A study of the effectiveness of chemical additives on the characteristic flow of crude oils

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ABSTRACT

This article aims to study the effect of the concentration with additives on the kinematic viscosity of crude oils. Additionally, the influence of solvents that reduces the viscosity of heavy oil with significance to their functions in the flow rate of crude oil, which is transported by conveyor pipes to long distances. Different concentrations of polymers with different types named as Polyvinyl chloride (PVC), Sodium dodecyl sulfate (SDS) and Carboxymethyl cellulose (CMC) were tested in order to analyze the experimental data. The results demonstrate that the impact of the additives to the viscosity and comparing at different temperatures. The data can be used to investigate the types of additives that can increase or reduce the viscosity of crude oils. Furthermore, the outcomes show that the addition of PVC at a concentration of (100ppm) and temperature range (30-50 C^O) reduces the viscosity of crude oil to the ultimate value the 12.63% at 30C^o. However, the viscosity decreases drastically up to (100ppm), and then the amount of viscosity is increased.

Keywords: Kinematic viscosity, Polymers (PVC, SDS and CMC), Friction factor in pipes.

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1. Introduction

Crude oil viscosity is an essential physical property that influences and controls the oil flow through porous media and pipes[1]. Generally, the internal resistance of the fluid to flow is defined as the viscosity. The oil viscosity has a crucial function of the pressure, temperature, gas solubility and gas gravity[2,3]. Whenever possible, oil viscosity requires to be calculated by laboratory measurement at reservoir pressure and temperature[2,3]. According to reports from the International Energy Agency, half of the world's importable oil resource is represented by heavy crude oil represents[4]. Heavy oil is considered as petroleum, which has a density equal or lower than 20 API; however, if petroleum has 10 API or less, it will be considered as extra-heavy oil or bitumen[5]. The export of oil to the world markets requires important technology in the production chain. Additionally, the pipeline is the most convenient way to transport crude oil continuously and economically. Nevertheless, it is challenging to transport crude oil through the pipes due to the increased internal friction of crude oil inside it by viscosity (it is a major cause of the low flow capacity)[6]. Crude oil is exported through conveyor pipes for long distances up to thousands of kilometers. Basically, the pumps are used to pump crude oil inside the conveyor pipes. The rate of export of crude oil per day depends on the viscosity of crude oil, the capacity of the pump, and the number of pumps along the transport distance of crude oil. High molecular weight polymers are used to increase the efficiency of pumping crude oil. This technique is essential from the economic side, and this is achieved by injecting polymers with crude oil in a turbulent flow condition. Additionally, it gives good results when pumping crude oil for long distances without loss of pressure[7]. Crude oil is defined as a complex mixture of hydrocarbons associated with other organic matters in small quantities[8]. Non-hydrocarbon compounds include compounds containing oxygen, sulfur, nitrogen, and a small number of minerals (no more

than 5%). Crude oil consists of carbon elements (83 - 87%), hydrogen (10 - 14%), sulfur (0.1 - 3%), oxygen (1.5%) and nitrogen (0.1%), as well as heavy metals such as vanadium, mercury, cadmium, Nickel and others in small quantities[9]. Hydrocarbons components contain paraffin & circular paraffin and aromatic, where the proportions of these components vary from one oil to another according to the geological formation of the reservoir[10]. Hydrocarbon and non-hydrocarbon components are crucial in modifying (increasing and decreasing) crude oil viscosity[11]. It is necessary to increase the flow rate of crude oil in pipelines to avoid any additional costs and time spent in building new pipelines, which in consequence obtain the same improvement in the required flow. In the literature, several laboratory experiments have been conducted to determine the best polymer with a concentric ratio that reduces viscosity. Consequently, this leads to an increase in the flow rate of crude oil without affecting the chemical properties of crude oil. Many researchers conducted practical experiments to reduce the viscosity of crude oil in order to increase the rate of flow through the pipelines, from these experiments, the researchers (Hazlina Husin, Azlinda Azizi and Afuza Husna) used polymer, surfactant, chemical additive and emulsification in the petroleum industry to increase pump efficiency by reducing the viscosity of crude oil[12]. Other researchers used (TEA) to increase the flow and reduce the viscosity of crude oil, they used Niger crude oil to evaluate the efficiency of triethanolamine (TEA) as an additive by measuring the pour point and viscosity of processed and unprocessed crude oil[13]. While others studied the effect of polyacrylamide (PAM) on increasing the rate of flow of crude oil, they concluded that the concentration of the additive and the diameter of the pipe have a role in the increase or decrease in the flow rate of crude oil[14].

2. Experimental

2.1. Materials and the laboratory measurements

In this research, we studied the effect of three polymeric materials on a sample of Kirkuk crude oil (API = 34.8) to determine the efficiency of pumping crude oil in to conveying pipes. The molecular weight polymers Carboxymethyl cellulose (CMC-MW.T = 300.75) & Polyvinyl chloride [-C_2H_3Cl-] (PVC-M.WT=160000) and Sodium dodecyl sulfate [$CH_3(CH_2)_{11}SO_4Na$](SDS-M.WT = 288.38) are dissolved in the Toluene at a temperature of (30C°). Then added to the crude oil by concentrations ranging from (100-200 ppm) with a temperature range between (30-60 C°). We have used U-tube Viscometer for measuring the viscosity, electronic balance, water bath in addition to the thermometer. A laboratory unit was designed and constructed to test a suitability oil viscosity. In the beginning, the first test was measured without using additives, and then, the measurement was conducted for different additives with different concentrations. The kinetic viscosity was calculated according to equation (1):

$$\nu = kt\phi \tag{1}$$

Where k is a constant given by the manufacturer (0.065mm/s^2), t refers to the time required for fluid to fall through the tube (s), and Ø is the inner diameter of the tube (m). A pipeline system device was designed for: 1) measuring the pressure difference between the two ends of a tube; and 2) reducing the drag and friction coefficient before and after the addition of polymers in different concentrations and different levels of temperature. It is performed depending on the following laws: 1) taking in to consideration that the length of the tube in the pipeline system is (3m); 2) surface friction of the tube is (Ɛ=0.0000064 m), which was found from special tables; and 3) the speed of fluid was (2.021m/s).

$$R_e=(u*D)/ V \tag{2}$$

$$A=((Ɛ/D)/ 2.5497)^{1.1098} +(7.149/R_e)^{0.8981} \tag{3}$$

$$1/(f)^{0.5}= -4 \log[(Ɛ/D)/3.7065 – ((5.0452)/R_e)*\log(A)] \tag{4}$$

$$\Delta P=(2*f*L*u^2)/D \tag{5}$$

$$D.R=(\Delta P - \Delta P_{D.R})/\Delta P \tag{6}$$

where,
Re=Reynolds number.
U=Velocity(m/sec).
D=Tube diameter(m).
V=kinematics viscosity(m^2/s).
A=The parameter A appears in eq.(3).
Ɛ=Tube surface roughness(m).
f=Friction factor.

ΔP=Pressure drop(N/m^2).
ΔPD.R=Pressure drop after polymer addition(N/m^2).
L=Tube length(m).
D.R=drag reduction.

3.   Results and discussion

3.1. Polymer effect on viscosity

We can observe from Table 1 that the viscosity of crude oil decreases and increases at different levels of temperatures 30, 35, 40, 50 and 60 C^0 when adding polymer (PVC). These changes (decrease and increase) in viscosity of crude oil are occurred in different proportions depending on the percentage of the polymer (PVC) added at the same and different temperatures. Consequently, in crude oil, there is a direct relationship between the temperature and the speed of polymer degradation. However, other circumstances have an inverse relationship. As shown in Figure 1. the viscosity of crude oil gradually decreases and then increases at the same temperature by increasing the percentage of polymer (PVC) at fixed rates. The best explanation of this case indicates that the ratio of oxygen compounds gradually decreases in the mixture. This occurs because it degrades with increasing the polymer (PVC), and then reduces the viscosity of crude oil. In the end, most of the polymer is not degraded due to the absence of oxygen compounds in the mixture, and therefore the viscosity of crude oil increases.

Table 1. Effect of polymer (PVC) concentration on the viscosity of crude oil at different levels of temperature

| Temp. (C°)	Pure		100 ppm		120 ppm		140 ppm		160 ppm		180 ppm		200 ppm	
	Time (s)	Visc. mm^2/s	Time (s)	Visc. mm^2/s	Time (s)	Visc. mm^2/s	Time (s)	Visc. mm^2/s	Time (s)	Visc. mm^2/s	Time (s)	Visc. mm^2/s	Time (s)	Vis. mm^2/s
30	99	6.435	86.492	5.622	90.476	5.881	94.692	6.155	98.984	6.434	102.753	6.679	107	6.955
35	85	5.525	81.492	5.297	84.923	5.520	90.784	5.901	95.584	6.213	100.138	6.509	105	6.825
40	76.6	5.124	76.923	5.000	78.338	5.092	79.569	5.172	81.092	5.271	82.615	5.370	84	5.460
50	62.8	4.082	61.492	3.997	62.784	4.081	63.892	4.153	65.092	4.231	66.784	4.341	68.015	4.421
60	50	3.250	52	3.380	52.646	3.422	53.492	3.477	54.338	3.532	55.246	3.591	56.061	3.644
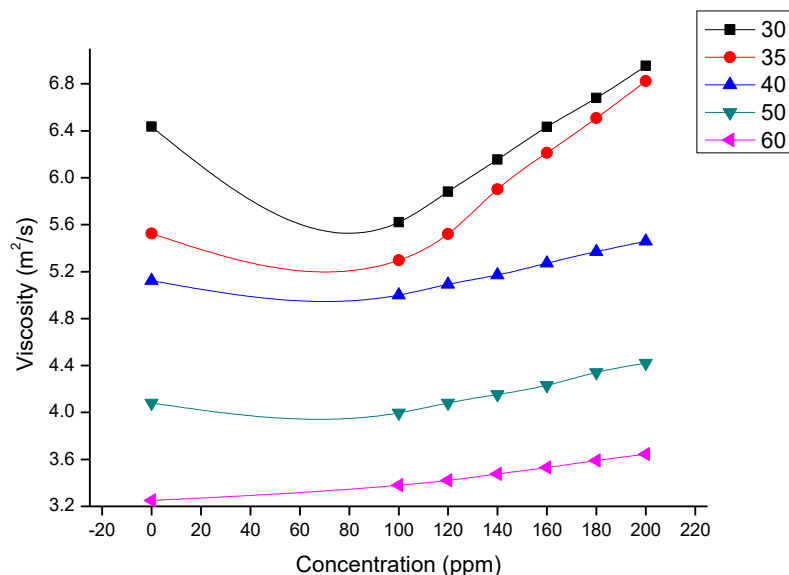
Figure 1. Effect of polymer (PVC) concentration on the viscosity crude oil

The compounds that attack polyvinyl chloride are the oxygen compounds and these compounds dissolution PVC. The hydrogen represents the main part of the reaction in both PVC-PVC and PVC-solvent[16]. At some point, it can be assumed that the speed of the frontal reaction is equal to the speed of the reverse reaction, which can be represented in the following equation.

$$PVC - H \ldots Cl - PVC + O - solvent \rightleftarrows PVC - H \ldots O - solvent + Cl - PVC$$
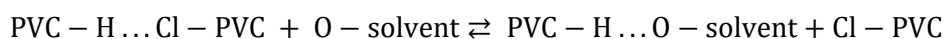
Oxygen compounds in crude oil include tetrahydrofuran, cyclohexanone, Cyclopentanone and dimethylformamide. These compounds are characterized by high molecular weights (which increase the viscosity of crude oil), and they are dissolution the PVC polymer. The polymer dissolution depends on the type of the oxygen compound so that whenever the compound is electronically stable, the following actions occur: 1) the polymer PVC decomposition speed increases; 2) the decomposition time decreases; and 3) the speed of diffusion increases[16]. As shown in Table 1, as observed at 60 C°, crude oil viscosity increases when it is added in different ratios from the polymer (PVC). The explanation for this situation is that when the temperature increases, the speed of the oxygen compounds decomposition in the polymer (PVC) significantly increases. Therefore, as noted in Figure 1, the speed of the equilibrium state will increase. Furthermore, for this reason, all oxygen compounds will deplete and crude oil viscosity will increase at all additions of the (PVC) ratio. Moreover, one can observe from the two Tables 2 and 3 that the viscosity of crude oil increases at temperatures (30, 35, 40, 50 and 60 C°) when adding the polymer (CMC) or (SDS). This increase in viscosity of crude oil occurs at different rates depending on the percentage of polymers (CMC-SDS) added at the same and different temperatures. Accordingly, as illustrated in Figures 2 and 3, there is no degradation between polymers (CMC or SDS) and oxygen compounds or any relationship between the temperature and the speed of polymer degradation in crude oil. Therefore, polymer (PVC) is the best polymer that reduces the viscosity of crude oil by 12.63% at (100 ppm and 30 C°). On the contrary, at 35, 40 and 50 C°, the viscosity decreases by 4.12%, 2.41% and 2.08%, respectively.

Table 2. Effect of polymer (CMC) concentration on the viscosity of crude oil at different levels of temperature

Temp. (C°)	pure		100 ppm		120 ppm		140 ppm		160 ppm		180 ppm		200 ppm	
	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Vis. mm²/s
30	99	6.435	113	7.345	113.261	7.362	113.40	7.371	113.553	7.381	113.769	7.395	114	7.412
35	85	5.525	93.492	6.077	95.630	6.216	98.092	6.376	100.476	6.531	102.8	6.682	105	6.825
40	76.6	4.979	84.8	5.512	85.584	5.563	86.076	5.595	86.784	5.641	87.461	5.685	88.015	5.721
50	62.8	4.082	67.246	4.371	67.861	4.411	68.338	4.442	69.061	4.489	69.476	4.516	70	4.551
60	50	3.252	55	3.575	55.646	3.617	56.261	3.657	56.723	3.687	57.4	3.731	58.046	3.773

Table 3. Effect of polymer (SDS) concentration on the viscosity of crude oil at different levels of temperature

| Temp. (C°)	pure		100 ppm		120 ppm		140 ppm		160 ppm		180 ppm		200 ppm	
	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Visc. mm²/s	Time (s)	Vis. mm²/s
30	99	6.435	107.615	6.995	108.323	7.041	108.938	7.081	109.569	7.122	110.276	7.168	111	7.215
35	85	5.525	102.0462	6.628	102.661	6.673	103.261	6.712	103.892	6.753	104.338	6.782	105	6.825
40	76.6	5.124	87	5.655	89.4	5.811	91.615	5.955	94	6.110	96.092	6.246	98.492	6.402
50	62.8	4.082	67	4.355	67.723	4.402	68.507	4.453	69.061	4.489	69.738	4.533	70.492	4.582
60	50	3.250	57	3.705	57.369	3.729	57.830	3.759	58.2	3.783	58.661	3.813	59	3.835
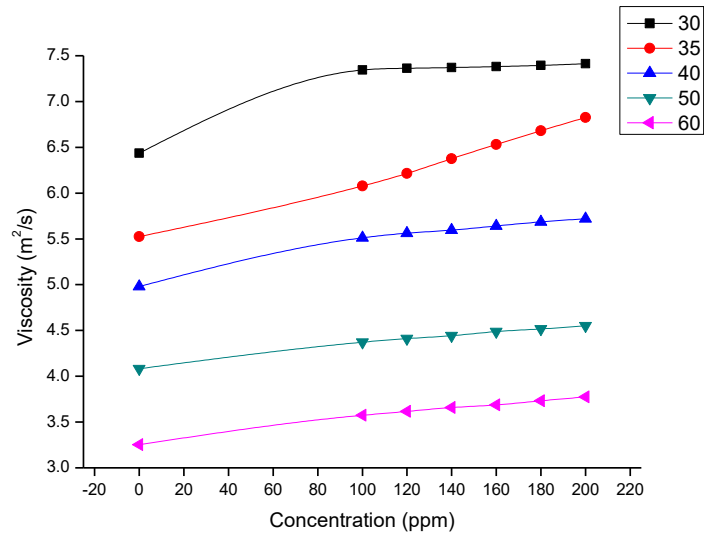
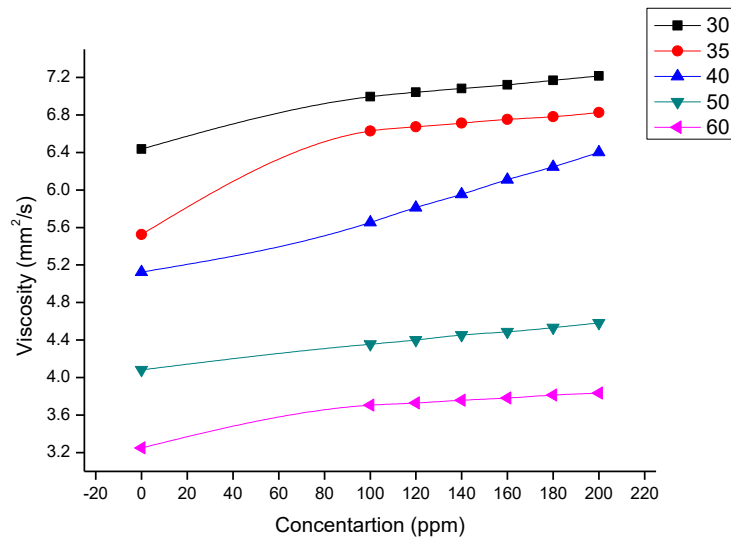Figure 2. Effect of polymer (CMC) concentration on the viscosity crude oil

Figure 3. Effect of polymer (SDS) concentration on the viscosity crude oil

3.2. Polymer effect on Reynolds number

As seen in Tables 4 and 5, and Figures 4 and 5, the fluid flow at the temperatures (30, 35, 50 and 60 C°) is stable even after the addition of the polymer. However, at the temperature (40 C°) the fluid flow becomes turbulent then becomes stable after the addition of polymer. Therefore, we can conclude that the polymer does not reduce the fluid viscosity but increases it.

Table 4. Effect of polymer (CMC) concentration on the Reynolds number of crude oils at different levels of temperature

Temp.(C°)	$R_{e(pure)}$	$R_{e(100ppm)}$	$R_{e(120ppm)}$	$R_{e(140ppm)}$	$R_{e(160ppm)}$	$R_{e(180ppm)}$	$R_{e(200ppm)}$
30	9971.522922	8736.113	8715.94	8705.297789	8693.504	8677.045	8657.144
35	11613.8914	10558.95	10322.84	10063.79391	9824.95	9602.926	9401.722
40	12887.47741	11641.28	11534.56	11468.58803	11375.07	11287.03	11216
50	15719.439	14680.11	14546.98	14445.46376	14294.22	14208.76	14099.48
60	19731.47294	17948.74	17740.32	17546.2811	17403.51	17198.27	17006.82

Table 5. Effect of polymer (SDS) concentration on the Reynolds number of crude oils at different levels of temperature

| Temp. (Cº)	$R_{e(pure)}$	$R_{e(100ppm)}$	$R_{e(120ppm)}$	$R_{e(140ppm)}$	$R_{e(160ppm)}$	$R_{e(180ppm)}$	$R_{e(200ppm)}$
30	9971.523	9173.231	9113.301	9061.82	9009.653	8951.835	8893.52
35	11613.89	9681.163	9615.877	9560.004	9501.962	9461.331	9401.722
40	12522.78	11346.91	11042.29	10775.27	10501.92	10273.25	10022.92
50	15719.44	14734.04	14576.73	14409.78	14294.22	14155.47	14004.09
60	19743.62	17318.96	17207.5	17070.16	16961.87	16828.42	16731.88
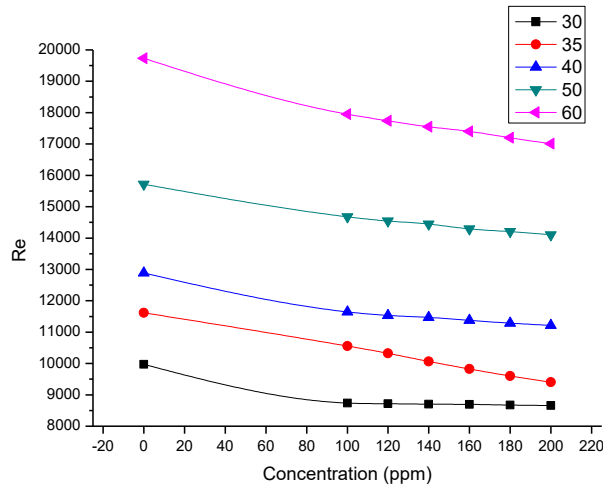
Figure 4. Effect of polymer (CMC) concentration on the Reynolds number of crude oils at different levels of temperature
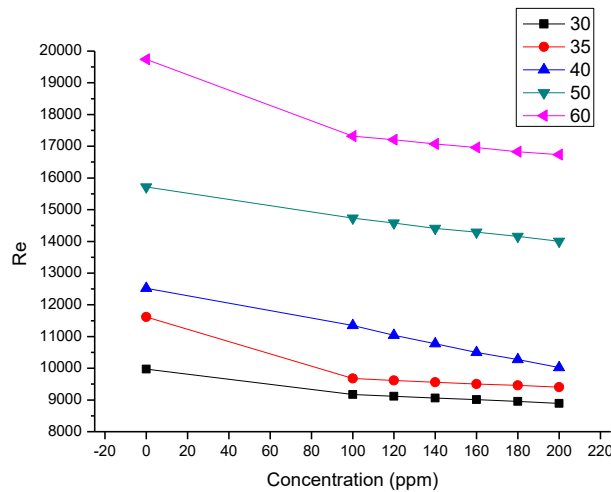

Figure 5. Effect of polymer (SDS) concentration on the Reynolds number of crude oils at different levels of temperature

Furthermore, the fluid movement is stable at temperatures (30 and 35Cº), but after adding 100 ppm of a polymer becomes turbulent flow. When the polymer concentration increased, the fluid flow gradually approaches stability. On the other hand, in the temperatures (40, 50 and 60 Cº) the fluid flow is disturbed and remained on the same flow even after increasing the concentration of polymer. However, this change gradually decreases because the polymer does not decompose when its concentration is high. Furthermore, the amount of oxygen compounds decreases gradually because these compounds decompose in this type of polymer (see Table 6 and in Figure 6).

Table 6. Effect of polymer (PVC) concentration on the Reynolds number of crude oils at different levels of temperature

| Temp.(C°)	$R_{e(pure)}$	$R_{e(100ppm)}$	$R_{e(120ppm)}$	$R_{e(140ppm)}$	$R_{e(160ppm)}$	$R_{e(180ppm)}$	$R_{e(200ppm)}$
30	9971.522922	11413.50943	10910.857	10425.14216	9973.072739	9607.239108	9225.988497
35	11613.8914	12113.79082	11624.41123	10873.87731	10327.8207	9858.157935	9401.721612
40	12522.78493	12833.35	12601.48272	12406.56419	12173.54392	11949.11546	11752.15201
50	15719.439	16053.7278	15723.29086	15450.69829	15165.85913	14781.55955	14514.08052
60	19743.61538	18984.24556	18751.24196	18454.63043	18167.25651	17868.76915	17608.87761
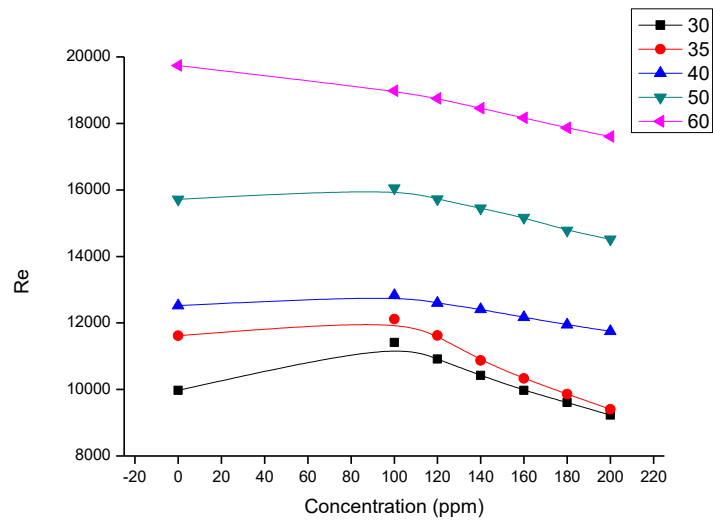
Figure 6. Effect of polymer (PVC) concentration on the Reynolds number of crude oils at different levels of temperature

3.3. Polymer effect on friction factor and pressure drop

The relationship between the friction coefficient and the pressure drop with polymer concentrations increases linearly when the polymer concentration increases at different temperatures as observed in the Tables (7, 8, 9 and 10) and in the Figures (7, 8, 9 and 10).

Table 7. Effect of polymer (CMC) concentration on the friction factor of crude oil at a velocity of 2.021 m/s.

Temp. (C°)	f(pure)	f(100ppm)	f(120ppm)	f(140ppm)	f(160ppm)	f(180ppm)	f(200ppm)
30	0.0078	0.008075	0.008079	0.00808201	0.008084857	0.008089	0.008094
35	0.00751	0.007691	0.007735	0.00778563	0.007833562	0.00788	0.007923
40	0.00732	0.007504	0.007522	0.00753258	0.007548065	0.007563	0.007575
50	0.00697	0.007088	0.007104	0.00711585	0.007134063	0.007144	0.007158
60	0.00661	0.006756	0.006775	0.00679235	0.006805462	0.006825	0.006843

Table 8. Effect of polymer (CMC) concentration on the pressure drop of crude oil at a velocity of 2.021 m/s

Temp. (Cº)	ΔP(pure)	ΔP(100ppm)	ΔP(120ppm)	ΔP(140ppm)	ΔP(160ppm)	ΔP(180ppm)	ΔP(200ppm)
30	6.023584	6.232469	6.236218	6.2382	6.240401	6.243479	6.247212
35	5.795822	5.936486	5.970666	6.009437	6.046436	6.081969	6.115172
40	5.64795	5.792408	5.805774	5.814122	5.826071	5.837446	5.846712
50	5.381642	5.471056	5.483143	5.492463	5.506518	5.514552	5.524921
60	5.100826	5.214839	5.229191	5.242764	5.252884	5.267634	5.281615

Table 9. Effect of polymer (SDS) concentration on the friction factor of crude oil at a velocity of 2.021 m/s

Temp.(Cº)	f(pure)	f(100ppm)	f(120ppm)	f(140ppm)	f(160ppm)	f(180ppm)	f(200ppm)
30	0.007804	0.007973	0.007987	0.007998	0.00801	0.008024	0.008037
35	0.007509	0.007863	0.007877	0.007889	0.007901	0.00791	0.007923
40	0.007369	0.007553	0.007605	0.007652	0.007702	0.007745	0.007794
50	0.006972	0.007082	0.0071	0.00712	0.007134	0.007151	0.00717
60	0.006608	0.006813	0.006824	0.006837	0.006847	0.00686	0.006869

Table 10. Effect of polymer (SDS) concentration on the pressure drop of crude oil at a velocity of 2.021 m/s

| Temp. (Cº)	ΔP (pure)	ΔP (100ppm)	ΔP (120ppm)	ΔP (140ppm)	ΔP (160ppm)	ΔP (180ppm)	ΔP (200ppm)
30	6.023584	6.154098	6.164532	6.173572	6.182805	6.193126	6.20363
35	5.795822	6.069318	6.079865	6.08897	6.098508	6.105233	6.115172
40	5.688151	5.829696	5.869723	5.906092	5.944644	5.977981	6.015681
50	5.381642	5.466203	5.480429	5.495761	5.506518	5.519595	5.534065
60	5.100099	5.258931	5.266966	5.276965	5.28493	5.294841	5.302079
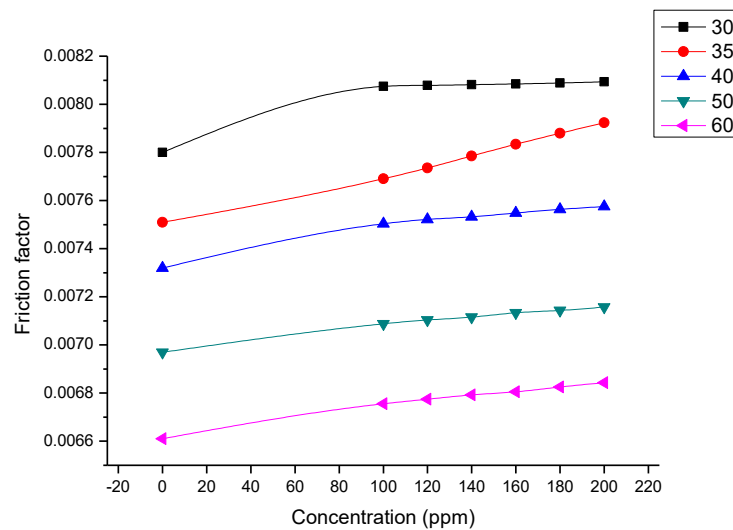
Figure 7. Effect of polymer (CMC) concentration on the friction factor of crude oil at different levels of temperature
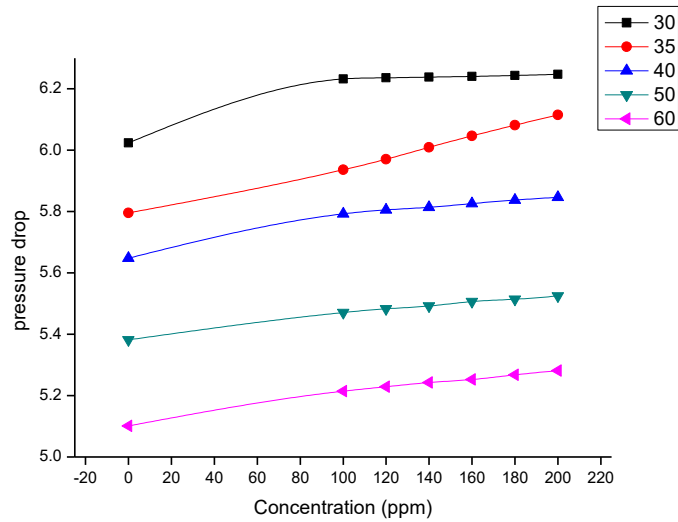
Figure 8. Effect of polymer (CMC) concentration on the pressure drop of crude oil at different levels of temperature
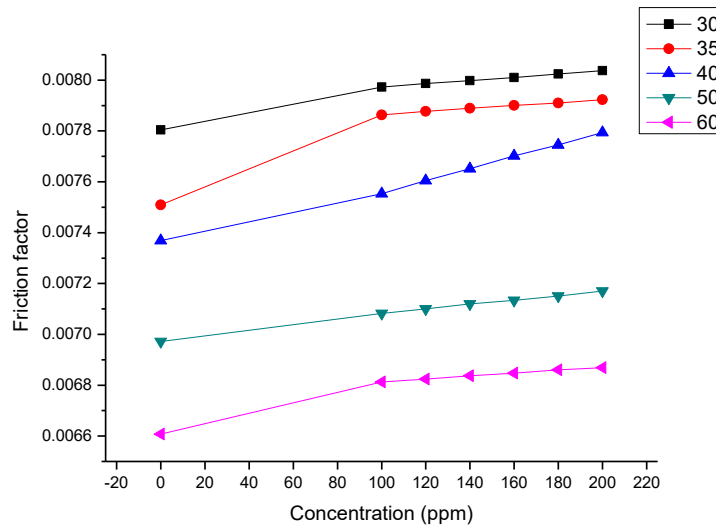

Figure 9. Effect of polymer (SDS) concentration on the friction factor of crude oil at different levels of temperature
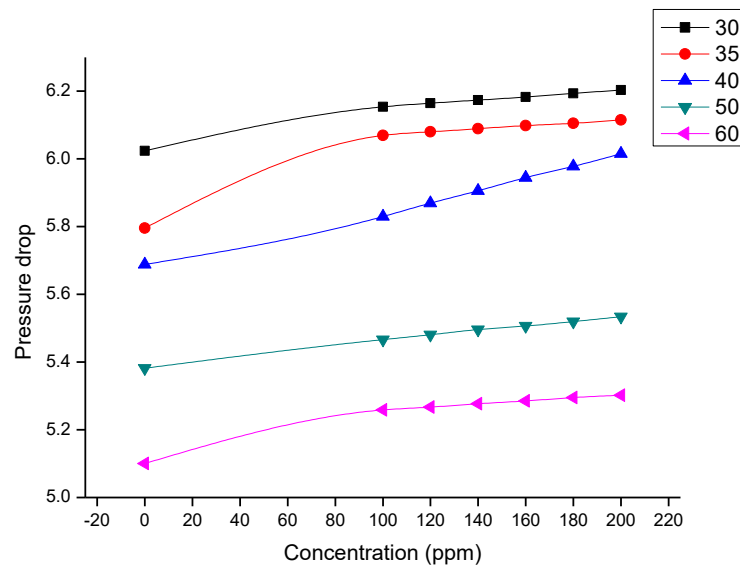

Figure 10. Effect of polymer (SDS) concentration on the pressure drop of crude oil at different levels of temperature

The relationship between friction coefficient and pressure drop with polymer concentrations is linearly reduced to a certain extent and then linearly increases. This relationship depends on the availability of oxygen and polymer compounds together in crude oil at temperatures (30, 35, 40 and 50 C°). However, at a temperature (60 C°) this relationship increases linearly when the polymer concentration increases. Finally, the best value for the friction coefficient and pressure drop is obtained at (100 ppm) and temperature (30 C°) as observed in Tables 11 and 12, and in Figures 11 and 12.

Table 11. Effect of polymer (PVC) concentration on the friction factor of crude oil at a velocity of 2.021 m/s

Temp. (C°)	f(pure)	f(100ppm)	f(120ppm)	f(140ppm)	f(160ppm)	f(180ppm)	f(200ppm)
30	0.007804	0.007542	0.007628	0.007716	0.007804	0.007879	0.007961
35	0.007509	0.00743	0.007507	0.007634	0.007734	0.007827	0.007923
40	0.007369	0.007325	0.007358	0.007386	0.007421	0.007456	0.007487
50	0.006972	0.006937	0.006972	0.007001	0.007033	0.007076	0.007108
60	0.006608	0.006668	0.006687	0.006712	0.006737	0.006763	0.006787

Table 12. Effect of polymer (PVC) concentration on the pressure drop of crude oil at a velocity of 2.021 m/s

| Temp. (C°)	ΔP(pure)	ΔP(100ppm)	ΔP(120ppm)	ΔP(140ppm)	ΔP(160ppm)	ΔP(180ppm)	ΔP(200ppm)
30	6.023584	5.821143	5.88747	5.955724	6.023345	6.081268	6.144991
35	5.795822	5.735214	5.794509	5.892517	5.969933	6.041217	6.115172
40	5.688151	5.653816	5.67934	5.701305	5.728201	5.75479	5.778702
50	5.381642	5.354605	5.381325	5.403961	5.428211	5.461947	5.486154
60	5.100099	5.146808	5.161662	5.180944	5.200038	5.220319	5.238363
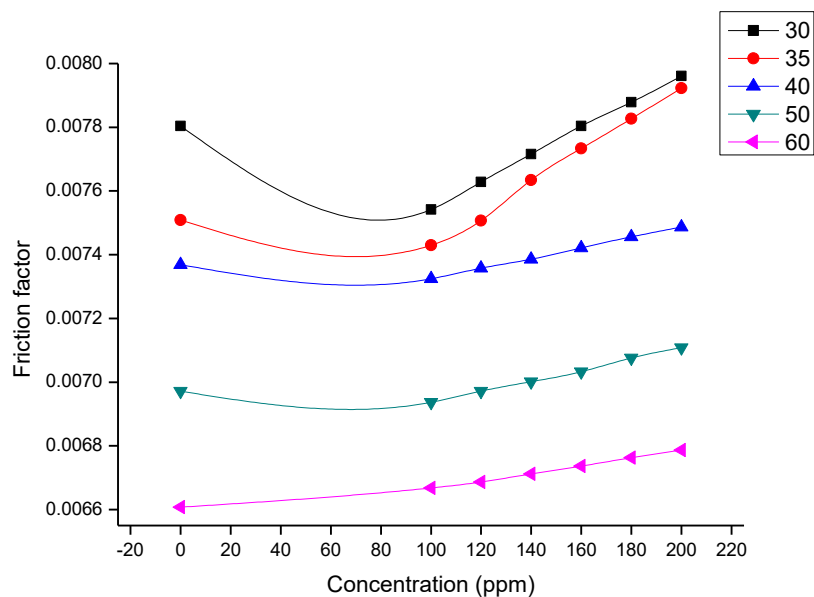
Figure 11. Effect of polymer (PVC) concentration on the friction factor of crude oil at different levels of temperature
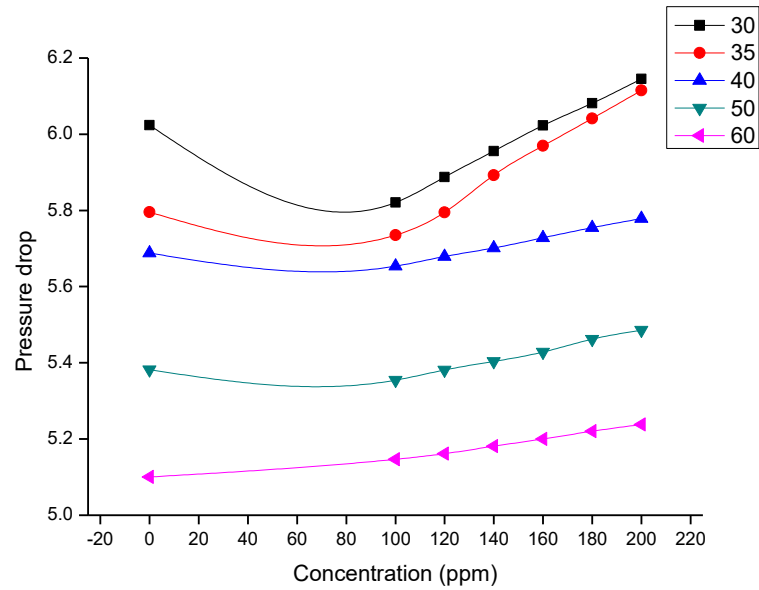
Figure 12. Effect of polymer (PVC) concentration on the pressure drop of crude oil at different levels of temperature

3.4. Polymer effect on drag reduction

As observed in Tables 13 and 14, the relationship between the concentration of CMC and SDS polymers with drag reduction of crude oil is that the drag reduction reduces with increasing the concentration of polymer. However, Table 15 shows the concentration of PVC polymer increases linearly, and the best drag reduction occurs at concentration of (100 ppm) and (30 C°) (see Figures 13, 14 and 15).

Table 13. Effect of polymer (CMC) concentration on the drag reduction of crude oil at a velocity of 2.021 m/s.

Temp. (C°)	$D.R_{(100ppm)}$	$D.R_{(120ppm)}$	$D.R_{(140ppm)}$	$D.R_{(160ppm)}$	$D.R_{(180ppm)}$	$D.R_{(200ppm)}$
30	-0.03468	-0.0353	-0.03563	-0.03599	-0.03651	-0.03713
35	-0.02427	-0.03017	-0.03686	-0.04324	-0.04937	-0.0551
40	-0.02558	-0.02794	-0.02942	-0.03154	-0.03355	-0.03519
50	-0.01661	-0.01886	-0.02059	-0.0232	-0.0247	-0.02662
60	-0.02235	-0.02517	-0.02783	-0.02981	-0.0327	-0.03544

Table 14. Effect of polymer (SDS) concentration on the drag reduction of crude oil at a velocity of 2.021 m/s

Temp. (C°)	$D.R_{(100ppm)}$	$D.R_{(120ppm)}$	$D.R_{(140ppm)}$	$D.R_{(160ppm)}$	$D.R_{(180ppm)}$	$D.R_{(200ppm)}$
30	-0.02167	-0.0234	-0.0249	-0.02643	-0.02815	-0.02989
35	-0.04719	-0.04901	-0.05058	-0.05222	-0.05339	-0.0551
40	-0.02488	-0.03192	-0.03831	-0.04509	-0.05095	-0.05758
50	-0.01571	-0.01836	-0.02121	-0.0232	-0.02563	-0.02832
60	-0.03114	-0.03272	-0.03468	-0.03624	-0.03818	-0.0396

Table 15. Effect of polymer (PVC) concentration on the drag reduction of crude oil at a velocity of 2.021 m/s

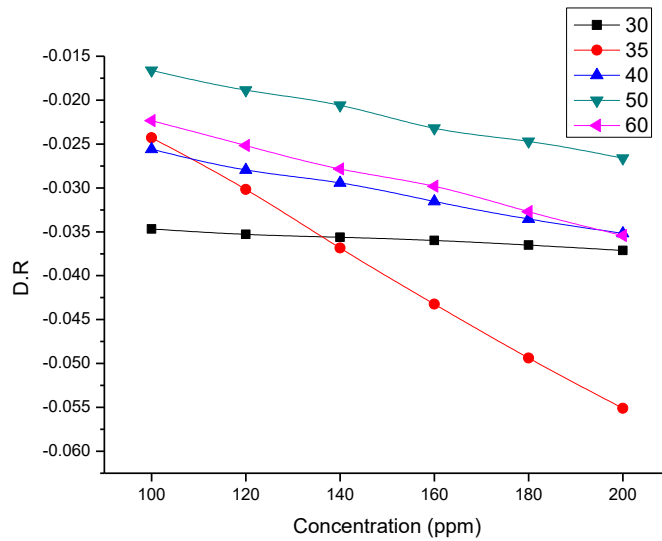| Temp. (C°)	D.R$_{(100ppm)}$	D.R$_{(120ppm)}$	D.R$_{(140ppm)}$	D.R$_{(160ppm)}$	D.R$_{(180ppm)}$	D.R$_{(200ppm)}$
30	0.033608	0.0225969	0.011266	3.96978E-05	-0.00958	-0.02016
35	0.010457	0.0002265	-0.01668	-0.03004081	-0.04234	-0.0551
40	0.006036	0.0015491	-0.00231	-0.007040978	-0.01172	-0.01592
50	0.005024	5.873E-05	-0.00415	-0.008653378	-0.01492	-0.01942
60	-0.00916	-0.012071	-0.01585	-0.019595645	-0.02357	-0.02711

Figure 13. Effect of polymer (CMC) concentration on the drag reduction of crude oil at different levels of temperature
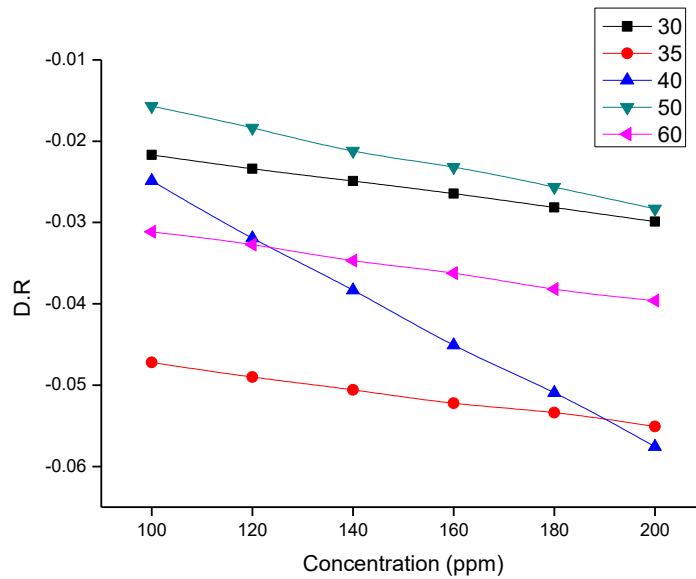

Figure 14. Effect of polymer (SDS) concentration on the drag reduction of crude oil at different levels of temperature
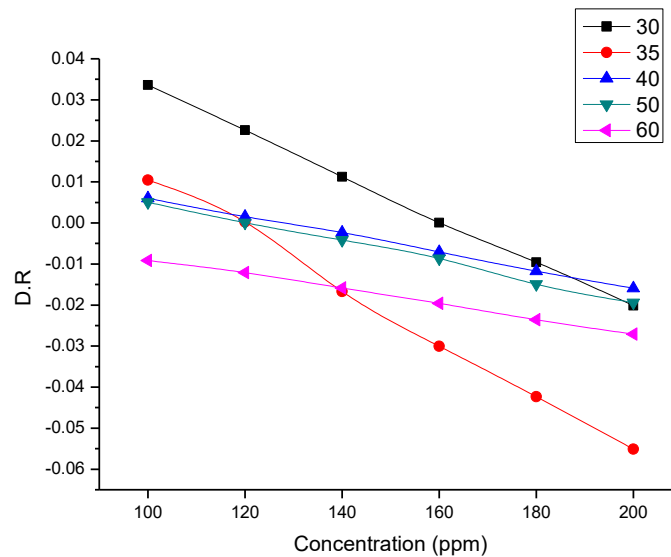
Figure 15. Effect of polymer (PVC) concentration on the drag reduction of crude oil at different levels of temperature

4. Conclusion

In this article, we evaluated the effect of the concentration with additives on the kinematic viscosity of crude oils. Additionally, we studied the influence of solvents that reduces the viscosity of heavy oil with significance to their functions in the flow rate of crude oil. Based on the findings, we conclude:

1. PVC is the best polymer that reduces the viscosity of crude oil and reduces the friction factor of the fluid at the temperature of (30 C^O) and the concentration of (100 ppm). Additionally, it gives the best drag reduction for the fluid in the practical experiments. After that the viscosity and friction factor of the fluid increases linearly because the proportion of oxygen compounds decreases gradually in crude oil. This type of polymer reduces and dissolves oxygen compounds only and does not affect the chemical properties of crude oil.

2. The best effect of the polymer (PVC) is on heavy crude oil more than light crude oil because the heavy crude oil contains more proportion of oxygen compounds.

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