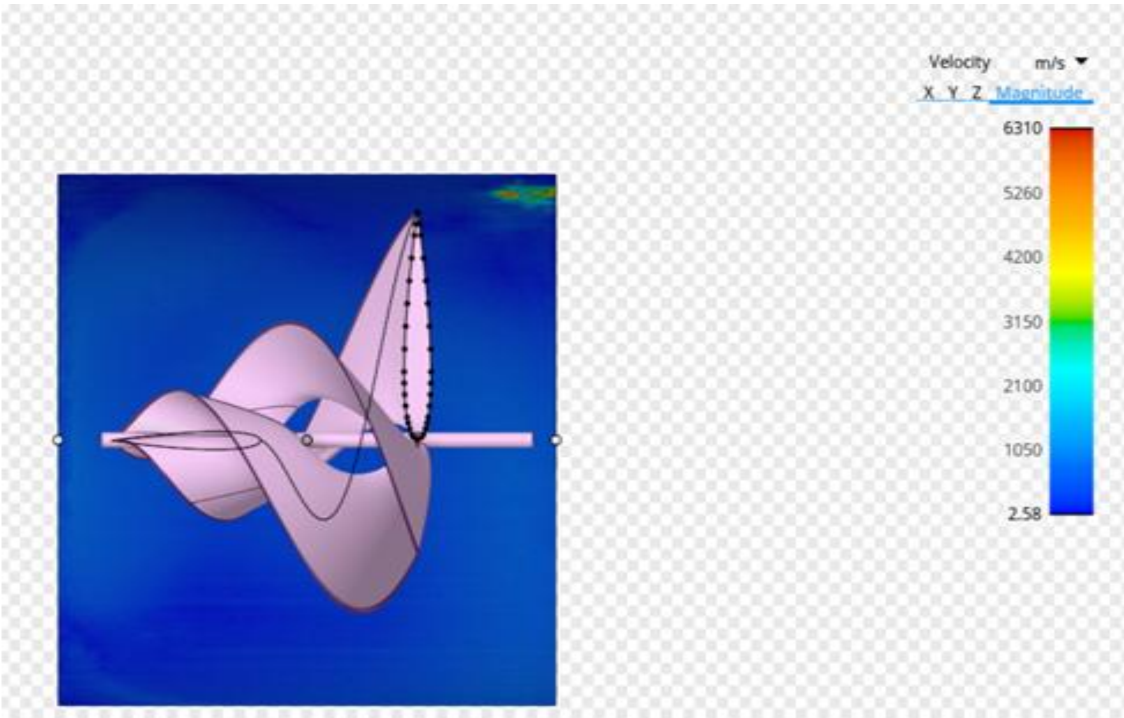

contour-2
Static Temperature
3.36e+01
3.27e+01
3.18e+01
3.09e+01
3.01e+01
2.92e+01
2.83e+01
2.74e+01
2.65e+01
2.57e+01
2.48e+01
[ C ]

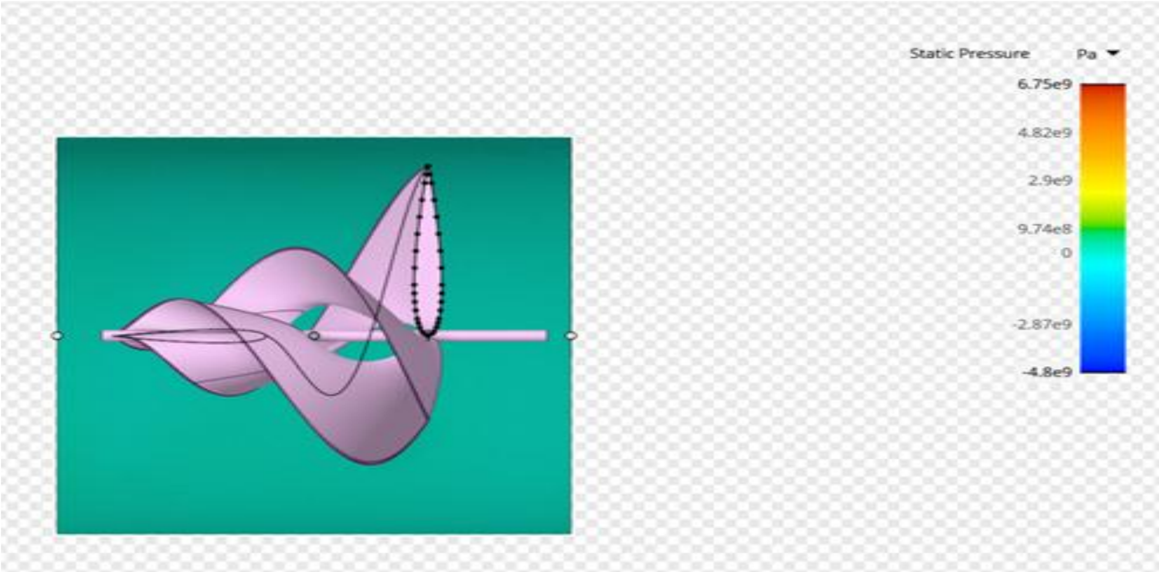

contour-4
Velocity Magnitude
1.20e+03
1.08e+03
9.58e+02
8.38e+02
7.18e+02
5.99e+02
4.79e+02
3.59e+02
2.39e+02
1.20e+02
0.00e+00
[ m/s ]

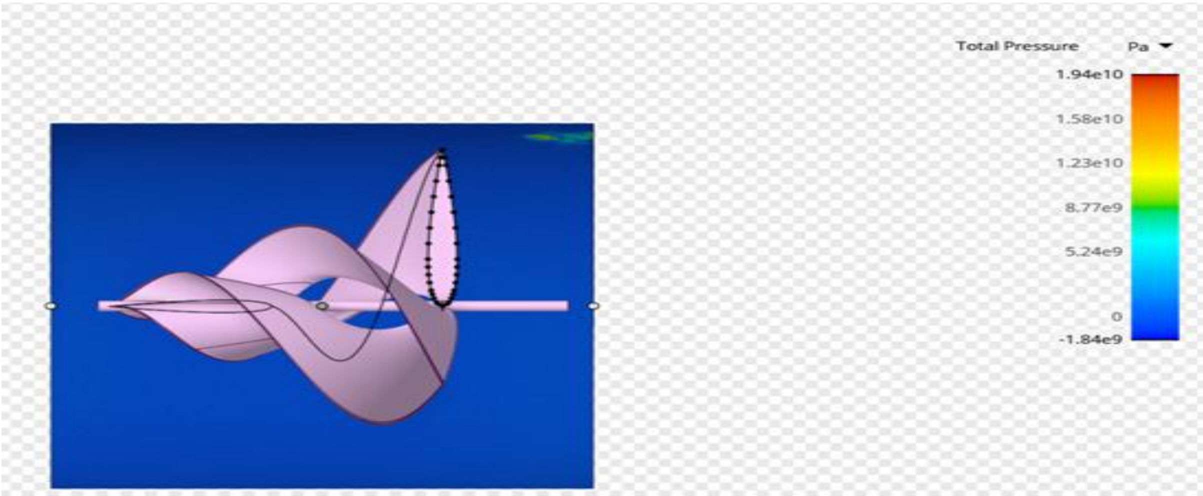
### 4.3 NACA Airfoil induced Results

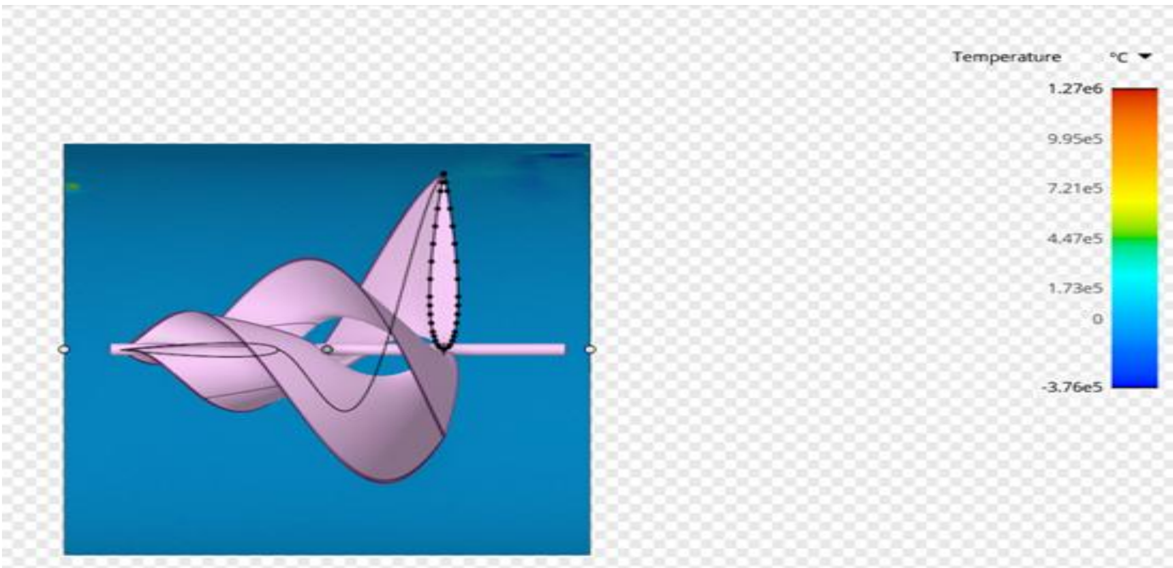
The result parameters of the NACA Airfoil induced design is taken into account as given below.The velocity ranges from 2.58 to 6310m/s,the temperature ranges from -3.76e5 to 1.27e6 degree celcius,static pressure ranges from -4.8e9 to 6.75e9,and total pressure is from -1.84e9 to 1.94e10 Pa.

| **Velocity** | **Temperature** | **Static pressure** | **Total Pressure** |
|---|---|---|---|
| 2.58 to 6310m/s | 3.76e5 to 1.27e6 degree celcius | -4.8e9 to 6.75e9 Pa | -1.84e9 to 1.94e10 Pa. |




Static Pressure
Pa
6.75e9
4.82e9
2.9e9
9.74e8
0
-2.87e9
-4.8e9


Total Pressure
Pa
1.94e10
1.58e10
1.23e10
8.77e9
5.24e9
0
-1.84e9


Temperature
°C
1.27e6
9.95e5
7.21e5
4.47e5
1.73e5
0
-3.76e5

## 5. Conclusion

From the above Ansys simulations, we can conclude that the original design and the 2nd wave pattern design is more feasible for the implementation of energy harvesting from incoming air due to its favourable parameters like nominal temperature, pressure,etc.

The 2nd and 3rd authors, Tushant.S and A.Prasanna, completed the Designing and Ansys simulations for the above Designs Patterns.The 1st author, Mr.S.Venkatesh is our guide for this project, and the 4th and 5th authors Mr.Venkatesana and Mr G.Madhankumar were consulted on this project by Mr.S.Venkatesh. All 5 authors contributed their shares towards making this research paper.The reason for choosing this topic for the research paper is to emerge into the advancements and optimizations of wind turbines for efficient harvesting of wind energy.This project is funded among the 2nd and 3rd authors equally.I would like to thank all of my co authors to make this research paper possible.

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