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Effect of wind speed and angle of attack on aerodynamic characteristics of naca0012 airfoil.

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Abstract

The study of the aerodynamic properties of wings is considered one of the most prominent topics in the field of aircraft manufacturing in general and drones in particular. This research focuses on studying the aerodynamic properties of an unmanned aerial vehicle wing with a streamlined aerodynamic section that falls under the NACA 0012 classification. The wing is made of aluminium, with dimensions of 30 x 30 cm. It was tested at angles of attack (0, 5, 10, 15, 18 degrees) and at speed values of 12, 15, 18, 21, and 23 metres per second to determine the aerodynamic features of the test section. This test was done through a subsonic tunnel. These parameters are crucial in understanding how a wing behaves under different flight conditions. One of the most prominent results reached in this research is the increase in drag forces when the angle of attack and wind speed increase. The maximum value obtained is 9.6 Newtons at an angle of attack of 18 degrees and a wind speed of 23 m/s. The maximum lift factor was 0.1856 at an angle of attack of 15 degrees and an average wind speed of 21 m/s.

Keywords— Aerofoil, NACA 0012, Lift force, Drag force, Angle of Attack, Drone.

1.Introduction

The drone is characterized by its low speed and its ability to carry out many tasks without exposing the crew to danger. Drones are similar to monoplanes in terms of aerodynamic properties [1]. This paper demonstrates the aerodynamic properties of a drone fuselage by using a similar naca0012 airfoilThe drone requires a high lifting force and this would achieve good results for the design research [2]. Drones are usually classified into autonomous, semi-autonomous, and remote-controlled aircraft, which covers a range of designs from multi-rotor and fixed-wing aircraft to VTOL (vertical take-off and landing) drones that do not require a pilot on board. Nowadays, engineers are at the forefront of designing and manufacturing innovative products more economically and quickly, thanks to the assistance of modern computer systems in the design and evaluation process of new composite materials... Polymer matrix composites are extensively utilized in the industry due to their low production costs and adequate mechanical characteristics, often produced as symmetrical and asymmetrical laminates [3]. These composites, when reinforced with continuous fibers, are characterized by their light weight, high strength, enhanced stiffness, corrosion resistance, and vibration damping capabilities. Their favorable strength/weight and stiffness/weight ratios have led to their application in the automotive, sports, and aerospace sectors to facilitate the construction of lightweight structures [4]. the aircraft is able to firmly attach itself to the surface and withstand external forces such as wind and vibrations. This landing strategy offers improved safety and flexibility compared to traditional landing methods, as it eliminates the need for a runway or landing gear. Additionally, the use of suction technology allows for precise control and maneuverability during the landing process. The research also discusses the potential applications of this landing strategy in various fields such as military operations, emergency response, and cargo transportation. Overall, this study highlights the feasibility and advantages of using suction technology for pilotless aircraft landings on concrete surfaces [6]. In order to harness the aerodynamic capabilities of drones, researchers have explored their potential applications in the field of agriculture. This particular domain remains relatively unexplored, prompting the development of a specialized drone model tailored specifically for agricultural purposes. To achieve this, a unique design was implemented, featuring an aluminum cylinder affixed to the drone's wing. This cylinder is equipped with a net, strategically positioned to capture insects during agricultural operations [7].

Adel Ahmed [8], the study investigates the impact of surface roughness on a NACA 0012 airfoil, analyzing pressure distribution, lift coefficients, and drag coefficients. Data from two rough surfaces (80 µ and 120µ) is compared to a smooth surface. Results show that roughness significantly influences airfoil flow, with drag coefficients increasing with roughness. An experimental investigation was performed by Mahbubur Rahman [9] the study investigates the effect of a vortex generator (VG) on a NACA0012 airfoil at varying angles of attack. It found that VG increases lift and decreases drag coefficients, impacting fluid flow and aerodynamic forces. Luo et al [10] used micro-cylinder at the leading edge; the boundary layer separation on the NACA 0012 airfoil was numerically controlled. 600,000 is the Reynolds number, and the high attack angles range from 16º to 23 º. It was discovered that the micro-cylinder can increase airfoil efficiency by delaying the flow separation. The performance of the NACA 0012 airfoil with and without shark skin-inspired denticles was experimentally studied by Domel et al. [11] in 2017 at a Reynolds number of 40,000, a varied attack angle ranging from 0 to 24 degree, and an airfoil chord length of 68 mm. The outcomes showed that applying this technique improves the airfoil's aerodynamic performance by lowering drag and raising lift. In 2018, experimental study has been presented by Yasser Ahmed et al. [12] this study focuses on designing a fuzzy logic controller to control boundary layer separation using suction-delayed separation technique from the NACA 0015 airfoil surface. The model uses five holes and four BMP180 piezoelectric pressure sensors to sense pressure difference. The model was tested without suction to determine stall condition, and after applying suction, the lift coefficient and stall angle increased by 14.72% and more than 17°, respectively. The fuzzy logic rules showed steady enhancement at the range of suction coefficient CQ universally acceptable. Haci Sogukpinar [13] quantitatively explored the aerodynamic performances of NACA 0012 airfoils with various changes in order to achieve high lift coefficients and post-stall airfoils. The chord line and the fixed suction sides make up the two sections of the NACA 0012 airfoil. New kinds of airfoils are produced by varying the pressure side's thickness. Next, using COMSOL software, numerical experiments are carried out by varying the thickness of NACA 0012 from the lower surface and at different relative thicknesses, modifying asymmetrical airfoils and creating and simulating NACA 0012-10, 0012-08, 0012-07, 0012-06, 0012-04, 0012-03, 0012-02, and 0012-01.

A survey of the literature shows that detailed studies of surface pressures, mean and fluctuating velocities over the surface and in the wake region of the wing along with lift and drag forces need to be carried out for different airfoil configurations. A justifiable need to test a standard NACA profile in close ground proximity was hence strongly felt. Although the present facility does not allow simulation of a very high Reynolds number, it was felt that useful data can be generated which can enhance our understanding of the ground effect phenomenon

2. Aerodynamic characteristics.

2.1 Lift Force for Aircraft (F_L):

A fundamental aspect of designing aircraft wings and tails understands the relationship between lift coefficient and angle of attack. This relationship is mostly determined by the choice of airfoil and its geometry [7].

$$.F_L = C_L \, A \, \frac{\rho U^2}{2} \ldots\ldots\ldots..(1)$$

Stands for the air density, "U" wind velocity, "A" refers to the body or airfoil's surface area, and "CL" lift coefficient.

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2. 2 Drag Force (F_{ad})

The force that acts in the direction parallel to the relative stream represents the drag (d) this force can be calculated by the equation in the following.

$$Fd = C_d \, A \, \frac{\rho U^2}{2} \ldots \ldots \ldots \ldots (2)$$

Where C_d is the drag coefficient

2.3 Angle of Attack:

It's the angle between the direction of stream lines and chord line (Figure.1).

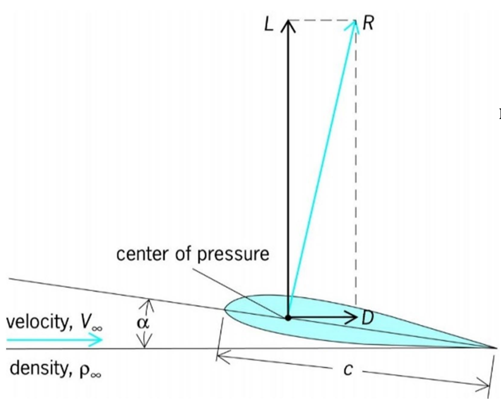

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Figure 1 Angle between the direction of stream lines and chord line.

Some symobel:

α :Angle of attak., **C**: chord line**.**, **D:**drage force., **L :**Lift force.

R:resultant force.

2. Material and methodology

The wing section chosen in the current study is NACA 0012 (15% t/c symmetrical cross section with 0% camber ratio) with chord length (300 mm) and span length (300 mm) in the aerodynamic lab of the mechanical department of the College of Engineering at University of Thi-Qar. Figure 2 shows the NACA section 0012 drawn by importing data from the online airfoil tool.

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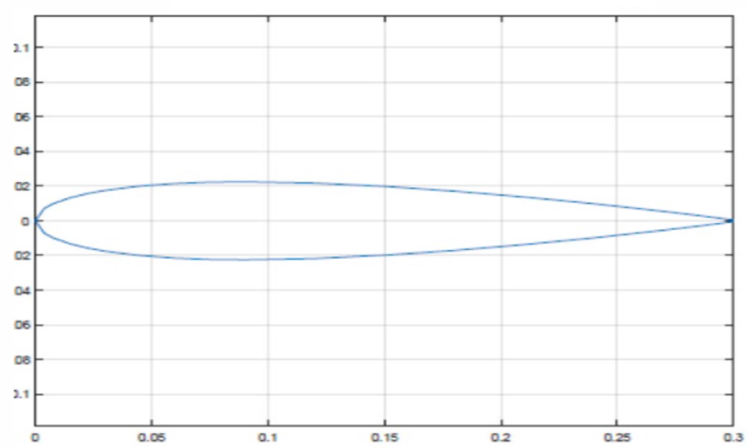
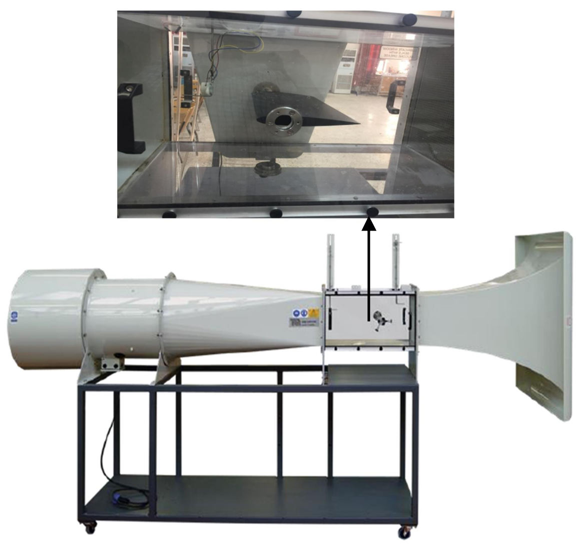


Figure 2 shows thenaca0012 diagram.

To test the aerodynamic properties of the airfoil, a T-Q subsonic wind tunnel was used at the Fluids Laboratory at University of Thi Qar as shown in the Figure 3. The wind tunnel speed ranges from 0 to 30 m/s. The wind tunnel was equipped with two static pitot tubes before and after the test section to evaluate the difference in pressure, and a load cell mounted on a semicircular protractor to measure the lift and drag forces in the wind tunnel for different speeds ranging between (12, 15, 18, 21, 23) and angles of attack between (0, 5, 10, 15, 18).



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flight time and thus a greater distance. The second part is the mechanics, as the internal structure of the drone was designed to make a stable structure in this experiment, the drag and lift coefficients were verified for different angles of attack at low relative air speeds, as shown in Table 1. This table shows that the

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maximum drag force was 9.62 N at AOA 18 º and relative speed of 23 m/s, the maximum lift force was 5.3 N at AOA 15 and 23 m/s relative speed.

3.1 Effect of Air Speed on Drag Coefficient

A key factor that influences drones is their aerodynamic characteristics, particularly the drag force. This force encapsulates the connection between drag and the velocity of the air surrounding the drone, and it is determined by two important factors: the drag coefficient and the relative speed between drone and air. These parameters help the scientist to understand how the drone interacts with the air and how it experiences resistance during flight. Figure 4 depicts the effect of the air speed on the drag coefficient at different AOA. It can be seen from this figure that drag force and coefficient increased linearly with an increase in the angle of attack and air speed. For this, the angles that develop the low stall conditions were preferred when adopting NACA 0012 as the wing for drone.

3.2 Effect of AOA on the Lift Coefficient

The lift force is created when air flows from areas of high pressure to areas of low pressure. This phenomenon allows the airfoil to generate lift by exploiting the pressure difference between its upper and lower surfaces in the values. Figure 5 shows the effect of AOA on the lift coefficient (CL) of NACA0012 at different speeds of air. It was noted during the testing of NACA 0012 in wind tunnel to determine the lift and drag coefficients of the wing at different speeds of 12, 15, 18, 21, and 23, and angles of attack of (0, 5, 10, 15, 18 degree.

Table 1 the drag and lift coefficients for different angles

AOA	Speed	Fd (N)	Cd	FL	Cl	CL/CD
0	12	1.49	0.192	0	0	0
	15	2.47	0.2032	0	0	0
	18	3.744	0.2138	0	0	0
	21	5.26	0.2209	0	0	0
	23	7.0215	0.2458	0	0	0
5	12	1.508	0.1937	0.7	0.0882	0.4553
	15	2.55	0.2098	1.195	0.0984	0.469
	18	3.85	0.2202	1.756	0.1004	0.4559
	21	5.548	0.2332	2.567	0.1078	0.4623
	23	7.104	0.2487	3.122	0.1093	0.4395
10	12	1.586	0.204	0.98	0.126	0.6176
	15	2.71	0.223	1.77	0.1456	0.6529
	18	4.14	0.2367	2.82	0.1611	0.6806

	21	6.358	0.2673	3.795	0.1594	0.5963
	23	8.05	0.2824	4.493	0.1573	0.557
15	12	1.667	0.2144	1.18	0.1517	0.7076
	15	2.758	0.227	1.944	0.16	0.7048
	18	4.251	0.243	2.94	0.168	0.6914
	21	6.5	0.2726	4.42	0.1852	0.6809
	23	8.51	0.298	5.3	0.1855	0.6225
18	12	1.721	0.2214	0.915	0.1177	0.5316
	15	2.816	0.2318	1.865	0.1535	0.6622
	18	4.437	0.2536	2.874	0.1643	0.6479
	21	7.29	0.3061	3.82	0.1605	0.5243
	23	9.62	0.3367	4.513	0.15875	0.4714

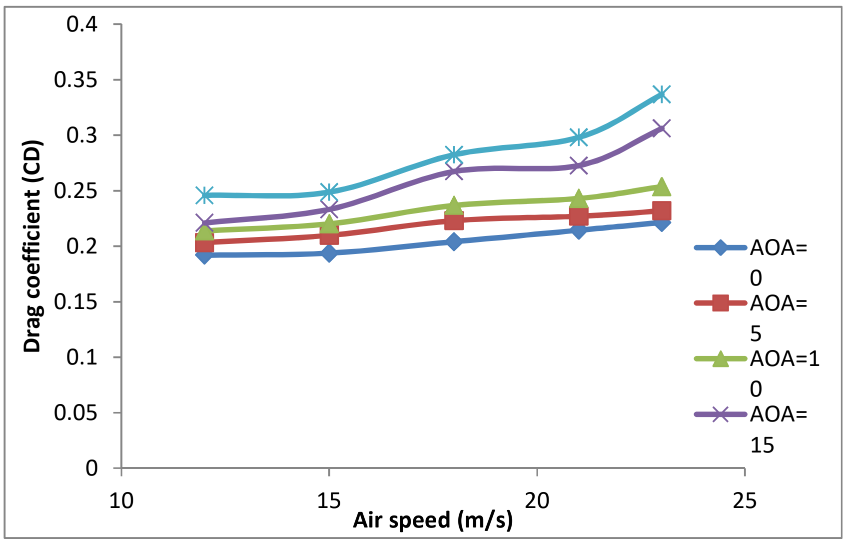

Figure 4. Effect of AOA on the drag coefficient of NACA0012.

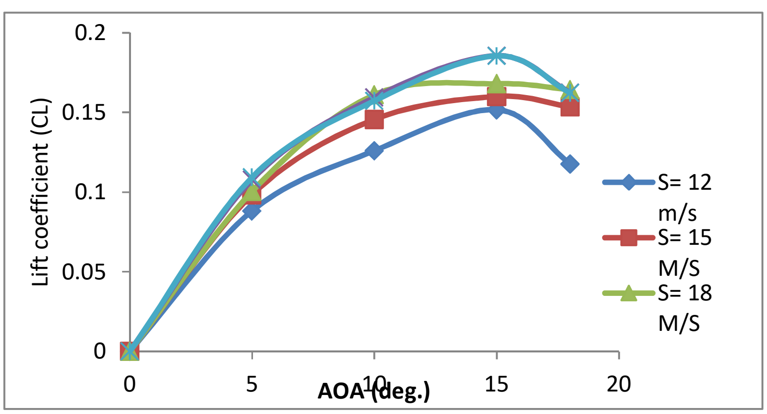

Figure 5. The change in the lift coefficient as a function of the relative air speed.

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4. Conclusion

This study, which was conducted at University of Thi Qar in the Gas and Fluid Dynamics Laboratory on the NACA type 0012 aerodynamic section, is a contribution to the study of the aerodynamic properties of the aforementioned wing section if it were used in the manufacture of drones. Lift and drag forces were effectively measured at different wind speeds and multiple angles of attack. The most prominent thing that can be concluded from the results of this study is: Drag forces increase when both the angle of attack and wind speed increase, as the maximum drag force was 9.62 N recorded at AOA of 18 degree and a wind speed of 23m/s, and the maximum lifting force was 5.3 N obtained at an angle of 15 degrees and 23 m/s. It was also found that the critical angle that achieves the conditions of stagnation this study came to give a deeper insight into the behavior of the airfoil near the critical angles, which is crucial to the performance of drones...

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References:

[1]Amerio, A., P. J. Boschetti, and E. M. Cardenas(2005). "Aerodynamic optimization of an UAV design." AIAA 5th Aviation .

[2] Gupta, Suraj G., Dr Mangesh Ghonge, and Pradip M. Jawandhiya(2013). "Review of unmanned aircraft system (UAS)." International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume2.

[3] Ming, Chong Shao.(2010) "Unmanned Air Vehicle (UAV) Wing Design and Manufacture." Bachelor Thesis Dissertation, National University of Singapore

[4] Salman, Mohammed D., Kadim Karim Mohsen, and Aiman Basem Abttan. "Pseudorandom Noise Impulsive Response Analysis and Aerodynamic Forces of Unmanned Aerial Vehicle Structure." (2019).

[5] Zimmerman, Nathan M. Flight control and hardware design of multi-rotor systems. Diss. Marquette University, 2016.

[6] Ang, Jim David,Lester Librado,Carl Johan Salaan,JonthanMaglassang "Drone with Pneumatic-tethered Suction-based Perching Mechanism for High Payload Application." 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2022.

[7] Adel Ahmed Abdel-Rahman and W. Chakroun" Surface roughness effects On flow over aerofoils" (1997).

[8] Mahbubur Rahman, Md. Amzad Hossain, Md. Nizam Uddin and Mohammad Mashud" Experimental Study of Passive Flow Separation Control Over A NACA 0012 Airfoil" (2015)

[9] D. Luo, D. Huang, and X. Sun, "Passive flow control of a stalled airfoil using a micro cylinder," J. Wind Eng. Ind. Aerodyn., vol. 170, no. March, pp. 256–273, 2017

[10] A. G. Domel, K. Bertoldi, M. Saadat, G. V. Lauder, J. C. Weaver, and H.Haj-Hariri, "Shark skin-inspired designs that improve aerodynamicperformance," J. R. Soc. Interface, vol. 15, no. 139, pp. 1–9, 2018.

[11] Ahmed, Y., & Saeed, N. (2018). Control of Boundary Layer over NACA0015 Using Fuzzy Logic by Suction Technique. Journal of University of Babylon for Engineering Sciences , 26 (9), 69-89.

[12] Sogukpinar, H. (2018, February). The effects of NACA 0012 airfoil modification on aerodynamic performance improvement and obtaining high lift coefficient and post-stall airfoil. In *AIP conference proceedings* (Vol. 1935, No. 1). AIP Publishing.

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