THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.3.02

REGARDING THE USE OF FINITE ELEMENT MODELING FOR PROPULSION SYSTEM SIZING IN V.T.O.L. DRONES

Adrian LEOPA
"Dunarea de Jos" University of Galati, Engineering and Agronomy Faculty of Braila, Romania
e-mail: adrian.leopa@ugal.ro

ABSTRACT

At the moment, VTOL drones have proven their efficiency in several areas, for this reason, they have become indispensable tools for a large category of applications. This paper presents aspects related to the dimensioning stage of the propulsion system of a drone based on finite element modeling, to establish the traction force necessary to ensure sustentation.

KEYWORDS: drone, modeling, finite element

1. Introduction

Currently, VTOL drones (vertical take-off and landing) are used in various fields due to the multiple advantages they present: small size, vertical take-off/ landing, flight in narrow spaces, high precision and others.

These are versatile systems that have found multiple uses, such as:

- monitoring environmental factors with high-precision sensors;
- assessment of soil quality and vegetation status of crops using multispectral cameras;
- crop herbicide;
- performance of cartographic and topographical tasks;
- objective surveillance missions;
- extinguishing fires.

As regards the monitoring of environmental factors, this is a vital activity from the perspective of ensuring a high level of human, animal and plant quality of life. For this reason, in some countries in urban agglomerations or areas bordering industrial zones, there are fixed weather stations for which they fulfil this role. However, for unforeseen situations such as natural or man-made disasters, there are several devices capable of measuring the concentrations of pollutants and transmitting this information to a decision-making forum.

In the agricultural field, VTOL drones have imposed themselves by drawing up orthophoto plans capable of providing useful information on soil quality parameters and crops of interest. Subsequently, the same type of drones can be used to treat crops differently based on previously made orthophoto plans, thus achieving a saving of treatment substances.

In terms of surveillance of targets, VTOL drones can replace the human factor and can cover large areas both day and night.

In certain situations, these drones can be used to extinguish or isolate fires.

2. Aspects regarding the dimensioning of the propulsion system

Currently, there is a multitude of propulsion system configurations for VTOL drones, for this reason, the theoretical study presented in this paper has as its main objective the determination of flight parameters for a single bipal propeller.

In order to choose the propulsion system, the following steps were taken:

1. Establishing the program for numerical modelling;
2. Establishing the propeller model;
3. Modelling.

Due to its proven performance in the field of scientific research, the Ansys Workbench program was chosen as the medium for numerical modelling.

When choosing the propeller model, the following parameters should be considered: diameter, pitch, number of blades and its mass. The advantage of finite element modelling is that the above-mentioned parameters can be easily modified in order to characterize the dependence between them and flight parameters.

To describe the steps that were taken in order to evaluate the traction force developed by a twin blade

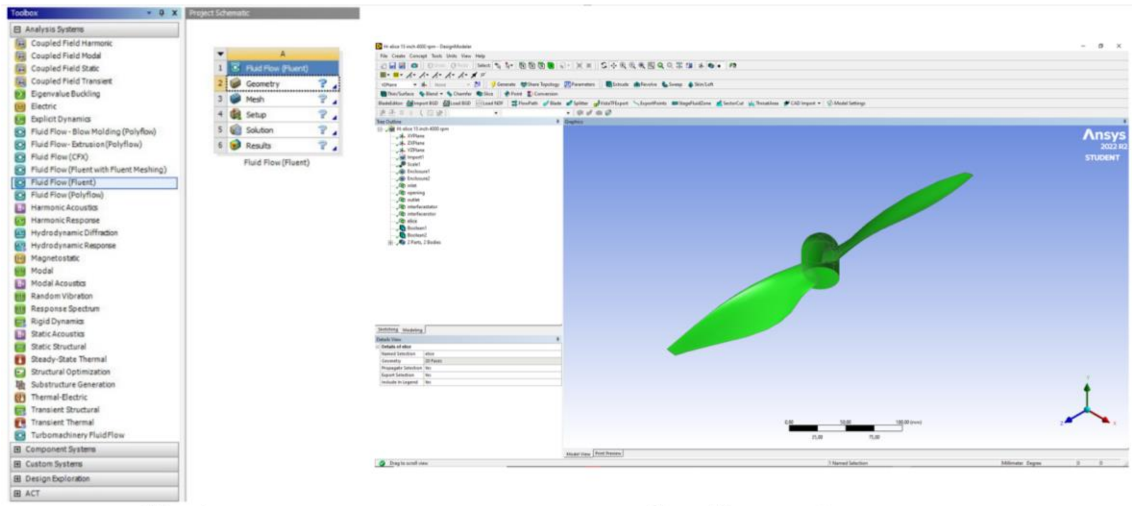
N°. 3 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.3.02

propeller of 15-inch diameter and 8-inch pitch, model taken from source [1].

3. Flow modelling in Ansys Workbench

From the Ansys program window, the Fluid Flow (Fluent) analysis system for airflow modelling was chosen. Subsequently, from the menu of the Fluent system, the geometry environment opens in which the 3D model of the propeller is imported in the form of a file compatible with it.

In the next step, a "Rotor fluid" is created that will completely encompass the propeller, Fig. 2.



Fluent Propeller geometry

Fig. 1. *Propeller geometry*

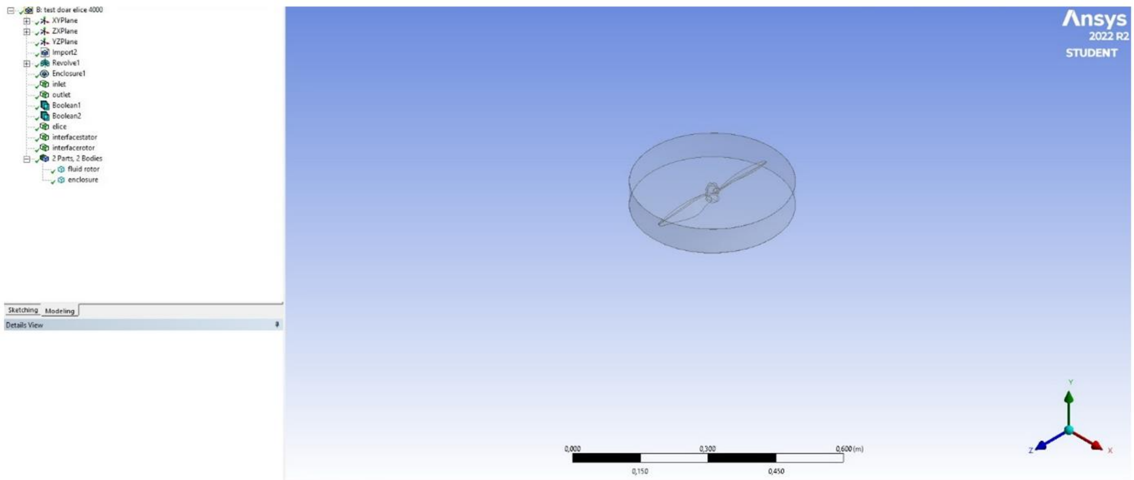


Fig. 2. *Fluid rotor*

The medium in which flow modelling will be done is created by defining a volume with the "enclosure" function and will be referred to as a "Fluid body".

Subsequently, the *rotor fluid* will be subtracted from the *fluid body* by calling the *boolean* function (*subtract*), but keeping the tool bodies. Then, the propeller will be subtracted from the rotor fluid with the help of the same Boolean function, this time without preserving tool bodies.

Once these steps are performed, we proceed to another stage in the same analysis system, namely: finite element model verification, and mesh module. At this stage, the previous model obtained will be discretized, Fig. 4.

After the verification stage with finite elements, the phase of establishing the analysis parameters is completed, in which the propeller material, speed, direction of rotation, environment in which it works and others are chosen.

N°. 3 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.3.02

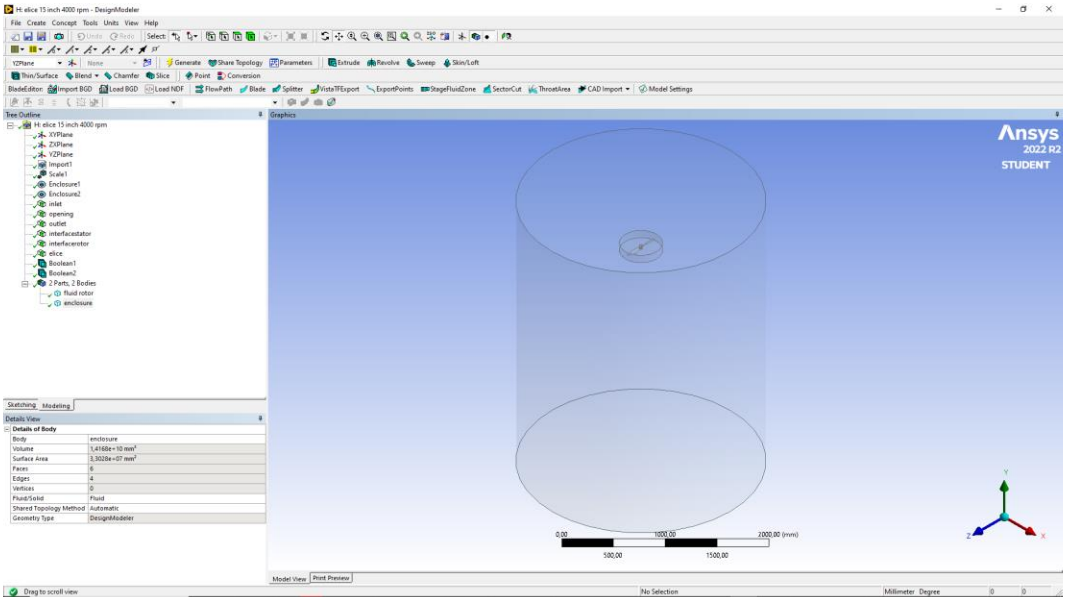


***Fig. 3.** Enclosure*

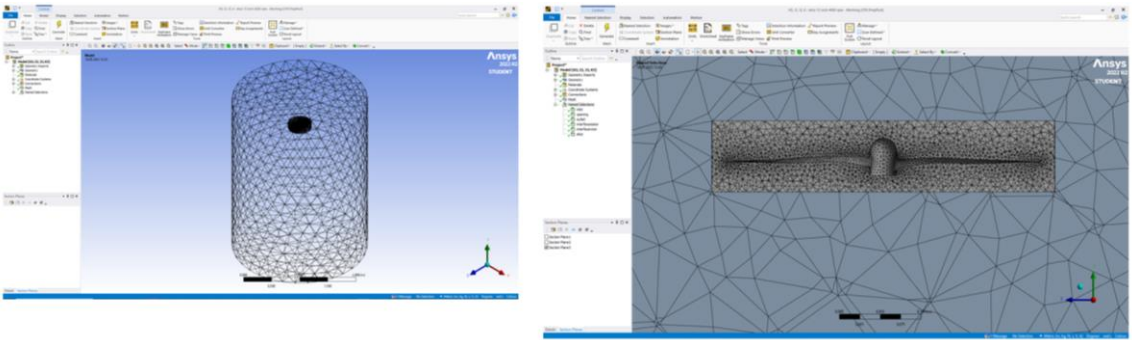


***Fig. 4**. Division into finite elements*

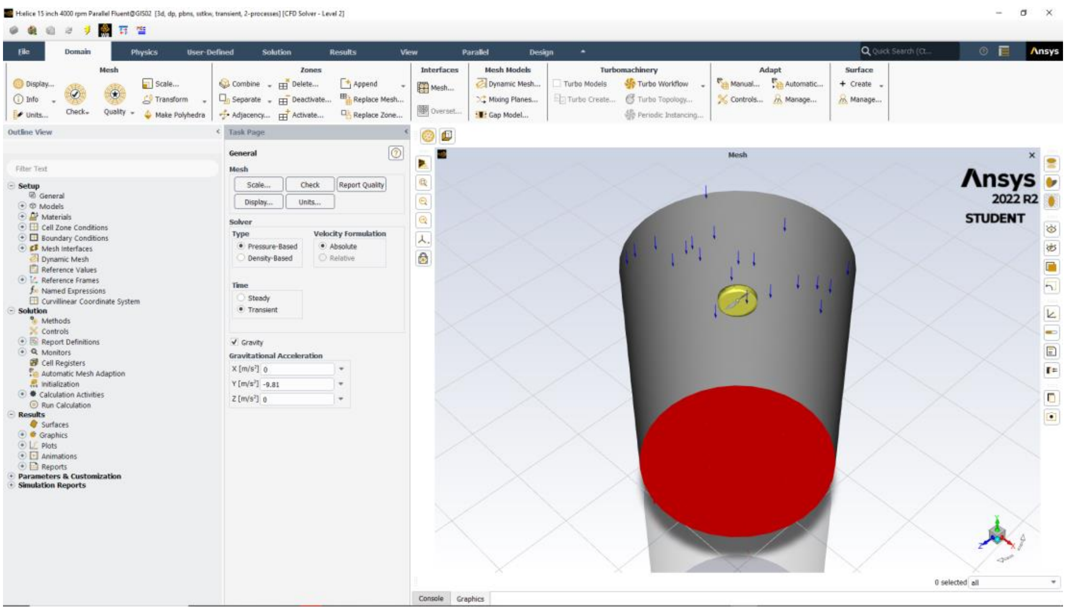


***Fig. 5.** Establishment of calculation factors*

Nº. 3 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.3.02

After solving the finite element model, variations in the obtained parameters are plotted as follows:

1. Figure 6 evaluates the speed variation during propeller operation at 7000 rpm, specifying the maximum value of 138.6 m/s;

2. Figure 7 shows the possibility of calculating the tractive force developed by the propellers, for the conditions considered this force being 35.4 N.

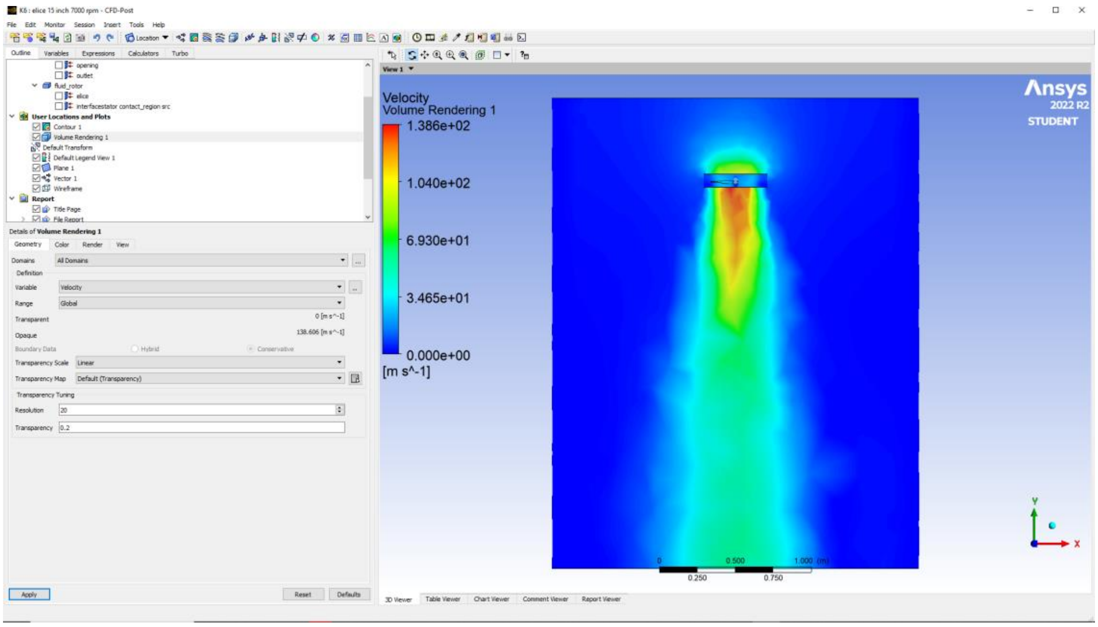


Fig. 6. *Air flow*

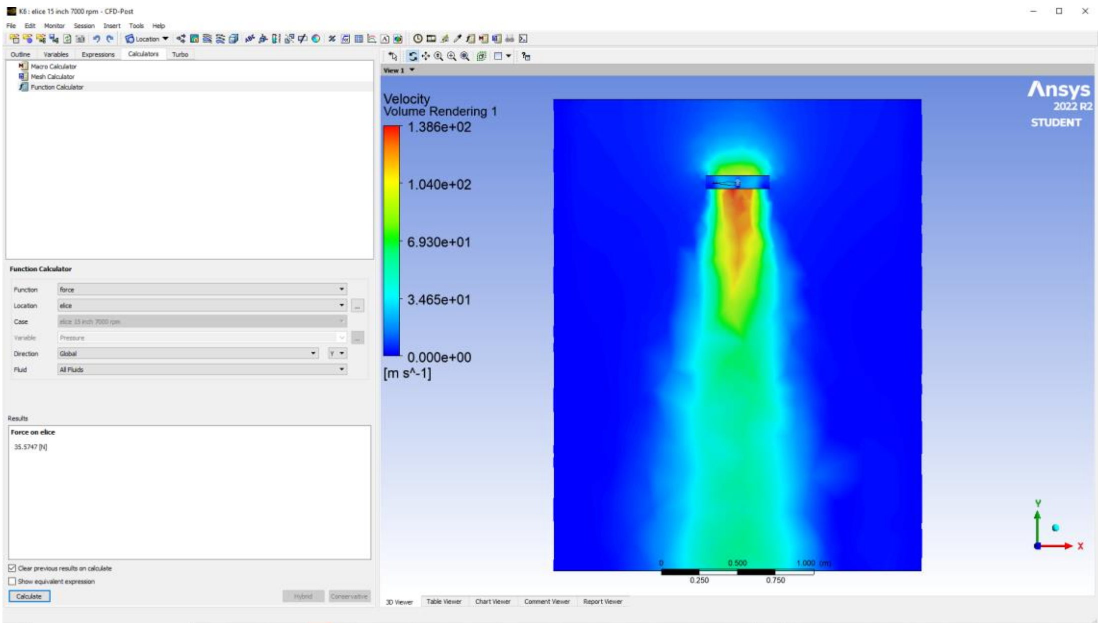


Fig. 7. *Determination of traction force*

The test of this propeller was carried out considering the following speed values: 4000, 5000, 6000 and 7000 rpm, given the dependence between the thrust generated by the propeller and its speed is shown in Figure 8.

Based on dependency generated based on numerical modelling, Fig. 8, interpolation determines the function that best approximates the graph.

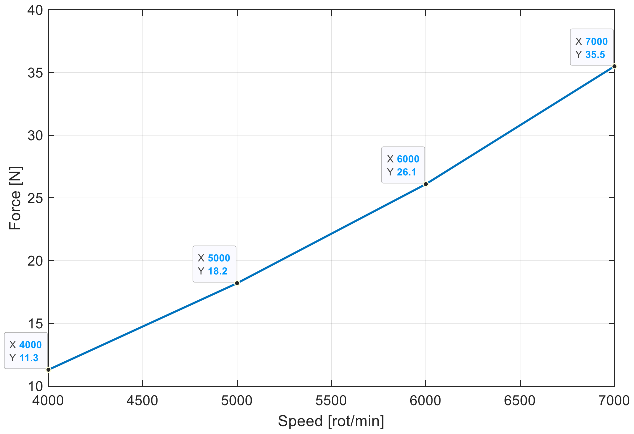


Fig. 8. *Dependence between propeller speed and thrust generated*

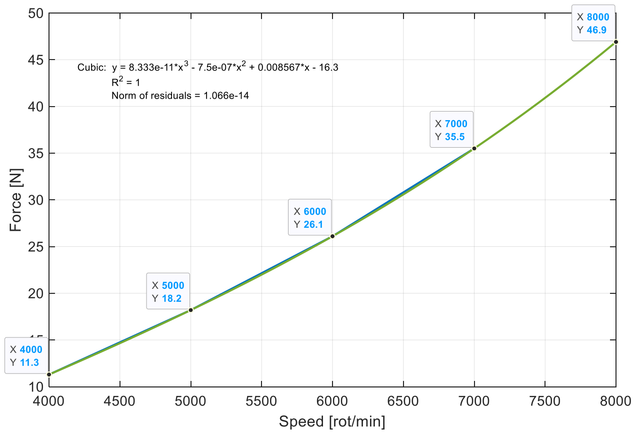


Fig. 9. *Extrapolation of the dependence between propeller speed and generated thrust*

The next step is to experimentally validate this dependence between thrust and propeller speed.

4. Conclusions

This paper presents the steps to be taken to numerically model the operation of a propeller and, implicitly, determine the value of the traction force depending on its speed. If this dependence is subsequently experimentally validated, the tractive force can be estimated for higher speed values without having to run the experimental part. Although numerical modelling can be performed for any speed value, it should be noted that experimental validation for high speeds is more expensive because the risks taken are higher.

Acknowledgements

Thank you to Assoc. Prof. PhD Eng. Florin Nedelcuț for his guidance in understanding fluid flow modelling.

References

[1]. ***, https://grabcad.com/library/low-reynolds-propeller-for-ultra-light-aircrafts-1.

[2]. Silviu Butnariu, Gheorghe Mogan, *Analiza cu elemente finite în ingineria mecanicã, Aplicatii practice în ANSYS*, Editura Universităţii Transilvania din Braşov 20.