EXPERIMENTAL INVESTIGATION ON AUTOMOTIVE HOT WIRE ANEMOMETER TO DETERMINE DYNAMIC FLOW RATE

Thilagar D[1], Venkatesan M[2] & Arul Slvan S[3]

Department of Automobile Engineering, Anna University (M I T Campus)

[1]dsthilagar@gmail.com
[2]arul@annauniv.edu
[3]venkatesanmoorthy94@gmail.com

ABSTRACT **Hot wire/film anemometry are modern trend for research and automobiles industry to predict the air velocity accurately for long duration of time and still now also. Response rate is a key factor to determine performance of automotive electronics. In engine intake manifold, air flow rate is monitored using hot wire anemometer. The major disadvantage is due to temperature and humidity of air hot wire anemometer performance is affected, thus desired air flow is not achieved. In order to overthrown this drawback, for hot wire mass air flow (MAF) sensor using Mat-lab / Simulink is developed C programmed and it is carry out in hardware using Digital Signal Controllers (dsPIC) with it's verified that the estimation error is only $\pm 1\%$ over full – scale value, so the flow rate error is minimized.**

Keywords **air flow sensor, hot wire anemometer, automotive sensors, constant current & temperature anemometer.**

I. INTRODUCTION

Measuring air flow rate accurately is a prime factor which constituent the performance of various devices in different fields. In automobiles evaluation of air flow into intake manifold is a vital factor which identify the performance of the engine. For automotive applications due to variation in air density, temperature and other factors, mass air flow sensors are preferred than volumetric flow sensor. There are two types of mass air flow sensors, vane meter and hot wire type. Both these type of mass sensors don't have direct technology to measure the quantity of mass airflow rate which is fed in to the engine intake manifold. Hence there are different kinds of assisting sensors and technology implemented to predict the air flow rate accurately [1] and to improve the flow.

In vane type mass air flow sensor, the amount of air flow in to the engine is identify by the deflection of the spring load flap which is present in this sensor. In this sensor generally a screw is provided to vary the flow rate. Since this sensor is of mechanical type, air temperature sensor is fixed to determine the air density and hence the flow rate of the air can be determined. Since this is a mechanical type sensor the overall response is low which affects the quantity of air flow.

Hot wire sensor has its principle concurrent to that of hot wire anemometer in which a heated wire is swing in the engine intake air stream. The basic operation of this sensor is that flow rate will be determined due to modify in the resistance of the heated wire due to variation in the temperature of the wire. When air flows supported by the heated wire there will be reduction in temperature which change equilibrium, in turn the detected changes of resistance causes the current flow to vary which is directly proportional to the mass of air flowing past the wire.

Hot wire sensors are preferred due to their response rate which is comparatively high to that of the conventional vane type sensors. Thought they are efficient still there is a need to improve the response rate dynamically for better air mass flow to the engine. Various new technologies and simulation systems can be efficiently incorporated to reduce the error of the sensors.

In this project Mat-lab / Simulink is developed C programmed is developed to improve the error rate which provides better control over the mass flow rate which improves the performance of the engine. Mat-lab / Simulink uses interpolation methods to predict the error rate to obtain the near accurate change in temperature which should be compensated for the corresponding change in input parameters. Mat-lab / Simulink code is developed using C programming language. Its focus on software compensated, computational intelligence, Mat-lab / Simulink inference system, it's incorporates intelligence of temperature compensation mass air flow sensor system. They will monitored continuously correct temperature required, ambient effect online by absorbing sensor behavior. It will achieve experiment at different temperature and simulation variations are verified both in fuzzy compensation effectively. The performance are provided without compensates and with compensated is provided for output voltage of hot wire mass air flow sensor. Only error caused in the sensor measurement by temperature variations, rather that results are better improvement of accuracy. Temperature sensitivity corrected by software programing previously obtained data of memory, for further improvement of hardware trim techniques the accuracy will be increased when compared.

Air velocity is measured in the form of heat transfer form a heated wire / film placed between the paths of measured area. The anemometer working at two mode like that constant temperature condition or constant current condition, for high velocities condition at isothermal conditions wind tunnel measurements are used, but out case assortment of applications in mismatched fields by using thermal anemometer (how wire / film anemometer). I in unique case hot wire / film sensors is used mass air flow sensor to measure the mass of air flow in-take manifold into a internal combustion engine as a automotive applications. The above air flow measurement data are used control the engine to optimize and regulate the maximizing fuel efficiency, engine performance. For the independently of air temperature the hot wire / film anemometer mass air flow sensor it give high accurate and reliable results, in order to achieve error less result both mass air flow and temperature of the air (heat transfer process) are compensated of changes in temperature, for the error less or reduced error mass air flow measurements. This type of thermal flow sensors are proposed by a few researchers like [1], [2], [3], (Noraznafulsima Khamshah et all (2012), P.G.S.A Bandara (2011), S.J. Balla et all (1998) in practical in hardware problems occurred its effects high-accuracy test results measurement is cannot achieved as he requirement.

II. MATERIALS AND MEASUREMENTS

A.Experimental Setup

Line diagram

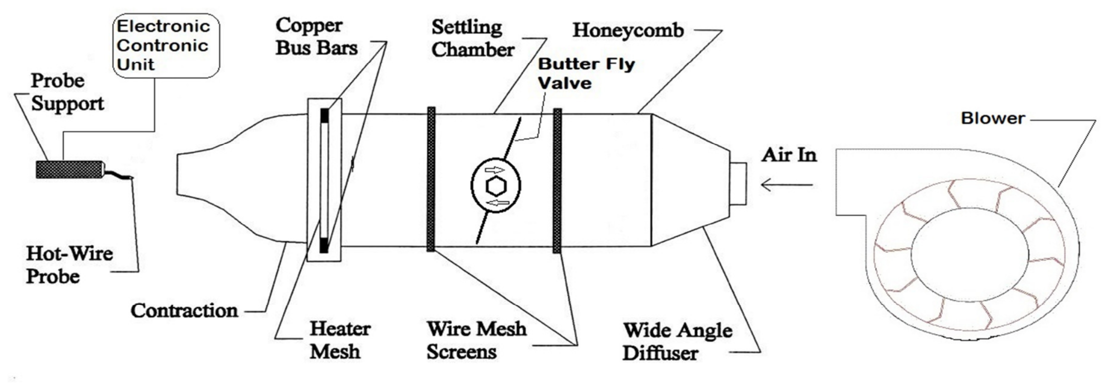

Fig No: 01 Wind tunnel witch relative hot wire anemometer

Fig No: 01.1 Wind tunnel witch relative hot wire anemometer

A line diagram showing [2] a plan view of the small perspective thermal wind tunnel and how wire / film anemometer arrangement is given in Fig. The centrifugal electric blower (type EB 40) supplied air it will operate at a maximum full load speed of 13000 RPM, 335W. The above setup is used to control of the air flow, blower jet diameter is 20 mm contration exit is designed for air flow duct arrangement, and like heater similarly to the other components are ø 50 mm fine wire stainless steel mesh. During the experiments perspective framework have mesh in the duct was used to secure the heater in position, polystyrene and pipe lagging are using in wind tunnel as thermally insulated. The blower velocity is 2.3 m^3 /min. The local conditions and Flow velocity were calculated based on ambient dynamic pressure respectively. Hot wire probe calibration facility were determined by jet exit characteristics. Wind tunnel velocity deliver across air mean flow speed of 4 m/s, the jet exit plane was uniform to within 21%.

The small changes in air displacement in hot wire anemometer can be measure, its quite small device on active surfaces in the hot wire anemometer is used for accurately measurement using wind tunnel models for turbulence and air flow, small insects is used to catch the movement of air clearly.

B. Working Procedure

The arrangement of wind tunnel one side is attached by blower after with diffuser the air flow is passing through the diffuser the air pressure is dropped down and study flow will carried, and fine small fine wire mesh is paced in between flow after that the butter fly valve is used to vary the flow quantity of air, just a small distance hot wire mesh (copper) is fixed in between the tunnel its used to pre heating the air in the HWA, the end of the this section nozzle is fixed so that the constant and study air flow given to the HWA. The other end is fixe to the HWA is attached to the digital control unit and display unit.

1. Switch on the blower the air from the blower to tunnel passing through channel.
2. By operating the butter fly valve by diverse the angle and position to achieve the adequative air flow and wire mesh arrangement in the tunnel for study flow of air, heating coil is used to maintain air temperature.
3. The air flow is adequate passed to the HWA then it response is sea to digital bode by the help of Electronic Control Unit (ECU)

They are commonly used material for anemometer are different for different purposes or varying usages for the application, material like tungsten, platinum, and an alloy of platinum iridium tungsten. The coefficient of resistance is higher for platinum iridium tungsten then platinum. The hot wire anemometer can further two more concepts.

1. CCA (Constant-Current Anemometer)
2. CTA (Constant-Temperature Anemometer)

The specific inconstant (current, voltage, temperature) constant values device exigent to maintain by some sort circuit, of voltage output form these anemometers.

C. Constant Current Mode

The flow velocity is approximately [3] fixed electric current flows around the wire is exposed in a invariable currant velocity, the convective heat loss form the wire to moving fluid is equipoise between internal heat generation and hear loss to electrical resistance (Joule heating) an stabile temperature resulting of wire.

A new stabile temperature is attained by convective losses in change in wire temperature adjust itself, since coefficient is a function of the flow velocity, equilibrium wire temperature, convection is measured the velocity. The connection among the resistance and temperature is known a priori and the wire temperature can be assessed in terms of its electrical resistance.

D. Constant Temperature Mode

Wire is accommodated to maintain a constant temperature through current and temperature mode, using feedback circuit constant temperature is maintaining, therefore used to assess the flow velocity and current needful holding the wire at constant temperature harmonious to the convective heat loss.

E. Probe Types

Hot-Wire Sensors

Characteristics to make it a useful device:

- High Temperature Coefficient of resistance.
- High Specific Resistance.
- High Mechanical Strength.
- Good Oxidation Resistance.
- Low Thermal Conductivity.
- Availability in small diameters.

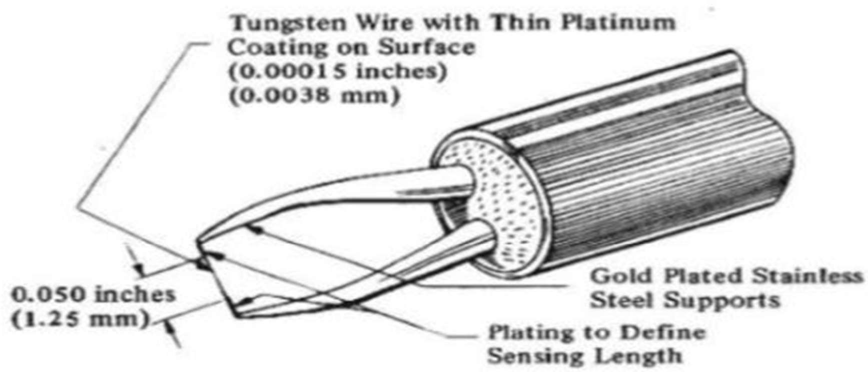

Fig.02 Hot wire anemometer

The high temperature coefficient of resistance, (0.004/ ˚C) for tungsten wire are strong, tungsten, platinum and platinum-iridium alloy is most commonly used materials for hot wire anemometer. Has excellent temperature coefficient (0.003/ ˚C) and good oxidation resistance for platinum but very wear for particular high temperatures. Platinum and tungsten is compromise between platinum- iridium wire have great oxidation resistance, more strength than the platinum and inferior temperature coefficient of resistance (0.00085/˚C). The ends support needles to enhance bond with the plate is coating with thin platinum. The hot wire materials are tungsten is preferable for more popular.[3]

F. Hot-Film Sensors

A conduct film of Ceramic substrate coted is essential for hot film sensors is n shown in Figure (03) is a quartz rod with a platinum film on the surface. It provides heavy metal contact to gold plating on the ends of the rod isolates the sensitive area for the fastening sensor to the supports. 1000 angstrom units of metal film thickness on ordinary film sensors have good physical strength and effective thermal conductivity, platinum is most films substrate material and it has a virtuous oxidation resistance and consequent long-term stability. Many measurements that have earlier been very complex with the more fragile and less strong hot wires ruggedness and constancy of film sensors.[3]

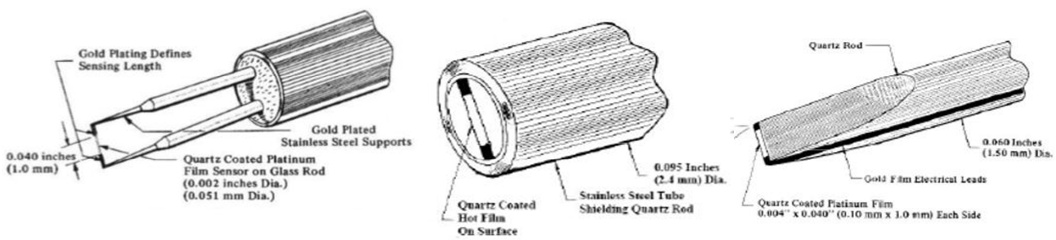

Fig 02.1 Hot film anemometer

Advantages of typical Hot wire Anemometer

- Excellent Frequency response.
- Magnitude can be measured in more velocity range.
- Temperature measurements.
- Uninterrupted turbulent phase and scattered bubbles phase for flow containing of measurements of two phase.
- Have low noise levels.
- Measurement of turbulent measures like vortices, dissipation rate etc.

G. Theory of Operation

The premeditated the air velocity based on power consumed in the wire, heat transfer and air dynamic for a hot wire anemometer operation relationships at a wire delivered constant current. The temperature transform in the constant current case off quantity of energy lost can be calculated. Operation of velocity of the circumferential area of air for amount of heat consumed by convection of wire.

H. Heat Transport Equations

The laws of thermodynamics all thermal equipment are governed, the first law thermodynamics is a discription of the conservation of energy, [4]

$$E_0 - E_i + E_s = 0$$

Note- steady state condition where $Es = 0$

The three type of medium for transfer heat like conduction, convection and radiation for the mechanisms that govern heat transfer. The fundamental mode of heat transfer to permit exercise of this device and convective heat transfer required to be a significant. Unnecessary thermal bias and heat loss form the grasping elements of conduction and radiation heat transfer would not aid operation of the device but rather reduce the sensitivity. To be minimized to reduce haggard energy and achieve low power operation, was conduction and radiation losses to needed.

I. Convection

The convection heat transfer from a surface into a fluid (moving or static) is given by Newton's Law of Convection Cooling. The heat loss at thermal equilibrium is given by:

$$q = hA_s\,(T_S - T_F)$$

The convection cooling coefficient is used to simplify the equation as the heat transfer rate is a function of material properties, fluid used, flow efficiency, etc. Of these the flow efficiency is a function of surface geometry, flow velocity and fluid viscosity. Distinction between static and moving fluids is made by variation of the convection cooling coefficient as the variation of heat flow cannot be determined simply by fluid velocity for all fluids. This makes "h" a complex variable, and it is usually accepted as a coefficient with published ranges for given materials or structure profile under preset conditions of fluids and flow rates. The radiation heat transfer increases rapidly with temperature. This would considerably complicate the temperature versus power response of the device by adding a thermal loss that could potentially dominate and practically reduce the sensitivity of the device to an inoperable level.

To avoid this potential hazard the functioning temperature of the instrument must be kept below the region where radiation heat transfer is considered a significant mode of heat loss. Provided all temperatures are kept below this region, Black body radiation could be considered negligible and the heat loss from the device modeled by convection alone resulting to the temperature relationship.[3]

J. Total Heat Loss

A device analysis is greatly simplified as boundary conditions and model approximations, considered negligible conduction transfer and radiation very small enough. Let Es = 0, considering a system in thermal equilibrium equation is conservation of energy equation of becomes.

$$E_\mathrm{i} = \mathrm{hA_s}\,(\mathrm{T_F\text{-}Ts})$$

The resistive elements equal to P = I2R consider a wire that's immersed in a wind flow for the system temperature on the input power Ei being linear dependence. Thermal equilibrium with environmentally heated by electrical current input, wire, the power lost to convective heat transfer form electric power inputs.

$$\mathrm{I^2R_w = hA_s\,(T_s\text{-}T_F)}$$

The wire resistance Rw is also a responsibility of temperature agreeing to,

$$\mathrm{R_W = R_{Ref}\,[1 + \alpha\,(T_S\text{-}T_{Ref})]}$$

The heat transfer coefficient h is a responsibility of fluid velocity Vf agreeing to King's law,

$$\mathrm{h = a + b{*}V^C{}_F}$$

In king's law "a" and "b" are improperly constant. Obviously they are not; they depend on the wire diameter and on the fluid temperature. Combining the above two equations, can eliminate the heat transfer coefficient "*h".*

$$a + b * v_f^c = \frac{I^2 R_W}{A_S(T_S - T_F)}$$

K. Constant-Current Hot-Wire Anemometers

For a hot-wire anemometer powered by a constant current *I*, If the fluid temperature is measured independently and the velocity of flow is a function of the temperatures of the wire, fluid velocity can be reduced to a responsibility of wire temperature T_F alone. The measured wire resistance R_w is turn, the wire temperature is related to that. Therefore, the fluid velocity can be related to the wire resistance.[3]

III. RESULT AND DISCUSITION

TABLE I

Table **Sl. No**	**Mass air flow l/ Min**	**Voltage variance/ Temperature 50˚C**	**Voltage variance / Temperature 60 ˚ C**	**Voltage variance / Temperature 70 ˚C**	**Voltage variance / Temperature 80 ˚ C**	**Voltage variance / Temperature 90˚ C**	**Voltage variance/ Temperature 100˚C**
1	50	0.6093	0.6065	0.6108	0.4883	0.4250	0.4062
2	200	1.1116	1.1041	1.1043	1.0221	0.9786	0.9601
3	350	1.6139	1.6016	1.5977	1.5558	1.5323	1.5140
4	500	2.1162	2.0992	2.0912	2.0896	2.0859	2.0679
5	650	2.2418	2.2357	2.2146	2.2130	2.2113	2.2064
6	800	2.2918	2.2736	2.2646	2.2530	2.2343	2.2264

In six different flows were applied has been varied from 50 to 100 °C study the output voltage sensor, for the hot wire mass flow sensor data. For the standard temperature 50 °C at data acquisition (DAQ) device for data recording, data post processing and measurement display by using how wire MAF sensor for reflex or given input voltage, output voltage, calculated as per the average sampling data for the temperature variation for each voltage output. The mass air flow graph drawn for output voltage Vs temperature variance is shown in figure 04 , temperature they will effect accuracy of how wire sensor measurement output voltage the equation give absolute error measurement are below. [1]

$$e_i = V_{T_i} - V_{50\,^{\circ}C}$$

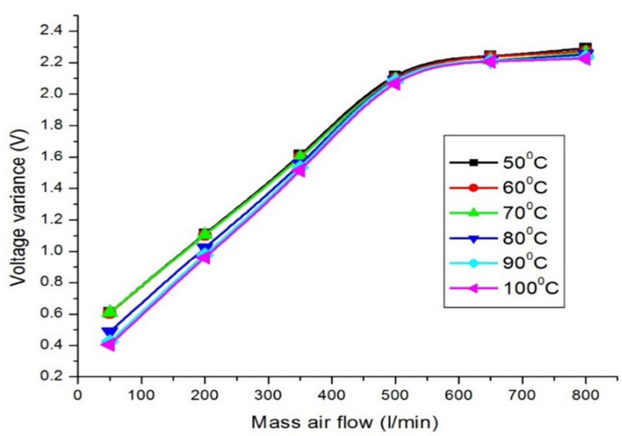

Fig No: 03 Voltage Vs Mass air flow

Where $V_{50^{\circ}C}$ and T_i temperature is that the voltage measured at standard temperature, V_{Ti} is the voltage measured at the temperature. According to that, the percentage error in the measurement is. [4]

$$\%e = \frac{V_{T_i} - V_{50^{\circ}C}}{V_{50^{\circ}C}}$$

According to the collected data, the absolute error and percentage of error for each output voltage have been.

IV APPLICATIONS

Emission limits for motor vehicles, comply with the legally specified motor vehicle rules by government of India, a specific air-fuel ratio must be precisely maintained. The existent air mass flow and output this in the shape an electrical signal to the govern electronics is used as per required application of sensors which accurately record. In internal combustion engines for precise adoption of the injected fuel amount to current power necessity, for the sensors used to evaluate the air-mass flow also estimate atmospheric pressure and air temperatures [3].

V CONCLUTION

In automotive application hot wire mass flow sensor study describes a technique using Mat-lab / Simulink for the important error due to temperature variation. The temperature variation range 50 to 100°C, it Mat-lab / Simulink remuneration has been utilized effect of temperature on the sensor characteristics. The ±1% error in full scale value are estimated, for the digital signal controller dsPIC real time implementation hardware setup presented. The output voltage achieved the requested temperature compensation to embed in a dsPIC by C Programming Language. The intelligent technique areas applicability to how wire mass air flow sensor temperature compensations will be high. For the optimized parameters involve in hot wire mass air flow sensor for the hardware temperature compensation. Genetic algorithm or ant colony is another common intelligent method with support of software compensation techniques.

VI REFERANCE

[1] Noraznafulsima Khamshah et all (2012) using Temperature compensation of hot wire mass air flow sensor by using fuzzy temperature compensation scheme, Vol. 8(4), pp. 178-188.
[2] S.J. Balla et all (1998) Appraisal of a hot-wire temperature compensation technique for velocity measurements in non-isothermal flows International Journal of Heat and Mass Transfer 42 (1999) 3097 – 3102.
[3] P.G.S.A Bandara (2011) A Constant Current Hotwire, Department of Physics Faculty of Science University of Peradeniya. (S/06/552)
[4] Ahmed. N. Abdalla et all (2012) Optimization of hot wire mass airflow sensor by using fuzzy logic controller, procedia engineering 38 (2012) 226 – 237.
[5] Massimiliano Melani et all (April 2008) Hot Wire Anemometric MEMS Sensor for Water Flow Monitoring.
[6] Kei Toda et all (October 1996) Simple temperature compensation of thermal air-flow sensor.
[7] S. P. Lee et all (1995) Temperature compensation of hot-wire anemometer with photoconductive cell.
[8] Torsten Berning et all (2015) Applying hot wire anemometry to directly measure the water balance in a proton exchange membrane fuel cell e Part 1: Theory.
[9] C. J. Fraser, et all (1990) Digital processing of hot wire anemometer signals in intermittently turbulent flows.
[10] S. F. Benjamin et all (2001) measuring flow velocity at elevated temperature with a hot wire anemometer calibrated in cold flows.
[11] Xiaolong Yang a et all Harmonic analysis and optimization of the intake system of agasoline engine using GT-power.

NOTATIONS

E_o - The total energy leaving a body.
E_i - sum of energy entering a body, (including internal heat generation)
E_s - Energy stored in that body,
q - Power transfer to or from the surface.
I - Input current.
R_w - Resistance of the wire.
T_F - Temperature of the fluid.
T_S - Temperature of the surface of the wire.
h - Convection cooling coefficient.
A_S - Surface area exposed to the fluid.
α - Temperature coefficient of resistance
R_{Ref} - Resistance at the reference temperature
T_{Ref} - Reference temperature
a, *b*, and *c*- Constant coefficients
v_F - Fluid velocity
a,b, and c- coefficients obtained from calibration.
v_f - fluid velocity.