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ORIGINAL ARTICLE

The effect of micro/nanoparticles on pressure drop in Oil pipeline: Simulation

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Abstract

A high pressure drop happens when heavy oil with high viscosity moves through the oil pipeline. A variety of methods to avoid this pressure drop is available. One of which is injection of chemicals to reduce the viscosity and ultimately reduce pressure drop. Using the Pipesim software, the effect of dispersion of nano and micro-particles into the oil has been simulated to study the amount of the pressure drop pipelines. The effects of the parameters such as the type and concentration of particles, temperature, oil rate, inside diameter of pipe and the flow type were examined. Simulating the experimental data by the software, gives promising experimental results. The results show that the copper micro-particles with 0.1 wt% concentrations have the lowest pressure drop per unit length. At low temperatures the effect of concentration of micro particle is important and at high temperatures effects of temperature is dominant. It is noteworthy that in higher rates, the presence of any amount of particles has a favorable impact on the pressure drop. For laminar and turbulent flow, pressure drop will decrease when the oil viscosity decreases. On the contrary for transient flow, pressure drop will increase when the viscosity reduces.

Keywords: *Micro/Nano-particles; Oil; Pipeline; Pipesim; Pressure drop; Viscosity.*

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INTRODUCTION

With respect to scientific advancement in the world and increasing rate of energy consumption; despite of the emergence new energy such as nuclear energy; need of human to hydrocarbon energy sources and fossil fuels can't be ignored [1] so that the need for such fuels will be increased up to 50% for 20 following years [2,3]. Until today, the oil has been mainly extracted from the conventional oil reservoir while due to reducing the amount of conventional oil reservoir in the world and Iran; we should look for new sources such as the unconventional reservoir. However, due to special conditions in this type of oil reservoir, extraction and production are followed by several problems [4]. Heavy oil reservoirs is one of the unconventional reservoirs, due to the high viscosity of oil, production of these reservoirs have encountered with some problems. Similarly, because of the high pressure drop along the pipeline, transferring them are also problematic. There are several techniques and chemical materials to solve these problems for example, the oil production is increased by injection of hot water, steam, solvent and etc by reducing oil viscosity. However the oil viscosity is increased again into the transfer pipelines. Also in order to reduce pressure drop in oil pipelines, some methods are employed in industry such as injection of chemicals (such as DRA: Drag Reducing Agent) [5, 6].

Nanotechnology is one of the techniques, which has been penetrated in all sections of oil and gas industries within less than one decade including production, exploitation, drilling, enhanced oil recovery and etc. Despite of short lifetime, this

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science could improve upstream and downstream oil industries by employing different methods including change in oil properties and reservoir rock (reduced surface tension [7,8], wettability alteration [9,10], reduction of viscosity, and etc) and at the same time it causes reducing pressure drop in transfer pipelines by decreasing the drag force and the friction.

Nanoparticles allow the easier motion of oil layer through each other by being embedded between oil layers; as a result, the viscosity reduces [11]. Alternately, according to Einstein's correlation, presence of solid particles in the fluid may generally increase viscosity of fluid [12]. While, along with increasing viscosity, a chemical reaction, under title of aquathermolysis, is being done and it can reduce viscosity of fluid [13]. Most of the nanoparticles which have been used to reduce viscosity, were metal and metal oxide nanoparticles [14-16]. Shokrlu *et al.*. observed that the presence of nickel nanoparticle leads to decrease the percentage of asphaltene in oil thus fluid viscosity reduces [15, 17-20]. Chen *et al.*. observed Keggin nanoparticle facilitates the aquathermolysis process, on average 10% of oil heavy molecules are altered into light molecules and heavy oil viscosity are averagely reduced up to 90% [21]. The effect of many metal nanoparticles and metal oxides including iron, copper, nickel, zinc oxide, alumina, titanium, iron oxide, tungsten oxide (III) on viscosity of heavy oil has been investigated till now. Shokrlu *et al.*., with study on various nanoparticles at different temperatures, reported that the particles in nano size reduce viscosity better than particles with micro size [16]. Afzal *et al.*. with study on various nanoparticles in different concentration and at different temperatures reported that in some cases, the viscosity is reduced even more than 50 % of primary state and also nickel oxide and iron oxide are most effective nanoparticles in reduction of viscosity [22]. Also, Li *et al.*. investigated that nickel nanoparticle might extremely reduce oil viscosity [23]. Jain *et al.*. could reduce viscosity up to 90 % by adding silica nanoparticle to the polymer [24]. Esmaili *et al.*., by using Linearization model, has studied the parameters of pipe diameter, input pressure, and also way of changing temperature in gas transferring pipeline in Persian Gulf with slug flow [25]. Pipesim software is one of the packs of Schlumberger Company, which mainly uses in simulation of wells and surface equipment in the petroleum engineering. This software is widely uses by many engineers of oil and gas industries for computations of pressure drop of single-phase and multi-phase fluids flow inside pipelines, casing tube, coiled tubing, and etc. There are a lot of correlation those could be chosen for fluid dynamic, phase behavior, viscosity, etc. In this paper we have used black oil to introduce fluid to the software. As we wanted to consider the viscosity of fluid with particle to the software. We entered dead oil viscosity of each fluid to the software directly and the software can interpolate that for other temperature. And we have set the software to use Chew and Connally correlation for live oil. In this software also the correlation to calculate pressure drop can be selected. There are a lot of choice such as Beggs and brill, Dukler *et al.*., Panhandle, etc. and in this paper Beggs and brill has been chosen. The angle of pipe also can be adjusted. In this paper the pipe has been considered horizontal. Similarly, this software possesses a lot of potential and capabilities in design, sensitometry, and optimization of process [26].

In this study, pipesim software has been used for simulation the effect of injecting nano and micro particles in oil and studying the reduction of oil pressure drop in oil transfer pipelines. Also, the effect of type of nano and micro-particle, particle size, weight fraction of dispersed particle, temperature, volume flow rate, inside diameter of pipe, and type of flow have been also studied.

To ensure of accuracy in the results of the simulated model, the published results in reliable resources were used.

EXPERIMENTAL

Pipesim software was used for simulation of oil transfer pipeline. In this simulation, a horizontal pipeline is considered that the specifications of this pipeline are given in Table 1. Oil is the fluid that flows in this pipeline at single-phase (Table 2). Because of software limitation, particles are not introduced to that directly, therefore the effect of the particles on oil have been considered equal to effect of them on viscosity which are collected from published experimental result [17]. Viscosity of crude oil depends on temperature so the viscosity is given at three temperatures in Table 3. The type and size of particles, which have been used for injection of crude oil in the pipeline, are presented in Table 4.

The basic simulation model has been prepared in order to be used by means of the existing conditions at all phases in Tables (1-3). The results of pressure drop derived from basic simulation have been compared with the experimental results in reference [27] and after ensuring from accuracy of the model, the effect of particles which were introduced in Table 4 on rate of pressure drop have been examined. Also the effect of particle type, weight friction of the dispersed particle, temperature, oil volume flow rate and inside pipe diameter on the simulated model have been investigated.

Table 1: Pipeline specifications

No.	Specifications	Quantity
1	Diameter	50, 30, 15 in
2	Roughness	5.1μm
3	Length	1000m
4	Thickness	0.50in

Table 2: Oil properties

No.	Specifications	Quantity
1	API	14
2	Density(kg/m^3)	962.78
3	Rate (m/sec)	2, 4, 6, 8
4	Temperature(C)	25, 50, 80

Table 3: Oil viscosity

No.	Temperature(C)	Viscosity (cp)
1	25	8492
2	50	1214
3	80	234

Table 4: Type and size of particles

No.	Material type	Particle size (nm)
1	Fe	6000-9000
2	Fe	40-60
3	Fe_2O_3	<50
4	Ni	<100
5	Cu	10000

RESULTS AND DISCUSSION

The results of the simulated model in Pipesim software are acceptable with the experiential result in reference [26]. It should be mentioned the fitted parameter was friction factor for model. As demonstrated in Table 5, the amount of relative error in pressure drop for the viscosity under 700 cP is not ignorable, but for the rest of viscosity the relative error is not exceed 7 %. It is noteworthy all viscosity those are used in this study were above 900 cP. So the relative error in pressure drop resulted from the simulated model with respect to the experiential result can be ignored.

Effect of type and weight fraction of Micro/ Nanoparticle on pressure drop

The impact of type and size of particles on pressure drop in oil transfer pipeline, ratio of with particle to without particle, $\left(\frac{\Delta P_x}{\Delta P_c}\right)$ at temperature 25 ^oC and flow rate 0.912 m³/s are given in Fig. 1. The best particle in terms of reducing pressure drop inside pipeline is copper micro-particle with 0.1 wt% concentration. Also this trend is observed at temperatures 50 ^oC and 80 ^oC and varies rate in laminar and turbulent condition.

Effect of temperature on pressure drop

The effect of temperature on pressure drop per length for Cu micro particle (0.1 wt %) has been shown in Fig. 2. The figure shows that as temperature is increased, the pressure drop reduces. The effect of temperature, at higher temperature, prevails over micro-particle. But, this trend is reversed at lower temperatures (Table 6). Thus, the pressure drop mechanism can be expressed as a function of particle and temperature, other parameters are constant, and this mechanism was observed for all diameters.

Effect of inside diameter on pressure drop

Fig. 3 shows the effect of inside diameter on pressure drop per length for copper micro-particle (0.1 wt% and 25 ^oC). In this figure, as inside diameter is increased, the pressure drop reduces. Pressure drop is a function of pipe diameter and particle, other parameters are constant. The inside diameter of pipeline is assumed as the prevailing mechanism over reducing pressure drop as the pipe inside diameter is increased, while in smaller inside diameters the particle is considered as the dominant mechanism (Table 7). This mechanism was observed to all rates.

Effect of flow on pressure drop

The effect of flow regime for two types of fluids has been investigated in Table 8. In Table 8, for a fully laminar and turbulent flow, the pressure drop has reduced with decreasing viscosity but this trend is reversed in the transient flow, whereas viscosity decreases, the pressure drop increases.

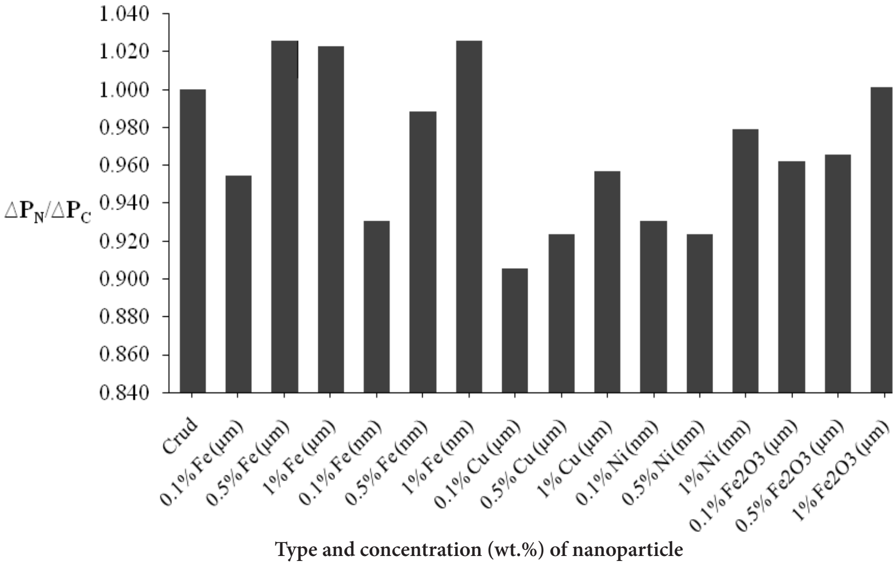

Fig. 1: Effect of type and size of particles on pressure drop (25 °C)

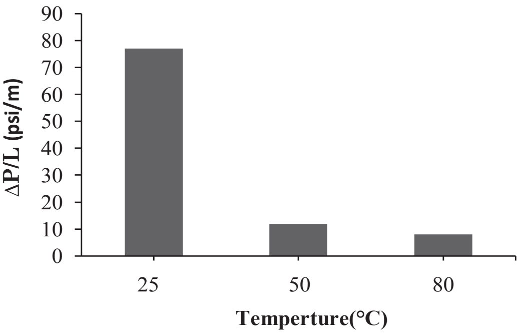

Fig 2: Effect of temperature on pressure drop per length

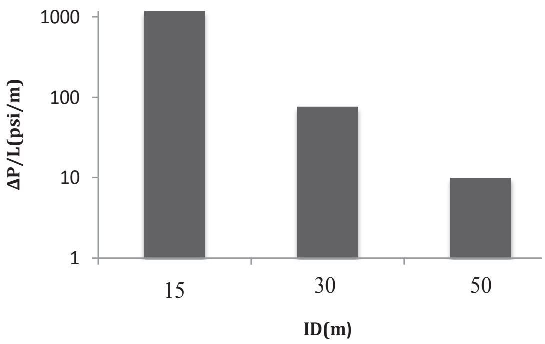

Fig. 3: Effect of inside diameter on pressure drop

Table 5: Comparison of the data obtained with previous work

No.	Temperature(°C)	Viscosity(cp)	Pressure drop(Pa/m) (Experimental)	Pressure drop(Pa/m) (Model)	Relative Error (%)
1	60	3064	33.43	31.66	5.28
2	70	1287	13.56	13.39	1.29
3	82	606	6.29	7.58	-20.64
4	95	319	3.22	4.16	-29.47

Table 6: Effect of temperature on pressure drop (30 inch and 0.912m³/s)

No.	Fluid Type	Nano / Micro	Amount (wt %)	Temperature(°C)		
				25	50	80
1	Crude oil	------	-------	85.141	12.473	8.128
2	Crude oil	Micro	0.1	77.042	11.888	8.008

Effect of velocity on pressure drop

The effect of velocity on pressure drop in oil transfer pipeline for copper micro-particle (0.1 wt%, and 25 °C) is given in Table 9 and Fig. 4. These show that while velocity is increased, pressure drop increases too. But, presence of particle reduces pressure drop.

It should be noted that the trend of all parameters in Figures and Tables are identical for all of mentioned particles in Table 4.

Table 7: Effect of inside diameter on pressure drop (25 ºC and 0.912 m³/s)

No.	Type	Inside Diameter (in)		
		15	30	50
1	Crude oil	1305.77	85.105	11.063
2	Crude oil + 0.1% Micro Cu	1185.78	77.042	10.008

Table 8: Pressure drop per length with viscosity and flow regime

No.	velocity (m/sec)	Flow Type	Pressure drop per length (psi/m)	
			Crude oil	Crude oil + 0.1 wt% Micro Cu
			1214 cp	1157 cp
1	2	Laminar	12.473	11.888
2	4	Transient	29.733	30.136
3	6	Transient	76.143	77.507
4	8	Turbulent	137.255	135.363

Table 9: Effect of velocity on pressure drop per length

No.	Material	Velocity (m/sec)		
		2	4	6
1	Crude oil	85.105	169.717	253.725
2	Crude oil + 0.1 wt% Micro Cu	77.042	153.619	229.731

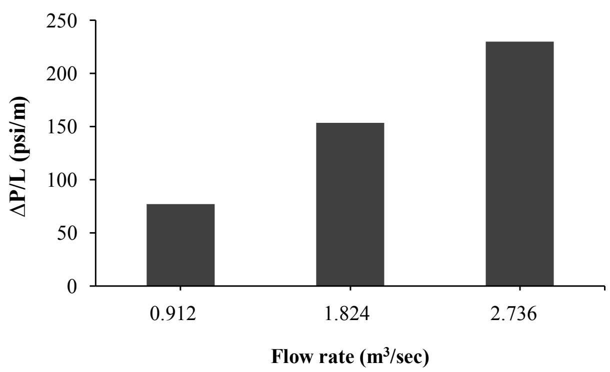

Fig. 4: Effect of flow rate on pressure drop per length

CONCLUSION

In this study, effect of Nano/Micro-particles type, temperature, inside diameter of pipeline, flow regime, and rate on reduction of pressure drop in pipeline were investigated by using Pipesim software. The results show:

- Copper micro particle with 0.1 wt% was concluded maximum reduction in the pressure drop.

- As temperature rises, the effect of Nano/Micro-particle on viscosity and thus pressure drop is reduced and rising temperature is assumed as dominant mechanism.

- The pressure drop reduces, as inside diameter increased. In higher diameter, the inside diameter of pipeline is assumed as dominant mechanism and the effect of Nano/Micro-particle decreases.

- In fully laminar and turbulent flow, as viscosity is reduced, the pressure drop decreases but in transitional flow this trend is vice versa.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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