LIFT AND DRAG CHARACTERISTICS OF NACA 2313 AND 2321 FOR WINGLETS

Compiled as one of the requirements for completing the Undergraduate Study Program in the Department of Mechanical Engineering, Faculty of Engineering

By:

ABDALRAHIM ABAKER MOHAMED ALI
D 210 170 001

MECHANICAL ENGINEERING DEPARTMENT
INTERNATIONAL PROGRAM
IN AERODYNAMICS/MECHANICAL ENGIMEERING
MUHAMMADIYAH UNIVERSITY OF SURAKARTA
2021

APPROVAL

LIFT AND DRAG CHARACTERISTICS OF NACA 2313 AND 2321 FOR WINGLETS

PUBLICATION ARTICLE

By:

ABDALRAHIM ABAKER MOHAMED ALI
D 210 170 001

Approved to be examined by the :

Consultant

Waluyo Adi Siswanto, Ir.M. Eng, Ph.D.

ACCEPTANCE

LIFT AND DRAG CHARACTERISTICS OF NACA 2313 AND 2321 FOR WINGLETS

By:

ABDALRAHIM ABAKER MOHAMED ALI
D 210 170 001

Accepted and Approved by Board of Examiners
Mechanical Engimeering
Universitas Muhammadiyah Surakarta
On 29 Mar 2021
and declared to meet the requirements

Team of Examiners:

1. **Waluyo Adi Siswanto, Ir.M. Eng, Ph.D.** ( )
   (Head Master of Examiner)
2. **Wijianto, ST.M. Eng.Sc** ( )
   (Member I of Examiner)
3. **Supriyono, ST.,MT.,Ph.D.** ( )
   (Member II of Examiner)

Dean,

Ir Sunarjono., M.T., Ph.D

TESTIMONY

I hereby declare that in the manuscript of this publication there are no works that have been submitted for obtaining a bachelor's degree in a university and to my knowledge there are also no works or opinions that have been written or published by other people, unless in writing they are referred to in the text and mentioned in Bibliography.

If in the future there is evidence of untruth in my statement above, then I will take full responsibility.

Surakarta, 14 Mar 2021

Author

ABDALRAHIM ABAKER MOHAMED ALI

D 210 170 001

KARAKTERISTIK LIFT DAN DRAG NACA 2313 DAN 2312 UNTUK WINGLET

Abstrak

Penelitian ini bertujuan untuk mengetahui karakteristik gaya hambat dan kiri antara dua airfoil NACA. Airfoil NACA 2313 dan NACA 2312 untuk performa yang lebih baik dari penerbangan pesawat sayap. Penelitian dilakukan dalam studi simulasi. Studi kasus penelitian ini menggunakan tutorial Xflr 5 untuk menganalisis koordinasi airfoil, data koordinasi airfoil diubah menjadi Catia dan tutorial Auto-cad untuk ilustrasi bentuk sayap ditinjau dari ketebalan maksimum dan panjang airfoil. . Menggunakan NACA 2323 dan NACA 2312 untuk menyelidiki karakteristik kiri dan seret untuk pesawat sayap. NACA 2313 dan NACA 2312 dimaksudkan untuk meningkatkan efisiensi pesawat wig dengan winglet. Sasaran dari mahasiswa ini adalah mempelajari karakteristik gaya angkat dan gaya hambat pada desain sayap sayap pesawat NACA 2313 dan NACA 2312 untuk meningkatkan kinerja koefisien aerodinamika platform sayap. Studi eksperimen telah dilakukan pada sayap kecil Raked. Tutorial Catia digunakan untuk mensimulasikan bentuk sayap dengan winglet dan winglet tanpa winglet. Arus masuk kecepatan angin pada 30 derajat, distribusi tekanan pada permukaan atas sayap ditingkatkan, dan pada permukaan hembusan sayap, tekanan berkurang. Kesimpulannya. Analisis airfoil NACA 2313, NACA 2312. Pada sudut serang 10^{o}, airfoil terkena kecepatan angin 30 m / s, yang sesuai dengan Re = 150.000. Arus masuk kecepatan angin pada 30 derajat. Distribusi tekanan meningkat di permukaan atas, dan di permukaan hembusan, distribusi tekanan menurun. Aliran udara menciptakan berbagai penurunan tekanan di sepanjang permukaan airfoil. Penggunaan wing foil NACA 2312 dengan winglet akan meningkatkan efisiensi sayap pesawat hingga 5,6% yang akan meningkatkan performa sayap pesawat.

Kata kunci: karakteristik left and drag, airfoil empat digit NACA, aerodinamika, raked winglet, dan sayap pesawat.

Abstract

This research aims to investigate left and drag characteristics between two NACA airfoil. NACA 2313 and NACA 2312 airfoil for better performance of the wing aircraft flight. The research done in simulation studies. This research study case is used Xflr 5 tutorial to analyzed the airfoil coordination, the data of the airfoil coordination was converted to the Catia and the Auto-cad tutorial for the shape illustration of the wing in terms of the maximum thickness and length of the airfoil. Uses the NACA 2323 and NACA 2312 for investigating the left and drag characteristics for the wing aircraft. NACA 2313 and NACA 2312 intended to improve the efficiency of the wig aircraft with winglets.   The target of the present student investigates the characteristics of lift and drag in NACA 2313 and NACA 2312 airfoil winglet design to improve the performance of the aerodynamics coefficient of the wing platform. The experiment study had done on a Raked winglet. Catia tutorial used to simulate the shape of the wing with winglet and wing without winglet. The inflow of the wind velocity at 30 degrees, the pressure distribution on the upper surface of the wing was increased, and in blow surface of the wing, the pressure had lowered. In conclusion. The analysis of the NACA 2313, NACA 2312 airfoil. At 10^{o} of angle of attack, the airfoil subject to the wind velocity of 30 m/ s, that is corresponding to Re = 150.000. The inflow of the wind velocity on the 30 degrees. The pressure distribution had increased in the upper surface, and in the blowing surface, the pressure distribution had lowered. Airflow creating various pressure drops along the airfoil surface. The use of NACA 2312 wing foil with the winglet will increase the efficiency of the wing aircraft by up to 5.6% that will improve the performance of the wing aircraft.

Keywords: left and drag characteristic, NACA four digits airfoil, aerodynamics, Raked winglet, and Wings of aircraft.

1. INTRODUCTION

The NACA four digits airfoil is used in aircraft for its varus purposes. Such aerodynamic benefits in terms of left and drag characteristics.

The winglet is a device that reduces the induced drag of the aircraft and saves fuel. Since the beginning of the 2000s, aircraft designers have been using extra 'parts' on the wing ends. These small extensions usually referred to as winglets, are intended to increase the aircraft's performance by reducing drag. These unusual wingtips have aerodynamic advantages that come from nature; many birds, especially gliding birds, curl up their wings at the ends to improve their flight efficiency.

Whirlpools steal energy from plane movement, so wingtips in theory reduce fuel consumption by reducing drag. To put it simply, during the take off and landing of a plane, the high-pressure air converts the wingtip into low-pressure air, forming the wingtip vortex. This drag occurs because the pressure of the wingtip vortex is lower than the pressure of the air passing over the wing. In the last decade, winglets have become more popular, with aircraft manufacturers installing them not only to reduce drag but also because they can improve fuel efficiency by up to 5%. In fact, on modern jets today, winglets of any type or form are pretty much standard equipment, and some airlines are also upgrading them to older aircraft. Notice that all winglets are the same because their function is the same. A West Jet Boeing 737 800 with branded winglets.

To reduce the drag a device called a winglet is placed vertically at a set of angles on the end of the aircraft wing (Khamis and Rameshkumar, 2016). The winglet is played a very important role in improving aircraft performance. Aircraft designers are performing research to improve aircraft efficiency which will be a benefit to both aircraft manufacturers and operators. Several different types of winglet devices have been developed to improve efficiency and the selection of the winglet device depends on the specific situation and the aircraft type.

2. METHOD

In this chapter, the author will conduct a thorough discussion of the research carried out covering the design of airfoil coordinate using Xflr5 then the data of the airfoil coordinates with be exported to Auto-Cad tutorial for the design of the aerofoil. Moreover, the wing with winglet also will be generated in the Catia application, the data will be taken from Xflr5. the author made a comparison between two airfoils NACA 2313 which obtain in this report and another airfoil NACA2312 which already had been investigated by another publisher. The result of the comparison of the airfoils and the wing will be discussed in the analysis.

When a fluid is moving through the wing, air particles are forced to narrow at the wing's upper surface, while the air particles moving at the wing's lower surface are expanded.

The airfoils developed by the National Advisory Committee for Aeronautics, NACA (NASA's predecessor) in the 1930s and 1940s are among the most accurate tools and commonly used databases. The Cambered airfoil sections of all NACA families are obtained by integrating a mean line with a distribution of the thickness (Ramesh, 2013).

The section of upper and lower coordination of the airfoil given used the following equations: NACA four digits series is the first airfoil used in the NACA family. In NACA 2313

The first digit 2% is referred to as the max-camber, in the percentage of the chord (m), the second digit 30% is referred to as the max-camber position (p). The last two digits refer to the max-thickness (t) of the airfoil in chord percentage. Using this m, p, and t values, we can use the below relationships to determine the coordinates for an entire

The history of airfoil shape creation is lengthy and includes various contributions by scientists from around the world. In the early twentieth century, the principles of classical hydrodynamics had been widely applied to airfoils, and it was possible to mathematically model the lifting properties of certain airfoils types. In 1929 the National Aeronautics Advisory Committee (NACA) began to study the characteristics of standardized airfoil series in an attempt to determine specific characteristics. The airfoils are made up of a thickness membrane wrapped around a medium line of chamber as seen in Fig, (6) mean chamber line is situated halfway between the airfoil's top and bottom surfaces and intersects the chord line at the leading edges and trailing edges.

Choosing a suitable airfoil is possible from the airfoil sections previously developed and written. NACA and Eppler are two efficient Airfoil services. The Eppler airfoils descriptions have been posted in (Eppler, 1990) The NACA airfoils were published in the book of Abbott and Von Doenhoff (Abbott *et al*., 1945). Names for Eppler airfoil begin with the letter "E" followed by three numbers. The Eppler airfoils are usually for a very small number of Reynolds, Wortman airfoils for a medium (sailplane-ish) number of Reynolds, and NASA low-speed airfoils (e.g. LS (1)-0413) and Medium Speed Airfoils e.g. MS (1)-0313) is for the Reynolds numbers "moderate" (Ramesh, 2013).

With an angle of attack, the lift force decreases almost linearly until a limit value is reached, whereupon the wing is said to stall. The drag force variance with an angle of attack is approximately parabolic. Having the highest lift and the least potential drag i.e. the best possible lift to drag ratio is optimal for the wing. The variance of all of these aerodynamic properties (lift force, drag force, and lift-to-drag ratio) with an angle of attack for a typical aircraft.

3. FINDING AND DISCUSSION

In this chapter, the foils, wing, and wing with winglet analysis and discussion of the research carried out covering the analysis of airfoil coordinate using Xflr5 and data of Auto-Cad tutorial. Moreover, the data will be analyzed from Xflr5. the author made a comparison between two airfoils NACA 2313 which obtain in this report and another airfoil NACA2312 which already had been investigated by another publisher to have a big prove for the efficiency of the winglet. The result of the comparison of the airfoils and the wing will be analyzed and discussed in this session.

The analysis of the batch foil NACA 2313 airfoil generated in XFLR5 mode "foil direct design". The use of xflr5 in this project for analysis of the data of airfoil which gives condition is referred to as a polar in the XFLR5, wing analysis starts with the airfoil detection, which is conducted in "Foil Direct Design" mode. The NACA 2413 airfoil wing is being used for this mission

The foil to an analysis of NACA 2313 The analysis of the NACA 2313 foil was done correctly in xflr5, the foil polar analysis was done after iterations started with 1st thread and finished in 2nd iteration.

If the air movement rate along the surface of the wing increases, the pressure along the length of the wing surface decreases, according to the Bernoulli theorem. Similarly, an improvement in the attack angle increases the separation between the upper and lower portions of the airfoil pressure coefficient (Figure 5). The NACA 2312 airfoil receives considerably more pressure loss with increasing angle of attack in the same manner that an aircraft wing increases with increasing angle of attack.

Table 1. proper upper and lower surfaces of the airfoil coordinates format NACA 2313

Upper service			Lower service		
x	y		x	y	
1	0	0	0	0	0
0.98939	0.00230	0	0.09561	-0.04286	0
0.96985	0.00646	0	0.19000	-0.04837	0
0.94659	0.01126	0	0.29771	-0.04769	0
0.92108	0.01636	0	0.38138	-0.04497	0
0.89454	0.02147	0	0.49335	-0.03965	0
0.78595	0.04045	0	0.57790	-0.03448	0
0.67664	0.05650	0	0.69136	-0.02668	0
0.59465	0.06644	0	0.77671	-0.02042	0
0.48576	0.07653	0	0.89019	-0.01171	0
0.37847	0.08223	0	091800	-0.00950	0
0.27476	0.08153	0	0.94471	-0.00734	0
0.19963	0.07575	0	0.96896	-0.00534	0
0.08858	0.05503	0	0.98915	-0.00365	0
0	0	0	1	0	0

Table 2. Proper upper and lower surfaces of the airfoil coordinates format NACA 2312

Upper service			Lower service		
x	y		x	y	
1	0.00126	0	0.00002	0.00078	0
0.98969	0.00338	0	0.00015	-0.00213	0
0.97029	0.00729	0	0.01088	-0.01666	0
0.94716	0.01181	0	0.11752	-0.03951	0
0.92208	0.01655	0	0.21669	-0.04244	0
0.89625	0.02126	0	0.32249	-0.04066	0
0.79139	0.03867	0	0.40345	-0.03790	0
0.68600	0.05344	0	0.51121	-0.03291	0
0.58056	0.06539	0	0.61976	-0.02666	0
0.47545	0.07411	0	0.70151	-0.02154	0
0.39732	0.07813	0	0.81068	-0.01441	0

0.29575	0.07866	0	0.91929	-0.00703	0
0.19709	0.07206	0	0.94542	-0.00520	0
0.08548	0.05182	0	0.96947	-0.00343	0
0.00852	0.0166	0	0.98946	-0.00203	0
0.00044	0.00376	0	1	-0.00126	0

Because sets of coordinate points are described by the airfoil geometry, the more points defined would improve the model's accuracy. A good description would result in an airfoil geometry described by one hundred points for both the top surface and the bottom surface.

You will find it in the Appendix, which then provided the related X for each of the hundred points along the upper and lower surface of the airfoil, X, Y, and z will coordinate. With the coordinates specified, they must be given in the following format in a text document.

For the experiment, the airfoil was tested at specific AoA 10^o in the xflr5 foil subjected to winds velocity at 30 m / s, corresponding to Re = 150.000. Airflow creating various pressure drops along the airfoil surface.

The angle of attack started from 0.295 in NACA 2313 and 0.33 in NACA 2312 with the lower lift coefficient, the increase of the angle of attack by up to 10^o then lift coefficient increased up 1.149 in NACA 2313 and 1.148 in NACA 2312. That is means the lower angle of attack decreases the lift ratio while the increases of angle of attack increase the lift ratio of the wing.

In this model the increase of drag force in 10^o AoA and 1.5 x 10^5 Reynolds number the Cd = 0.026 for NACA 2313, and 0.029 for NACA 2312.

Not only the lilt coefficient but also the rise in the drag coefficient by up to 0.026 in NACA 2313 and 0.029 in NACA 2312 for Reynold numbers of 15x10 (graphic, 1). It is found that the drag increases as the angle of attack increases. finds that the highest drag coefficient, Cd increases around the wing with winglet compared to the wing without, at a high angle of attack, the induced drag increase and then the impact of winglet increase to decrease induced drag.

In NACA 2313 the drag coefficient in 3^o and 4^o AoA increase more than the NACA 2312 in the same degree angle of attack before started to fall. In this model the maximum lift force and drag force in 8^o angle of attack and 1.5 x 10^5 Reynolds number the Cl/Cd = 59.47 for NACA 2313, and 60.04 for NACA 2312.

Since lift and drag are both aerodynamic forces, the lift to drag ratio is an indicator of the airplane's aerodynamic performance. If it generates a significant volume of lift or a small amount of drag an aircraft has a high L/D ratio.

The comparison between the two foils in graphic (2) shows that both wings have a higher lift and drag ratio if compared with the wing without a winglet.

In 8^o angle of attack, the lift and drag coefficient increased up to 59.47 in NACA 2313 and up to 60.04 in NACA 2312 maximum then start to fall until 43.52 in NACA 2313 and 39.7 in NACA 2312 at 10^o AoA with 150.000 Reynolds Number that is mean the result in both wings almost same.

Table 3. velocity Coefficient of lift, drag, and moment at different angles of attack, at Reynolds number 150.000 NACA 2313

α	Cl	Cd	Cm
[°]	[-]	[-]	[-]
[0°]	0.295	0.013	-0.063
[2°]	0.534	0.012	-0.066
[4°]	0.717	0.014	-0.058
[6°]	0.899	0.015	-0.049
[8°]	1.055	0.018	-0.036
[10°]	1.149	0.026	-0.018

Table 4. velocity Coefficient of lift, drag, and moment at different angles of attack, at Reynolds number 150.000 NACA 2312

α	Cl	Cd	Cm
[°]	[-]	[-]	[-]
[0°]	0.330	0.012	-0.073
[2°]	0.516	0.012	-0.064
[4°]	0.707	0.013	-0.056
[6°]	0.893	0.015	-0.047
[8°]	1.041	0.019	-0.035
[10°]	1.148	0.029	-0.019

Tables (3), and (4) above show the analysis data of the two airfoil models, the angle of attack, lift coefficient, drag coefficient, and moment coefficient in a high Reynolds Number of 150.000 degrees.

The NACA 2313 airfoil model is used in this report. Five airfoils were used to create the model of the wing with a winglet. Five models all from the same NACA foil with different shapes of chord length. The essential model size is located in the tip.

Table 5. The dimension of the raked winglet

Type of wing model	Cant angle degree	Back sweep	The ratio of winglet root chord to the chord of wingtip
Raked winglet	65	60	0.30

Blended winglet was shaped in an analysis of the airfoil which had done in Xflr 5. The cant angle degree was showed in an angle of 65 degrees and with 60 degrees back sweep. The ratio of the winglet chord to chord of the wingtip is 0.30.

The purpose of this chapter was to analysis harmonic with all the possible criteria. the steps start by generating harmonic currents from specified harmonic sources and identified the problem by used Xflr 5 (Batch foil Analysis). Then wing airfoil and winglets were simulated successfully.

4. CONCLUSION

The target of the present student investigates the characteristics of lift and drag in NACA 2313 and NACA 2312 airfoil winglet design to improve the performance of the aerodynamics coefficient of the wing platform. The experiment is done on a Raked winglet. Used Catia tutorial to design the shape. The experimental methods used in this report were very effective, on generate the airfoil coordination and wing geometry.

The result of simulations showing that the Cl/Cd in the NACA 2313 is higher than in NACA 2312 that already has been used by many aircraft companies and that is mean based on the result of the data in (table 4) NACA 2313 gave high left coefficient than the NACA 2312 and that helps improve it take off while the Cd decreased in NACA 2313 to show improvement in landing.

For the simulation, the airfoil was tested at specific angles of attack 10^o in the foil subjected to winds velocity at 30 m / s, corresponding to Re = 150.000. Airflow creating various pressure drops along the airfoil surface.

In 8^o angle of attack the lift and drag coefficient increased up to 59.47 in NACA 2313 and up to 60.04 in NACA 2312 maximum then start to fall until 43.52 in NACA 2313 and 39.7 in NACA 2312 at 10^o AoA with 150.000 Reynolds Number that is mean in low angle of attack the coefficient of the drag will increase and that increases the vortex.

Use of the NACA 2312 with the winglet will increase the efficiency of the aircraft by up to 5.6% that also improves the performance of the aircraft. Compare to another NACA 2312 digits airfoil there was no much difference in data and that shows the careful simulation investigation was done. The drug and the left force investigation showed better improvement in the aircraft

Ascertained the best performance of wing airfoil in terms of Cl/Cd The vortex of the wingtip was developed according to the wing able to produce wing ratio Cl/Cd higher than the one. But if the wing ratio was given less than one then there will not be wingtip vortices developing. That will not operate a positive lift coefficient. The pressure distribution of the upper surface was given higher than the lower pressure surface, which produced wing ratio Cl/Cd hither than one.

BIBLIOGRAPHY

Abbott, I. H. Von Doenhoff, A.E.V., and Stivers, L. S. “Summary of Aerofoil Data”, NACA Report No. 824, 1945.

Airframe and powerplant mechanics. (2015). Washington DC: U.S. Department of Transportation Federal Aviation Administration, pp.30-31

Bojja, A., and Garre, P., "Analysis on Reducing the Induced Drag Using the Winglet at the Wingtip", International Journal of Engineering Research & Technology (IJERT), Vol. 2, pp. 51-53, 2013.

Eppler, R., "Airfoil Program System: PROFIL98, # User's Guide, Richard Eppler, Stuttgart, c.1998.

Eppler, R., “Airfoil Design and Data”, Springer-Verlag, Berlin, 1990.

Gavrilovic, N. N., Rasuo, B. P., Dulikravich, D. S. & Parezanovic, V. B., 2015. Commercial Aircraft Performance Improvements using

Gavrilovic, N. N., Rasuo, B. P., Dulikravich, D. S. & Parezanovic, V. B., 2015. Commercial Aircraft Performance Improvements using Winglets. FME Transactions, Volume 43, pp. 1-8. Neal, L., Harrison, N. & Mujezinovic, D., 2004. Wingtip Devices. Virginia: Virginia Polytechnic Institute and State University.

Gratzer, L. B., “Blended Winglet,” ed: Google Patents, 1994.

Gratzer, L. B., “Spiroid-tipped wing,” ed: Google Patents, 1992.

Houghton, E., and Carpenter, P., "Aerodynamics for engineering students”, Oxford: Butterworth-Heinemann, (2003).

Ira H. Abbott, Albert E. Von Doenhoff, and Louis S Stivers Jr, Summary of Airfoil Data, 1945.

Khamis Ali Al Sidari, G.R.Rameshkumar, “Design of Winglet Device for Aircraft”, in International Journal of Multidisciplinary Sciences and Engineering, vol.7 No.1, 2016.

Laurence K. Loftin Jr., M Irene Poteat, Aerodynamic Characteristics of several NACA airfoil sections at seven Reynolds number from 0.7x10^6 to 9.0x10^6, Langley Memorial Aeronautical Laboratory, 1948.

Pari, K., and Jodha, P., aircrafts winglets analysis in SFD,2015

Ramesh, P., “Numerical and Experimental investigation of the effect of geometry modification on the Aerodynamic Characteristics of a NACA 64 (2)-415 wing”, M.Sc. Thesis, Royal Institute of Technology, Stockholm, Sweden, 2013.

Ramesh, P., “Numerical and Experimental investigation of the effect of geometry modification on the Aerodynamic Characteristics of a NACA 64 (2)-415 wing”, M.Sc. Thesis, Royal Institute of Technology, Stockholm, Sweden, 2013.

Roche, U. L., “Wing with a wing grid as the end section,” ed: Google Patents, 1998.

Silambarasan, J., and Tamilamudhan, P,. “Optimization on a 3D Wing for Aerodynamic Lift using NACA 2412 Airfoil” IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 01, 2015.

Whitcomb, R. T., “A Design Approach and Selected Wind-Tunnel Result at High Subsonic Speed for Wing Tip Mounted Winglets”, NASA TN D-8260, 1976.