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Experimental Analysis and Investigation effect of DRA (Drag Reducing Agent) in liquid Hydrocarbon Pipelines

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Abstract

Oil and gas industry is one of the most capital-intensive industry in the world. Each step of oil and gas processing starting from exploration, exploitation, up to abandonment of the field, consumes large amount of capital. Optimization in each step of process is essential to reduce expenditure. In this paper, optimization of fluid flow in pipeline during oil transportation will be observed and studied in order to increase pipeline flow performance.

This paper concentrates on chemical application into pipeline therefore the chemical can increase overallpipeline throughput or decrease energy requirement for oil transportation. These chemicals are called drag reducing agent, which consist of various chemicals such as surfactants, polymers, nanofluids, fibers, etc. During the application of chemical into pipeline flow system, these chemicals are already proven to decrease pump workfor constant flow rate or allow pipeline to transport more oil for same amount of pump work. The first application of drag reducer in large scale oil transportation was in Trans Alaskan Pipeline System which cancel the need to build several pump stations because of the successful application. Since then, more company worldwide started to apply drag reducer to their pipeline system.

In this paper, one of the method is studied and experimented For given pipeline system the most optimum DRA is DRA for pipeline section. Different type of oil and pipeline geometry will require different chemical drag reducer.

Keywords: pipeline, drag reduction agent (DRA).

Introduction

Drag reducing agents (DRA) are high molecular weight substances that are added to a pipeline in order to reduce turbulence and thereby increase the capacity and efficiency of flow through the pipeline. Turbulence in pipelines is caused by friction or interaction between the flowing fluid and the pipe wall. Drag reducing agents reduce the interaction and contact between the wall and the fluid. They are injected in flow streams in small quantities. Drag reducing agents are commonly used in oilfields. They help decrease the pressure drop along the pipeline. This helps lower the pumping cost and energy consumption. Drag reducing agents are prone to degradation due to their high molecular weight.

Using just a few parts per million of the drag reducer helps to reduce the turbulence inside the pipe. Because the oil pushes up against the inside wall of the pipe, the pipe pushes the oil back down causing a swirling of turbulence to occur which creates a drag force. When the polymer is added, it interacts with the oil and the wall to help reduce the contact of the oil with the wall.

Knowing what will create the ideal drag reducer is key in this process. Ideal molecules have a high molecular weight, shear degradation resistance, are quick to dissolve in whatever is in the pipe, and have low degradation in heat, light, chemicals, and biological areas.

With drag reduction, there are many factors which play a role in how well the drag is reduced. A main factor in this is temperature. With a higher temperature, the drag reducing agent is easier to degrade. At a low temperature the drag reducing agent will tend to cluster together. This problem can be solved easier than degradation though, by adding another chemical, such as aluminum to help lower the drag reducing agent's inter-molecular attraction.

Other factors are the pipe diameter, inside roughness, and pressure. Drag is higher in smaller diameter pipe. The rougher the inside surface of the pipe, the higher the drag, or friction, which is measured by the Reynold's number. Increasing the pressure will increase flow and reduce drag but is limited by the maximum pressure rating of the pipe.

One of the most important issues in oil and gas transportation is the existence of turbulence flow in pipeline. Turbulence condition can be described as irregular and erratic movement of fluid when nonlinear inertial effect is superior than viscous effect, generally the fluctuated properties are velocity, temperature, and density. Turbulence flow to happen, energy is needed in order of the inertial effect to dominate over viscous effect. Therefore, the existence of turbulence implies great amount of energy

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lost to form turbulence leaving less energyto support fluid flow. This creates inefficiency in fluid pipeline transformation as the fluid flow could be faster for same energy input or require less energy for same flowrate.

Limiting turbulence formation can increase energy efficiency as well as increase the throughput of pipeline transportation. Because it is not economical to reduce turbulence by lowering flowrate as it limits field productivity, a better way is invented, that is the use of certain chemical called Drag Reduction Agent or DRA. Drag Reduction Agent is a long chain additive with heavy molecular weight. The effect of DRA application is called Drag Reduction which defined as increase of pumpability of fluid due to addition of small amount of additive into the fluid system in the pipeline.

Phenomenon of drag reduction was first observed by British chemist Toms in 1948. Thirty years later the addition of DRA to pipeline system was first applied by Trans Alaskan Pipeline System in July 1st, 1979. This application proved to be successful in increasing pipeline throughput and eliminating the need for additional

pump stations. TAPS thus able to operate near to the optimal production rate of Prudhoe Bay of more than 1.5 MMBBL per day. Since then, the application of drag reducing agent have become popular worldwide. However, until today there is no particular DRA developed for every type of crude oil. Before application of DRA to pipeline system, some testing should be conducted to test the compatibility of prospected DRA to fluid flowing inside the pipeline. This paper discusses one of the selection method to obtain best DRA for a certain case using laboratory observation. The DRA is choosen based on criteria such as: increasing oil flow in the pipeline and optimum drag reduction.

1. Method

This study was done by conducting experimental trail.

1.1 Drag Reduction

Drag reduction is a phenomenon in which the turbulence of flow inside pipeline significantly decreased as the effect of addition of small amount of additives. Drag reduction can result on reduction of pressure drop along pipeline system and at a time also reduce energy requirement for fluid flow. There are formulas to measure drag reduction perceived by fluid flow as presented in Equation (1) and Equation (2).

<u>Percent of Drag reduction (%DR):</u>

$$\%DR = \frac{\Delta P - \Delta P_p}{\Delta P} \times 100 \ldots\ldots\ldots\ldots\ldots \ldots\ldots (1)$$

<u>Throughput Increase (%TI):</u>

$$\%TI = \left[\left(\frac{1}{1 - \frac{\%DR}{100}}\right)^{0.55} - 1\right] \times 100 \ldots\ldots (2)$$

Percent of drag reduction indicated the performance of DRA, but do not reflect the output of the pipeline as it is calculated by %TI. Studies that have been done in the past concluded that drag reduction only happen in turbulence flow region because there was no significant change in pressure drop observed in laminar flow region. Hoyt (1989) also observed that drag reduction have maximum value which is when additional concentration of additive no longer resulting increase in percent of drag reduction.

1.2 Type and Mechanism of DRA

There are three major type of drag reducing agent that frequently used in pipeline transportation system, which included;

- Polymer based DRA
- Surfactant based DRA
- Nanofluid

Polymer additives that used as drag reducing agent must be in a form of a long-chained polymer which has heavy molecular weight. The polymer chain in fluid flow dampens the forming of eddie current and as the result turbulence is greatly reduced.

Other than those, some additive also observed to have drag reducing properties such as fibres, microbubbles, and compliant coating. Each type of DRA has different mechanism in reducing drag within the pipeline system. Although still effectively established, drag reducing agents are believed to work in some manner such as turbulence suppression, extension of laminar range limit to higher Reynolds Number, near wall flow modification, and friction reduction in fully developed turbulence flow.

Surfactant additives work by forming bilayer sheet micelle. Hydrophobic part of micelle avoids contacts with polar molecule of crude oil. On the other hand, hydrophylic part of micelle contacts with polar molecule allowing the hydrophobic part of micelle to concentrate in the center of bilayer micelle formation. Micelle function in similar manner as polymer chain that dampens the formation of eddie current in fluid flow.

Nanofluid is a relatively new additive used as drag reducer. Nanofluid is believed to work in different way with polymer and surfactant additives. Nanofluid, such as Nano-SiO_2, work by filling the crevices of pipe wall resulting reduction of pipe relative roughness.

1.3 Drag Reduction using Polimer

Polymer works as drag reducing agent by dampening the formation of eddie current so turbulence can be highly reduced, as concluded by several researchers. It has also observed that polymer performance affected by several factors, such as: effect of concentration, channel size and geometry, molecular weight, chain flexibility, and flowrate.

1.3.1 Effect of Concentration

Concentration was observed proportionally related with drag reduction until maximum drag reduction is reached. This happens due to the concentration of additives increase more chains of polymer and dampening the formation of eddie current. Maximum value of drag reduction is reached when addition of polymer concentration no longer increase performance of drag reduction or even reduce the performance.

1.3.2 Effect of Channel Size and Geometry

Effect of channel size is still in controversy, different researcher provided different answer with different logical and scientific expalanation. Karami and Mowla (2012) investigated that drag reduction decrease as diameter of channel increase. The explanation for this is that pipe with smaller diameter has larger degree of turbulence (Re) due to larger relative roughness (c/D) compared to pipe with larger diameter. Higher degree of turbulence meansthat addition of polymer will result on higher decrease of pressure drop thus the effect of drag reduction is more significant.

In terms of channel geometry, some researches concluded that the effect of drag reduction is more prominent in straight pipe rather than in curved pipe. It has also been observed that radius of curvature of the pipe has significantly effect on delaying the onset of drag reduction and reducing the impact of drag reducing agent applied. Radius of curvature also reduces maximum drag reduction that can be achieved by polymer application.

1.3.3 Effect of Molecular Weight

General understanding based on results of some research concluded that drag reduction increased by increasing molecular weight, heavier polymer potentially has better ability to absorb and prevent formation of eddie current that composed turbulence.

1.3.4 Effect of Chain Flexibility

Flexibility of polymer chain is attributed to its ability to reduce drag. Flexible chain will serve as better cushion to absorb and dampen the formation of turbulence flow by reducing eddie current generation.

1.3.5 Effect of Chain Flowrate

Flowrate of fluids in pipeline is directly related ro Reynold number (Re) of fluid flow. Increasing flowrate means increase in degree of turbulence, allowing drag reducer to produce bigger margin of drag reduction. Mowla and Naderi (2008) studied the effect of polymer concentration on the percentage of drag reducer effectiveness for four types of drag reducer agent that presented in Figure 1.

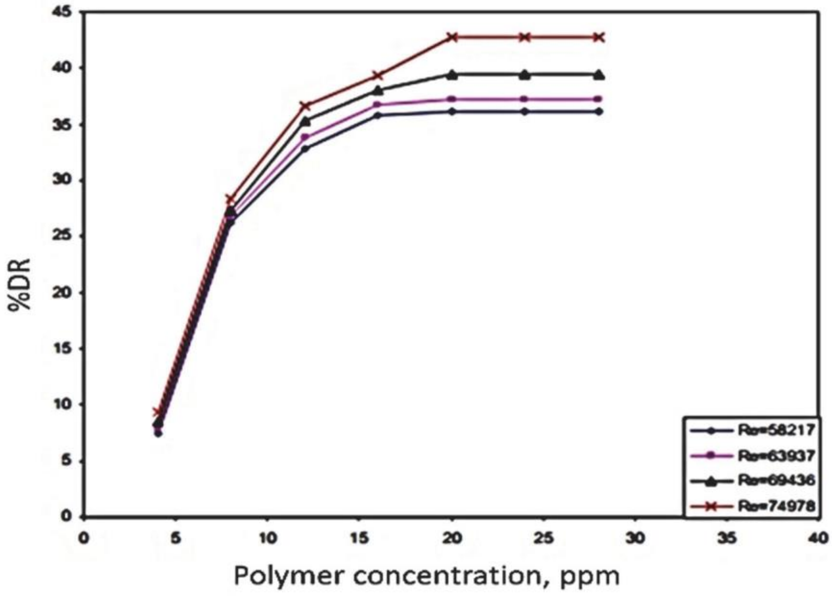


Figure 1. Comparison of DR performance at different flowrate (Mowla and Naderi, 2008)

1.4 Drag Reduction Using Surfactant

Surfactant additives reduce drag inside the pipeline by forming micelles as results of interaction between polar and nonpolar molecule of surfactant and oil. These micelles will help reduce flow turbulence by functioning as shock absorber that reduce formation of eddie current. There are several factors that affect surfactant performance as DRA that discussed below.

1.4.1 Effect of Concentration

Percent of drag reduction increase along with increase of surfactant concentration as discussed by Abdul-Hadi and Khadom (2013) and depicted in Figure 2. Higher concentration of surfactant inside fluid flow provides more micelle structure that can reduce formation of turbulent flow. Behaviour of surfactant concentration is the sameas polymer concentration, at some point of concentration, drag reducing performance of surfactant will reach its maximum value.

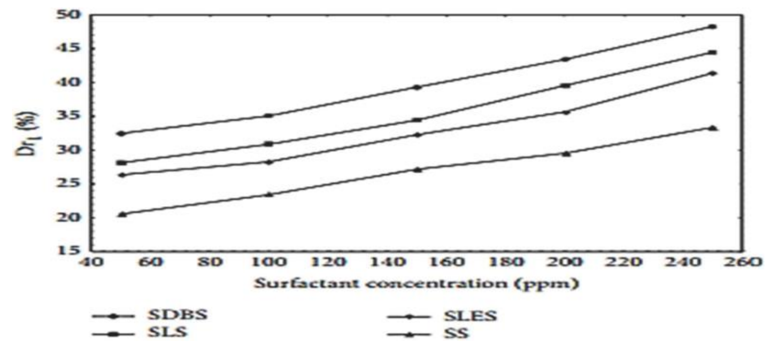
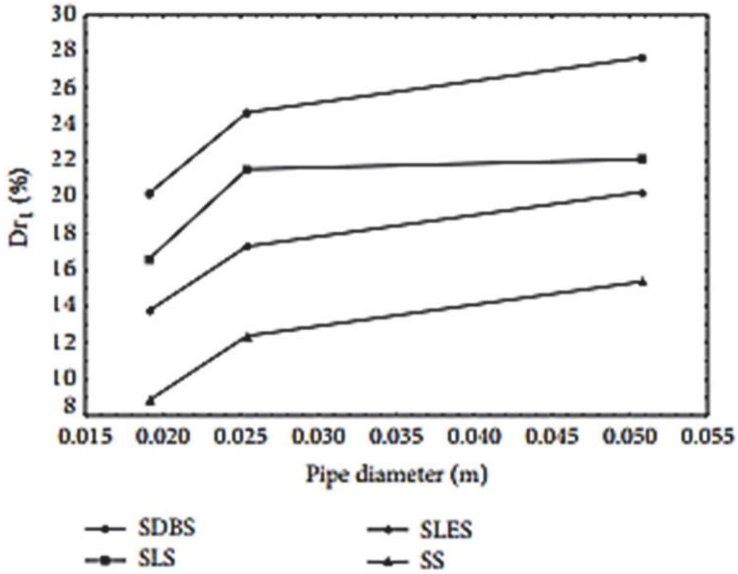


Figure 2. Effect of surfactant concentration on precent of drag reduction (Abdul-Hadi and Khadom, 2013)

1.4.2 Effect of Diameter

Effect of diameter or channel size on drag reduction still not clearly established, several researchers believe that drag reduction is higher in small pipe because of higher degree of turbulence due to larger relative roughness (c/D). Figure 3 shows the effect



of pipe diameter on drag reduction. There is also other point of view that dragreduction is higher in larger pipe diameter because eddie current formed in larger pipe absorb greater amount of energy.

Figure 3. Effect of pipe diameter on drag reduction (Abdul-Hadi and Khadom, 2013)

1.4.3 Effect of Flowrate

Performance of drag reducer observed to be proportional to flowrate of fluid flow. Increase of fluid flow rate results on increase of degree of turbulence (Re) as shown in Figure 4. Higher turbulence allows drag reducer to create greater margin of drag reduction.

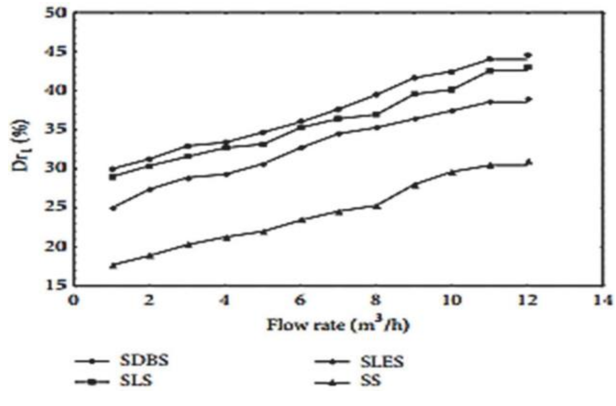


Figure 4. Effect of flowrate on drag reduction

1.5 Drag Reduction using Nanofluid

Nanofluid contains particles that are very small in size, to the degree of nanometer. These particles are suspendedin base fluid as colloidal suspension. Nanofluids works differently compared to surfactant and polymer as drag reducer. Nanofluid reduce drag inside the pipeline using mechanism called surface modification. Nanoparticle ofthe fluid reside in crevices along pipeline inside wall, making the pipeline a smoother conduit for fluid flow. Smooth pipe wall will affect turbulence as it will reduce Reynold Number (Re) by lowering relative roughness of the pipe. The most common nanofluid applied as drag reducer is Nano-SiO_2. Nano-SiO_2 is relatively cheap and easier to find and proven to give good result as drag reducer.

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1.5.1 Effect of Concentration

Concentration is an essential factor in nanofluid application that should be monitored carefully. Amount of nanofluid that should be applied to a pipeline system depends on roughness of pipe inner surface. As concentration increase, drag reduction will also increase as the surface of the pipe get smoother. Maximum drag reduction will be reached when all crevices in pipeline wall completely filled with nanofluid particle. Minimum value of drag reduction is observed when drag reduction effect monitored firstly as concentration of nanofluid

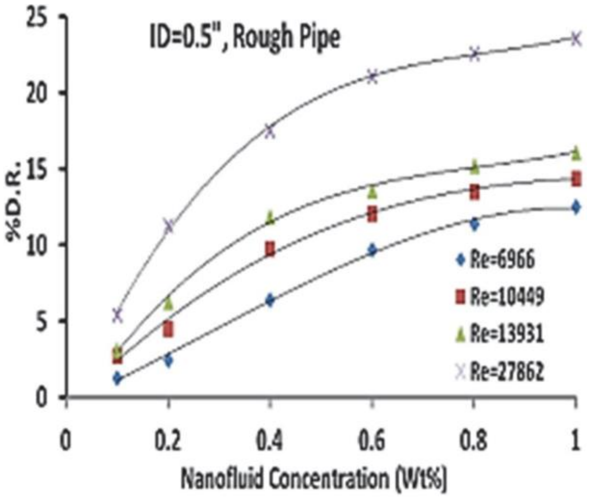

Figure 5. Effect of nanofluid concentration and Reynold Number on percentage of drag reduction

applied increase. At very small concentration, nanofluid will not provide any drag reduction because the nano-particle in the flow is not enough to fill pipe roughness. Figure 5 shows the effect of nanofluid concentration and Reynold number on percentage of drag reduction.

1.5.2 Effect of Pipe Roughness

Nanofluid drag reducer performs better in rougher pipe. Effect of drag reduction observed at same concentration of nanofluid but gets higher as pipe roughness increase, indicated by the value of Reynold Number.

1.5.3 Effect of Flowrate

Higher flowrate will increase degree of turbulence in fluid flow inside a pipeline system. The performance shows similarity with surfactant and polymer application this condition gives the drag reducer the ability to reduce drag by larger margin thus higher drag reduction achieved.

1.5.4 Effect of Pipe Diameter

Similar with drag reduction by polymer and surfactant. Drag reduction increases as pipe diameter decrease as presented in Figure 6. Small diameter pipe has higher Reynolds number as results of higher relative roughness of the pipe.

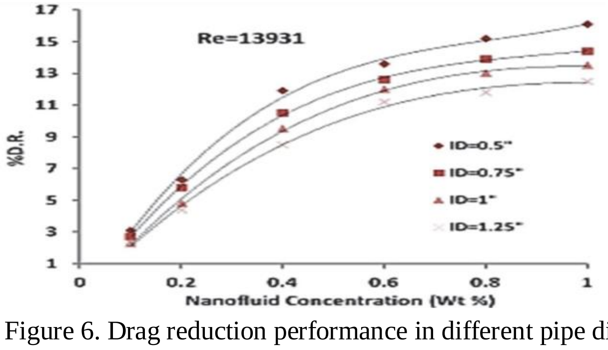

Figure 6. Drag reduction performance in different pipe diameter

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1.5.5 Effect of Multiphase Flow

In nanofluid application as drag reducer, observed that drag reduction in multiphase flow is higher than in single-phase flow presumably because of reduction of surface tension by nanoparticle along with surfacemodification that reduce dissipation rate due to turbulence flow. This effect can be enhanced by adding sodium dodecyl sulphate (SDS) to fluid flow. Figure 7 shows the effect of multiphase flow on drag reduction.

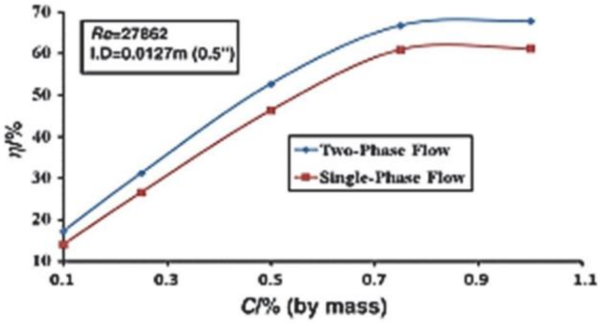


Figure 7. Effect of multiphase flow on drag reduction (Pouranfard, Mowla, and Esmaeilzadeh, 2013)

1.6 Challenge on Drag Reducer Agent Application

During the application of DRA in continuous turbulent flow inside pipeline, there are two major problem suffered by drag reducer related to degradation, those are mechanical degradation and dry out. Mechanical degradation occurs as result of interaction with flow turbulence or during extreme agitation when fluid pass through centrifugal pump. Dry out happens when solvent of drag reducer evaporates leading to precipitation of drag reducing agent, this eliminates the effect of drag reduction.

Polymer drag reducer is very susceptible to degradation as the polymer molecule can permanently breakrelatively easily when subjected to extreme shear stress, this leads to reduction in drag reducing capability of polymers. There are several factors that affect polymer resistance to mechanical degradation which are molecular weight and molecular weight distribution of polymer, temperatue, polymer concentration, degree of turbulence, polymer preparation, and flow geometry. Effect of temperature to polymer degradation is observed to be very complex because there is critical temperature at which the behaviour of temperature toward degradation shifts. Below this critical temperature, degradation delayed as temperature increases and above the critical temperature, degradation increase with increase in temperature.

Chemical additives applied as drag reducer is well known to be toxic as they are non-biodegradable, mostly the oil-soluble ones. On the other hand, water soluble additives are less toxic. Sound disposal strategy should be made to prevent chemical pollution on the environment.

1.7 ***Consideration During DRA***

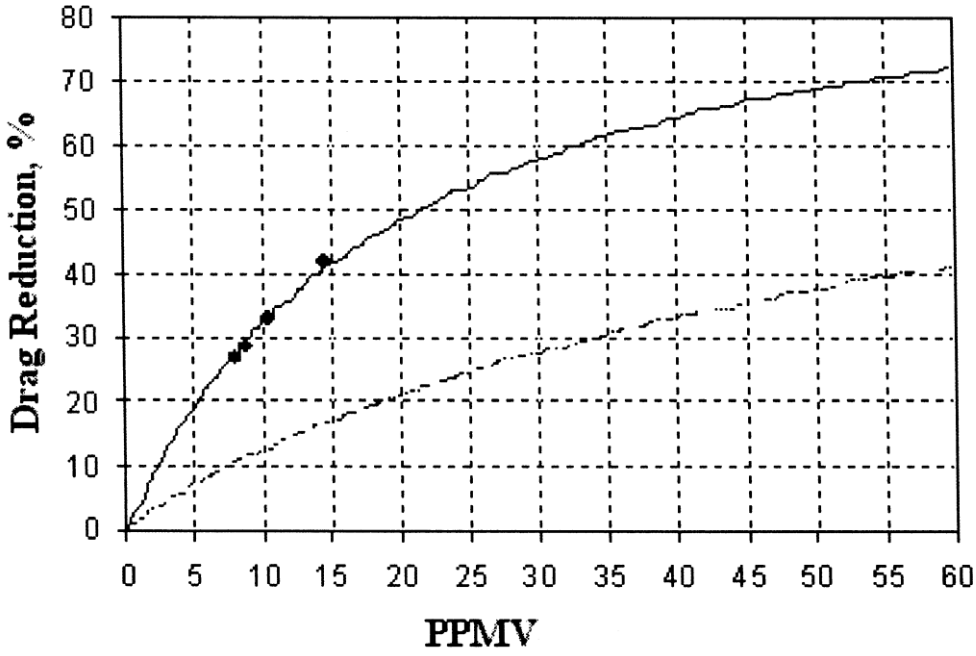
Until now there is no certain type of drag reducer that is applicable for all type of oil. Prior to drag reduction application some detailed test should be done to determine which kind of additive is suitable for the crude oil. As result of numerous research, there are several general knowledges about drag reducer that can be considered during period of selection:

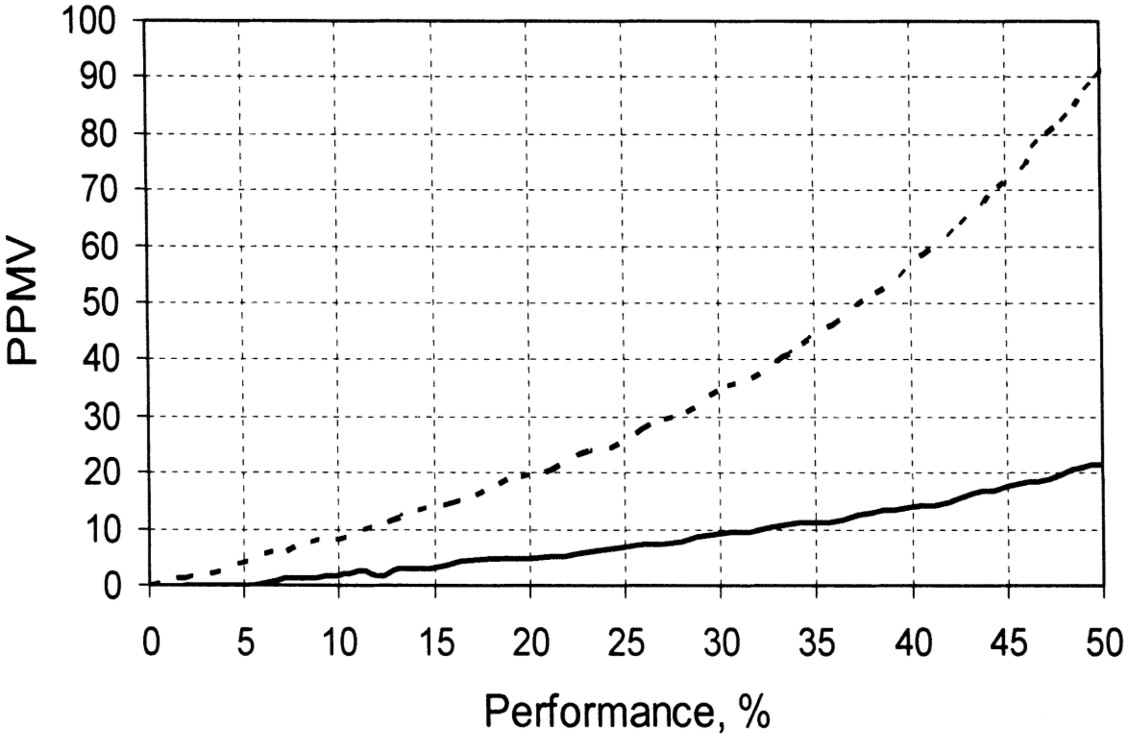
- DRA should be effective at low concentration. Addition of drag reducer into pipeline fluid flow is carried out continuously so it needs drag reducer in large amount. Drag reducer that can be effective at low concentration help reduce capital cost for DRA application. In long term despite the concentration needed is low, volume of DR required will still large due to continuous application.
- Crude oil in question should not cause problem in refinery process. Increasing pipeline throughput becomes useless when existing facilities can not handle the crude.
- Drag reducer should have molecular weight larger than one million grams per mole.
- Drag reducer should be shear degradation resistance up to certain level.
- Drag reducer should have good solubility in pipeline fluid.
- Drag reducer should be able to resist heat, chemical, and biological degradation.

1.8 Experiment

This experiment is based on actual field pipeline system conducted using HSD oil sample from that source. The pipeline and field management wanted to increase field production without replacing the existing pipeline with new bigger pipeline.

2. Results





Thus, the principal effect of DRAs is to reduce the velocity fluctuations in the normal direction and Reynolds stresses thereafter. Cationic surfactants are another class of DRA which form rod-like micelles. Under shear stress, micelles line up in the direction of flow and build the so-called shear-induced state, which leads to a damping of radial turbulence and a subsequent reduction in pressure loss.

The existence of multiphase flow (oil/gas and oil/water/gas mixture) in pipelines is common in the oil and gas industry. This is due to the fact that oil and gas wells are drilled far away from the separation site, which necessitates transport by multiphase pipeline flow.

Drag reducing agents have been used for a long time to lower the friction component of the pressure in a single phase flow during the transport of oil or gas in pipelines. However, recently it has been shown that DRAs are also effective in multiphase flow and work very well on all components of pressure drop: frictional, acceleration, and gravitational

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Symbol

DR Drag reduction DRA Drag reducing agent

%DR Percent of drag reduction

%TI Throughput increase

ΔP Pressure drop without DRA

ΔPp Pressure drop with DRA