

DESIGN AND FABRICATION OF BLADELESS DUCT ENGINE

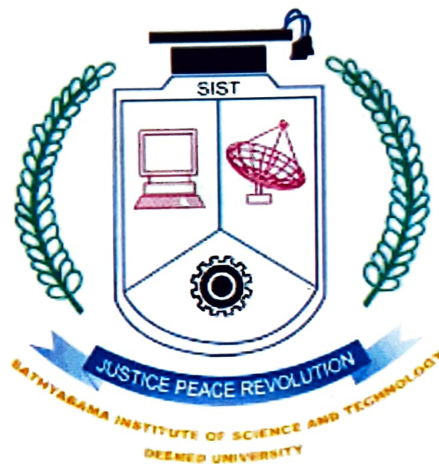
Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering degree in
Aeronautical Engineering

By

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**DEPARTMENT OF AERONAUTICAL ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND
TECHNOLOGY**

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A++" by NAAC

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APRIL - 2024



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **BHARATH S (40260006)** and **PRASANNA BALAJI S (40260018)** who carried out the project entitled "**Design and Fabrication of Bladeless Duct Engine**" under my supervision from November 2023 to April 2024.

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We **Bharath S (40260006)** and **Prasanna Balaji S (40260018)**, hereby declare that the project report entitled "**Design and Fabrication of Bladeless Duct Engine**" Done by us under the guidance of **Mr. G. Madhan Kumar., M.E., (Ph.D.)** is submitted in partial fulfilment of the requirement for the award of Bachelor of Engineering degree In Aeronautical Engineering.

Date: 05-04-2024

Place: Chennai



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ABSTRACT

The project titled "Design and Fabrication of Bladeless Duct Engine" represents a comprehensive exploration into groundbreaking propulsion technology. This research is centered on the development and construction of a bladeless duct engine, a revolutionary concept with the potential to reshape propulsion systems in various applications. The study covers the entire engineering process, ranging from the initial design and modeling phases to the hands-on fabrication of a prototype for the bladeless duct engine. Its primary goals include optimizing aerodynamic performance, improving energy efficiency, and mitigating noise emissions. The overarching aim of the project is to advance propulsion technology by leveraging the principles of fluid dynamics and cutting-edge engineering techniques. Through an examination of the feasibility and practicality of bladeless duct engines, this research paves the way for new possibilities in propulsion systems, spanning industries such as aviation, transportation, and energy generation. This abstract provides a summary of the project's scope, objectives, and the potential ramifications it holds for future technological advancements.

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LIST OF ABBREVIATIONS

SYMBOLS	DESCRIPTION
BDE	Bladeless Duct Engine
EDF	Electric Ducted Fan
UAV'S	Unmanned Arial Vehicles
CFD	Computational Fluid Dynamics
FEA	Finite Element Analysis
CFJ	Co-Flow Jet
AOA	Angle Of Attack
ECA	Engineless CFJ Aircraft
PIV	Particle Image Velocimetry
EA	Electric Airplane
VTOL	Vertical Take Off and Landing
MAV	Micro Aerial Vehicle
CTA	Constant Temperature Anemometer
HEP	Hybrid Electric Propulsion
PCM	Parallel Compressor Model
BLI	Boundary Layer Ingestion
ES	Large Eddy Simulation
BLDC	Brush Less DC
ESC	Electronic Speed Controller

CHAPTER 1

INTRODUCTION

The realm of propulsion technology has continuously evolved and innovated over time, driven by an unwavering pursuit of greater efficiency, reduced emissions, and enhanced performance. Among the most recent and captivating advancements in this field is the Bladeless Duct Engine. This concept challenges traditional methods of propulsion and holds the potential to revolutionize various industries.

The Bladeless Duct Engine stands in contrast to conventional engines that rely on spinning blades or propellers for thrust generation. Instead, it adopts a radically different approach by harnessing the principles of fluid dynamics and aerodynamics within an enclosed duct or chamber. This novel technology has garnered significant attention due to its capacity to address persistent limitations associated with traditional propulsion systems.

This introductory passage serves as an entry point for a deeper exploration of Bladeless Duct Engines. In the subsequent sections, we will delve into the core principles underpinning this propulsion concept, its versatile applications across different industries, the advantages and challenges it presents, and the ongoing research and development endeavors aimed at realizing this state-of-the-art technology. As we embark on this journey, we will uncover the transformative potential of Bladeless Duct Engines and their pivotal role in shaping the future of propulsion systems.

For over a century, propellers have remained the preferred means of propulsion for aircraft, helicopters, and watercraft. However, the rise of multi-rotor technology has underscored the constraints associated with this conventional propulsion method, posing a hurdle for emerging sectors such as drone deliveries and 'flying cars.' Apart from evident safety concerns, there is a diminishing returns issue when propeller blades spin at higher speeds, resulting in reduced effectiveness in converting energy into thrust. One major factor contributing to this efficiency bottleneck tied to RPM is that as blades rotate more rapidly, the vortex patterns in

the airflow become more pronounced, impeding propulsion efficiency. This constraint limits both payload capacity and operational range."

The idea for the Bladeless Thruster system was inspired by Dyson, a British tech manufacturer known for their product called the Air Multiplier—a fan that is quieter, more energy-efficient, safer, and notably lacks traditional blades. The Bladeless Thruster system consists of two primary components: either an Electric Ducted Fan (EDF) or a specially designed compressor, and a discharge frame. The electronic elements are responsible for drawing in air from the surroundings and directing it towards the discharge frame. The discharge frame is securely positioned to accelerate the incoming airflow. Similar principles involving pressure variations across an airfoil's surface are applied to the nozzle ring. As air is induced through the suction mechanism, a low-pressure area is created at one end of the ring, while a combination of induced and accelerated flows generates a high-pressure region at the opposite end of the ring. These principles are grounded in fundamental concepts of lift generation and can be employed to develop an advanced bladeless propulsion system for Unmanned Aerial Vehicles (UAVs).

Bladeless fans have gained widespread recognition due to their distinctive design and remarkable effectiveness, significantly impacting the fan sector. Currently, there is a lack of research on bladeless fans and a noticeable absence of studies dedicated to improving fan design. Therefore, the main goal of this article is to explore the performance of bladeless fans with various designs. In this research, we have created a prototype of a bladeless fan and conducted numerical simulations to evaluate its aerodynamic and aeroacoustics characteristics. Our analysis covers the entire fan prototype, including the wind channel, base, rotor, and stator. Additionally, we have investigated the effects of geometric parameters of the wind channel, focusing solely on the wind channel in our simulations. We have examined the impact of variables like slit width, cross-sectional height, slit placement, and cross-sectional profile. Importantly, as the wind strength increases, the generated noise consistently goes up. Among these parameters, the slit width of the wind channel has the most significant influence. When the slit is positioned farther from the leading edge, the bladeless fan produces a stronger airflow, but

this comes with an increase in noise. From Dyson to Jetoptera™, encompassing the evolution and comparative analysis of bladeless ducts.

The "Design and Fabrication of the Bladeless Duct Engine" signifies a pioneering and inventive approach to propulsion technology that has the capacity to bring about a significant transformation in the aerospace and transportation sectors. This innovative idea disrupts the conventional methods of propulsion by doing away with traditional blades and rotors, replacing them with a more effective and environmentally conscious ducted system. Within this introduction, we will delve into the core principles of the bladeless duct engine, its importance in tackling current propulsion challenges, and the potential advantages it presents, such as enhanced efficiency, reduced noise levels, and a greater focus on sustainability. As we explore the intricacies of this captivating technology, we will unveil the resourcefulness and engineering expertise that form the foundation of its design and construction. This research and development initiative not only pledges to propel the field of propulsion forward but also pledges to make a significant contribution to a worldwide future of transportation systems that are more sustainable and environmentally friendly.

1.1 USES OF BLADELESS DUCT ENGINE:

Bladeless duct engines, also known as bladeless turbines or jet less engines, have versatile applications:

- **Aerospace Propulsion:** Quieter and more fuel-efficient aircraft and spacecraft propulsion.
- **Power Generation:** Reduced maintenance, emissions, and enhanced efficiency in gas and steam turbines.
- **Wind Energy:** Efficient wind energy capture with minimal impact on wildlife and aesthetics.
- **Marine Propulsion:** Quieter and eco-friendly marine transportation.
- **Industrial Ventilation:** Improved air circulation and energy efficiency in factories and warehouses.

- Agricultural Applications: Noise reduction and fuel efficiency in agricultural machinery.
- Pumping Systems: Efficient water pumps and industrial fluid systems with low maintenance.
- Space Exploration: Reliable and quiet propulsion for space missions.
- Urban Transportation: Noise reduction and energy efficiency in buses and trains.
- Environmental Monitoring: Power source for UAVs and drones in eco-friendly data collection.
- Emergency Generators: Quiet and practical emergency power generators.

1.2 MODELLING AND DESIGNING OF BDE:

Designing a bladeless duct engine involves complex engineering across various domains:

- Conceptual Design: Define objectives, application, resources, and timeline.
- Aerodynamic Analysis: Use CFD to optimize duct shape for wind energy capture.
- Structural Design: Employ FEA to ensure durability against wind loads.
- Energy Conservation System: Choose generators or piezoelectric devices for power conversion.
- Control And Monitoring: Implement algorithms and sensors for performance optimization.
- Prototype Development: Validate design with scaled-down prototype and iterative improvements.
- Scaling Up: Upscale design considering manufacturing and logistics.
- Environmental Consideration: Assess carbon footprint and wildlife impact.
- Regulatory Compliance: Ensure adherence to safety and environmental regulations.
- Cost Assessment: Analyze expenses including materials, installation, and maintenance.

- Testing And Enhancement: Continuously optimize efficiency through testing, especially field testing.
- Deployment: Deploy validated design for renewable energy or specific applications.

1.3 CONCEPTUAL DESIGN OF BDE:

Creating a conceptual design for a bladeless duct engine involves several key steps:

- Establish Purpose and Goals: Define objectives and targets for efficiency and power output.
- Conceptualize Design: Envision the overall structure and components of the engine.
- Understand Aerodynamic Principles: Utilize the Coandă effect for energy generation.
- Design the Duct: Optimize shape and materials for efficient airflow.
- Select Energy Conversion Method: Choose from various mechanisms like piezoelectric generators.
- Consider Control and Regulation: Plan for managing and adjusting engine operations.
- Materials and Durability: Balance lightweight and durability in material selection.
- Address Safety and Environmental Impact: Mitigate risks and environmental effects.
- Prototype Development and Testing: Validate concept and performance with scaled-down prototype.
- Continuous Improvement: Iteratively enhance design for optimization.
- Estimate Costs: Assess projected expenses and budget constraints.
- Thorough Documentation: Create detailed records for future reference and communication.
- Future Prospects: Identify areas for further development and research to enhance technology.

1.4 BASIC CONSTRUCTION OF BDE:

A bladeless duct engine, also known as a bladeless fan or air multiplier, operates without conventional fan blades, gaining popularity through Dyson.

- Air Intake: Draws air through small vents or openings at the base.
- Air Amplification: Motor generates forceful airflow, accelerated through a narrow opening.
- Coanda Effect: Air adheres to curved surface, creating circular or spiral pattern.
- Diffusion: Generates low-pressure zone, attracting surrounding air for continuous flow.
- Airflow Multiplication: Curved surface and Coanda effect amplify initial airflow, creating high-velocity consistent airflow, hence the term "air multipliers."

CHAPTER 2

LITERATURE SURVEY

w. B. Brower, Jr. (1970) The survey investigates both theoretical and practical aspects of Project Tube flight conducted at Rensselaer Polytechnic Institute, with a primary emphasis on innovative high-speed ground transportation. Tube flight entails a vehicle design reminiscent of an aircraft fuselage, buoyed by air cushion apparatus, and driven within a non-evacuated tube utilizing diverse flow induction techniques. Principal areas of research encompass the guide way, propulsion and energy requirements, supporting mechanisms, and preliminary testing on a smaller scale.

N. W. M. KO et al (1977) This paper outlines a study focusing on the initial segment of three annular jets: the basic configuration without a central bullet, and variants with a conical and an elliptical bullet. By analyzing mean velocity and turbulence intensity measurements, the initial region is categorized into three zones: initial merging, intermediate, and fully merged. Similarity in velocity and turbulence intensity profiles is observed across these zones, compared with single-jet similarity curves.

J. Allen (1989) The Tesla Turbine, also called a shear-torque turbine, was analyzed by defining its operation and principles. First-order differential equations were derived and solved via iteration to model the turbine, and computer simulations provided insights into efficiency changes with parameter variations. An experimental model validated the theoretical findings, highlighting the turbine's distinct features and potential applications.

Luc G. FRECHETTE (2000) This thesis presents a microfabricated motor-driven compression system integrating high-speed rotating parts for electrical-to-fluidic power conversion. It features a centrifugal compressor on gas-lubricated bearings, powered by an electrostatic induction micromotor, all on a 1.5 cm silicon chip. Fabrication involves thin film processing, deep reactive ion etching, and wafer fusion bonding. Initial exploration focuses on gas-lubricated bearings using all-silicon devices, followed by integrating thin film electrical components to develop

the micromotor. Stable operation is achieved with hydrostatic journal bearings, enabling rotor speeds up to 1.4 million revolutions per minute. Motor-driven devices demonstrate typical operation but are limited to 15,000 revolutions per minute due to breakdown at 100V amplitude, with the cause remaining undetermined.

Ge-Cheng Zha et al (2005) Wind tunnel tests show the superior performance of the co-flow jet (CFJ) airfoil, especially with a smaller injection slot (0.65% chord length). It significantly boosts maximum lift (113% to 220%), stall margin (100% to 153%), and reduces drag coefficient (30% to 127%) across different momentum coefficients. Correlation analysis favors jet kinetic energy over momentum coefficient for lift and stall margin. Thicker injection slots lead to smaller stall angles and higher power requirements. CFJ airfoil may exceed the inviscid limit of maximum lift coefficient. Despite lacking configuration optimization, CFJ airfoil shows potential for further enhancement.

Ge-Cheng Zha et al (2006) The study compares an airfoil with injection only to a CFJ airfoil with both injection and suction, using similar injection momentum coefficients. CFD simulations reveal that suction in the CFJ airfoil significantly enhances mixing and energy transfer between the jet and main flow, leading to higher circulation, increased lift, elevated stall angle of attack, reduced drag, and lower energy consumption. The CFJ airfoil demonstrates significantly lower equivalent drag compared to the airfoil with injection only. Since any airfoil with jet injection requires jet suction to comply with mass conservation, the study suggests that suction on the suction surface, such as in the CFJ airfoil, is more advantageous than drawing jet mass flow from the aircraft engine inlet.

Baoyuan Wang et al (2007) Three CFJ airfoils were studied, each with progressively doubled injection slot sizes, utilizing a RANS CFD solver employing a 1-equation Spalart-Allmaras model. Under identical angles of attack (AoA), the airfoil featuring the largest injection slot size exhibited roughly twice the jet mass flow rate, alongside momentum coefficients nearly doubled as well. Interestingly, the CFJ airfoil with the largest slot size demonstrated the lowest stall angle of attack (AoA). Decreasing the injection slot size by half led to a rise in stall AoA and

maximum lift coefficient. However, further reduction of the injection slot size by half resulted in an increased stall AoA but a decrease in the maximum lift coefficient, attributed to the diminished momentum coefficient. This trend mirrors experimental observations. While computed lift and drag closely approximated experimental data at low AoA, both were underestimated at high AoA, likely due to the RANS model's limitations in handling turbulence mixing under such conditions.

B. P. E. Dano et al (2010) The research delves into the jet mixing dynamics of a co-flow jet (CFJ) airfoil to shed light on mechanisms that enhance lift, reduce drag, and increase stall margin. Employing Digital Particle Image Velocimetry, flow visualization techniques, and aerodynamic force measurements, the study unveils insights into the mixing behavior of CFJ airfoils. At low angles of attack (AoA) and low momentum coefficients, prominent mixing occurs between the wall jet and primary flow, characterized by sizable coherent structures. With an increase in momentum coefficient, these large structures diminish. At high AoA, where flow separation occurs, the CFJ induces an upstream flow strip amidst counter-rotating vertical shear layers, forming a vortex-free region known as UFS. Turbulence facilitates mixing between the CFJ and the primary flow, aiding in maintaining attachment at high AoA to enhance lift generation. Furthermore, heightened CFJ momentum coefficient amplifies turbulence within the jet injection mixing zone during flow separation.

S. Gopinath et al (2015) The paper computationally analyzes the impact of swirling co-flow and non-circular subsonic compressible inner jets on centerline velocity decay, mass entrainment, and jet spreading rate. Three exit shapes—elliptical, rectangular, and circular inner jets—are compared under three co-flow conditions: no co-flow, straight co-flow, and swirling co-flow from a circular annular duct. Swirling co-flow, generated by a swirler with 50° oblique angular vanes, significantly affects inner jet boundary conditions, altering major features like potential core length, centerline velocity decay, and jet spread rate. Velocity vector plots illustrate streamwise corner vortices, highlighting swirling co-flow's impact on jet flow field. Elliptical inner jet with swirling co-flow shows heightened velocity decay and

spreading rates compared to circular and rectangular counterparts of equivalent area.

B. Wiedow et al (2015) This dissertation explores the fluid dynamics of slot jet propulsion for enhancing thrust in UAVs, with the goal of devising a design devoid of external moving components. Weight and power estimates for lift requirements are derived from quadcopter rotor designs. Experiments investigate the effects of slot jet- induced flow entrainment and interactions with airfoils. Different configurations are tested, varying slot jet velocity and airfoil parameters. Experimental data, along with Particle Image Velocimetry, are employed to analyze turbulent mixing and thrust. Findings indicate that higher slot jet velocities and inward angles result in increased thrust, with efficiency optimized at larger spacing. The feasibility of utilizing slot jet propulsion for UAV lift is suggested by the results.

Alexis M. Lefebvre (2015) This thesis delves into the performance and potential applications of co-flow jet (CFJ) flow control, utilizing both experimental testing and computational fluid dynamics (CFD) simulations. It assesses CFJ's energy consumption, its ability to enhance lift, reduce drag, increase stall margin, remove dynamic stall, and its performance across different Mach numbers. The evaluation encompasses stationary airfoils, pitching airfoils, and 3D CFJ wings. Following this analysis, CFJ technology is utilized in the design of an ultra-high wing loading general aviation electric airplane (EA).

Ruixiong Li et al (2016) A bladeless turbine, emerging as a promising power generation system, underwent analysis on its operational characteristics. An experimental platform employing an incompressible working medium was designed constructed to explore turbine performance parameters. Relationships among these parameters were scrutinized through experiments, while numerical simulation software was utilized to study flow characteristics of the working medium inside the turbine. Analysis of entry and exit losses was conducted, with data from simulations aligning with calculations using a partial loss model developed herein. This model accurately calculates partial loss of a bladeless turbine, making it suitable for turbine design and optimization.

Nuno Vinha et al (2016) Prospective propulsion systems might rely on harnessing energy from high supersonic flows. Traditional supersonic turbines, which operate under such extreme conditions, encounter difficulties due to flow disruptions induced by blades, resulting in aerodynamic inefficiencies and limited operational capabilities, especially during startup. This situation presents opportunities for bladeless turbine arrangements. This article presents a concept for an axial bladeless turbine capable of extracting mechanical power from high supersonic flows within an annular channel. Power generation is accomplished through tangential drag forces acting on rotating inner and outer end-walls, providing advantages in terms of simplicity, cooling, and maintenance. Reynolds-averaged Navier–Stokes simulations offer detailed insights into the aerodynamic performance of this bladeless configuration. This unconventional axial turbine design emerges as a viable option for extracting power from supersonic flows with minimal pressure losses.

Ruixiong Li et al (2016) The bladeless turbine shows promise as a novel power generation system. An experimental platform was constructed to explore its operational characteristics using an incompressible working medium. Performance parameters were analyzed through experiments, while numerical simulation software was employed to study flow characteristics within the turbine. Entry and exit losses were investigated, and simulation data aligned with calculations using a developed partial loss model, affirming its suitability for bladeless turbine design and optimization.

Mohammed-Baker Habhab et al (2017) In 1913, Nikola Tesla introduced the bladeless turbine concept, encountering challenges such as maintaining laminar flow between rotor disks and limited practical applications due to its smooth flow outputs. These constraints can be addressed by scaling down to the microfluidic flow regime. Presented here is a microscale Tesla pump, manufactured using a Digital Light Processing (DLP) based 3D printer. This miniaturized pump operates at a low Reynolds number of 1000 and achieves a flow rate of up to 12.6 mL/min at 1200 rpm, producing 53 μ W of pump power. When integrated with a Tesla-valve based mixer network, it forms a fully Teslainspired microfluidics system.

James Braun et al (2017) This study optimizes axial bladeless turbines for supersonic flows encountering oblique shock waves. Using 3D Unsteady Reynolds Averaged Navier Stokes simulations via CFD++, the turbine's performance was enhanced by shaping the end wall to increase pressure forces. A sinusoidal wave-based parametrization was proposed, with parameters such as wave amplitude and helix angle significantly impacting power extraction, potentially increasing by 210%.

Yunchao Yang et al (2018) This paper explores the enhancement of lift using Co-Flow Jet (CFJ) active flow control for circular cylinders at a Reynolds number of 3×10^6 .

The investigation surpasses the theoretical lift limit of 4π through zero-net mass-flux CFJ. Validated Computational Fluid Dynamics (CFD) simulations, employing a 2D Reynolds-Averaged Navier-Stokes (RANS) solver with a Spalart-Allmaras turbulence model, reveal a super-lift coefficient of 28 at $C_\mu = 0.8$. Parametric studies involve varying configurations of CFJ injection and suction slots. The circulation between injection and suction aids in attaching the flow field around the cylinder, thereby detaching the stagnation point from the surface.

Daniel Valdenegro et al (2018) The research aimed to develop a bladeless multirotor UAV to address safety concerns posed by exposed propellers. Inspired by Dyson's bladeless fan, the project focused on bladeless technology, including cross-section geometry, airflow properties, impellers, motors, and power sources. Using CAD and CFD, a nozzle design was created to attach to an Electric Ducted Fan (EDF), forming a bladeless thruster prototype. Four such thrusters were 3D printed and tested, initially in pairs to assess stability in pitch or roll, and then in a full configuration to evaluate stability in all three dimensions.

Debiao Meng et al (2018) In turbine design, the shape of blades plays a crucial role in both structural integrity and aerodynamic efficiency. This research presents a method that integrates fluid-structure coupling analysis to illustrate multidisciplinary design optimization. Moreover, an approach based on uncertainty is introduced to bolster blade reliability and safety. Utilizing design of experiment techniques, response surfaces are constructed, leading to enhanced adiabatic

efficiency and reduced equivalent stress, ultimately resulting in improved turbine performance.

Yunchao Yang et al (2019) The Co-Flow Jet (CFJ) technology shows promise in enhancing aircraft performance by augmenting lift and reducing drag with minimal energy consumption. This paper explores the benefits of CFJ hybrid electric propulsion (HEP) in a conceptual design for a regional airliner, using the ATR72-500 as a baseline. The CFJ-HERA extends the range of the ATR72-500, utilizing an optimized CFJ wing configuration. Two aspect ratios, 12 and 20, are compared, both achieving significantly higher productivity efficiency and longer ranges than the baseline. The CFJ-HERA design demonstrates the potential of CFJ technology in advancing hybrid propulsion aircraft.

A. Bahrami et al (2019) This paper presents an experimental study of a flow control technique applied to a co-flow jet's airfoil, comparing jet-on and jet-off conditions. Using the CFJ0025-065-196 airfoil at a Reynolds number of 10^5 , turbulence components were measured via hot wire anemometry in a wind tunnel. The analysis examines the impact of average velocity and boundary layer thickness on the airfoil for various coflow velocities and angles of attack. Results indicate that increasing velocity difference delays separation, particularly at higher angles of attack, leading to improved lift and reduced drag coefficients, demonstrating the efficacy of this flow control method.

Gandomkar M et al (2019) This research assesses the Coanda effect phenomenon for underwater propulsion by means of experimental and numerical investigation. The Coanda effect, characterized by a jet flow adhering to a convex surface, is leveraged to enhance flow volume rate through a nozzle-diffuser channel. Experimental Bollard tests investigate system behavior regarding gap size and jet flow rate, complemented by numerical simulations. The outcomes reveal strong alignment between numerical predictions and experimental observations. Projections based on the numerical model suggest the viability of employing water flow multipliers as efficient underwater propulsion systems, offering performance on par with conventional propellers.

James Baur et al (2020) A novel type of bladeless turbines has been developed to extract power from axial inflows at supersonic speeds without inducing swirl. This turbine design incorporates a wavy hub surface to create shocks and expansion fans, facilitating torque generation. Initially, a baseline turbine is conceptualized, and the power extraction mechanism is analyzed. MATLAB is utilized to parameterize the turbine surface, which is then imported into Hex press for meshing, followed by CFD++ for solving the steady Reynolds-averaged Navier-Stokes (RANS) equations. This approach simplifies the work extraction principle from a complex three-dimensional unsteady problem to a two-dimensional steady phenomenon. An experimental campaign is outlined, which includes discussions on the operational envelope, scaling considerations, and characterization of the bladeless turbine under various mass flow rates, speeds, and geometrical configurations.

Christof Ocker et al (2020) This research delves into the aerodynamic performance and noise emission of airfoils and fan blades featuring perforated leading edges through experimental analysis. Sixteen airfoils with various leading-edge designs were subjected to testing in a wind tunnel, employing aluminum alloy airfoils fabricated using additive manufacturing techniques. Aerodynamic performance was evaluated utilizing a wind tunnel balance, while acoustic measurements were carried out using a planar microphone array. Subsequently, fan blades with four perforated leading-edge designs were produced with the objective of mitigating turbulence ingestion noise in axial fans. Assessments were conducted under both free inflow and grid-generated turbulent inflow conditions. The results indicate a reduction in noise dependent on frequency, yet also reveal a compromise in aerodynamic performance.

Kewei Xu et al (2020) This paper investigates the performance of a micro-compressor with integrated co-flow jet (CFJ) airfoil injection and suction ducts, simulating wind tunnel testing conditions using a 3D Reynolds Averaged Navier-Stokes (RANS) solver with the k- turbulent model. Boundary conditions from wind tunnel testing are applied, and five RPMs are simulated. Results show good agreement with experimental measurements, with a maximum discrepancy of less

than 3% in static pressure ratio. However, the micro-compressor operates off-design due to low static pressure near the CFJ injection area, resulting in decreased efficiency from 80% to about 25%. This mismatch is attributed to loose integration between the CFJ airfoil and the compressor, highlighting the need for an integrated design process to avoid such pressure discrepancies.

Andrei Evulet (2021) A vehicle comprises a main body and a fluid generator producing a fluid stream, with at least one tail conduit fluidly connected to the generator. First and second fore ejectors, located on starboard and port sides, respectively, include outlet structures for fluid flow. At least one tail ejector, connected to the tail conduit, also features an outlet structure for fluid flow. A primary airfoil element includes a closed wing with leading and trailing edges defining an interior region. Within this region, at least one propulsion device is partially located.

Andrei Evulet (2021) A vehicle consists of a main body and a gas generator that produces a stream of gas. The generator is fluidly connected to at least one fore conduit and a tail conduit. There are first and second fore ejectors attached to the fore conduit, and at least one tail ejector connected to the tail conduit. The fore ejectors have structures at their outlets for directing the gas flow from the fore conduit, and similarly, the tail ejector has a structure at its outlet for directing the gas flow from the tail conduit. Positioned downstream of the first and second fore ejectors are leading edges of first and second primary airfoil elements, respectively. Additionally, downstream of the outlet structure of the tail ejector, there is at least one secondary airfoil element with a leading edge.

Jonas Voigt et al (2021) This methodological study assesses boundary layer ingestion (BLI) as a means to enhance propulsion efficiency by utilizing the low momentum inflow of the wing or fuselage boundary layer for thrust generation. A multi-segment parallel compressor model (PCM) is developed to calculate power savings from full annular BLI, considering adverse effects on fan performance due to varying inlet distortions and boundary layer suction. This model allows for evaluation of synergies between BLI and active laminar flow control as a drag

reduction measure, contributing to lower fuel consumption and environmental impact of future transport aircraft.

Siyang He et al (2022) In this study, a novel fluidic flow monitoring method for non-full pipe conditions in large pipelines is proposed, utilizing triboelectric nanogenerators (TNPFS). The TNPFS simultaneously monitors flow velocity and liquid level, with flexible blades generating periodic electrical signals for velocity monitoring. Liquid level monitoring employs a variable area interdigital electrode design based on liquid-solid contact electrification principles. Experimental results show a linear relationship between voltage frequencies and flow velocities, and peak number trends correlate with liquid level. A real-time monitoring system effectively measures flow rates from 94 to 264 L/min with less than 1.95% error compared to actual measurements. The TNPFS demonstrates good responsiveness in sewage, offering a promising solution for fluidic flow monitoring, particularly in large pipelines with non-full flow conditions.

Andrei Evulet (2022) The vehicle consists of a main body housing a fluid generator that produces a fluid stream. The generator is connected to at least one fore conduit and at least one tail conduit. Positioned on the starboard and port sides of the vehicle, first and second fore ejectors are attached to the fore conduit. Each fore ejector has a structure at its outlet for directing fluid flow. Additionally, at least one tail ejector, also featuring an outlet structure for fluid flow, is connected to the tail conduit. A primary airfoil element is affixed to the tail section, with its surface situated directly downstream of the first and second fore ejectors, allowing fluid flow from these ejectors to pass over its surface.

Shubham Tomar et al (2022) The aim is to provide bladeless cool air, enhancing comfort and productivity. Bladeless air coolers are essential for alleviating stress and maintaining productivity, particularly during hot weather. This project focuses on an innovative bladeless air cooler with improved cooling efficiency achieved through blade rotation, although the blades are not visible. It employs advanced Air Multiplier Technology to draw and compress air, ensuring safety and variable

cooling options. Additionally, the cooler can provide hot air during winter seasons via a nichrome wire coil. This versatile bladeless air cooler serves both cooling and heating purposes, offering superior performance compared to traditional coolers in daily life.

Md. Sazzat Hossain et al (2022) A bladeless air conditioning fan is innovatively designed to provide silent and blade-free cooling, offering relief from summer heat. It incorporates a miniature Peltier-based cooling system and a blower mechanism to draw in air from the bottom and emit cool air from the top. The product features a noise cancellation module to minimize sound disruption. This compact and portable bladeless fan doubles as an air conditioner, offering both functionality and aesthetics. Compared to conventional coolers, this bladeless air conditioner excels in cost-effectiveness, style, size, and shape.

Ruochen Wang et al (2022) The study investigates the impact of key parameters in Co-Flow Jet (CFJ) technique on airfoil aerodynamics using numerical simulations. Parameters include jet momentum coefficient, injection slot location and size, suction slot location and size, and suction slot angle. Validated by a CFJ6415 airfoil case, the numerical method shows good agreement with experiments. Results indicate larger jet momentum coefficients enhance lift, reduce drag, and enlarge stall margin, while smaller coefficients improve aerodynamic efficiency at low angles of attack. Injection slot location has minimal influence on lift coefficient. Increasing injection slot size initially decreases then increases power coefficient and aerodynamic efficiency. Drag coefficient rises consistently with downstream suction slot location. Smaller suction slot sizes or larger angles improve CFJ airfoil aerodynamics by reducing drag.

CHAPTER 3

AIM AND OBJECTIVES

The objectives and goals of a bladeless duct engine project, much like any engineering endeavor, are pivotal in steering the process of design, development, and execution. Here, you will find the standard aims and objectives for a bladeless duct engine project:

3.1 AIM:

- **Efficiency Enhancement:** Bladeless duct engines aim to achieve more effective air movement with lower energy consumption compared to traditional fans.
- **Noise Reduction:** They strive to minimize noise levels, especially in noise-sensitive environments like homes and offices.
- **Safety Priority:** Efforts are made to eliminate potential hazards associated with exposed blades, making them suitable for various settings.
- **Customizable Airflow:** Users can tailor direction and intensity according to their preferences for greater control.
- **Compact and Aesthetic Designs:** They feature designs that are compact and aesthetically pleasing, aiming for seamless integration into different environments while saving space.
- **Environmental Responsibility:** Bladeless duct engines focus on reducing environmental impact through energy-efficient operations and the use of sustainable materials.

3.2 OBJECTIVES:

In the design and testing phases of bladeless duct engines, a comprehensive approach is necessary to address various critical aspects. Firstly, defining precise performance metrics is crucial to evaluate factors such as airflow velocity, noise levels, energy consumption, and overall efficiency. This helps in setting clear objectives and benchmarks for the product's performance. Safety standards play a pivotal role in ensuring that the design adheres to or exceeds regulatory requirements related to consumer product safety. This includes eliminating potential hazards associated with exposed blades and

other safety concerns to safeguard users and comply with legal mandates. Customization options allow for the integration of adjustable features like variable airflow settings and direction control, catering to diverse user preferences and needs. This enhances usability and versatility, contributing to a more tailored user experience. Cost efficiency goals aim to optimize the design and manufacturing processes to ensure affordability without compromising on performance or reliability. This involves streamlining production methods and material selection to minimize production costs. Environmental impact assessment involves evaluating the device's carbon footprint, energy efficiency, and material usage to minimize ecological repercussions. By setting objectives to reduce environmental harm, companies can contribute to sustainability efforts. Fostering innovation and uniqueness is essential for standing out in the market. This entails differentiating the bladeless duct engine design from existing solutions through novel features, technologies, or design elements, potentially leading to patents or proprietary designs. Enhancing user experience involves delivering a seamless and pleasant airflow experience, ergonomic controls, and user-friendly features. Prioritizing user satisfaction can lead to increased product adoption and customer loyalty. Regulatory compliance ensures that the design meets industry-specific regulations and standards concerning safety, emissions, and performance. This is vital for market entry and maintaining credibility with consumers and regulatory bodies. Reliability and durability objectives focus on guaranteeing consistent performance throughout the device's expected lifespan. This includes rigorous testing procedures to identify and address potential weaknesses or failure points. Market acceptance goals involve targeting specific market segments such as residential, commercial, or industrial sectors and achieving a favorable reception among consumers. Understanding market needs and preferences is crucial for successful product penetration and adoption. Lastly, allocating resources for ongoing research and development enables companies to stay competitive and adaptable in response to emerging technologies and market trends. Market.

CHAPTER 4

METHODOLOGY AND COMPUTATIONAL ANALYSIS

4.1 METHODOLOGY:

The methodology for this project will involve experimental testing in a wind tunnel to validate the numerical simulations and optimize the design of the duct and impeller.

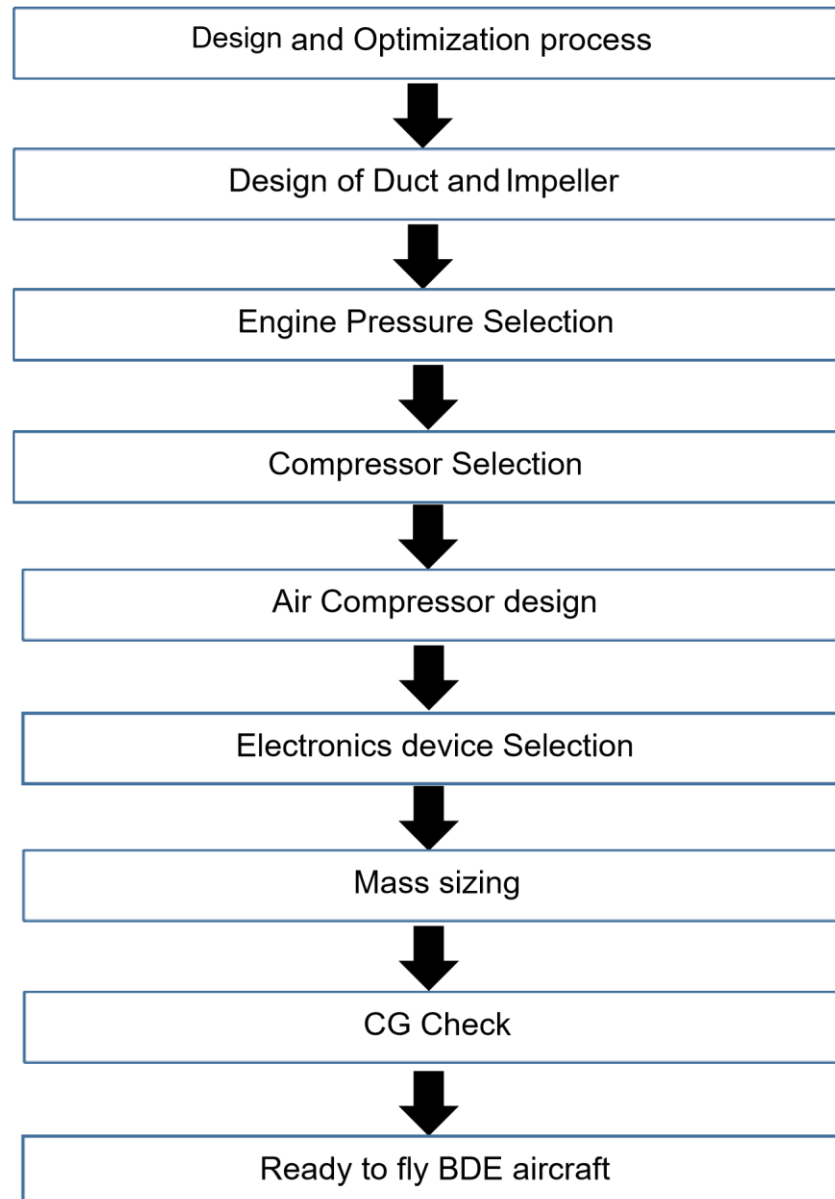


Fig 4.1: Methodology

4.2 DESIGN:

4.2.1 Design of duct:

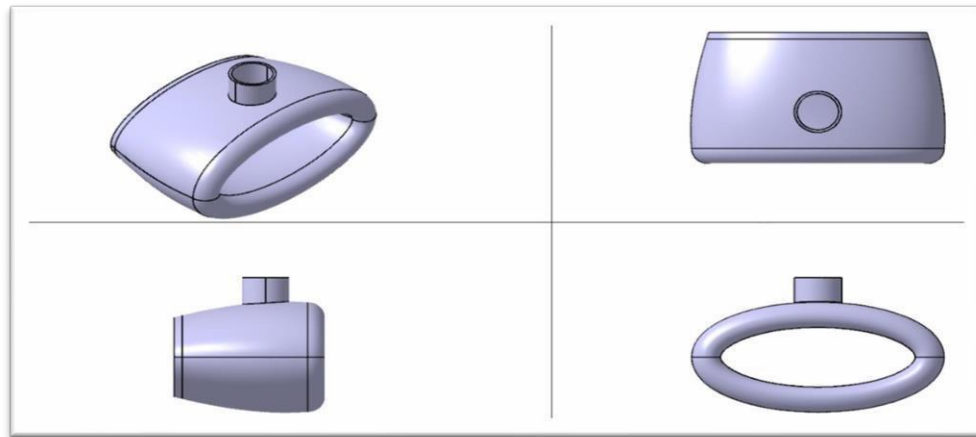


Fig:4.2 : Designed Duct

Ducts serve as conduits for transporting fluids, gases, or materials from one location to another and are essential across various sectors and applications. In HVAC systems, ductwork distributes treated air for maintaining indoor comfort, while engine ducts in aeronautics regulate airflow to aircraft engines, impacting performance. Ducts are also vital in industrial processes for conveying liquids or gases. Proper design and maintenance are crucial for ensuring the effective and safe operation of these systems.

4.2.2 Design of Impeller:

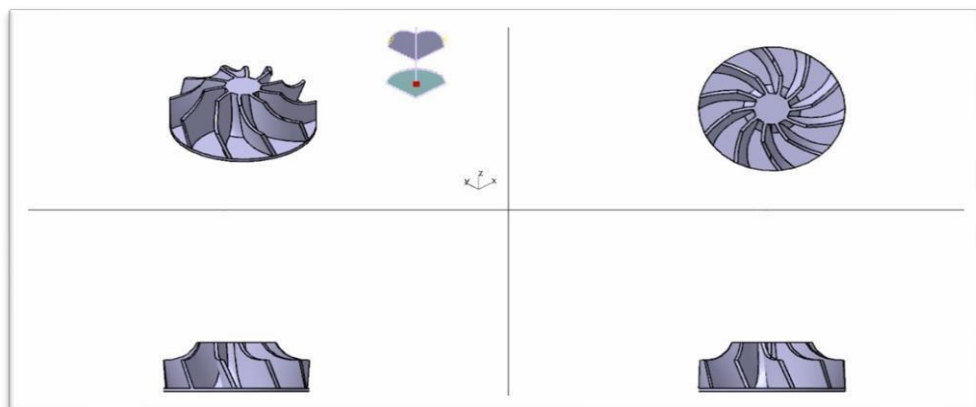


Fig:4.3 : Designed impeller

Impellers, crucial components in mechanical systems, facilitate fluid transfer in diverse applications. From household gadgets like blenders to industrial machinery like pumps and turbines, impellers induce fluid motion efficiently. In water treatment, oil refining, and chemical production, impellers maintain specified flow rates and pressures. Design and material selection ensure effectiveness, robustness, and reliability, while proper maintenance and balance extend service life and sustain peak performance.

4.2.3 Design of BDE Aircraft:

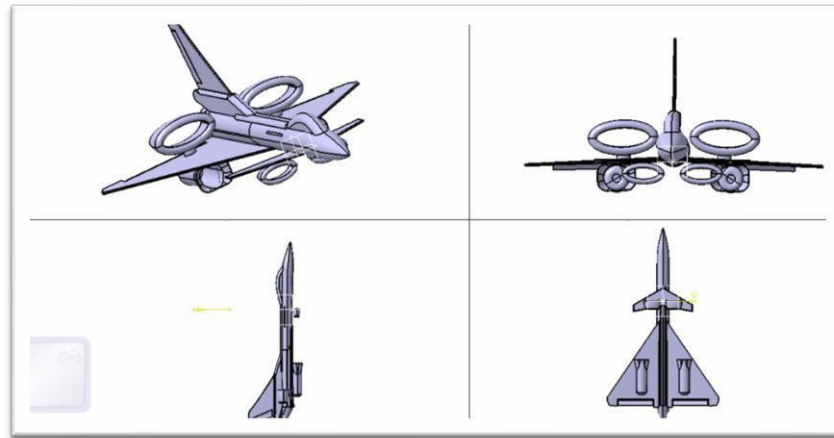


Fig:4.4 : Aircraft Design

Designing a bladeless duct engine for aircraft using CATIA involves: conceptualizing objectives, modeling components, simulating performance, ensuring integration, rigorous testing, iterative refinement, and comprehensive documentation, achieving efficiency, reliability, and regulatory compliance.

4.3 COMPUTATIONAL ANALYSIS:

Computational analysis in the field of aeronautics, often known as Computational Fluid Dynamics (CFD), plays a crucial role in the creation, advancement, and examination of aircraft and aerospace systems. CFD employs computer-based simulations and mathematical models to gain insights into and forecast the behavior of fluids, typically air, in proximity to an aircraft or its individual

components. Here's a concise overview of the applications of computational analysis in aeronautics:

4.3.1 Aerodynamic Analysis: CFD is widely employed for the thorough evaluation of an aircraft's aerodynamic performance. Engineers employ simulations to analyze the flow of air over the aircraft's surface, allowing for the assessment of lift, drag, and other aerodynamic characteristics. This process contributes to the development of more efficient and fuel-conserving aircraft.

4.3.2 Structural Analysis: Computational techniques have the capability to anticipate the response of aircraft structures, encompassing elements like wings, fuselage, and landing gear, under varying loads and conditions. This is instrumental in guaranteeing the structural soundness and safety of the aircraft.

4.4 ANALYSIS OF DUCT:

Mesh statistics

Description	Value
Status	Mesh
Mesh vertices	81868
Tetrahedra	308502
Pyramids	3362

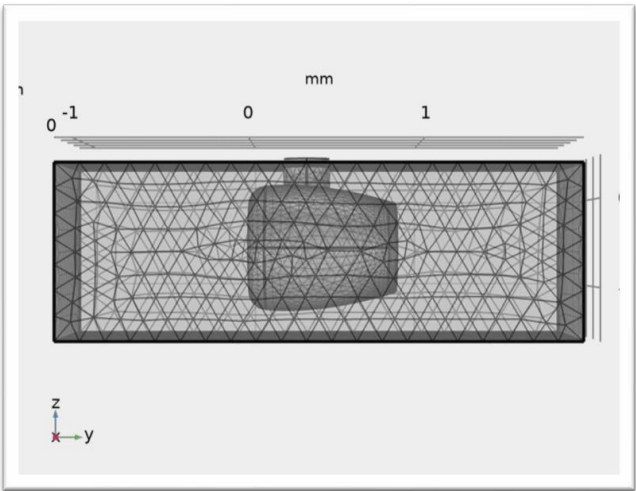


Fig4.5 Meshing of Duct

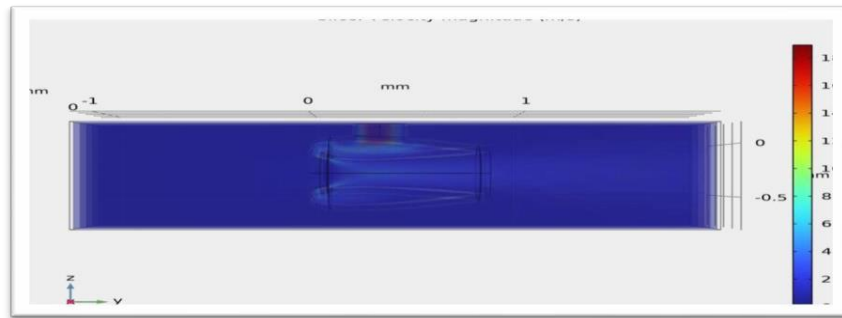


Fig:4.6 : Velocity Distribution

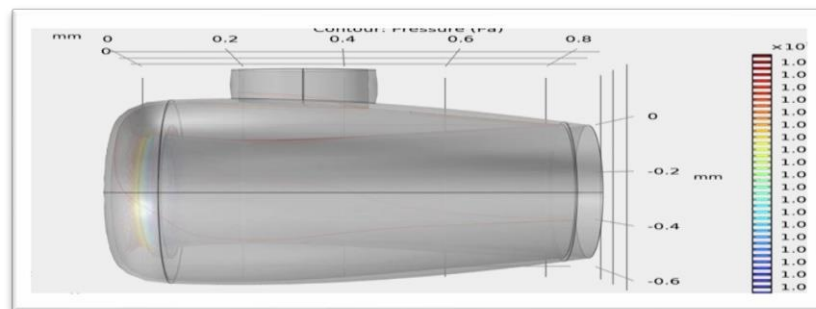


Fig:4.7 : Pressure Distribution

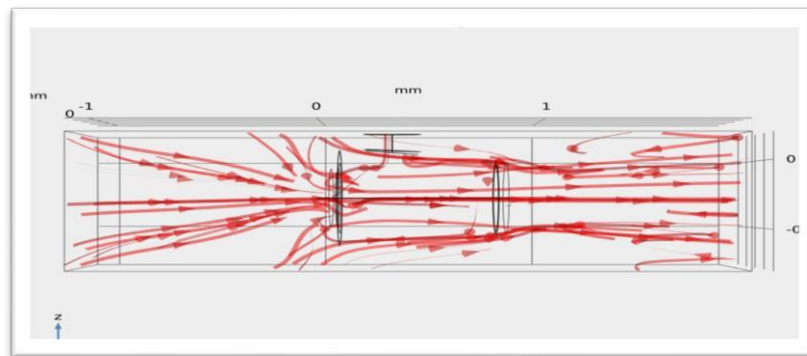


Fig:4.8 : Velocity Flow

CHAPTER 5

RESULT AND CALCULATIONS

5.1 VELOCITY COMPUTATION:

In ANSYS, the process of calculating the velocity distribution within a simulation as part of a fluid flow analysis typically involves the following key stages:

5.1.1 Preprocessing:

Geometry Preparation involves importing or creating a model. Mesh Generation constructs a detailed mesh, ensuring quality for accurate computations. Boundary Conditions Definition specifies parameters like inlets, outlets, and walls for simulation accuracy, adjusting velocities as needed. Use tools like ANSYS Meshing for efficient mesh construction.

5.1.2 Solver Configuration:

For fluid flow simulations in ANSYS, begin by selecting the suitable analysis system like Fluent. Define fluid properties such as density and viscosity. Configure solver settings for analysis type (steady-state or transient), turbulence models, and convergence criteria.

5.1.3 Executing the Simulation:

Run the simulation with the chosen settings. ANSYS will utilize the input data to resolve the fluid flow problem and generate the velocity field throughout the computational domain.

5.1.4 post-processing:

Following the completion of the simulation, you can engage in post-processing activities to visualize and extract velocity data. ANSYS offers various tools, with CFDPost being a notable example. Here's how to compute and visualize the velocity field: In post-processing with ANSYS, import simulation results and generate velocity visualizations like contour plots or streamline displays. Extract velocity data for further analysis at defined locations or paths. ANSYS offers various post-processing capabilities, but specifics may vary based on your

version and simulation. For detailed guidance, consult ANSYS documentation, tutorials, and user communities.

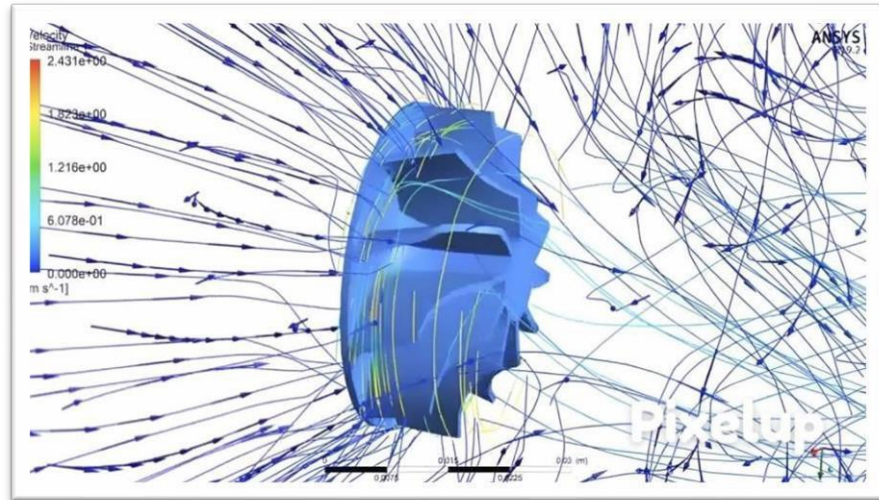


Fig:5.1 : Velocity Streamline

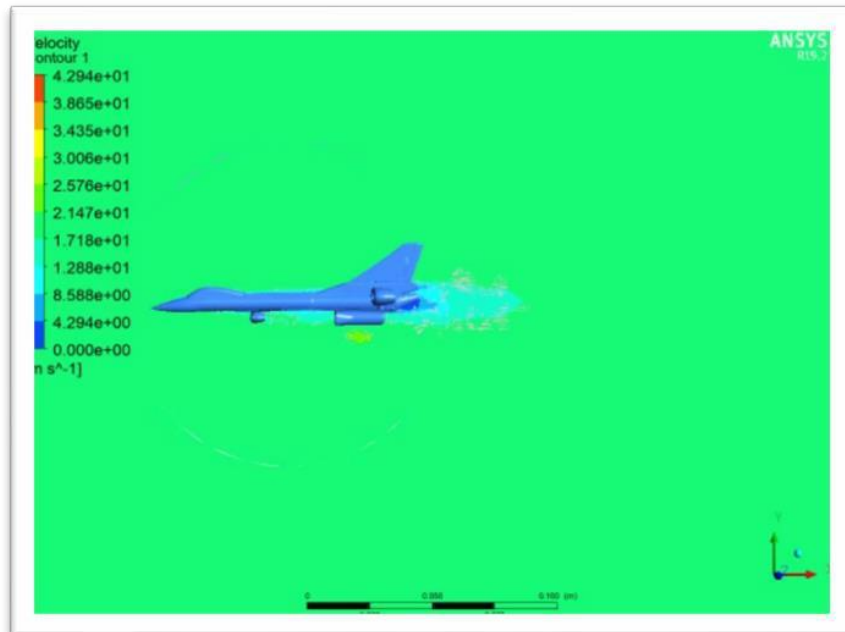


Fig:5.2 : Velocity Contour

5.2 PRESSURE COMPUTATION:

To calculate pressure in ANSYS, a typical procedure involves a series of steps within the context of a simulation. Below, I'll outline the general process for pressure calculation in ANSYS:

In the preliminary setup phase, prepare the geometry in ANSYS either by importing existing models or creating new ones. Generate a mesh to divide the geometry into elements, ensuring quality to facilitate accurate pressure calculations, utilizing ANSYS Meshing or external tools. Define boundary conditions such as inlets, outlets, and wall properties, and specify pressure values as required for the simulation. In the solver configuration stage, choose the appropriate system for analysis, be it structural or fluid flow, and define material properties including density and viscosity. Configure solver settings for the analysis type, turbulence models, and convergence criteria. Proceed to solve the problem by executing the simulation with the specified settings, allowing ANSYS to utilize the provided data to compute the pressure distribution across the computational domain. In the postprocessing stage, utilize ANSYS tools such as CFD-Post or Mechanical-Post to visualize and extract pressure data. Import simulation results and create pressure visualizations such as contour plots or vector representations. Extract pressure data from specific locations for further analysis. ANSYS offers various postprocessing capabilities, with specifics varying depending on the version and simulation; consult ANSYS documentation for comprehensive guidance on data visualization and analysis.

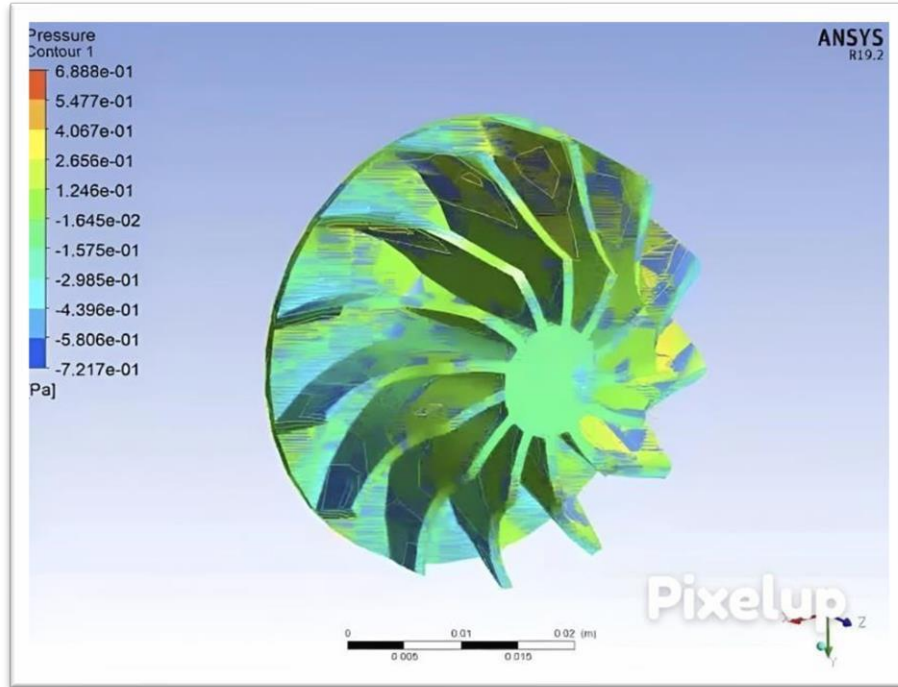


Fig:5.3 : Pressure Streamline

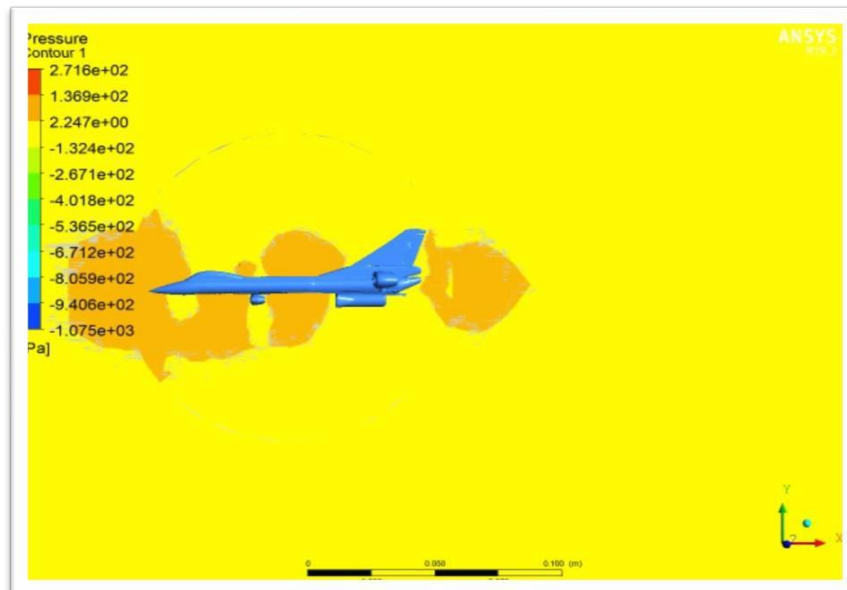


Fig:5.4 : Pressure Contour

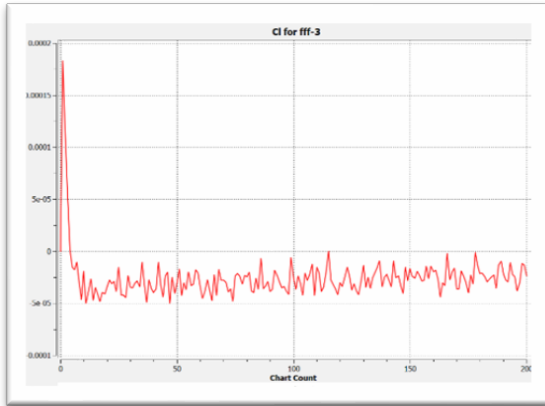


Fig:5.5 : Cl Graph

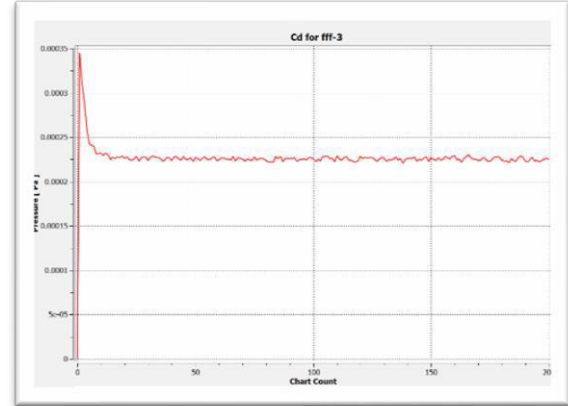


Fig:5.6 : Cd Graph

5.3 FABRICATION:

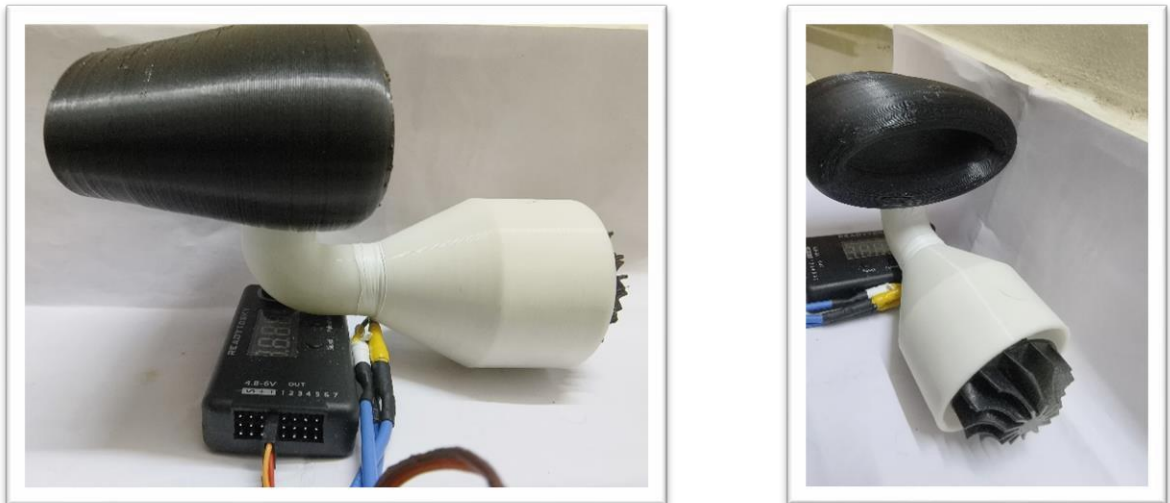
We have designed our impeller using 3D printing by using the material PLA. PLA, short for Polylactic Acid, is a widely employed substance in the realm of 3D printing. This thermoplastic material is known for its eco-friendly nature, being crafted from renewable sources such as cornstarch or sugarcane, and it is biodegradable.



Fig:5.7 : 3D Printed Impeller



Fig:5.8 : 3D Printed Duct



Fi: 5.9 : Engine Set-up

5.4 ELECTRONICS:

BLDC Motor:

- Popular among hobbyists and drone enthusiasts.
- Compact, lightweight design.
- Excellent power-to-weight ratio.
- Suitable for multirotor drones and RC aircraft.

- High-quality components: precision bearings, efficient windings. Smooth operation, minimal vibration. Produces significant thrust and power.
- Enables agile, responsive flight maneuvers.
- Known for durability, longevity.
- Withstands harsh flying conditions, frequent use.
- Favored for performance, reliability, value.



Fig:5.10 : BLDC Motor

Servo motor:

- Widely used micro servo motor.
- Compact size, versatile.
- Commonly used in RC vehicles, robotics, model airplanes.
- Lightweight design, precise control capabilities.
- Features plastic gearbox.
- Operates on 4.8V to 6V voltage range.
- Compatible with most standard power sources.
- Offers sufficient torque and speed.
- Suitable for controlling small mechanical components.
- Achieves precise movements.
- Affordable, reliable.
- Popular among hobbyists, DIY enthusiasts.



Fig:5.11 : Servo Motor

LiPo Battery:

The description "orange 11.1V 360mAh 30C 3S lithium polymer battery pack" provides information about a specific type of lithium polymer (LiPo) battery commonly used in remote-controlled vehicles, drones, and other electronic devices. Here's a breakdown of what each part of the description means:

- **Orange:** This likely refers to the color of the battery's outer casing or wrapping. It's purely aesthetic and doesn't affect the battery's performance.
- **11.1V:** This indicates the nominal voltage of the battery pack. In this case, it's 11.1 volts. This type of battery is known as a 3-cell (3S) LiPo battery, where each cell has a nominal voltage of around 3.7 volts.
- **360mAh:** This is the capacity of the battery, measured in milliamper-hours (mAh). It indicates how much charge the battery can hold and how long it can power a device. In this case, it's 360 milliamper-hours.
- **30C:** This is the discharge rate of the battery, expressed as a multiple of its capacity. In this case, 30 times the capacity of the battery (360mAh). It indicates the maximum continuous discharge rate of the battery, which is 30 times its capacity, or 10,800 milliamperes (mA) in this case.

3S: This refers to the number of cells in the battery pack. Each cell has a nominal voltage of around 3.7 volts, so a 3S battery pack has a total nominal voltage of around 11.1 volts.



Fig:5.12 : LiPo Battery

Transmitter:

The "FS-i6G 6CH PPM RC transmitter" refers to a radio control (RC) transmitter produced by Flysky. Here's a breakdown:

- Brand: Flysky
- Model: FS-i6G
- Channels: 6CH (6 channels)
- PPM: Pulse Position Modulation (a method of transmitting RC signals)
- Functionality: Allows users to control RC vehicles or aircraft wirelessly using radio signals. It typically includes joysticks, switches, and knobs to manipulate the vehicle's movement, speed, and other functions.

This transmitter is commonly used in hobbyist RC applications, such as controlling drones, airplanes, cars, boats, and other remotely operated vehicles.



Fig:5.13 : RC Transmitter

RC Receiver:

A RC receiver, short for radio control receiver, is an electronic device that receives signals transmitted from a radio control transmitter and translates them into commands for controlling the movement and functions of a remotely operated vehicle or device. Here's a brief overview:

- **Function:** The receiver picks up radio signals transmitted wirelessly by the RC transmitter and converts them into electrical signals.
- **Channels:** RC receivers come in various configurations, typically ranging from 2 to 8 channels or more. Each channel corresponds to a specific function or control on the vehicle, such as throttle, steering, or auxiliary functions.
- **Compatibility:** Receivers are designed to be compatible with specific transmitters, often from the same manufacturer, and operate within a certain frequency range.
- **Output:** Once the signals are received and processed, the receiver sends corresponding electrical signals to the servos, motors, or other components of the vehicle to execute the desired actions.

Power Source: RC receivers are powered by a separate power source, such as a battery pack or a built-in BEC (Battery Eliminator Circuit) that draws power from the main battery of the vehicle.

- Antenna: Most RC receivers have an antenna to capture radio signals effectively. The antenna may be external or integrated into the receiver casing.
- Binding: Before use, the receiver typically needs to be "bound" or paired with the transmitter to establish a secure communication link.
- Size and Form Factor: RC receivers vary in size and form factor, depending on the specific application and the number of channels required. Some receivers are compact and lightweight for use in small vehicles, while others may be larger and more robust for high-performance models.

Overall, RC receivers play a crucial role in enabling precise and responsive control of RC vehicles and devices, facilitating a wide range of recreational and professional applications in hobbies, sports, and industries such as aerial photography, racing, and surveillance.



Fig:5.14 : RC Receiver

ESC:

ESC 30A is suitable for powering motors with a maximum current draw of up to 30 amps. It's commonly used in medium-sized RC aircraft, drones, and vehicles where

moderate power requirements are needed. ESCs play a crucial role in controlling the speed and direction of brushless motors used in these applications

SimonK firmware, combined with a 30A ESC, offers precise motor control, efficient power management, and smoother performance, making it a popular choice among hobbyists and enthusiasts looking to optimize the performance of their RC vehicles and drones.

- SimonK: SimonK is a custom firmware developed for ESCs. It's known for its fast response times and optimized performance, particularly for multirotor aircraft like quadcopters and hex copters. SimonK firmware is often preferred by hobbyists and enthusiasts for its smoother throttle response and better compatibility with multirotor flight controllers.
- ESC 30A: ESC stands for Electronic Speed Controller. The "30A" designation indicates the maximum continuous current the ESC can handle. In this case, it can handle a continuous current of up to 30 amps.



Fig:5.15 : ESC

Extension Cable:

The "Safe Connect Twisted 30cm 22AWG Servo Wire" refers to a specific type of wiring commonly used in radio control (RC) applications.

- **Safe Connect:** This likely refers to a feature or design aspect intended to enhance safety in the connection process, ensuring secure and reliable connections between the servo and receiver.
- **Twisted:** The wires are twisted together, which helps reduce electromagnetic interference (EMI) and signal noise, resulting in cleaner and more reliable signal transmission.
- **30cm Length:** Indicates the length of the wire, which is 30 centimeters. This length is suitable for various RC applications, providing flexibility in positioning components.
- **22AWG:** This refers to the American Wire Gauge (AWG) rating of the wire. AWG 22 indicates the thickness of the wire, with lower numbers representing thicker wires. AWG 22 is commonly used in RC applications for servos, offering a balance between flexibility and current-carrying capacity.
- **Servo Wire:** Specifically designed for connecting servos to RC receivers or other control devices. Servo wires typically have three conductors: signal, power (usually red), and ground (usually black or brown).



Fig:5.16 : Connectors

Servo Hinges:

Servo hinges, also known as servo arms or servo horns, are mechanical components used in conjunction with servos in radio control (RC) applications.

- **Attachment Point:** Servo hinges directly attach to servo output shafts via splined or toothed holes, ensuring a secure connection.
- **Control Linkage:** They transmit servo rotational motion to control surfaces like ailerons or elevators in RC vehicles or aircraft.
- **Variety of Designs:** Available in diverse configurations to suit different applications, with variations in length, shape, and attachment points.
- **Material:** Made of lightweight and durable materials such as plastic, nylon, or metal alloys, chosen based on strength, weight, and cost factors.
- **Adjustability:** Some hinges offer adjustable arms or mounting holes for fine-tuning control response and range of motion.
- **Compatibility:** Designed to match specific servo models and sizes, ensuring proper fit and secure connection with the servo shaft.

Overall, servo hinges play a crucial role in translating the rotational motion of servo motors into precise movement of control surfaces or mechanisms in RC vehicles, aircraft, robots, and other remote-controlled devices. They are essential components for achieving accurate and responsive control in various RC applications.



Fig: 5.17 : Hinges

5.5 WEIGHT ESTIMATION:

Estimating the weight of a bladeless duct engine aircraft involves various factors:

- **Aircraft Size:** Larger aircraft typically have higher weight due to more powerful engines and components.
- **Materials:** Choice of lightweight materials like carbon fiber composites reduces overall weight.
- **Bladeless Duct Engine:** Contributes to aircraft weight; its size, power output, and materials influence weight.
- **Additional Components:** Avionics, landing gear, fuel systems, and payload add to aircraft weight.

Without specific details, weight estimation is challenging.

For small to medium-sized aircraft, weight may range from a few hundred to several thousand kilograms.

Advanced CAD software and engineering analysis optimize weight during design.

- Payload weight - 0.9 KG
- Weight of the motor - 0.06 KG
- Weight of the battery - 0.170 KG
- Overall weight (approx.) -1.1 KG

5.6 ASSEMBLING:

The concept of a bladeless duct engine for aircraft propulsion is an intriguing one, often associated with technologies like the "ionic wind" or "ionic thrusters." While such technology has shown promise in small-scale experiments and prototypes, the practical application to full-scale aircraft remains largely speculative as of my last update in January 2022. However, I can outline a general approach to assembling such an aircraft based on existing knowledge and assumptions:

Design Phase: This phase involves conceptualizing the aircraft's design, including its aerodynamics, structure, and propulsion system. The design must accommodate the bladeless duct engine's unique characteristics and requirements.

Materials Selection: Choose appropriate materials for constructing the aircraft's airframe, ensuring strength, durability, and weight considerations are met. Composite materials are commonly used in modern aircraft construction to achieve these criteria.

Bladeless Duct Engine Integration: The bladeless duct engine would be integrated into the aircraft's design, typically positioned either within the fuselage or embedded in the wings.

This integration requires careful engineering to ensure optimal airflow and performance. **Power Source:** Bladeless duct engines often require a power source, such as high-voltage electricity, to ionize air and generate thrust. Power generation and distribution systems must be integrated into the aircraft's design to support the engine's operation.

Flight Control Systems: Implement flight control systems to manage the aircraft's stability, maneuverability, and control surfaces. These systems may need to be adapted to accommodate the unique characteristics of bladeless duct propulsion.

Testing and Iteration: Conduct extensive testing, both in controlled environments and during flight tests, to validate the aircraft's performance, safety, and efficiency. Iterate on the design as necessary to address any issues or optimize performance.

Regulatory Approval: Obtain regulatory approval from aviation authorities, demonstrating compliance with safety and operational standards. This process may involve rigorous testing, documentation, and certification procedures.

Production and Deployment: Once the aircraft has been successfully tested and approved, proceed with production and deployment. This phase involves

manufacturing multiple units of the aircraft for commercial or military use, as applicable. **Operational Training and Maintenance:** Provide training for pilots and maintenance personnel on operating and servicing the bladeless duct engine aircraft. Develop maintenance protocols to ensure the aircraft remains in optimal condition throughout its operational lifespan.

Continued Development: Continue researching and developing the technology to further improve the efficiency, reliability, and practicality of bladeless duct engines for aircraft propulsion. This may involve refining design concepts, exploring new materials, and advancing related technologies.

It's worth noting that the feasibility and practicality of bladeless duct engine aircraft depend on various factors, including technological advancements, regulatory considerations, and market demand. As such, while the concept is intriguing, its widespread adoption and deployment may still be some time away.

5.7 THRUST ESTIMATION:

Table:5.1 : Velocity and Thrust Variation table

S.No	Pressure (Pascal)	Velocity(m/s)	Thrust(N)	Thrust/Weight
1	102325	3	12.98	0.95
2	103325	5	22.08	1.62
3	104325	10	31.17	2.29
4	105325	12.5	40.26	2.96
5	106325	15	49.35	3.63
6	107325	20	58.44	4.30
7	108325	25	67.53	4.96
8	109325	30	76.62	5.63
9	110325	33	85.72	6.30
10	111325	38	94.81	6.97

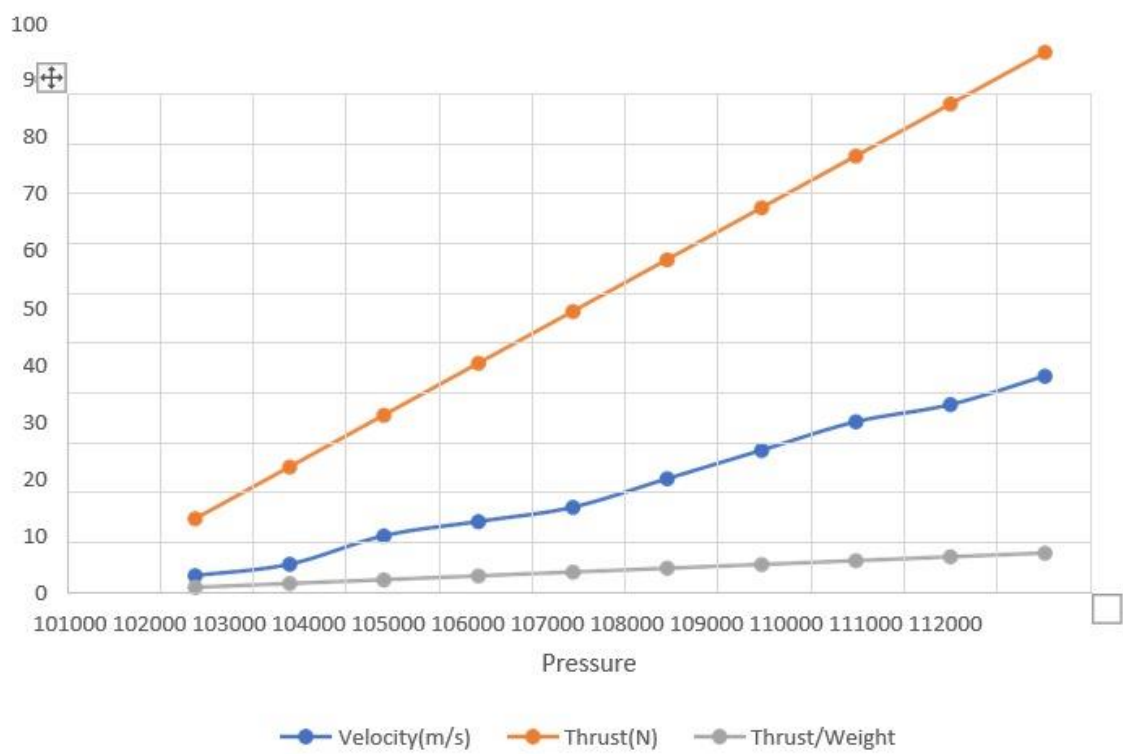


Fig:5.18 : Velocity, Thrust, Thrust/Weight variation Graph

5.8 FINAL PRODUCT:



Fig:5.19 : Isometric View

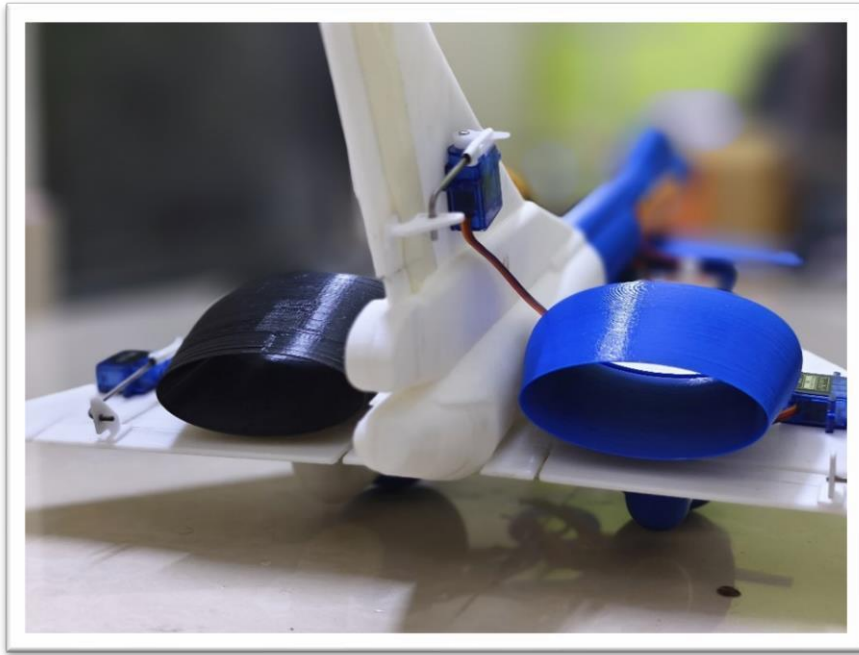


Fig:5.20 : Back View



Fig:5.21 : Top View



Fig:5.22 : Front View

CHAPTER 6

CONCLUSION

The study delved into the exploration of CFJ (Coanda Flow Jet) airfoils and bladeless duct fluidic propulsion systems, with additional considerations for integrating micro compressors and assessing Jetoptera's patented model of drone cars.

CFJ Airfoils and Shear Layer Growth: CFJ airfoils were scrutinized for their potential in augmenting thrust and power output by capitalizing on shear layer growth. This suggests that CFJ airfoils hold promise for enhancing fluidic propulsion systems due to their ability to manipulate airflow and generate increased thrust.

Micro Compressor Design: The study contemplated incorporating micro compressors into CFJ airfoils to mitigate limitations associated with prolonged electrical operation. However, it was noted that the feasibility of such integration for extended electrical runs remains uncertain and necessitates further investigation. This implies that while integrating micro compressors holds potential benefits, there are technical challenges that need to be addressed before its practical implementation.

Jetoptera's Model Drone Cars: The research acknowledged Jetoptera's development of a patented model of drone cars, hinting at advancements in propulsion systems applicable to both aerial and potentially ground transportation. However, the study does not provide specific details about Jetoptera's model, leaving room for interpretation regarding its significance and potential impact on transportation technologies.

Future Research Directions: The study suggests several future research avenues. Firstly, there's an emphasis on optimizing turbopump and turboshaft systems, indicating the importance of refining key components integral to propulsion systems. Additionally, there's a call for the development of advanced electrical subsystems to enhance operational efficiency, highlighting the necessity of incorporating cutting-edge technologies to improve performance.

REFERENCE

1. A AM, Ravi A, Luke Dsouza A, Kumar S, Professor A. Development of Bladeless Thruster for an UAV Application. vol. 7. 2020.
2. A AM, Ravi A, Luke Dsouza A, Kumar S. DESIGN, DEVELOPMENT AND ANOV BLADELESS THRUSTER. n.d.
3. Aguirre J, Wang B-Y, Zha G-C. Conceptual Design and Study of “Engineless” Airplane Using Co-Flow Jet Airfoil AIAA 2007-4441. 2007.
4. Alexandria Engineering Journal 2016; 55:223–33.
5. ALLEN J. Examining the Tesla Turbine, American Institute of Aeronautics and Astronautics (AIAA); 1989.
6. Andrei Evulet EW. Fluidic Propulsive System and Thrust and Lift Generator for Aerial Vehicles.
7. US Patent Application Number US10919636B2 2021.
8. Andrei Evulet JInc, EW (US). Configuration for Vertical Take-off and Landing system for Aerial Vehicles. US Patent Application Number US11001378B2 2021.
9. Ang Li by, Chen J, Blaisdell G, Wayne Chen W. STATEMENT OF THESIS APPROVAL. 2019.
10. Aslam H, Arif MZ, Ali M, Javed A. Design and CFD Analysis of Bladeless Ceiling Fan. Proceedings of 18th International Bhurban Conference on Applied Sciences and Technologies, IBCAST 2021, Institute of Electrical and Electronics Engineers Inc.; 2021, p. 782–7.
11. Bahrami A, Hoseinzadeh S, Heyns PS, Mirhosseini SM. Experimental investigation of co-flow jet’s airfoil flow control by hot wire anemometer. Review of Scientific Instruments 2019;90. <https://doi.org/10.1063/1.5113592>.
12. Braun J, Paniagua G, Falempin F, Le Naour B. Bladeless turbines for unsteady high-speed flows. 21st AIAA International Space Planes and
13. Braun J, Paniagua G, Falempin F, Le Naour B. Design and Experimental Assessment of Bladeless Turbines for Axial Inlet Supersonic Flows. J Eng Gas Turbine Power 2020;142.

- 14.** Brower WB. PROJECT TUBEFLIGHT TUBEFLIGHT-A REVIEW. 1970.
- 15.** Chan DWT. Similarity in the initial region of annular jets: three configurations. vol. 4. 1978.
- 16.** Chen H, Chen B. Aerodynamic Performance Enhancement of Tiltrotor Aircraft Wings Using Double-Row Vortex Generators. *International Journal of Aeronautical and Space Sciences* 2021; 22:802–12.
- 17.** Dano B, Kirk D, Zha G. Experimental Investigation of Jet Mixing Mechanism of Co-Flow Jet Air foil. 5th Flow Control Conference, Reston, Virigina: American Institute of Aeronautics and Astronautics; 2010. <https://doi.org/10.2514/6.20104421>.
- 18.** Dano BPE, Zha G, Castillo M. Experimental Study of Co-Flow Jet Airfoil Performance Enhancement Using Discrete Jets. 2011.
- 19.** Dano BPE, Zha G, Castillo M. Experimental Study of Co-Flow Jet Airfoil Performance Enhancement Using Discrete Jets. 2011.
- 20.** DESIGN AND ANALYSIS OF BLADELESS AIR COOLER. n.d.
- 21.** Experimental and Numerical Investigation of Using Coanda Effect for Producing Underwater Propulsion. 2019.
- 22.** Gopinath S, Sundararaj M, Elangovan S, Rathakrishnan E. Mixing characteristics of elliptical and rectangular subsonic jets with swirling co-flow. *International Journal of Turbo and Jet Engines* 2015; 32:73–83.
- 23.** Jafari M, Afshin H, Bozorgasareh H. Available online at www.jafmonline.net. vol. 8. 2015.
- 24.** Jafari M, Afshin H, Farhanieh B, Sojoudi A. Numerical investigation of geometric parameter effects on the aerodynamic performance of a Bladeless fan.
- 25.** Lefebvre A, Zha GC. Co-flow jet airfoil trade study part I: Energy consumption and aerodynamic efficiency. 32nd AIAA Applied Aerodynamics Conference, American Institute of Aeronautics and Astronautics Inc.; 2014.
- 26.** Li H, Jin XH, Deng HS, Lai Y Bin. Experimental investigation on the outlet flow field structure and the influence of Reynolds number on the outlet flow field for a bladeless fan. *Appl Therm Eng* 2016; 100:972–8.
- 27.** Li R, Wang H, Yao E, Li M, Nan W. Experimental study on bladeless turbine using incompressible working medium. *Advances in*

- Mechanical Engineering 2017;9. <https://doi.org/10.1177/1687814016686935>.
- 28.** Ocker C, Pannert W, Merkel M, Geyer TF, Czwielong F, Krömer F, et al. Experimental investigation of the impact of 3d-metal-printed perforated leading edges on airfoil and axial fan noise. AIAA AVIATION 2020 FORUM, American Institute of Aeronautics and Astronautics Inc, AIAA; 2020, p. 1–16. <https://doi.org/10.2514/6.2020-2529>.
 - 29.** Othman MNK, Razlan ZM, Hazry D, Wan K, Shahriman AB, Yaacob S, et al. Internal air flow analysis of a bladeless micro aerial vehicle hemisphere body using computational fluid dynamic. AIP Conf Proc, vol. 1635, American
 - 30.** Paniagua G, Cuadrado D, Saavedra J, Andreoli V, Meyer T, Solano JP, et al. Design of the Purdue Experimental Turbine Aerothermal Laboratory for Optical and Surface Aerothermal Measurements. J Eng Gas Turbine Power 2019;141.
 - 31.** Ravi D, Rajagopal TKR. Numerical Investigation on the Effect of Geometric Shape and Outlet Angle of a Bladeless Fan for Flow Optimization using CFD Techniques. International Journal of Thermo fluids 2022;15. Safety: Design and Development of a Bladeless Thruster for Autonomous
 - 32.** Sazzat Hossain M, Nehal Hossen M, Nasif Hossain M, Uddin N, Mahbub M, SazolAhmmed M, et al. Ecofriendly Design and Development of Bladeless Air Conditioning Fan. n.d.
 - 33.** Shiau YR, Fang J, Huang YC. Design and Analysis of a Vertical Electric Ducted Fan for Unmanned Aerial Vehicles. J Phys Conf Ser 2023; 2542:012016. [33] Tomar S, Aatif Sohel S, Mansuri R, Puri S, Khandal S, Surve S, et al.
 - 34.** Voigt J, Friedrichs J. Development of a multi-segment parallel compressor model for a boundary layer ingesting fuselage fan stage. Energies (Basel) 2021;14.
 - 35.** <https://doi.org/10.3390/en14185746>. [12] Xu K, McBreen B, Ren Y, Zha G. Analysis of microcompressor performance with integrated co-flow jet airfoil ducting system. AIAA Scitech 2020 Forum, American Institute

- of Aeronautics and Astronautics Inc, AIAA; 2020, p. 1–17.
<https://doi.org/10.2514/6.2020-0047>.
- 36.** Wang B, Haddoukessouni B, Levy J, Zha G-C. Numerical Investigations of Injection Slot Size Effect on the Performance of Co-Flow Jet Airfoil. 2007.
 - 37.** Wang R, Zhang G, Ying P, Ma X. Effects of Key Parameters on Airfoil Aerodynamics Using Co-Flow Jet Active Flow Control. Aerospace 2022;9.
<https://doi.org/10.3390/aerospace9110649>.
 - 39.** Wang ZN, Tucker PG. Hierarchical Turbulence and Geometry Modelling of Fan Stage Flows. AIAA Aviation and Aeronautics Forum and Exposition, AIAA AVIATION Forum 2021, American
 - 40.** Institute of Aeronautics and Astronautics Inc, AIAA; 2021.
<https://doi.org/10.2514/6.2021-2767>.
 - 41.** Yang Y, Zha G. Conceptual Design of the Co-Flow Jet Hybrid Electric Regional Airplane, American Institute of Aeronautics and Astronautics (AIAA); 2019.
 - 42.** Yang Y, Zha G. Super lift coefficient of cylinder using co-flow jet active flow control. AIAA Aerospace Sciences Meeting, 2018, American Institute of Aeronautics and Astronautics Inc, AIAA; 2018. <https://doi.org/10.2514/6.20180329>.
 - 43.** Zha G-C, Carroll BF, Paxton CD, Conley CA, Wells A. High Performance Airfoil Using Co-Flow Jet Flow Control 2005.
 - 44.** Zha G-C, Gao W, Paxton CD, Palewicz A. Numerical Investigations of CoFlow Jet Airfoil with and without Injection 2006

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Arief Rachman, Her-Mann Tsai, Ge-Cheng Zha. "Application of Co-Flow Jet Concept on Thin Airfoil at High Angle of Attack", 3rd AIAA Flow Control Conference, 2006

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