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PITOT-TUBE HEATING IN AIRCRAFTS BY SKIN EFFECT

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Abstract

A pitot-tube is positioned mainly to function the Airspeed Indicator (ASI), Altimeter and the vertical speed indicator (VSI). Any difference in the Pitot tube causes a great change in these flight instruments. The idea of this project is to use skin effect to become distributed within a conductor and attached to the tube overall to maintain the temperature. Skin effect as we describe, is the tendency of an alternating current (AC) to become distributed within a conductor such that current density is largest near the surface of the conductor, and decrease with greater depths within the conductor. The heat produced in the outer heat tube, can be measured and regulated with a microprocessor based, controller. This regulates the temperature reducing the risk of Pitot-tube melting and thereby avoiding pitot-tube icing at higher altitudes. The main idea is to avoid air crashes due to the misreading created due the pitot tube icing. This also lowers the power consumption, increased heating element lifespan and does not endlessly waste electricity when not in icing conditions mainly with the help of the micro controller.

I. INTRODUCTION:

The Pitot tube is an instrument used in various fields for velocity measurement with the principle of pressure difference, which is simple and is taken for granted today. In aircrafts, the Pitot tube value is utilized for the operation of the airspeed indicator (ASI), altimeter, and vertical speed indicator (VSI). The altimeter is an instrument that measures the height of an aircraft above a given pressure level. The VSI, which is sometimes called a vertical velocity indicator (VVI), indicates whether the aircraft is climbing, descending, or in level flight. The ASI is a sensitive, differential pressure gauge which measures and promptly indicates the difference between pitot (impact/dynamic pressure) and static pressure.

The pitot-static system is a combined system that utilizes the static air pressure, and the dynamic pressure due to the motion of the aircraft through the air. The Pitot tube has a small opening at the front which allows the total pressure to enter the pressure chamber. The total pressure is made up of dynamic pressure plus static pressure. In addition to the larger hole in the front of the pitot tube, there is a small hole in the back of the chamber which allows moisture to drain from the system should the aircraft enter precipitation. The pitot needs to be checked prior to take off to ensure any blockage in the Pitot tube. In case there is any blockage, the reading will vary and causes the pilot to interpret it wrongly.

A. Problems faced on pitot tubes:

The main problem faced by pilots during flight is the blockage of Pitot tube. Once the pressure in the Pitot tube is trapped, No change is noted on the airspeed indication should the airspeed increase or decrease. The total pressure in the Pitot tube does not change due to the blockage; however, the static pressure will change. Because airspeed indications rely upon both static and dynamic pressure together, the blockage of either of these systems affects the ASI reading. A blockage of the static system also affects the altimeter and VSI. Trapped static pressure causes the altimeter to freeze at the altitude where the blockage occurred. In the case of the VSI, a blocked static system produces a continuous zero indication.

B. **Pitot icing:**

The blockage is caused mainly due to Pitot tube icing. Ice can be present on any part of the aircraft. It causes destructive vibration and hampers true instrument readings. The presence of moisture in the air and the decrease in temperature with the increase in altitude causes pitot icing. Pitot icing is one of the major reasons for blockage in Pitot tube. The probability of pitot icing is more than 80% in high speed aircrafts. In order to avoid risks in aircrafts or to avoid air-crashes heating systems should be equipped in order to avoid pitot icing.

C. Proposed method: skin effect heating:

The main problem faced by the pilots are the blockage or icing of pitot tubes that in turn causes problems in the three instruments in the aircraft. So in order to bring a solution to this problem the method of skin effect heating is used in pitot tubes to stop Pitot tube icing.

D. Skin effect: principle of operation:

In a current flow, if the frequency is very high, the current is restricted to a very thin layer near the conductor surfaces or the skin of the conductor. Because of this extreme case, the entire phenomenon of non-uniform distribution of time – varying currents in the conductors is known as skin effect.

E. Skin Effect for Heating:

Skin Effect heating is simply another way to heat a tube, using electricity. The skin effect heating system is an electrically traced pipe heating system designed to provide heat to the conductor evenly along the tube. Impendence on a tube creates heat energy that flows to Pipe and Process Fluid. Conductive Heat is transferred to the tube. Electricity flows on inside of tube, so zero potential. This is a proven technology that has been used for many years and only needs one Power Supply Connection Point.

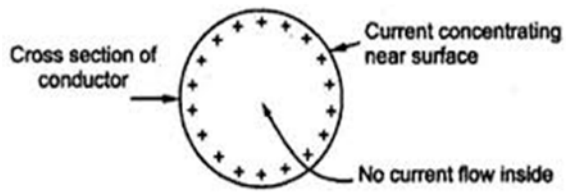

Figure 1 Cross section view of conductor on skin effect

II. DESIGN IDEA

As mentioned earlier, the pitot tubes on aircrafts tend to freeze at higher altitudes due to moisture blockage and fall of temperature. In order to avoid this Pitot tube icing, skin effect heating is used as a heating element. To explain the design in detail, it is prior to mention the components of the design.

The 6 Main Components are:

- Pitot tube
- Sensor – RTD
- Micro-Controller
- Skin Effect Cable
- Power source – transformer

DESCRIPTION:

1. **Pitot tube** :

The actual tube on the aircraft is around 10 inches (25 centimeters) long with a 1/2 inch (1centimeter) diameter. The slot is provided in the Pitot tube in order to weld the skin effect cable on the Pitot tube for heating. The heat will be transmitted from the cable to the Pitot tube by the principle of skin effect. The material of the Pitot tube is Aluminum alloy.

2. **Sensor – RTD** : Resistance Temperature Detector

Sensors or elements used to measure temperature by correlating the resistance of the **RTD** element with temperature. This sensor is mainly used in this design is to sense the temperature of the Pitot tube, and accordingly switch on the skin effect heating. This RTD is connected with the microcontroller accordingly to switch the skin effect heating automatically when the temperature of the pitot tube drops down to 5^{o}C. This drop of temperature automatically happens when the altitude increases as the flight reaches its maximum range. Therefore the resistance temperature detector (RTD) is the most important component in this design.

3. **Microcontroller** :

We use a microcontroller for continuously monitoring the temperature of the Pitot tube with the help of the Resistance Temperature Detector (RTD) sensor. The permissible range of temperature is set to be 40-50 ^{o}C. If the temperature goes above or below this range, we use a DIAC switch to turn off the AC current supply to the Pitot tube. We propose to use an ARDUINO UNO chip for monitoring purpose and also to send signal to the DIAC switch for turning ON and turning OFF.

The **specifications** of the microcontroller are as follows:

Microcontroller: AT mega 328

Operating Voltage: 5V
Input voltage (recommended): 7-12V
Input Voltage (limits): 6-20V
Digital I/O pins: 14 (of which 6 provide PWM output)
Analog input pins: 6
DC current per I/O pin: 40 mA
DC current for 3.3V pin: 50 mA
Flash memory: 32 kB (of which 0.5KB used by boot loader)
SRAM: 2KB (AT mega 328)
EEPROM: 1KB (AT mega 328)
Clock speed: 16MHz

The program for the ARDUINO chip for controlling the temperature as mentioned above is as follows:

```
float temp;
//temperature(degree Celsius) variable
int rd;
void setup()
{
 pinMode(11, OUTPUT);
 //switch pin 1
  pinMode(10, OUTPUT);
 //Switch pin 2
  pinMode(A1, INPUT);
 //lm35 input
}
void loop()
{
rd=analogRead(A1);
//input voltage from thermocouple
 temp=(5.0 * rd * 100.0)/1024.0;
 //calibration of the reading to degree celsius
   if(temp<10)
  //turning on the thyristor
   {
    analogWrite(11,255);
//the output can be varied to match the diac rating
 analogWrite(10,0);
}
 if(temp>50)
 //turning off the thyristor
  {
  analogWrite(11,0);
  analogWrite(10,255);
//the output can be varied to match the diac rating
  } }
```

This closed loop temperature control system provides only the required heat energy to maintain the tube at the set temperature. The above program has been programmed in order to control the powering system for the skin effect and thereby maintaining the temperature of the Pitot tube precisely without causing any damage to the instruments.

4. **Skin effect cable** :

The skin effect heating has to be done on a conductor, which has high frequency and low resistivity. The probe is heated by a high-quality copper heating element whose temperature is accurately measured and regulated by a microprocessor-based controller.

As skin effect the skin depth in the conductor is a point where the current density will fall to 1/e of its value near the surface. The current density will also decrease exponentially, from its value at the surface J_s according to the depth d from the surface.

$$J = J_S * e^{-d/\delta} \quad \text{-------------- equation 1}$$

Here, δ is known as the skin depth.

$$\delta = \sqrt{2\rho/\omega\mu} \quad \text{-------------equation 2}$$

ρ = resistivity of the conductor.

ω=angular frequency of the current

μ = absolute magnetic permeability of the conductor

RESISTANCE OF THE CONDUCTOR

Effective resistance due to current confined near the surface of the large conductor, can be solved as if the current flowed uniformly through a layer of thickness δ. Based on the DC resistivity of the material, we have:

$$R = L\rho/\pi(D-\delta) \cong L\rho/\pi D\delta \quad \text{----------equation 3}$$

Where, R is the resistance of the material, L is the length of the cable; D is the diameter of the cable and δ is the skin depth. The Skin Depth varies as inverse of square root of conductivity.

Skin depth also varies as the square root of permeability.

In copper, the skin depth has been seen to fall as square root of frequency.

At a frequency of 60 HZ the skin depth which is found out to be in copper was **8470 µm**.

Due to accumulation of electron charges on the surface of the conductor, the effective resistance of the conductor increases. As, the conductor resistances increases, heat will be produced in the conductor, which will be sufficient to heat the Pitot tube.

5. Power source – Transformer

In order to give AC for the skin effect heating a step up transformer is to be used to be as the power source. The voltage required for 60Hz frequency – frequency for copper the heating element, 200 V is required. This can be provided with the help of the Step Up voltage transformer. Depending on the size of the power transformer, it may be externally mounted from the control enclosure. A step up transformer is shown in the figure 2

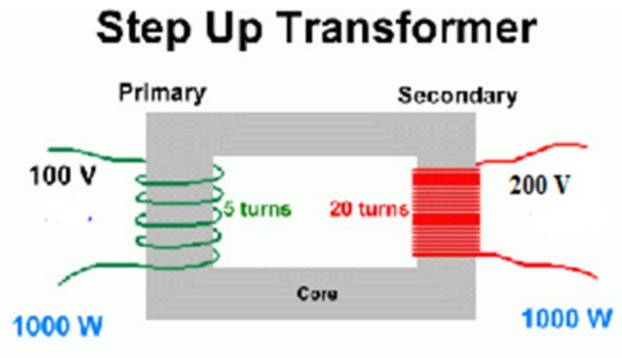

Figure 2 step up transformer

III. DISCUSSION: Comparison with the earlier design:

The main highlight of this design is that the Pitot tube is programmed in such a way that the heating is switched on automatically when the Pitot tube's temperature drops down and switches off when the temperature goes above the set temperature. Therefore the pilot need not worry about the overheating of the Pitot tube and melting of it. And also the worry about the heater switch is disregarded.

IV. OVERALL DESIGN:

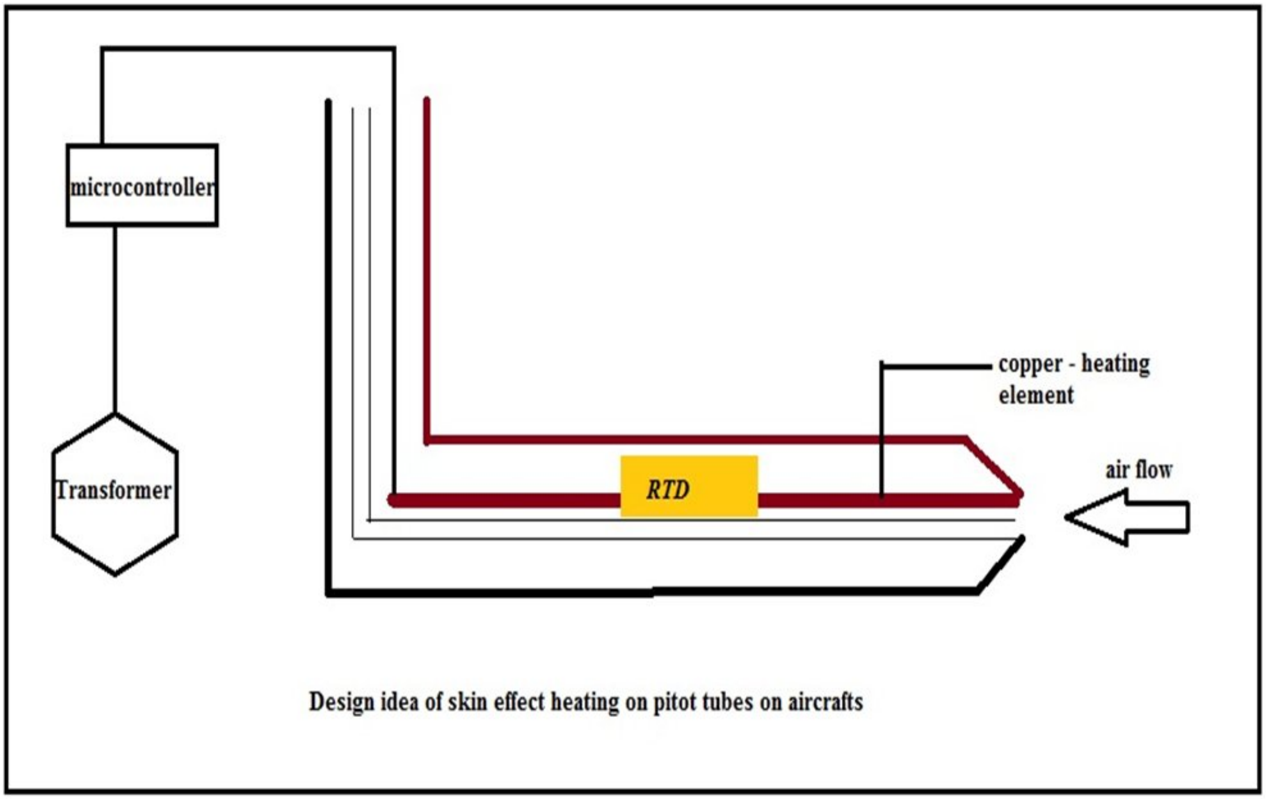

Figure 3 skin effect heating design on aircrafts for pitot tubes

V. CONCLUSION:

The main advantage to this skin effect heating is

- lower power consumption,
- increased heating element lifespan, and
- A much cooler pitot on the ground when de-icing is not necessary. Clean Operation & Lower Installation Costs
- No pollution stacks, fuel lines, or holding tanks.
- Accurate Temperature Control
- Minimal Maintenance – No combustion controls that need adjusting; easily replaceable, if needed.
- Lowered Safety Concerns
- Controlled Costs

This unique technique ensures that the pitot can be rapidly de-iced when required, but does not needlessly waste electricity when not in icing conditions. This system will be of a great serve to the aircraft systems and instruments department.

VI. ACKNOWLEDGEMENT:

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