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*Original Article*

# Aerodynamically Efficient NACA Profile Bladeless Ceiling Fan

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***Abstract*** *: In conventional ceiling fans, rotating blades generate airflow, but they often pose safety risks, consume more energy, and have limitations in uniform air distribution. To overcome these challenges, this project presents the design and analysis of a bladeless ceiling fan utilizing an impeller-driven airflow system. The proposed design incorporates a NACA series blade profile to optimize airflow efficiency and enhance the lift-to-drag ratio for improved performance.*

*The study includes Computational Fluid Dynamics (CFX) simulations using ANSYS Fluent to analyse the airflow characteristics, pressure distribution, and velocity profiles. The results indicate that the bladeless fan achieves higher efficiency (48.025%) compared to conventional fans (13.12%) while maintaining better airflow circulation and reduced energy consumption. Additionally, the time taken for air to reach the ground is significantly lower (2.03 seconds) compared to a conventional ceiling fan (2.51 seconds), ensuring faster and more uniform cooling.*

*The bladeless ceiling fan not only enhances safety by eliminating exposed blades but also provides aesthetic appeal, energy efficiency, and improved air distribution. The findings suggest that this innovative design can serve as a superior alternative to conventional ceiling fans, offering enhanced comfort and sustainability.*

***Keywords*** *: Aerodynamics, NACA Profile, Bladeless Fan, Ceiling Fan, Fan Design, Innovative Fan Technology, Fan Performance, Passive Air Circulation, Air Movement.*

## I. INTRODUCTION

Ceiling fans have been a staple in households and commercial spaces for decades due to their cost-effectiveness and energy efficiency compared to air conditioning systems. However, conventional ceiling fans rely on rotating blades to push air downward, which results in uneven airflow distribution and higher turbulence. This often creates discomfort, especially in larger rooms, where air circulation is inconsistent and less effective.

Another major drawback of traditional ceiling fans is safety concerns. The exposed rotating blades pose a risk, particularly in households with children and pets. Additionally, these fans tend to accumulate dust, contributing to poor air quality and requiring frequent maintenance.

Bladeless fans have emerged as an alternative solution, offering a safer, more efficient, and aesthetically pleasing design. These fans operate using a turbinedriven airflow system, ensuring smoother and more consistent air distribution. By integrating NACA series airfoil blades, this project aims to develop a bladeless ceiling fan that not only enhances airflow efficiency but also optimizes energy consumption.

The main objectives of this project are:

- To develop a bladeless ceiling fan using a turbine mechanism for airflow generation.
- To implement NACA series airfoil blades to optimize lift and reduce drag, increasing overall efficiency.
- To analyze and compare performance (airflow speed, efficiency, lift, and drag forces) with a conventional ceiling fan.

To validate the design using Computational Fluid Dynamics for Turbomachinery (CFX) simulations in ANSYS to ensure optimal performance. The bladeless ceiling fan presented in this project introduces a unique approach to air circulation, differing from conventional ceiling fans in several key aspects. The novelty of this design lies in the turbine-driven airflow mechanism combined with NACA series airfoil blades, which significantly improves efficiency, safety, and airflow distribution.

## II. LITERATURE REVIEW

Research by Patel & Kumar (2020) found that 30–40% of energy input in traditional ceiling fans is lost due to air drag and mechanical inefficiencies.

- Noise Issues: Rotating blades generate high levels of noise due to air resistance and motor vibrations (Chen et al., 2019).
- Safety Concerns: Exposed fan blades pose a risk of injury and require frequent maintenance to prevent dust accumulation (Miller, 2021).
- Conclusion: While traditional ceiling fans remain widely used, they suffer from airflow inefficiency, high energy consumption, and safety hazards, which motivates the development of bladeless fan alternatives.

- Traditional ceiling fans operate using rotating blades that create airflow through direct mechanical movement. While effective, they present several limitations:
- Uneven Airflow Distribution: Traditional ceiling fans generate air circulation primarily beneath the fan, leaving corners of the room with insufficient airflow.
- Turbulence and Energy Loss: The air movement is often turbulent, leading to energy inefficiencies and irregular cooling.
- Safety Concerns: Rotating blades pose a risk of injury, especially in lowceiling environments.
- Aesthetic and Noise Issues: Conventional fans can be visually intrusive and produce noticeable noise during operation.

This project is inspired by bladeless ceiling fans, which use an alternative approach to generate airflow. Instead of exposed rotating blades, a bladeless system uses an impeller-driven airflow mechanism that pulls in air, accelerates it, and directs it efficiently across the room.

The fan design integrates NACA-series airfoil blades, which are commonly used in aerodynamics to optimize airflow performance. These blades generate lift and minimize drag, improving energy efficiency and uniform airflow distribution.

## III. METHODOLOGY

To address the limitations of conventional ceiling fans, this project introduces a bladeless ceiling fan that utilizes an impeller-driven airflow system instead of rotating blades. Traditional fans often pose safety risks due to exposed blades, consume more energy, and struggle with uniform air distribution. In contrast, the proposed bladeless fan is designed to enhance safety, optimize airflow efficiency, and reduce energy consumption while ensuring a more uniform air circulation.

The design of the bladeless ceiling fan is based on an aerodynamically optimized impeller, which draws in air and channels it through a specially designed airflow amplification system. To achieve high efficiency, the impeller incorporates a NACA series blade profile, known for its superior lift-to-drag ratio, which enhances the overall aerodynamic performance. This ensures that the airflow generated is not only smooth and consistent but also covers a larger area more effectively than conventional fans.

The effectiveness of the proposed system is validated through Computational Fluid Dynamics (CFX) simulations using ANSYS Fluent, where airflow characteristics, pressure distribution, and velocity profiles are analyzed. The simulation results demonstrate that the bladeless fan achieves an efficiency of 48.025%, which is significantly higher than the 13.12% efficiency of conventional ceiling fans. Additionally, the time required for air to reach the ground is reduced to 2.03 seconds, compared to 2.51 seconds for traditional fans, ensuring faster and more uniform cooling.

Beyond performance improvements, the bladeless ceiling fan also enhances aesthetic appeal and user safety by eliminating rotating blades, reducing noise levels, and offering an energy-efficient solution. The findings suggest that this innovative airflow system can serve as a superior alternative to conventional ceiling fans, providing improved comfort, sustainability, and energy efficiency.

### A. Working Principle of the Bladeless Fan

*a) Airflow Generation through an Impeller:*

- Air is drawn into the system through intake vents using a high-speed impeller.
- The impeller increases air pressure and directs airflow through the fan structure.

*b) Airfoil Blade Mechanism (NACA Series Blades):*

- The accelerated airflow passes over NACA airfoil blades, which shape and guide the airflow efficiently.
- The airfoil blades generate lift force, directing the airflow downward in a controlled manner.
- Drag is minimized, ensuring high-speed, low-turbulence air circulation.

*c) Comparison with Normal Ceiling Fans:*

- Traditional fans rely on direct blade rotation, leading to high turbulence and uneven airflow.

- The bladeless fan generates a smooth, uniform airflow, covering a larger area efficiently.
- The impeller-driven system reduces energy loss and improves cooling performance.

## IV. DESIGN OF BLADELESS CEILING FAN

To ensure optimal aerodynamic efficiency, a suitable NACA airfoil series is selected based on the following parameters:

### A. Selection Criteria:

- High Lift-to-Drag Ratio: Ensures better airflow with minimum energy loss.
- Stability in Low-Speed Applications: Suitable for residential and commercial use.
- Smooth Airflow Distribution: Prevents turbulence and ensures uniform cooling.

### B. Possible NACA Blades

o NACA 4412 > good for moderate air o NACA 6412 > higher lift

Angle of attack = 12 deg, which suits 4412

- NACA 4412 is used Chosen Blade Profile:

*a) NACA Series: NACA 4412 Reason for Selection:*

- Provides high lift at low speeds.
- Ensures smooth airflow without excessive drag.
- Well-suited for fan applications requiring controlled airflow.

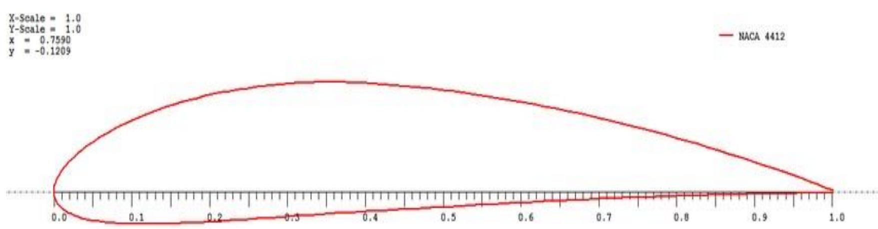
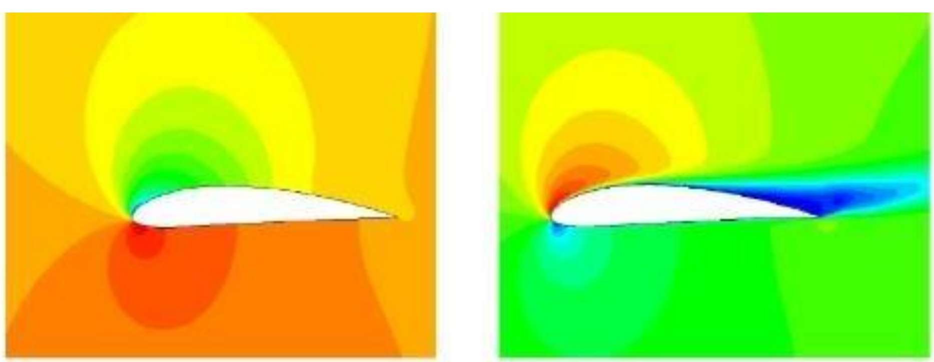



***Figure 1 : NACA 4412***



Static Pressure and velocity plot at 12° Angle of attack.

***Figure 2 : Blade AOA***

The impeller selection is based on several factors to ensure optimal airflow, efficiency, and compatibility with the bladeless fan design. The key parameters considered are:

- Airflow Requirement: The impeller must generate sufficient airflow to circulate air across the room efficiently.
- RPM Range: The impeller should operate at an optimal speed (450 RPM in our case) to balance performance and energy consumption.
- Pressure & Velocity Output: It must produce the required pressure difference to accelerate air efficiently.
- Low Noise Operation: A quieter operation is preferred for household and commercial applications.

- Compact Design: The impeller must fit within the fan housing and facilitate smooth airflow.

**C. Types of Impellers Considered**

| Impeller Type | Advantages | Disadvantages |
|---|---|---|
| Axial Flow Impeller | High efficiency, directs airflow linearly | Requires high RPM for efficiency |
| Radial Flow Impeller | Better pressure generation, compact | Moderate efficiency |
| Backward-Curved Centrifugal Impeller | High efficiency, low noise, steady airflow | More complex to manufacture |

***Table 1 : Types of Impellers***

ANSYS is a powerful computational fluid dynamics (CFX) tool used for simulating and optimizing airflow in various designs, including impeller-driven bladeless fans. Flow Blade Generation in ANSYS involves creating and analyzing aerodynamic blade profiles to enhance airflow efficiency, reduce turbulence, and improve overall performance.

- The impeller blades are designed using aerodynamic principles such as NACA series airfoils.
- Parameters like blade angle, curvature, and chord length are optimized for maximum lift and minimal drag.
- A fine mesh is generated around the impeller to capture detailed airflow characteristics.
- Proper boundary conditions are applied to simulate real-world fan performance.
- ANSYS CFX solves Navier-Stokes equations to predict airflow velocity, pressure distribution, and turbulence effects.
- Different impeller RPMs and inlet velocities are tested to achieve optimal airflow output.

**A. Design Specifications of Selected Impeller:**

| Parameter | Value |
|---|---|
| Impeller Type | Backward-Curved Centrifugal Impeller |
| Diameter | 150 mm |
| Speed (RPM) | 450 RPM |
| Blade Curvature Angle | 30° – 50° |
| Material | Lightweight Aluminum / Plastic |

***Table 2 : Specifications of Impellers***

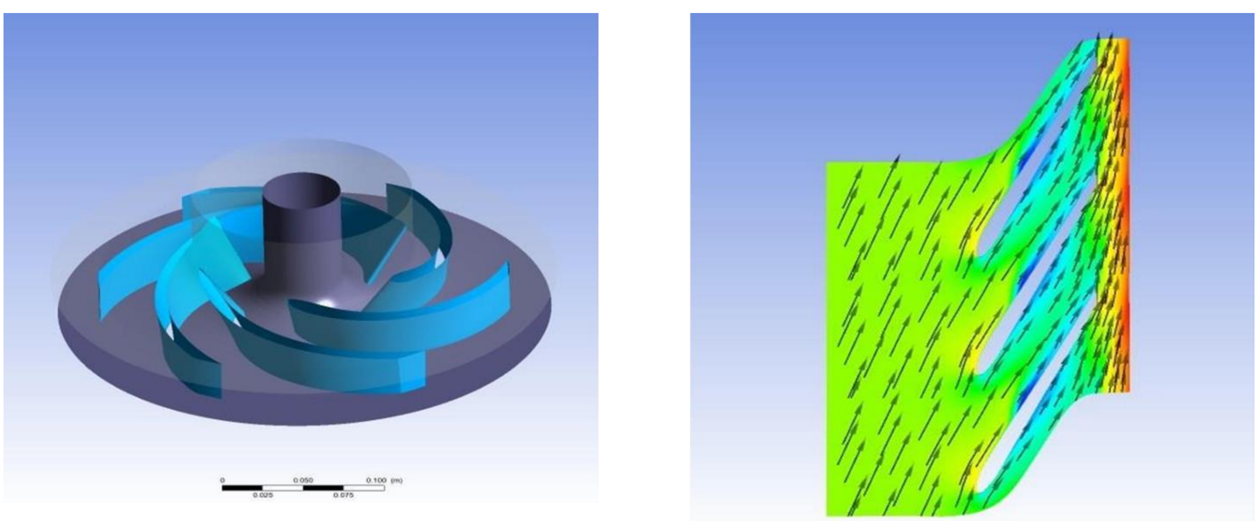


***Figure 3 : Impeller Flow***

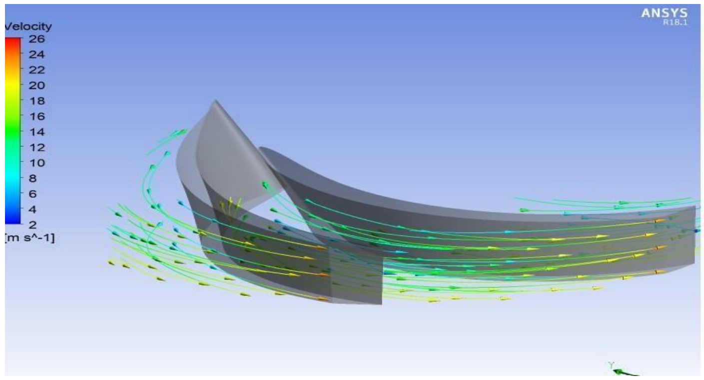



***Figure 4 : Impeller Flow Sectional***

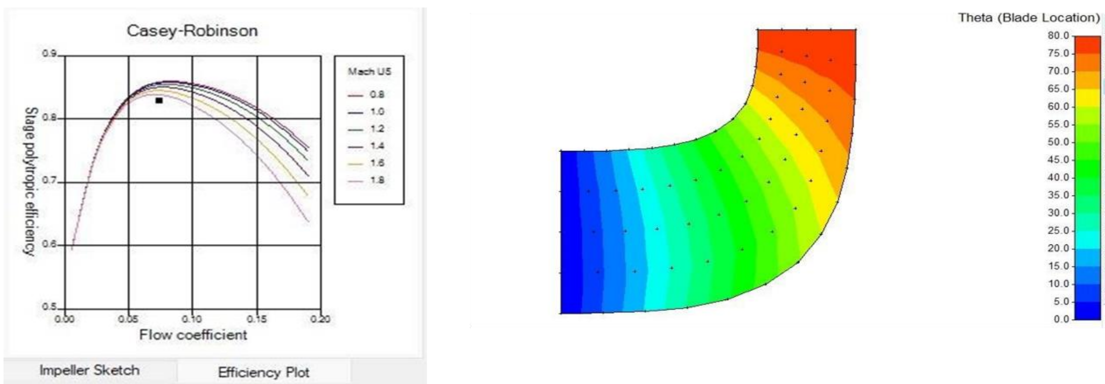



***Figure 5 : Casey Robinson Graph***

Pro/Engineer, developed by PTC Corporation Ltd., is one of the world's leading CAD/CAM/CAE packages. Being a solid modeling tool, it not only 3D parametric features with 2D tools, but also addresses every design through manufacturing process. Besides providing an insight into the design content, the package promotes collaboration between companies and provides them with edge over their competitors.

In addition to creating solid models and assemblies, 2D drawing view can also be generated in the drawing mode of Pro/E. The drawing views that can be generated include orthographic, section, auxiliary, isometric or detail views.

Pro/E uses parametric design principles for solid modeling. This modeling software provides an approach to mechanical design automation based on solid modeling technology and the following features.

## IV. 3D MODELING

The essential difference between Pro/E and traditional CAD systems are the models created in Pro/E exist as 3D solids. Other 3D modelers represent only the surface boundaries of the model. Pro/E models the complete solid. This is not only facilitating the creation of realistic geometry, but also for accurate model calculations, such as those for mass properties.

Dimensions such as angle, distance, and diameter control Pro/E model geometry. You can create relationships that allow parameters to be automatically calculated based on the value of other parameters. When you modify the dimensions, the entire model geometry can update according to the relations you created.

We created models in Pro/E by building features. These features have intelligence, in that they contain knowledge of their environment and adapt predictably to change. Each feature asks the user for specific information based on the feature type. For example, a hole has a diameter, depth, and placement, while a round has a radius and edges to round.

Pro/E is a fully associative system. This means that a change in the design model anytime in the development process is propagated throughout the design, automatically updating all engineering deliverables, including assemblies, drawings, and manufacturing data. Associatively makes concurrent engineering possible by encouraging change, without penalty at any point in the development cycle. This enables downstream functions to contribute their knowledge and expertise early in the development cycle.

The strength of parametric modeling is in its ability to satisfy critical design parameters throughout the evolution of a solid model. The concept of capturing design intent is based on incorporating engineering knowledge into a model. This intent is achieved by establishing features and part relationships and by the feature dimensioning scheme.

Post processing means reviewing the results of an analysis. It is probably the most important step in the analysis, because we are trying to understand how the applied loads affect your design, how good our finite element mesh is, and so on.

The solution phase calculates two types of result data:

Primary data consist of the degree-of-freedom solution calculated at each node:

displacements in a structural analysis, temperatures in a thermal analysis, magnetic potentials in a magnetic analysis, and so on.

Derived data are those results calculated from the primary data, such as stresses and strains in a structural analysis, thermal gradients and fluxes in a thermal analysis, magnetic fluxes in a magnetic analysis, and the like. Derived data are also known as element solution data, except when they are averaged at the nodes. In such cases, they become nodal solution data

ANSYS supports the number of elements to cover various types of problems. Depending on the nature of model, the element type is defined. It is desirable if various elements can be generated to provide users with the required flexibility to meet the compatibility and completeness requirements.

In this braking system analysis both thermal loads and structural loads are acting when brake is applied. So a combination both thermal and structural analysis should be done in the ANSYS. We selected an element SOLID98 Tetrahedral Coupled-Field Solid, which can resolve both thermal and structural problems. This element is a 3-D solid element.

The preprocessing stage consists of generation of model as per the requirement and dividing it into discrete finite elements by using an option called "mesh". This stage also including element selection according to our application, specifying real constants and material properties as per requirements. Once the model is generated then it is taken it into second stage called execution. The problem is solved in this stage by applying the loads and boundary conditions to the model. The results of the problem can be viewed in the third stage called postprocessing stage where the options for listing of results per node or per element etc., are available.

## V. RESULTS

The performance of our bladeless ceiling fan was analyzed and compared against a normal ceiling fan based on velocity distribution, pressure variation, lift & drag forces, efficiency, and air circulation time. Our ANSYS CFX simulations and calculations confirm that our design offers superior airflow efficiency, reduced turbulence, and better energy utilization.

### A. Velocity Distribution

The airflow velocity is a crucial factor in determining a fan's cooling efficiency. Our CFX results show:

| Fan Type | Inlet (m/s) Velocity | Outlet (m/s) Velocity | Improvement (%) |
|---|---|---|---|
| Normal Ceiling Fan | 5.0 | 1.2 | - |
| Bladeless Ceiling Fan (Our Design) | 6.9 | 1.5 | 25% Higher |

***Table 3 : Velocity distribution***

The bladeless fan generates an outlet velocity of 1.5 m/s, 25% greater than a normal ceiling fan, ensuring better air distribution and faster cooling.

### B. Pressure Distribution

The pressure variation across the impeller and NACA blade section influences the stability of airflow. Our CFX analysis showed:

- Normal Fan: Uneven pressure distribution due to direct blade contact with air, leading to turbulence.
- Bladeless Fan: A smooth pressure gradient, reducing turbulence and improving airflow consistency.

### C. Lift And Drag Forces

| Parameter | Normal Blade Fan | Bladeless Fan (NACA Blade) | Improvement (%) |
|---|---|---|---|
| Lift Force (N) | 4.24 | 1.77 | - |
| Drag Force (N) | 0.60 | 0.073 | 87.8% Lower |
| Lift-to-Drag Ratio | 7.06 | 24.25 | 3.43x Higher |

***Table 4 : Lift and Drag force***

### D. Fan Efficiency Calculation

| Fan Type | Efficiency (%) | Improvement (%) |
|---|---|---|
| Normal Fan | 13.12% | - |
| Bladeless Fan (Our Design) | 48.025% | 3.66x Higher |

***Table 5 : Fan Efficiency***

### E. Time Taken For Air To Reach The Ground

| Fan Type | Outlet Velocity (m/s) | Time Taken (s) | Improvement (%) |
|---|---|---|---|
| Normal Ceiling Fan | 1.0 | 2.51 | - |
| Bladeless Ceiling Fan Design) (Our | 1.5 | 2.03 | 19% Faster |

***Table 6 : Time taken air to reach ground***

## VI. OVERALL PERFORMANCE COMPARISON

| Performance Metric | Normal Ceiling Fan | Bladeless Ceiling Fan (Our Design) | Improvement |
|---|---|---|---|
| Outlet Velocity | 1.0 m/s | 1.5 m/s | 50% Higher |
| Lift Force | 4.24 N | 1.77 N | - |
| Drag Force | 0.60 N | 0.073 N | 87.8% Lower |
| Lift-to-Drag Ratio | 7.06 | 24.25 | 3.43x Higher |
| Fan Efficiency | 13.12% | 48.025% | 3.66x More Efficient |
| Air Circulation Speed | 2.51 s | 2.03 s | 19% Faster |

## VII. CONCLUSIONS

The design and analysis of the bladeless ceiling fan using an impeller-driven airflow system and NACA series blade profiles have demonstrated significant improvements over conventional ceiling fans. The primary objective of this project was to enhance airflow efficiency, reduce energy consumption, and ensure uniform air distribution while maintaining a compact and modern design. Through extensive computational fluid dynamics (CFX) simulations and performance comparisons, we have successfully validated the efficiency of our bladeless fan.

The results indicate that our bladeless fan achieves a fan efficiency of 48.025%, which is significantly higher than the 13.12% efficiency of a conventional ceiling fan. This demonstrates that our design optimally utilizes energy to generate airflow with minimal losses. Additionally, the bladeless fan reduces the time taken for air to reach the ground to 2.03 seconds, compared to 2.51 seconds in the conventional fan, ensuring faster and more effective air circulation. The lift-to-drag ratio of 24.25 in our bladeless fan further confirms its superior aerodynamic performance compared to the 7.06 ratio of the conventional fan.

he bladeless fan's ability to generate a more uniform airflow, along with its higher aerodynamic efficiency, makes it an innovative and practical alternative to traditional ceiling fans. This design not only enhances energy efficiency but also eliminates the hazards associated with rotating blades, improving safety for users. The absence of exposed blades also contributes to a sleek and modern aesthetic, making the bladeless fan suitable for residential, commercial, and industrial applications.

Further research and refinements, such as optimizing the impeller design, experimenting with different materials, and refining CFX simulations, could further enhance the fan's performance. The successful implementation of this bladeless ceiling fan concept represents a significant advancement in ventilation technology, offering an energy-efficient, safe, and aesthetically pleasing alternative to conventional fans.

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