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Flow characteristics of fluid and its effectiveness on orifice plate using pneumatic proportional control

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A number of studies on effect of temperature on the flow characteristics of various fluids have been carried out. The aim of this work was to examine the flow characteristics of hexane upon the influence of temperature as well as the effectiveness response of orifice plate using pneumatic proportional control. Knowledge of the past on temperature impact as one aspect of the information set held by various scientific and a well established finding in engineering is that changes in composition can change the effect of temperature on the flow characteristics of hexane in a flow line system. The particular aspects of temperature impact on the research work highlighted are density, viscosity and pressure characteristics. The effect of temperature on flow characteristics of hexane was examined within the temperature range of 283 to 323 K and Bernoulli's equation knowledge of the past was used in developing the model for this paper. The mathematical models developed were simulated using the numerical concept of polynomial expression of the best fit. The effects of temperature on the functional parameters were examined and proportional gain at various error range of E = 0.1 to 0.5 were considered during the investigation. These effects on the variation of the results were attributed to the temperature, flow characteristics of the hexane and its effectiveness on orifice plate using pneumatic proportional control.

Key words: Effect, temperature, hexane, effectiveness, flow characteristics, orifice plate.

INTRODUCTION

The current worldwide complain against pneumatic proportional control has attracted the attention of engineers. In process of investigating the fluid flow characteristics and its influence on the orifices plate using pneumatic proportional control, may result to analysis of some functional parameters, such as the effect of temperature pressure and viscosity, on the flow rate of the substance (hexane) under investigation.

The investigation has to be carried out in such a way as to protect and preserve the failure of the orifices plate while still achieving desire economic benefiting of the research work. In Nigeria today, most of the industrial equipment in operation uses pneumatic system of both upstream and downstream sectors as their operations have rapidly increased. The essence of the studies is to examine the pneumatic proportional control principles on the orifices plate upon the influence of flow characteristics as well as the possible error range effect on the system. The research is conducted with the aim to compare and contrast the variations experienced due to

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constant area, which its influence was examined and reported to be depended of pressure drop and temperature (Perry and Green, 1984; Byron et al., 1976; Williams, 1989; HS, 1978; Bergen et al., 1999 Eckman, 1958; Gerard, 1998). Investigation conducted revealed that variation in temperature and pressure may either increase or decrease the density and viscosity of the substance as reported (Winkler, 1997; LENTECH, 2005; Chrysikopoulos et al., 2003; Glaso, 1980; Al-Marhoun, 2003). As the fluid flow through the orifices plate it pressure decreases and the fluid then is forced to converge to pass through the small hole; the point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called vena contracta point (Donald, 1950). As it does so, the velocity and the pressure changes. Beyond the vena contracta, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the vena contracta, the volumetric and mass flow rates can be obtained from Bernoulli's equation, as reported by various researchers (Labedi, 1990; Uyigue and Umoh, 2007; Bradford et al., 2006; Ukpaka, 2012).

Similarly, research conducted revealed that various works have been done in flow characteristics; attempt has been made to monitor and predict the pressure drop at constant area in a horizontal orifice plate using different fluids as presented (Cunningham, 1951; Fried, 2000; Winkler, 1997; JICA, 2000; Zhn et al., 2001). Only a small number of rivers are appropriate for the use of this technology, since the plate must remain completely immersed. That is, the approach pipe must be full, and the river must be substantially free of debris. In the natural environment large orifice plates are used to control onward flow in flood relief dams. In these structures a low dam is placed across a river and in normal operation the water flow through the orifice plate unimpeded as the orifice is substantially larger than normal flow cross section as presented by (Jiang et al., 2002, Consider, 1957; Eckman, 1958). However, in floods, the flow rate rises and floods out the orifice plate which can then only pass a flow determined by the physical dimensions of the orifice. Flow is then held back behind the low dam in a temporary reservoir which is slowly discharged through the orifice when the flood subsides.

MATERIALS AND METHODS

Materials used for the investigation includes: hexane, 2 inche pvc pipe, pump, thermometer, heater, batch reactor, speed sound density meter, cylindrical viscometer.

Sample collection

The hexane sample was collected from the Chemical/Petrochemical Engineering Laboratory in Rivers State University of Science and Technology Nkpolu, Port Harcourt. The sample was used in setting up the main experimental work for the investigation.

The flow diagram of the experimental set-up

The flow diagram illustrating the experimental set up for the investigation conducted upon, the effect of temperature on the flow characteristics.

Experimental procedure

The hexane sample was collected from the Department of Chemical/Petrochemical Engineering Laboratory in Rivers State University of Science and Technology, Nkpolu, Port Harcourt using glass bottles of 10 L each. All the samples collected were introduced into the batch reactor set-up to achieve 50 L of hexane as raw material for the investigation. Thermometer was immersed into the glass reactor where a heater was inserted and glass reactor was filled with water as shown in Figure 1, above. The electric heater was connected to the electrical source, which heated up the water component in glass batch reactor. The temperature of the heater was controlled at various operating conditions of 283 to 323K. The glass bottle containing the fluid experienced the process of conduction, conversion and radiation. Similarly, another thermometer was immersed into the glass bottle containing the hexane, this was necessary to enable us know the actual operating temperature of hexane before subjecting into flow characteristics. A pump of 0.5 Hp was inserted and regulated within the speed sound density meter inserted along the flow line as shown in Figure 1. The density of the fluid was measured using speed sound density meter and viscosity capillary viscosity respectively at different operating temperature. The pressure drop on the flow line was examined based on the effectiveness the orifice plate. The output temperature of the hexane was measured, as well as the density and viscosity. The system was design in a manner in which the proportional gain was estimated using mathematical tools and operational principle. The Bernoulli's equation knowledge of the past was applied in resolving the problem of orifice plate effect on the effectiveness of flow in pipe system using the principles that governs flow characteristics as shown in Figure 2.

The model

In developing the mathematical model the following assumptions were considered:

1. The research was conducted at various operating temperature
2. The process of conduction, convention and radiation of heat from the water zone into the hexane zone was experienced as thermometer is immense before allowing the flow of the raw material under investigation to ascertain the required temperature in the reactor.
3. The investigation was conducted using 2 inches pvc pipe connected to achieve a total length of 21 m with the displacement velocity of 1m/s in the system.

By assuming steady-state, incompressible (constant fluid density) laminar flow in a horizontal pipes no change in elevation with negligible frictional losses. Bernoulli's equation reduces to an equation relation the conservation of energy between two points on the same stream line is given as

$$P_2 + \frac{1}{2}\rho V_2^2 = P_1 \quad (1)$$

Where P_1 is output pressure and P_2 is final pressure (N/m^2), ρ is

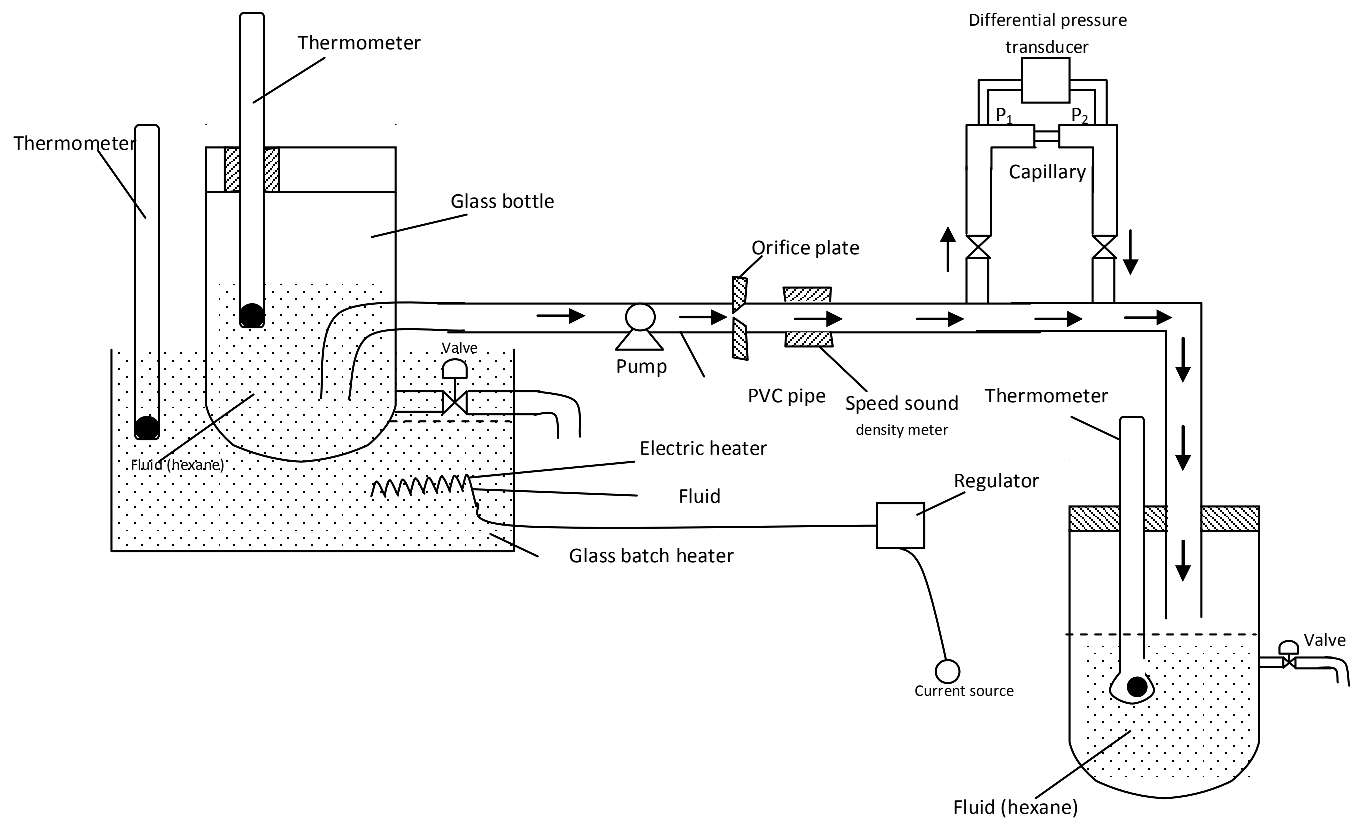

Figure 1. Experimental set-up to investigate the effect of temperature on flow characteristics of fluid.

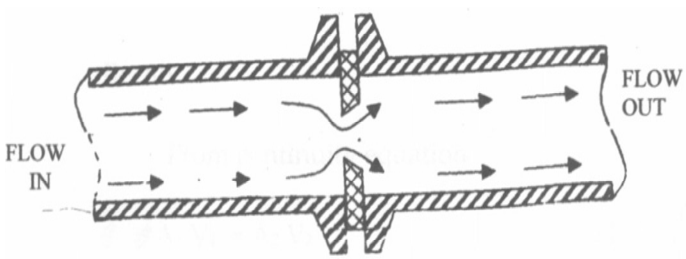

Figure 2. Simple diagram of fluid flowing through a pipe.

density (kg/m^3), V_2 is final velocity (m/s). Recalling the process known as continuity equation, the following expression can be obtained as

$$A_1V_1 = A_2 V_2 \tag{2}$$

Where A_1 is the cross-sectional area of the pvc pipe (mm), A_2 is the cross-sectional area of the orifices (mm), ϕ is the flow (m^3/s)

$$\text{but } V_1 = \frac{\phi}{A_1} \; and \; V_2 = \frac{\phi}{A_2} \tag{3}$$

substituting Equation (3) into (1) we have

$$P_1 - P_2 = \frac{1}{2}\rho\left(\frac{\phi}{A_2}\right) - \rho\left(\frac{\phi}{A_1}\right)^2 \tag{4}$$

Where P_1 is input pressure or initial pressure (N/m^2), P_2 is output or final pressure N/m^2

Solving for ϕ from Equation (4) we have

$$\phi = A_2 \sqrt{\frac{2(P_1 - P_2)/\rho}{1 - (A_2/A_1)^2}} \tag{5}$$

Expressing Equation (5) in term of diameter relationship of

$$A_2/A_1 = \frac{(2\cancel{\pi} r_2)^2}{(2\cancel{\pi} r_1)^2} = \left[\frac{(d_2^2)}{(d_1^2)}\right]$$

Since r = d/2 and $r_2^2 \neq r_1^2$ therefore equation (5) can be written as

$$\phi = A_2 \sqrt{\frac{1}{1 - (d_2/d_1)^4}} \sqrt{\frac{2(P - P_{21})}{\rho}} \tag{6}$$

The above expression for Equation (6) gives the theoretical volume flow rate. Introducing the beta factor into Equation (6)

Factor $\beta = d_2/d_1$ as well as the coefficient of discharge Cd, therefore Equation (6) becomes

$$\phi = C_d A_2 \sqrt{\frac{1}{1-\beta^4}} \sqrt{\frac{2(P_1 - P)_2}{\rho}} \quad (7)$$

Finally, introducing the meter coefficient C which is defined as $C = \frac{Cd}{\sqrt{1-\beta^4}}$ to obtain the final equation of the volumetric flow of the fluid through the orifice, we have

$$\phi = CA_2 \sqrt{\frac{2(P_1 - P_2)}{\rho}} \quad (8)$$

Equation (9) can be obtained by multiplying the density of the fluid with the mass flow rate at any section in the pipe is given as

$$\dot{M} = \rho\phi = CA_2 \sqrt{2\rho(P_1 - P_2)} \quad (9)$$

A fluid passing through the orifice construction above will experience a drop in pressure across the orifice. This charge can be used to measure the flow rate of the fluid. Hence, to calculate the flow rate (ϕ) of the fluid passing through an orifice plates enters the parameters above. Hence, we have

$$\phi = CA_2 \sqrt{\frac{2(P_1 - P_2)}{\rho}} \quad (10)$$

Considering material balance of the orifice and the fluid passing through the orifice is at steady state condition. Therefore, the rate of accumulation and consumption is equal to zero. Therefore Equation (8) can be expressed as:

$$\frac{2(P_1 - P_2)}{\rho} = \frac{\phi^2}{C^2 A_2^2}$$

$$\Delta P = P_1 - P_2 = \frac{\phi^2 \rho}{2C^2 A_2^2}$$

Equation (10) can also be written as

$$\Delta P = \frac{\phi^2 \rho}{2C^2 A_2^2} \quad (11)$$

Orifice plate and pneumatic proportional control model

Considering the mathematical expression as presented in Equation (12)

$$\Delta P = P_1 - P_2 = \frac{\phi^2 \rho}{2C^2 A_2^2} \quad (12)$$

Where Δp = change in pressure (N/m^2)

Recalling the pneumatic proportional control model where the output pressure can be expressed as;

P = Po + Kc E

Considering the concept that P = P_1 –P_2 = ΔP, where P = output signal, P_o is output signal when there is no error, K_c is proportional gain, E is error

Therefore Equation (10) and (12) combing yields

$$\frac{\phi^2 \rho}{2C^2 A_2^2} = P_0 + K_c E \quad (13)$$

Therefore rearranging Equation (13) we have

$$\phi^2 \rho = 2C^2 A_2^2 (P_o + K_c E) \quad (14)$$

$$\phi^2 = \frac{2C^2 A_2^2 (P_o + K_c E)}{\rho} \quad (15)$$

If 2C^2 = γ, therefore substituting the expression into Equation (15) we have

$$\phi = \sqrt{\frac{\gamma(P_o + K_c E)}{\rho}} \mathrm{A}^2{}_2 \quad (16)$$

From Equation (16) making density (ρ) the subject of the formula, we have

$$\rho = \frac{2C^2 A_2^2 (P_o + K_c E)}{\phi^2} \quad (17)$$

From Equation (16) making E the subject of the formula we have

$$K_c E = \left[\frac{\phi^2 \rho}{2C^2 A_2^2} - P_o\right] \quad (18)$$

$$E = \frac{\left[\frac{\phi^2 \rho}{2C^2 A_2^2} - P_o\right]}{K_c} \quad (19)$$

Similarly, from Equation (16) making K_c the subject formula, we have

Table 1. Evaluation of functional parameters of hexane.

Component	Temperature (K)	Densiy (kg/m^3)	Pressure (pa)	Viscosity (Ns/m^2)	Flow rate φ (m^3/s)
Hezane	283	678	10	0.62	0.095837251
Hezane	293	668	20	0.57	0.136545051
Hezane	303	658	30	0.51	0.168498825
Hezane	313	649	40	0.45	0.195910108
Hezane	323	639	50	0.4	0.220741388

$$K_c\ E + P_o = \frac{\phi^2 \rho}{2C^2 A_2^2} \tag{20}$$

where P_o is output signal when there is no error

$$K_c = \left[\frac{\phi^2 \rho}{2C^2 A_2^2} - P_o\right] /\mathrm{E} \tag{21}$$

$$K_c = \frac{\left[\frac{\phi^2 \rho}{2\ C^2 A_2^2} - P_o\right]}{E} \tag{22}$$

Computational procedure

The following parameters were arbitrarily chosen, orifice flow coefficient (dimensionless) (C) = 0.62; cross sectional area of the orifice A_2 = 0.9 m^2, temperature within the range of 283 to 323K and including all experimental data obtained from the investigation as presented in this paper.

RESULT AND DISCUSSION

The results obtained from the research work are presented in Figures. The relationship among, density, temperature, viscosity, pressure, flow rate, proportional gain is presented in Figures and Tables 1, 2 and 3.

The graph presented in Figure 3 illustrates the relationship between density and temperature. It is seen that increase in temperature resulted to decrease in density. The equation of the best fit was established using polynomial and it is given as P = - 0.97T + 687.5 and the square root is given as R^2 = 0.9997 which is the best fit of the root.

From Figure 4, the variation in pressure was studied with the variation in temperature. The results obtained in Figure 4 illustrate increase in pressure with increase in temperature. The equation of the best fit was P = T with R^2 = 1.

Figure 5 illustrates the relationship between viscosity and temperature. It is seen that from Figure 5, viscosity decreases with increase in temperature. The polynomial expression is given as V = - 0.0056T +0.678 and R^2 = 0.9987.

The relationship between flow rate and temperature is illustrated in Figure 6. The results obtained showed that increase in temperature yielded increase in flow rate. The polynomial expression of the curve is given as ϕ = 0.0031 T + 0.0708 with R^2 = 0.9899

The result presented in Figure 7 illustrates the relationship between proportional gain and temperature. Increase in proportional gain is experience with the temperature of 283 to 290K and suddenly decrease within the temperature range of 290 to 300K and finally increased within the temperature range of 300 to 323K at different values of KcE = 0.1, 0.2, 0.3, 0.4 and 0.5. The polynomial expression of the graph as shown in Figure 7 is given as KcE(0.1) = - 0.0008T^4 + 0.1081T^3 – 47147T^2 + 79.788T – 408.56 with R^2 = 1, KcE (0.2) = -0.004T^4 + 0.054T^3 – 2.3574T^2 + 39.894T – 204.28 with R^2 = 1, KcE (0.3) = - 0.0003T^4 + 0.0361T^3 – 1.5716T^2 26.596T – 136.19 with R^2 = 1 and K_cE(0.4) = - 0.002T^4 + 0.027T^3 – 1.1787T^2 + 19.947T – 102.14 with R^2 = 1, K_cE(0.5) = - 0.0002T^4 + 0.0216T^3 – 0.9429T^2 + 15.958T – 81.712 with R^2 = 1.

The result presented in Figure 8 illustrates the relationship between the proportional gain and density. It is that a decrease in proportional gain for the various values of KcE = 0.1, 0.2, 0.3, 0.4 and 0.5 was observed with increase in density at 650 kg/m^3 and suddenly increased in proportional gain within the density range of 650 to 660 kg/m^3 and finally a decrease in proportional gain was observed with increase in density as presented in Figure 8. The variation in density can be attributed to the variation in proportional gain as well as the functional parameters. The polynomial expression of the graph as shown in Figure 8 is given as KcE(0.1) = - 0.001ρ^4 +2.6419ρ^3 – 2598.2ρ^2+ IE + 06ρ – 2E+08 and R^2 = 1, K_cE(0.2) = - 0.0005 ρ^4 + 1.3221 ρ^3 – 1299.1 ρ^2 + 567648 ρ - 9E + 07 with R^2 = 1, K_cE(0.3) = - 0.0003ρ^4 + 0.8806ρ^3 -866.06ρ^2 + 378432ρ - 6E + 07 with R^2 = 1, K_cE(0.4) = - 0.00032ρ^4 + 0.66052ρ^3 – 649.542ρ^2 + 2838242ρ - 5E + 07 with R^2 = 1, K_cE(0.5) = - 0.0002ρ^2 + 0.5284ρ^3 – 519.63ρ^2 + 227059ρ - 4E+07 and R^2 = 1.

The relationship between proportional gain and

Table 2. Mathematical computation of the functional parameters at various operating temperature, density, pressure and viscosity as well at various errors (E).

Component	Temperature K	Density (kg/m^3)	Pressure (N/m^2)	Viscosity (NS/m)	Flow rate φ(m^3/s)	Proportional gain (Kc)	Coefficient of proportional gain (Kc *10e14)
				E = 0.1			
Hezane	283	678	10	0.62	0.09584	1.77636E-14	17.7636
Hezane	293	668	20	0.57	0.13655	3.55271E-14	35.5271
Hezane	303	658	30	0.51	0.16850	0	0.0000
Hezane	313	649	40	0.45	0.19591	7.10543E-14	71.0543
Hezane	323	639	50	0.4	0.22074	2.13163E-13	213.1628
				E = 0.2			
Hezane	283	678	10	0.62	0.09584	8.88178E-15	8.881784197
Hezane	293	668	20	0.57	0.13655	1.77636E-14	17.76356839
Hezane	303	658	30	0.51	0.16850	0	0
Hezane	313	649	40	0.45	0.19591	3.55271E-14	35.52713679
Hezane	323	639	50	0.4	0.22074	1.06581E-13	106.5814104
				E = 0.3			
Hezane	283	678	10	0.62	0.09584	5.92119E-15	5.921189465
Hezane	293	668	20	0.57	0.13655	1.18424E-14	11.84237893
Hezane	303	658	30	0.51	0.16850	0	0
Hezane	313	649	40	0.45	0.19591	2.36848E-14	23.68475786
Hezane	323	639	50	0.4	0.22074	7.10543E-14	71.05427358
				E = 0.4			
Hezane	283	678	10	0.62	0.09584	4.44089E-15	4.440892099
Hezane	293	668	20	0.57	0.13655	8.88178E-15	8.881784197
Hezane	303	658	30	0.51	0.16850	0	0
Hezane	313	649	40	0.45	0.19591	1.77636E-14	17.76356839
Hezane	323	639	50	0.4	0.22074	5.32907E-14	53.29070518
				E = 0.5			
Hezane	283	678	10	0.62	0.09584	3.55271E-15	3.552713679
Hezane	293	668	20	0.57	0.13655	7.10543E-15	7.105427358
Hezane	303	658	30	0.51	0.16850	0	0
Hezane	313	649	40	0.45	0.19591	1.42109E-14	14.21085472
Hezane	323	639	50	0.4	0.22074	4.26326E-14	42.63256415

Table 3. Evaluation of functional parameters at constant temperature, density, viscosity, pressure.

E	Flow rate (φ)	Proportional gain (Kc)	Coefficient of proportional gain (Kc*10e14)
	At temperature = 283 K		
0.1	0.095837251	1.77636E-14	17.76356839
0.2	0.095837251	8.88178E-15	8.881784197
0.3	0.095837251	5.92119E-15	5.921189465
0.4	0.095837251	4.44089E-15	4.440892099
0.5	0.095837251	3.55271E-15	3.552713679

Table 3. Contd.

	At temperature = 293 K		
0.1	0.136545051	3.55271E-14	35.52713679
0.2	0.136545051	1.77636E-14	17.76356839
0.3	0.136545051	1.18424E-14	11.84237893
0.4	0.136545051	8.88178E-15	8.881784197
0.5	0.136545051	7.10543E-15	7.105427358
	At temperature = 303		
0.1	0.168498825	0	0
0.2	0.168498825	0	0
0.3	0.168498825	0	0
0.4	0.168498825	0	0
0.5	0.168498825	0	0
	At temperature = 313K		
0.1	0.195910108	7.10543E-14	71.05427358
0.2	0.195910108	3.55271E-14	35.52713679
0.3	0.195910108	2.36848E-14	23.68475786
0.4	0.195910108	1.77636E-14	17.76356839
0.5	0.195910108	1.42109E-14	14.21085472
	At temperature = 323K		
0.1	0.220741388	2.13163E-13	213.1628207
0.2	0.220741388	1.06581E-13	106.5814104
0.3	0.220741388	7.10543E-14	71.05427358
0.4	0.220741388	5.32907E-14	53.29070518
0.5	0.220741388	4.26326E-14	42.63256415

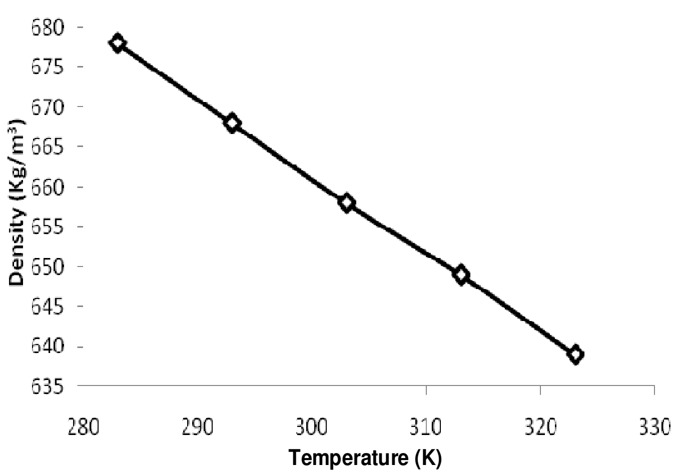

Figure 3. Graph of density against temperature for hexane.

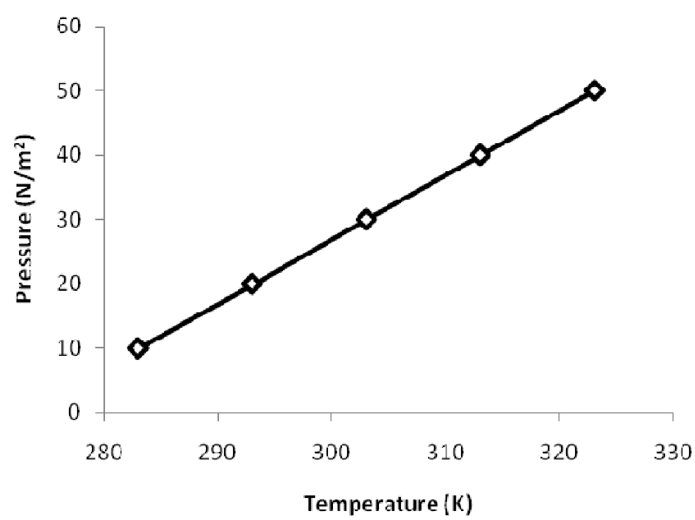

Figure 4. Graph of Pressure against temperature for hexane.

pressure is shown in Figure 9. Increase in proportional gain is experienced with increase in pressure within the range of 20 to 30 N/m^2 and sudden decrease was observed in proportional gain within the range of 30 to 40 N/m^2. Above 40 N/m^2 an increase in pressure for the value of KcE = 0.1, 0.2, 0.3, 0.4 and 0.5. The variation in the proportional gain can be attributed to the variation in

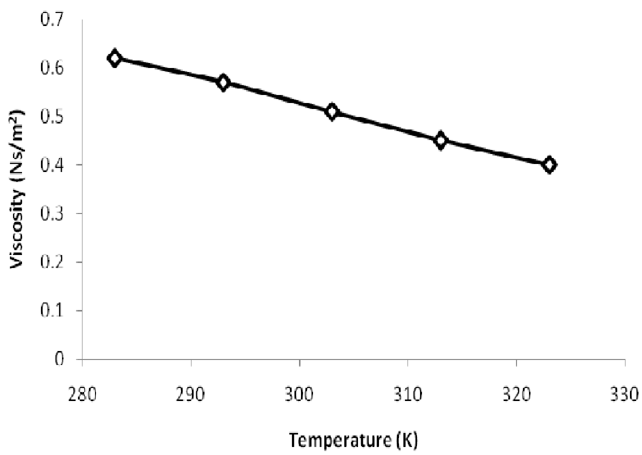

Figure 5. Graph of viscosity against temperature for hexane.

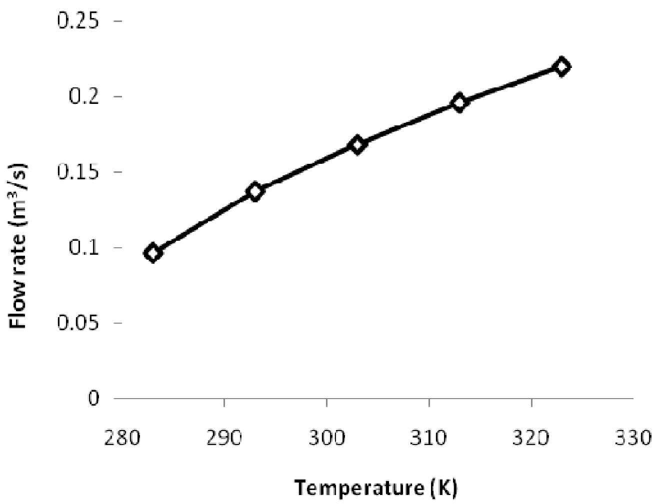

Figure 6. Graph of flow rate against temperature for hexane.

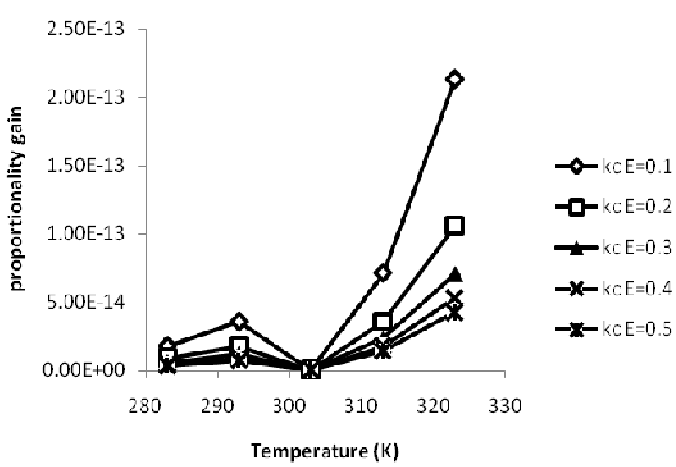

Figure 7. Graph of proportional gain verses temperature for various component of E.

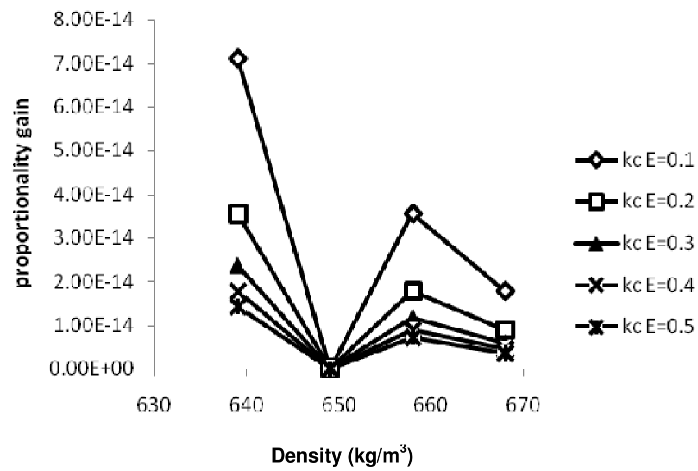

Figure 8. Graph of proportional gain verses density for various component of E.

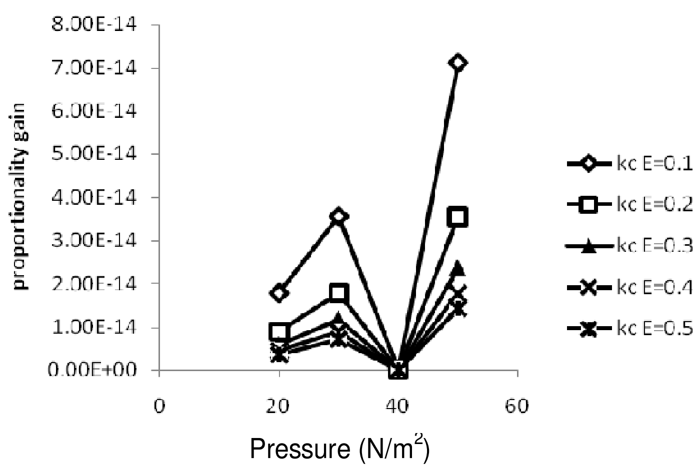

Figure 9. Graph of proportional gain verses pressure for various component of E.

pressure as well as effect of temperature in the system. The polynomial expression of the graph as shown in Figure 9 is given as KcE(0.1) $= - 0.1081P^3 – 4.7147P^2 + 79.788P - 408.56$ with $R^2 = 1$, $K_cE(0.2) = - 0.0004P^4 + 0.054P^3 - 2.3574P^2 + 39.894P - 204.28$ with $R^2 = 1$, $K_cE(0.3) = - 0.002\rho^4 + 0.027\rho^3 – 1.1787\rho^2 + 19.947\rho - 102.14$ with $R^2 = 1$, $K_cE(0.4) = - 0.0002P^4 + 0.0216P^3 – 0.929P^2 + 15.958P + 15.958P - 81.712$ with $R^2 = 1$, $K_cE(0.5) = - 0.0002P^4 + 0.0216P^3 – 0.929P^2 + 15.958P + 15.958P - 81.712$ with $R^2 = 1$.

Figure 10 illustrates the variation in the proportional gain flow rate. Increase in proportional gain was observe with increase in flow rate within the range of 0.15 to 0.17 m^3/s and suddenly the proportional gain decreased with increase in flow rate with the range of 0.175 to 0.2 m^3/s. An increase in proportional gain was finally experience

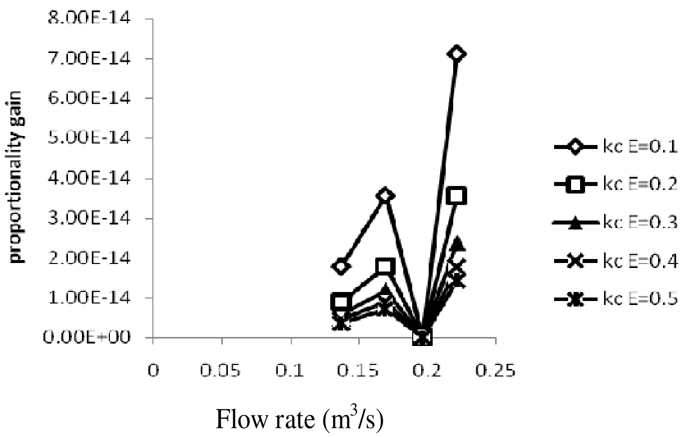

Figure 10. Graph of proportional gain verses flow rate for various component of E.

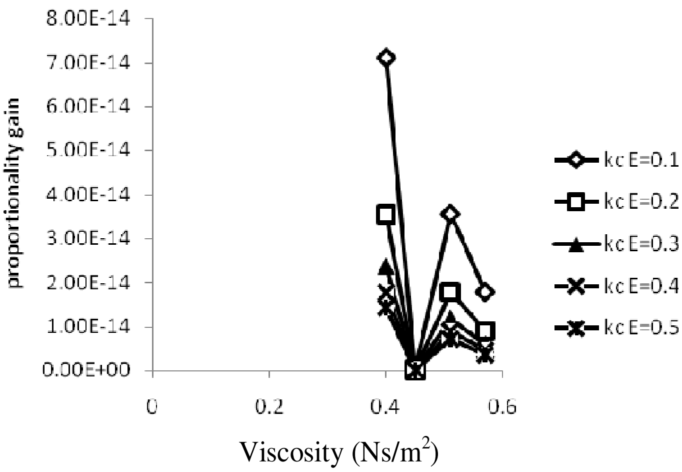

Figure 11. Graph of proportional gain verses viscosity for various component of E.

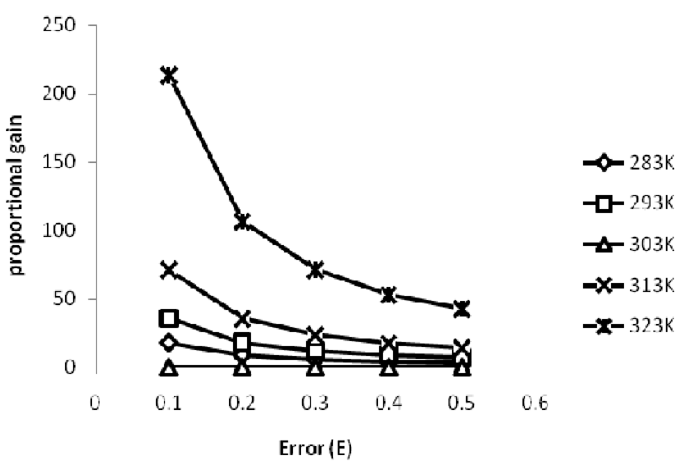

Figure 12. Graph of proportional gain verses Error at different operating temperature.

with increase flow rate for the various values of KcE = 0.1, 0.2, 0.3 0.4 and 0.5. The polynomial expression of the graph as shown in Figure 10 is given as KcE(0.1) = $518185\phi^3 - 219220\ \phi^2 + 30008\ \phi - 1299.7$ with R^2 = 0.991, $K_cE(0.2) = 3E + 06\phi^4 + 2E + 06\ \phi^3 - 631494\ \phi^2 + 67649\ \phi - 2570.5$ with $R^2 = 1$, $K_cE(0.3) = - 2E + 06\phi^4 + 2E + 06\ \phi^4 + 2E + 06\phi^3 - 420996\ \phi^2 + 451000\phi - 1713.7$with $R^2 =1$, $K_cE(0.4) = - IE + 06\phi^4 + 994512\ \phi^3 - 252597\phi^2 + 27060\phi - 1028.2$ with $R^2 = 1$, $K_cE\ (0.5) = - 1E + 06\phi^4 + 994512\phi^3 - 252597\phi^2 + 27060\phi - 1028.2$ with $R^2 = 1$.

The relationship between the proportional gain and viscosity is presented in Figure 11. And results obtained indicate decrease in proportional gain with increase in viscosity within the range of 0.4 to 0.49 Ns/m^2. And increase was observed in proportional gain within an increase in density for a range of 0.49 to 0.57 Ns/m^2 and suddenly decreased with increase in viscosity for the various components of KcE = 0.1, 0.2, 0.3, 0.4 and 0.5.The variation in the proportional gain can be attributed to the variation in viscosity. The polynomial expression of the graph as shown in Figure 11 is given as $KcE(0.1) = 8707.3V^2 - 9633.8V + 2661.3$ with R^2 = 0.9218, $K_cE(0.2) = - 206297V^4 + 397625V^3 - 280742V^2 + 85537V - 9391.9$ with $R^2 = 1$, $K_cE(0.3) = - 123778V^4 + 23857V^3 -168445V^2 + 51322V - 5635.1$ with $R^2 = 1$

Figure 12 illustrates the relationship between the proportional gain and error at different operating temperature. The result obtained indicates decrease in proportional gain with increase in error at different operating temperature conditions. The variation in the proportional gain can be attributed and other functional parameter and coefficient. The polynomial expression of the graph as shown in Figure 12 is given as KcE(0.1) = $1.7764E^{-1}$ and $R^2 = 1$, $K_cE(0.2) = 3.5527E^{-1}$ and $R^2 = 1$, $K_cE(0.3) = 0$, R^2 = N/A, $K_cE(0.4) = 7.1054E^{-1}$ and $R^2 = 1$, $K_cE(0.5) = 21.316E^{-1}$ and $R^2 = 1$.

Conclusion

In this present study baseline experiments were performed to determine the concentration of the density viscosity of hexane. To this end the hexane substance was investigated for the flow characteristic and temperature potential impact on the effectiveness of the orifice plate in term of response to action. The Bernoulli's equation was used as a guideline in the establishment of the developed mathematical model which was correlated to the pneumatic proportional control. The correlation was useful in the evaluation of the proportional gain and its effect upon the functional parameters considered on this study.

This study has also demonstrated that there is a significant difference in flow characteristics due to the application of different temperature which leads to different polynomial expression as presented in Figure. Some caution is needed in extrapolating from these findings, given that this is a particular hexane substance with relatively intensive in industrial activities. A reduced temperature system, for examples, may result in a more favorable outcome for petrochemical process, depending on the process condition needed.

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