Pipeline Drag Reducers

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Abstract

Pipeline drag reducers have proven to be an extremely powerful tool in fluid transportation. High molecular weight polymers are used to reduce the frictional pressure loss ratio in crude oil pipelines, refined fuel and aqueous pipelines.

Chemical structure of the main used pipeline drag reducers is one of the following polymers and copolymers classified according to the type of fluid to; low density polyethylene, copolymer of 1-hexane cross linked with divinyl benzene, polyacrylamides, polyalkylene oxide polymers and their copolymers, fluorocarbons, polyalkylmethacrylates and terpolymer of styrene, alkyl acrylate and acrylic acid.

Drag reduction is the increase in pump ability of a fluid caused by the addition of small amounts of an additive to the fluid. The effectiveness of a drag reducer is normally expressed in terms of percent drag reduction.

Frictional pressure loss in a pipeline system is a waste of energy and it costly. The drag reducing additive minimizes the flow turbulence, increases throughput and reduces the energy costs. The Flow can be increased by more than 80 % with existing assets.

The effectiveness of the injected drag reducer in Mostorod to Tanta crude oil pipeline achieved 35.4 % drag reduction and 23.2 % flow increase of the actual performance. The experimental application of DRA on Arab Petroleum Pipeline Company (Summed) achieved a flow increase ranging from 9-32 %.
Introduction:

Oil transportation companies are experiencing a need to increase their efficiencies and transport capabilities. The frictional pressure drops or drags, responsible for energy losses and limiting the throughput of oil pipelines, can be significantly reduced by injecting long chain polymers (flow improvers).

Pipeline flow improvers, or drag reducing agents, have been utilized in the Petroleum industry for more than 35 years. The first application of drag reducers in the petroleum industry was to reduce the down-hole pressure loss during pumping of fluids down hole to fracture-tight formations. One of the first large-scale pipeline applications was to increase the throughput of crude oil on the Trans-Alaskan Pipeline in 1979. Because of the reduction of the apparent viscosity, drag reducers are useful in saving energy required for pumping.

By reducing the frictional pressure loss, drag reducing agents (DRA) can increase throughput by more than 90% of the pipeline’s mechanical capacity.

Drag Reducers are used in pipeline systems for:

1. Throughput improvement
2. Power optimization
3. By-passing intermediate pump stations
4. Batch management
5. Scheduled maintenance
6. Shortening barge download time
7. Peak shaving
8. Operating pressure reduction
Drag Reducers Mechanism:

Drag reduction, as defined by Savins, is the increase in pump ability of a fluid caused by the addition of small amounts of an additive to the fluid. The effectiveness of a drag reducer is normally expressed in terms of percent drag reduction. At a given flow rate, percent drag reduction is defined as:

\[
\% \text{D.R} = \frac{\Delta P_0 - \Delta P_p}{\Delta P_p} \times 100
\]  
Equation 1

\(\Delta P_0\) is the base frictional pressure drop of the untreated fluid.

\(\Delta P_p\) is the frictional pressure drop of the fluid containing reducing polymer.

Percent drag reduction is a measure of drag reducing additive performance, but it does not reflect the primary end use of drag reducers. Normally, the reduced frictional pressure drop is used to increase flow rate without exceeding the safe pressure limits within the pipeline system. The relationship between percent drag reduction and percent flow increase can be estimated using the following equation:

\[
\% \text{Flow increase} = \left( \frac{100}{100 - \% \text{D.R}} \right)^{0.556} - 1 \right) \times 100
\]  
Equation 2

Where % D.R. is the percent drag reduction as defined in Equation 1. Equation 2 assumes that frictional pressure drop is proportional to flow rate raised to the 1.8 power, for both treated and untreated fluids, and that the discharge pressure is constant for both the baseline and increased flow rates.

Drag reduction occurs by the interactions between elastic macromolecules and turbulent flow macrostructures. In turbulent pipe flow, the region near the wall, comprising a viscous sub layer and a buffer layer, plays a major role in drag reduction.
The most serious problem in the effectiveness of drag reducers is the chain degradation of polymers by shear strains in turbulent flow. Ultra high molecular weight polymers are more susceptible to shear-induced degradation, and polymers with linear chain-structure are more vulnerable than branched polymers and natural gums of semi-rigid structure. The mechanism of shear degradation is assumed to be associated with chain elongation. The chain degradation is often observed when the shear rate is increased to a critical point, after which drag reduction sharply decreases.

Table (1): Types of Drag Reducers Agents

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear low density polyethylene</td>
<td>α-Olefins up to 10 mole %&lt;sup&gt;9&lt;/sup&gt;</td>
</tr>
<tr>
<td>Copolymer of linear α-olefin with crosslinkers&lt;sup&gt;10&lt;/sup&gt;</td>
<td>α-olefins are 1-hexene, 1-octene, 1-decene, and 1-dodecene. Cross linkers are divinylbenzene or organosiloxanes with pendent vinyl groups.</td>
</tr>
<tr>
<td>Polyacrylamides, polyalkylene oxide polymers and their copolymers&lt;sup&gt;11-13&lt;/sup&gt;</td>
<td>Water soluble drag reducer for emulsions</td>
</tr>
<tr>
<td>Fluorocarbons&lt;sup&gt;14&lt;/sup&gt;</td>
<td>For asphaltenic crudes oils</td>
</tr>
<tr>
<td>Polyalkylmethacrylates&lt;sup&gt;15-19&lt;/sup&gt;</td>
<td>Esters with C-10 to C-18 and ionic monomers reduces friction in flow of hydrocarbons by a factor of 5 at concentrations of 25 ppm</td>
</tr>
<tr>
<td>Terpolymer of styrene, alkyl acrylate and (acrylic acid or methacrylic acid)&lt;sup&gt;20&lt;/sup&gt;</td>
<td>Styrene includes also t-butyl styrene (drag reducer for hydrocarbon fluids)</td>
</tr>
</tbody>
</table>
CH₂ = CH – C\(\text{\text{-}}\)O

CH₂ = CH – C\(\text{\text{-}}\)O – H

CH₂ = C – C\(\text{\text{-}}\)O – H

Acrylamide
Acrylic acid
Methacrylic acid

CH = CH₂

CH = CH₂

CH₂ = CH₂

Styrene
p-Divinylbenzene
1-Hexene

Fig. (1): Monomers for Copolymers of Acrylamide and Acrylic Acid and Styrenics.

Linear low density polyethylene is a copolymer of ethylene and olefins. It is obtained by copolymerization utilizing Ziegler-Natta catalysts. Concentrates may be prepared by precipitating the polymer from a kerosene solution with isopropanol. The resulting slurry concentrate dissolves rapidly in hydrocarbon streams.

**Effect of Flow Improver Additives on Paraffin Deposition**

In waxy crude's, the wax has a tendency to become deposited during storage of the crude oil in the tanks and also while flowing through pipelines. The deposition in the pipeline severely affects the pipeline throughput. The deposits have to be periodically removed from the storage tanks and the pipelines by pigging operations.
**Experimental Application of Drag Reducer on Petroleum Pipeline Company (PPC) Oil Pipeline Networks**

Two main pipelines were selected to conduct Drag Reduction Trials:

The first is the Crude Oil line from Mostorod to Tanta

The second is the Fuel Oil line between Mostorod and Suez.

Three different commercial chemicals, A, B and C and a Pump skid were used in the trial.

**Test 1: Crude Oil – Pipeline Test.**

DRA (A) & (C) injected in the Mostorod to Tanta Line.

**Test 2: Fuel Oil – Pipeline Test.**

DRA (A) & (B) injected in the Mostorod to Suez Line.

**Crude Line Test:**

The purpose of this test was to demonstrate the use of DRA in reducing the frictional pressure loss on a pipeline system. In order to check the effectiveness of the injected Drag Reducer, it is first necessary to determine the baseline conditions, the pressure and flow rates experienced on the line when no DRA is injected. It is also necessary to have a complete line filled with the crude oil and to collect data for at least a couple of hours to reflect normal static conditions. On obtaining steadily consistent data, the DRA is injected. Pressure and Flow Rates data are monitored during line fill and comparisons are made between line fill conditions with and without DRA.

**Baseline Data Collection:**

Normal operating conditions, during the pumping of Crude Oil in the Mostorod to Tanta Pipeline, were monitored for two days. Discharge Pressure and Flow Rates, at Mostorod and arrival pressure at Tanta, were logged. After analysis and discussion the baseline flow rate was determined to be 328 m3/hr. This was achieved with a pressure difference of 45 kg/cm² between Mostorod and Tanta.
DRA (A) Injection:

Injection of DRA (A) was started at 12:00 AM on the first day at a predetermined rate until line fill was completed. Line fill is considered to be the moment at which the treated Crude Oil has displaced all the untreated Crude Oil from the pipeline sections. With baseline data collection, pressure and flow rates are monitored every hour until line fill is completed and the data has stabilized.

DRA (C) Injection:

Injection of DRA (C) was started 12:00 PM on the second day and data collection are monitored in the same manner as in the previous test.

Crude Oil Line Test Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st day</td>
<td>10:00 PM</td>
<td>Start of Crude Oil at Mostorod.</td>
</tr>
<tr>
<td>2nd day</td>
<td>12:00 AM</td>
<td>Start DRA (A) injection at Mostorod.</td>
</tr>
<tr>
<td>2nd day</td>
<td>07:00 PM</td>
<td>Line Fill to Tanta – DRA (A).</td>
</tr>
<tr>
<td>2nd day</td>
<td>11:00 PM</td>
<td>Trial DRA (A) Complete.</td>
</tr>
<tr>
<td>2nd day</td>
<td>12:00 PM</td>
<td>Start DRA (C) injection at Mostorod.</td>
</tr>
<tr>
<td>2nd day</td>
<td>10:00 PM</td>
<td>Trial DRA (C) complete.</td>
</tr>
</tbody>
</table>

Mostorod to Tanta Test Results

Within a few hour of injecting DRA (A) the flow rate was increasing steadily. The enclosed graph of flow rate against time shows that such increase continued during line fill, then leveled off producing a steady state condition representing a 23.2% flow increase. Reference to the enclosed data table and graphs. Drag reduction of 35.4% was achieved at a dosage of 115 ppm, with approximately 11.5 US gallons of DRA (A) per hour. The DRA (C), although producing a flow increase, did not match the DRA (A) performance.

DRA (A)

Drag Reduction: 35.4%
Flow Increase: 23.2%
Fuel Oil - Pipeline Test

Data was collected and logged in the same manner as for the Crude Oil Pipeline test above. Additional information such as pressure and temperature at the heater station was also logged.

DRA (B) Injection:

Injection of DRA (B) was started on the 1st day and similar to the Crude Oil test, flow increase could be seen after only a few hours, with the injection rate at 150 ppm flow rate continued to increase before leveling off at 290 m³/hr. This represents a 13.7% flow increase over the 255 m³/hr baseline flow rate.

DRA (A) Injection:

Injection of DRA (A) was started 3rd day. Once again the injection rate was set at 150 ppm. It can be seen from the enclosed graph of Drag Reduction against time. The effect of the DRA (A) was to reduce the Drag Reduction and hence reduce the Flow rate. Since the trend was obvious, there was no point in wait for a complete line fill and the test was terminated at 19:00 hours.

Fuel Oil Line Test Schedule

Mostorod To Suez

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st day</td>
<td>09:00 PM</td>
<td>Begin Baseline Data Collection</td>
</tr>
<tr>
<td>1st day</td>
<td>01:00 PM</td>
<td>Start DRA (B) injection at Mostorod</td>
</tr>
<tr>
<td>3rd day</td>
<td>02:00 PM</td>
<td>Line Fill to Suez – DRA (B)</td>
</tr>
<tr>
<td>3rd day</td>
<td>07:00 PM</td>
<td>Trial DRA (B)Complete</td>
</tr>
<tr>
<td>3rd day</td>
<td>08:00 PM</td>
<td>Start DRA (A) injection at Mostorod</td>
</tr>
<tr>
<td>4th day</td>
<td>07:00 PM</td>
<td>Trial DRA (A) complete</td>
</tr>
</tbody>
</table>
Mostorod To Suez Test Results

Significant benefits could be seen in a very short time after injecting the DRA (B). The enclosed graph shows a Drag Reduction of 19.5 % at Line Fill, resulting in a flow rate increase of 13.7 %. It was equally obvious that the DRA (A) did not perform as well in the Fuel Oil as it did in the Crude Oil.

DRA (B)
Drag Reduction : 19.5 %.
Flow Increase : 13.7 %.

![Graph showing flow rate and pressure differential over time for BPP DRA(A) Trial Mostorod to Suez]
Petroleum Pipeline Company

DRA Trials

<table>
<thead>
<tr>
<th>Pipeline</th>
<th>Mostorod – Suez</th>
<th>Mostorod – Tanta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid Treated</td>
<td>Fuel Oil</td>
<td>Crude Oil</td>
</tr>
<tr>
<td>Baseline Flow Rate</td>
<td>255</td>
<td>328</td>
</tr>
<tr>
<td>Achieved Flow Rate</td>
<td>290</td>
<td>404</td>
</tr>
<tr>
<td>Flow Rate Increase, %</td>
<td>13.7 %</td>
<td>23.2 %</td>
</tr>
<tr>
<td>Drag Reduction, %</td>
<td>19.5</td>
<td>35.4</td>
</tr>
<tr>
<td>DRA Dosage, ppm</td>
<td>150</td>
<td>115</td>
</tr>
</tbody>
</table>
Conclusions and Recommendations

All the tests gave positive results. In both pipelines a significant and demonstrable flow increase resulted during a short period of time after DRA was injected. It was not necessary to wait until a line fill before improvements were clearly shown. The DRA could therefore be used simply to speed up the transfer of oils from one location to the other or, equally important, it could be used to maintain flow rates at a lower pressure difference. This is of particular significance if there are Main Oil Line pump failures or if part of the pipeline has to be pressure down rated for any reason. Significant energy savings can also be made by the use of the DRA. The speed of Pumps can be reduced to bring down operating costs.

Experimental Application of DRA on Arab Petroleum Pipeline Co. (Summed)

- Pipeline Data:
  * Length: 370 km
  * Diameter: 42"

- Crude Types:
  * Arabian Light (AL)
  * Arabian Medium (AM)
  * Arabian Heavy (AH)
  * Iranian Light (IL)
  * Iranian Heavy (IH)

- Application Result:

<table>
<thead>
<tr>
<th>Flow Increase (%)</th>
<th>DRA Concentration (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AL</td>
</tr>
<tr>
<td>9-11</td>
<td>17</td>
</tr>
<tr>
<td>19-21</td>
<td>34</td>
</tr>
<tr>
<td>28-32</td>
<td>47</td>
</tr>
</tbody>
</table>
References


7 Chang, H. F. D.; Meng, J. S. Physicochem. Hydrodyn. 9, 33, 1987


