FLUID FLOW MEASUREMENT SYSTE USING HOT WIRE ANEMOMETER

A Thesis Submitted in Partial Fulfilment
of the Requirements for the Degree of

Bachelor of Technology
in
Electronics and Instrumentation Engineering
By

NIRUPA MAJHI (108EI023)

MONALISHA TOPNO (108EI032)

Department of Electronics & Communication Engineering
National Institute of Technology, Rourkela
2012

FLUID FLOW MEASUREMENT SYSTE USING HOT WIRE ANEMOMETER

A Thesis Submitted in Partial Fulfilment
of the Requirements for the Degree of

Bachelor of Technology
in
Electronics and Instrumentation Engineering
By

NIRUPA MAJHI (108EI023)

MONALISHA TOPNO (108EI032)

Under the guidance
of
Prof. Tarun Kumar Dan

Department of Electronics & Communication Engineering
National Institute of Technology, Rourkela
2012

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

DECLARATION

We hereby declare that the project work entitled "**Fluid Flow Measurement System Using Hot Wire Anemometer**" is a record of our original work done under Prof. Tarun Kumar Dan, National Institute of Technology, Rourkela. Throughout this documentation wherever contributions of others are involved, every endeavor was made to acknowledge this clearly with due reference to literature. This work is being submitted in the partial fulfillment of the requirements for the degree of Bachelor of Technology in Electronics and Instrumentation Engineering at **National Institute of Technology, Rourkela** for the academic session 2008 – 2012.

The results embodied in the thesis are our own and not copied from other sources, wherever materials from other sources are put, due reference and recognition is given to original publication.

NIRUPA MAJHI (108EI032) MONALISHA TOPNO (108EI032)

NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA

CERTIFICATE

This is to certify that the thesis entitled "**FLUID FLOW MEASUREMENT SYSTEM USING HOT WIRE ANEMOMETER**", submitted by Ms. NIRUPA MAJHI (108EI023) and Ms. MONALISHA TOPNO (108EI032) for the award of Bachelor of Technology Degree in 'ELECTRONICS & INSTRUMENTATION' Engineering at the National Institute of Technology (NIT), Rourkela is an authentic work carried out by him under my supervision.

Date:

Prof. TARUN KUMAR DAN
Department of Electronics and Communication Engineering
National Institute of Technology, Rourkela-769008

ACKNOWLEDGEMENT

We would like to take this opportunity to express my gratitude and sincere thanks to my respected supervisor Prof. Tarun Kumar Dan for the guidance, insight, and support that he has provided throughout the course of this work. The present work would never have been possible without his vital inputs and mentoring.

We would like to thank all my friends, faculty members and staff of the Department of Electronics and Communication Engineering, N.I.T Rourkela for their extreme help throughout my course of study at this institute.

NIRUPA MAJHI (108EI023) MONALISHA TOPNO (108EI032)

ABSTRACT

The hot-wire anemometer has been used extensively for long time as a research tool in fluid mechanics. A thorough study of this process and detailed analysis of different technique in which this method can be enhanced has been done. In hot-wire anemometry a small electrically heated element exposed to a fluid medium for the purpose of measuring a property of that medium is used. Usually, the property being measured is the velocity. Since these elements are sensitive to heat transfer between the element and its environment, temperature and composition changes can also be sensed.

Taking different types of probes and different types of fluid we compare the behavior of sensor so that we can determine the best condition for measurement of property particularly velocity.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

Introduction

1.1 DEFINATION AND BREIF REVIEW

The thermal anemometry has been widely used for many years as a research tools and Industries .Here hot wire anemometer will refer to use a small electrically heated element exposed to a flowing fluid for measuring the velocity and other properties like turbulence , flow pattern , level of that fluid . The principle of hot-wire anemometer is based on heat transfer by convection method from a heated element placed in the fluid flow and any changes in the fluid medium will cause a change in heat loss in sensor .It is an ideal tool for measuring velocity fluctuation in time domain in turbulent flows.

There are two types of probe (1) hot wire and (2) hot film.

1.2 HOT WIRE SENSORS

Figure.1.1 shows tungsten hot wire anemometer probe. The typical diameter of probes ranges from 0.0038 to 0.005 mm and length from 1.0 to2.0 mm. The most commonly used wire materials are tungsten, platinum and platinum-iridium alloy. Though tungsten wires are strong and have a high temperature coefficient of resistance, (0.004/^{o}C) in many gases they cannot be used in high temperature because of low oxidation resistance. In the case of platinum , it has good oxidation resistance as well as has a very good temperature coefficient (0.003/^{o}C), but is very weak specially at high temperatures. The platinum-iridium wire is a compromise between tungsten and platinum having good oxidation resistance, and high strength than platinum, but it has a low resistive coefficient of temperature (0.00085/^{o}C). Now-a-days tungsten is more popular as compared to other hot wire material. To raise bond with the plated ends and the support needles a thin platinum coating is usually applied.

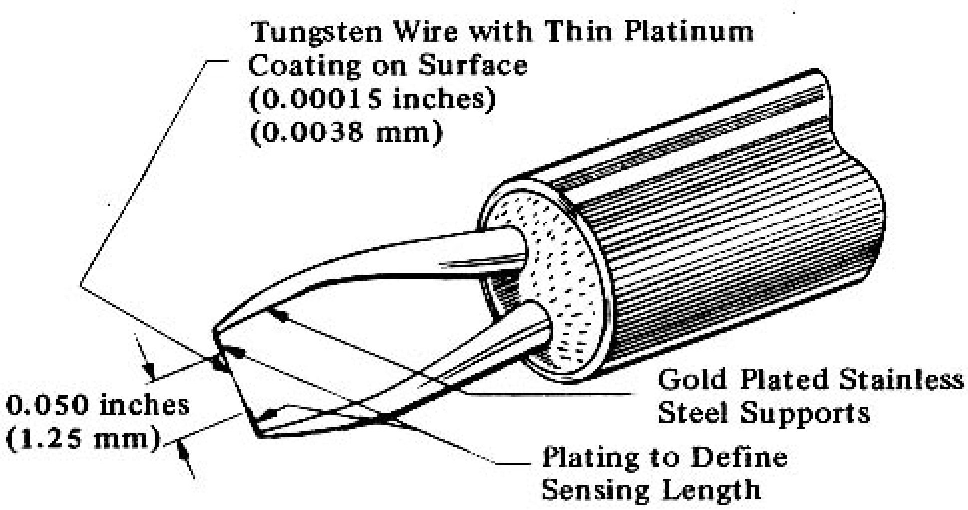


Figure 1: Tungsten Hot Wire Sensor and Support Needles- 0.00015" Dia. (0.0038 mm)

1.2.1 CLASSIFICATION OF HOT WIRE PROBES

On the basis of number of sensors used hot wires probes are classified into one-, two- and three-dimensional versions as single-, dual and triple sensor probes. Probes having two or more sensors give information about magnitude as well as direction of velocity of fluid flow when placed under different angles to the flow vector.

(a)

(b)

(c)

Figure 1.2 (a) Single Sensor Probe, (b) Dual Sensor Probe, (c) Triple Sensor Probe

1.3 HOT FILM SENSORS

Figure 1.3: shows film type sensors and used in regions where a hot wire probe breaks, such as in water flow measurements. Most films are made of platinum because of its good oxidation resistance property and the resulting long-term stability.

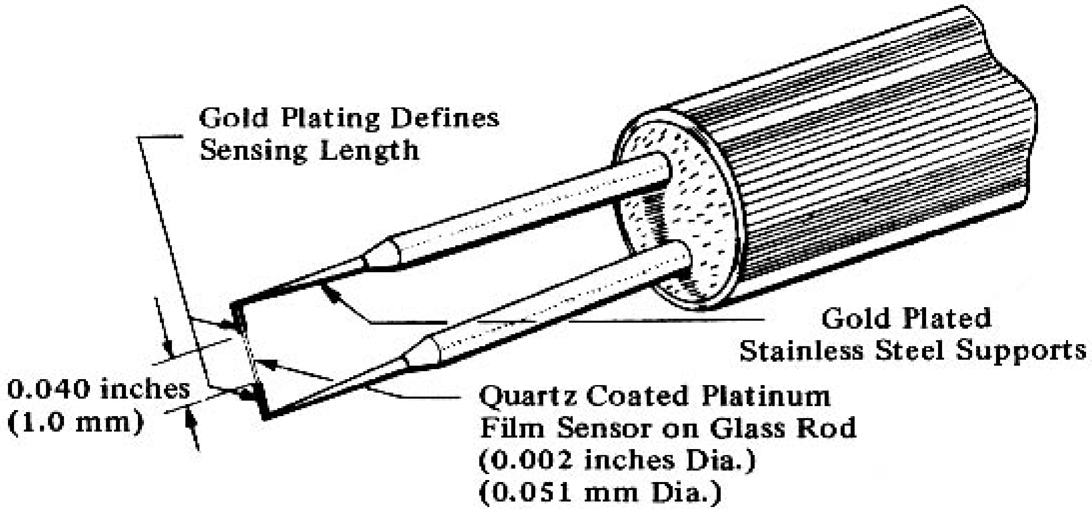


Figure 2: Cylindrical Hot Film Sensor and Support Needles- 0.002" Dia. (0.051 mm)

The hot wire anemometer can be operated in either of the modes (1) constant temperature or (2) constant current. Mostly we have concentrated on constant temperature mode.

1.4 CONSTANT TEMPERATURE HOT WIRE ANEMOMETER

For the measurement of velocity and wall shear stress Constant temperature anemometry (CTA) has been used for nominally four decades. The temperature hence resistance of the wire is kept constant using a servo amplifier. Initially the bridge is balanced by adjusting the variable resistor R3 while rest of two resisters R2 and R4 are fixed .The change in flow velocity causes the change in resistance R1 and to keep the resistance constant accordingly the current is needed to fed into the sensor. The advantages of constant temperature anemometer are it is easy to use, it has high frequency response, low noise, accepted standards .Its bridge circuit is shown below in Figure 1.4.

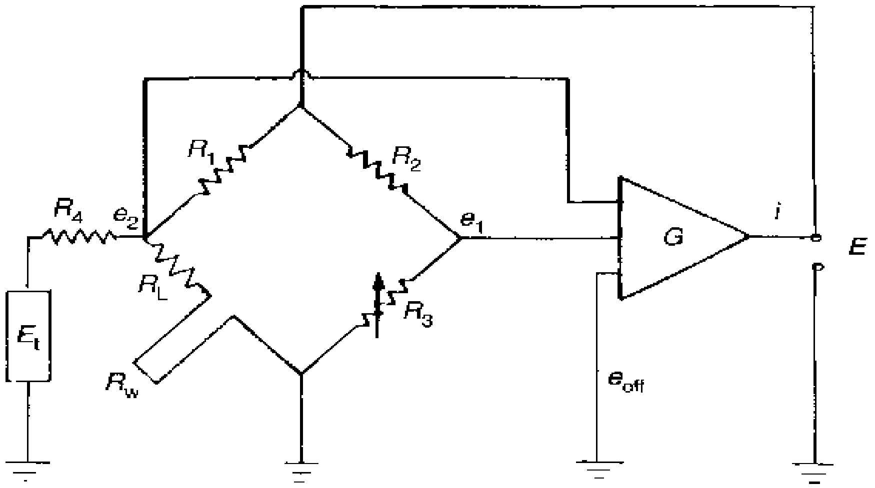


Fig 1.4: Bridge circuit of constant temperature anemometer

1.5 CONSTANT CURRENT ANEMOMETER (CCA)

Current across the wire exposed to flow is kept constant. Variation in resistance of wire caused by fluid flow is measured by monitoring the voltage drop across filament. Figure 4 shows the basic circuitry of constant current anemometer. It has few disadvantages such as it is difficult to use, its output decreases with velocity, there is very high exist risk of probe burnout.

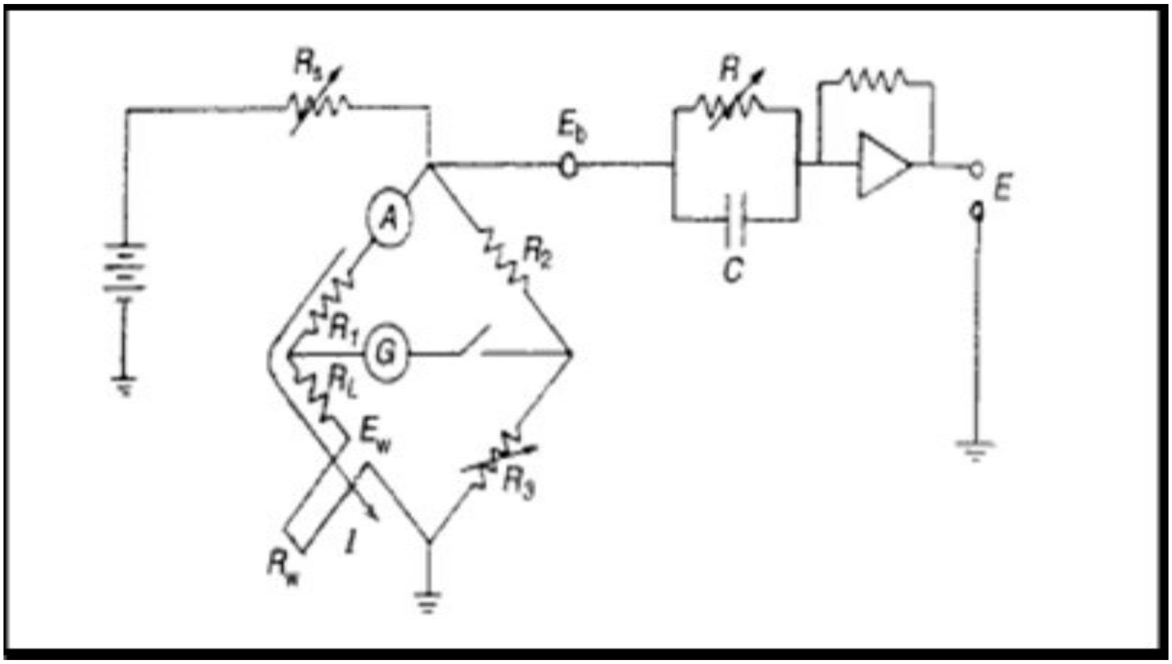


Figure 1.5: Circuit Diagram of Constant Current Anemometer

CHAPTER 2

HEAT TRANSFER EFFECTS IN MEASUREMENT SYSTEM

2.1 INTRODUCTION

The temperature of sensing element at any instant of time and depends upon the rate of transfer of heat both to and from sensors. Transfer of heat takes place as a result of three possible types of mechanism-**conduction, convection and radiation.** This chapter is concerned with heat transfer between sensing element and the fluid in which it is situated. Here the main heat transfer mechanism is convection.

From Newton's law of cooling the convective heat flow W watts between a sensor at T°C and fluid at T_f °C is given by:

$$\mathbf{W = U\,A\,(T - T_f)}$$

where U $Wm^{-2}\,°C^{-1}$ is the convection heat transfer coefficient and Am^2 is the heat transfer area. Heat transfer coefficients are calculated using the correlation:

$$\mathbf{Nu = \Phi\,(Re, Pr)}$$

between the three dimensionless numbers:

Nusselt Number $\quad Nu = \frac{Ud}{k}$

Reynolds Number $\quad Re = \frac{vdp}{\eta}$

Prandtl Number $\quad \mathrm{Pr}=\dfrac{c\eta}{k}$

The function Φ is found out experimentally; its form depends on the shape of sensor, the type of convection and the direction of fluid flow in relation to the sensor. For example the correlation for forced convection cross-flow in a cylindrical tube is

$$\mathrm{Nu} = 0.48\,(\mathrm{Re})^{0.5}(\mathrm{Pr})^{0.3}$$

2.2 FLUID FLOW SENSOR WITH SELF- HEATING CURRENT

If current I is passed through a resistive element, like a fine metal wire or semiconductor film, then the element is heated to a temperature T which is greater than T_f , the temperature of the surrounding fluid. The temperature of resistive element T and resistance R_T depends on the harmony between electrical power i^2R_T and the rate of total convective heat transfer between element and fluid, the element is used as a fluid velocity sensor. The heat balance equation is:

$$i^2c - U(v)\,A\,(T - Tf) = M\,C\,\frac{dT}{dt} \tag{1}$$

where $U(v)$ is the convective heat transfer coefficient between sensor and fluid. If i_o, R_{To}, T_o, v_o represent steady equilibrium conditions then:

$$i^2R_{To} - U(v_o)\,A\,(T_o - Tf) = 0 \tag{2}$$

Δi , ΔR_T, Δv , ΔT are the small deviations from the above equilibrium values , we have:

$$i = i_o + \Delta i\,, \qquad T = T_o + \Delta T$$

$$R_T = R_{To} + \Delta R_T \qquad U(v) = U(v_o) + \sigma\,\Delta v \tag{3}$$

In (3) σ = $\left(\frac{\partial U}{\partial v}\right)_{vo}$ i.e the rate of change of U w.r.t v, calculated at equilibrium $v_{o.}$ From (1) and (2) we have:

$$(i_0{}^2 + \Delta i\,)^2\,(R_{T0} + \Delta R_T) - (U(v_0) - \sigma\Delta v)A(T_0 + \Delta T - T_F)\Delta v = MC\frac{d\Delta T}{dt}(\,T_0 + \Delta T\,) \qquad (4)$$

Neglecting all the terms involving the multiplication of small quantities gives:

$$(i_0{}^2 + 2\,i_0\Delta i)R_{T0} + i_0{}^2\Delta R_T - U(v_0)A(T_0 - T_F) - U(v_0)A\Delta T - \sigma A(T_0 - T_F)\Delta v = MC\frac{d\Delta T}{dt} \qquad (5)$$

Subtracting (2) from (5) gives:

$$2i_0R_{T0}\Delta I + i_0{}^2\Delta R_T - U(v_0)A\Delta T - \sigma A(T_0 - T_F)\Delta v = MC\frac{d\Delta T}{dt} \qquad (6)$$

ΔT can be eliminated by setting $K_T = \Delta R_T/\Delta T$ i.e. $\Delta T = (1/K_T)\Delta R_T)$, where K_T is slope of the resistive element – temperature characteristics; thus

$$\left[\frac{U(v_o)A}{K_T} - i_o^2\right]\Delta R_T + \frac{MC}{K_T}\frac{d\Delta R_T}{dt} = 2i_oR_{T_o}\Delta i - \sigma A(T_o - T_F)\Delta v \qquad (7)$$

ie

$$\Delta R_T + \tau_v\frac{d\Delta R_T}{dt} = K_I\Delta i - K_v\Delta v \qquad (8)$$

Where,

$$\tau_\upsilon = \frac{MC}{[U(\upsilon_o)A - i_o^2K_T]}\ , \quad K_I = \frac{2K_Ti_oR_{T_o}}{[U(\upsilon_o)A - i_o^2K_T]}$$

$$K_\upsilon = \frac{K_T\sigma A(T_o - T_F)}{[U(\upsilon_o)A - i_o^2K_T]} \qquad (9)$$

Taking the laplace Transform of [14.26] gives:

$$(1 + \tau_\upsilon s\,)\Delta\overline{R}_T = K_I\Delta\overline{\imath} - K_\upsilon\Delta\overline{\upsilon}$$

i.e.

$$\boldsymbol{\Delta R_T = \frac{K_I}{(1+\tau_\upsilon s)}\Delta i - \frac{K_\upsilon}{(1+\tau_\upsilon s)}\Delta\upsilon} \quad (10)$$

Transfer function for fluid velocity sensor

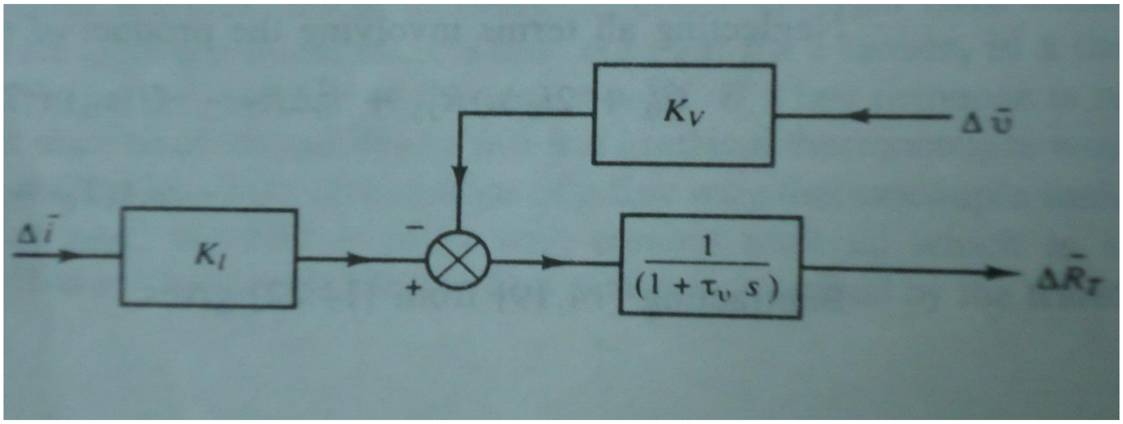


Fig 2.1: Block diagram of thermal velocity sensor

2.3 CONSTANT TEMPERATURE ANEMOMETER SYSTEM FOR FLUID VELOCITY MEASUREMENTS

2.3.1 Steady-State characteristics

From the above results the steady-state equilibrium equation for a fluid velocity sensor with self-heating current is:

$$i_0^2 R_{T_o} = U(\upsilon)A\,(T_o - T_F) \quad (11)$$

In a CTA system the resistance R_{T0} and temperature T_o of the sensor are maintained at constant values. From (11) we see that if the fluid velocity *v* increases, causing an increase in U(*v*) ,them the system must increase the current *i* through the sensor in order to re-establish equilibrium. Since sensor resistance R_{To} , remains constant , the voltage drop iR_{To} across

the element increases , thus giving a voltage signal dependent on fluid velocity sensors .This is :

$$\mathrm{Nu} = 0.24 + 0.56\,\mathrm{Re}^{0.5} \tag{12}$$

Giving $$\mathrm{U} = \frac{0.24\mathrm{k}}{\mathrm{k}} + 0.56\mathrm{k}\left(\frac{\rho\upsilon}{\mathrm{d}\eta}\right)^{0.5} \tag{13}$$

$$\mathrm{U} = \mathrm{a} + \mathrm{b}\sqrt{\mathrm{v}} \tag{14}$$

Where

$$\mathrm{a} = \frac{0.24\mathrm{k}}{\mathrm{d}}\,,\ \mathrm{b} = 0.56\mathrm{k}\left(\frac{\rho}{\mathrm{d}\eta}\right)^{0.5} \tag{15}$$

We see that since a and b depends upon sensor dimension d and the fluid properties k, ρ, η , they are constants only for a given sensor in a given fluid . This means that if a sensor is calibrated in certain fluid, the calibration results will not apply if the sensors is placed in a different fluid . Figure 6 is a schematic diagram of a constant-temperature anemometer system. This is a self – balancing bridge which maintains the resistance R_T of the sensor at a constant value R. An increase in fluid velocity *v* causes T and R_T to fall in the short term, thus unbalancing the bridge; this causes the amplifier output current and current through the sensor to increase thereby restoring T and R_T to their required values . Since $R_T = R$ and $R_T = R_o(1 + \alpha T)$ for a metallic sensor , then the constant temperature T of the sensor is:

$$\mathrm{T} = \frac{1}{\alpha}\left(\frac{\mathrm{R}}{\mathrm{R_o}} - 1\right) \tag{16}$$

From (2) , (14) and (16) we have:

$$\mathrm{i}^2\mathrm{R} = \mathrm{A}\left(\mathrm{a} + \mathrm{b}\sqrt{\upsilon}\right)\left[\frac{1}{\alpha}\left(\frac{\mathrm{R}}{\mathrm{R_o}} - 1\right) - \mathrm{T_F}\right] \tag{17}$$

Since $$\mathrm{E_{OUT}} = \mathrm{iR}$$

$$E_{OUT}^2 = AR(a + b\sqrt{\upsilon}\left[\frac{1}{\alpha}\left(\frac{R}{R_o} - 1\right) - T_F\right] \tag{18}$$

$$\mathbf{E_{OUT}} = (\mathbf{E_o^2} + \boldsymbol{\gamma}\sqrt{\boldsymbol{\upsilon}})^{\mathbf{1/2}} \tag{19}$$

where

$$E_o^2 = ARa\left[\frac{1}{\alpha}\left(\frac{R}{R_o} - 1\right) - T_F\right] \text{ and } \gamma = ARb\left[\frac{1}{\alpha}\left(\frac{R}{R_o} - 1\right) - T_F\right] \tag{20}$$

2.3.2 DYNAMIC CHARACTERISTICS

We now calculate the transfer function of the constant- temperature anemometer system to see if the frequency response is sufficient to detect rapid velocity fluctuations due to turbulence and vortex shedding. A block diagram of a thermal velocity sensor derived in 2.2 .the system equations are:

Sensor $$\Delta R_T = \frac{K_I}{(1+\tau_\upsilon s)}\Delta i - \frac{K_\upsilon}{(1+\tau_\upsilon s)}\Delta\upsilon \tag{21}$$

Bridge $$\Delta V = K_B \, \Delta \, R_R \tag{22}$$

Amplifier $$\Delta i = K_A \Delta V \tag{23}$$

Output voltage $$\Delta E_{OUT} = R\Delta i \tag{24}$$

Resultant change in bridge resistance $\Delta R_R = \Delta R - \Delta R_T$

$$= -\Delta R_r \; (since \;\; \Delta R = 0) \tag{25}$$

From (22)-(25)

$$\Delta R_T = \frac{-1}{RK_AK_B}\,\Delta E_{OUT} \; and \; \Delta i = \frac{\Delta E_{OUT}}{R} \tag{26}$$

Substituting (25) in (21) gives:

$$\frac{-1}{RK_AK_B}\Delta E_{OUT} = \frac{1}{(1+\tau_v s)}\left[\frac{K_l}{R}\,\Delta E_{OUT} - K_v\Delta v\right]$$

Rearranging we have:

$$[\,(\,1 + K_lK_AK_B) + \tau_v s\,]\Delta E_{OUT} = K_\theta K_A K_B R\Delta v$$

Giving

$$\boldsymbol{\frac{\Delta\bar{E}_{OUT}}{\Delta\bar{v}}\,(s) = \frac{K_{CTA}}{1+\;\tau_{CTA}{}^{S}}} \tag{27}$$

where

$$K_{CTA} = \frac{K_v K_A K_B R}{1 + K_I K_A K_B} \; and \; \tau_{CTA} = \frac{\tau_o}{1 + K_I K_A K_B}$$

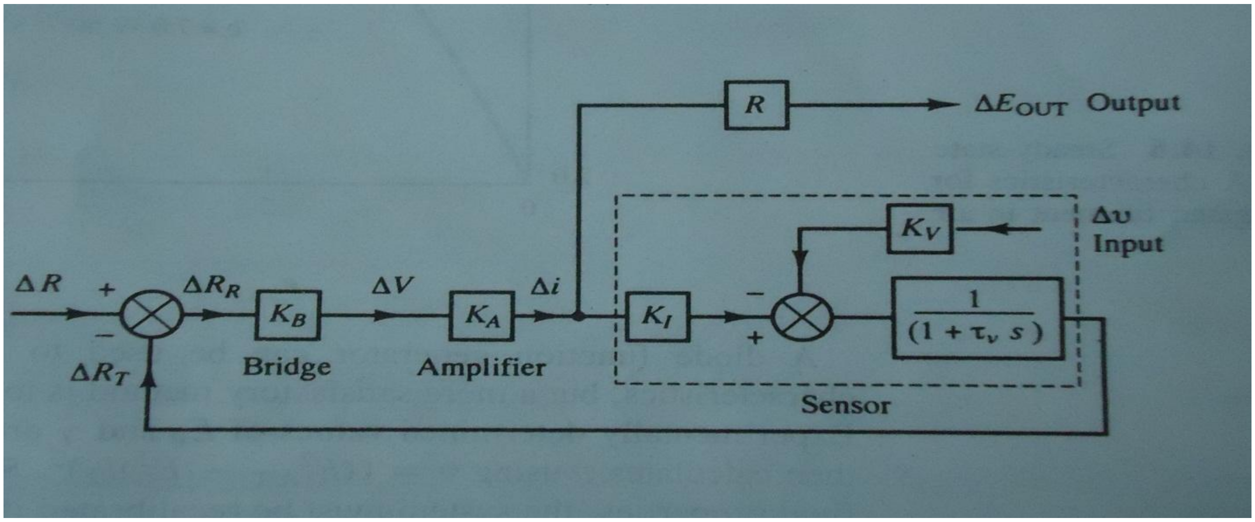


Fig 2.2: Block diagram of constant temperature anemometer

CHAPTER 3

RESULTS AND OBSERVATION PART I

Having described the total process of hot wire anemometry ,now we come up to the observation part. We have seen that a few factors affected the working of hot wire anemometry. Let us see how the fluid whose velocity is being measured affects the measurement.

First we will consider for **CONSTANT TEMPERATURE ANEMOMETER**

Earlier we have seen that equation

$$E_{out}^{2} = Eo^{2} - ɣ\sqrt{v} \qquad \textbf{(28)}$$

Where $$Eo^{2} = ARa\left[\frac{1}{\alpha\left(\frac{R}{Ro}-1\right)} - Tf\right]$$

$$ɣ = ARb\left[\frac{1}{\alpha\left(\frac{R}{Ro}-1\right)} - Tf\right]$$

a and b here are $a = \frac{0.24k}{d}$

$$b = 0.56\left(\frac{ƥ}{dη}\right)$$

k , ƥ and η depends on the fluid whose flow velocity is to be used.

Here are values of few fluids which we will be using to check the dependence of the fluid on flow velocity.

Table 1.0

Properties	alcohol	Water	Glycerine	Olive oil
k(fluid thermal conductivity) in W/m°C	0.17	0.016	0.28	0.17
þ (fluid density) in Kg/m^3	785	1	1261	800
η (fluid viscosity) in Pas	0.001074	0.0013	1.2	0.081

Calculating the values of a and b for different fluid we plot the graph of fluid velocity versus output voltage using programming in Matlab

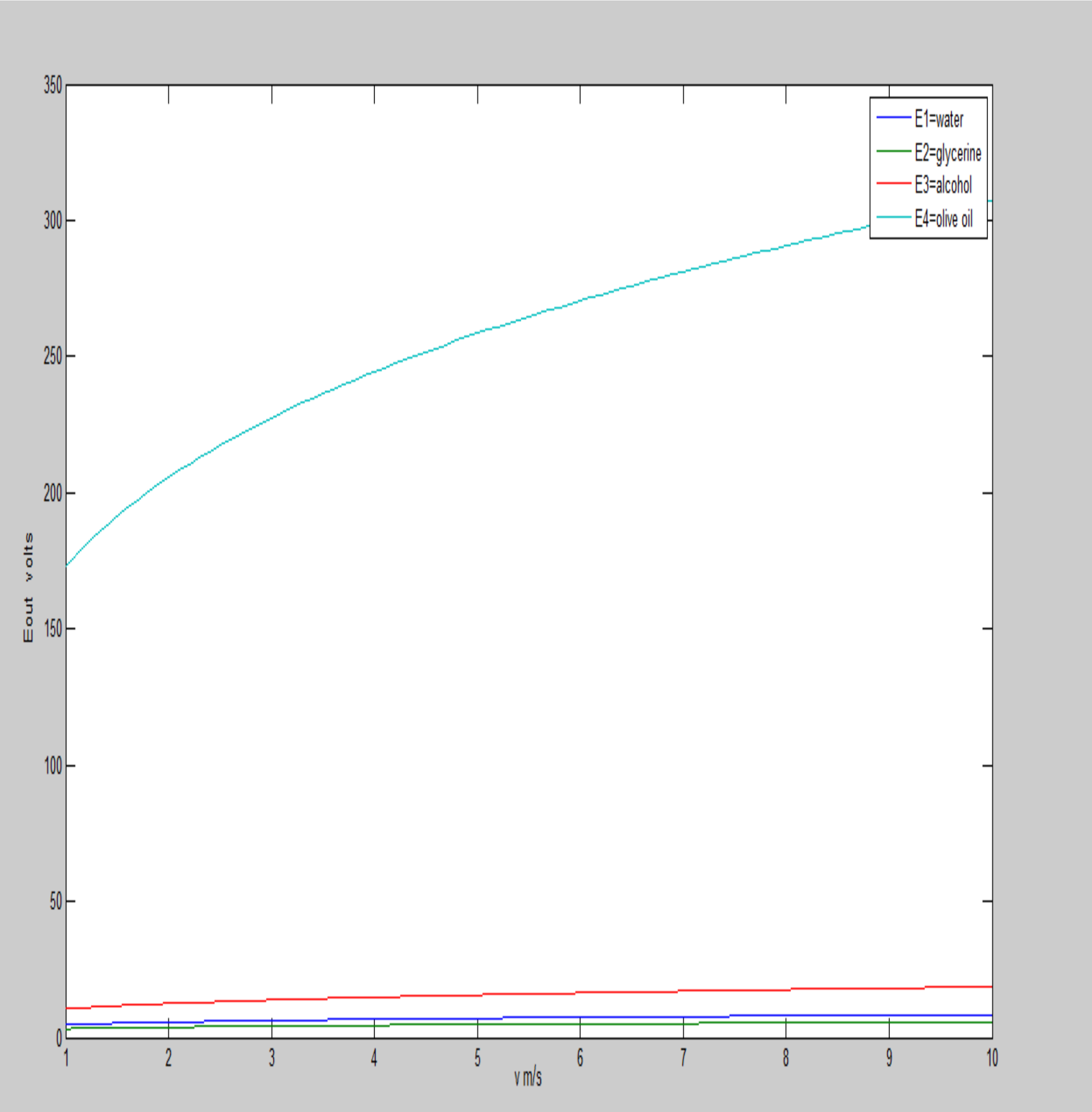


Fig 3.1

After observing this we now go for change in diameter which depict the change in sensor or sensor diameter.We take 4 different diameter d=0.2,d=0.2,d=0.5,d=0.9

With the change in d the constant a and b change and hence Eo^2 and ɣ. Now again we plot the flow velocity versus output voltage

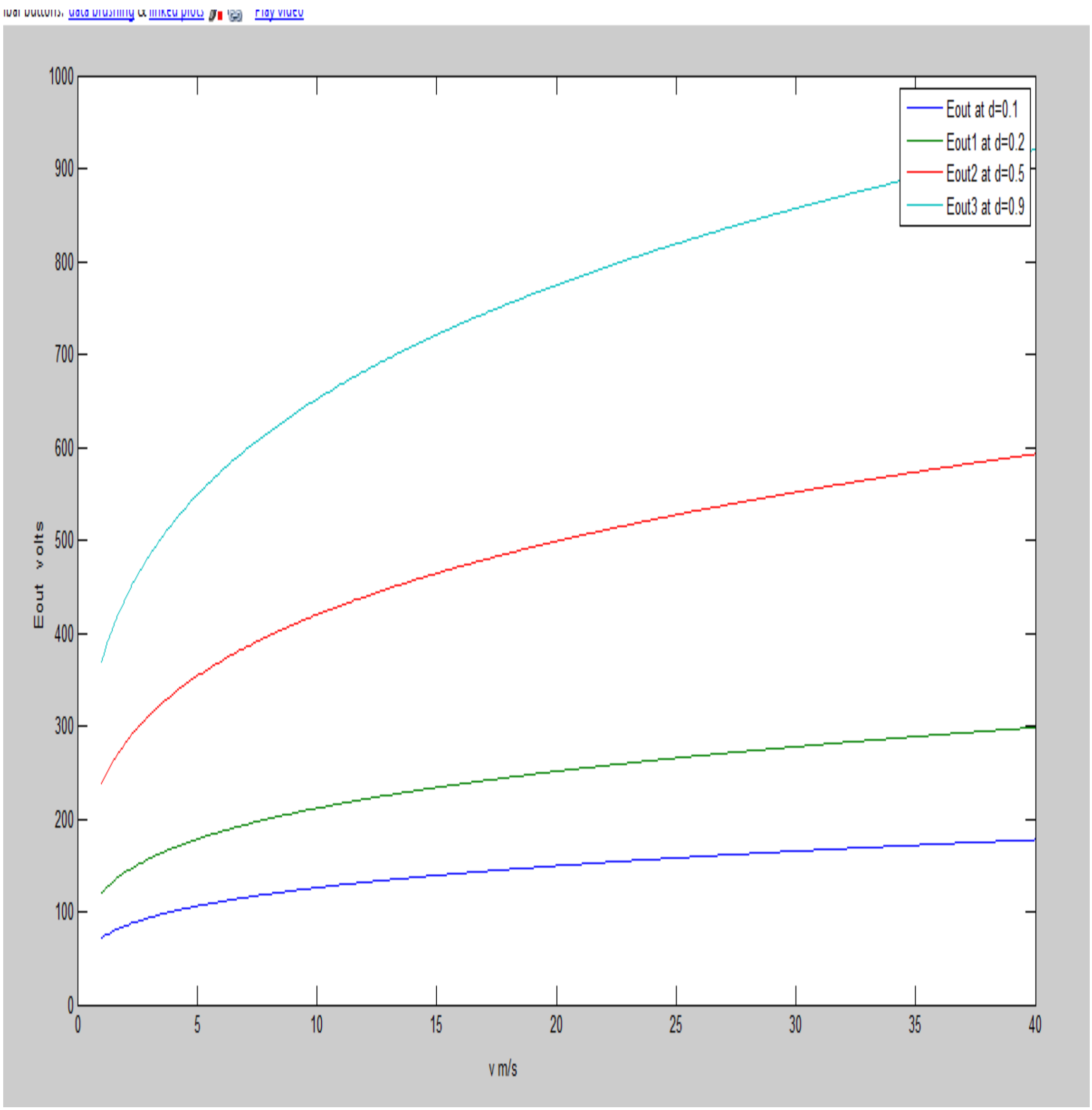


Fig 3.2

We observed from the curves the behavior of a constant temperature anemometer so the same thing is carried out for **CONSTANT CURRENT ANEMOMETER.**

Using the same values of different characteristic fluid and substituting it in the equation

$$v = (i^2Ro + t(i^2Ro\alpha - Aa) + AaTf)/bTf \tag{29}$$

Here T_f = fluid temperature

T = temperature of the wire

Plotting temperature versus the flow graph we get the graph

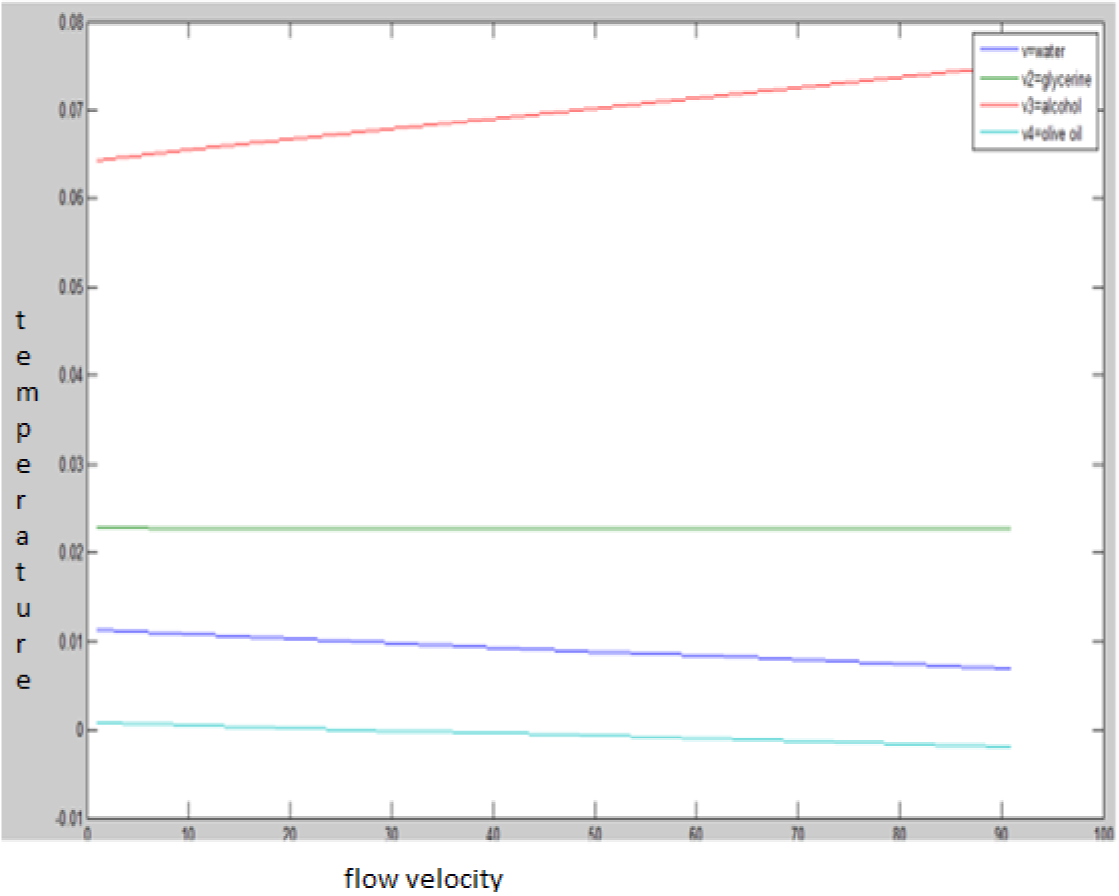


Fig 3.3

Now changing the diameter of the sensor the flow versus temperature graph is obtained

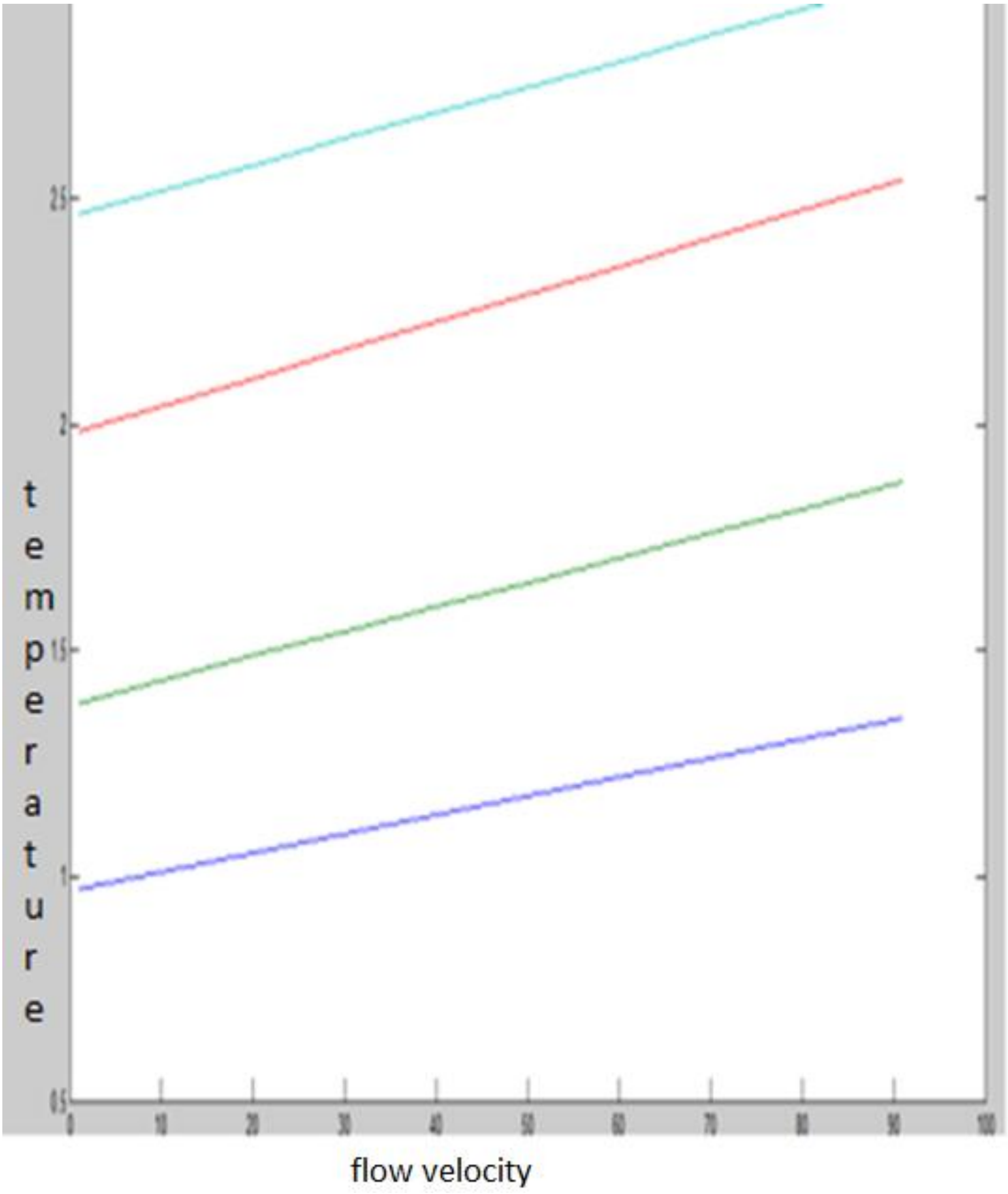


Fig 3.4

The characteristic observed were static after this we determine the dynamic response to see if the frequency response is sufficient to detect rapid velocity fluctuation due to turbulence and vortex shedding

The system equations are

Sensor $\Delta Rt = \frac{KI}{1+ţs}\Delta i - \frac{Kv}{1+ţs}\Delta v$

Bridge $\Delta V = K_B \, \Delta \, R_R$

Amplifier $\Delta i = K_A \Delta V$

Output voltage $\Delta E_{OUT} = R\Delta i$

Resultant change in bridge resistance $\Delta R_R = \Delta R - \Delta R_T$

$$= -\Delta R_T \; (since \;\; \Delta R = 0)$$

From the above equation we get

$$\Delta R_T = -\frac{1}{KaKb}\Delta Eout$$

$$\Delta i = \frac{\Delta Eout}{R}$$

$$-\frac{1}{RKaKb}\Delta Eout = \frac{1}{1+ţs}\left[\frac{KI}{R}\Delta Eout - K\Delta v\right]$$

Rearranging we have

$$[\,(1 + K_l K_A K_B) + \tau_v s\,]\Delta E_{OUT} = K_\theta K_A K_B R \Delta v$$

TRANSFER FUNCTION OF CTA SYSTEM IS

$$\frac{\Delta Eout}{\Delta v}(s) = \frac{Kcta}{1 + ţctas}$$

Where $Kcta = \frac{KaKvKbR}{1+KaKvKb}$

$$ţ\,cta = \frac{ţv}{1+KiKaKb}$$

Taking $ţ\,cta = 1ms$

And Kcta =2 we get the response of the system

First for an sinusoidal input with ῳ= 2

Thus the bandwidth of the system is 0-160 Hz i.e between 0-160 Hz which is easily sufficient for vortex detection and is adequate for most turbulence measurement applications.

When the input is sinusoidal wave then the following curve is obtained

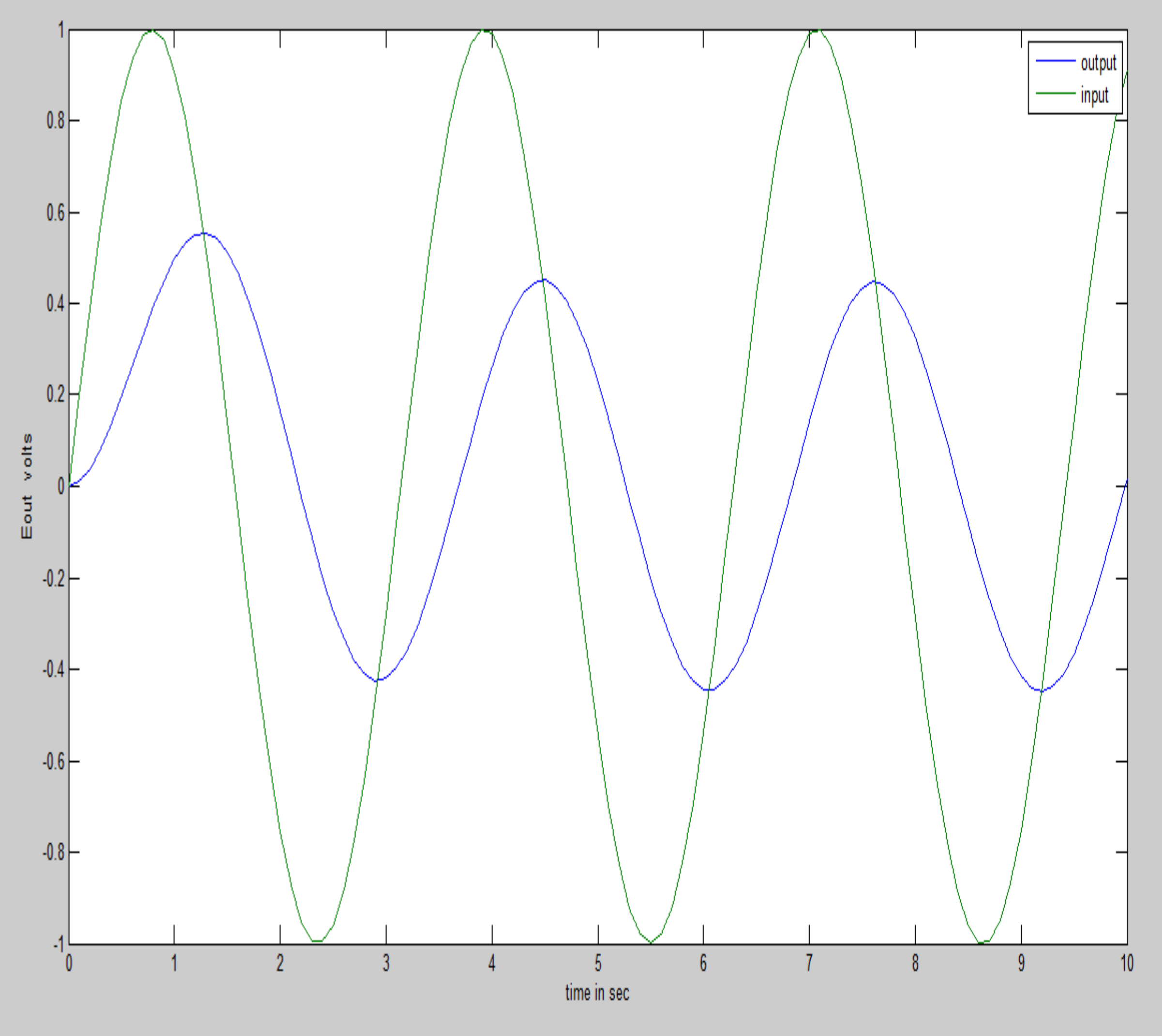


Fig 3.5

We now would see how the system would respond when a square wave input is given

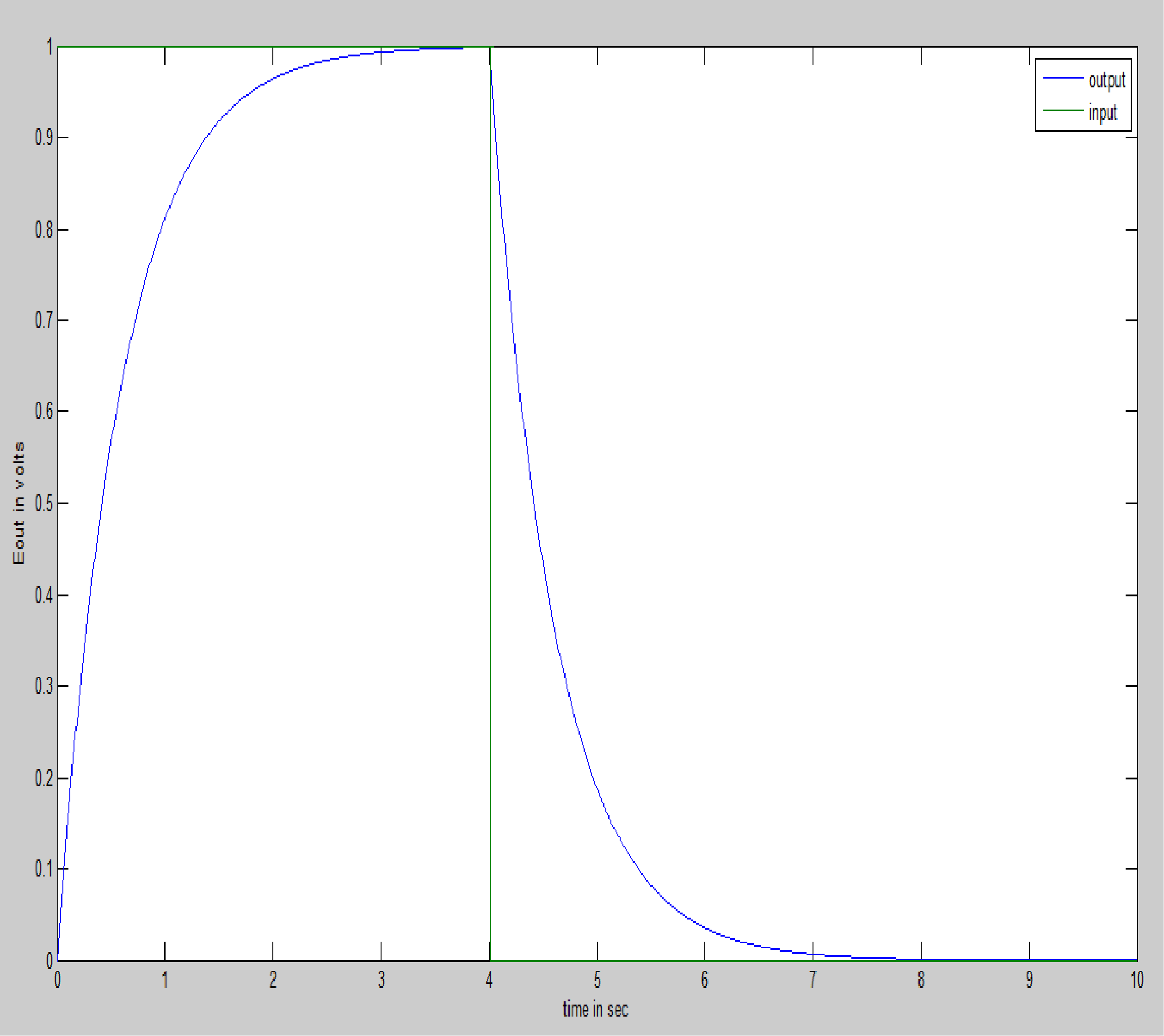


Fig 3.6

CHAPTER 4

RESULTS AND OBSERVATION

PART II

Now we carry out simulation in P-spice in order to get the practical results and compare them with the theoretical output obtained in the previous chapter.

This circuit which will be simulated in P-spice has one Wheatstone bridge and a differential amplifier using **Opamp** whose gain is 2.5.

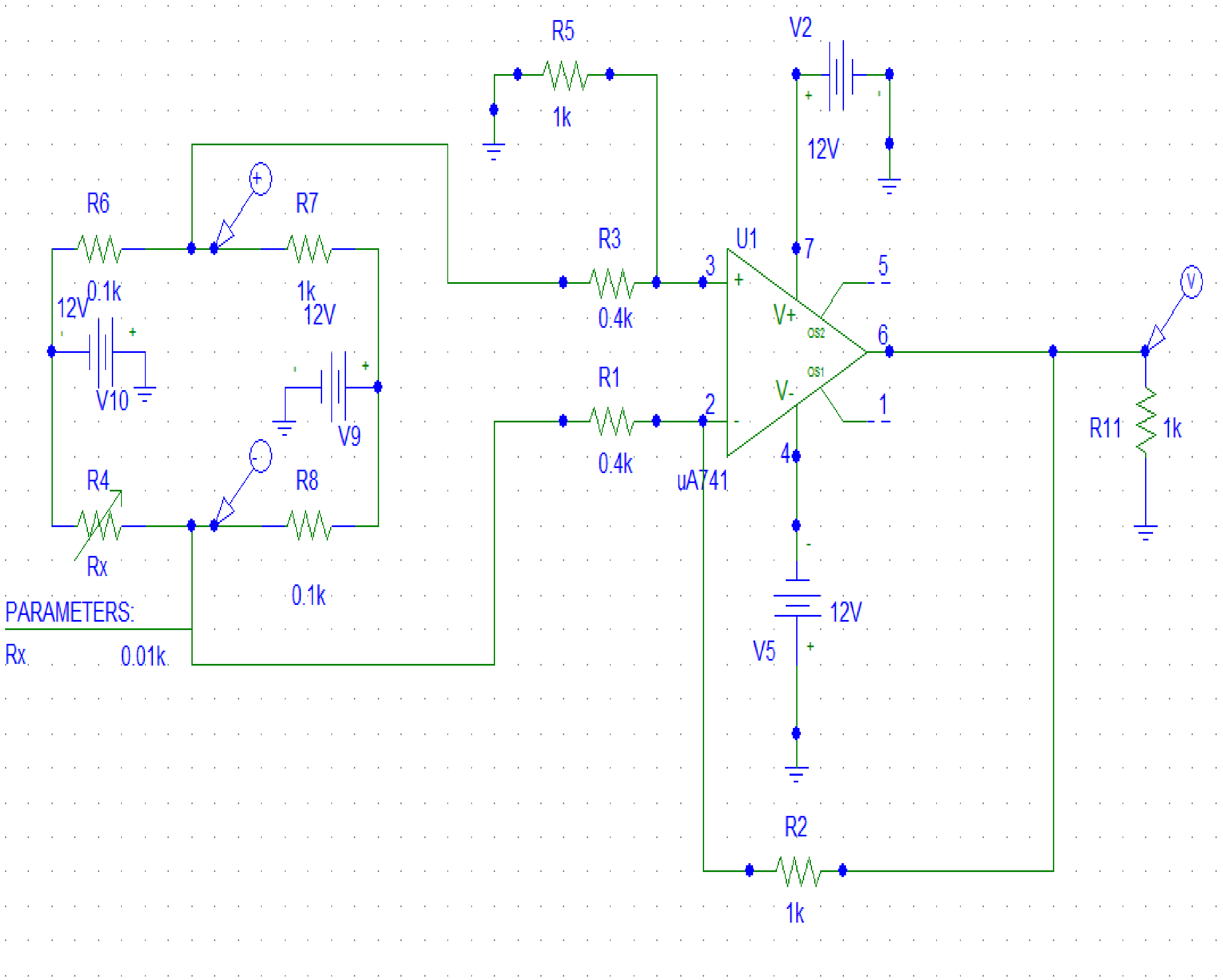


Fig 4.1

Actually in the process the voltage of the amplifier is the measure of current that has to be supplied in order to keep the temperature constant and hence the resistance. But practically this is not possible since a proper environment is needed for feedback. Since we cannot provide proper environment this experiment will be a total failure so we just measure the voltage amplifier by the amplifier and the output voltage of Wheatstone bridge. Amplifier is used to increase the sensitivity and also remove the error due to attenuation. After designing the circuit we plot the amplified output and output of Wheatstone bridge versus the change in resistance of the sensor which depicts the change in velocity

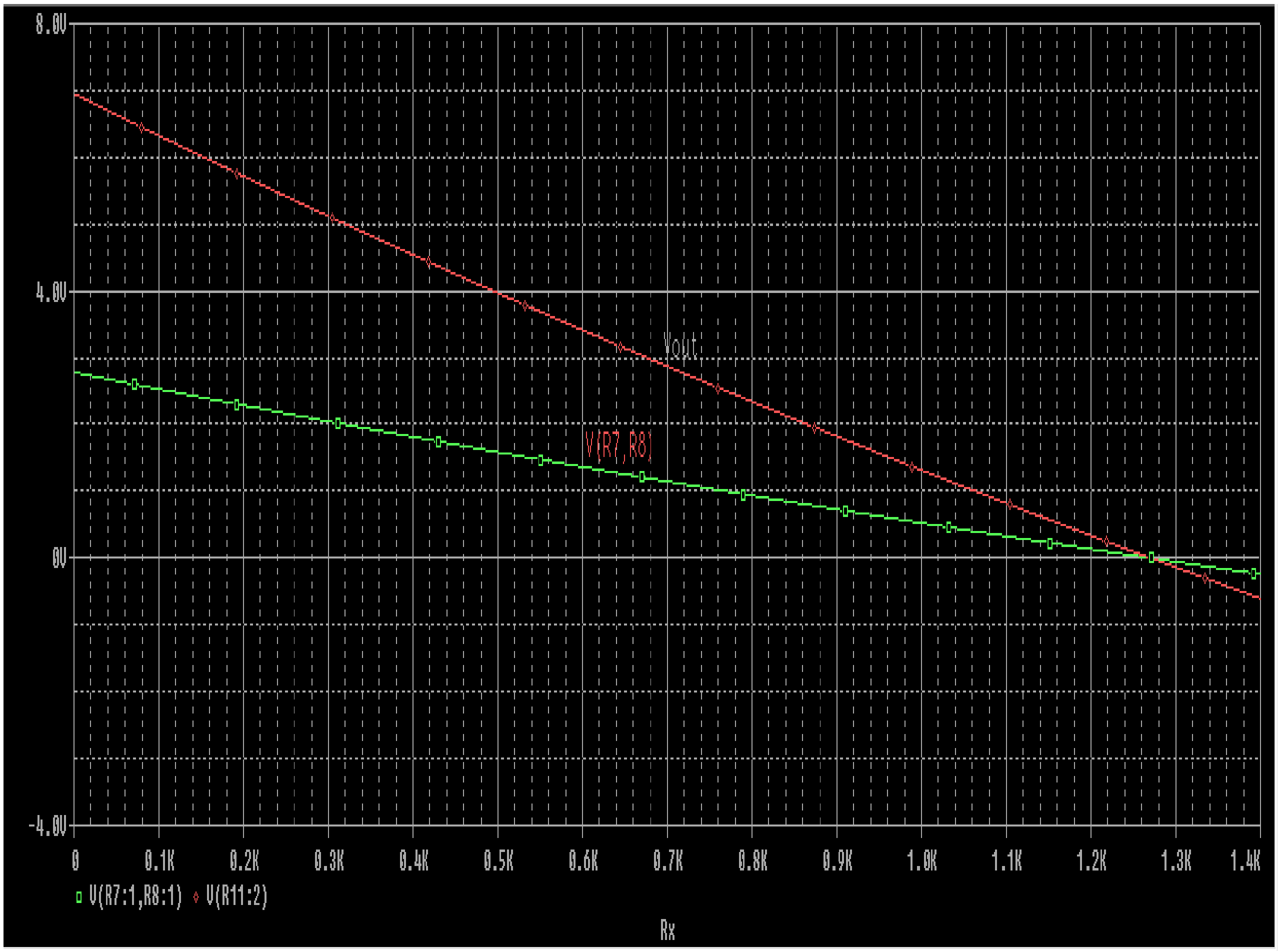


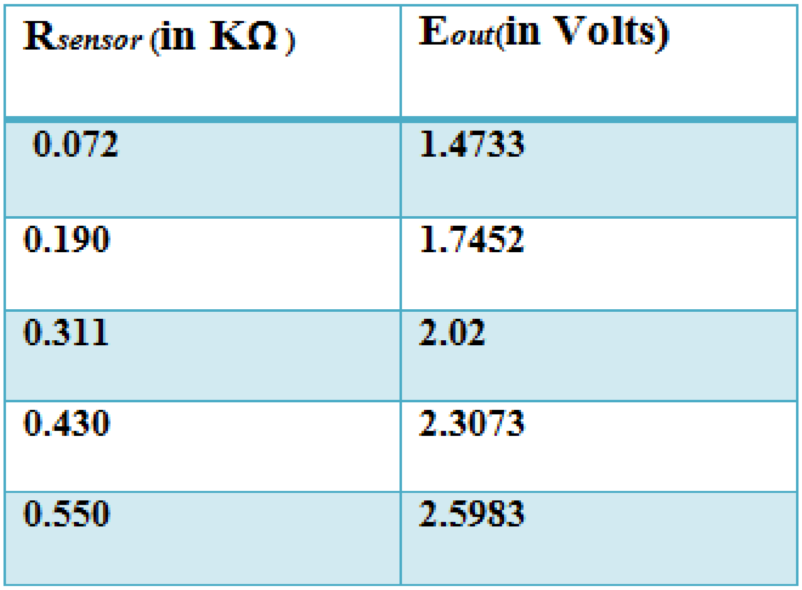
Fig 4.2

V(R7,R8)(V(R7:1,R8:1))=output voltage of the Wheatstone bridge

Vout(V(R11:2))=output voltage of the amplifier

We now find coordinates of five different points on the curve which represents the output voltage of Wheatstone bridge. From these coordinates we will find the flow velocity and see how the dependence of flow velocity in the resistance. Resistance is changed by the change in flow velocity.

Table 1.1



R_{sensor} (in KΩ)	E_{out}(in Volts)
0.072	1.4733
0.190	1.7452
0.311	2.02
0.430	2.3073
0.550	2.5983

We now have the values of output voltage so we can calculate the flow velocity from the equation - **(28)** plot resistance versus flow velocity for different fluids.

Table 1.2

R_{sensor} (in KΩ)	Q_a(flow of the alcohol in m/s)	Q_g(flow of the glycerine)	Q_w(flow of the water)	Q_o(flow of the olive oil)
0.072	6.39×10^{-10}	4.87×10^{-3}	1.29×10^{-4}	1.5578×10^{-7}
0.190	6.56×10^{-7}	8.507x10-3	1.195x10-3	1.5503×10^{-4}
0.311	2.23×10^{-6}	0.0125	5.561x10-3	5.2681×10^{-4}
0.430	4.258×10^{-6}	0.0164	0.011	1.0043×10^{-3}
0.550	6.4765×10^{-6}	0.02011	0.018	1.5275×10^{-3}

Plotting these values we obtained the following graph

. Flow velocity versus resistance for different liquid

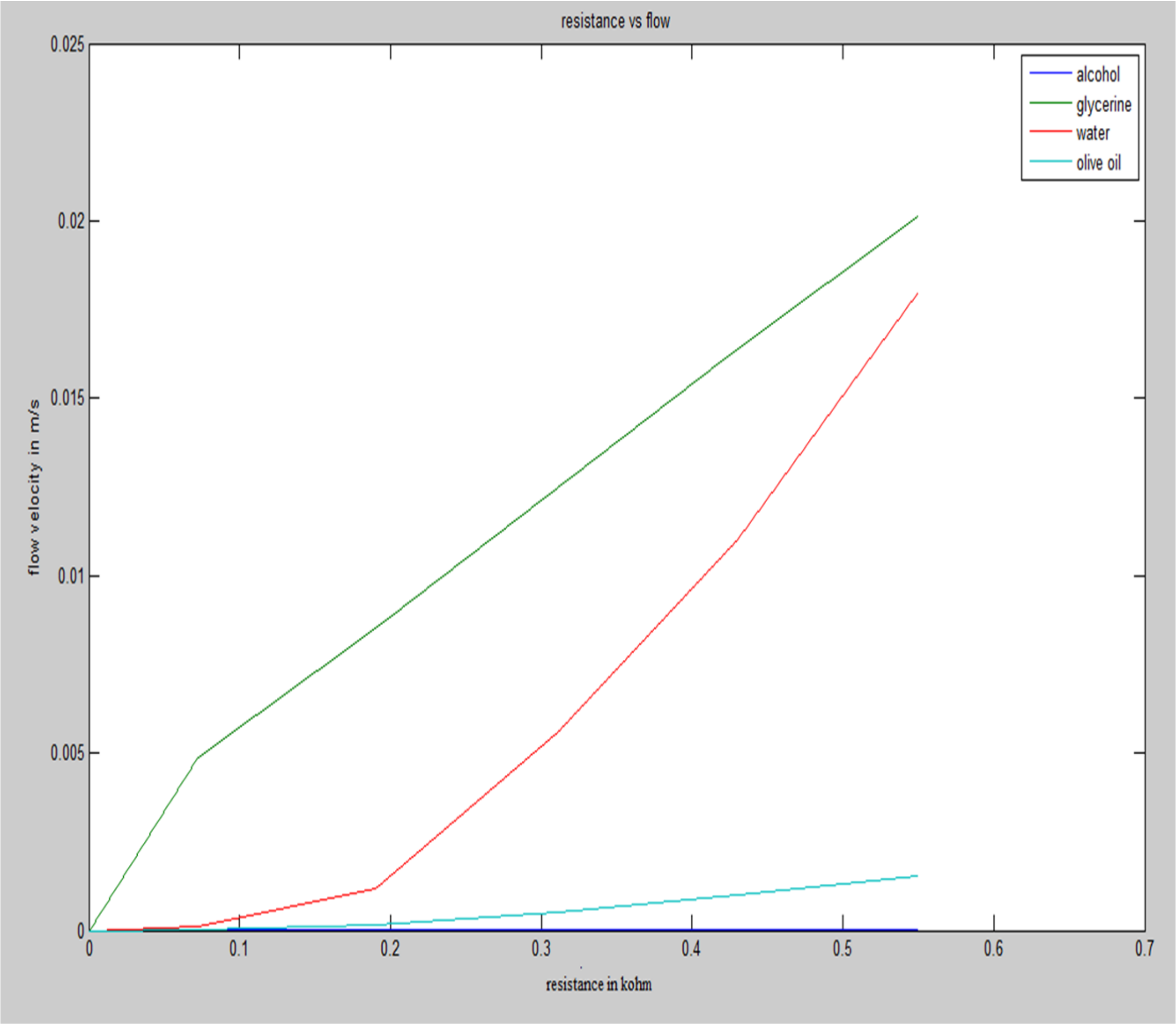


Fig 4.3

Table 1.3

E_{out}(in Volts)	Q_a(flow of the alcohol in m/s)	Q_g(flow of the glycerine)	Q_w(flow of the water)	Q_o(flow of the olive oil)
1.4733	6.39×10^{-10}	4.87×10^{-3}	1.29×10^{-4}	1.5578×10^{-7}
1.7452	6.56×10^{-7}	8.507×10^{-3}	1.195×10^{-3}	1.5503×10^{-4}
2.02	2.23×10^{-6}	0.0125	5.561×10^{-3}	5.2681×10^{-4}
2.3073	4.258×10^{-6}	0.0164	0.011	1.0043×10^{-3}
2.5983	6.4765×10^{-6}	0.02011	0.018	1.5275×10^{-3}

We know plot the flow velocity versus output voltage for different fluids

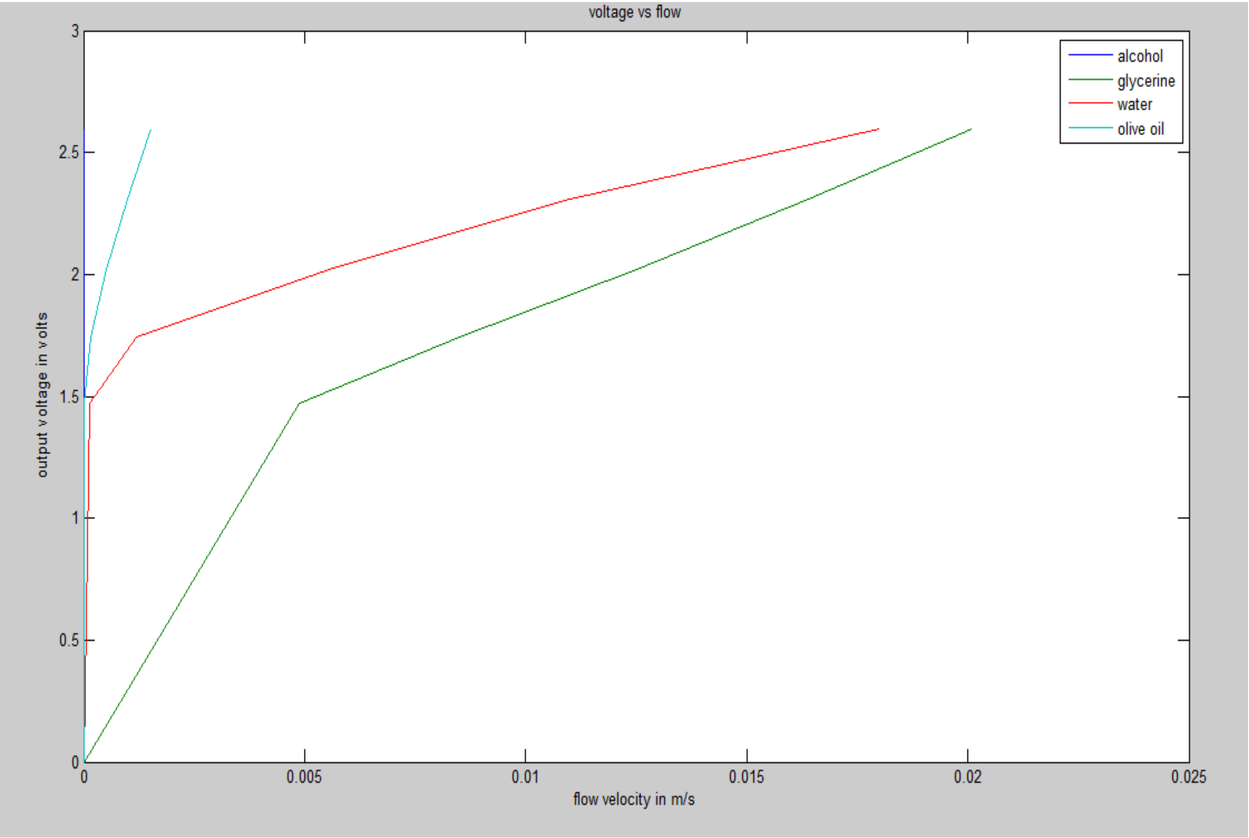


Fig 4.4

After plotting for different fluids we put the output voltage values in equation **(28)** and obtain the values of flow velocity for different diameters as done earlier but the difference is just the fluid remains same so the fluid characteristic don’t change the value of a and b but the diameter does.

Table 1.4

Rsensor (in KΩ)	Diameter=0.2cm	Diameter=0.3cm	Diameter=0.4cm	Diameter=0.5cm	Diameter=0.6cm
0.072	0.3915	0.4680	0.5128	0.5486	0.5770
0.190	0.4025	0.4730	0.5158	0.5506	0.5784
0.311	0.4119	0.4773	0.5184	0.5524	0.5794
0.430	0.4195	0.4809	0.5205	0.5538	0.5807
0.550	0.4258	0.4839	0.5223	0.5550	0.5816

Plotting these points we obtain the graph below

Resistance versus the flow velocity

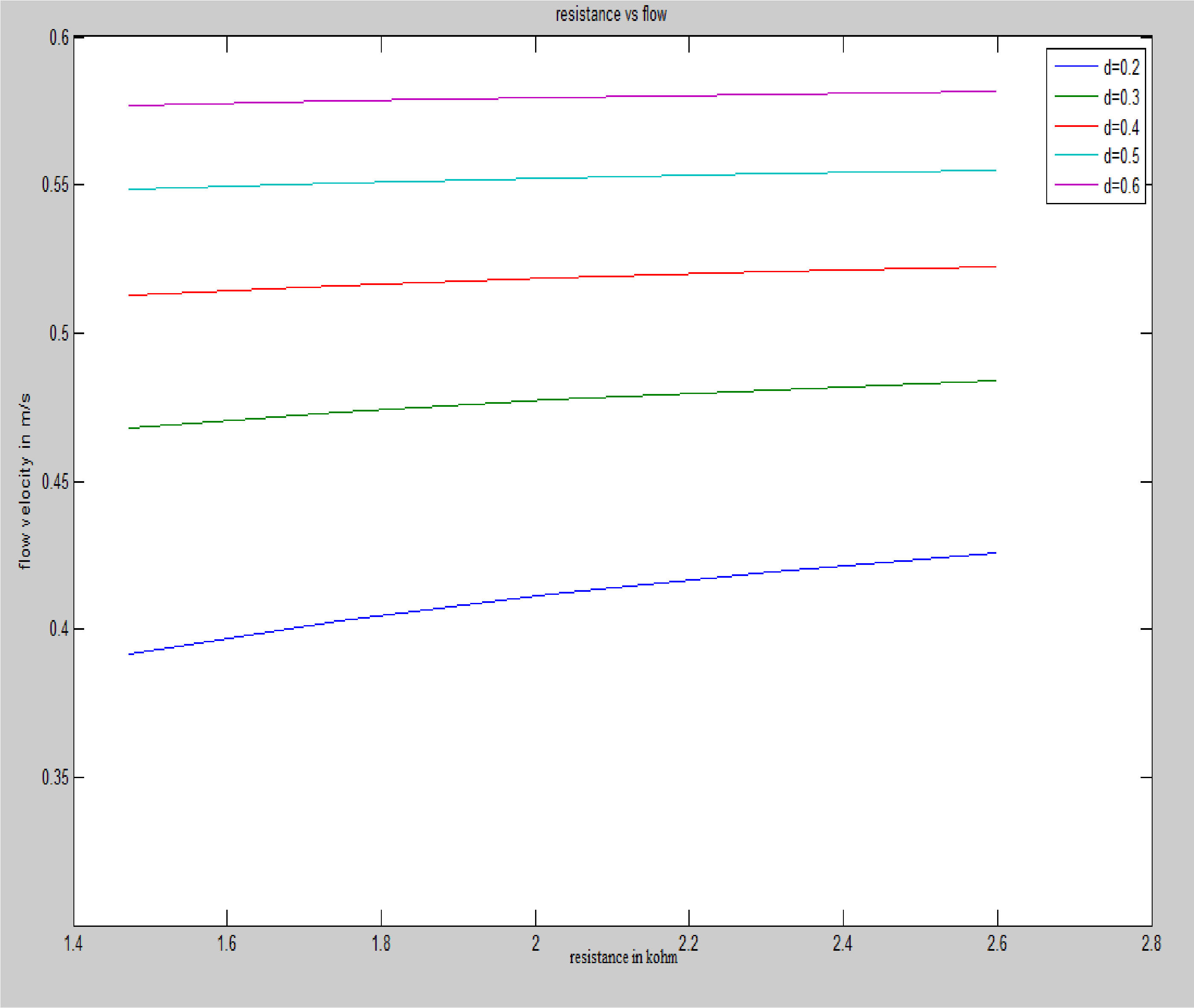


Fig 4.5

Now we obtain the values of flow velocity corresponding to the output voltage for different values of diameter.

Table 1.5

E_{out}(in Volts)	Diameter=0.2cm	Diameter=0.3cm	Diameter=0.4cm	Diameter=0.5cm	Diameter=0.6cm
0.072	0.3915	0.4680	0.5128	0.5486	0.5770
0.190	0.4025	0.4730	0.5158	0.5506	0.5784
0.311	0.4119	0.4773	0.5184	0.5524	0.5794
0.430	0.4195	0.4809	0.5205	0.5538	0.5807
0.550	0.4258	0.4839	0.5223	0.5550	0.5816

Plotting the values of the above table we get a output voltage versus flow velocity curve

Output voltage versus flow velocity

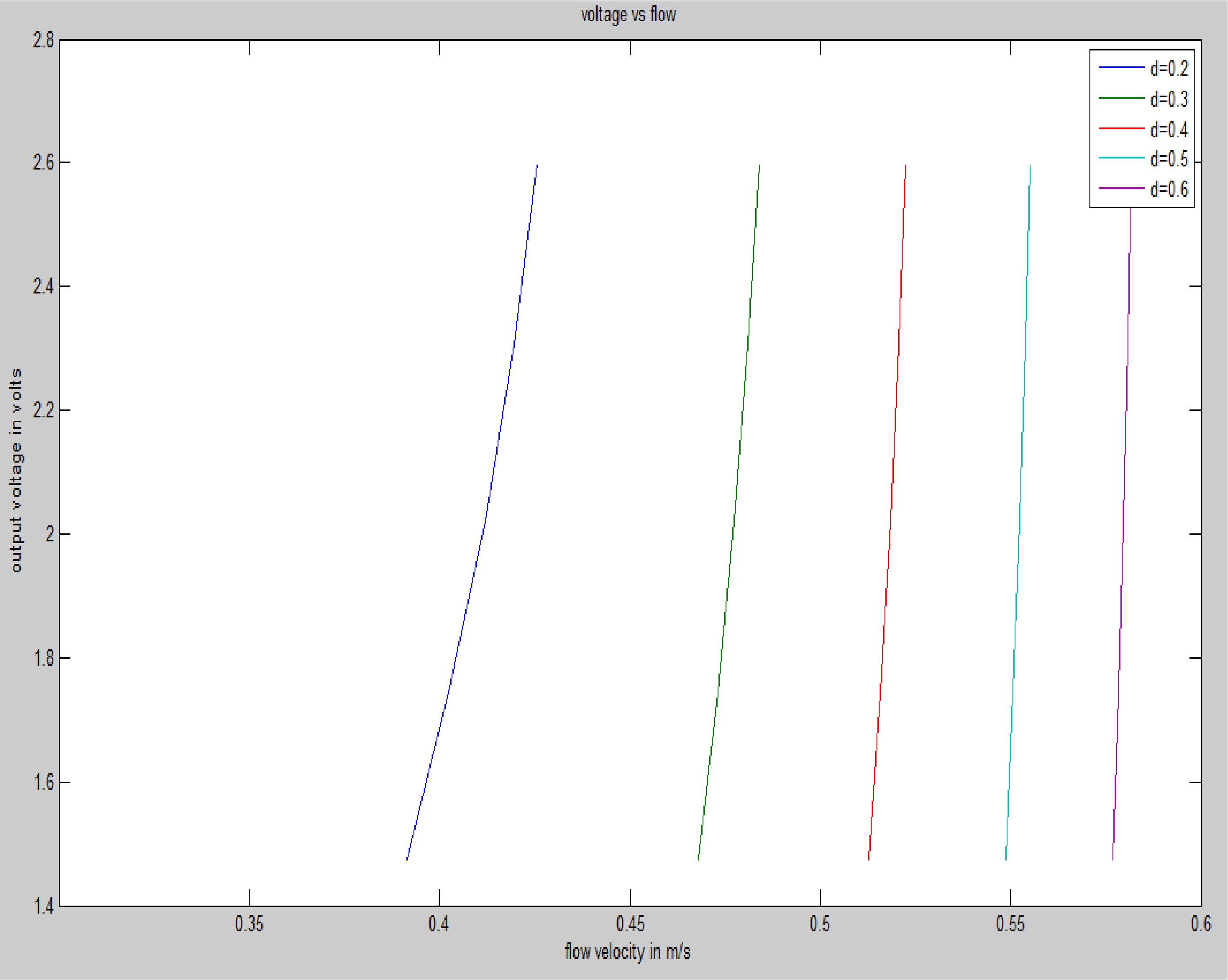


Fig 4.6

CHAPTER 5

CONCLUSION AND REFERENCES

This experiment particularly shows how to measure flow velocity of a fluid.

The resistance of the sensor changes which is detected by the Wheatstone bridge and a feedback current is supplied to the sensor in order to keep the temperature constant and hence the temperature .this happens in case of constant temperature type anemometer .in the other type i.e. constant current type the current flowing through the sensor is kept constant and the change in resistance is observed. Practically this process was not possible in case of constant current type anemometer there is not much application because there are a lot of demerit one of them is the there is a chance of breaking of the sensor due to overheating . so this was not a proper method and therefore we didn’t carry out the practical experiment of this type.

Constant temperature needs a particular type of sensor. It basically uses the wire made up of platinum and tungsten which is very costly in order to get. Temperature above the room temperature is needed to be maintained which is practically not possible in ordinary labs.

When the current is supplied to the sensor the temperature of the sensor should increase and hence the resistance which cannot be achieved because the heat would be radiated out and would not contribute totally to the increase in resistance which would cause error.

Keeping all these factors in mind we did simulation of the circuit

in P-spice .So in order to change the flow we changed the resistance of the sensor (one arm of the Wheatstone bridge). This change caused a change in the output voltage which was amplified using a differential amplifier just to increase the sensitivity. The output obtained by the Wheatstone bridge is put into the equation (28) in order to get the value of flow velocity.

And finally we obtain the velocity of the fluid flow by back calculating using the Wheatstone bridge output.

Effect of change in fluid

We calculated the change in output readings for different fluids such as alcohol, water, glycerine and olive oil. Fluid density and fluid thermal conductivity are directly proportional to the output voltage. Therefore the graphs obtained for same dimension or same sensor high output voltage is obtained for the liquid with high conductivity and density. From this observation we conclude that if a less conductive or less dense fluid is used then the amplifier gain should be high enough to detect the changes in resistance.

Effect of change in dimensions

Dimension change means the change in sensor. When the heat exchange area is increases which is done by increasing the diameter the sensitivity increases as we have seen in fig the output is highest for the higher value of diameter.

Comparison of theoretical output with the simulated output

When we compare fig 3.1 and figure 4.2 we can see that both have similar behavior fig 3.1 represents the theoretical output and fig 4.2 represents the practical simulated output

Since the theoretical output has error and we have only considered 5 points of the graph the graph is not smooth as fig 3.1

The same thing is seen when we compare fig 3.2 and fig 4.4 just a smoothness of the curve differs.

References

[1] Stainback, P.C. and Nagabushana, K.A,” Review of Hot-Wire Anemometry Techniques and the Range of their Applicability for Various Flows”, Electronic Journal of Fluids Engineering, Transactions of the ASME.

[2] J Jagoda , N Komerath and J Seitzman,” **Unsteady Velocity Measurements in a Jet Using a Hot Wire Anemometer**”,

[3] JAN F. KREIDER,” A Simple Stable Constant-Temperature Hot-Wire Anemometer”,IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, JUNE 1973.

[4] Noraznafulsima Khamshah1, Ahmed N. Abdalla2*, S. P. Koh3 and Hassan Farhan Rashag” Issues and temperature compensation techniques for hot wire thermal flow sensor: A review”, International Journal of the Physical Sciences Vol. 6(14), pp. 3270 –3278, 18 July, 2011.

[5] John G Olin(PhD), Seira Instruments, ”Industrial Thermal Mass Flow Meters”, Measurement and Control.

[6] John P Bentley ,” Principles of Measurements System” Third Edition, Pearson Publication.

[7] Ernest O.Doeblin.”Measurement Systems Application and Design”,Third Edition, International student Edition.