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Preparation and Application of Natural and Low Cost Palm Fibers as an Effective Drag Reducing Agent for Flow Improvement in Iraqi Crude Oil Pipelines

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ABSTRACT

Flow of crude oil in pipelines suffers from a problem of fluid flow pressure drop and high energy consumption for fluid pumping. Flow can be enhanced using either viscosity reduction or drag reduction techniques. Drag reduction (DR) is considered as a most effective and most applicable method. The technique contributes in reducing the frictional energy losses during the flow by addition of little amounts from drag reducing agents. The present work focuses on preparation and application of a new natural and low cost material derived from palm fiber (PF) that has been tested as a drag reducing agent (DRA) for crude oil flow enhancement. This objective has been achieved through designing and constructing of an experimental rig consisting of: a crude oil pipe, oil pump, pressure sensors, solenoid valve and programmable logic control. The additive material (PF) is prepared with different diameters (75µm, 125µm, 140µm) and tested with different concentrations as: 100, 200, 300, 400, and 500 mg/L for reducing the drag inside the oil pipe. The experimental results showed that the fiber with 125µm diameter and 100ppm is the best where the percentage of drag reduction reached 43%. Furthermore, the results of this work proved that PF is an efficient and low cost DRA that can be applied successfully in crude oil pipelines as well as its contribution in the waste management.

1. Introduction

The pipeline is a means of transporting crude oil from the fields to the plant, which is the most efficient, safety, cost-effective and environmentally friendly. However due to high viscosity and density of crude oil, this causes losses in the pressure and increasing friction. the reduction of friction and pressure drop can be achieved by adding a small concentration of additives without changing the pipeline conditions, these additives are useful to reduce drag in crude oil and known as a drag reducing agent (DRA) [1,2]. Since the phenomenon of drag reduction occurs in turbulent flow, it is necessary to consider the turbulence processes that are present in the flow [3].

One of these additives known as fibers, fiers are long cylinder like objects with high length to width ratio. They oriented themselves in the main direction of the flow to reduce the drag stated that fiber suspension happens in a large set of natural and man-made materials. The inspection of microstructure of fiber suspension has experienced a lot of interest due to the mechanical, thermal and electrical

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properties of the corresponding fiber composite are very sensitive to the direction distribution and spatial arrangement of fibers. Such suspension has complicated rheological properties that are various from those of the suspending liquid, even at very low concentrations [4,5].Numbers of studies have been done by Vaseleskiet al. 1974 [6] and Lee et al. 1974 [7] where they studied turbulent drag reduction in homogeneous mixture of polymeric solution and fibers. Their results indicated a maximum drag reduction of 95%. They further observed that the polymer possesses the ability to augment the drag reduction when mixed with fiber suspension, although no reduction of the drag is achieved with polymer alone. The addition of fibers to a degraded polymer solution leads to increase the percentage drag reduction more than use degraded polymer.. In addition of the coconut fiber develops the DR% of the following suspensions.PVC pipe was used with three divers internal diameter (0.0127, 0.0254 and 0.0381 m) and the pressure drop is taken at four divers points of 0.5, 1.0, 1.5 and 2.0 m long. DR% was exhibited to rise by rising the additive concentration reaching ultimate amount at 55.58% with concentration up to 250 ppm of fiber in water [8]. John W,et al 1973 [9] studied the drag reduction (DR) of dispersions of Chrysotile asbestos fibers in aqueous solutions of Aerosol OT and in ethylene glycol, and of glass microfibers in water at a pH of 3 were studied as a function of concentration and temperature with a rotating disc apparatus which showed a DR up to 40% at 150ppm and Reynolds number 6.6×10^-5 . Sharma R,et al 1978 [10] applied asbestos fiber as DR with 19mm ID and length 2m of acrylic pipe ,the result showed that asbestos reduced the drag up to 40% that happened at about concentration 100ppm on Reynolds number around 20,000. SalimN, et al 1998 [11] applied wood pulp fiber in water was observed that a small amount of fiber in suspension causes drag reduction and reduces the heat transfer coefficient and Appeara drag reduction up to 40%. alone.Lin et al. 2006 [12] Investigated the effect of distribution of fiber suspension in Newtonian fluids. They proved the ability of suspended fibers to suppress the turbulence. The flow rate is considerably increased at the same pressure drop due to the relatively lower turbulent intensity with fiber suspension. Takuya K,et al2012 [13] also revealed that Bamboo fiber suspensions with average length1.19 mmand average diameter13.3μm, The measurement part of pressure drop was made of acrylic pipe with inner diameter of 5, 10, and 15 mm and otherpipes were made of stainless steelreduced drag by up to 20%. in addition Hayder A, et al 2010 [14] showed paddy husk fiber which also reduced the drag in pipes up to 32% .Paul K,et al 2011 [5] used Micro fibrillated cellulose (MFC) on water with concentration between 0.02 – 0.2% . . Pipe line was made of PVC, with length 3m and two inner diameters 45mm and 57mm. At 0.15% concentration and 57mm diameter the maximum DR% was 9%. J Warashina et al 2015 [15] employed nata de coco fiber as DRA on water . pipe line was made of stainless steel,with 5.1m long and 0.015m internal diameter . maximum drag reduction was 25% at 50ppm concentration. Amir E, et al 2017 [16] used olyacrylonitrile fibers of largerlengths (6 mm) demonstrated minor and a rectangular pipe with 6m length are used, drag-reducing effects (up to 3%). Ahmed, S. M., et al 2017 [17] used Kenaf core pulp fiber DR increase to about 5.09% at concentration 0.6%.wt. Gharehkhani, Samira, et al. 2017 [18] added a small amount of fiber to water , the maximum drag reduction of 24% occurred at0.6 wt.% concentration andpipe diameter of 40 mm. Wulandari W, et al 2018[19] applied coconut fiber suspension in water with circular pipeID 38 mm, mm, it can be concluded that the coconut fiber suspensions has an effect on the drag reduction about 7.6% with concentrations 1000 ppm.

In this study palm fiber are used to improve flow crude oil in pipe lines because of the natural fibers are environmentally friendly, waste material, Available in Iraq, low cost and easy to prepare and handle.

2. Expermental work

2.1. fiber preparation

The fiber was collected from palm trees in Baghdad city, Iraq .Palm fiber contains over 48.93%cellulose and 30.52% lignin.[20] A weight of 75 g of fiber was cut, washed five times the first three times with tap water and second two times with distilled water and dried after each wash under the sun for 48 hour. The dried fiber put in an oven at 70°C for 24h to dry well. The dried fiber is grinded with an electrical grinder for 30 minute. Then it was sieved in a sieve to obtain three different diameters (75μm, 125μm, 140μm). figure(1) shows the samples of fiber

Figure 1. samples of palm fibers: (a) Sample with diameter 75µm(b) Sample with diameter 125µm (c) Sample with diameter 140µm.

2.2. expermental set-up

Drag reduction was measured in a closed flow loop.The experiment is performed in a re-circulatory flow facility which is shown in Figure(2).This system consists of Control unit, oil pump,Pressure gauge, Pressure Sensor, PVC pipe with a diameter of 0.5 inch and length of 2m, , oil tank.

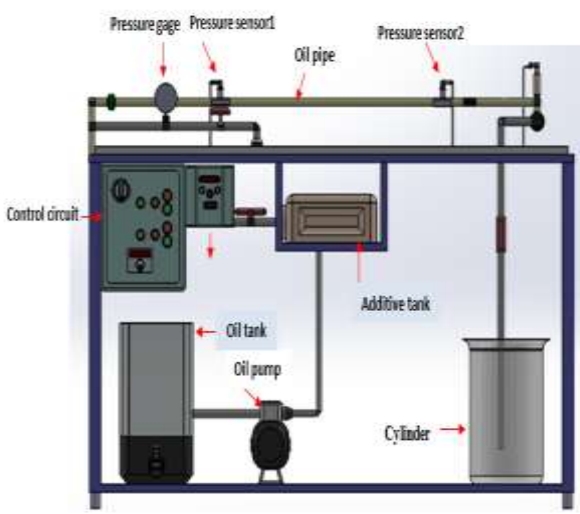

Figure 2. The experimental system

2.3 Experimental procedure

Five concentrations are weighted (100ppm, 200, 300ppm, 400, 500ppm) by electronic balance for each diameter. Fiber was stirrer with crude oil for 20 minute using magnetic stirrer then the mixture added to oil tank. The friction factor, pressure drop, drag reduction, density, viscosity, Reynolds number and power consumption is

Table 1. Device specifications

device	Type	Specifications
oven	Memert	Max temp +*300* 0C
Electric tread-mill	Stain-lesssteelRRH A500	220 V, 2300W
sieve	AS200	230V ,50HZ ,430W
Oil pump	WCB75	220/380V,750W,50L/min,Max Head 30m,0.3Mpa (43 psi)
Pressure Sensor	PA-21Y/81554.3 3	Rang 0-10 bar,Out /GND 4-20mA
Accurate elec-tronicbalance	FRAGILE	230V50HZ,0.001g-500g
Magneticstirrer	78-1HOT PLATE &STIRRER	250V, 6A
Viscometer	Cannon-Fenske-routine	Size 200, Constant (cst/s)=0.1, Kinematic Vis (cst) from 20 to100
Pycnometer	Duran	Volume 25.81cm3

calculated before and after additive. Table (1) shows the device specifications .

3.Experimental calculation:

Percentage of drag reduction

Pressure drop reading through the pressure sensor before and after additive .Percentage of drag reduction can be calculated by:[21]

$$\mathbf{DR} = \frac{\Delta p_b - \Delta p_a}{\Delta p_b} \qquad (1)$$

Where pa is a pressure drop before additive and pb is pressure drop after additive.

Power consumption, Reynolds number and friction factor

Flow rate Q (m3/s), Re Reynolds number density **ρ**, viscosity **μ**,u velocity, D diameter of pipe, f friction factor , L length of pipe[22,23]

$$\mathbf{P_E} = \mathbf{Q.\Delta p}$$
(2)

$$\mathbf{Re} = \frac{\rho u D}{\mu} \qquad (3)$$

$$\mathbf{f} = \frac{\Delta P.D}{2\, L\, \rho\, .u2} \qquad (4)$$

4.Results and discussion

4.1 fiber test

These three samples are tested length by Optical Microscope shown in figures (4.1).this sample have different diameter and length.

Sample (A) is a fiber with diameter 75µm and average length6.5um,(B) is a fiber with 125µm diameter and average length 12µm and (C) have 140µm diameter and 16.5 average length.

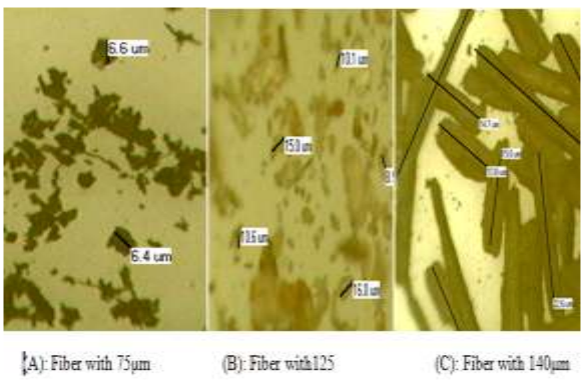

Figure 3. Fiber test

4.2 Effect of palm fiber addition:

Figures (4-9), show the effect of three fiber diameter (75 µm, 125 µm, 140 µm) and five concentrations (100,200,300,400,500) ppm on friction factor, pressure drop, drag reduction, viscosity, Reynolds number and power consumption.
Figure (4), indicated the effect of palm fiber on friction factor, where the friction factor decreases from 0.0052 when there is zero addition to (0.0032, 0.0034 and0.00253) at fiber diameter (75µm, 140µm and 125µm) respectively and 100ppm of concentration. This is due to the fact that the fiber acts as a broom inside the crude oil pipes, pushing the plankton, thus preventing adhesion of the crude oil particles to the inside tube surface, this reduces the friction between the crude oil molecules and the inner surface of the pipe. In addition, fiber mesh is made near the wall of the crude oil pipeline; this grid limits the formation of eddy currents thus lead to reduce the friction inside the pipe flow. After 100 ppm the friction factor increased gradually. This behavior can be attributed to fibers aggregations at elevated concentrations.

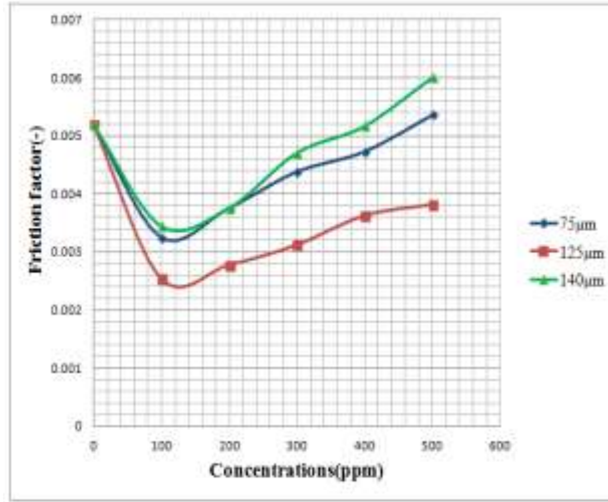

Figure 4. Effect of PF on friction factor

Figure (5), illustrates effect of fiber on pressure drop, where the pressure drop decreases from 46000Pa when there is no addition to(32000Pa, 33000Pa and 26000Pa) at 75µm, 140µm and 125 µm respectively of fiber diameter and 100ppm. Because of the low friction between the crude oil molecules and the inner surface of the pipe, crude oil molecules provide energy in the form of pressure. After 100 ppm the pressure drop increased gradualy.

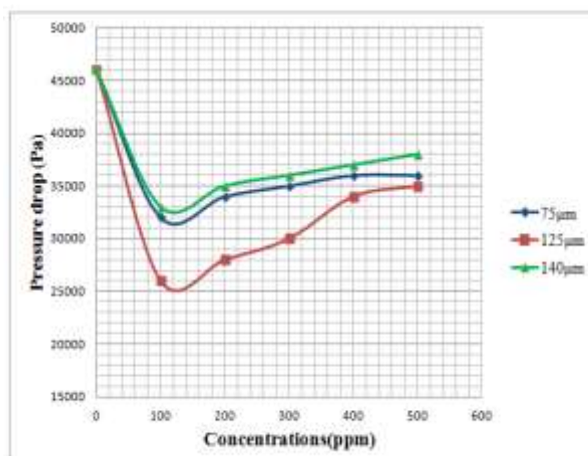

Figure 5. Effect of PF on pressure drop

Figure (6), represent the impact of fiber on DR, where at 100ppm of fiber concentration the percentage of drag reduction increases by 30.43% ,28.26% and 43%. at 75µm 140µm and 125 µm diameter respectively. Drag is known to disability in flow and clouds between fluid molecules, where drag is proportional to the friction inside the pipe so the lower the friction, lead to reduce the drag. After 100 ppm the DR% decreased gradually.

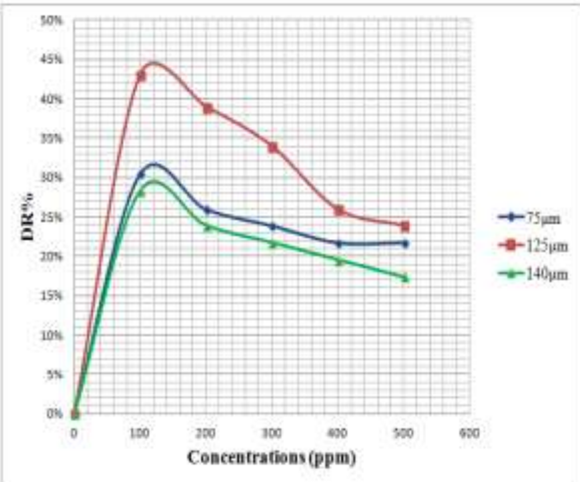

Figure 6. Effect of PF on DR

Figure (7), shows the effect of fiber on viscosity, where at 75µm and140µm of fiber diameter and concentration of 100ppm, the viscosity decreases from 21.5cstc to 14.5cst, at 125µm and 100ppm the viscosity decreases to be 14cst. Viscosity is the resistance of the fluid to displace one layer on the other layer; the fibers are formed in longitudinal chains that allow the layers of fluid to slide over each other and thus reduce the viscosity of the fluid. After 100ppm the viscosity increased gradually.

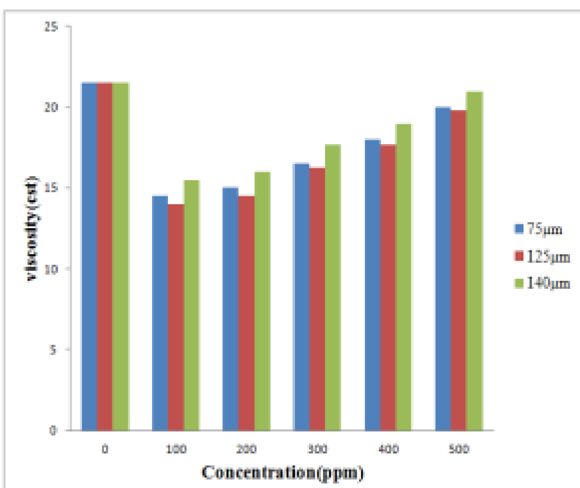

Figure 7. Effect of PF on viscosity

Figure (8), represent the effect of fiber concentration on Reynolds number, where Reynolds number ranges from 3264.121 when there is no addition to 5323.894 in the range of turbulent flow when using 100ppm of 125µm fiber. The Reynolds number increase with increasing the flow velocity and decreasing the viscosity of fluid. After 100 ppm Reynolds number decreased gradually.

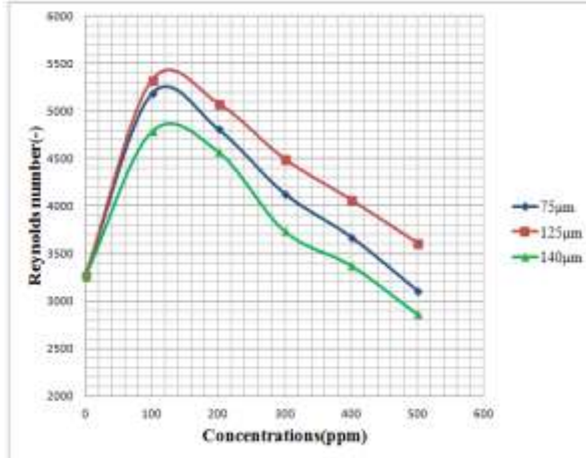

Figure 8. Effect of PF on Reynolds number

Figure (9), illustrates the effect of fiber on power consumption, where the power consumption decreases from 32.2 watt at zero addition to (22.4, 23.1 and18.2) watt at 100ppm for each of 75µm,140µm and 125 µm respectively. The power consumption to pump the crude oil is directly proportional to the pressure drop inside the pipe, the lower in the pressure drop lead to the lower in the power consumption. After 100ppm the power consumption decreased gradually

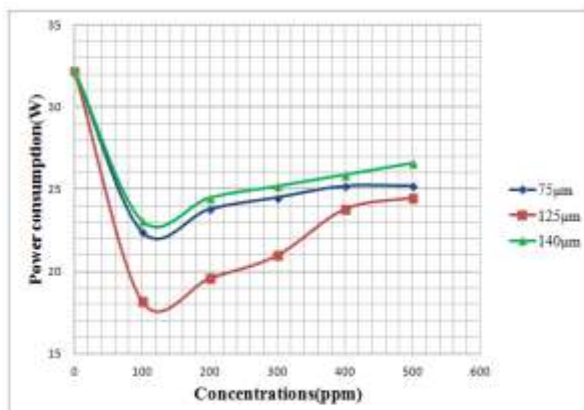

Figure 9. Effect of fiber addition on power consumption

5. Conclussion:

The experimental work in a Perspex pipe of 0.5 inch diameter and 2m long to study the effect of palm fiber on the drag reduction and hence power consumption. The following conclusions can be obtained from experimental results.

The results showed that addition of 100ppm of palm fiber with a diameter 125µm to crude oil in a pipe , the friction factor decrease from (0.0052 to 0.00253), the pressure drop decrease from (46000 to 26000)Pa and the DR% has increased by 43% so the power consumption decrease from (32.2 to 18.2) watt.

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