SECTIONAL DESIGN OF TURBOJET ENGINE WITH FEA AND CFD ANALYSIS OF TURBINE BLADE AND NOZZLE.

OBJECTIVES:

1. Understanding the complete working mechanism of an aerodynamic Turbojet Engine, including design details and significance of Compressor, Turbine, Combustor and Nozzle.

2. Component Design in Creo Parametric:

- *Modeled a single-stage axial compressor.*
- *Modeled a high-pressure turbine stage.*

3. Validation in Ansys:

- *Validated the turbine blade's structural integrity using Finite Element Analysis (FEA).*
- *Analyzed nozzle thrust performance using Computational Fluid Dynamics (CFD).*

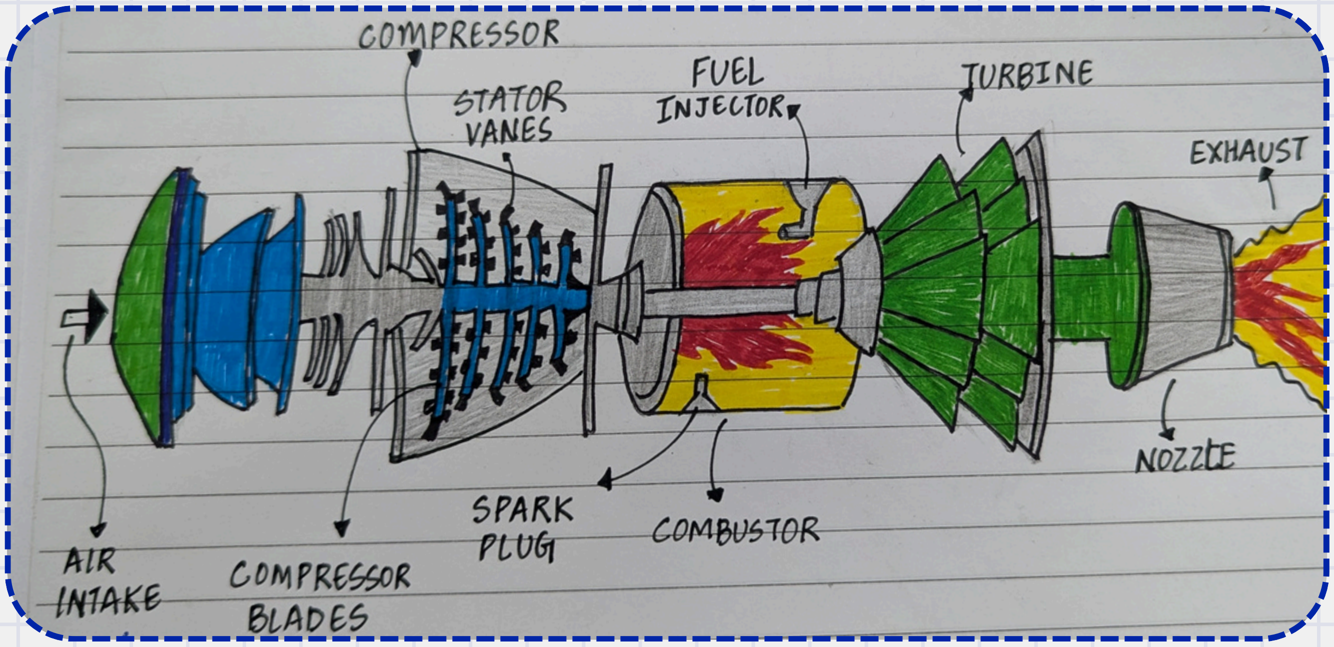
TURBOJET ENGINE

- *Jet Engine is based on Newton's third law:*

"Every Action has equal and opposite reaction."

The engine pushes a massive amount of air (exhaust + air) out of the back.

In return, the aircraft attached to it pushes forward.

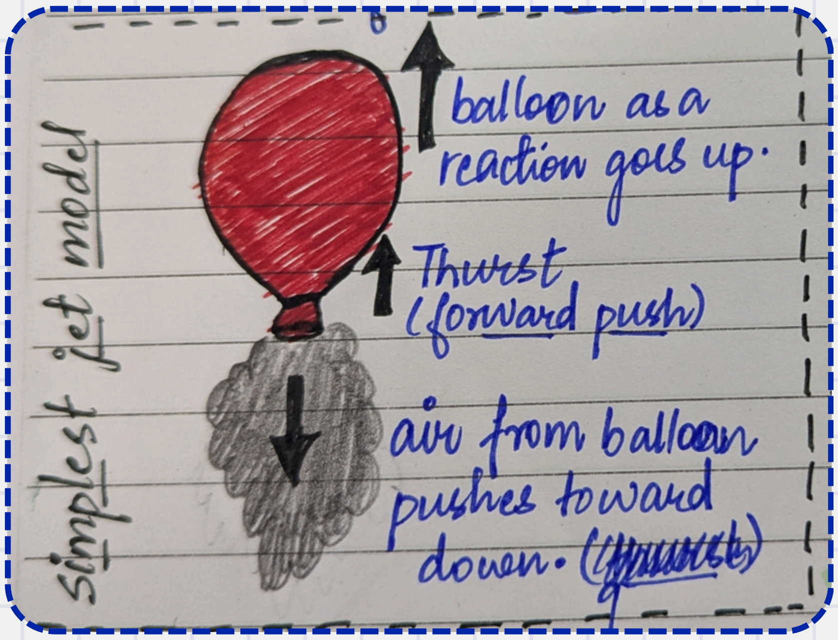


FOUR STEPS OF TURBOJET:

1. ***Suck:*** *Air intake from the engine's mouth. A massive amount of air is engulfed from the atmosphere.*
2. ***Compress:*** *The intaken air is compressed in a compressor, increasing its pressure and temperature. Highly compressed air holds much more Potential Energy.*
3. ***Combust:*** *The high-pressure air is mixed with fuel and ignited, creating a controlled and continuous explosion. This extreme heating causes a massive expansion of the air mixture.*
4. ***Blow:*** *This extremely hot gas has one place to go: out from the back. It blasts out through two final sections - the Turbine and Nozzle, generating the THRUST!*

SIMPLEST JET MODEL (BALLOON):

- *Air from balloon pushes toward down (Action)*
- *Balloon as a reaction goes up*
- *Thrust (forward push)*

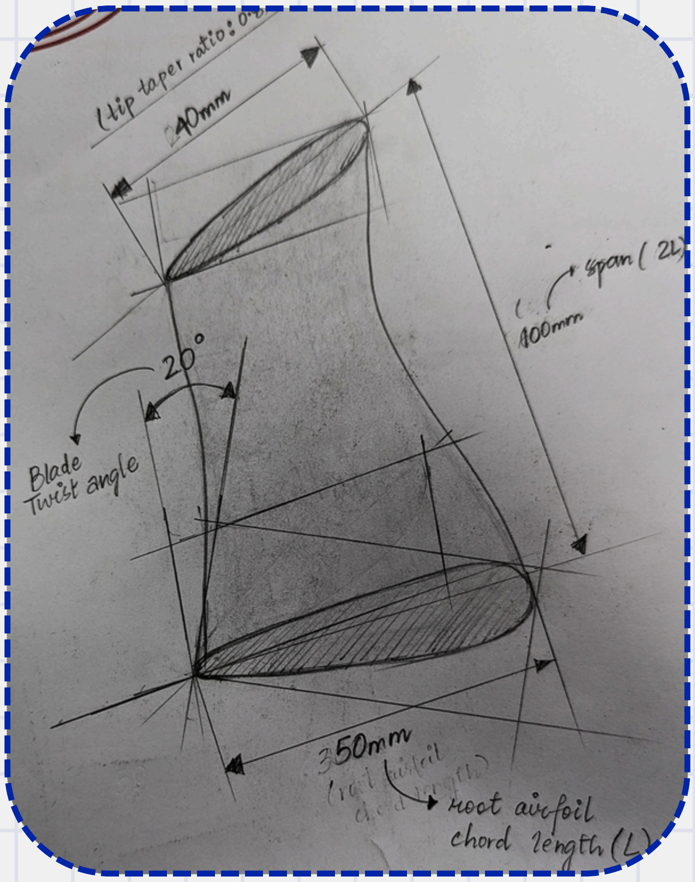


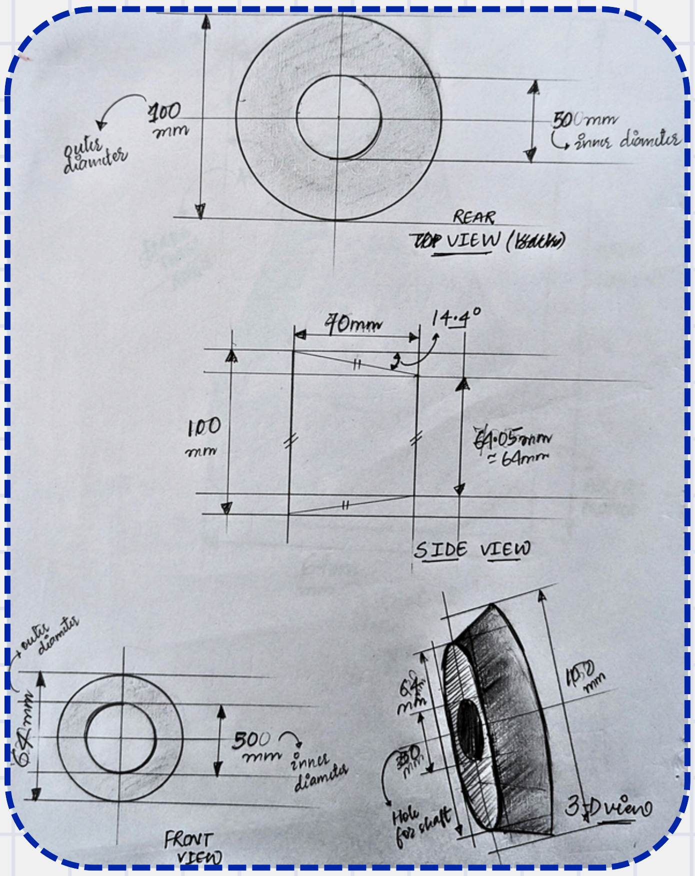
CAD MODELING OF COMPONENTS IN CREO PARAMETRIC

COMPRESSOR

- *A series of rotating discs with blades attached, looking like complex fans. Each row of rotating blades (rotor) is followed by a row of stationary blades (stator).*
- *The rotor spins and throws the air backward, increasing its pressure, temperature, and speed. The stators then slow the air down, converting speed into more pressure. This happens over and over through many stages, resulting in extremely high-pressure air ready for combustion.*

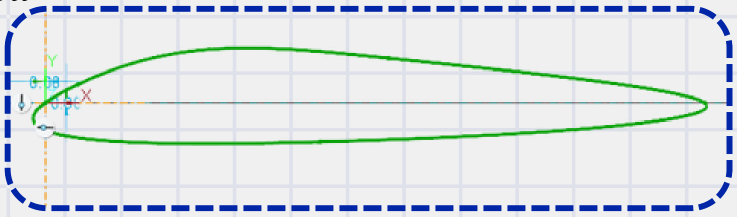
DESIGN SKETCHES:



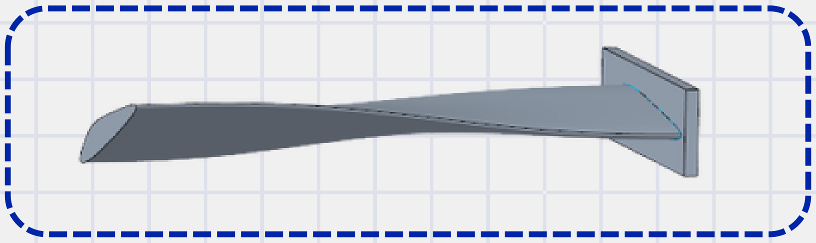


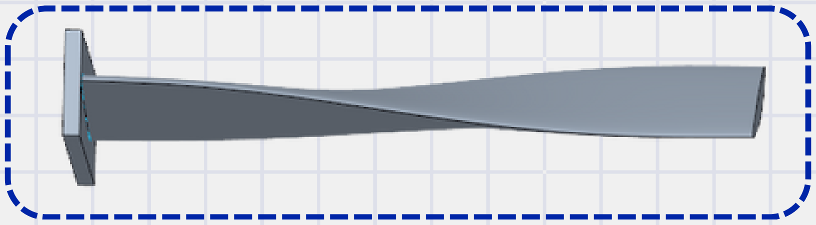
COMPRESSOR BLADE DESIGN & MODELING

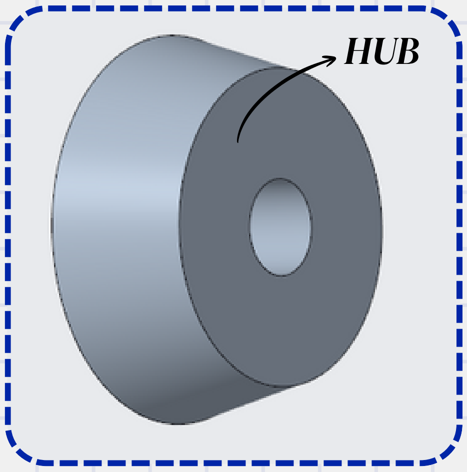
- ***Airfoil Generation:** A NACA 65-series airfoil was generated from a coordinate (.pts) file and imported into Creo to ensure an aerodynamically precise profile.*



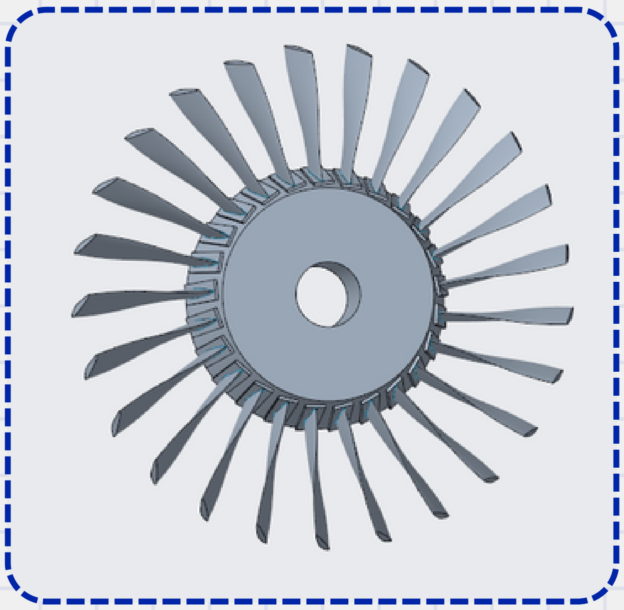
- ***3D Blade Modeling:** The 3D blade was created using the Blend tool, applying both taper and twist from the root to the tip to optimize its performance across the entire span.*

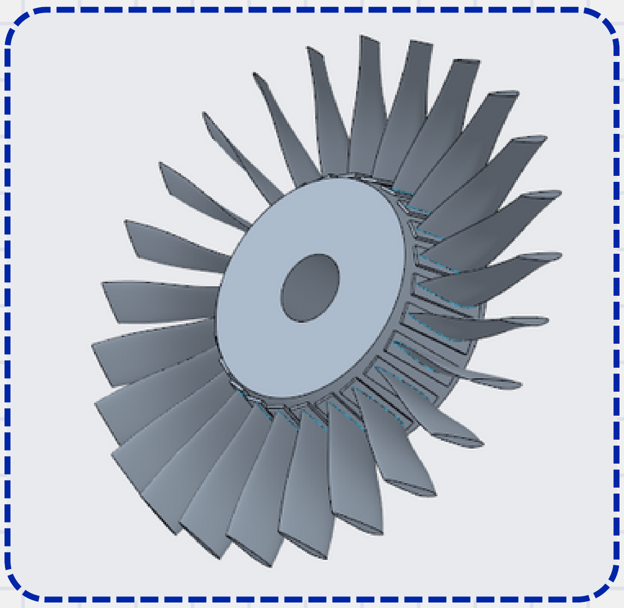






- ***Stage Assembly:** The final rotor was assembled by constraining a single blade to a revolved hub, then using the Axis Pattern feature to create all 25 blades.*



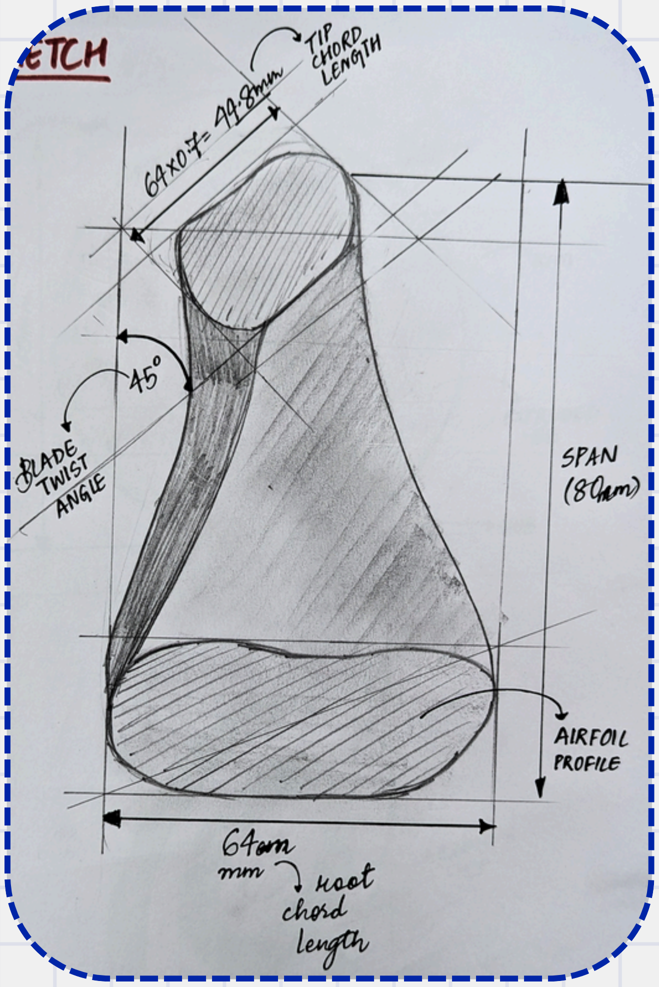


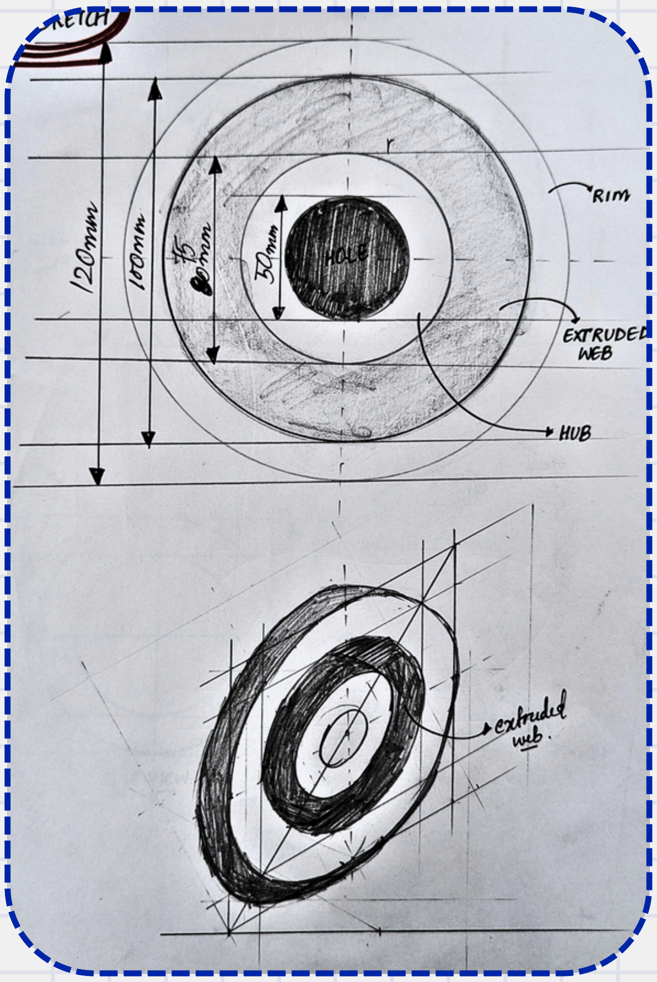
CAD MODELING OF COMPONENTS IN CREO PARAMETRIC

TURBINE

- *Another set of blades that looks similar to the compressor, but they are designed to work in reverse.*
- *After the combustion process, the hot gas blasts through the turbine blades, making them spin like a windmill. The turbine is connected to the compressor by a long shaft running through the center of the engine.*

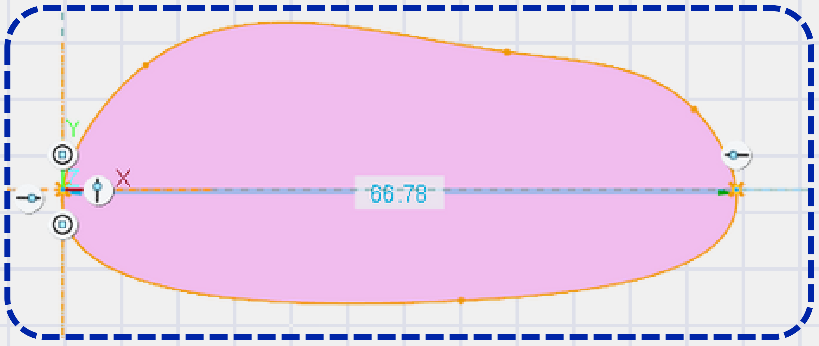
DESIGN SKETCHES:



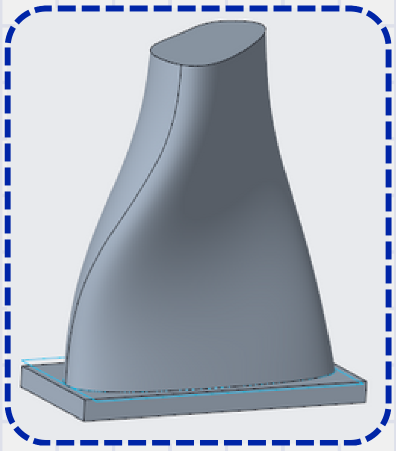


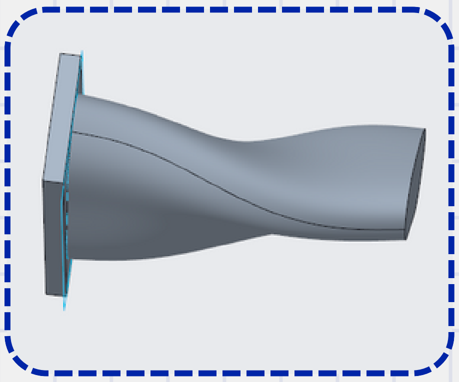
TURBINE BLADE DESIGN & MODELING

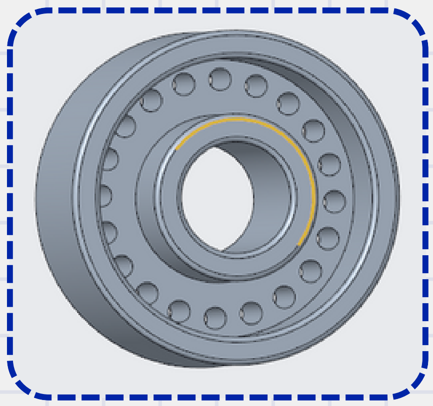
- *Airfoil Research: A more authentic profile was required due to high thermal loads. Research identified the VKI LS-89, a public-domain airfoil specifically designed for a high-pressure turbine stage, as the ideal candidate.*



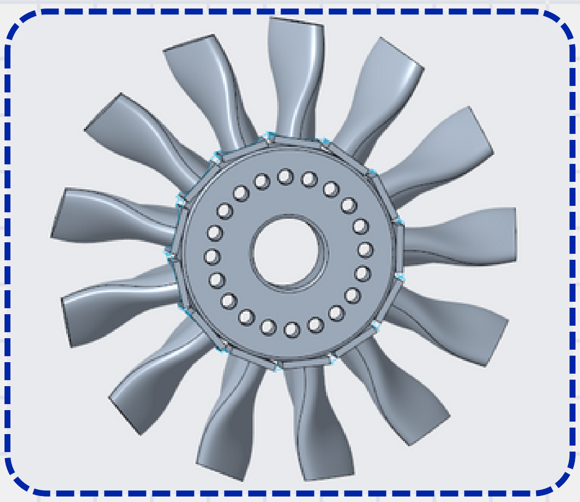
- *3D Blade Modeling: The LS-89 coordinate data, which defined a blunt trailing edge for internal cooling, was processed and imported. The blade was modeled using the Blend tool with a significant twist and taper to maximize energy extraction from the expanding gas.*

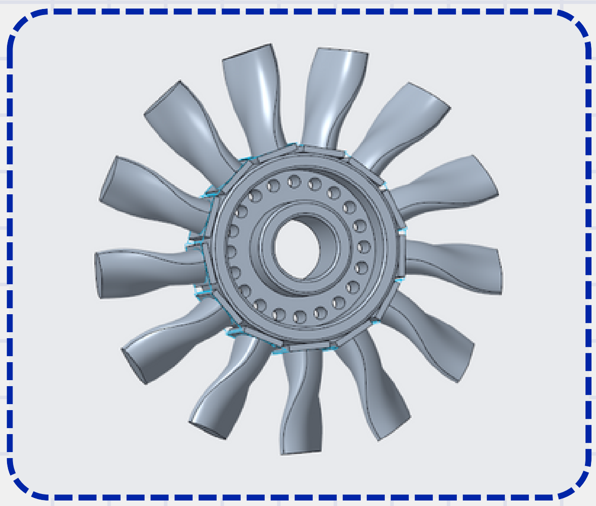






- *Stage Assembly: The central turbine disc was modeled using the Revolve feature with an intricate, webbed profile to reduce weight while maintaining strength under high thermal and mechanical loads.*
- *The final turbine stage was created by constraining a single blade to the disc and then using the Axis Pattern feature to create all 13 blades.*



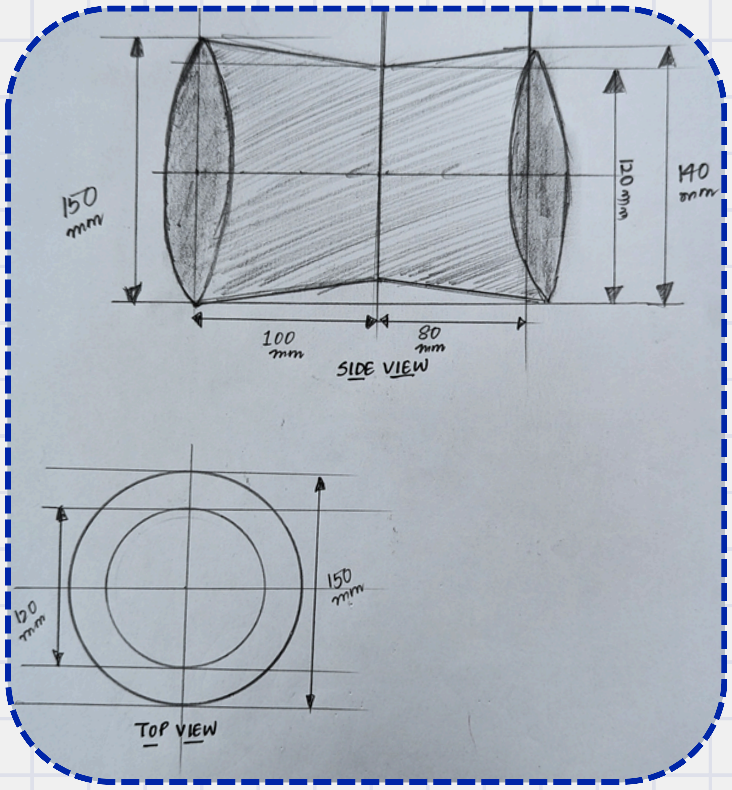


CAD MODELING OF COMPONENTS IN CREO PARAMETRIC

NOZZLE

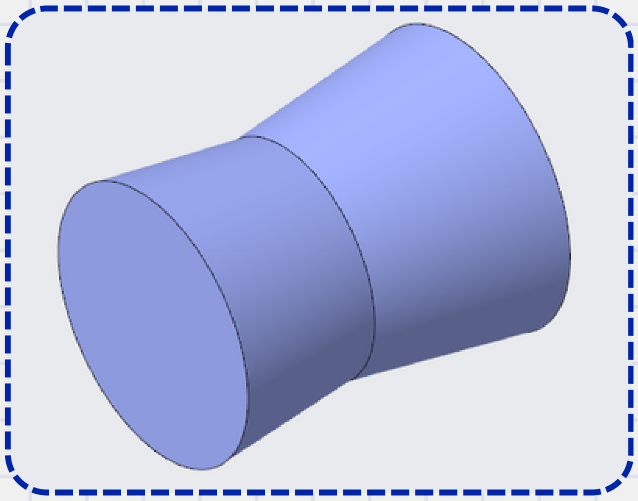
- *The final component of the engine, designed to accelerate the hot, high-pressure exhaust gas to its maximum possible velocity.*
- *This high-speed exhaust produces the thrust that pushes the engine forward,baccordance with Newton's Third Law.*

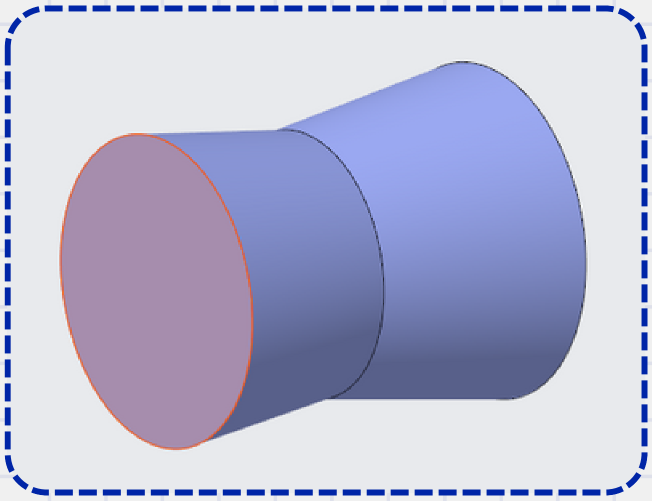
DESIGN SKETCHES:



NOZZLE DESIGN & MODELING

- ***Conceptual Design:*** *An innovative convergent-divergent (C-D) nozzle was chosen over a standard convergent nozzle. This design is more efficient at high pressure ratios and allows the exhaust gas to reach supersonic speeds, maximizing thrust.*
- ***3D Modeling:*** *The C-D nozzle's profile, defined by its inlet, throat, and exit diameters, was sketched as a 2D half-profile. The final 3D solid model was then created in a single, efficient step using the Revolve feature.*

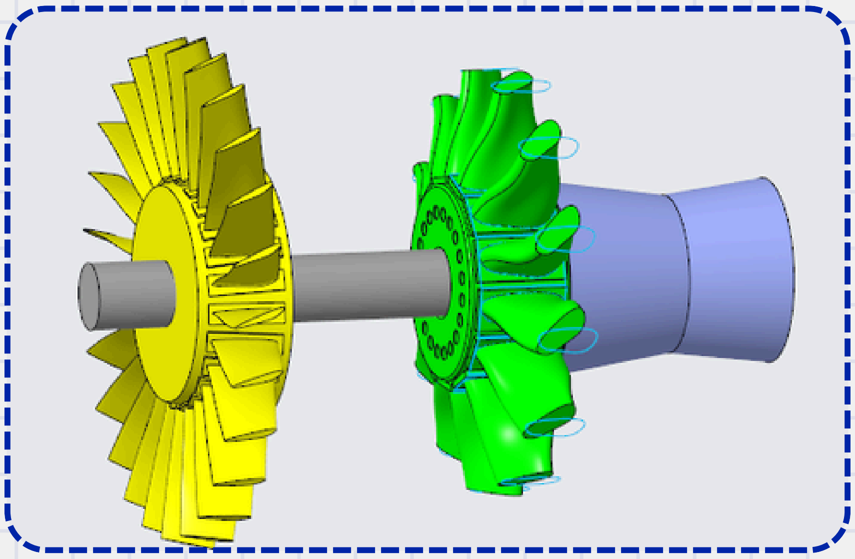


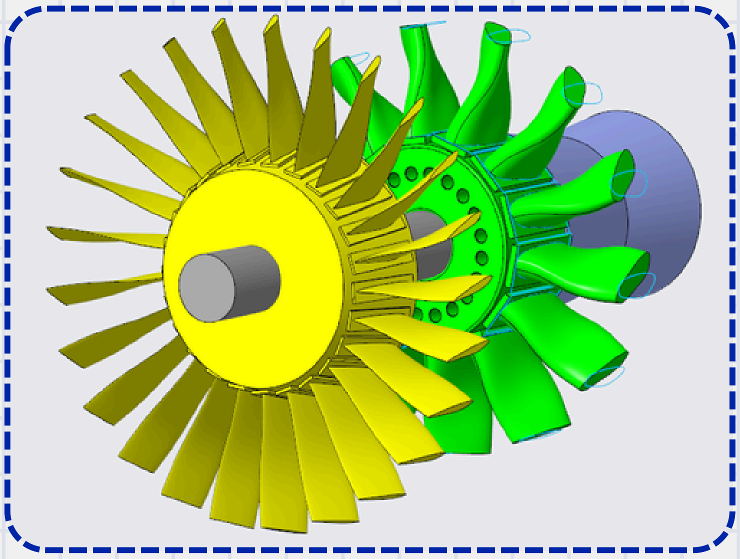


FINAL ASSEMBLY

- *This assembly represents the core rotational and exhaust section of a turbojet engine, with the compressor and turbine linked by a central shaft to form a single, integrated rotating group known as the "spool."*

- *The layout follows the primary aerodynamic flow path: air is first drawn in and pressurized by the 25-blade compressor stage, then (conceptually) mixed with fuel and ignited, and the resulting hot gas expands through the 13-blade turbine stage, which powers the compressor. Finally, the exhaust gas is accelerated through the convergent-divergent nozzle to produce thrust.*





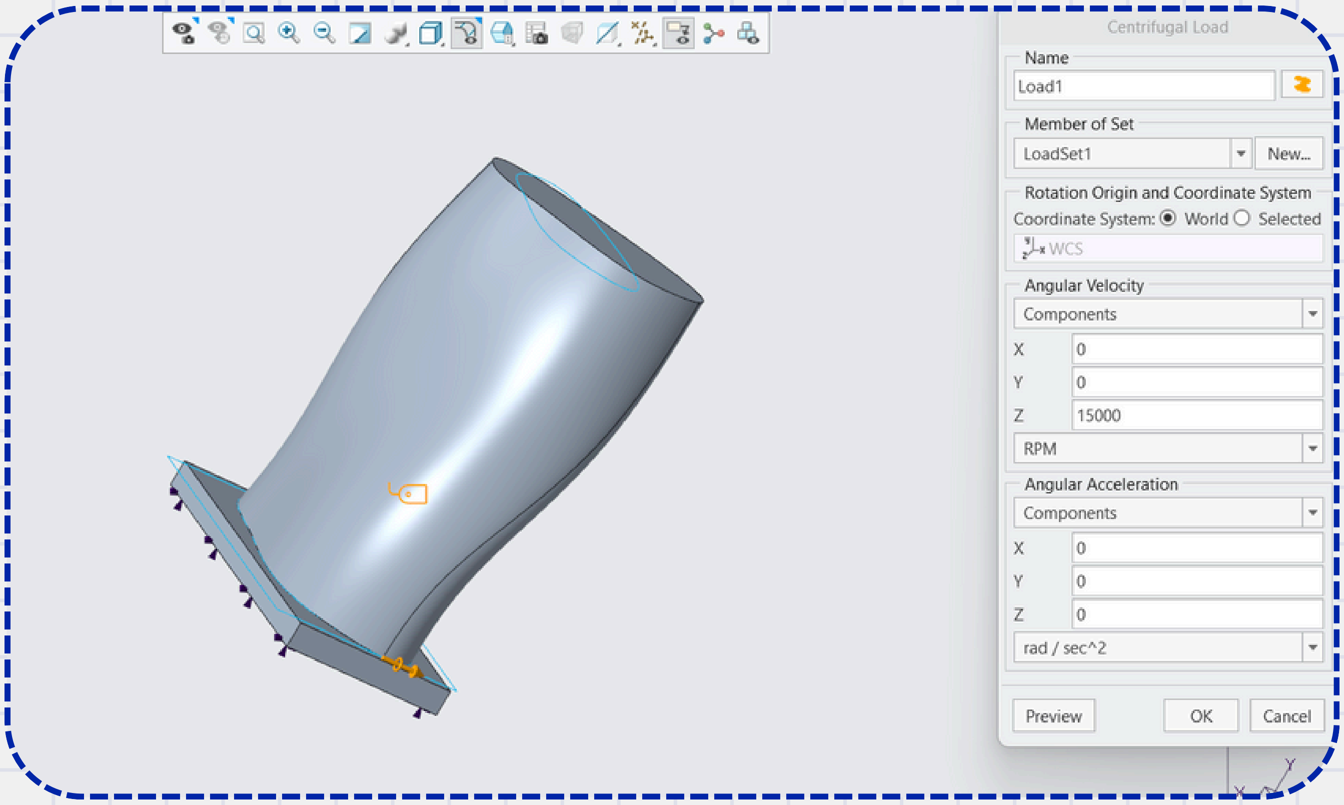
FINITE ELEMENT ANALYSIS (FEA) OF THE TURBINE BLADE

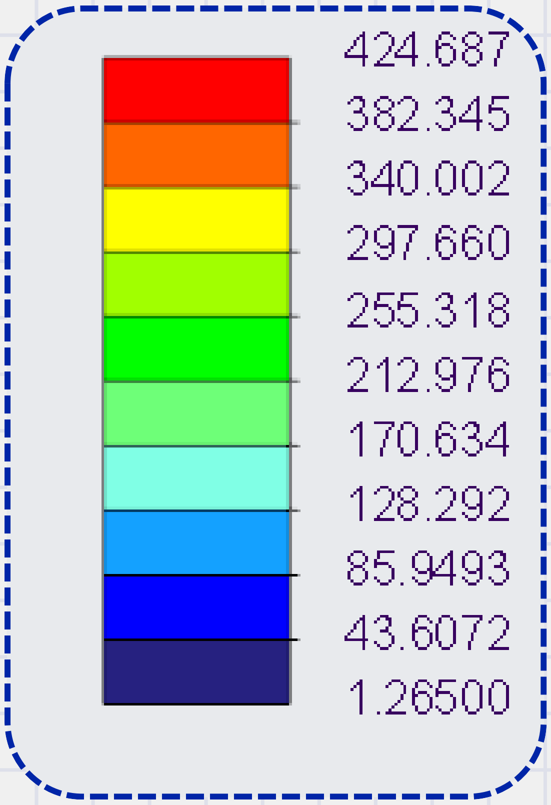
OBJECTIVES:

- *To validate the structural integrity of the turbine blade under the immense centrifugal forces experienced during high-speed operation (15,000 RPM).*

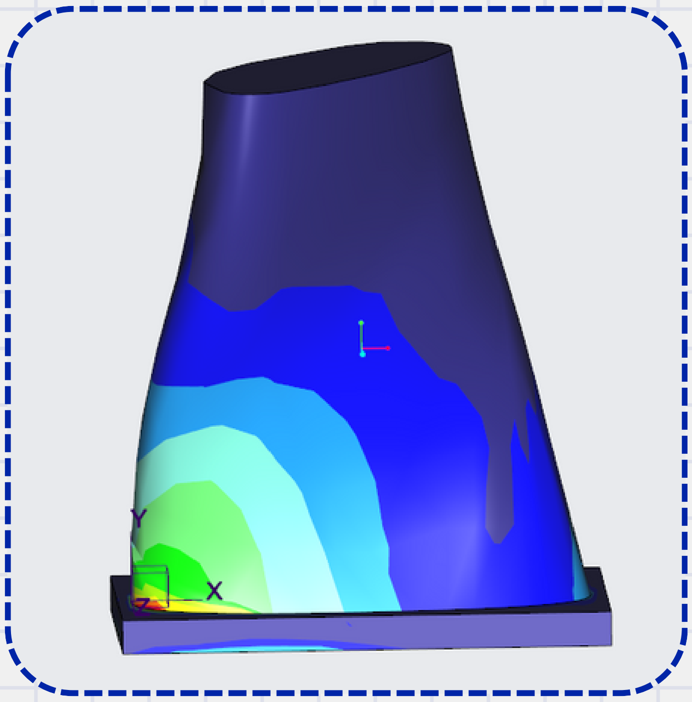
FEA DETAILS:

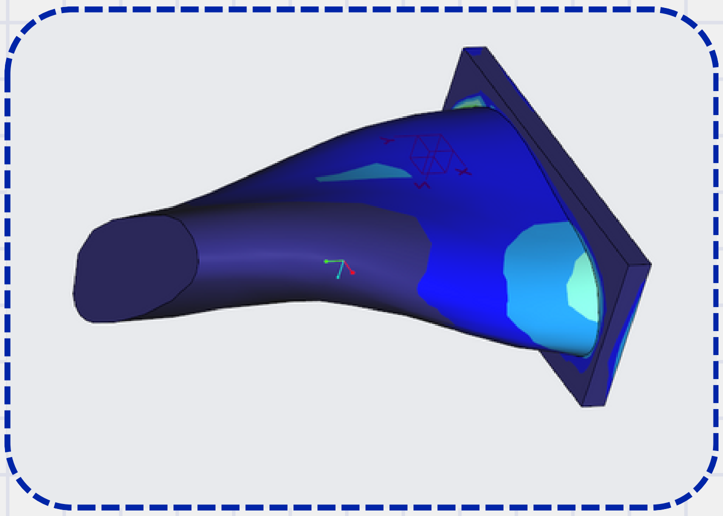
- *A Finite Element Analysis (FEA) was performed in CREO to validate the turbine blade's structural integrity against centrifugal force during high-speed rotation.*
- *To ensure a realistic simulation, a custom material definition for Inconel 718 was created by inputting its specific mechanical properties, including its 1035 MPa yield strength.*
- *The blade's root was fully constrained, and a load equivalent to 15,000 RPM was applied. An adaptive meshing technique was used to improve accuracy in high-stress areas.*

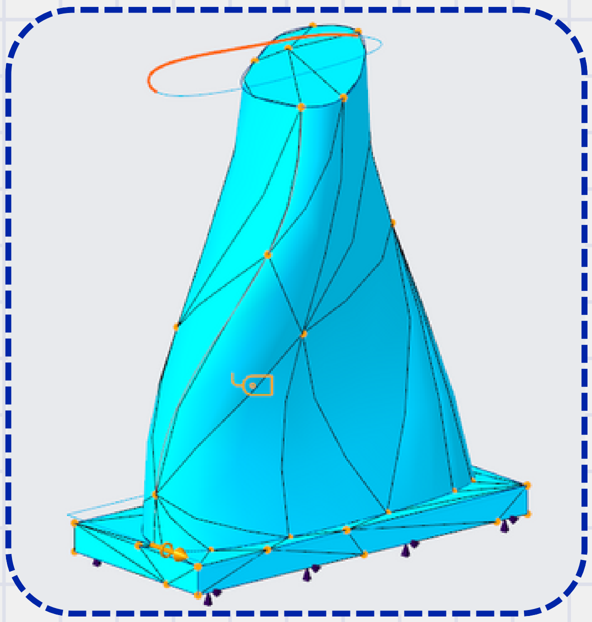




- *The results showed a maximum von Mises stress of 440 MPa concentrated at the blade root, confirming a robust design with a high safety factor of 2.35.*







FINITE ELEMENT ANALYSIS (FEA) OF THE TURBINE BLADE

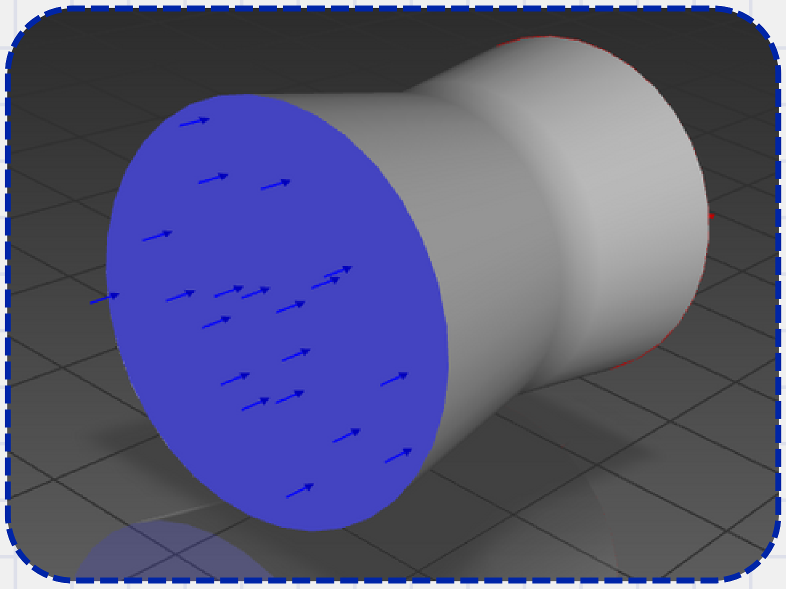
OBJECTIVES:

- *To analyze and compare the thrust performance of an innovative convergent-divergent (C-D) nozzle against a standard convergent nozzle using Ansys Fluent.*

METHODOLOGY:

1. Geometry Preparation

- *First, the internal fluid volume of the nozzle was modelled as a solid part in Creo. This "fluid domain" defines the exact space where the simulation will take place.*



2. Meshing

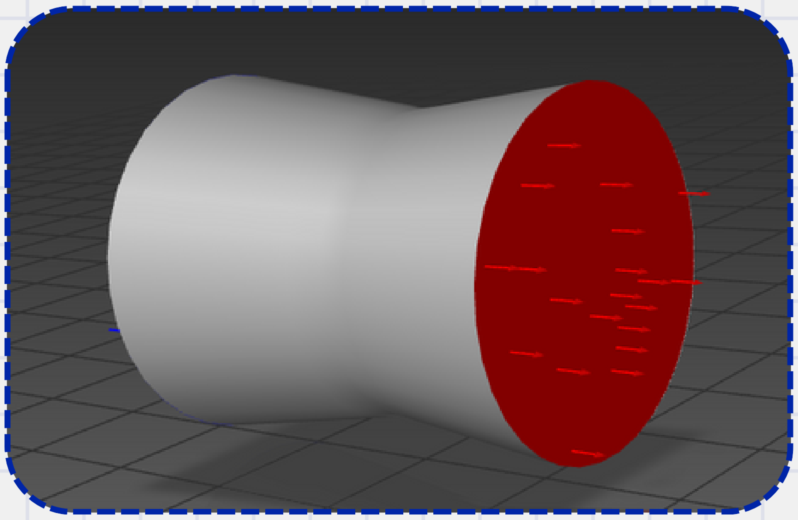
- *The fluid domain was then imported into Ansys and discretised into thousands of small elements. This "meshing" process breaks down the complex problem into simple pieces that the solver can analyse.*

3. Boundary Conditions

- *Realistic physics were applied to the model. High-pressure and high-temperature conditions were set at the inlet, with ambient pressure at the outlet, to simulate the gas flow from the engine.*

4. Solution & Convergence

- *The simulation was run until the solution "converged," meaning the results stabilized. The residual plots were monitored to ensure the final solution was accurate and reliable.*



5. Post-Processing & Results

- *The results were visualized, showing the gas accelerating to supersonic speeds. A final thrust calculation confirmed that the innovative C-D nozzle produced an 8.1% thrust gain over a standard convergent nozzle under these optimized conditions.*

RESULTS:

- *The results were visualized, showing the gas accelerating to supersonic speeds. To quantify the performance gain, the same CFD analysis was conducted on a baseline standard convergent nozzle.*
- *The final thrust calculation confirmed that the innovative C-D nozzle produced an 8.1% thrust gain over the standard design under these optimized, high-pressure conditions.*