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DOI:

Title:	AERODYNAMIC ANALYSIS OF ALOUETTE III ROTARY WINGS
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Section: ENGINEERING

Issue: 1(19)/2020

Received: 15 January 2020	**Revised:** 27 January 2020
Accepted: 9 March 2020	**Available Online:** 15 March 2020

Paper available online HERE

Research and Science Today
WWW.RSTJOURNAL.COM
Spring 2020
No. 1(19)/2020
ISSN-P: 2247-4455 / ISSN-E: 2285-9632

AERODYNAMIC ANALYSIS OF ALOUETTE III ROTARY WINGS

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ABSTRACT:
EVER SINCE THE FIRST MODELS APPEARED, THE HELICOPTER HAS REPRESENTED AND WILL BE A SOLID SUBJECT OF STUDY, ALWAYS BEING A PLACE OF IMPROVEMENT IN ITS TECHNOLOGY WITH THE EVOLUTION OF SCIENCE. IN THIS PAPER I WILL PRESENT SOME IDEAS REGARDING THE AERODYNAMIC PERFORMANCES OF THE BEARING ROTORS, USING NUMERICAL SOFTWARE SIMULATIONS BASED ON A SCALE MODEL OF THE SA 316B HELICOPTER.

KEY WORDS: ROTOR, XFLR5, QBLADE, HELICOPTER, ROTARY WINGS, ALOUETTE III

LIST OF ACRONIMS AND ABBREVIATIONS

Cl	Lift coefficient	**Cp**	Power coefficient
Rot	Rotational speed	**RPM**	Rotations per minute
Rho-ρ	Density	**R**	Rotor radius
r	Rotor hub radius	**V**	volume
TSR	Tip Speed Ratio	**ISA**	Internat. Standard Atmosphere
E	Glide Ratio	**AoA**	Angle of attack

1. INTRODUCTION

The Alouette III [2]has its origins with an earlier helicopter design by French aircraft manufacturer Sud-Est, the SE 3120 Alouette, which, while breaking several helicopter speed and distance records in July 1953, was deemed to have been too complex to be realistic commercial product. Having received financial backing from the French government, which had taken an official interest in the venture, the earlier design was used as a starting point for a new rotorcraft that would harness the newly developed turboshaft engine; only a few years prior, Joseph Szydlowski, the founder of Turbomeca, had successfully managed to develop the Artouste, a 260 hp (190 kW) single shaft turbine engine derived from his Orédon turbine engine. This engine was combined with the revised design to quickly produce a new helicopter, initially known as the SE 3130 Alouette II.

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[1] Student, “ Henri Coandă” Air Force Academy, Brașov
[2] "The French Navy Is Finally Retiring These Antique Helicopters After 55 Years of Service."

During April 1956, the first production Alouette II was completed, becoming the first production turbine-powered helicopter in the world. The innovative light helicopter, soon broke several world records and became a commercial success.As a result of the huge demand for the Alouette II, manufacturer Aérospatiale took a great interest in the development of derivatives, as well as the more general ambition of embarking on further advancement in the field of rotorcraft.

In accordance with these goals, the company decided to commit itself to a new development programme with the aim of developing a more powerful helicopter that would be capable of accommodating up to 7 seats or a pair of stretchers. The design team was managed by French aerospace engineer René Mouille.The design produced, which was initially designated as the SE 3160, featured several improvements over the Alouette II; efforts were made to provide for a higher level of external visibility for the pilot as well as for greater aerodynamic efficiency via the adoption of a highly streamlined exterior.

Fig.1 Alouette III

2. GENERAL CONSIDERATIONS

The helicopter is an aircraft which uses rotary wings to produce lifting forces for propulsion and command. The rotor blades[3] are rotating around a vertical axis, describing a disc in horizontal or nearly horizontal plan. The helicopter can generate aerodynamic forces even when the aircraft speed is zero, which a fixed wings aircraft don’t because it needs translational speed to generate lifting forces.

2.1. The helicopter rotor

The conventional consists of two or mode blades identically equidistant, attached to a central hub. The blades are maintained in a uniform rotational speed usually by a torque moment applied to the main rotor[4]. Lifting and dragging forces which action on these blades produce lift, drag, and other forces and momenta of the rotor.

The mechanical aspect of the rotor hub is build that way to permit flapping and lagging of the blade. This thing permits a fundamental classification[5] of the rotor types,as shown below:

- fully-articulated rotor

[3] Cottez, Henri. Dictionnaire des structures du vocabulaire savant. Paris: Les Usuels du Robert. 1980. ISBN 0-85177-827-5.

[4] Munson, Kenneth. Helicopters and other Rotorcraft since 1907. London: Blandford Publishing, 1968. ISBN 978-0-7137-0493-8. 85-92

[5] Rotorcraft Flying Handbook: FAA Manual H-8083-21.. Washington, D.C.: Federal Aviation Administration (Flight Standards Division) , 2001. ISBN 1-56027-404-2. 115-143

- semi-rigid rotor
- rigid rotor

2.2. The configuration with a single main rotor

This is the most common configuration nowadays, generalized in the past 30 years but without remaining the single one. It consists, basically, of an aerodynamic fuselage, a main rotor and a tail rotor. The last one is a tiny auxiliary rotor, vertically placed, used to conteract the momentum produced by the main rotor and to command the steering. It is placed on the top of the helicopter tail and it has the thrust orientated in the same way as the main rotor blades are rotating.

3. SOFTWARE ANALISYS

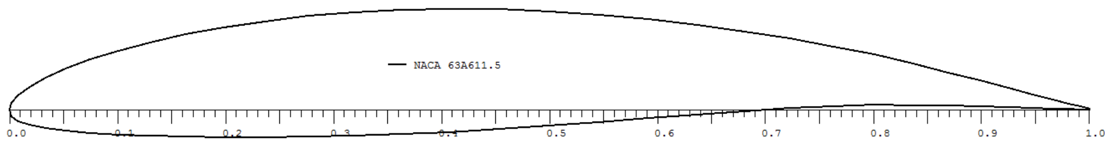

Fig.2 NACA 63A611.5

3.1. Software description

QBlade[6] is an open source wind turbine simulation and calculation software

The integration of the XFOIL/XFLR5 functionality allows the user to design airfoils and analyze them in 2D and 3D.

The software is adequate for teaching, as it provides an easy way to simulate a model wind turbine and see it's efficiency.

QBlade also provides processing functionality for the rotor and turbine. In addition to that, the software is a very flexible and user-friendly platform for wind turbine blade design.

XFLR5[7] is an airfoil design and analysis program XFOIL, the most "user-friendly" of its type.

XFOIL is an interactive program for the design and analysis of subsonic isolated airfoils. Given the coordinates specifying the shape of a 2D airfoil, Reynolds and Mach numbers, XFOIL can calculate the pressure distribution on the airfoil and hence lift and drag characteristics. The program also allows inverse design - it will vary an airfoil shape to achieve the desired parameters. It is released under the GNU GPL.

XFLR5 uses the vortex panel method and integral boundary layer equations to calculate airfoil pitching moment at different angles of attack, drag and lift . Direct comparisons of up to three airfoils at a time may be performed. Changes to the performance characteristics of an airfoil may be made in seconds.The airfoil can be defined using NACA feature or introducing the specific coordinates.Results show an excellent comparison to published wind tunnel data.

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[6] David Marten, Qblade short manual, available at https://www.researchgate.net/publication/281279669_Qblade_Short_Manual_v08

[7] *** Guidelines for XFLR5 v6.03, 2011, 72

3.2. NACA 63A611.5 airfoil analysis

Simulation parameters:

Rho	1.225 kg/m^3	Viscosity	1.465 pa·s
Relax factor	0.35	Max ε	0.0001
Reynolds nr.[6]	1’650’000	Velocity	70m/s

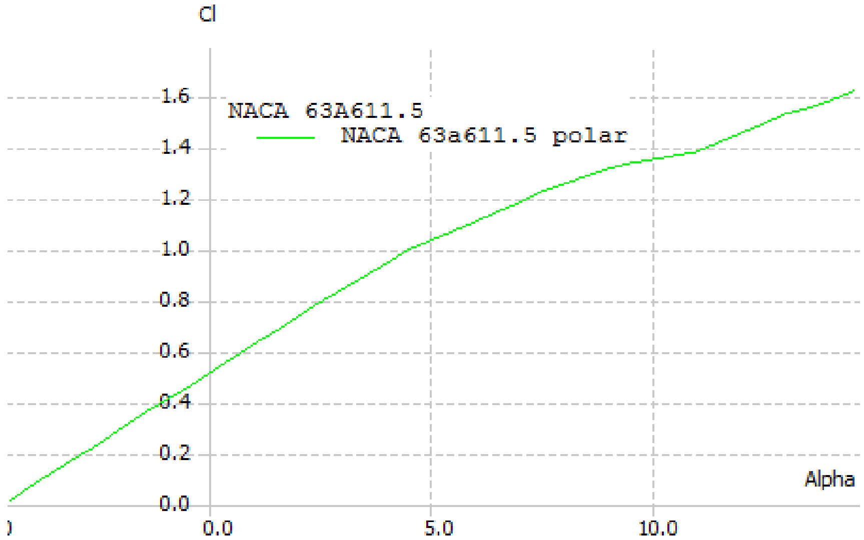


Fig.3 Lift coefficient at different AoA

The lift coefficient of a fixed-wing aircraft varies with angle of attack. Increasing angle of attack is associated with increasing lift coefficient up to the maximum lift coefficient, after which lift coefficient decreases. A symmetrical wing has zero lift at 0 degrees angle of attack. The lift curve is also influenced by the wing shape, including its airfoil section and wing plan form. [8]A swept wing has a lower, flatter curve with a higher critical angle. For NACA 63A611.5 the highest value of lift coefficient **(1.615)** corresponds with an angle of **14.5°** (*see fig.3*).

The glide ratio[9] (*see fig.4*) (E) is numerically equal to the lift-to-drag ratio, but is not necessarily equal during manoeuvres, especially if speed is not constant. A glider's glide ratio varies with airspeed, but there is a maximum value which is frequently quoted. Glide ratio usually varies little with vehicle loading; a heavier vehicle glides faster, but nearly maintains its glide ratio.

[8] Principles of Flight, Nordian Aviation Training Systems, 2017, ISBN 8281071486, 43-44
[9] Principles of Flight, Nordian Aviation Training Systems, 2017, ISBN 8281071486, 46-48

ISSN-P: 2247-4455 / ISSN-E: 2285-9632

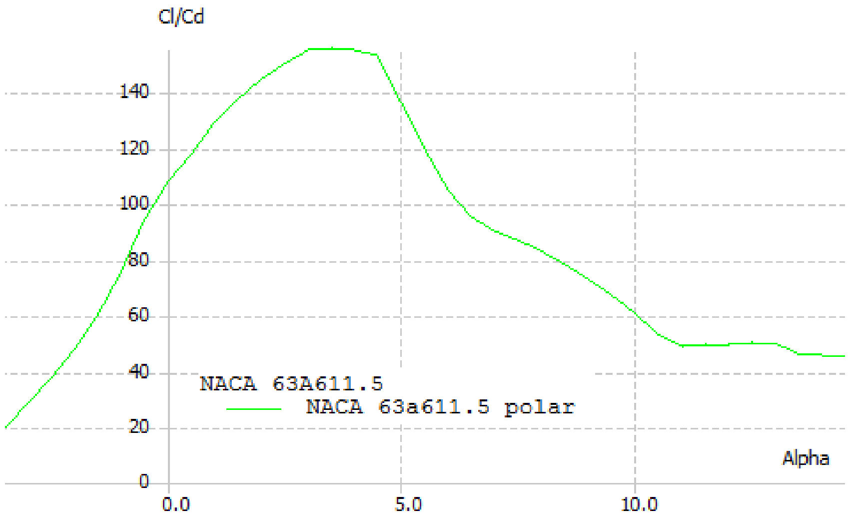


Fig.4 Glide ratio of NACA 63A611.5

In aviation, induced drag[10] tends to be greater at lower speeds because a high angle of attack is required to maintain lift, creating more drag (*see fig.4*). However, as speed increases the angle of attack can be reduced and the induced drag decreases. Parasitic drag, however, increases because the fluid is flowing more quickly around protruding objects increasing friction or drag. Pilots will use this speed to maximize endurance (minimum fuel consumption), or maximize gliding range in the event of an engine failure.

In fluid dynamics, a stall[11] is a reduction in the lift coefficient generated by a foil as angle of attack increases. This occurs when the critical angle of attack of the foil is exceeded. The critical angle of attack is typically about 15 degrees, but it may vary significantly depending on the fluid, foil, and Reynolds number. The graph shows that the greatest amount of lift is produced as the critical angle of attack is reached. This angle is 14.5 degrees in this case, but it varies from airfoil to airfoil. In particular, for aerodynamically thick airfoils (thickness to chord ratios of around 10%), the critical angle is higher than with a thin airfoil of the same camber. Symmetric airfoils have lower critical angles. The graph shows that, as the angle of attack exceeds the critical angle, the lift produced by the airfoil decreases (see fig 5).

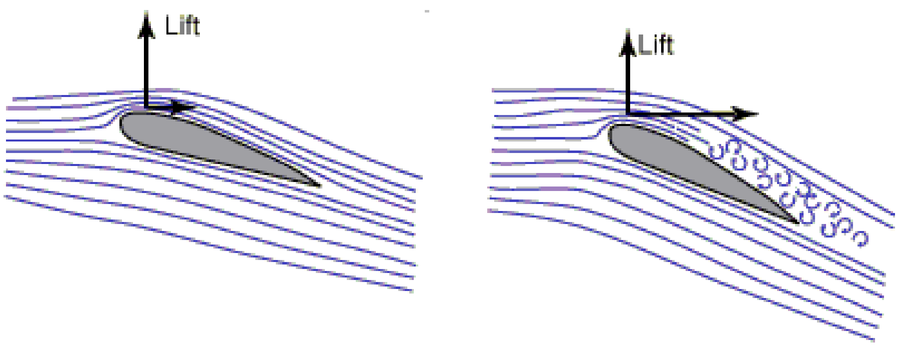


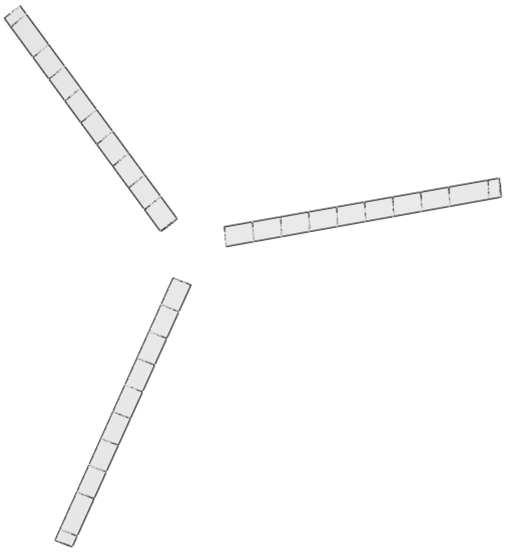
Fig.5 Stall point illustration

[10] Renard, C. (1889). "Nouvelles experiences sur la resistance de l'air". L'Aéronaute. 22: 73–81.
[11] *Anderson, John David (1997). A History of Aerodynamics and its Impact on Flying Machines. New York, NY: Cambridge University Press. ISBN 0-521-45435-2.*

3.3. ANALISYS OF 3 BLADED ALOUETTE III ROTOR

Rotor parameters

Diameter	11.02m	Disc area	95.38 m^2
Maximum RPM	353RPM	Disc loading	33.2 kg/m^2



Station(mm)	Chord(mm)
600	355.000
1100	353.47
1600	351.939
2100	350.409
2600	348.879
3100	347.349
3600	345.818
4100	344.288
4600	342.758
5300	341.379
5501	340.000

Fig.6 Alouette III original rotor - stations and chord lenghts[12]

A propeller creates a thrust force out of the supplied power[13]. The magnitude of this force is not constant for a given propeller, but depends on the velocity of the incoming air and the rotational velocity of the propeller itself. Thus tests of propellers usually cover a wide regime of operating conditions.The area under the graph illustrates the efficiency of the propeller

The relationship between the wind speed and the rate of rotation of the rotor in characterized by a non-dimensional factor known as Tip speed ratio TSR. Power coefficient as a function of the TSR for a four bladed rotor determines the curve of power(see fig.8). Maximum power occurs at the optimal TSR[14].

[12] Alouette III Pilot handbook, 92

[13] Prisacariu V. The aerodynamic analysis of the profiles for flying wings , Journal of Defense Resource Management ISSN 2068-9403

[14] ***XFLR5 guidelines v6.04 p51

ISSN-P: 2247-4455 / ISSN-E: 2285-9632

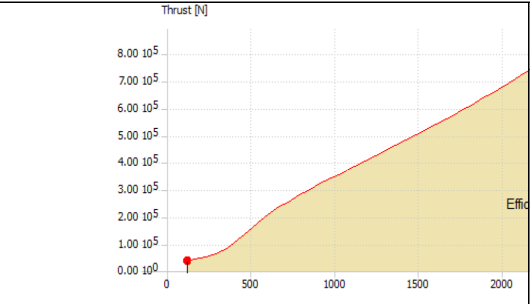


Fig. 7 Rotor efficiency

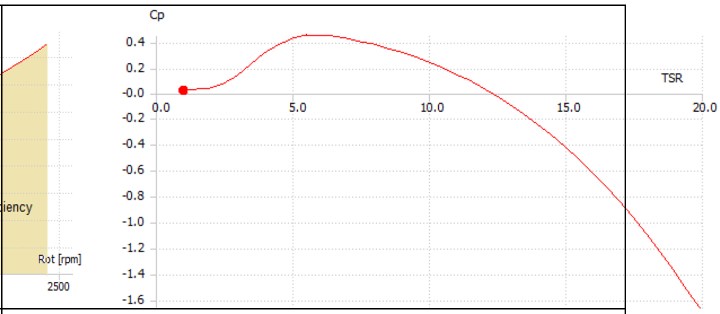


Fig. 8 The curve of power

3.4. ANALYSIS OF MODIFIED ALOUETTE III ROTOR

A. 2 Bladed rotor

Simulation parameters

Rho	1.225	Viscosity	1.465
Relax factor	0.35	Max ε	0.0001
Reynolds nr.	1’289’000	Velocity	70m/s

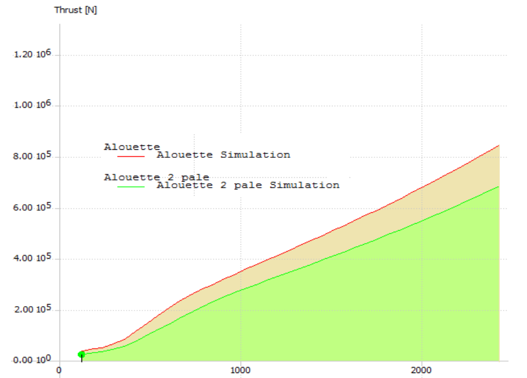


Fig.9 2 vs 3 blade rotors efficiency

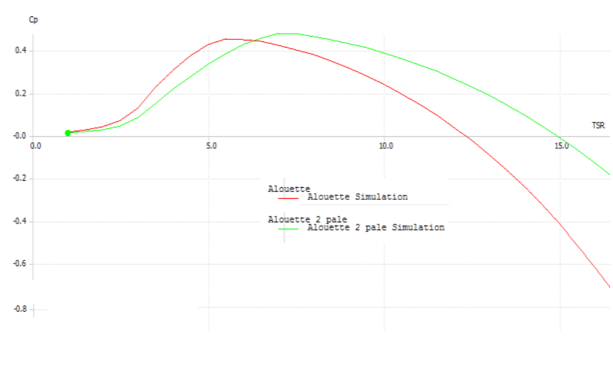


Fig.10 The curves of power

Consequences:

Air flow: from 8646m^3/minute to 5765m^3/minute that means: apx 34% lower

- lower Maximum Takeoff Weight apx 1450Kg
- lower Service Ceiling apx 2150m
- lower Maximum speed apx 75 Kts
- **lower fuel consumption**

B.4 Bladed rotor

Simulation parameters

Rho	1.225	Viscosity	1.465
Relax factor	0.35	Max ε	0.0001
Reynolds nr.	1’289’000	Velocity	70m/s

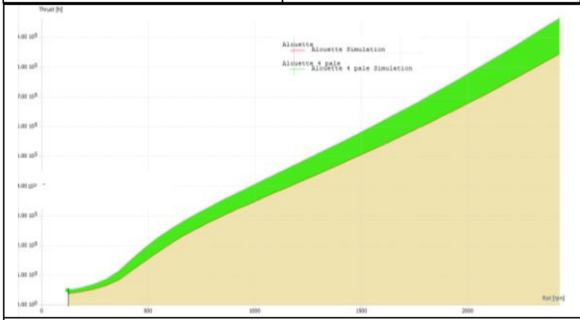


Fig.11 3 vs 4 blade rotor efficiency

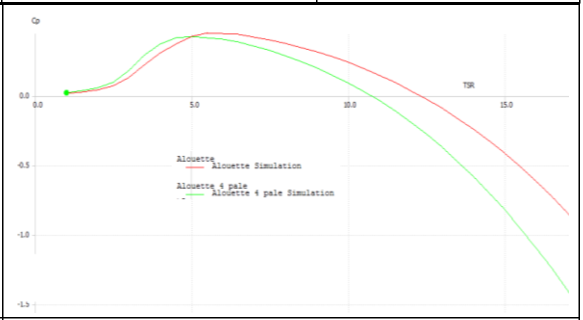


Fig.12 The curves of power

Consequences:

Air flow: from 8646m^3/minute to 11528m^3/minute that means: apx33% higher

- higher Maximum Takeoff Weight apx 2900Kg
- higher Maximum Speed apx 150Kts
- higher Service Ceiling apx 4200m
- **higher fuel consumption**

CONCLUSION

The effect of the number of the blades; more blades mean higher lift and efficiency, but for this to happen there must be considered a powerful powerplant and/or a higher fuel consumption

The effect of the number of the blades; less blades mean less lift and efficiency, but for this to happen there must be considered a weaker powerplant and/or a lower fuel consumption

The airfoil must prefferably have a high critic point to delay the separation of the limit layer.

Author contributions regarding the theme

- Determine blade number influence of the Alouette III main rotor
- Determine NACA 63A611.5 airfoil aerodynamic performances
- Execute a 1:1 model of the rotor using NACA 63A611.5 airfoil and real dimensions

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