

Series 2026 - Study #5

CFturbo BLADERUNNER

Design of a Micro Gas Turbine Jet Engine for a Drone



Image 1: Artist's concept of a drone powered by a jet engine [5]

Turbojets offer high power density and low mechanical complexity, enabling compact and lightweight propulsion systems well suited for high-speed, space-constrained applications such as UAVs, missiles and other attritional airframes. However, as single-stream engines, turbojets exhibit inherently lower propulsive efficiency than turbofans, placing greater importance on aerodynamic design quality and component-level performance.

Within this work, a compressor–turbine pair is developed to meet specified thrust and turbine inlet temperature targets representative of a high-speed drone application, based on industry-derived requirements. A Brayton-cycle-based analysis first defines the component-level design requirements, which are then refined through manual iteration. Parametric geometry is generated and adjusted within CFturbo and coupled with external CFD and optimization tools for performance evaluation and design space exploration.

The thrust of turbojets is typically between 250 N to about 2,300 N. Manufacturers include JetCat [1] and PBS Aerospace [2]. The present study shows the aerodynamic design of a drone engine with 250 N thrust.

Structure and function of the turbojet

Turbojets are single-shaft jet engines in which the compressor and the turbine sit on a single common shaft, with the turbine providing the drive power for the compressor. To minimize space and weight, the compressor is designed as a radial wheel with a subsequent axial diffuser, the turbine as an axial stage (Fig. 2).

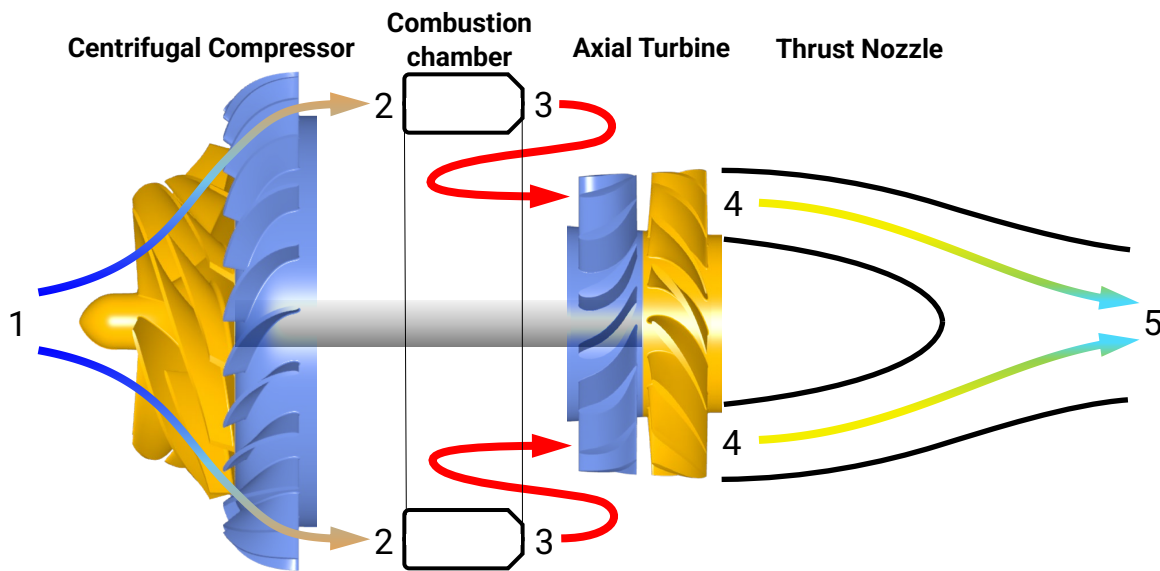
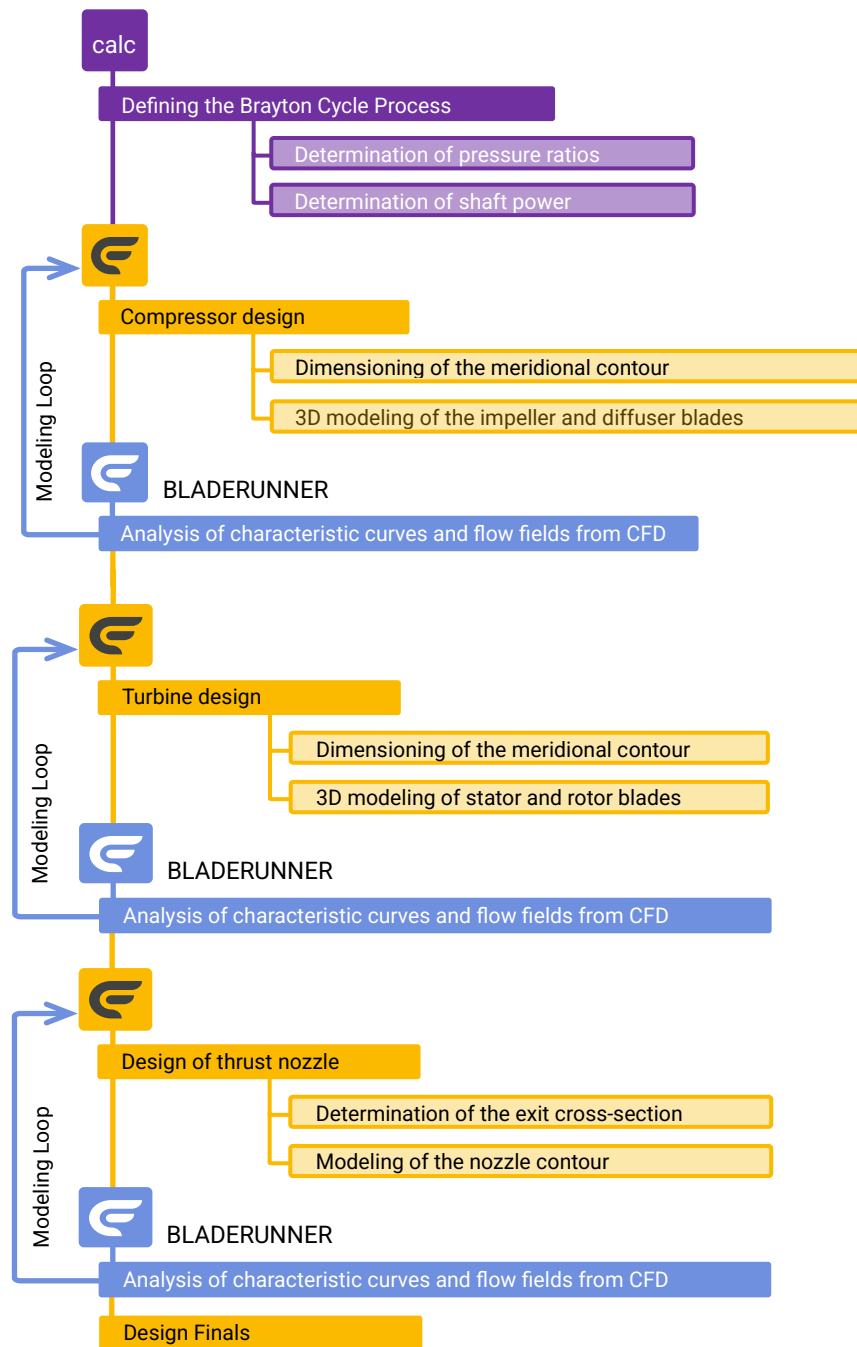


Figure 2: Diagram of a turbojet as a single-shaft engine, thermodynamic classification (digits) After compression (1-2), the air is fed into the combustion chamber (2-3), where it heats up strongly and expands. The hot gas first drives the turbine (3-4) and then is expanded in the nozzle to atmospheric pressure to generate the necessary thrust. The thermodynamic changes in state as well as the heat fluxes and the converted mechanical power are described by the Brayton cycle.

Design steps in CFturbo and CFturbo BLADERUNNER



Determination of the Brayton cycle process

Determination of the pressure ratios and the shaft power required for the compressor

For a target thrust of 250 N, the intake air mass flow is determined to be 0.5 kg/s based on similar industry designs. The combustion chamber outlet temperature is a moderate 750°C, which allows for a comparatively inexpensive design of the turbine in terms of materials and cooling.

Using estimated isentropic efficiencies for the compressor, turbine and thrust nozzle, the appropriate pressure ratios and temperature changes as well as the fuel consumption to achieve the thrust can be calculated iteratively.

Table 1: Brayton cycle Process: Specifications with dashed outline, important quantities in bold

Total gas turbine

Thrust	F	250 N
Massenstrom Luft	mL	0,5 kg/s
Combustion chamber outlet temperature	t3	750 °C
Thermal efficiency	η_{GT}	20,2 %

Compressors

isentropic efficiency	η_v	0,8
Ambient temperature	T1	293,2 K
Outlet temperature isentrop	T2,s	419,8 K
Outlet temperature polytropic	T2	451,5 K
specific compressor work	wV	162,0 kJ/kg
Net shaft power	PW, V	81,0 kW
Recording power (rounded up)	PW, V	85,0 kW

Pressure ratio	π_v	3,5
Ambient pressure	p1	1000,0 hPa
Exit pressure	p2	3500,0 hPa

Combustion chamber

Outlet temperature combustion chamber

= Inlet temperature turbine	T3	1023,2 K	750,0 °C
Heat flux supplied	QBK	327,5 kW	
Calorific Value Kerosene (Jet A-1)	Hi,K	43100 kJ/kg	
Mass flow kerosene (rounded up)	mK	0,010 kg/s	0,59 kg/min

Rel. pressure loss	Δp_{2-3}	6,0 %
Exit pressure	p3	3290,0 hPa

Turbine

Shaft power	PW, T	85,0 kW	= Input power compressor PW,V
specific turbine work	wT	166,7 kJ/kg	
isentropic efficiency	η_T	0,85	

Outlet temperature polytropic	T4	869,8 K	596,7 °C	Exit pressure	p4	1672,8 hPa
Outlet temperature isentrop	T4,s	842,8 K	569,6 °C	Pressure ratio	π_T	2,0

Thrust nozzle

isentropic efficiency	η_D	0,95
Outlet temperature isentrop	T5,s	750,5 K
Outlet temperature polytropic	T5	756,5 K
Exit velocity	v5	509,7 m/s
Thrust	F	259,9 N
Beam power	PD	66,2 kW

$p_5 = p_1$	1000 hPa	
Pressure ratio	π_D	1,7

This process predicts an overall thermal efficiency of 20.2%, a conservative estimate for basic jet engines. At this stage an increase in thermal efficiency beyond 20.2% is possible through more efficiency components or by increasing the pressure in the combustion chamber, but this leads to a larger impeller and a stronger shaft, and thus to additional weight and larger dimensions.

Compressor design, dimensioning and 3D modeling of impeller and Diffuser

The compressor and turbine are designed for a relatively high speed of 120,000 rpm in order to achieve compact dimensions.

The design point of the compressor is defined by the quantities

- Air mass flow 0.5 kg/s
- Pressure ratio 3.5
- Speed 120,000 1/min
- Ambient pressure 1 bar at 20°C

CFturbo combines basic fluid mechanics and thermodynamic equations with empirical relationships from current technical literature [3] to provide complete geometry of impeller and diffuser in the first step.

The blade entry angles are selected to be parallel to incoming flow while backwards curved exit blade angles ensure a high peak efficiency of the impeller. Splitter blades allow for good flow control at exit while minimizing the geometric obstruction at the blade inlet (Fig. 3).

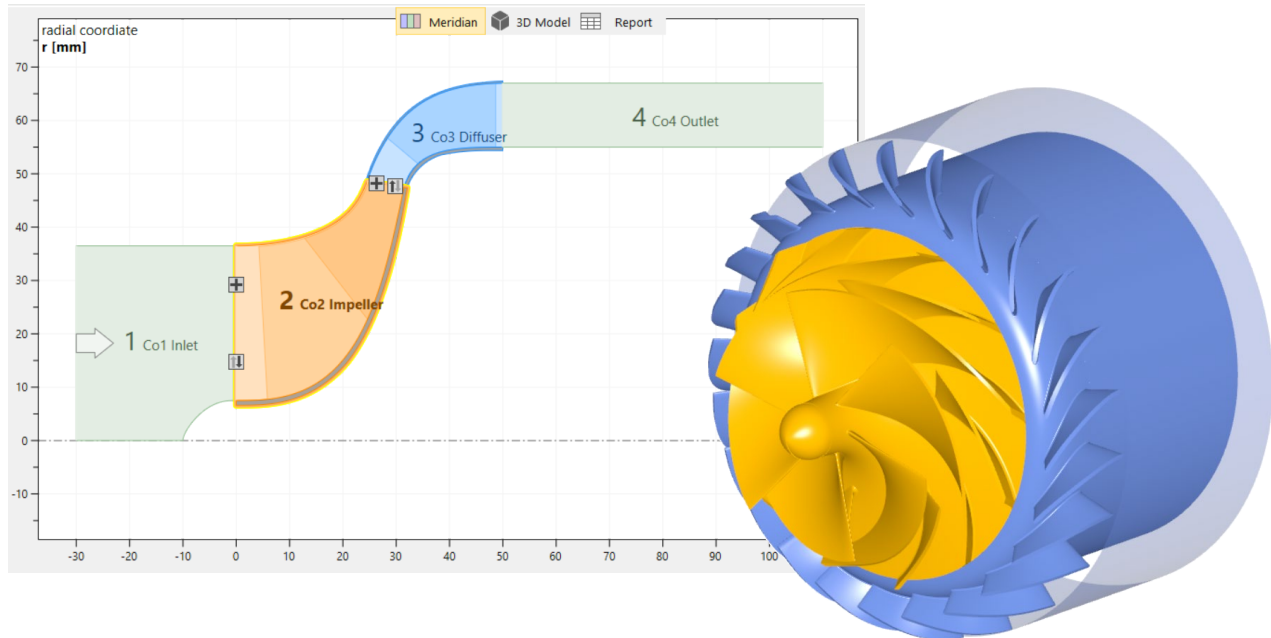


Figure 3: Initial design of the compressor: Impeller with splitter blades, diffuser with short blades

Fast results from flow simulations in the background with CFturbo BADERUNNER
Evaluation of characteristic curves and analysis of flow fields

The flow simulation for the design point shows an incomplete flow deflection in the diffuser with high residual swirl, as well as flow separation. These inefficiencies reduce the peak efficiency to 73.0 % (Fig. 4).

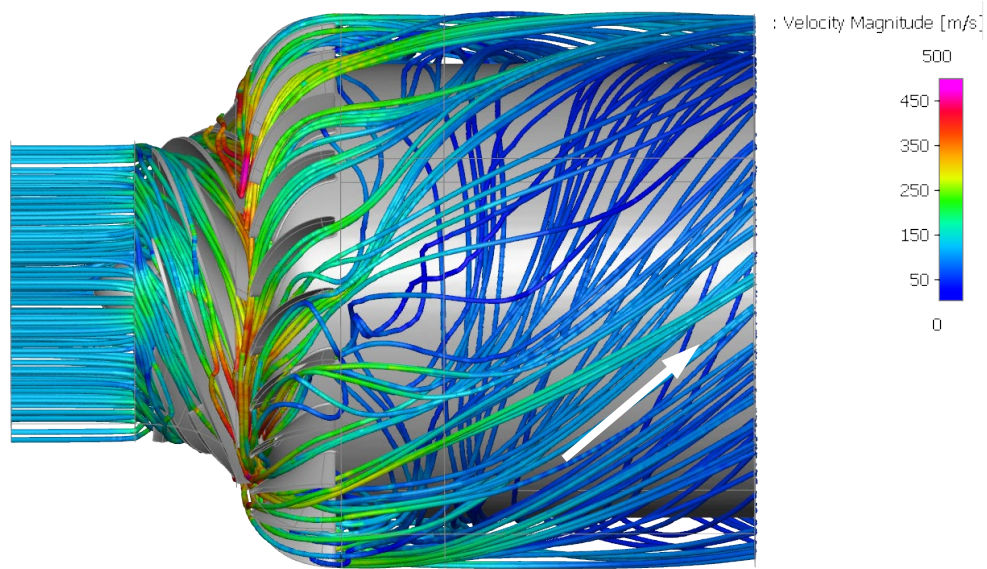


Figure 4: Initial design of the compressor: strong flow detachments in the diffuser, residual swirl

The improvement of the initial design is carried out on the fully parameterized model in CFturbo by

- Diagonal flow control in the impeller for less flow deflection
- An vaneless diagonal diffuser with a lower channel height for uniform flow slowing
- An axial diffuser with elongated blades for deflection-free flow
- Adjustment of the number of blades and the blade exit angle on the impeller for optimal pressure increase at the design point

To inform this design CFturbo BLADERUNNER is used to easily simulate full performance curves in the background for designs of interest, with simulation fidelity being adjustable to achieve fast iteration or most accurate deliverables.

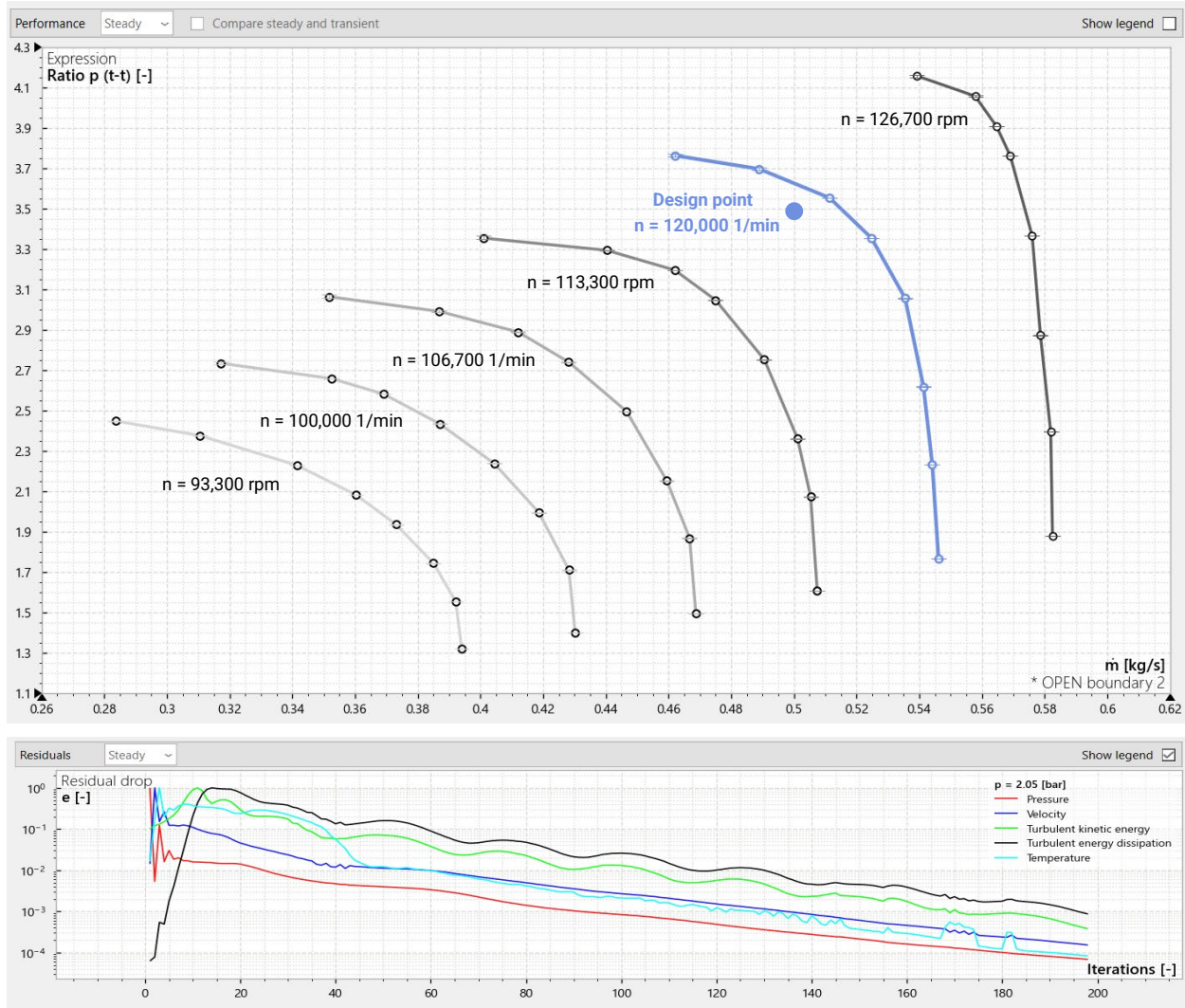


Figure 5: Compressor map of the final design (top), convergence behavior (bottom)

Typical compressor characteristic curves are bounded by the so-called surge and choke limits at low and higher relative mass flow rates respectively, with the targeted mass flow being well away from both to ensure stability and to prevent low performance and damage to the components. These objectives are met at the desired pressure rise as shown in Figure 5.

The final design is shown in Figure 6. This design achieves the required performance by minimizing exit swirl and flow detachment resulting in a total-to-total efficiency of 80%.

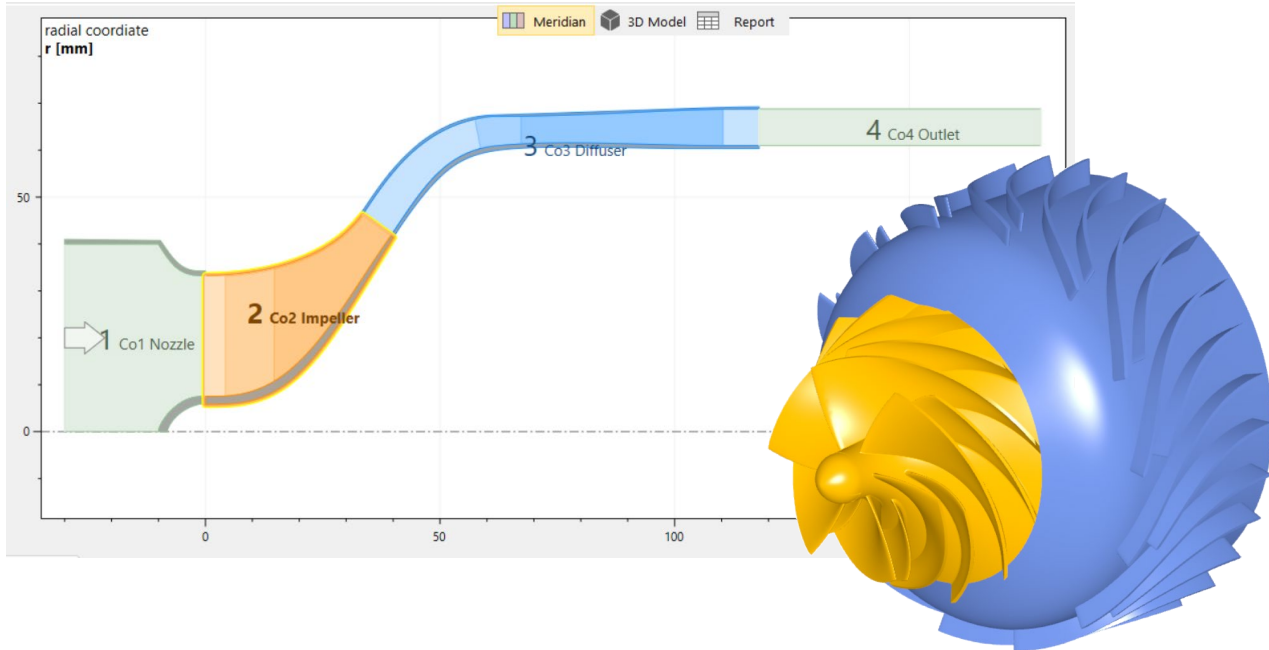


Figure 6: Final design: diagonal impeller and long diffuser blades with splitter blades

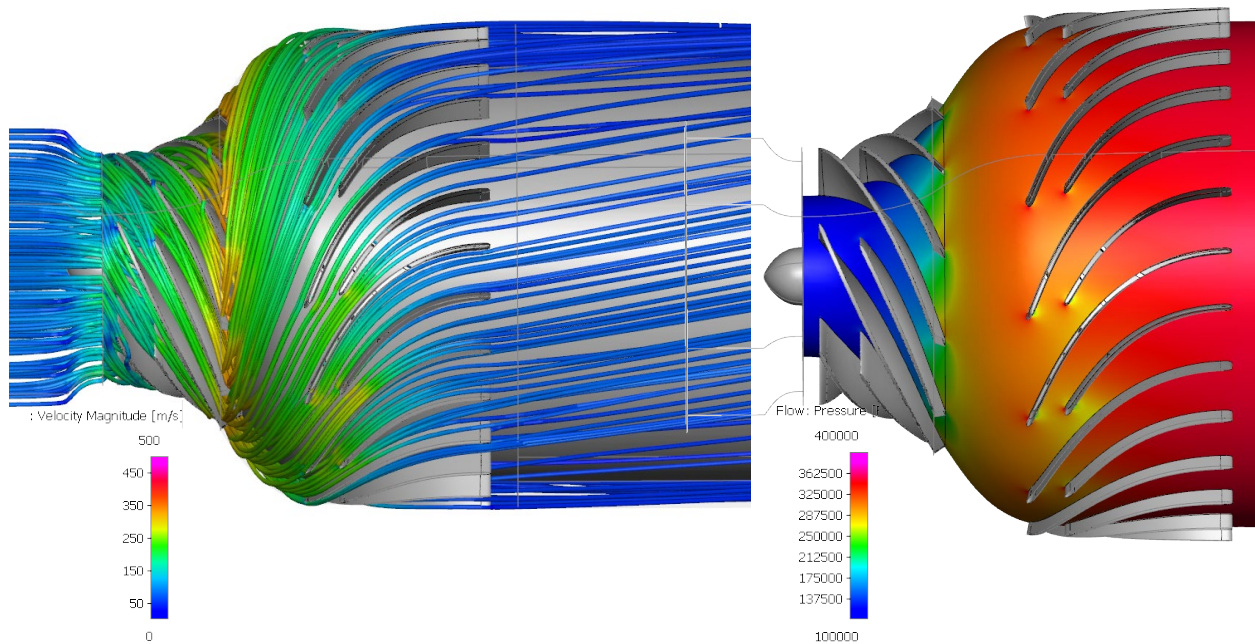


Figure 7: Final design: detachment-free diffuser flow, (left), uniform pressure build-up (right)

Design of the turbine

3D modeling of the stage

The design goal for a gas turbine is to generate the necessary shaft power to drive the compressor while inducing the lowest possible pressure drop and exit swirl. This results in the highest possible backpressure to generate the necessary thrust in the nozzle.

The design of our turbine is described in a previous study "Mini Case Study Series 2025 – Study #4 – Design of the Gas Turbine of a Turbopump" [4] and will be condensed here for brevity.

As with the compressor, CFturbo automatically designs a complete 3D geometry of the turbine meridional contour and blades with the appropriate blade angles as determined by 1D relations. A tip gap of 0.3 mm is used. The design point defined at

- Total mass flow rate 0.51 kg/s (air and fuel products)
- Speed 120,000 RPM
- Shaft power 85 kW = input power of the compressor with mechanical loss

while the pressure ratio is freely adjusted, here to $\pi_T = 2.05$.

At the end of the modeling loop, the turbine achieves an isentropic efficiency of 88.9 % and delivers exactly 85 kW of shaft power (Fig. 8).

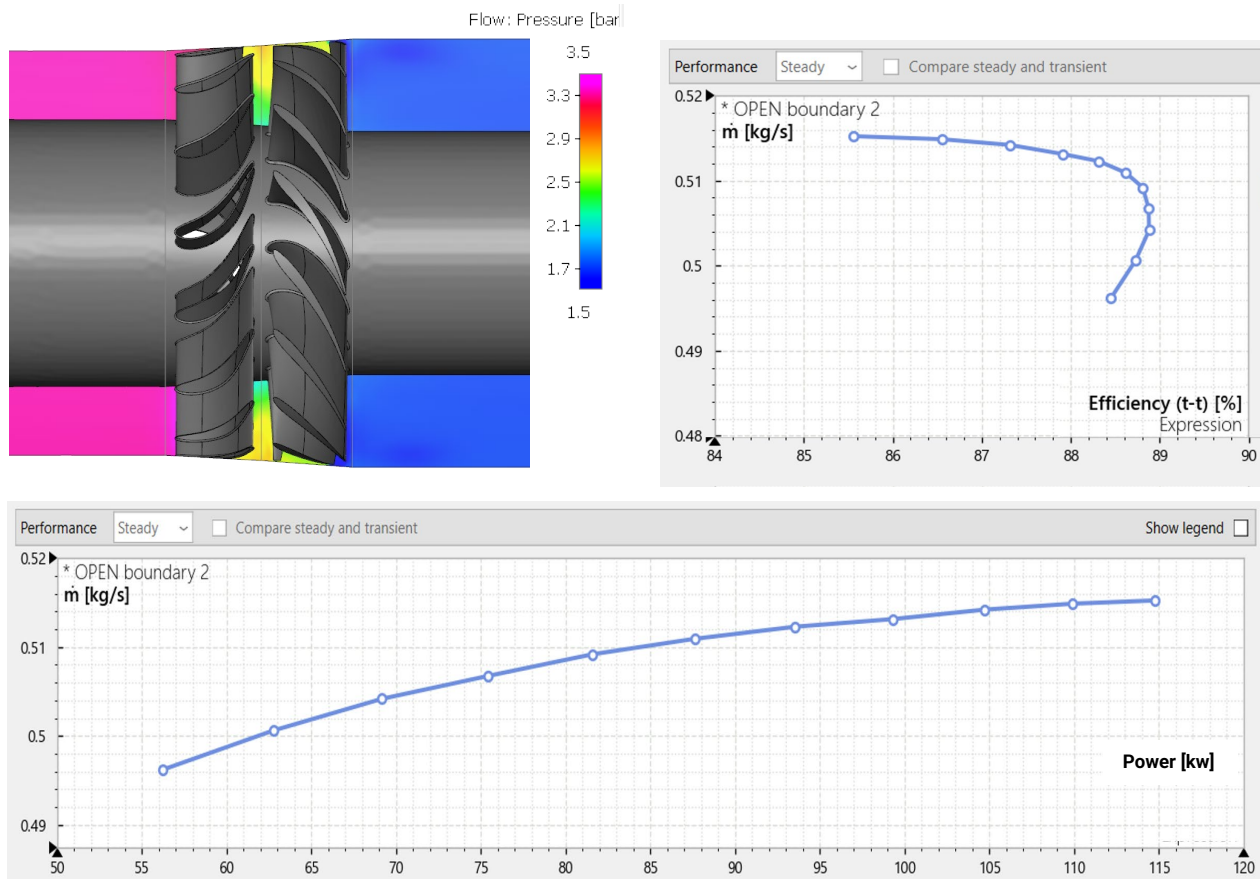


Figure 8: top: pressure-contour plot of the stage and efficiency curve, bottom: shaft power

Adjustment of the thrust nozzle

Determination of the outlet cross-section and modeling of the nozzle contour

In the last step, a thrust nozzle and outflow chamber is modeled and simulated (Fig. 9). The appropriate contraction ratio of the nozzle for the expansion to ambient pressure results from the total pressure at the turbine outlet.

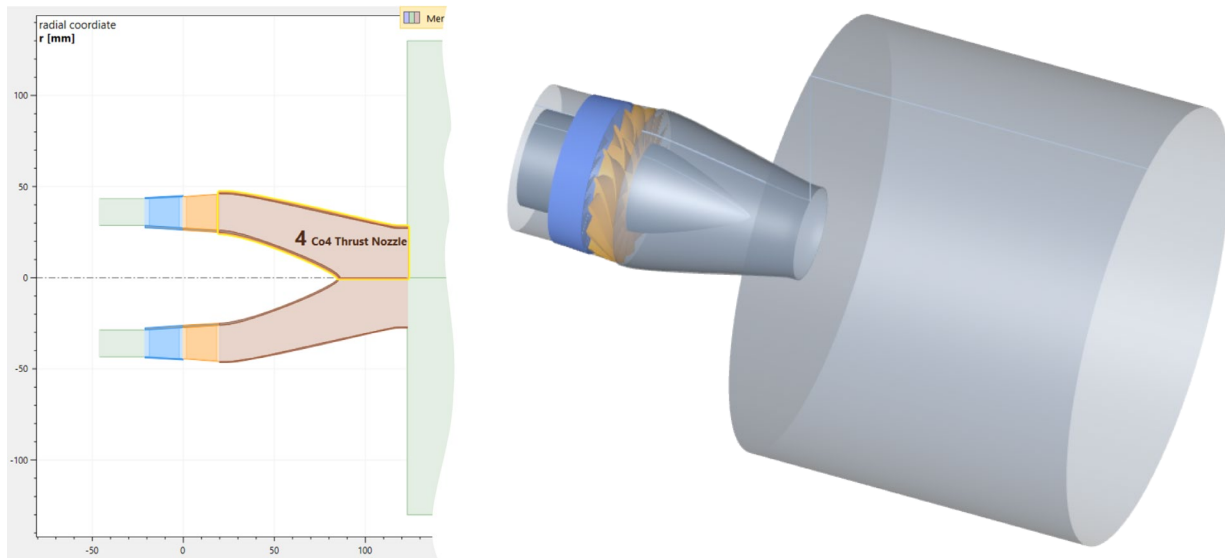


Figure 9: Meridian section and 3D view of the turbine with thrust nozzle and outflow chamber

The flow simulation results in a swirl-free nozzle flow with an exit velocity of 510 to 520 m/s, so that the desired thrust of 250 N is achieved (Fig. 10).

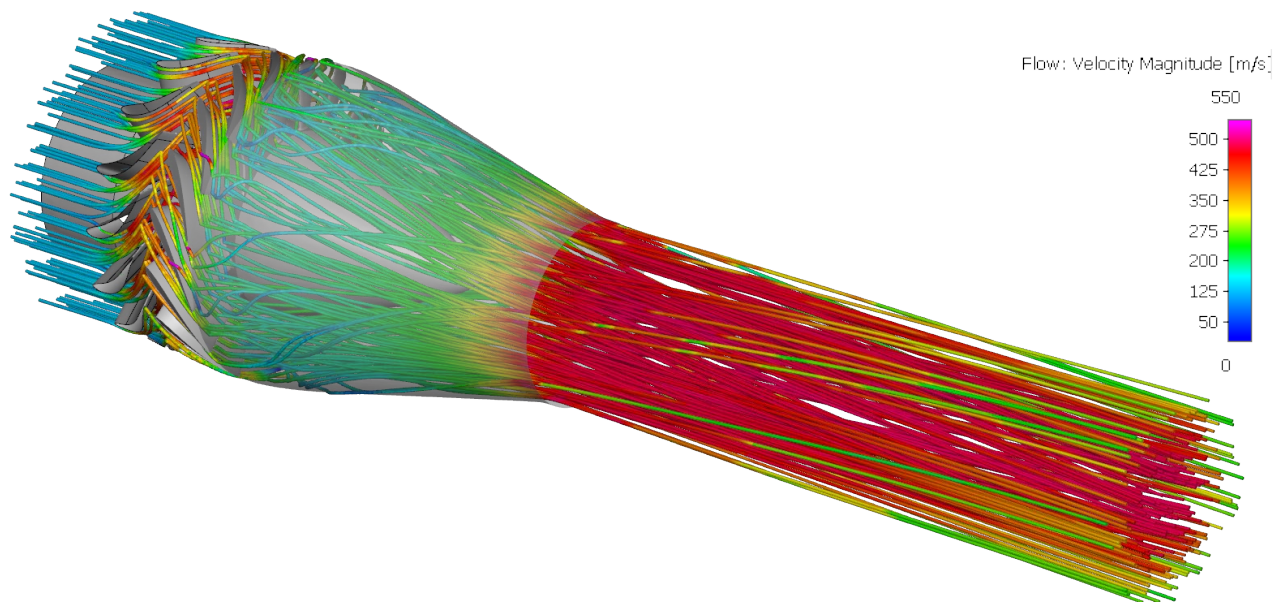


Figure 10: Streamlines in turbine components, thrust nozzle and free jet

Recalculating the Brayton cycle relations using newly validated efficiencies for the compressor turbine and nozzle, a final thermal efficiency of 27.7% and thrust of 276.8N is found.

The geometries generated in CFturbo, including the rough contour of a combustion chamber to complete the flow chamber, can be exported in all common CAD formats and combined to form an overall model (Fig. 11).

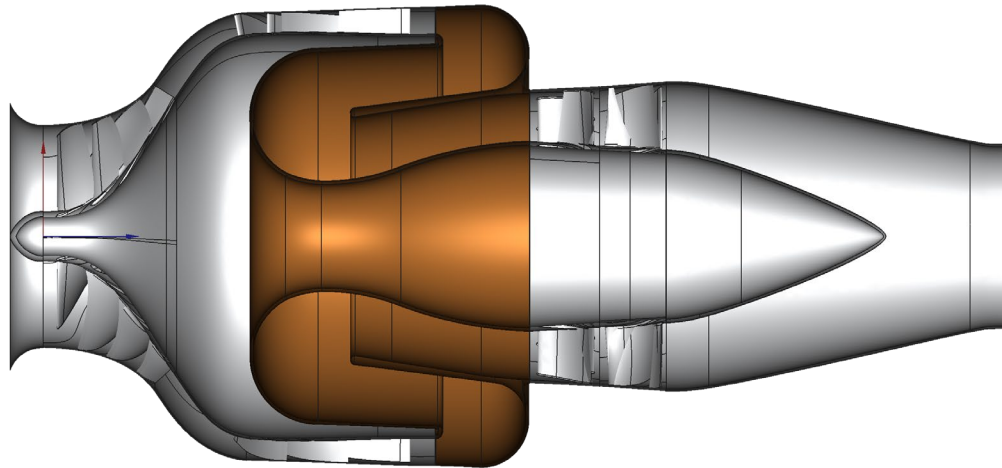


Figure 11: Overall model of the turbojet with bronze-colored combustion chamber

CONCLUSION

This case study is used to demonstrate an integrated, end-to-end design workflow for turbojet development, spanning preliminary thermodynamic sizing, parametric 3D turbomachine design, and final performance validation. The workflow is implemented in a modular and robust manner, providing streamlined data transfer between geometry generation, meshing, and CFD providing a reliable foundation for both automated and manual design.

These capabilities are particularly important for modern turbomachinery development, where design cycles are increasingly driven by rapid iteration and optimization-driven workflows. By consolidating geometry, performance data, and sensitivity insights within a single workflow, this approach reduces design turnaround time and supports more informed exploration of compact, high-performance turbojet configurations. Future work is planned to further optimize these designs to prove the workflow functionality.

LITERATURE

- [1] JetCat <https://www.jetcat.de/en/products/produkte/jetcat/kategorien/professional>
- [2] PBS TJ200, <https://www.pbsaerospace.com/aerospace-products/engines/turbojet-engines/jet-engine-pbs-tj200>
- [3] Radial Flow Turbocompressors, M. Casey, C. Robinson, Cambridge University Press, 2021
- [4] CFturbo BLADERUNNER – design of the gas turbine of a turbopump, CFturbo GmbH, Study #4, 2025
- [5] PBS TJ80; DT <https://defenceturkey.com/news/pbs-unveils-new-high-thrust-lightweight-engine>