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Drag Force Reduction of Flowing Crude Oil by Polymers Addition

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ABSTRACT
Studying of effect polymers addition on drag force for flowing crude oil are presented. Two types of Iraqi crude oil have been studied namely, Karkok crude oil with API=35.8 and Basrah crude oil with API=31.2 .
Three types of linear polymers (poly isobutylene PIB150K, PIB90K and poly isoprene PIP) are used, the polymers are injected through pumping system at different concentrations rounded between (10-50) ppm with temperatures range of 30^o to 50^oC. Several experiments were carried out to determine the best concentration of polymer which is satisfied lowest drag force on of crude oil flow rate .The results show that the best execution are realization for PIB150K at 30 ppm and 45^oC for two types of crude oil.

Keywords: Crude Oil, Polymer, Drag Force.

تقليل قوة الاعاقة لجريان النفط الخام بإضافة البوليمرات

الخلاصة
في البحث المقدم تم دراسة تأثير أضافة مواد بوليمرية الى عينات من النفط الخام المحلي مختلف الكثافة نفط خام البصرة(API=31.2) ونفط خام كركوك (API=35.8). ،استخدمت ثلاثة انواع من البوليمرات الخطية (البولي ايزوبيوتلين والبولي ايزوبرين) على كفاءة عملية ضخ النفط الخام
تم حقن مادة البولي آيزوبيوتلينPIB بنوعيها PIB150K وPIB90K ومادة الآيزوبرين(PIP) وبتراكيز مختلفة تتراوح بين10 أجزاء بالمليون و50 جزء بالمليون(ppm 50-10) وبمدى حراري يتراوح بين 30-45 oم في منظومة الضخ المختبرية وقد لوحظ تأثير كل من تركيزالبوليمر ودرجة حرارة على معدل سرعة جريان النفط الخام. اظهرت نتائج التجارب العملية ان افضل كفاءة اعطتها مادة البولي آيزوبيوتلين PIB150K وبتركيز لا يتعدى 30 جزء بالمليون ودرجة حرارة 45^o م لكلا النوعين من النفط الخام.

INTRODUCTION

Since many years , high molecular polymers are used for increasing of pumping efficiency of crude oil through translation pipes due to mechanism of drag reduction. This technique is important for scientific and economic side and this is achieved by injecting traces of polymers with crude oil in the turbulent flow condition and gives evident helpful to pumping crude oil for long distances with out losses in the pressure, such as pumping system in the refining for purification to its components or translation to harbors for export .
Ram(1) suggest using a polymer of high molecular weight poly isobutylene which added as a solute with kerosene to the crude oil to drag reduction.
Beaty and Wiley(2) described that quality and propertied of crude oil have important role on pumping efficiency. The results show that the crude oil having high API gravity give a low percent of drag reduction and vise versa.
Such additives are used in Iraq at 1983 for a first attempt, where polymer material added to the Turkish-Iraq line act as a flow improver and proved its efficiency and activity.

Motier and Kostelinke show that the structure of crude oil and their constituents such as paraffinic, naphthenics and aromatics nature is important parameter gives a resistance to the flow .

The work which rep[resent by Lester described that the increasing of drag reduction in pipes of hydrocarbon liquids translation by adding high molecular weight of polymers dissolved in original fluid . the pressure drop is constant at laminar boundary although adding or not, while we get a low pressure drop compared with no addition.

Baranov presented study about the effect of addition materials such as , PMC and PAM on the effect of drag reduction , when added PAM at conc. 100 ppm to the water flowing with high rate (Re>14000)

The present study concerned to investigate the effect of polymers addition to the crude oil on the drag force reduction. The investigated parameters will be the polymer concentration, temperature and flow rate of crude oil

Polymers

In some cases addition of natural or manufacturing polymers to the fluid flowing through the pipes to increase the pumping system , such as translate of crude oil from wells or refining using different types of polymers with tracers quantities the polymer consist of big molecular constructed by relation of small units (monomer) by a polymerization which the series connection of monomer molecules to produce high molecular weight polymers take place it connect the monomer with other excluding matrix structure of reactants.

The polymers are classified to linear branches, cross linking , or homogenous , copolymer , composite .

Three types of polymers are used which have high molecular weight, one is called poly isobutylene with two categories (PIB150K) and (PIB90K), the third was known poly isoprene (PIP).

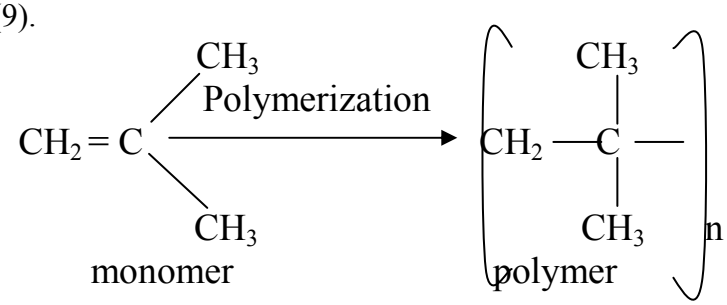
2.1 Poly isobutylene (PIB150K)

PIB consider a linear polymer although of presence of little branches in n hydrocarbon chain which are prepared by addition polymerization or cationic polymerization using BF3 as intermediate agent the cooperated catalyst was react with water to produced complex catalyst where gives a proton n to isobutylene molecule and generate carbonic ion which considered the active center of polymer chain.

$$BF_3 + H_2O \rightarrow H^+ + (BF_3OH)^-$$

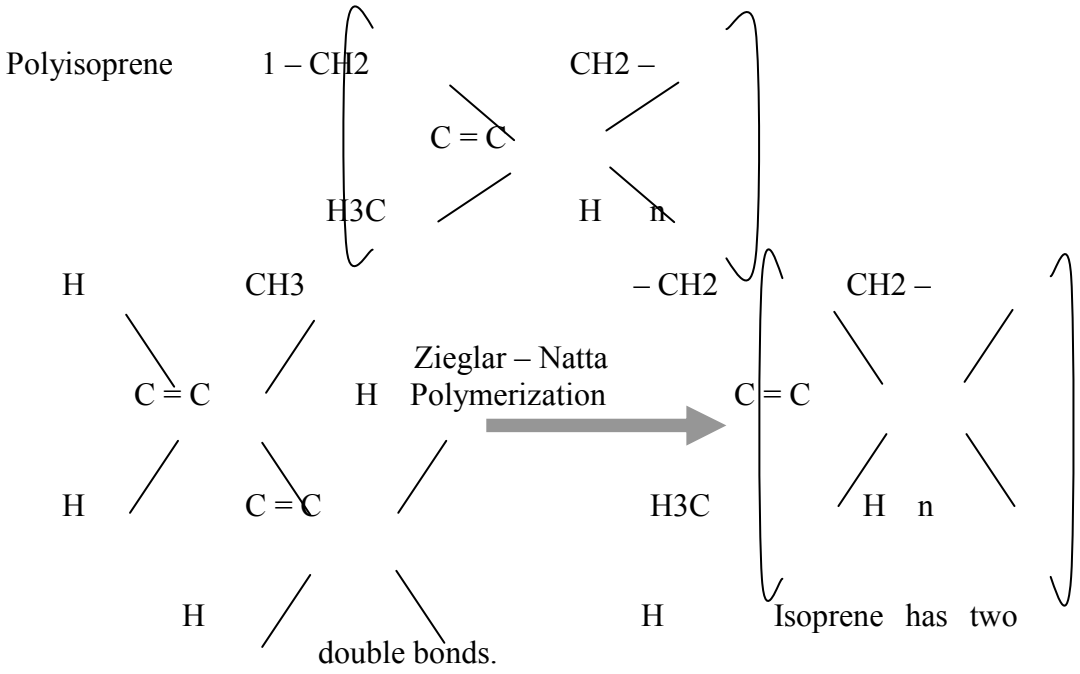
$$H^+ + (CH_3)_2C = CH2 \rightarrow (CH_3)_3C^+$$

Then, the carbonic ion was react with the monomer to produce carbonic ion at end of each step (9).



SYNTHESIS POLY ISOPRENE (PIP)

The polymerization process is carried out to pure isoprene using intermediate agent such as Zieglar Natta Polymerization(11 ،10).



The polymers are used have the following features:
insoluble in crude oil or in any its fraction, without affecting on its specification and can not precipitated on the wall of the pipes.
form a homogeneous mixture with crude oil or their fractions,
stable in the range of used temperature.
association during transportation or storage process.
high activity at low concentrations less than 25 ppm.
Uses of polymer in drag reduction of flowing crude oil depends on solubility of polymer in the solvent when the molecules of solvent are diffuse slowly through the polymer to produce jelly state and strong bonds between polymer and crude oil that follow vanish jelly state gives an actual solution is introduce when the mixing and heating are used to increase this process.
Fig.(1-a) show that the diffusion of solvent molecules through polymer structure due to the intensive of cross linking C–C per unit volume abd vive versa as described by Fig.(1-b)(8 ، 7).

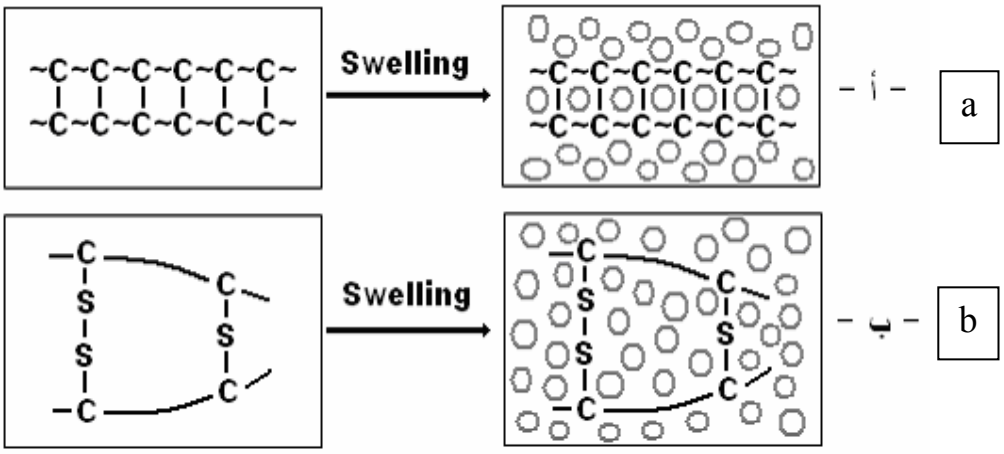


Fig.(1) Overlapping of Polymer and Solvent Molecules

Mechanism of drag reduction

Drag can be defined the amount of the pressure head losses due the friction of turbulent flow inside the pipes which causes the reduction of plug flow amount, so extra energy should be supply for pumping of fluid.

The percent of drag reduction D.R% represents the criteria of polymer performance , when polymer was injected to the fluid stream as flows :

$$F.I\% = \left(\left(\frac{1}{1 - D.R} \right)^{0.55} - 1 \right) \times 100\% \tag{1}$$

where

$$D.R = \frac{\Delta P - \Delta P_{D.R}}{\Delta P} \tag{2}$$

The flow rate can be estimated due to pressure drop through the as follows(13)

$$Q = C_D A_o \sqrt{2g\Delta h} \tag{3}$$

where

$$C_D = \frac{C_V}{\sqrt{1 - \left(\frac{A_o}{A_1} \right)^2}} \tag{4}$$

Where A0 and A1 the areas of flow orifice and tube respectively. The approximation value of discharge coefficient(13) CD= 0.61 at Re>104

$$Q = u.A_c \tag{5}$$

$$R_e = \frac{4\,\rho\,Q}{\pi\,\mu\,D} \tag{6}$$

The friction coefficient of flow rate is calculated as function of relative roughness of tube surface to diameter (ε/D) and Reynolds number (12)

$$\frac{1}{\sqrt{f}} = -4\log\left(\frac{\varepsilon/D}{3.7065} - \frac{5.0452}{R_e}\log A\right) \tag{7}$$

The parameter A appear in eq.7 was given by :

$$A = \left(\frac{\varepsilon/D}{2.5497}\right)^{1.1098} + \left(\frac{7.149}{R_e}\right)^{0.8981} \tag{8}$$

The pressure drop is calculated from :

$$\Delta P = \frac{2 f l \rho u^2}{D} \quad \text{or} \quad \Delta P = \frac{32 f l \rho Q^2}{\pi D^5} \tag{9}$$

The calculations are required measuring of viscosity and density of crude oil at different temperature as described in Table (1)

Table (1) viscosity and density of crude oil at different temperature

Temperature ^oC	Basarh crude oil			Karkok crude oil		
	k.viscosity m^2/s	density kg/m^3	viscosity $N.s/m^2$	k.viscosity m^2/s	density kg/m^3	viscosity $N.s/m^2$
30	$33.75*10^{-6}$	892.157	0.31	$5.72*10^{-6}$	850.285	.00486
35	$33.10*10^{-6}$	891.411	.0295	$5.04*10^{-6}$	848.165	.0042
40	$32.98*10^{-6}$	888.962	.029	$4.46*10^{-6}$	844.546	.0037
45	$32.30*10^{-6}$	885.229	.0285	$4.23*10^{-6}$	841.943	.0035

EXPERIMENTAL WORK

The equipment used in the present work are:

pumping system rig. 4. electromagnetic mixer
viscometer 5. digital balance
dens meter 6. stop watch

and the materials used are :

1.polymers. 2. crude oil 3. Naphtha. 4. Acetone. 5. kerosene.

reduction Introducing the polymer in crude oil field depend on the solubility of polymer

Pumping system operation

The laboratory of pumping system scheme is described in Fig. (2) , which operate at different conditions of temperate pressure , flow rate and concentration of polymer .

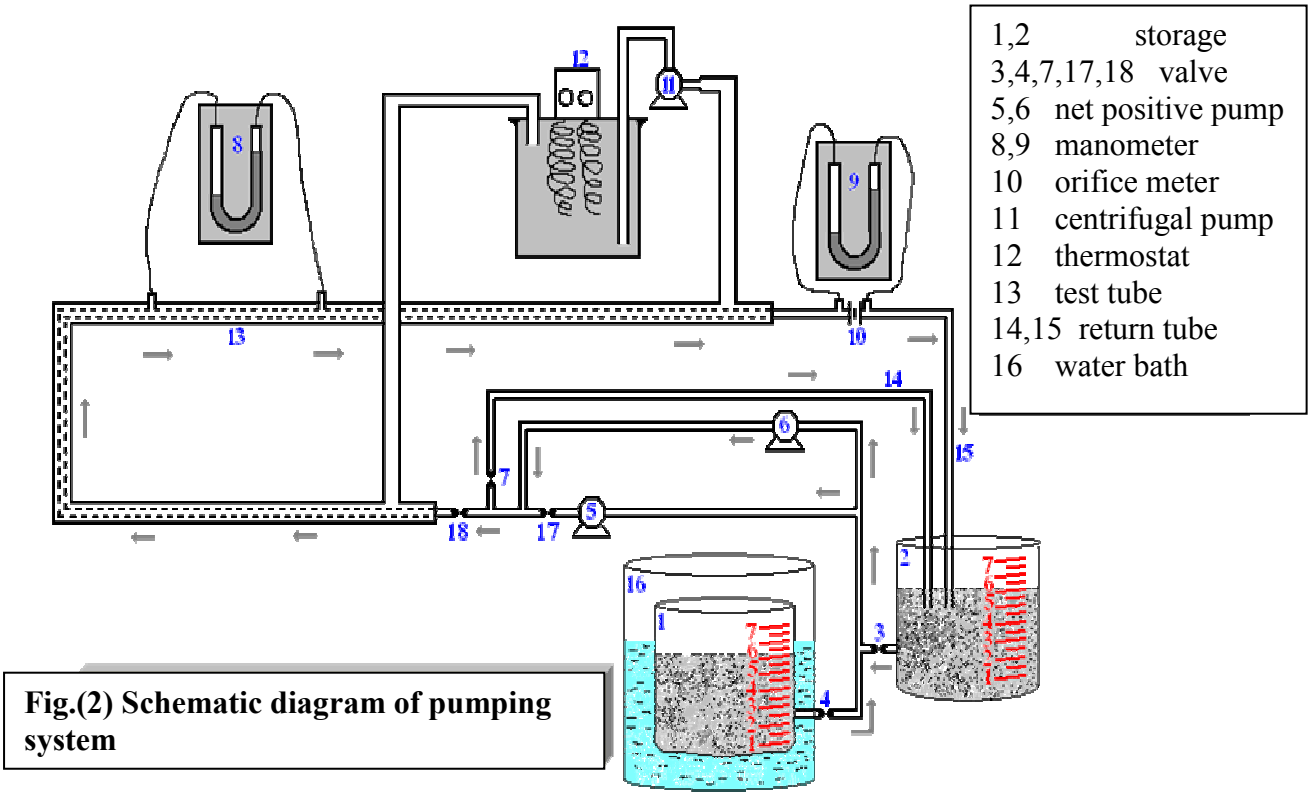


Fig.(2) Schematic diagram of pumping system

Preparation of specimens .

1 . polymer is cutting to small species and dissolved in kerosene by aa ratio of 1: 9 , where the slide begin with swelling and dissolved after 72 hrs be over .

2. using electromagnetic mixer to produce or to get a homogeneous solution .

3. the solution is divided into three groups due to polymer types.

4. added 0.25 ml of polymer to 25 l of crude oil to get a concentration of 10 ppm , and so on to get 20 ppm and 30 ppm.

To operate the pumping system the following steps are followed:

pumps 5 and 6 are turn on for 3 hrs 14 &15are input in storage 1 and 2 respectively. The pump are start on for to verify a perfect mixing of crude .

turn off of pump 5 and opening valves 3,4 and 7 with a proper position . The tubes are introduce to storage 1 and turn on pumps 5 and 6 for 15 minutes, then record the pressure drop across the orifice meter.

repeat step 2 with change the slot of valve to get a different discharge flow rate .

the centrifugal pumps is turn on for recirculation water through cooling loop for adusted of temperature.

repeat steps 2 and 3 for various temperature.

the injection of polymer at various concentration up to 50 ppm through the pumping system.

Results and discussion

Figs. 3 and 4 show the relation between the concentration of PIB150K polymer and drag reduction of Kurkok crude oil, the relation was increased linearly and then become stable, the best drag reduction occurs at concentration of 40 ppm , velocity 1.19 m/s and 40^{o} C.

Figs. 5 and 6 show the relation between the concentration of PIB150K polymer and drag reduction of Basrah crude oil , the drag reduction are increase with increasing the concentration of polymer. The results show that thee concentration of PIB150 with concentration 30 ppm at 40^{o} C lead to drag reduction 20.3% for velocity 6.5 m/s and 15.5% for velocity 4.6m/s

Figs. 7,8 and 9 described the relation between flow rate and drag reduction at different temperatures and constant concentration . The results show the best percent of drag reduction occurs at velocity of 1.8 m./s, concentration of 50 ppm and temperature 45^{o} C which is 32%.

The relationship between the friction factor and drag reduction are represented in Figs.10 and 11, the relation was decreasing exponentially due to injection the polymer into the flowing fluid which causes the drag reduction of flow, according the different physical properties of the type of crude oil n, observed that the coefficient of friction reach to 0.003 at 50 ppm , temperature 45^{o} C and velocity 1.19m/s for Kurkok crude oil while, friction factor reach to 0.00085 at 40 ppm , temperature 45^{o} C and velocity 4.65m/s for Basrah crude oil

Conclusions

1.The best conc. of polymer PIB150K is 30ppm when added to the Kurkuk crude oil at temperature 35oC and velocity of 1.85 m/sec which gives the percent of drag reduction 22.23%.

2.The best conc. of polymer PIB150K is 30ppm when added to the Basrah crude oil at temperature 45oC and velocity of 6.65 m/sec which gives the percent of drag reduction 20. 3%.

3.The friction factor is gradually reduced when the polymer concentration is increased.

4.The performance of polymer is better when transport of the light crude oil than the heavy crude oil.

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NOMENCLATURE:

symbols	meaning	units
A_c	Cross sectional area	m^2
API	API gravity =141.5/sp.gr.-131.5	-
C_D	Volumetric discharge coefficient	-
D	Tube diameter	m
$D.R\%$	Percent of drag reduction	-
f	Friction factor	-
h_f	Head loss	m
Δh	Liquid height difference	m
g	Gravity acceleration	m/sec^2
l	Tube length	m
m	Mass	kg
$-\Delta P$	Pressure drop	N/m^2
$-\Delta P_{D.R}$	Pressure drop after polymer addition	N/m^2
Q	Volumetric flow rate	m^3/sec
Re	Reynolds number	-
u	Velocity	m/sec
Greek letters		
ε	Tube surface roughness	m
μ	Dynamic viscosity	$N.s/m^2$
ν	kinematics viscosity	m^2/s
ρ	Liquid density	kg/m^3

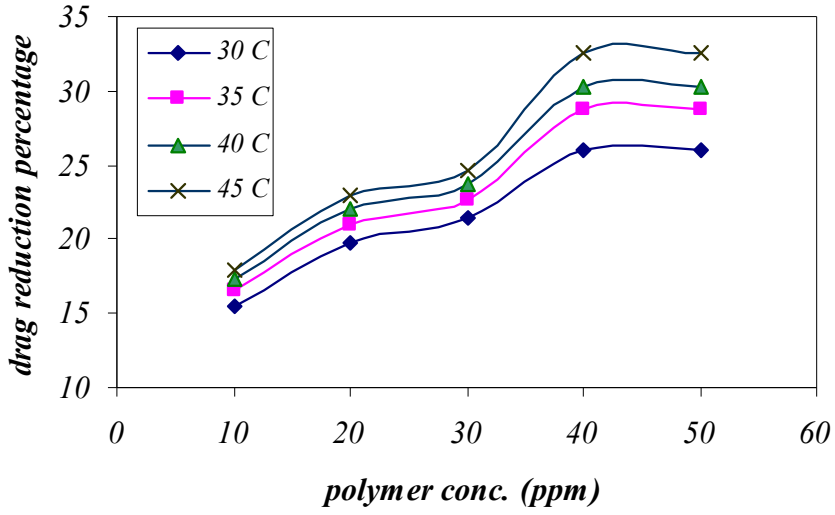

Fig.(3) Effect of polymer concentration PIB150K on the drag reduction of Kurkuk crude oil at velocity 1.85 m/s

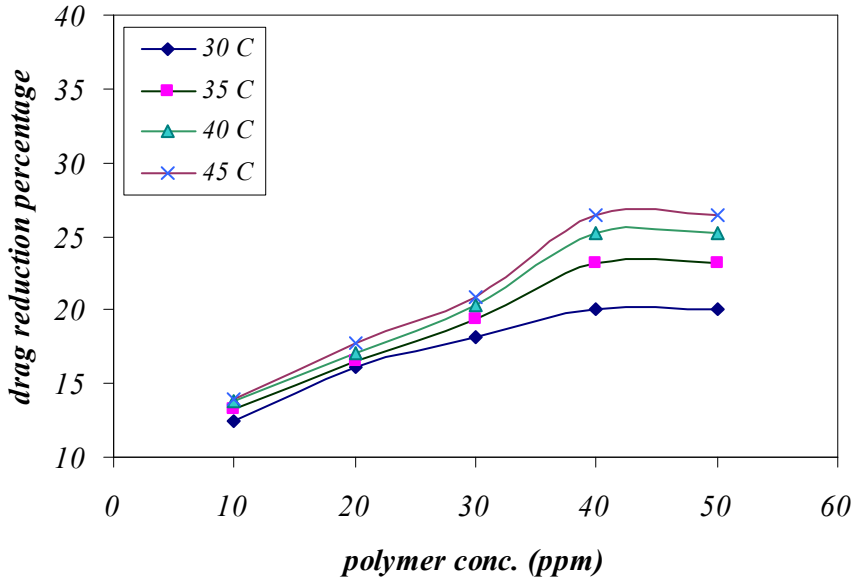

Fig.(4) Effect of polymer concentration PIB150K on the drag reduction of Kurkuk crude oil at velocity 1.19 m/s

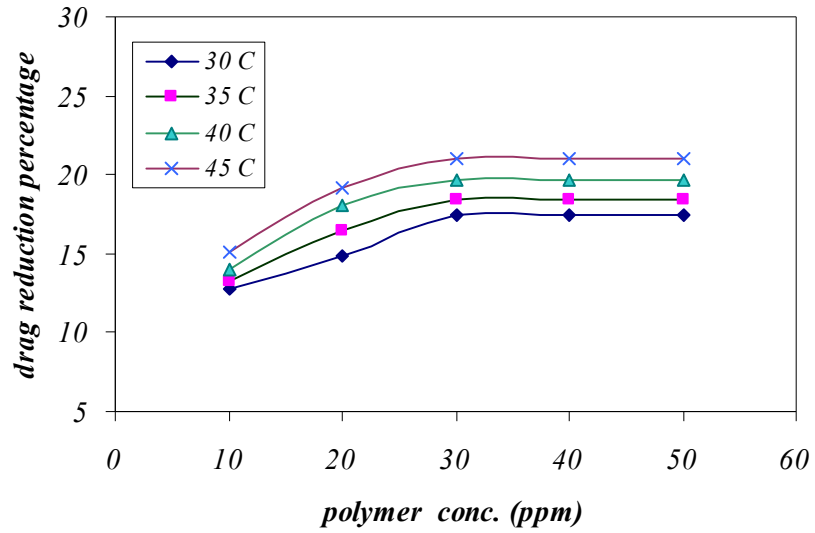

Fig.(5) Effect of polymer concentration PIB150K on the drag reduction of Basrah crude oil at velocity 6.64m/s)

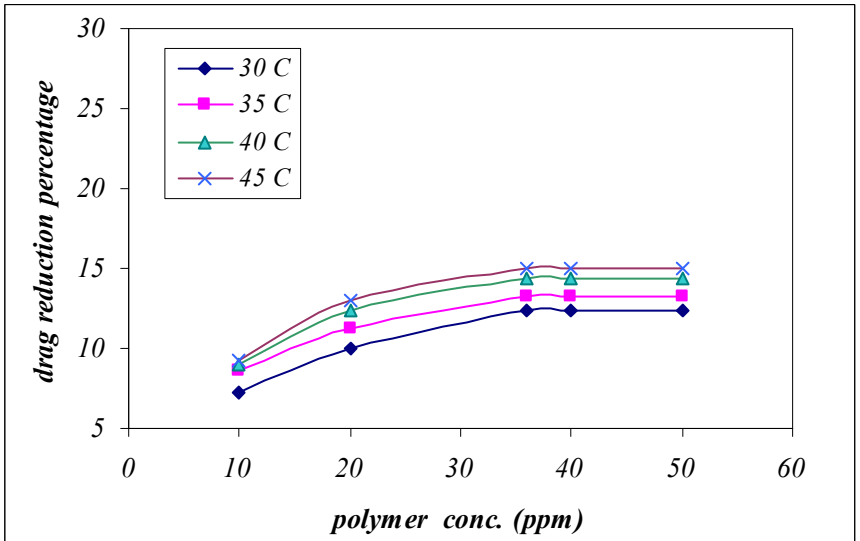

Fig.(6) Effect of polymer concentration PIB150K on the drag reduction of Basrah crude oil at velocity 4.64m/s))

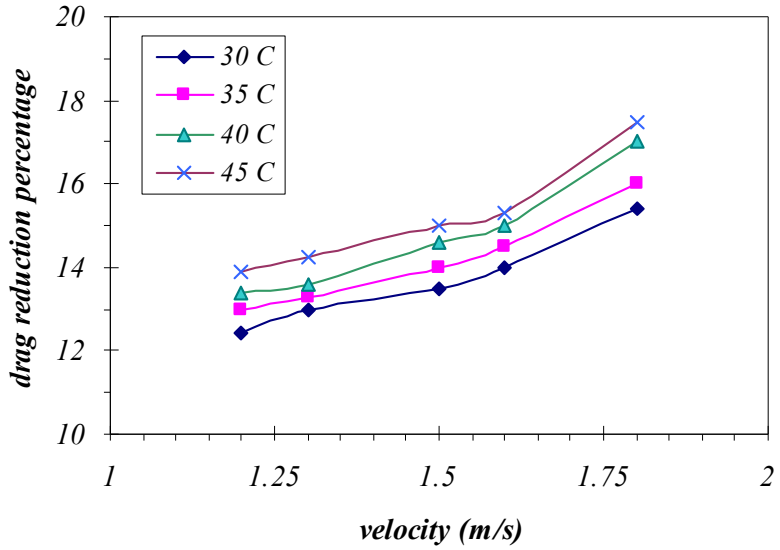

Fig.(7) Effect of flow rate on drag reduction of Basrah crude oil at polymer conc. 10ppm .

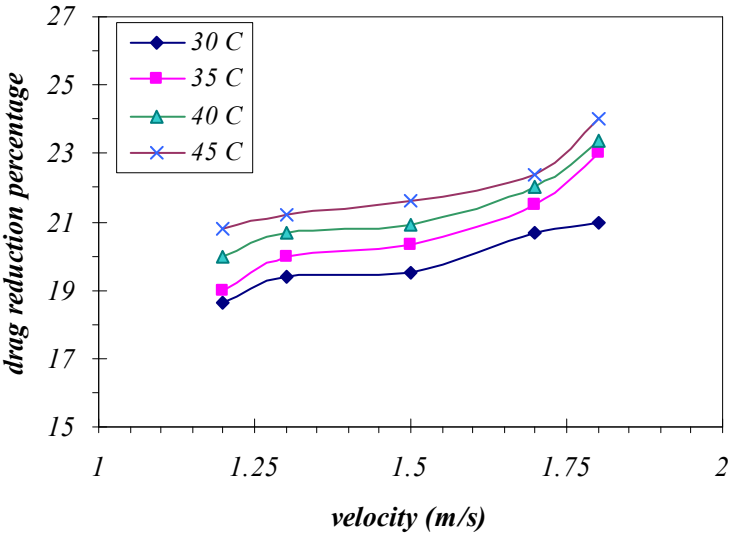

Fig.(8) Effect of flow rate on drag reduction of Basrah crude oil at polymer conc. 30ppm .

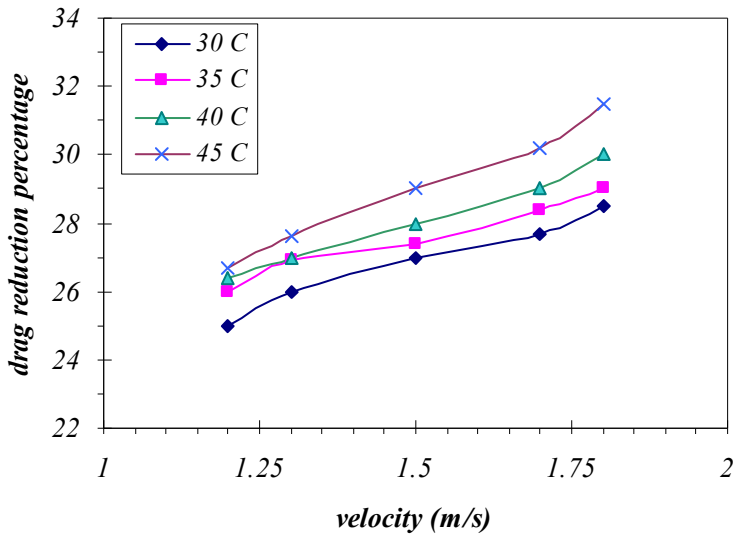

Fig.(9) Effect of flow rate on drag reduction of Basrah crude oil at polymer conc. 50ppm .

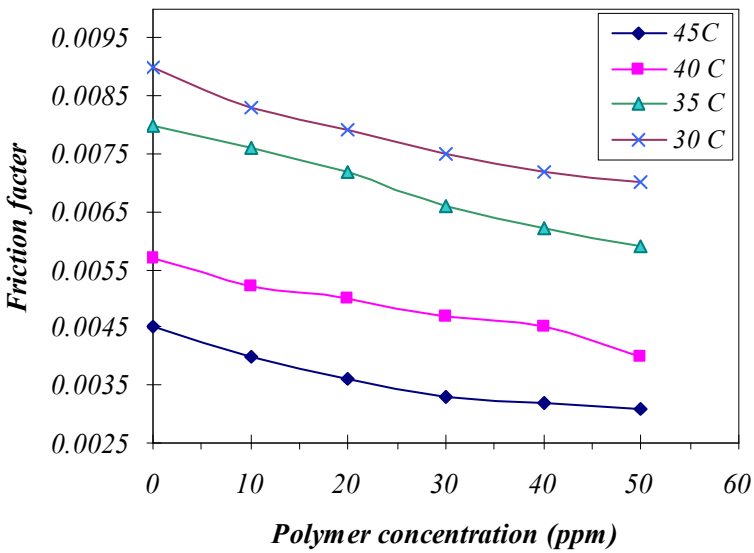

Fig.(10) Effect of polymer concentration on the friction factor of Kurkuk crude oil at velocity 1.19 m/s

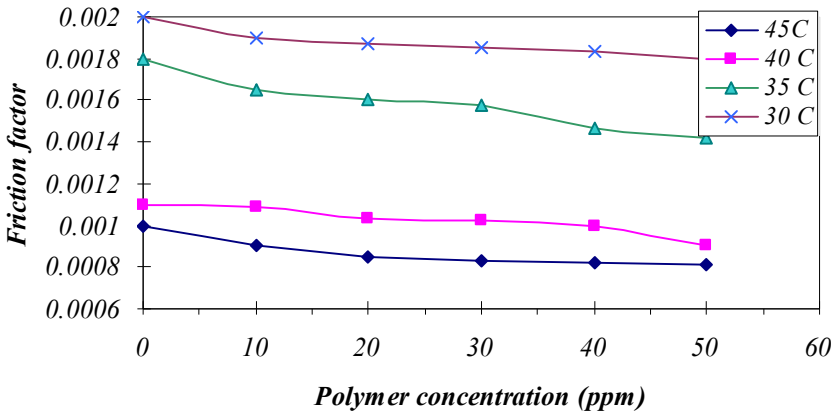

Fig.(11) Effect of polymer concentration on the friction factor of Basrah crude oil at velocity 4.64 m/s