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Investigation of Coanda Effect on Different Curved Plates

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ABSTRACT: *The paper presents research results on aerodynamics of Coandă airfoil. The Coandă propulsion allows amplification and even multiplication of the lift forces due to the increased air volume entrained. The aim of this work consists of establishment of geometric and aerodynamic parameters at which, the lift force produced by Coandă airfoil is maximum. Lift increases as the angle of attack increases and at certain point it becomes maximum. For curved plates it is not dependent on the altitude or angle of attack as fixed curved-wing (plate) UAVs are. For this research work an open circuit type wind tunnel was used to provide subsonic gliding flow over the plates to determine the curvature which provides the best result. That is why an open circuit type D.C. wind tunnel was also designed along with two curved plates for this investigation. Data analysis were done experimentally under standard atmospheric conditions. The outcomes were graphically shown and results were explained. The results were analyzed and found to satisfy the theory.*

Keywords-*Coandă Effect, D.C. wind tunnel, Curved plates, Lift, Drag*

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I. INTRODUCTION

Nowadays commercial aircrafts are facing problems regarding high cost of fuel consumption. The cost can be minimized by using Coandă Effect which will improve the aerodynamic properties of the parts which are responsible for lift, thrust and drag. This phenomena was named after Romanian aerodynamics pioneer Henri Coandă, who was the first to recognize the practical application of the phenomenon in aircraft development. The Coandă effect is the tendency of a fluid jet to stay attached to a convex surface .This project is based on Coandă Effect and its variation on different curved plates. Mostly the effect varies with the radius of the curvature of the plate. The only practical application of this effect was made by the Usines Chasson, a motor car radiator manufacturer in France. This company studied the use of the basic Coanda Nozzle in order to induce flow through a radiator with the idea of utilizing the exhaust gases as the working fluid. Then some research works were done in this field some of the major researches based on Coandă Effect are Investigation of Hysteresis of the Coandă Effect on Flat Plate by Zygmunt Wierciński at Institute of Fluid-Flow Machinery, Gdansk. An investigation of the two-dimensional Coandă effect by Palermo, Frank Joseph, at The University of Arizona. Quite a few aircraft have been built with extra engines specifically designed to direct flow over the top of the wing, where the camber is most pronounced. Air directed over the wing can be "bent down" towards the ground using flaps and a jet sheet blowing over the curved surface of the top of the wing for usually temporary high lift effect which is a practical use of Coandă Effect in recent days.

Practical uses of Coandă Effect are also found in medical science in cardio vascular color Doppler mapping, maritime engineering, industrial galvanizing and other perspectives.

In this project a brushless D.C. motor (BLDC) is used as a thrust generator which directs the flow gliding over the wooden plates and the Tygon tubes connected to the sensors show the pressure distribution over the points. Finally pressure distribution was converted into drag and lift by proper calculation.

Thus analysis for an efficient Coandă Effect which has different aspects in aerodynamics was done in this project. This project also discusses the variation of Coandă Effect with radius of curvature and explore the potential of using the Coandă Effect in building more capable and inexpensive aerodynamic system as well as the applications in different arena of Aerodynamics.

II. LITERATURE REVIEW

Investigation of Hysteresis of the Coandă Effect on Flat Plate was done by Zygmunt Wierciński at Institute of Fluid-Flow Machinery, Gdansk. They described their result as the hysteresis phenomenon on flat plate is Reynolds number dependent of the fluid passing over it.

An investigation of two dimensional Coandă Effect was made of a two-dimensional jet ejected tangentially to a cylinder by. Frank Joseph Palermo at The University of Arizona. This tangential ejection results in a clinging flow over the cylinder, known as the "Coandă Effect".

CFD simulation on Coanda Effect UAV was done by Md. Enamul Haque at Khulna University of Engineering & Technology.

III. DESIGN

The main objective of this project is to investigate the variation of Coandă effect with respect to radius of curvature of plates using an open circuit D.C. wind tunnel. Design of the plates and wind tunnel was based on the following assumptions and parameters.

3.1 Design Assumptions:

The design is based on availability, cost, reliability, efficiency and serviceability in atmospheric condition.

i. Any changes in weather are neglected.
ii. Materials used in this project are supposed to sustain thrust generated by the wind tunnel.
iii. Materials used in this project are supposed to remain unchanged till end.

3.2 Design Parameters

A number of design parameters affect the capacity of a Coandă-effect screen structure. Some of these parameters are primarily related to the structure

- Drop height from upstream pool to start of screen plate (or from upstream weir crest to start of screen)
- Plate slope
- Curvature (arc radius) of screen plate
- Length of plate

3.3 Design of the Curved Plates:

Considering availability, cost and other preconditions wood is chosen for this project as plate material. The size of the plates are chosen randomly as per they fit the wind tunnel as designed. Chosen sizes are quarter of 15" and 20" radius curved spheres. CAD model is shown in Fig. 1

Figure 1CADModel of the Wooden Screen Plates

3.4 CAD Model of Open Circuit Wind Tunnel:

The apparatus will include BLDC motor (Brush Less Direct Current Motor), Propeller, ESC, Plate holder and outer casing leaving space for air inlet and outlet. The dimension of the tunnel is (20"X 20" X 40"). CAD model is shown in Fig. 2.

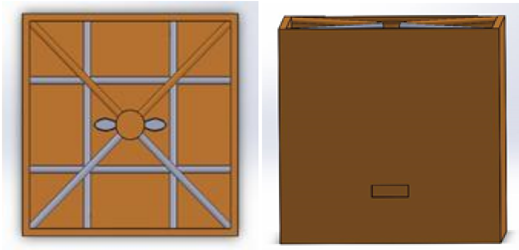

Figure 2 Top View and Right Side View of Open Circuit DC Wind Tunnel

IV. CONSTRUCTION

4.1 Construction of Curved Plates:

Wooden plates were made from 7.5" and 10" wooden cubes by removing chips leaving 7.5" radius curved surface and 10" radius curved surface respectively. Then polishing was done over the surfaces for smooth finishing. Then points were drilled for Tygon tubing along the Chord line

Figure 3 Prepared Wooden Curved Plates

4.2 Construction of Curved Plates:

The outer body of the tunnel was made of plywood as per the design considerations, length 20 inch, width 20 inch and height of 40 inch. Plywood was used as it is non porous, so air leakage is tends to zero aside the plates. Thrust generator is controlled by Arduino with proper coding. Power is supplied to the motor via ESC and D.C. power supply.

Figure 4 Constructed Open Circuit Wind Tunnel

4.3 Circuit Design:

Circuit design to run the Thrust generator is as follows which is controlled by variable resistor for having different speed zones.

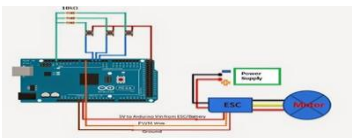

Figure 5 Circuit Design of Open Circuit D.C. Wind Tunnel

V. CALCULATION

5.1 Inputs and Boundary Conditions:

The problem considers flow around the curved plates. For that we take some initial inputs and boundary conditions for our problem which are shown in the Table 1.

Table 1 Inputs and Boundary Conditions

No	Input	Value
1	Velocity of flow	0.15 Mach
2	Operating temp	310K
3	Density of fluid	1.225 Kg/m^3
4	Kinematic viscosity	1.4607*E^-6
5	Reynolds number	4.6*E^-6
6	Fluid	Air as ideal
7	V_1	239.79ms^{-1}
8	V_2	214.45ms^{-1}
9	V_3	177.55ms^{-1}

5.2 Measurements:

[1]. Experiments were conducted using of a two curved plates in the open circuit wind tunnel.
[2]. The wind tunnel was started.
[3]. The RPM was set to obtain the desired upstream air velocity, the pressure readings for the 23 points were recorded.
[4]. The speed was readjusted.
[5]. Finally justification was analyzed.
[6]. For each wind speed setting, record of manometer heights are required for the every locations, the atmospheric pressure and the 23 airfoil surface points pressures are also important. These Manometric heights were recorded using Digital manometer.

5.3 Sample Calculation of Finding:

$$\text{Cd, V1} = \frac{D}{0.5 * \rho * v^2 * A}$$

Here,
C_d= Coefficient of Drag
D=Drag Force
ρ=Density of working fluid
A= Area of the curved plate
V= Speed of fluid flow

5.4 Sample Calculation of Finding:

$$\text{Cl, V1} = \frac{L}{0.5 * \rho * v^2 * A}$$

C_l= Coefficient of Lift
L=Lift Force
ρ=Density of working fluid
A= Area of the curved plate
V= Speed of fluid flow

I. Results

Drag coefficient for small plate is shown in the graph. It is seen that for different speed zones drag is maximum near the midpoint region where stagnation may prevail.

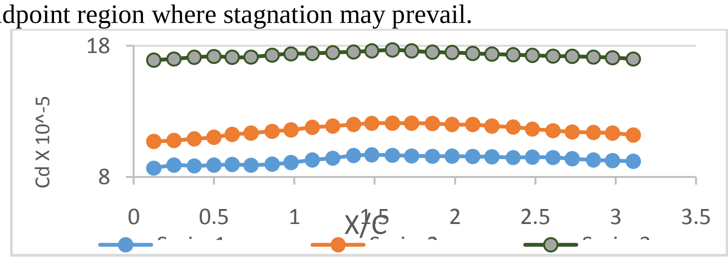

Figure 6 Drag coefficient on Small (7.5" radius) Plate

Lift coefficient also follows the trend of drag coefficient. Midpoint region is found price-worthy for performance. This region produces maximum life.

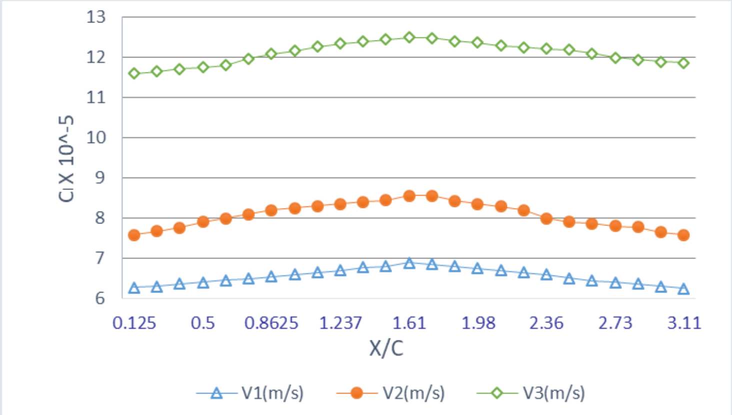

Figure 7 Lift Coefficient on Small (7.5" radius) plate

Drag is mostly unchanged throughout the surface, small deviations are found near the leading and tailing edges.

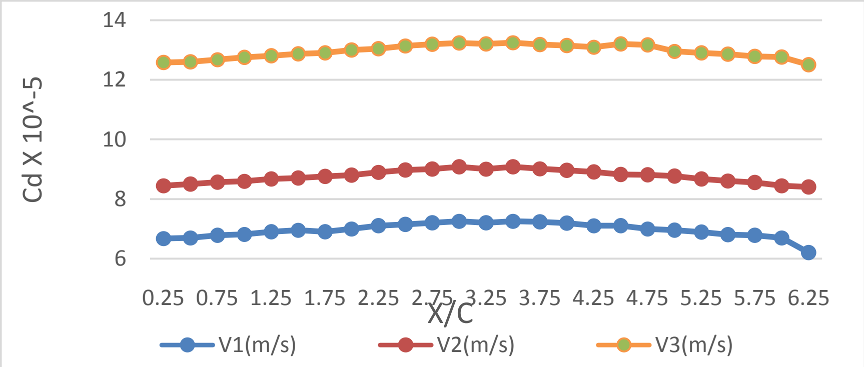

Figure 8 Drag coefficient on Large (10"radius) plate

Lift is symmetrically distributed centering the midpoint zone (points 11-15). In lower speed lift fluctuation is high. The distribution is as follows.

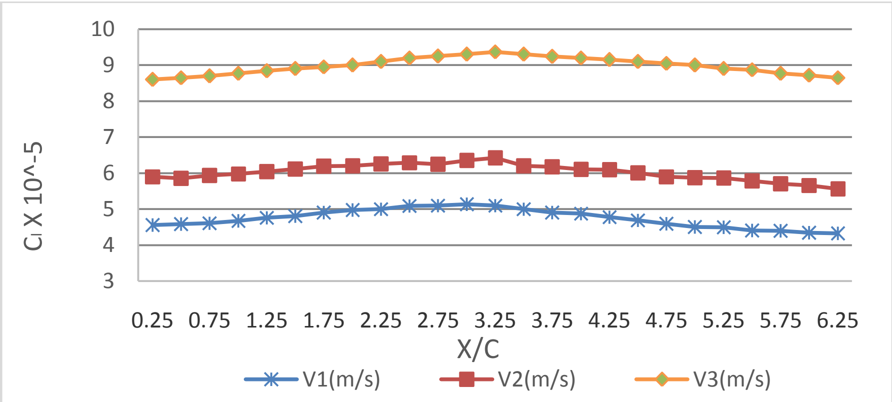

Figure 9 Lift Coefficient on Large (10"radius) plate

The variation of lift and drag with radius of curvature of the plates are as follows. The graph shows the performance of the plates, how they behave aerodynamically and justifies Coandă effect. The tendency of fluid to get attached to the nearby concave surface is clearly shown in the graph and justifies Coandă effect in the midpoint region and most for the small plate.

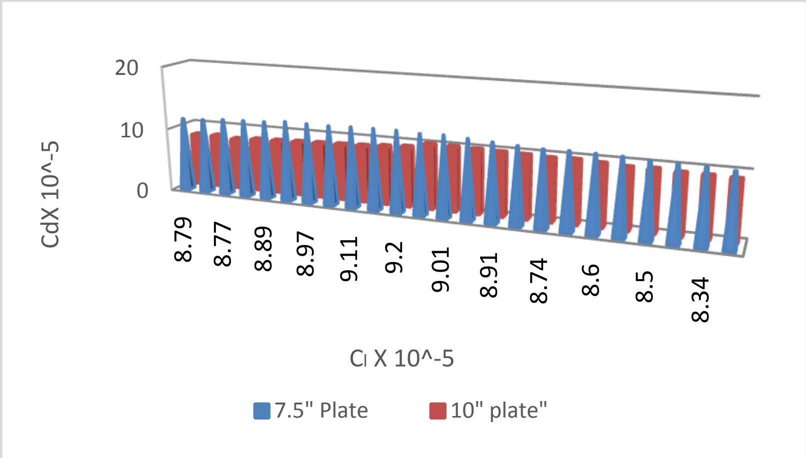

Figure 10 Variation of Lift and Drag Coefficient

VI. DISCUSSION

The velocity of the Coandă flow was found to be dependent on the viscous shear on the curved surface. Drag is mostly unchanged throughout the surface, small deviations are found near the leading and tailing edges for both the plates, but lift is much variable than drag. The payload is not located directly in the stream of air responsible for creating lift forces. The airflow necessary to create lift forces is not as dependent of the altitude or angle of attack as fixed curved-wing (plate) UAVs are, so the curved-wing UAV is more stable during the flight. In most cases lift is symmetrically distributed centering the midpoint region. Maximum lift and drag are found in the mid region (points 11-16). This region is found most effective for aerodynamic forces. Comparing and analyzing the data, it is found that for high speed operation, the larger plate has more lift than the small one but drag prevails most in the large plate for the same speed. Calculating all the four aerodynamic forces (Lift, Weight, Thrust, and Drag) smaller plate is found more result oriented and theoretically justified in this investigation.

So for a high lift demanding Coandă UAV, wing of larger radius of curvature should be used and to minimize drag on Coandă UAV, smaller radius of curvature wing to be used. These are the outcomes of this project.

VII. CONCLUSION

The surface pressure on the curved plates was found to agree with other studies. The majority of researchers in this field have been interested in the Coandă Effect as a lift device for STOL or VTOL aircraft. Coandă Effect amplifies and even multiplies the lift forces due to the increased air volume entrained. The conclusions of the present experimental results on the "Investigation of Coandă Effect on Different Curved Plates" are as follows

- The Coandă Effect was found to act even when the deflection surface was widely separated from the thrust generator.
- The larger the radius of the deflection surface, the larger the possible gaps.
- The ultimate vertical gap sizes depend on the entrainment properties of the jet sheet underside in the wedge between the jet sheet and the Coandă surface just before the jet sheet attaches itself to the surface.

If the suction pressure ΔP at this point becomes equal to $2(t/R)\ (\rho/2)V^2$ then the jet sheet will become attached and will follow the Coandă surface. Otherwise, it will not attach itself. As a further comment "Investigation of Coandă Effect on Different Curved Plates" was being investigated.

NOMENCLATURE:

V	Voltage (v)
I	Current (amp)
C_d	Coefficient of Drag
C_l	Coefficient of Lift
V_1	Speed at 8Volt
V_2	Speed at 10 Volt
V_3	Speed at 12 Volt
X/C	Points along Chord length

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