Journal of Engineering and Applied Sciences 13 (15): 6062-6071, 2018
ISSN: 1816-949X

Experimental Survey of Heat Transfer Enhancement for Kerosene with Polymer Additive under Turbulent Flow

Rafel Hekmat Hameed
Department of Mechanical Engineering, College of Engineering, University of Babylon, Hillah, Iraq

Abstract: An experimental rig facility has been designed and constructed to study heat transfer enhancement of kerosene with polymer flow in the developing region in an 80 mm ID 6 m long pipe. The temperature at all sections and at pipe wall as well as the velocity of working fluid through all pipe sections are measured with different concentration ratio of polymer additive. It was found that the polymer additive has a clear effect on heat transfer coefficient and Nusselt number in the fully developed region under turbulent flow conditions. The heat transfer coefficient is affected Reynolds number and thermal conductivity of pipe material. Results show that the heat transfer coefficient decreases with increasing the amount of polymer concentration. Also, the coefficient of heat transfer decreases with increasing Reynolds number. It was found that reduction percentage values of heat transfer coefficient due to the concentration ratio of polymer additive are about 42-52.7% than the percentage values without polymer additive. A good agreement is seen between these results and the available resultsin the literature.

Key words: Polymer, kerosene, additive, heat transfer coefficient, experimental investigation, agreement

INTRODUCTION

Kerosene as known paraffin, lamp oil is a combustible hydrocarbon liquid which derived from petroleum. It was composed of carbon chains that typically contain between 10 and 16 carbon atoms per molecule. It is miscible in petroleum solvents but immiscible in water. Kerosene is hydrocarbon fuel which works at a supercritical pressure is very important in the active cooling system of rocket. The hydrocarbon fuel is composed of several hundred hydrocarbons. Thus, the physical properties of the hydrocarbon fuel are more complex than those of water or carbon dioxide and the convective heat transfer is also more complicated as mentioned by Li *et al*. (2015). Kerosene and most fuels have drawbacks that reason those do not let their long term storage, make stiff conveyance and even utilize. A very small concentration of polymer is added represented by ppm. That means the percentage of polymer is added as one part in one million for volume of kerosene. It is significant that additive which progress several properties should not tumble another properties of fuel and its fineness. Also, raise time to reach flash point over flowing circulation in pipe proposed by Groysman (2014).

Lee *et al*. (2010) presented experimentally the reduction of drag in turbulent flow of kerosene when little quantities of a Polyiso Butylene (PIB) were appended. The impact of temperature and Reynolds number on the decrease of drag with reliance of time, the efficiency of drag reduction for PIB-kerosene was established to reduce with time because of degeneration the chain of polymer encouraged by drastic flow of turbulent. The variation in the efficiency of drag reduction was suited with time dependence. Also, the proposed model was found to describe drag reduction behavior in a turbulent flow. The model was considered to fit the experimental data better at all temperature except the early 10 min for the 25°C.

Dang *et al*. (2013) studied numerically the heat transfer characteristics for kerosene in smooth tubes. They found that the heat transfer deterioration was weakened as the heat flux decreased. That was considered enhancement of heat transfer. They suggested that heat transfer deterioration and recovery might be caused by the change in the turbulent kinetic energy in the vicinity of the pipe wall. In order to further enhance the heat transfer and suppress the heat transfer deterioration of supercritical fluids. They were investigate experimentally various heat transfer enhancement techniques such as internally ribbed tubes, helical coiled tubes and curved tubes.

Huang and Li (2017) investigated experimentally and numericallythe heat transfer executions of flight kerosene inflow in very small tubes in case of supercritical pressures. A model of turbulent kinetic energy with the promote treatment of wall was take into account the effect of turbulence. The results of experimental and theoretical were close. They illustrated two types of heat transfer decadence, first one happened in position where the temperature of the wall surpass the temperature of pseudo-critical value is 690 K while another take place when the temperature of bulk fluid surpass the temperature of pseudo-critical. The influence of mass flow rate, pressure, heat flux and the temperature of inlet on the deterioration of heat transfer were elaborated. The action of pressure on heat transfer is trivial deterioration. It can be revoke by rising pressure and flow rate and reducing the temperature of inlet and heat flux while the effect of heat flux on heat transfer was intricate. The major source for the deterioration of heat transfer was the dramatic distinction of thermo physical properties.

Dang *et al.* (2015) illustrated the kerosene contains other soluble gases such as oxygen about (170 ppm) and nitrogen. The circulation of kerosene results eddies and this will let the soluble gases to liberate. The liberation of the soluble gases could be related to the difference in local pressure of the different points in eddies in cross sectional area and along the pipe. It was found by adding polymer to kerosene was being enhanced at turbulent flow by reducing the drag force. The polymer additive was increased the time for kerosene to reach the flash point, and reduced the friction force and force of pressure drop. From the literature, it may be mentioned that most of works are experimental studies. They focused on calculation the convective heat transfer of supercritical hydrocarbon fuels such as kerosene. The deterioration and enhancement of heat transfer of kerosene flow were observed. It has not yet been established whether kerosene can flow through pipe to measure the temperature and the flow velocity. The aim of this study is to estimate the convective heat transfer coefficient of working fluid (pure kerosene and kerosene with polymer addition), inside circular pipe of 80 mm inside diameter. Also, the Nusselt number and Reynolds number are evaluated depending upon the transient measured data of temperature and velocity along the pipe.

Working fluid: Liquid kerosene was the most important part of the working fluid utilize in this experiment. Properties of kerosene and Poly Isobutylene polymer (PIB) were presented by Abulencia *et al.* (2009), kerosene has density of 770 (kg/m^3), specific heat 2010 (J/kg.°C), dynamic viscosity 0.0019 (kg/msec) and a flash point 59 °C. Poly Isobutylene polymer (PIB) was used by mixing with diverse concentrations ratio of 50, 75 and 100 ppm. The density of (PIB) polymer is 915 kg/m^3 and has a high molecular weight 10^6(g/mol), high ability soluble in kerosene with low affectivity on kerosene chemical property. The elaboration method of working fluid was mixed the polymer with the kerosene by using gradation flask with scales in mL. It was solved in the flask with a certain volume of kerosene. It takes 2 h to become aviscous liquid, then it was mixed in the reservoir with the kerosene. Working fluid (kerosene with polymer additive) has different properties. Thermo physical properties of working fluid such as density, thermal conductivity, viscosity and specific heat were measured with different concentration of polymer in laboratories of college of engineering materials at Babylon University. Table 1 shows these values of the measuring properties.

Table 1: Thermo physical properties of working fluid

Percentage of concentration (ppm)	Density (kg/m^3)	Specific heat (J/kg °C)	Dynamic viscosity (kg/msec)	Thermal conductivity (W/m °C)	Flash point (°C)
0	770.0	2010	0.0019	0.1040	50.0
50	809.0	1977.97	0.0021	0.1060	60.0
75	813.7	1877.72	0.0025	0.1070	60.5
100	857.4	1745.87	0.0029	0.1072	61.0

MATERIALS AND METHODS

Descriptionof experimental work: The experimental rig was designed and built in order to measure the temperature and velocity of kerosene flowing in horizontal circular pipe. It was found that the temperature of kerosene was increased from ambient temperature to its flash point within 90 min. This is due to the pumping power of kerosene through the gear pump and pipe breaks the blends of liquid hydrocarbon. The test section consists of circular pipe with length 6 m, 80 mm inside diameter and 2 mm thickness. This pipe isconstructedof two sections with different material which is connected to each other. The first section is carbon steel pipe with 4 m length and the second section is Pyrex glass pipe with 2 m length. The test rig is divided into five parts. Four parts are fixed on the carbon steel with length 1 m of each part, and it is presumed the glass pipe as one part with 2 m length. Schematic diagram for the experimental rig facility is given in Fig. 1. Kerosene without and with polymer concentrations as 50, 75 and 100 ppm are streaked by kerosene flow meter with several measurements. A temperature recorder model (BTM-4208SDS) with sensor of thermocouple type K is used to measure the temperature of working fluid inside the pipe and the temperature of the outside wall of the pipe. This apparatus has SD memory card and worked as auto data logger, the accuracy of this device is 0.01. Velocity of the working fluid inside the five sections of pipe is measured by using ultrasonic flow meter. It is transmitter GE infrastructure sensing model (AT868). Pressure transducer (killer type and model PR-32R/80710-34) was used to measure the inlet and out let pressure through flow pipe.

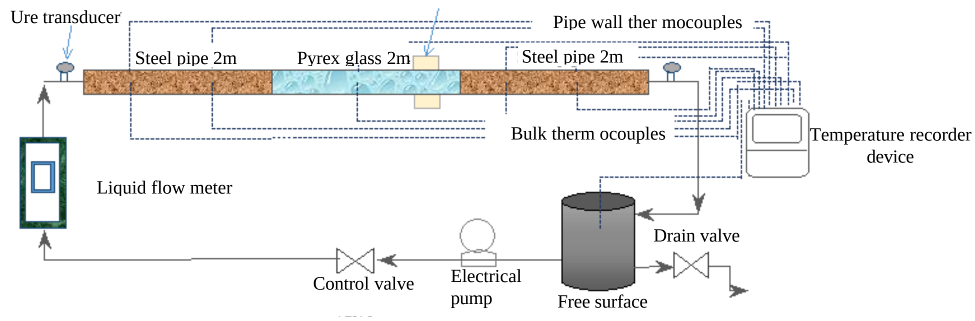

Fig. 1: Schmatic diagram of rig

Experimental procedure: During the experimental work the stainless steel reservoir tankhas dimensions 1 m of length, 0.5 m width and 0.5 m height with 250 L amplitude. It was replete of working fluid without and with polymer at various concentrations ratio of 50, 75 and 100 ppm. That means the polymer is added to reservoir tank as percentage of its volume. This percentage ppm is represented as one part in one million for volume of fluid in the tank. So that, 1ppm = 1 mg/L. The working fluid was forced through the test section by using positive displacement gear pump. Firstly, it was inflation only liquid kerosene through the rig system with different values of volume flow rate. Secondly, it was inflation kerosene together with polymer at distinct concentrations ratio 50, 75 and 100 ppm. The quantity of polymer required for concentration in part per million is calculated such as:

$$1\ \text{ppm} = \frac{2501}{1000000} = 0.00025\ \text{L}\times 1000 = 0.25\ \text{mL} \quad (1)$$

Volume of reservoir tank is 250 L. Then, this value is multiplied by the value of polymer concentration, so, Eq. 1 becomes:

$$1\ \text{ppm} = 0.25\ \text{mL}\times\text{Value of polymer concentration} \quad (2)$$

This result represents the percentage value of polymer concentration in litter per million. Thus, this value is converted to milliliter per million by multiplying the result by 1000. The volume flow rate was measured by a standard flow meter type (FM914231). It was calibrated in order to measure the actual volume flow rate of kerosene at each selection in the experimental work. Stop watch and volumetric flask was used to standardize the kerosene flow meter. Temperatures of working fluid were measured inside the circular pipe at five locations through working time. Also, it was measured the wall temperature of pipe at these locations. These readings of temperature were calibrated by utilization thermometer. Relation between thermometer reading and that measured by temperature recorder was third degrees of a polynomial function, which used to correct the temperature of recorder reading. Velocities of working fluid in these locations were measured by ultrasonic flow meter which was calibrated by kerosene flow meter.

Analysis of experimental data: The convective heat transfer coefficient is calculated from the convective heat transfer rate inside the pipe surface. This heat was generated through pumping of kerosene in a circular pipe with various values of velocity. The kerosene temperature was raised with time. Kerosene is a hydrocarbon fuel form of several hundred hydrocarbons. Thus, the physical properties of the hydrocarbon fuel are more complex than these of water or carbon dioxide and the convective heat transfer is also more intricate. Polyisobutylene polymer was mixed with kerosene in different ratio of concentrations 50, 75 and 100 ppm. The polymer addition was caused relief in the friction factor and pressure drop through the flowing of working fluid. The convective heat transfer coefficient was elaborated for each five sections which were supposed in the experimental work. Heat transfer coefficient of a working fluid was calculated with inside surface of a circular pipe for each section by using Newton's cooling law which was itemized by Cengel and Ghojar (2011) as:

$$q = hA(T_f - T_{win}) \quad (3)$$

$$h = \frac{q}{A(T_f - T_{win})} \quad (4)$$

where, T_f is temperature of working fluid inside pipe, which was measured by thermocouple type K in each section with time and with different values of volume flow rate. The rate of convection heat transfer (q) was estimated by formula as:

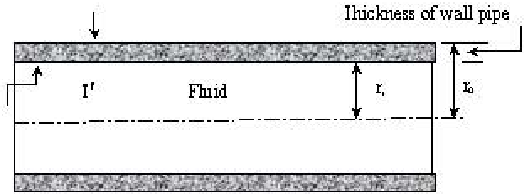

Fig. 2: Longitdinal of the pipe

$$q = mc_p (T_{in}\text{-}T_{out}) \tag{5}$$

where, the volume flow rate:

$$Q = uA \tag{6}$$

Then, the mass flow rate was given as:

$$m = \rho Q = \rho uA \tag{7}$$

It was found the mass flow rate from upper equation then, the convective heat transfer rate was calculated by Eq. 5. T_{win} is the inside pipe wall temperature. This temperature was not measured experimentally. It was calculated by Eq. 8 depending upon the outside wall temperature of the circular pipe, this was measured by thermocouple set up at the outside wall of the pipe for all sections as shown in Fig. 2:

$$q = 2\pi kL \frac{(T_{win}\text{-}T_{wout})}{Ln\,(r_{out}/r_{in})\,(r_o/r_i)} \tag{9}$$

$$\text{Then, } T_{win} = \frac{q\,Ln\,(r_o/r_i)}{2\pi kL} + T_{wout} \tag{8}$$

Then, the convection heat transfer coefficient at working time of 90 min is calculated in this research by using Eq. 4. Nusselt number of working fluid was calculated for five sections at time of 90 min as:

$$Nu \frac{hD}{K} \tag{10}$$

The flow velocity of working fluid was measured by ultrasonic flow meter for each section. It was found a slight change of velocity over time and it was a constant. The Reynolds number of working fluid for each section is determined depending upon the formula:

$$Re = \frac{\rho uD}{k} \tag{11}$$

The pressure is not use in the practical experiment because the present research do not study the friction factor or the drag reduction.

Estimating uncertainties: The experimental data of measuring the local temperature and the velocity were repeated five times to guarantee the repeatability. Three statistical concepts dealing with repeated measurement, these are average (x_{ave}), standard deviation (s) and Standard Error (SE). Equation of each concept is presented as follows. Average which is an estimate of the true value of the measurement:

$$\sum_{i=1}^{n} x_i \tag{12}$$

Standard deviation, illustrate a measure of the spread in the data:

$$\sqrt{\frac{\sum_{i=1}^{n} (x_i\text{-}x_{ave})^2}{N\text{-}1}} \tag{13}$$

Standard error, means an estimate in the uncertainty in the average of the measurement:

$$\frac{s}{\sqrt{N}} \tag{14}$$

The true measured value of (x_i) then given by $x_{ave}\pm SE$. In the above equations x_i represent the values for each measurements data of temperature and velocity, N is the total number of measurements. Thus, these values of temperature and velocity are called correction values and the average of experimental values which were repeating five times is called the true value. Then, the percentage error for the temperature and velocity is evaluated as:

$$\text{Error} = \frac{\text{Correction value-True value}}{\text{Correction value}} \times 100\% \tag{15}$$

These percentage are already given the accuracy calculation for q, Nu and Re.

RESULTS AND DISCUSSION

Table 1 shows the thermo physical properties of working fluid (kerosene with polymer) even of the flash point. These properties are measured with different concentration ratio of polymer additive. It explains that these properties increase with increasing the polymer concentration. This table has been observed that flash point of kerosene reach to 61°C with value of polymer concentration 100 ppm. That means, it is increasing the time to reach kerosene its flash point.

Table 2: Readings of velocity and temperature for different polymer concentrations at Q = 200 L/min and time = 90 min

Distance from inlet (m)	Concen. 0 ppm V (m/sec)	Concen. 0 ppm T (°C)	Concen. 50 ppm V (m/sec)	Concen. 50 ppm T (°C)	Concen. 75 ppm V (m/sec)	Concen. 75 ppm T (°C)	Concen. 100 ppm V (m/sec)	Concen. 100 ppm T (°C)
0.5	0.86	49.7	0.88	44.1	0.89	43.6	0.90	42.8
1.5	0.88	50.0	0.90	43.9	0.92	42.9	0.92	42.4
3	0.89	49.4	0.91	43.9	0.92	42.8	0.94	42.4
4.5	0.92	49.5	0.94	43.8	0.95	42.8	0.95	42.3
5.5	0.95	49.7	0.95	43.9	1.00	42.5	1.02	42.3

Table 3: Readings of velocity and temperature for different polymer concentrations at Q = 500 L/min and time = 90 min

Distance from inlet (m)	Concen. 0 ppm V (m/sec)	Concen. 0 ppm T (°C)	Concen. 50 ppm V (m/sec)	Concen. 50 ppm T (°C)	Concen. 75 ppm V (m/sec)	Concen. 75 ppm T (°C)	Concen. 100 ppm V (m/sec)	Concen. 100 ppm T (°C)
0.5	1.87	51.6	1.89	46.8	1.90	45.9	1.91	44.3
1.5	1.89	51.4	1.91	46.6	1.92	45.6	1.93	44.3
3	1.92	51.2	1.94	46.4	1.95	45.5	1.95	44.2
4.5	1.92	51.2	1.97	46.4	1.98	45.4	1.98	44.1
5.5	1.97	51.1	1.99	46.3	2.00	45.4	2.00	44.1

Table 4: Heat transfer coefficient with polymer concentration for different volume flow rate at t = 90 min section one

Concentration (ppm)	h (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	3884	4138	4694	5302
50	3775	4050	4542	5117
75	3673	3988	4209	4918
100	3583	3898	4030	4607

Table 5: Heat transfer coefficient with polymer concentration for different volume flow rate at t = 90 min, section two

Concentration (ppm)	h (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	2620	2862	3402	4234
50	2409	2650	3273	3815
75	2152	2315	2828	3490
100	1931	2093	2456	2990

Table 2 and 3 clarify the readings of flow velocity and the temperature of working fluid for each part in the pipe length at two volume flow rates 200 and 500 L/min, respectively. These readings were observed that the velocity values increase with increasing the ratio of polymer concentration and with pipe length while the temperature values relief with increasing the concentration of polymer. It was pointed these readings were measured five times in each section for pure kerosene and with the three values of polymer concentrations 50, 75 and 100 ppm. The readings are repeated in order to have more stable and accurate readings. It has been shown more reduction in temperature values with increasing the polymer concentration. This variation is between 49.7°C without polymer to 42.3°C with polymer additive while the increasing in velocity is not very significant as illustrated in Table 2 and 3. Also, these readings increase with increasing of volume flow rate of working fluid. This is happened due to the polymer decreases the friction and slide the boundary sub layer.

Table 6: Heat transfer coefficient with polymer concentration for different volume flow rate at t = 90 min, section three

Concentration (ppm)	h (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	2060	2570	3147	3896
50	1726	2223	2897	3156
75	1596	2077	2376	2852
100	1350	1836	2145	2325

Table 7: Heat transfer coefficient with polymer concentration for different volume flow rate at t = 90 min section four

Concentration (ppm)	h (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	2260	2670	3347	4096
50	1926	2323	3187	3565
75	1696	1977	2676	3252
100	1550	1836	2345	2700

Table 8: Heat transfer coefficient with polymer concentration for different volume flow rate at t = 90 min, section five

Concentration (ppm)	h (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	2060	2443	3287	3932
50	1812	2154	2787	3365
75	1548	1896	2265	3124
100	1424	1624	2034	2689

Table 4-8 demonstrate the heat transfer coefficient (h) with the inner surface pipe over flowing of working fluid for diverse concentration ratio of polymer additive. These tables point the values of heat transfer coefficientat working time of 90 min in five parts through the length of pipe at various values of volume flow rate. It has been observed that the amounts of heat transfer coefficient decrease with swelling the concentration ratio of polymer additive and with pipe length while it was increased with increasing the values of volume flow rate. Section three has the same behavior of these parameters but it was

Table 9: Heat transfer coefficient with Reynolds number for different polymer concentration at t = 90 min, section one

Q (L/min)	Reynolds No.	h (ppm) Concen. 0	Concen. 50	Concen. 75	Concen. 100
200	31720	3884	3775	3673	3583
300	55151	4138	4050	3988	3898
400	62720	4694	4542	4209	4030
500	68127	5302	5117	4918	4607

Table 10: Heat transfer coefficient with Reynolds number for different polymer concentration at t = 90 min, section two

Q (L/min)	Reynolds No.	h (ppm) Concen. 0	Concen. 50	Concen. 75	Concen. 100
200	32441	2620	2409	2152	1931
300	55872	2862	2650	2315	2093
400	63802	3402	3273	2828	2456
500	68848	4234	3815	3490	2990

Table 11: Heat transfer coefficient with Reynolds number for different polymer concentration at t = 90 min, section three

Q (L/min)	Reynolds No.	h (ppm) Concen. 0	Concen. 50	Concen. 75	Concen. 100
200	32802	2060	1726	1596	1350
300	56593	2570	2223	2077	1836
400	64162	3147	2897	2376	2145
500	69569	3896	3156	2852	2325

Table 12: Heat transfer coefficient with Reynolds number for different polymer concentration at t = 90 min, section four

Q (L/min)	Reynolds No.	h (ppm) Concen. 0	Concen. 50	Concen. 75	Concen. 100
200	33883	2260	1926	1696	1550
300	59116	2670	2323	1977	1836
400	66686	3347	3187	2676	2345
500	70651	4096	3565	3252	2700

Table 13: Heat transfer coefficient with Reynolds number for different polymerconcentration at t = 90 min, section five

Q (L/min)	Reynolds No.	h (ppm) Concen. 0	Concen. 50	Concen. 75	Concen. 100
200	34244	2060	1812	1548	1424
300	60197	2443	2154	1896	1624
400	67767	3287	2787	2265	2034
500	71372	3932	3365	3124	2689

Table 14: Nusselt number with polymer concentration for different volume flow rate at t = 90 min, section one

Concentration (ppm)	Nu (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	512	550	621	650
50	507	539	603	628
75	494	531	561	610
100	485	521	539	574

Table 15: Nusselt number with polymer concentration for different volume flow rate at t = 90 min, section two

Concentration (ppm)	Nu (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	389	392	459	529
50	358	365	446	482
75	323	329	402	448
100	291	301	361	404

Table 16: Nusselt number with polymer concentration for different volume flowrate at t = 90 min, section three

Concentration (ppm)	Nu (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	309	362	430	485
50	279	325	400	440
75	260	307	359	401
100	221	274	327	333

Table 17: Nusselt number with polymer concentration for different volume flow rateat time = 90 min, section four

Concentration (ppm)	Nu (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	325	370	450	502
50	282	332	432	445
75	263	305	389	425
100	242	284	351	374

Table 18: Nusselt number with polymer concentration for different volume flow rate at time = 90 min, section five

Concentration (ppm)	Nu (L/min) Q = 200	Q = 300	Q = 400	Q = 500
0	320	368	440	493
50	280	328	424	420
75	259	300	370	411
100	233	280	342	370

estimated less values than other section. Because of the value of thermal conductivity of Pyrex glass is less than the thermal conductivity value of carbon steel.

Table 9-13 illustrate the calculation of heat transfer coefficient through every section of flow pipe with the values of Reynolds number for different volume flow rate of the kerosene without and with additive polymer. It was increased with swelling the Reynolds number. That means boost with velocity increasing through each part.

Table 14-18 represent the analysis of Nusselt number for each section of flow pipe with different values of polymer concentration and volume flow rate through pipe length. It has been observed the reduction of Nusselt number with increasing the polymer concentration and raises the Nusselt number with increasing the amount of volume flow rate in each part.

Figure 3 and 4 represent the variation of heat transfer coefficient with distance through flow pipe length with different values of polymer concentration at various amount of volume flow rates 200 and 500 L/min, respectively. It has been dominated that the value of heat transfer coefficient decreases with pipe length and with swelling the ratio of polymer concentration. The flow of pure kerosene bore higher value of (h) than other flows with concentrations 50, 75, 100 ppm over flow pipe length. Also, the heat transfer coefficient is given a higher

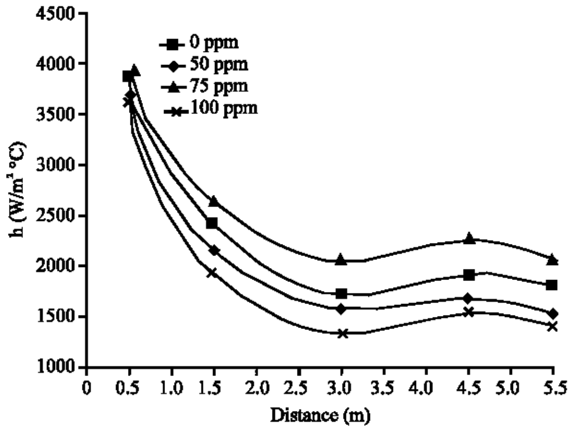

Fig. 3: Heat transfer coefficient with distance for different polymer concentration at Q = 200 L/min and t = 90 min

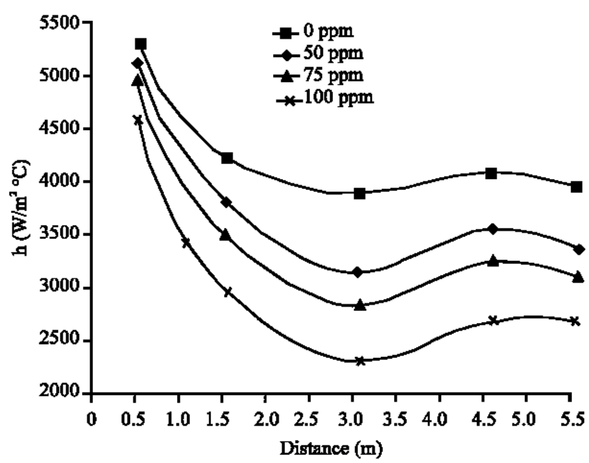

Fig. 4: Heat transfer coefficient with distance for different polymer concentration at Q = 500 L/min and t = 90 min

function behavior when increasing the value of volume flow rate. The temperature of working fluid inside the pipe was measured after working time of 90 min. It was institute the temperature of pure kerosene which was about 49.7 and 51.6°C. These temperatures decrease with increasing of the polymer concentration as pointed in Table 2 and 3. This is due to the polymer additive reduce the friction force and then, the temperature of working fluid decreases. Also, the pressure drop force increases, then, the drag reduction percentage rise. These results are consistent with experimental results of many researchers have working with crude oil and its fraction and they show how the drag reduction increases with increasing the temperature of working fluid such as Ali and Al-Ausia (2008). From these two figures, it was pointed at glass Pyrex pipe (section 3 with length 2 m), the

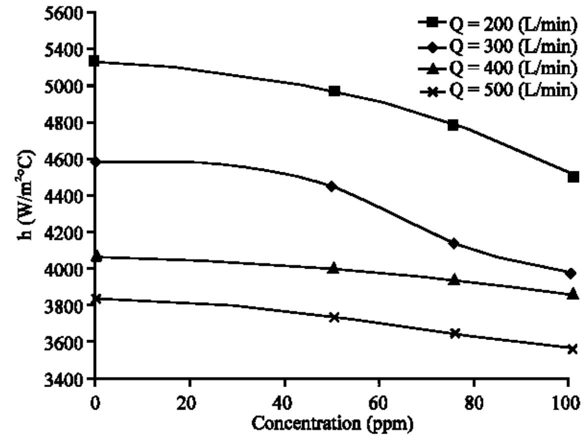

Fig. 5: Heat transfer coefficient versus different polymer concentration at section 1 and t = 90 min

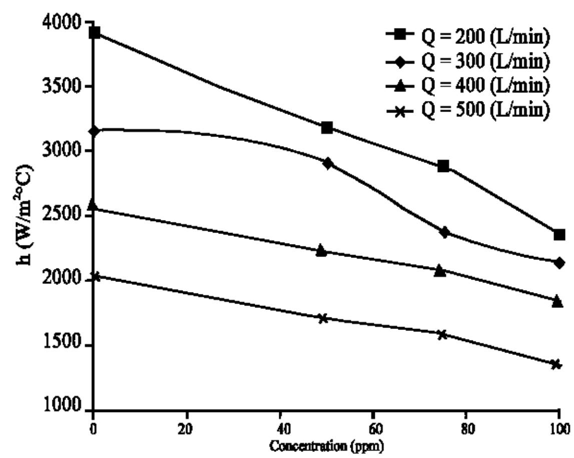

Fig. 6: Heat transfer coefficient versus different polymer concentration at section 3 and t = 90 min

heat transfer coefficient values less than other sections, because the thermal conductivity of glass Pyrex is less than carbon steel.

Figure 5 and 6 demonstrate the variation of heat transfer coefficient with polymer concentration ratio for different values of volume flow rate at sections one and three respectively at time of 90 min. It has been seen that the heat transfer coefficient decreases with increasing the concentration ratio of polymer additive and increases with increasing values of volume flow rate. It was observed that the values of heat transfer coefficient in section three is less than values in section one. This is due to the lower value of thermal conductivity of glass Pyrex. Reduction percentage values are 43% at ppm = 50, 47.4% at ppm = 75 and 52.7% at ppm = 100.

Figure 7 and 8 represent the variation of (h) with Reynolds number for different polymer concentration ratio with two values of volume flow rate, at working time

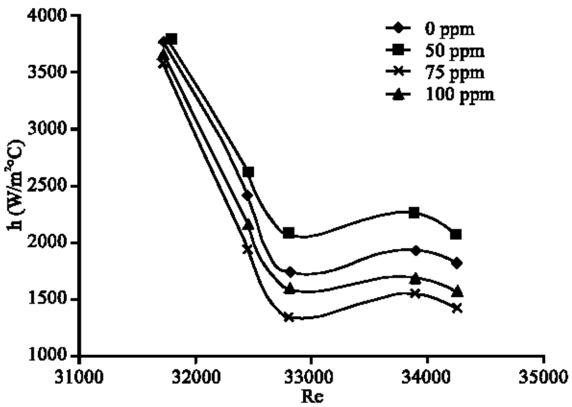

Fig. 7: Heat transfer coefficient with Reynolds number for different polymer concentration at Q = 200 L/min and t = 90 min

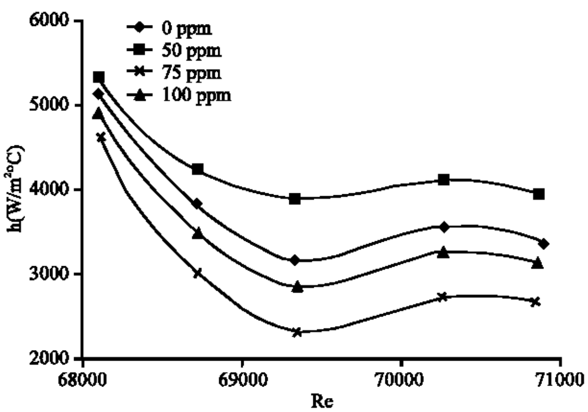

Fig. 8: Heat transfer coefficient with Reynolds number for different polymer concentration at Q = 500 L/min and t = 90 min

of 90 min. It was observed that value of (h) decreases with raising the Reynolds number. That means when the flow velocity increases, the friction force was drop due to the concentration of polymer additive. Then, it was found the reduction in the temperature of working fluid. This outcome was confirmed with result of Lee (2010). Also, it was found that the value of (h) decreases with increasing the polymer concentration and increases with increasing the value of volume flow rate.

Figure 9 and 10 give the response function of Nusselt number with pipe length through the flow of working fluid with different concentration ratio of working fluid and volume flow rate at working time of 90 min. It has been mentioned that the Nusselt number decreases through the length of pipe and with increasing the values of polymer concentration. This is due to the reduction in temperature of working fluid which was caused by polymer additive. These results were valid with experimental results of Abid Ali and Al-Ausi (2008).

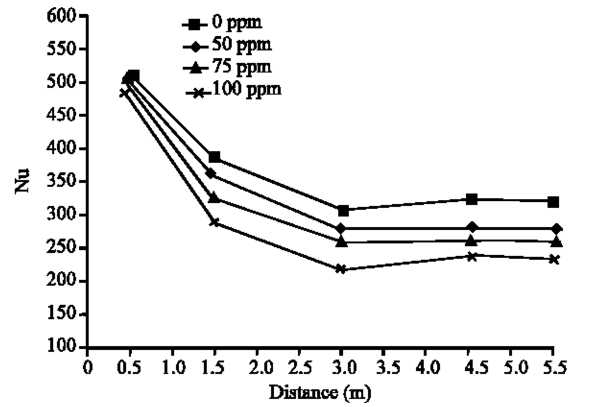

Fig. 9: Nusselt number with distance for different polymer concentration at Q = 200 L/min and t = 90 min

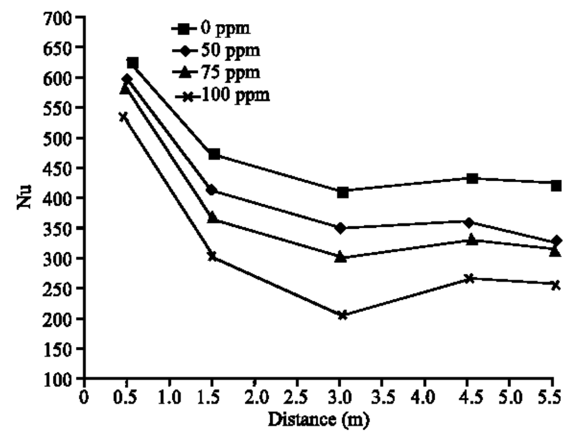

Fig. 10: Nusselt number with distance for different polymer concentration at Q = 500 L/min and t = 90 min

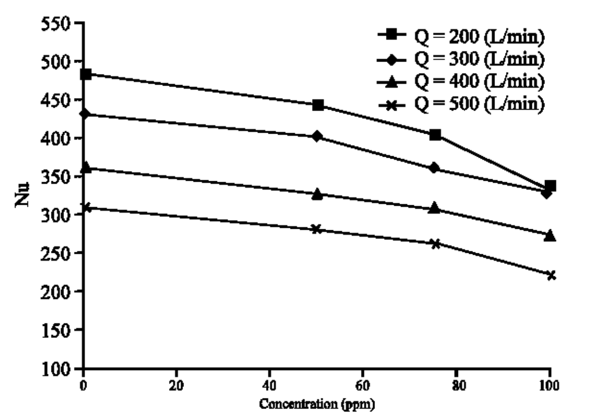

Fig. 11: Nusselt number versus different polymer concentration at section 1 and t = 90 min

Figure 11 and 12 dominate the variation of (Nu) with different values of polymer concentration ratio and

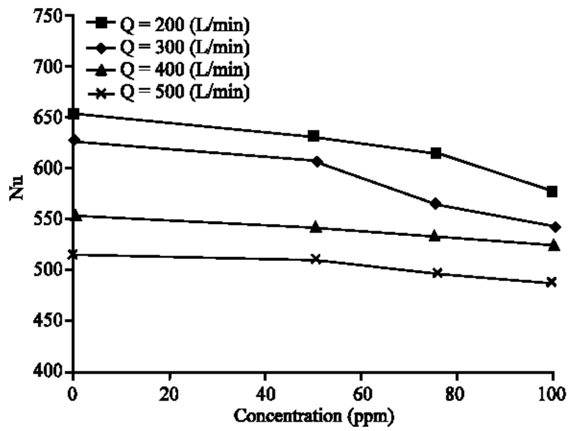

Fig. 12: Nusselt number versus different polymer concentration at section 3 and t = 90 min

volume flow rates which was presented at the same working time of sections one and three over the test pipe. It has been explained that (Nu) decreases with increasing the value of polymer concentration and increases with increasing the values of volume flow rate. From these figures, it has been noted the amounts of (Nu) in section three are less than section one. This is due to the thermal properties of glass Pyrex pipe are less than carbon steel pipe. These results are consistent with the results by Usui and Saeki (1993).

CONCLUSION

Convective heat transfer of kerosene in fully develop region under turbulent flow regime inside a circular pipe with different concentrations of polymer additive was adopted experimentally. Main conclusions extracted for this workare:The velocity values rise with increasing the polymer concentration and with distance of forward flowing in pipe length while it was found the reduction in the temperature.

The amounts of heat transfer coefficient decrease with increasing the values of polymer concentration and increase with increasing the volume flow rate.

Heat transfer coefficient values decrease with Reynolds number in each section of pipe with time. It was observed that the heat transfer coefficient dependent upon the thermal conductivity of the pipe. It was found the polymer additive was increased the time to reach the kerosene its flash point.

NOMENCLATURE

Latin symbols

A = Surface area (m^2)
c_p = Specific Heat (kJ/kg.°C)
D = Diameter (m)
h = Coefficient of convective heat transfer (W/m^2°C)
k = Thermal conductivity of pipe material (W/m°C)
L = Length of the pipe (m)
l = Volume (L)
m = Mass flow rate (kg/sec)
Nu = Nusselt number
N = Total number of measurement
Q = Volume flow rate (m^3/sec)
q = Rate of convection heat transfer (W)
Re = Reynolds number
r_i = Inner radius (m)
r_o = Outer radius (m)
S = Standard deviation
T_b = Bulk temperature of working fluid inside the pipe (°C)T_{win} Inside wall temperature (°C)
T_{wout} = Outside wall temperature (°C)
u = Velocity of working fluid (m/sec)
x_{ave} = Tue value of measurement

GREEK SYMBOLS

ρ = Density (kg/m^3)
μ = Dynamic viscosity (kg/m.sec)

ABBREVIATIONS

ppm = Part per million
PIB = Poly Isobutylene polymer
SE = Standard Error

REFERENCES

Ali, Q.M.A. and T.A. Al-Ausi, 2008. Drag force reduction of flowing crude oil by polymers addition. Iraqi J. Mech. Mater. Eng., 8: 149-161.

Cengel, Y.A. and A.J. Ghajar, 2011. Heat and Mass Transfer. 4th Edn., McGraw-Hill Education, New York, USA., ISBN:9780073398129, Pages: 924.

Dang, G., F. Zhong, L. Chen and X. Chang, 2013. Numerical investigation on flow and convective heat transfer of aviation kerosene at supercritical conditions. Sci. China Technol., 56: 416-422.

Dang, G., F. Zhong, Y. Zhang and X. Zhang, 2015. Numerical study of heat transfer deterioration of turbulent supercritical kerosene flow in heated circular tube. Intl. J. Heat Mass Transfer, 85: 1003-1011.

Groysman, A., 2014. Corrosion in Systems for Storage and Transportation of Petroleum Products and Biofuels: Identification, Monitoring and Solutions. Springer, Berlin, Germany, ISBN:978-94-007-7883-2, Pages: 157.

Huang, D. and W. Li, 2017. Heat transfer deterioration of aviation kerosene flowing in mini tubes at supercritical pressures. Intl. J. Heat Mass Transfer, 111: 266-278.

Lee, D.H., 2010. Skin-friction drag reduction by dilute polymer solutions in turbulent channel flow. Ph.D Thesis, Department of Mechanical Engineering, University of Michigan, Ann Arbor, Michigan.

Lee, K.H., K. Zhang and H.J. Choi, 2010. Time dependence of turbulent drag reduction efficiency of polyisobutylene in kerosene. J. Ind. Eng. Chem., 16: 499-502.

Li, W., D. Huang, G.Q. Xu, Z. Tao and Z. Wu *et al*., 2015. Heat transfer to aviation kerosene flowing upward in smooth tubes at supercritical pressures. Intl. J. Heat Mass Transfer, 85: 1084-1094.

Usui, H. and T. Saeki, 1993. Drag reduction and heat transfer reduction by cationic surfactants. J. Chem. Eng. Japan, 26: 103-106.