FABRICATION OF HALF WING AEROFOIL SHAPED FUSELAGE UAV MODEL AND INVESTIGATION OF IT'S POINT SURFACE PRESSURE ON WING SURFACES

Wing Commander G.M. Jahangir Alam (1), Md Mamun (2), Md. Abu. Taher Ali (3), Md. Quamrul Islam (4) and A.K.M. Sadrul Islam (5)

1 Department of Mechanical Engineering, MIST, Dhaka, Bangladesh,
jahangiralam105@yahoo.com
2-4 Department of Mechanical Engineering BUET, Dhaka, Bangladeswh,
mdmamun@me.buet.ac.bd, matali@me.buet.ac.bd and quamrul@me.buet.ac.bd
5 Department of Mechanical and Chemical Engineering, IUT, Gazipur, Bangladesh,
sadrul@iut-dhaka.edu

Abstract :

This paper explains the fabrication of a half wing (only right wing) UAV model of aerofoil shaped fuselage. NACA 4416 cambered aerofoil with chord length of 115 mm has been used for designing the right wing of the UAV model. Open circuit subsonic wind tunnel has been used to test the fabricated UAV model and collection of data. The air speed inside the wind tunnel could be controlled from 0 to 40 m/s by rotating a control knob. Point surface pressure of Aerofoil Shaped Fuselage UAV model at 25%, 50%, 75% and 90% from the root has been analyzed from -3o to 15o angle of attack. The difference of pressure between the lower surface pressure (pressure side) and the upper surface pressure (suction side) of the wings & fuselages determines the amount of maximum lift and drag force produced by such model. This paper explains the design parameters and investigation of the point surface pressure on the right wing surfaces of the "Aerofoil Shaped Fuselage" UAV model. The aerofoil shaped fuselage could be used for designing the future UAV to use many military and civil applications. The aerodynamic characteristics of Aerofoil Shaped Fuselage UAV model have been carried out at two different velocities (20 m/s & 40 m/s respectively). Finally, some conclusions have been drawn on the basis of the experimental result for this design.

Keywords: *Unmanned Air Vehicles (UAV), Aerofoil Shaped Fuselage, Aerodynamic Characteristics, Point Surface Pressure, Angle of Attack, Stalling Angle.*

1.0 INTRODUCTION:

An air vehicle having no onboard pilot and capable of pre-programmed operation as well as reception of intermittent commands either independently or from a human operator at a distance from the ground is called Unmanned Air Vehicle (UAV). The piloted aircraft were predominantly used for surveillance and reconnaissance missions but the vast technological improvements in anti-aircraft weapons, interceptor aircraft coupled with the high cost of state of the art aircraft and crew training led to the development of UAVs. Operation of UAV proved to be easy and adaptable for a variety of tasks. UAVs can carry out both military and civil applications like scientific data gathering, surveillance for law enforcement & homeland security, precision agriculture, forest fire monitoring, geological survey etc [1] & [2].

UAVs mostly fly under low speed conditions. The aerodynamic characteristics of the UAVs have many similarities than that of the monoplane configuration. Due to the UAV's potential for carrying out so many tasks without direct risk to the crew or humans in general, they are ideal for testing new concepts which have been put forward as a means to further increase the vehicle's capability and performance [3] & [4].

This paper explains the design parameters for fabrication of a half wing (only right wing) UAV model having "Aerofoil Shaped Fuselage" using NACA 4416 profile. The wings of a conventional UAV are producing the lift and it's fuselage has very little or no contribution on producing lift. But UAV requires higher lifting force with a smaller size [5]. As such, in order to maximize the efficiency of an UAV, it is assumed that the basic design of UAV could be changed and it should be such that all components of an UAV should contribute to the total lift. In such case, the concept of development of all lifting vehicle technology would bring good result for research on designing the future UAV [6] & [7]. The difference of pressure between the lower surface pressure (pressure side) and the upper surface pressure (suction side) of the wings & fuselages determines the amount of lift and drag force produced by an UAV model. This paper explains the investigation of the point surface pressure on the right wing surface of the "Aerofoil Shaped Fuselage UAV Model" at different angles of attack using AF100 subsonic wind tunnel.

2.0 EXPERIMENTAL MODEL DESIGN:

Four major parts of the half wing aerofoil shaped fuselage UAV model are right wing, right fuselage, horizontal stabilizer and vertical stabilizer. Up wing type blended model has been chosen and NACA 4416 cambered aerofoil has been used for fabrication of different parts of the model. Table 1 shows the important features of experimental design of half wing aerofoil shaped fuselage UAV model. Photograph of fabricated half wing aerofoil shaped fuselage UAV model is shown in Figure 2.1.

Nomenclature	Aerofoil Shaped Fuselage
Wing Design (Chord length, span and maximum thickness of each wing)	115 mm, 250 mm (either left or right wing) and 16 mm at 16% chord length from the root
Fuselage Design	Aerofoil Shaped as suitable for this design by maintaining the scale factor
Horizontal and Vertical Stabilizer	As suitable for this design by maintaining the scale factor
Number of Tapping points	Total thirty six (36) tapping points have been made on the right wing upper and lower surfaces for measuring point surface pressures.
	Sixteen (16) tapping holes have been fabricated at 25%, 50%, 75% and 90% from the root of both upper & lower surfaces of the right wing.
	Four (04) tapping points have been made near the stagnation point at the leading edge of right wing at 25%, 50%, 75% and 90% from the root near the stagnation point.
Position of Tapping points	The tapping points have been fabricated approximately 15%, 37.5%, 60% and 82.5% of chord length from the nose on upper and lower surfaces of the right wing.
Connection with the Wind Tunnel	All thirty six (36) tapping points are connected with the Pressure Display Unit of the wind tunnel through flexible plastic tubes.

Table 1: Important Features of Experimental Design of Half Wing Aerofoil Shaped Fuselage UAV Model

Fig 2.1: Photograph of Fabricated Half Wing Aerofoil Shaped Fuselage UAV Model

3.0 EXPERIMENTAL METHODOLOGY:

The half wing aerofoil shaped fuselage UAV model have been fixed with the wind tunnel through 3-Component Balance from one side. The other end of the model has been connected with Pressure display Unit of the wind tunnel through flexible plastic tubes. Some operating conditions have been applied and maintained at the wind tunnel during testing the fabricated model and collection of data. Table 2 shows the operating conditions which have been considered during testing the fabricated aerofoil shaped fuselage UAV model.

Table 2: Operating Conditions during Testing the Fabricated UAV Model at the Wind Tunnel

Nomenclature	Operating Conditions
Flow of air	Incompressible and subsonic
Air speed (v)	20 m/s and 40 m/s
Density of air (ρ_o)	1.225 kg/m^3
Operating pressure	1.01 bar
Absolute viscosity (μ)	1.789 x10^{-5} kg/m-s
Reynold's Number (Re)	1.37 x 10^5 and 2.74 x 10^5
Angles of attack (α)	-3° to 15°
Effect of temperature	Neglected

4.0 SUBSONIC WIND TUNNEL MODEL AF100:

Open circuit subsonic wind tunnel model AF100 has been used to test the fabricated half wing aerofoil shaped fuselage UAV model. This wind tunnel is incorporated with a computer based data acquisition system to provide different forces, moments and differential pressures automatically from the computer. The dimensions of the working section of AF 100 wind tunnel are 60 cm (length) x 32 cm (width) x 30 cm (height). Photograph of wind tunnel model AF 100 and it's working section are shown in Figure 4.1 & 4.2 respectively. Air enters the wind tunnel through an aerodynamically designed diffuser (cone) that accelerates the air linearly. A control knob could be rotated to control the speed of axial fan of the wind tunnel from 0 to 40 m/s. Wind tunnel model AF 100 is associated with some special accessories like Versatile Dada Acquisition System (VDAS), 3-Component Balance, differential pressure transducers, Pressure display Unit, smoke generator etc. Tapping pressures from different experimental models could be measured either from manometers or from the pressure transducers connected with the wind tunnel or directly from the computer through Versatile Data Acquisition System (VDAS). The fabricated models are to be inserted through the 3-Component Balance and the models could be rotated 360o freely & locked in the force plate to allow adjustment of the angle of attack of the models. Photograph of Right Wing of Aerofoil Shaped Fuselage UAV Model fitted with the Wind Tunnel is shown in Figure 4.3.

Fig 4.1: Photograph of Wind Tunnel Model AF 100

Fig 4.2: Photograph of Working Section of Wind Tunnel Model AF 100

Fig 4.3: Photograph of Right Wing of Aerofoil Shaped Fuselage UAV Model fitted with the Wind Tunnel

5.0 EXPERIMENTAL RESULT:

5.1 Static Pressure at Different Percentage from the Root of Aerofoil Shaped Fuselage UAV Model at 20 m/s

Surface static pressure of Aerofoil Shaped Fuselage UAV model at 25%, 50%, 75% and 90% from the root has been analyzed from -3o to 15o angle of attack at 20 m/s. The variation of static pressure with chord length of said model at 25%, 50%, 75% and 90% from the root at different angle of attack is shown in Figure-5.1 to 5.9. The difference in pressure produced by the lower surface and upper surface of the wings & fuselages determines the amount of lift and drag force produced by this model. The suction pressure mainly determines the amount of lift force to be produced by this model. It is seen that the difference of pressure between the lower surface (pressure side) and the upper surface (suction side) of the wings & fuselages is more at 25%, followed by 50% and next is 75% in all the cases. Pressure difference is found least at 90% from the root. Flow separation mostly starts after 90% from the root. The height of the upper surface suction peak of the wings is found maximum at 14° angle of attack. As such, stall angle is found at 14° angle of attack for this case. Afterwards, separation starts due to sudden flattening of the upper surface pressure distribution (reduction of suction peak) with further increase of angle of attack. Furthermore increase of angle of attack will further reduce the pressure differences which ultimately reduce the lift.

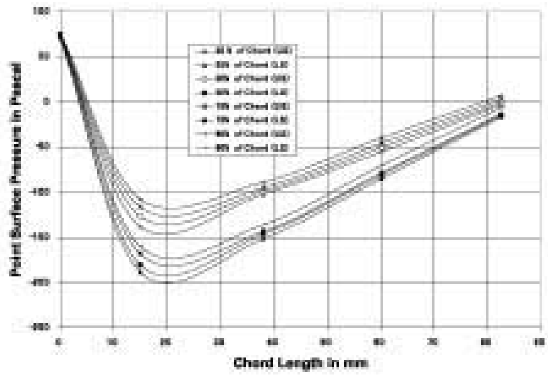

Fig 5.1: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at -3° AOA

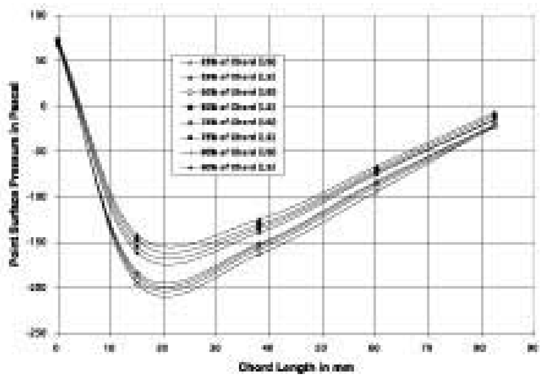

Fig 5.2: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 0° AOA

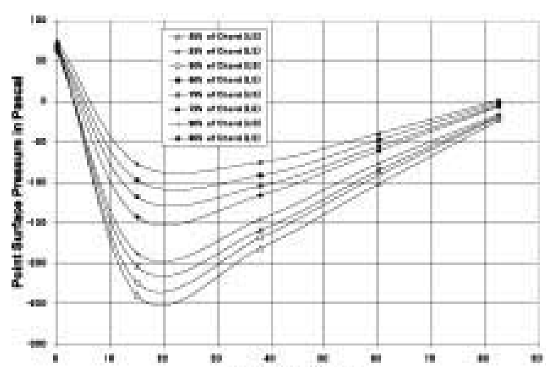

Fig 5.3: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 3° AOA

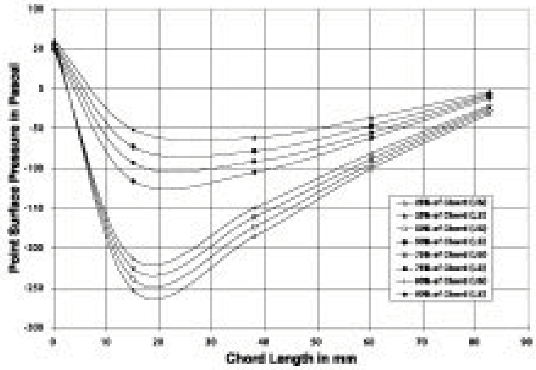

Fig 5.4: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 6° AOA

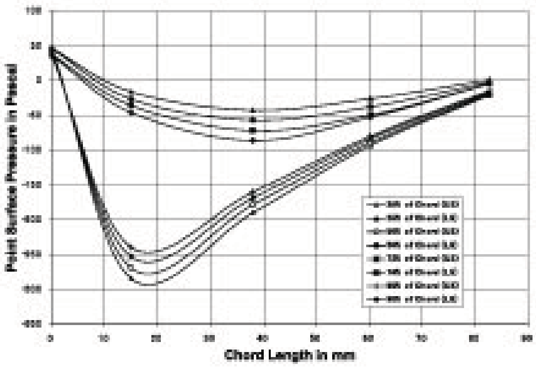

Fig 5.5: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 9° AOA

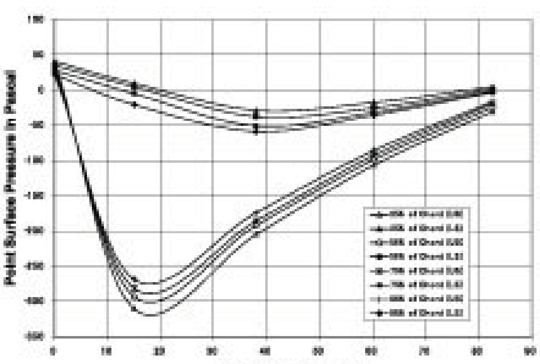

Fig 5.6: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 12° AOA

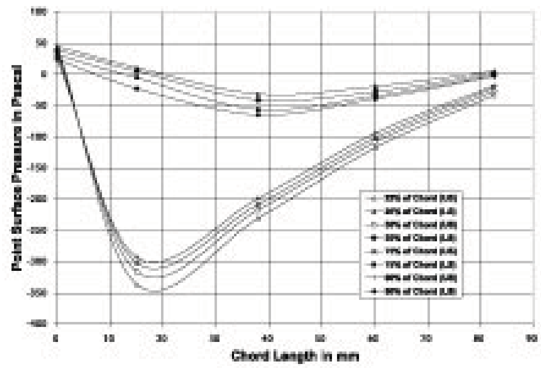

Fig 5.7: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 13° AOA

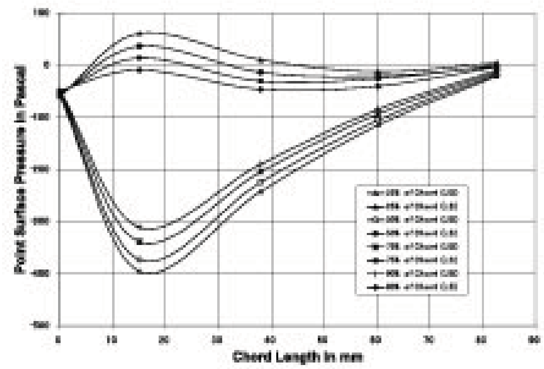

Fig 5.8: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 14° AOA

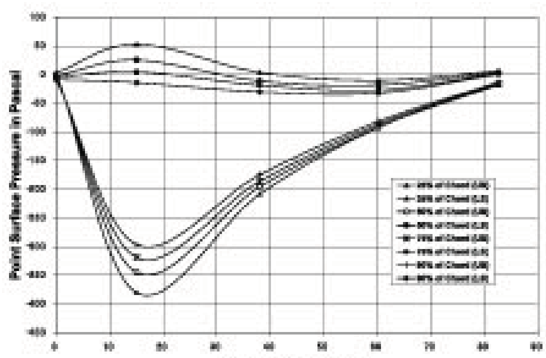

Fig 5.9: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 15° AOA

5.2 Static Pressure at Different Percentage from the Root of Aerofoil Shaped Fuselage UAV Model at 40 m/s

Surface static pressure of Aerofoil Shaped Fuselage UAV model at 25%, 50%, 75% and 90% from the root has been analyzed from -3o to 15o angle of attack at 40 m/s. The variation of static pressure with chord length of said model at 25%, 50%, 75% and 90% from the root at different angle of attack is shown in Figure-5.10 to 5.18. The difference in pressure produced by the lower surface and upper surface of the wings & fuselages determines the amount of lift and drag force produced by this model. The suction pressure mainly determines the amount of lift force to be produced by this model. It is seen that the difference of pressure between the lower surface (pressure side) and the upper surface (suction side) of the wings & fuselages is more at 25%, followed by 50% and next is 75% in all the cases. Pressure difference is found least at 90% from the root. Flow separation mostly starts after 90% from the root. The height of the upper surface suction peak of the wings is found maximum at 14° angle of attack. As such, stall angle is found at 14° angle of attack for this case. Afterwards, separation starts due to sudden flattening of the upper surface pressure distribution (reduction of suction peak) with further increase of angle of attack. Furthermore increase of angle of attack will further reduce the pressure differences which ultimately reduce lift.

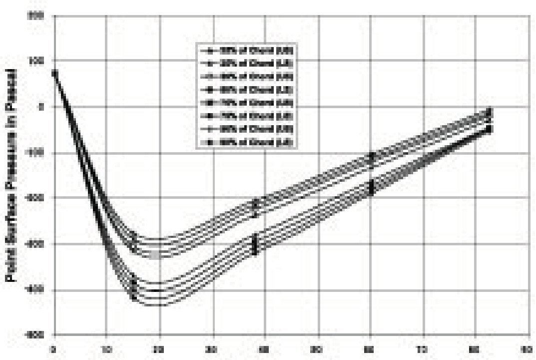

Fig 5.10: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at -3° AOA

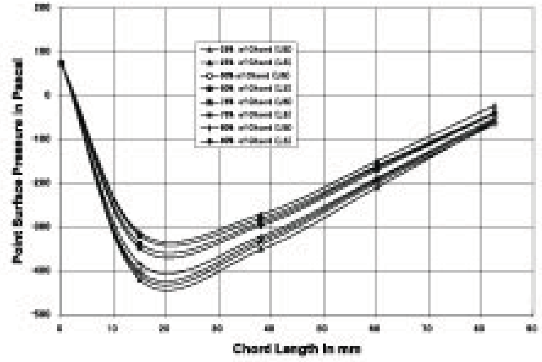

Fig 5.11: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 0° AOA

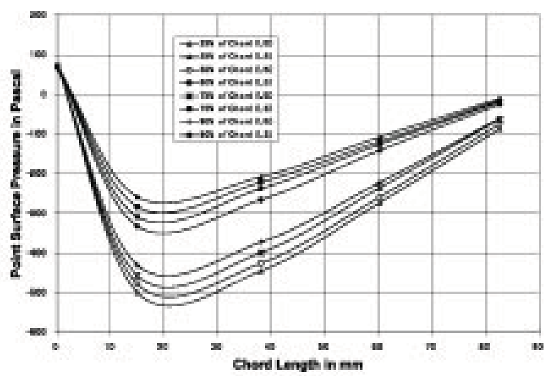

Fig 5.12: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 3° AOA

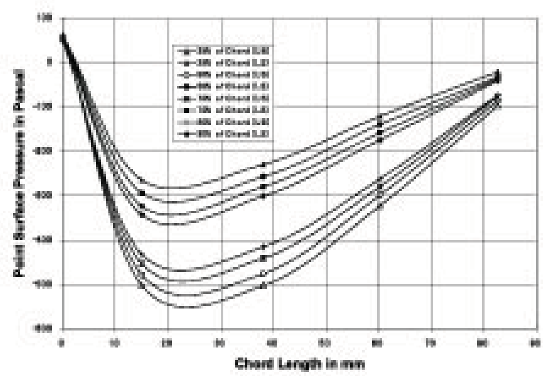

Fig 5.13: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 6° AOA

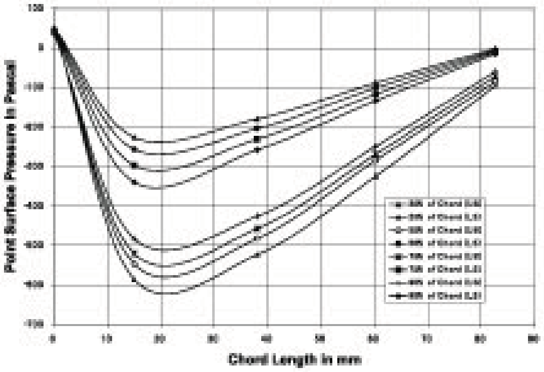

Fig 5.14: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 9° AOA

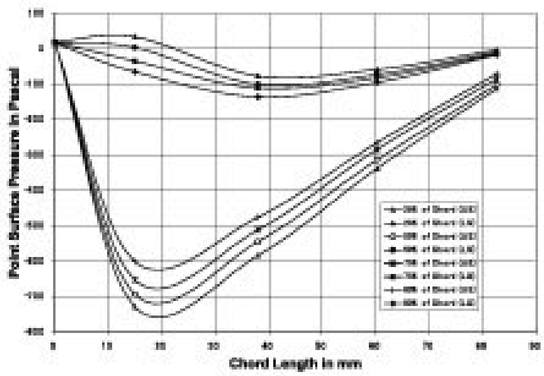

Fig 5.15: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 12° AOA

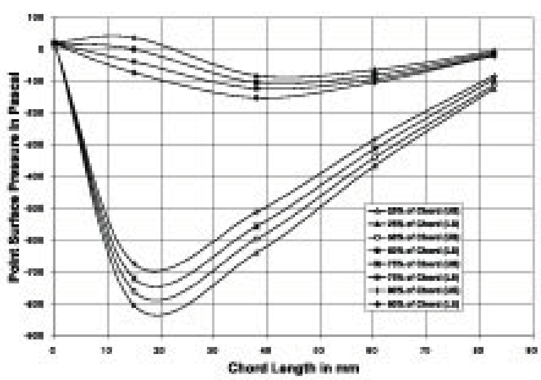

Fig 5.16: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 13° AOA

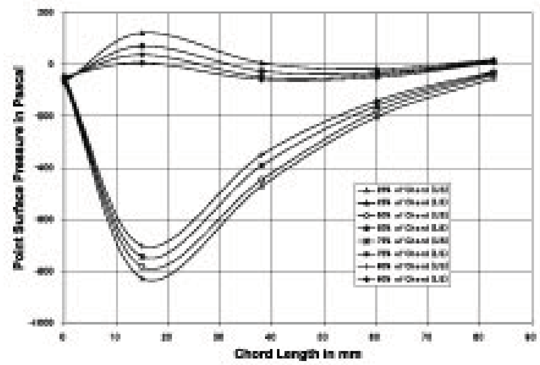

Fig 5.17: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 14° AOA

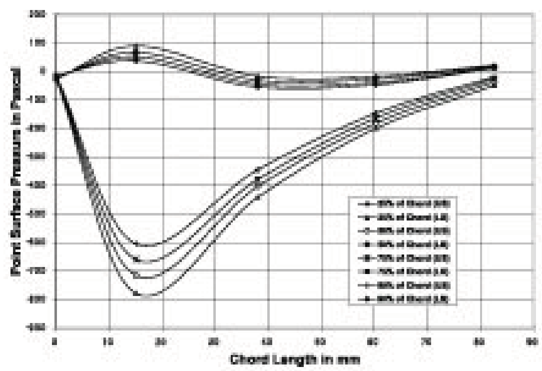

Fig 5.18: Point Surface Pressure at Different Percentage of Chord Length of Half Wing Aerofoil Shaped Fuselage UAV Model at 15° AOA

6.0 RESULT AND DISCUSSION:

The upper surface pressure of "Half Wing Aerofoil Shaped Fuselage UAV Model" is found more than that of the lower surface pressure from all the fabricated tapping points at 25%, 50%, 75% and 90% from the root at -3º angle of attack. As such, no lift has been produced at -3º angle of attack for this UAV model. However, lift has been started producing approximately from -2º angle of attack [7]. The difference in pressure between the upper and lower surfaces has been gradually increased up to 14º angle of attack [Figure-5.1 to 5.8 and 5.10 to 5.17]. Furthermore increase of angle of attack ie at 15º angle of attack, the pressure differences has been reduced which ultimately reduce the lift [Figure-5.9 and 5.18]. So, the stall angle for both the cases is found at 14º angle of attack. The difference in pressure developed between the lower surface and upper surfaces of the fabricated aerofoil shaped fuselage UAV model determines the amount of lift and drag force produced by this UAV model. Out of four parameters (25%, 50%, 75% & 90% from the root of the wing), the maximum difference in suction and positive pressure is found for both the cases at 25% from the root of the wing. The difference in suction and positive pressure has been found less in the subsequent tapping holes produced at 50%, 75% and 90% respectively for both the cases. It is also observed from both the study that the difference in suction and positive pressure is found maximum within 12 to 15% of chord length from the root [Figure-5.1 to 5.18]. The pressure difference of "Half Wing Aerofoil Shaped Fuselage UAV Model at 40 m/s" is found approximately two times greater than that of the "Half Wing Aerofoil Shaped Fuselage UAV Model at 20 m/s".

7.0 CONCLUSION:

Operation of UAV proved to be easy and adaptable for versatile tasks including military as well as many civil applications in the recent years. But UAV requires higher lifting force with a smaller size. To acquire more lift force, the difference in pressure between the upper and lower surfaces should be more from an objective. As such, the concept of development of all lifting vehicle technology might bring good result for research on designing future UAV to gain more lift force due to more difference in pressure between upper and lower surfaces. For this reason, the aerofoil shaped fuselage would be a good option for carrying out research in this field.

This paper explains the design parameters for fabrication of a half wing UAV model having "Aerofoil Shaped Fuselage" using NACA 4416 profile. This paper also explains the investigation of the point surface pressure on the right wing surfaces of the same UAV model at two different velocities (20m/s and 40 m/s respectively) and different angles of attack using AF 100 subsonic wind tunnel. The difference in pressure between the upper and lower surfaces has been gradually increased approximately from -2º up to 14º angle of attack. The pressure difference has been reduced with furthermore increase of angle of attack ie the stall angle is found at 14º angle of attack for "Aerofoil Shaped Fuselage UAV Model". The pressure difference of Aerofoil Shaped Fuselage UAV Model at 40 m/s is found approximately two times greater than that of the Aerofoil Shaped Fuselage UAV Model at 20 m/s.

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