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Study of Flow Field over Fabricated Airfoil Models of NACA 23015 with its Kline-fogleman Variant

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Abstract

This paper investigates and compares the flow over a typical scaled down model of Kline-Fogleman airfoil with a baseline airfoil model at different angles of attack in low subsonic speed. The intent of this study is to evaluate flight performance of one model of the NACA 23015 airfoil and one Kline-Fogleman variant of the NACA 23015. The airfoil models are fabricated with a chord length of 165mm and with a span of 300mm. Aerodynamic characteristics are studied at a free stream velocity of 25m/s in subsonic (blow down type) wind tunnel with the test-section size of 600 x 600 x 2000mm. It is an open cycle, intermittent suction type Wind Tunnel and makes use of the compressed air provided by a compressor. It has a maximum speed of 50m/sec and a compression ratio of 9:1.The settling chamber of the tunnel is of dimensions 1.8 x 1.8m^2. Measurements of static pressure revealed the quality of flow field experienced over the models.

The values of lift & drag coefficients for the airfoil in consideration with NACA 23015 shows stall characteristics at an angle of about $\alpha = 15^0$. The Kline-Fogleman airfoil resists stall even at an angle of $\alpha=45^0$. In fact it doesn’t stall completely but levels of with a very minute L/D ratio. This leveling off is observed for a range from $\alpha=45^0$ to $\alpha=60^0$. The Kline-Fogleman airfoil not only resists stalling for very high angles but also prevents the free fall usually observed at critical angle by leveling off.

The KF airfoils and derivative 'stepped' airfoils have gained an enthusiastic following in the world of foam constructed radio controlled model aircraft. This study pushes the utility of KF airfoil further more by applying its typical step over the NACA 23015 airfoil.

1. Introduction

1.1 Airfoil

An airfoil section which is the essential part of a wing has its primary task as a lift generator. The proper functioning of the airfoil is the prerequisite to the satisfactory performance of the lifting surface. An airfoil shaped body is moved through a fluid produces aerodynamic forces. The component of force perpendicular to the direction of motion is called Lift. The component parallel to the direction of motion is called Drag. The lift produced is primarily the result of its Angle of Attack and shape. When oriented at a suitable angle, the airfoil deflects the oncoming air resulting in a force on the airfoil in the direction opposite to the deflection. This force is known as aerodynamic force and can be resolved into two components lift and drag.

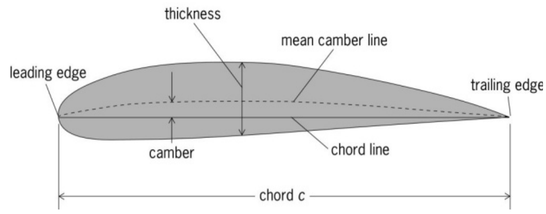

Fig. 1: Basic Airfoil

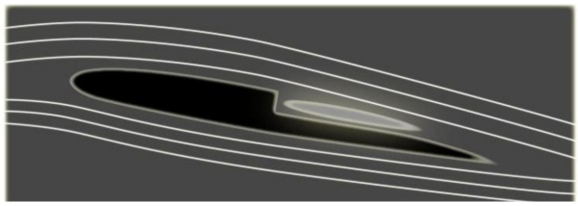

Fig. 2: Vortex attached to a KFm2 Airfoil

1.2 KLINE Fogleman Airfoil

The geometry of the Kline Fogleman is unique compared to the other airfoils. One surface of the airfoil is continuous and remains untouched but the other surface; either the upper or lower surface is partially notched or contains a series of steps depending on its type in the Kline Fogleman airfoil family. The two patents, US Patent # 3,706,430 and US Patent # 4,046,338, refer to the introduction of a step either on the bottom (KFm1) or on the top of an airfoil (KFm2), or both on top and bottom (KFm4). It can also be used with two steps on the top (KFm3), or two steps on the top and one on the bottom (KFm7). The steps all work extremely well on radio-controlled aircraft. The purpose of the step is to allow some of the displaced air to fall into a pocket behind the step and become part of the airfoil shape as a trapped vortex or vortex attachment as shown in Fig 2. This purportedly prevents separation and maintains airflow over the surface of the airfoil. The intent of this study was to evaluate flight performance of the KF airfoil and compare it with a baseline airfoil (NACA 23015).

2. Experimental Setup and Procedure

2.1 Wind Tunnel Facility

All the experiments were performed using the Subsonic Wind Tunnel facility available in the School Of Aeronautical Engineering, Hindustan Institute of Technology and Science, Chennai. The test-section size of the wind tunnel is 600 x 600 x 2000mm with removable side windows. It is an open cycle, intermittent suction type Wind Tunnel, which makes use of the compressed air provided by a compressor. It has a maximum speed of 50m/sec. It has a compression ratio of 9:1.The settling chamber is of dimensions 1.8 x 1.8m^2. The entry section is of Bell mouth entry type. Fig 3 and Fig 4 shows wind tunnel with the manometer used for the pressure measurements.

Fig. 3: Wind tunnel facility

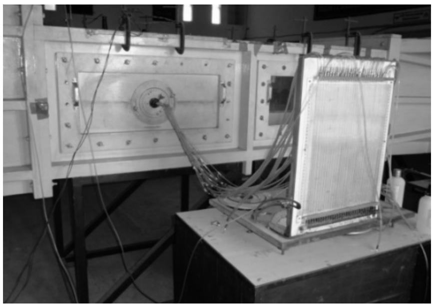

Fig. 4: Multi-bank Manometer

2.2 Details of the Models

Two scaled models were fabricated: one model of the NACA 23015 airfoil and one Kline-Fogleman variant of the NACA 23015 as shown in Fig 5. NACA 23015 have chosenas baseline airfoil as this airfoil is very similar to the customized airfoils being used in Airbus A320. KFm2 design is implemented on baseline airfoil, this is because the KFm2 airfoil is having comparatively high lift characteristics in subsonic speed. The Top-Step KF 50% airfoil is an all-around great performer. The models were machined from rich teak wood. The chord length of the airfoil is 165mm.The span of the models is 300mm. A total of 12 ports were drilled over the models, each having a diameter of 1.2 mm all ports having the same distance to each other. When the model is kept in the test section in such a way that the straight line connecting the ports makes a meridian angle of zero ($ø=0^0$), results in the pressure values on the leeward side of the body and correspondingly $ø=180^0$ results in the pressure values on the windward side of the body.The Top-step KF variant of the baseline model is built similar in dimensions with respect to the chord length and the span.

NACA Airfoil

The NACA five-digit series describes more complex airfoil shapes

1. The first digit, when multiplied by 0.15, gives the Coefficient of Lift.
2. Second and third digits, when divided by 2, give *p*, the distance of maximum camber from the leading edge (as per cent of chord).
3. Fourth and fifth digits give the maximum thickness of the airfoil (as per cent of the chord).

Where the chord wise location x and the ordinate y have been normalized by the chord. The constant 'm' is chosen so that the maximum camber occurs at x=p. Finally, k1 is determined to give the desired lift coefficient.

KFm2 Airfoil

The airfoil is generally having a hollowed out portion at about 50% of its chord length. The thickness of a general KFm model as per Kline &Fogleman is about 7-9%. Here the NACA profile is initially modelled and the cut is made at a length of 50% of its chord. The step is induced at 50% of the chord line i.e. a step is cut at 82.5mm from the leading edge.

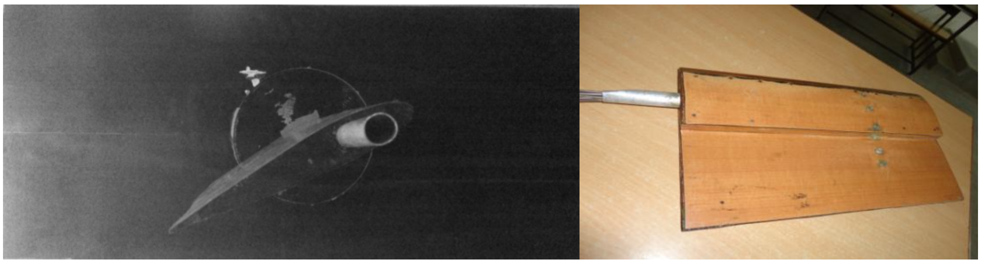

Fig. 5: The fabricated model of NACA 23015 mounted in the wind tunnel test section and its KF variant.

2.3 Experimental Procedure of Static Pressure Measurement

The pressure tapings on the face of the body were connected to the limbs of the ethanol manometer with the help of both 1.2 mm steel tubes and the polythene tubes. The data from the pressure ports was obtained. As the tunnel was run the readings from the manometer were taken. The same procedure was repeated for both the airfoils. These pressure measurements were taken for pitch angles of 0^0,-5^0 -10^0, 5^0, 10^0, 15^0 and 20^0 for the baseline airfoil. The readings for the KF variant was taken for angles of 5^0 intervals from 0 up to 70^0 .The readings of ethanol head from the manometer are then reduced to static pressures using appropriate relations. These measurements were repeated two or three times in some cases to check the reliability of the readings.The tests were performed at a free stream velocity of 25m/s at a stagnation pressure of 27 psig. A run time of approximately 10 seconds was maintained for all the experiments.

The values of lift & drag coefficients for the airfoils in consideration are as shown in Table 1 & Table 2

Table 1: lift & drag coefficients for NACA 23015.

AOA	C_L	C_D	C_L/C_D
-20	-0.374192	0.00935	-40.0205
-15	-0.380758	0.011343	-33.5758
-10	-0.374848	0.01454	-25.7804
-5	-0.22702	0.022396	-10.1367
0	0.056771	0.010369	5.474886

5	0.127083	0.012769	9.95248
10	0.280303	1.45E-02	19.29266
15	0.550473	0.022396	24.57928
20	0.407907	0.01946	20.96107
25	0.440294	0.016714	26.34278
30	0.463542	0.018838	24.60623
35	0.600505	0.024545	24.46502
40	0.631714	0.034796	18.15465
45	0.693312	0.064606	10.7301
50	0.701136	0.069515	10.0861
55	0.967308	0.09052	10.6861
60	1.017133	0.10354	10.6407
65	0.955949	0.12631	7.568
70	0.959562	0.14575	6.5836

Table 2: lift & drag coefficients forKFm2 variant.

AOA	C_L	C_D	
-10	-0.261829837	5.51E-03	-47.5082
-5	-0.101923	0.012723	-8.01106
0	0.0726107	0.016533	4.39166
5	0.301107	0.018547	16.23481
10	0.432401	0.023804	18.1651
15	0.642774	0.034885	18.4254
20	0.447808	0.031074	14.4109

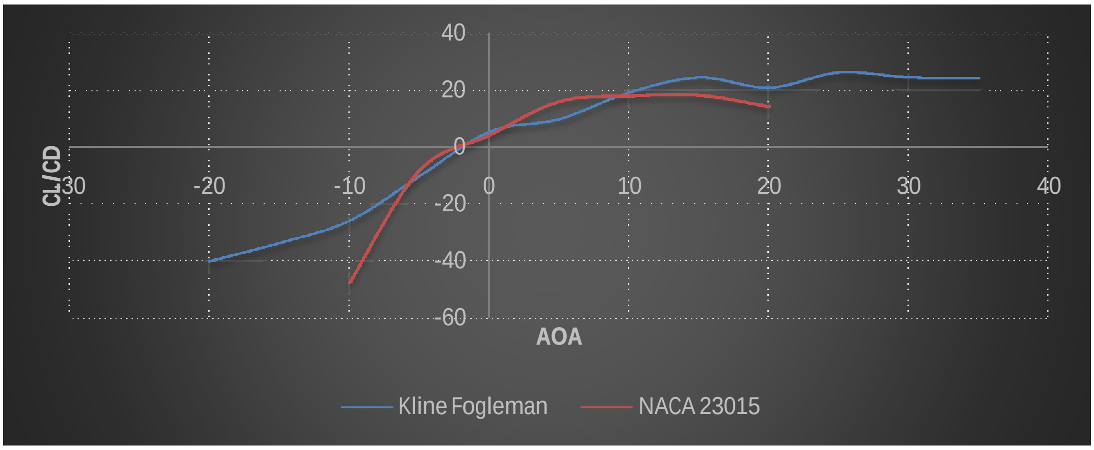

Fig. 6: Comparison graph of CL/CD vs. α for NACA 23015 vs. Kline Fogleman

3. Conclusion

An attempt was made to investigate and compare the flow over a typical scaled down models of NACA 23015 airfoil and Kline-Fogleman airfoils at different angles of attack in subsonic wind tunnel. NACA 23015 airfoil and its Kline-Fogleman variant (KFm2) was developed in Burma teak wood. Both were tested in wind tunnel for pressure tapping and the e lift and drag forces were calculated.Aerodynamic characteristics were studied at a free stream velocity of 25m/s in subsonic (blow down type) tunnel. Measurements of static pressure revealed the quality of flow field experienced.It was then found out through comparison that the Kline-Fogleman variant with a step at 50% chord length possessed superior lift characteristics as shown in the graph in Fig 6. More importantly the KFm2 variant resisted stalling even for very large angles of attack. The KFm2 did not stall till angles of $\alpha=45^0$after that it leveled off with a good L/D ratio.This can be of very good use as leveling off prevents the accidents caused by free fall at critical angles.

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