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3D CFD Modeling of the ANTONOV D-136 Turboshaft

Modelado CFD 3D del turboeje ANTONOV D-136

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ABSTRACT

An analysis was performed on the operation of turbines for the Mil Mi-26 helicopters, which use D-136 family turboshaft engines. Using the ANSYS tool, a motor was simulated, and operational factors were evaluated, focusing primarily on the pressures within the turbine and the kinetic energy of turbulence. Results of pressure concentration points and kinetic energy were obtained by defining inputs of rotational speed and wind velocity, as evidenced in the following images. The purpose of this study is to gather relevant information to aid future research in optimizing processes, whether internal or related to engine design.

RESUMEN

Se realizó un análisis sobre el funcionamiento de las turbinas de los helicópteros Mil Mi-26, los cuales utilizan motores turboeje de la familia D-136. Utilizando la herramienta ANSYS, se simuló un motor y se evaluaron factores operativos, enfocándose principalmente en las presiones dentro de la turbina y la energía cinética de la turbulencia. Se obtuvieron resultados de puntos de concentración de presión y energía cinética al definir entradas de velocidad de rotación y velocidad del viento, como se evidencia en las siguientes imágenes. El propósito de este estudio es recopilar información relevante que contribuya a futuras investigaciones para optimizar procesos, ya sean internos o relacionados con el diseño del motor.

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1. Introduction

Throughout history, inventions and improvements have contributed to the advancement of structures and elements that have enhanced the comfort and convenience of humanity. The field of mechanics is no exception. Innovations in engines and turbines have not only increased the operational efficiency of devices like helicopters but also opened new possibilities for civil transportation, mass cargo transport, military operations, and many other applications.

2. Thematic structure

Based on design information, it was possible to successfully simulate the type of engine and perform analysis using finite elements through the ANSYS tool.

2.1. Mil Mi-26 Helicopters

The Mil Mi-26 is a heavy transport helicopter used for both military and civilian missions. It is the largest and most powerful helicopter in production, primarily designed to transport extremely heavy loads. It uses two D-136 turboshaft engines and an eight-blade main rotor, one of the largest ever built, which is key to allowing the helicopter to lift such high weights.

2.2. Turboshaft Engine

Several studies provide a technical foundation for simulating and optimizing complex mechanical systems like turboshaft engines.

Turboshaft engines are a variant of gas turbine engines, specifically designed for applications requiring a favorable power-to-weight ratio, such as helicopters. These engines consist of a compressor, a combustion chamber, an expansion turbine, and a power transmission system.

The compressor compresses the incoming air before it is mixed with fuel and ignited in the combustion chamber. The resulting hot gases pass through the turbine, where the energy required to operate both the compressor and the power shaft that drives the helicopter's rotor is extracted.

Piracoca-Peralta [10], Campo-Ceballos [13], and Duarte Barón, K., Gil-Peláez, J. J., y Borrás Pinilla, C. [26] worked into turbine and thermal system modeling using tools such as ANSYS and COMSOL, approaching in the D-136 engine study.

Herrera, M., Aguirre, C [30], Monroy Moya, D. F., Rojas Sarmiento, D. A., y Barrera Prieto, F. [48], and Giraldo Ramos [50] explore energy eficiency and movement, which shares similar objectives in optimizing design under high-stress conditions. These works support the importance of 3D CFD Simulation of the ANTONOV D-136 Turboshaft Engine simulations in predicting fluid behavior, thermal performance, and system wear, all critical elements in aeronautical engine analysis.

2.3. D-136 Engines

The D-136 engines are turboshaft engines designed by the Ukrainian company Motor Sich, specifically for the Mil Mi-26 helicopters.

Espitia Cubillos et al. [34] investigated nanotechnology applications in structures, offering materials knowledge applicable to high-stress turbine components. Estupiñán Cuesta et al. [36] modeled asphalt mixtures via digital imaging, a technique like CFD-based surface diagnostics.

They generate 11,400 shaft horsepower (shp), giving the helicopter a total power of 22,800 shp, which is necessary to lift heavy loads and operate in non-optimal takeoff and landing conditions. Table 1 shows the data sheet for the D-136 engine's operating parameters.

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Table 1: D-136 Engine Data Sheet.

D136 Motor	
Power	11400shp (8500kW)
Rotation Speed	15000 rpm
Number of Stages	3 stages of compression and expansion
Compression Ratio	16:1
Inlet Temperature	1300 °C
Weight	1,200 kg
Dimensions	3,000 mm x 1,200 mm x 1,500 mm
Inlet Air Speed	220-270 m/s (792-972 km/h)

Source: own.

2.4. CFD Simulation using ANSYS

Computational Fluid Dynamics (CFD) is a branch of fluid mechanics that uses numerical methods and algorithms to analyze and solve problems involving fluid flows. The ANSYS software offers the ability to model phenomena such as turbulence, heat transfer, and chemical reactions in turbine engines. Through this tool, it is possible to analyze the behavior of air and gas flow within the D-136 engine turbines, allowing the identification of areas with high pressure, turbulence, or efficiency loss.

The use of virtual and remote laboratories for electronics education and based simulation let to digitally reproduce physical environments which helps to approach underscores how virtual tools can enhance engineering training and experimentation and reduce the use of physical prototypes as Rodríguez-García et al. [7] explores.

CFD techniques are also applied in complex engineering systems, providing insights that are transferable to aerospace applications. Rodríguez Umaña [47] developed a water conductivity measurement system with real-time data transmission, incorporating fluid flow and signal analysis. Herrera [30] explored bioreactor development using organic waste making emphasis in fluid movement and thermal response.

Estupiñán-Cuesta [28] compared GSM signal strength and OpenBTS, offering a methodology that validates simulation accuracy. Aguirre-Vargas [27] used updated fault estimation that could enhance fault modeling in engine simulations. Arteaga Erazo [32] employed electrical impedance spectroscopy in food quality, using boundary fluid properties comparable to multiphase flow simulations.

A similar approach is found in biomedical and robotic systems modeling, such as the integration of simulik VR-World and SolidWorks CAD to validate actuator models for prosthetics, where the 3D mechanical design is verified through simulation environments this highlights the flexibility of 3D scanning and CAD tool, no only for visualization but for robts simulation and even prototyping through 3D printing techniques [53]

2.5. Artificial Intelligence & Machine Learning

Vargas-Pardo and Giraldo-Ramos [8] presents the use of algorithms that optimize blade configurations or mesh density to improve simulation accuracy and turbine efficiency.

In the context of CFD, the use of AI to apply convolutional neural networks for human behavior assessment can be used to support the identification of turbulent regions, flow anomalies, or even predict performance trends based on simulation data. Jiménez-Moreno [9] and Martínez Quintero [40] introduced a modulation classification system based on intelligent algorithms, supporting efficient signal recognition.

Another task to be accomplished is the correct image analysis in which Montoya-Cabezas [41] applied image processing and AI to detect diseases in fruit crops, facilitating early intervention in agriculture and Gómez [31] compared YOLO and Haar Cascade for vehicle detection, emphasizing ai´s role in urban transportation.

Pacheco-Fandiño [18] combined bio-inspired models for cesarean diagnosis, connecting medical diagnostics and mechanical interpretation, it could help in engine systems detection. Ramos Suavita [52] simulated network vulnerabilities via HTTP/TCP flooding, indirectly contributing to system safety modeling.

2.6. Importance of Pressure and Kinetic Energy in Turbines

The performance of a turbine largely depends on the pressure profiles and kinetic energy of the flow passing through its stages. The pressure differences generated in the turbine enable the conversion of the thermal energy of combustion gases into mechanical work. If the pressures in the system are not properly controlled, efficiency losses can occur, as well as critical stress points that may reduce the lifespan of the components.

On the other hand, the kinetic energy of turbulence is an important parameter that describes the intensity of flow fluctuations within the turbine. High levels of turbulence can cause greater wear on parts, increase aerodynamic losses, and negatively impact engine efficiency. It is essential to identify regions where peaks in kinetic energy are concentrated to optimize the design and avoid long-term reliability issues.

2.7. Sustainability and Material Innovation

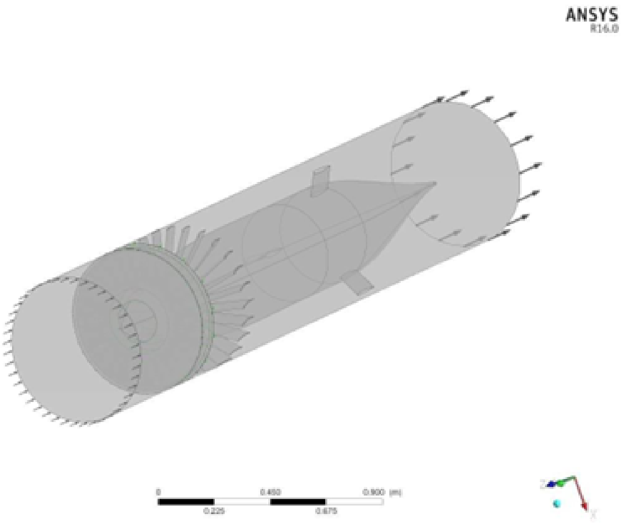
The future of CFD modeling and turbomachinery involves sustainability and innovation in materials. For this cases Castiblanco Forero and López Martínez [22] and Ramirez Ubaque [35] evaluated energy usage, one in residential rooftops, the other developed handmade coffee soap, a project highlighting sustainable production chains both encouraging sustainable thinking in energy systems.

Romero-Peña and Puerto-Leguizamón [19] worked on optical fiber design, making emphasis in material synthesis. Herrera [45] studied the psychophysiological response to sound, potentially informing design standards for noise reduction in turboshaft engines.

3. Experimental Development

The engine simulation was developed through 3D scanning, which was used to create the CAD model, and it was successfully exported to the ANSYS tool.

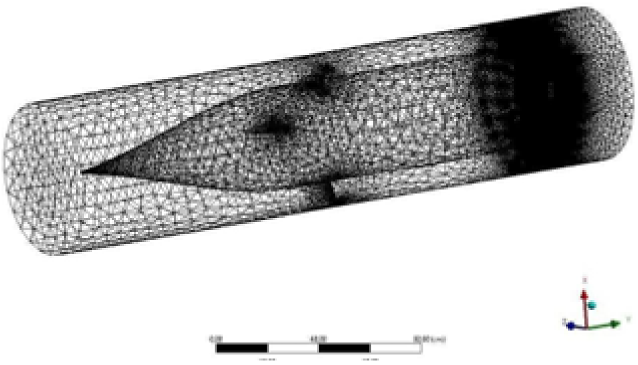
Figure 1: Model in ANSYS software.



Source: Own.

This system was developed as a mesh model to perform finite element analysis, considering 1,397,275 nodes and 7,666,047 elements.

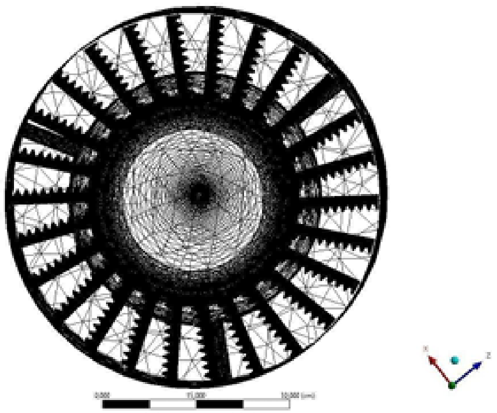
Figure 2: Mesh model of the engine.



Source: Own.

And the analysis was more focused on the blades of the engine, as these areas will contain the greatest pressure and energy concentrations of the turboshaft.

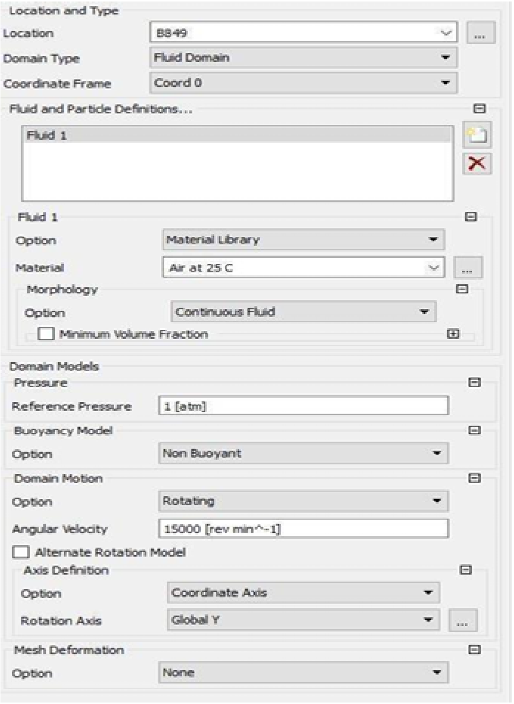
Figure 3: Mesh model of the engine blades.



Source: Own.

The inputs were defined as a rotational speed of 15,000 rpm and an incoming wind speed of 270 m/s.

Figure 4: ANSYS data input screen.



Location and Type
Location: B849
Domain Type: Fluid Domain
Coordinate Frame: Coord 0
Fluid and Particle Definitions...
Fluid 1
Fluid 1
Option: Material Library
Material: Air at 25 C
Morphology
Option: Continuous Fluid
☐ Minimum Volume Fraction
Domain Models
Pressure
Reference Pressure: 1 [atm]
Buoyancy Model
Option: Non Buoyant
Domain Motion
Option: Rotating
Angular Velocity: 15000 [rev min^-1]
☐ Alternate Rotation Model
Axis Definition
Option: Coordinate Axis
Rotation Axis: Global Y
Mesh Deformation
Option: None

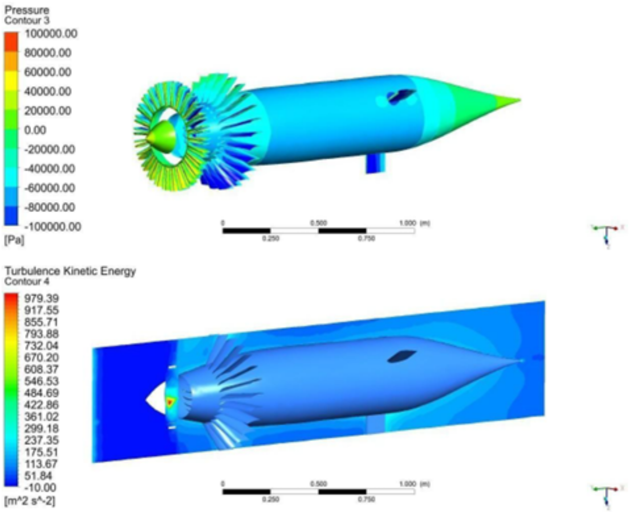
Source: Own.

The data obtained from research on these engines was entered. Those inputs were based on real life data.

4. Results

Based on the input values, the software provides the following results:

Figure 5: Turboshaft model showing pressure and kinetic energy results.



Source: Own.

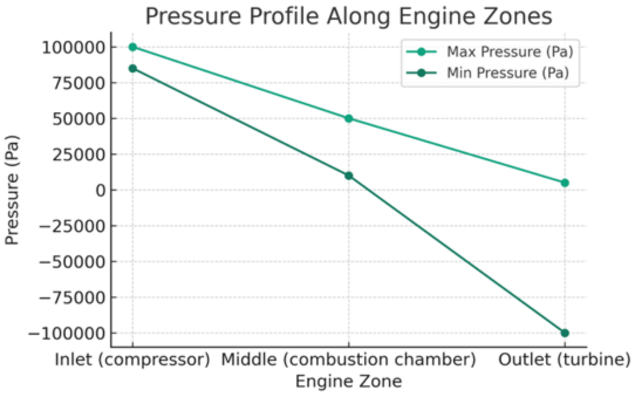
In this image, a pressure contour map is shown in the turbine of the D-136 engine. The pressure values vary significantly along the component, reflecting the different operating conditions of the engine.

Additionally, the turbulence kinetic energy contour is shn, which illustrates the flow behavior in the turbine.

The area closest to the compressor shows high pressure levels, around 100,000 Pa, indicating effective air compression before entering the combustion chamber. This increase is crucial for the engine's efficiency, as higher intake pressure improves the air-fuel ratio and, consequently, the generated power. As the air moves toward the rear of the turbine, the pressure values drop dramatically, reaching negative values (down to -100,000 Pa) as the air's energy is converted into mechanical energy, causing a pressure drop.

The following graph shows the pressures levels depending on the Engines zones

Figure 6: Pressure profile along engine zones.

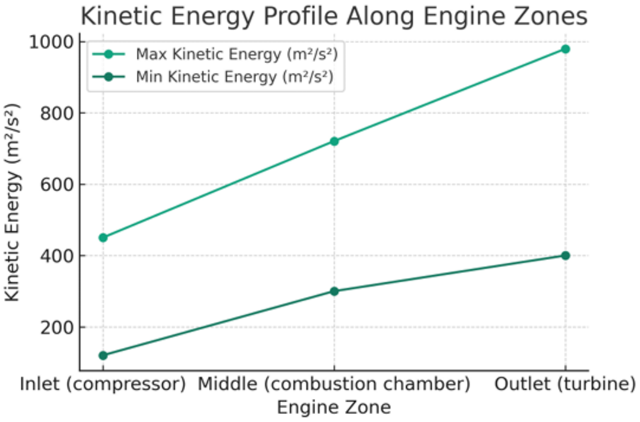


Source: Own.

Peaks in kinetic energy can be observed, particularly in areas near the turbine's exit, with values reaching up to 979.39 m²/s². This indicates a turbulent flow that may cause increased wear on the parts and contribute to aerodynamic losses. The variation in kinetic energy levels throughout the turbine reveals the presence of recirculation zones and vortices, indicative of flow inefficiencies. Future research could focus on mitigating these, as they affect the overall efficiency of the engine.

The following graph shows the kinetic energy levels depending on the Engines zones

Figure 7: Kinetic energy profile along engine zones.



Source: Own.

This approach allows for greater precision and clarity in understanding the operational behavior of the D-136 turboshaft engine.

Table 2: Pressure and Kinetic energy results.

Engine Zone	**Max Pressure (Pa)**	**Min Pressure (Pa)**	**Max Kinetic Energy (m^2/s^2)**	**Min Kinetic Energy (m^2/s^2)**
Inlet (compressor)	100,000	85,000	450.20	120.35
Middle (combustion chamber)	50,000	10,000	720.80	300.15
Outlet (turbine)	5,000	-100,000	979.39	400.10

Source: own.

This simulation allows for material analysis based on the calculations obtained, as well as design improvement studies that aim to increase efficiency by reducing noise levels. More specific studies can be conducted for each part of the turboshaft, considering changes in more specific factors such as dimensions or physical inputs.

5. Conclusions

This study successfully developed a 3D computational fluid dynamics (CFD) simulation model of the ANTONOV D-136 turboshaft engine using ANSYS CFX, providing insights into the internal aerodynamic behavior of the rotor-stator configuration.

The results revealed distinct variations in static and total pressure, especially in regions affected by blade rotation and compression, aligning with expected thermodynamic behavior in turboshaft engines.

Variations in the incoming wind speed within the working ranges conclude that there were no significant changes in pressure and kinetic energy outputs. It is important to respect the model's angles during the design phase, particularly those of the blades and the stator, as they result in significant changes in the outcomes. To reduce system noise levels, material analysis and possible redesign are necessary.

The simulation allowed for the visualization and analysis of pressure, velocity, and temperature distribution along the engine's flow path, demonstrating the feasibility of applying advanced CFD tools to complex aerospace components. Furthermore, the temperature gradients and flow acceleration patterns were consistent with the engine's design objectives, confirming the fidelity of the model. These findings are supported by quantitative outputs such as axial velocity profiles and thermal maps, offering a baseline for future aerodynamic optimization.

Beyond validating the CFD model, the implementation of structured meshing, boundary condition definition, and solver configuration demonstrated effective strategies for simulating aerospace systems so this research contributes to the broader field of turbomachinery simulation.

6. Projection of Future Work

Based on the results obtained, several future research directions can be identified:

- Parametric optimization of blade geometry to reduce high turbulence zones.
- Application of advanced coating or wear-resistant alloys in areas with high kinetic energy.
- Thermo-fluid dynamic simulations considering real combustion to evaluate performance under different air-fuel mixtures.
- Integration of Active Flow Control (AFC) systems to minimize recirculation.
- Experimental validation using a test bench to correlate CFD results with physical data.
- Application of the CFD model to other turboshaft engines to establish a replicable analysis methodology.

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