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EXPERIMENTAL INVESTIGATIONS OF CONVECTIVE HEAT TRANSFER OVER AN AIRFOIL SURFACE

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Abstract - As experimentation becomes more complex, the need for the co-operation in it of technical elements from outside becomes greater and the modern laboratory tends increasingly to resemble the factory and to employ in its service increasing numbers of purely routine workers. This experimentation involves calculation of flow and Convective heat transfer characteristics of an airfoil. Firstly we are placing the airfoil in the wind tunnel having pressure distribution measurement equipment. There we are placing Digital 2 –component force measuring Transducer by which we are getting the lift and drag values acting on the airfoil .so from the above information we are going to calculate the coefficient of drag so that we can know design considerations so as to reduce the drag and lift force acting on the airfoil shaped bodies. Another parameter we are analyzing here is the temperature distribution at various points which requires an airfoil drilled at different points and counter sunken with respective screws for thermocouples insertion. Thermocouples are used to measure the reading of the temperature distribution at given points .Initially the reading is taken without any heat input to the airfoil specimen, after giving the heat energy externally we are going to determine the value of convective heat transfer from the airfoil element to the surroundings. So according to this we are going to temperature distribution of the airfoil.

Keywords *- Wind Tunnel; Airfoil; Lift; Drag; Pressure Distributio.*

I. INTRODUCTION

All Airfoils are used to analyze drag and lift coefficient over its surface in a airfoil. This are widely used in many engineering applications .They are more significant in designing in aero dynamic applications, constructions of fans, compressors and turbines. Thermal flow over this airfoil surface is being an important research topic over a long time.

Thermal design is presently one of the primary causes of poor reliability in many of the mechanical products with increased heat from the components; temperature control becomes a crucial factor n the functioning of component. The effective working of airfoil shaped bodies can be increased by the temperature flow over it. The designer has to ascertain that the heat dissipated at various areas of the airfoil surface is effectively analyzed.

This work is done to study the thermal flow characteristics of an airfoil which was placed in wind tunnel and acted on a impinging flow of air i.e. the air will be forced all along the surface area of the airfoil. The main objective of the present study is to analyze and calculate the thermal flow characteristics over a airfoil surface. Also the drag force of the airfoil after heating is also determined..

II. MANUFACTURING OF AN AIRFOIL(NACA 0018)

As airfoil is a standard of measurement, manufacturing of it takes many production processes generally used in industries. By knowing the specifications of an airfoil the manufacturing process initiates chord, span, thickness, width and length. The process of making of airfoil is Material selection, Casting or manufacturing process, Surface finish.

A. Material Selection

As the standard airfoil NACA 0018contains aluminum as its raw material for manufacturing, the metal is which is sufficient enough for casting of airfoil is 3kgs.

B. Maintaining the Integrity of the Specifications

As casting process involves many numbers of methods, here the process taken is die casting. The process involves dies which will be in the shape of the required dimensions .we have two dies forming a hallow airfoil shaped space which may be used for the casting process. The process involves different step shaping the dies, Preparation of mould cavity, heating the metal, pouring the metal, Removal of cast from die. Dies are prepared by shaping the mild Steel plates of 30X30X3 $cm^{3,}$ as the melting point is more then Aluminum we have gone for mild steel. By having the cope and drag arrangement we have the ramming of moulding sand with required proportions of clay, sand and moisture. The die is made prepared for the pouring of the molten metal. Here the metal Is heated with the forging equipment ,i.e. with help of vent placed in forging bench and the blower which blows the air at that point vent there the crucible is placed and the coal is heated, therefore the conduction takes place and within minutes the metal is liquefied to molten form. Therefore the temperature at that point is very high.

Fig1. Shaping the Die for Airfoil Preparation

Fig 2. Forging Table for Heating

The molten metal is poured into the space provided of the mould cavity within seconds after the heating the process completed .after pouring the metal into the metal cavity within seconds it will solidify and the airfoil shape cast will formed in the mould cavity. Now here the casting is removed from the mould. Therefore by separating the cope and drag from the cavity we are going to obtained unfinished casting. Another process to be done to achieve complete airfoil is that surface finish.

In this process we are going to use bench grinding and hand grinding machines. Here the first is obtained after the certain coatings of grinding wheel over the surface of an airfoil .here the first operation at the edges to obtain the required specification of 25cm and thereafter by using different grinding wheels, we are going to finish the surface of the airfoil as required. Therefore the airfoil thus obtained with required specification. There are specially designed jigs and fixtures for holding the airfoil at the required position. One end with a particular diameter which will be inserted in the wind tunnel and one end with the rod which was screwed and placed with a nut for tightening purpose.

Fig 3. Surface Finish tools

III. EXPERIMENTAL INVESTIGATION

Convective heat transfer of an airfoil over its surface is calculated by having the above described equipment at their respective places. Different stages in the this experimental procedure are, Preparation of airfoil, Positioning of airfoil, Insertion of thermocouples to temperature indicators, Switching on the heater coil and obtaining the temperature, Switching on the wind tunnel motor

A. Preparation of an Airfoil.

The surface finished airfoil is made drilled at their sides for screw fixation of jigs and fixtures. At different positions another 12 holes are drilled for thermo couple fixing arrangement. At those 12 respective positions counter sunken nuts are screwed tightly along with thermocouple fixation.

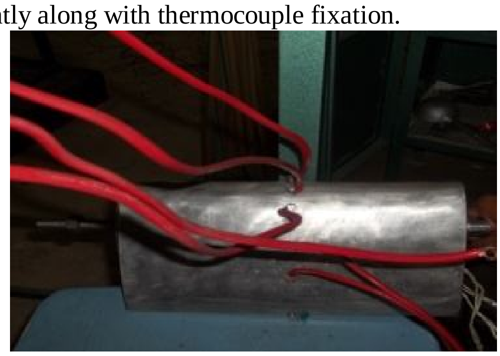


Fig 4. Airfoil with Thermocouples

The temperature sensing element senses the temperature and accordingly the experiment is carried. so at that respective areas distributed heat is taken by thermo couples. So from leading edge onwards total area is covered on the airfoil.

Thus twelve cover entire overall body and the other one covers the ambient temperature. Now by tightening the screw we are going to take temperature readings when airfoil is heated without slipping of the thermocouples from their respective positions.

After connecting thermocouples firmly to the airfoil surface then there after heater coils are connected on the either side surfaces of the airfoil. The heater coil connections are accordingly and made directed towards the supply for heat input through current. The heater coil should be kept with at most care in wind tunnel

B. *Positioning of the Airfoil*

Fig 5. Airfoil in Plexifible glass of Wind Tunnel

Airfoil should be poisoned in the wind tunnel according to the design made by the manufacturer. The airfoil should be used to evaluate the heat transfer of forced convection. The jigs and fixtures tightly fixed in the wind tunnel and the nut at the other end is fixed tightly to keep the airfoil in required position.

All the thermocouples are dragged through a vent through which was placed in the top position of the wind tunnel. Here the thermocouples are dragged through a hole which was placed in the position of the wind tunnel. Here the card board sheet paper is made a hole at the center and thus made all the thermocouples to pass through it, we can made easy the constructional features of the equipment.

By fixing the airfoil at required angle of incidence we are going to measure the temperature of the surface of the airfoil. Here we are going to connect the two terminals of the thermocouples to the respective ends of temperature indicators.

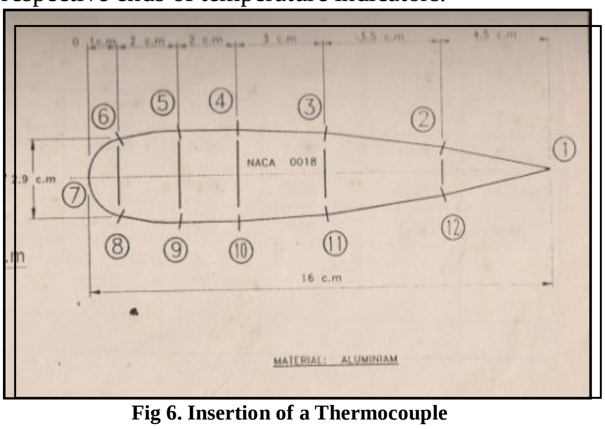


Fig 6. Insertion of a Thermocouple

Here we are going to vary the angle of incidence for different angles to analyze at different angles. Thus we have angles of +10, +20, 0,-20,-10 at different positions.

C. *Switching the Heater Element*

The heater coil element is switched on and the current gets started flowing in the coil so that coils gets heated. The airfoil surface started get heating up to required temperature. The airfoil surface gets heated and there after the heater coil gets switched off, here the wind blower comes in to picture.

Fig 7. Blower and Motor of a Wind Tunnel

By switching on the wind tunnel motor, wind blower which is suction type gets on and the forced convection over the airfoil surface gets take place and the readings accordingly are tabulated. Thus by varying the voltage at different velocities, we are getting different Reynolds numbers. The drag values of the cold airfoil are taken at different angle of incidence and their coefficient of drag is calculated and accordingly the graphs are plotted. The airfoil is heated and the drag forces and the coefficient of drags are evaluated and the two types of graphs are compared before and after heating the airfoil. Therefore by using the drag forces and Cd values we have gone for the calculation of the Nusselts number and the Reynolds number

Fig 8. Wind Tunnel Motor Starting Equipment

IV. EXPERIMENTAL PROCEDURE

As this experiment consists of calculation of convective heat transfer by forced convection over on a airfoil surface, which was placed in a wind tunnel having an induced blower fan ,which was running by the aid of DC motor. This experimental program consists of different stages for conducting this experiment are Wind Tunnel, Airfoil, Thermo couples, Temperature indicators, heating coils.

Fig 9. Wind Tunnel Accessories

NACA 0018 airfoil (Axial chord-16cm, span-29cm) with pressure taps to determine the pressure distribution. Cylinder (Diameter -8.9cm, span-25.8cm) with pressure taps to determine the pressure distribution. NACA 0018 airfoil (Axial chord-16cm, span-25cm) with a linkage mechanism and a digital 2-component force measuring transducer to determine the lift/drag characteristic. With a dual display, both the lift and drag are measured simultaneously. Sphere (dia-10cm), hemisphere cup (dia-10cm), and three flat plate models square (8.9cm*8.9cm), rectangle(10.9cm*7.3cm), circle(10cm dia) to determine drag characteristics.

A. Operating Procedure

Before the fan motor is turned on, the lift-drag indicator or the smoke generator or the multi-limb manometer has to be prepared (depending upon the use of the wind tunnel).

The following sections describe the initial steps to be followed in preparing the instruments. Now the multi-limbed manometer is prepared by Connect the manometer limbs to the various static pressure taps of the airfoil (or the cylinder) and fills the manometer reservoir with water.

B. Preparing the Lift and Drag Indicator

Fig 10. Lift Drag Transducer

The two-component load call is rigidly bolted below the test section to the frame provided. The airfoil (or any of the various models) is then bolted to the load cell through the small hole provided in the test section bottom surface. Care should be taken to ensure that the rod connecting the model to the load cell does not touch the wind tunnel walls. This should be checked even when the wind tunnel is under operation as the displayed readings will be erroneous when the model touches external objects. The lift and drag wires are connected between the balance and the digital force indicator. The indicator is then connected to 220V power supply and the system is ready for use. Initially, the lift and drag readouts should be set to zero with the model attached to it. This is achieved using the zero-set below the display.(Note: The maximum lift that can be measured by the instrument is 20kgf and drag measured is 5kgf). When the fan is turned on, the lift and drag values should be continuously monitored and care should be taken so that theses values do not exceed the maximum permissible values. This may occur at very high air velocities or high incidence angles.

C. Preparing the Smoke Generator

The generator consists of a heater located inside a box. A small blower is attached to the box to provide air supply. A thermostat is provided to cut off power to the heater element when its temperature raises beyond about 200 deg C. Diesel is made to flow in a controlled manner from a small vessel on the heater element through suitable values. The hot surface evaporates the diesel, producing smoke. The smoke is led through a tube into the test section via a copper tube.

Connect the lead wires of the heater to 220V, single phase Power supply (5A plug). Connect the lead wires of the blower to 440 Volts, 3 phase power supply. First switch on the heater power supply. Red LED indicator glows when the power is on and the green LED indicator glows when the heater is on. When the heater is heated to over 250deg C, thermostat cuts off power to heater and the green light will turn off. This will occur in about in 10 minutes. The heater is now ready to generate smoke. Next turn on the switch provided below the LED’s. This bypass the heater thermostat and supplies power to the heater. Adjust the diesel flow valves to allow diesel to flow slowly (drop by drop) into the heater box.

When smoke appears in the outlet, switch on the blower. At higher test section velocities smoke will not be sufficient. Reduce the test section velocity correspondingly. While turning off the smoke generator, first cut off the diesel supply, then turn off the thermostat by-pass switch, turn off the heater and let blower run till no more smoke comes out.

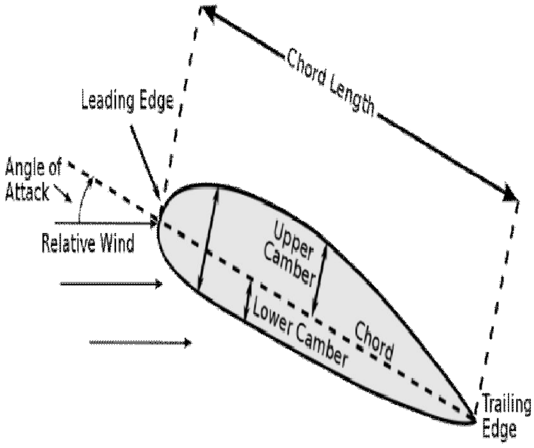
D. Starting the Wind Tunnel Axial Flow Fan

The rectifier control panel is connected to a 440 volts three phase power supply using suitable rating wire (5KW capacity). Connect the DC motor with the control panel through the 4 wires- A,AA(armature wires) and Z,ZZ(field coil wires) properly. Ensure that the speed control knob is at minimum and turn on the main power switch. Press the motor start button and then turn the speed control. knob slowly and smoothly to obtain the required test section velocity which can be observed from the U-tube manometer connected to the Pilot tube. It is advisable to limit the test section “q” to about 6cm of water column. This will correspond to about 60% in the control panel rheostat. If the direction of rotation of the fan is to be changed, interchange the field coil wires Z-ZZ wires in the control panel.

E. Airfoil

Fig 11. Airfoil (NACA 0018)

Airfoil or airfoil surface designed to develop a desired force by reaction with a fluid, especially air that is flowing across the surface. For example, the fixed wing surfaces of an airplane produce lift, which opposes gravity. Airfoils that are manipulated to produce variable forces are called control surfaces. Ailerons, control surfaces hinged to the trailing edges of wings, can produce rolling, which is rotational motion of the aircraft about a in running through its fuselage, or yawing, which is rotational motion about a line running from the top to the bottom of an aircraft. Modern aircraft have fairly complex arrays of control surfaces, including elevators, a rudder, and flaps. Elevators, which are hinged to the rear of the horizontal airfoil of the tail assembly, are used to produce pitching, which occurs when an airplane in level flight points its nose upward or downward.



The rudder, which is hinged to the rear of the vertical airfoil of the tail assembly, is used to produce yawing. Flaps are located near the ailerons to increase lift for takeoff and landing. Spoilers, which can be made to protrude from lifting surfaces to give controlled reduction of lift, often replace ailerons and elevators.

Heating Coils

Fig 12. Heating Coils

Heating coils are the insulating material coils having a heat input capacity of 1000 watts. Here the heat is distributed by passing the current through the coil, thereby heat is liberated from the coil and then through insulating of current material heat is get conducted to the surface of the airfoil. There are two types of coils with two different inputs of 500 watts and 600 watts power supply. The coil placed at their respective places i.e. either sides of the airfoil. The heat is distributed all over the surface uniformly within few minutes.

V. CALCULATIONS

A. Model calculation 1

Pitot tube reading (q) =0.7cm=0.7X10^{-2} m

q=hAΔT

h= QA(T_a-T_i)

ΔT= T_s-T_a= 39.6^{0}C-30^{0}C =9.6^{0}C

T_5=surface temperature = 39.6^{0}C

T_a=ambient temperature = 30^{0}C

h= 1000/16X25X10^{-4}X9.6 =2604watt/k. m^2

q= heat input =1000 watts

Heat transfer coefficient (h) = 2604 KJ/^{0}c.m^2

Reynolds number (Re) = □VL/μ

Velocity (V) = 1.08

Length (L) = m =16X10^{-2}

V= kinematic viscosity = 16X10^{-6} m^2/s

Re= 1.08X16X10^{-2}/16X10^{-6} = 10800

B. Model calculation 2:

Reynolds number (Re) = □VL/μ

Velocity (V) = 13√2 cm = 13√2.7X10^{-2}

=2.13m

Length (L) = 16X10^{-2} m

Kinematic viscosity (v) = 17.95X10^{-6} m^2/s

Reynolds number (Re) = VXL/v

= 2.13X16X10^2/17.95X10^{-6}

= 20.59X10

Drag force (Dg) = 0.24

C. Model calculation 3:

Coefficient of drag (C_D) = D/(1/2ev^2XA)

Drag force =+0.29

Velocity (V) = 13√q = 13√30X10^{-2} =2.25

A= Area = 16X25X$10^{-4}$$m^2$

e= density of air =1.16kg /m^3

=0.29/ (1/2X1.16X $(2.25)^2$X16X25X10^{-4})

=20.05X10^3

D. Model calculation 4:

Nusselt's number (Nu) =hL/K

K=thermal conductivity (k) =204.2 w/mK

L= length =16X10^{-2}m

h = heat transfer coefficient = 2604 kj/^{0}c.m^2

Nusselts number (Nu) =hL/K

=2604X16X10^{-2}/204.2

=2.04

Reynolds number =10,800

VI. CONCLUSIONS

On drawing a graph between Reynolds number and Coefficient of drag for an airfoil without heating, the graph follows decreasing order, where as the drag force increases with the Reynolds number. The same graphs are plotted for the airfoil heated which follows similar curve but there is a decreasing value as and when compared to the cold airfoil. The above fall in values is obtained because of the formation of thermal boundary layer over a surface the airfoil. When a graph is plotted between heat transfer coefficient and Reynolds number of a heated airfoil, the graph follows a falling curve. When a graph is plotted between nusselts number and Reynolds number, the graph goes on increasing with the Reynolds number for different angles of incidence. When the graph is plotted between the coefficients of drag of heated one the nusselts number follows a decreasing curve.

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