PERFORMANCE INVESTIGATION OF WATER-SOLUBLE ADDITIVES FOR DRAG REDUCTION AGENT IN PIPELINES

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(CHEMICAL ENGINEERING)
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Thesis submitted in fulfilment of the requirements
for the award of the degree of Doctor of Philosophy
(Chemical Engineering)

Faculty of Chemical Engineering and Natural Resources
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TABLE OF CONTENTS

APPENDICES 137

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

m	Meter
Ppm	Part per million
P	Fluid density
μ	Dynamic viscosity of fluid
D	Internal diameter
L	Pipe length
V	Average velocity
% DR	Percentage drag reduction
C	Concentration
L	Liter
ΔP	Pressure loss
TEM	Transmission Electronic Microscopy

LIST OF ABBREVIATIONS

Re	Reynolds Number
DR	Drag Reduction
DRA	Drag Reducing Agent
MW	Molecular weight
I.D	Internal diameter
ΔP	Pressure Drop (Pressure Different)
RDA	Rotating disk apparatus
^oC	Degree Celsius
%	Percent
L	Liter
Wt	Weight
TEM	Transmission Electronic Microscopy
TAPS	Trans-Alaska Pipeline System
PS	pump station
bbl/d	

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ABSTRACT

In the past few decades, several passive and active techniques to enhance the flow in pipelines have been suggested by scientists and implemented by the oil and gas industry. The most commercially feasible flow enhancement (drag reduction) technique is the injection of minute quantities of viscoelastic polymeric additives in the main flow stream. At the same time, this technique comes with a major disadvantage: the polymeric additives are resistant to the high shear forces exerted by the pumps and/or the turbulence inside the pipe. The present work addresses the said problem by proposing an alternative technique that involves the formation of polymer–surfactant complexes to create a highly shear-resistant additive through physical interaction with oppositely and similarly charged surfactants. Polyacrylic acid (PAA), Polyacrylamide-co-diallyl-dimethylammonium chloride P(AAm-co-DADMAC), hydroxypropyl cellulose (HPC), and polydiallyldimethylammoniumchloride (PDADMAC) polymers are adopted as drag-reducing agents (DRA). Sodium oleate and Tween 20 surfactants are also used as DRAs and complex creation agents. One of the major objectives of the present work is to prove that complexes can be formed even with similarly charged ingredients (i.e., polymers and surfactants). The experimental work is divided into three major phases. The first phase tests the flow behavior and shear resistance of the polymeric, surfactant, and complex DRAs using a rotating disk apparatus (RDA). The second phase detects the morphology of the formulated complexes using transmission electron microscopy (TEM) and cryo-TEM. The third phase conducts a pipeline drag reduction test using a closed-loop liquid circulation system, in which the pressure drop and flow rate measurements are taken to evaluate the drag reduction performance of a selected complex and its initial polymeric and surfactant substances. The RDA results show that, when tested at 700 ppm concentration and Re = 816650, all the polymeric additives have drag reduction potential with a maximum %DR of 16%, 32%, 40%, and 12% for PAA, P(AAm-co-DADMAC), HPC, and PDADMAC polymers, respectively. Moreover, when tested at 700 ppm concentration and Re = 816650, most of the surfactant additives show an acceptable drag reduction performance with a maximum %DR of 16% and 12% for sodium oleate and Tween 20 surfactants, respectively. The complexes created from the initial polymeric and surfactant additives significantly improve drag reduction performance and resistance to shear forces. The resistance of PAA is enhanced by 66% when tested at 500-ppm sodium oleate and Re = 489990. The resistance of PAA is massively enhanced by 203% when tested at 500-ppm sodium oleate and Re = 914648. The morphology of the formulated complexes is tested using TEM and cryo-TEM, and the results indicate that similarly charged polymer and surfactant molecules have the ability to form certain aggregates with the aid of the free counter ions in water. The TEM shows network-like aggregates that capture surfactant clusters in a network of polymers and small surfactant micelles. A similarly charged PAA–sodium oleate complex is tested in a pipeline system. The experimental results clearly indicate that the drag reduction performance of the polymers is massively improved by 51% when forming a complex with 1000-ppm concentration. In addition, the pressure drop reading results show that resistance to high-shear forces is highly modified when the complex is formed, and no detectable degradation is reported. It is believed that the same technique should be implemented using crude oil additives in the future due to the increasing need for such complexes in the oil and gas industry field.

ABSTRAK

Beberapa dekad yang lalu, beberapa teknik pasif dan aktif untuk meningkatkan aliran dalam saluran paip telah dicadangkan oleh ahli sains dan dilaksanakan oleh industri minyak dan gas. Teknik peningkatan aliran yang paling ekonomik dilaksanakan secara komersil (pengurangan seretan) adalah suntikan sekuantiti bahan tambahan polimer viscoelastic didalam arus aliran utama. Pada masa yang sama, teknik ini datang dengan satu kelemahan utama: bahan tambahan polimer dapat metahan daya ricih yang tinggi yang dikenakan oleh pam dan / atau kegeloraan di dalam paip. Kajian yang dikatakan boleh menangani masalah tersebut dengan mencadangkan teknik alternatif yang melibatkan pembentukan kompleks surfaktan polimer untuk mewujudkan aditif yang sangat tahan ricih melalui interaksi fizikal dengan surfaktan yang bercas berlawanan atau sama. Asid Polyacrylic (PAA), Polyacrylamide-co-diallyl-dimethylammonium klorida P (AAM-co-DADMAC),selulosa hydroxypropyl (HPC), dan polydiallyldimethylammoniumchloride (PDADMAC) polimer yang digunakan sebagai agen pengurangan seretan (DRA). natrium oleat dan surfaktan Tween 20 juga digunakan sebagai DRAs dan ejen penciptaan kompleks. Salah satu objektif utama kajian ini ialah untuk membuktikan bahawa kompleks boleh dibentuk walaupun dengan bahan-bahan yang sama cas (iaitu, polimer dan surfaktan). Kerja-kerja eksperimen dibahagikan kepada tiga fasa utama. Fasa pertama menguji kelakuan aliran dan rintangan ricih polimer, surfaktan, dan kompleks DRAs menggunakan alat cakera berputar (RDA). Fasa kedua mengesan morfologi kompleks yang dirumuskan menggunakan mikroskop elektron penghantaran (TEM) dan Cryo-TEM. Fasa ketiga menjalankan ujian pengurangan seretan paip menggunakan sistem peredaran cecair gelung tertutup, di mana kejatuhan tekanan dan ukuran kadar aliran diambil untuk menilai prestasi pengurangan seretan kompleks terpilih dan bahan-bahan awal polimer dan surfaktan. Keputusan RDA menunjukkan bahawa, apabila diuji pada kepekatan 700 ppm dan $\mathrm{Re} = 816650$, semua bahan tambahan polimer mempunyai keupayaan penurunan seretan dengan % DR maksimum sebanyak masing-masing pada 16%, 32%, 40%, dan 12% untuk PAA, P (AAM-co -DADMAC), HPC dan PDADMAC polimer. Selain itu, apabila diuji pada kepekatan 700 ppm dan $\mathrm{Re} = 816650$, kebanyakan bahan tambahan surfaktan menunjukkan prestasi pengurangan seretan dengan maksumim % DR masing-masing pada 16% dan 12% untuk natrium oleat dan Tween 20 surfaktan. Kompleks dicipta daripada bahan tambahan polimer dan surfaktan awal menunjukkan peningkatkan prestasi yang ketara pada pengurangan seretan dan rintangan kepada daya ricih. Rintangan PAA dipertingkatkan ke 66% apabila diuji pada 500 ppm kalium oleat dan $\mathrm{Re} = 489990$. Rintangan PAA dipertingkatkan secara besar sebanyak 203% apabila diuji pada 500 ppm natrium oleat dan $\mathrm{Re} = 914648$. Morfologi kompleks dirumuskan diuji menggunakan TEM dan Cryo-TEM, dan keputusan menunjukkan bahawa molekul-molekul polimer dan surfaktan bercas sama mempunyai keupayaan untuk membentuk agregat tertentu dengan bantuan ion pembilang bebas didalam air. TEM menunjukkan agregat rangkaian yang menangkap kelompok surfaktan dalam rangkaian polimer dan misel kecil surfaktan. PAA natrium kompleks oleat bercas sama diuji dalam sistem saluran paip. Keputusan eksperimen jelas menunjukkan bahawa prestasi pengurangan seretan daripada polimer meningkat secara besar sebanyak 51% apabila membentuk kompleks dengan kepekatan 1000 ppm. Di samping itu, keputusan bacaan kejatuhan tekanan menunjukkan bahawa daya tahan terhadap kuasa-kuasa tinggi ricih diubahsuai apabila terbentuknya kompleks, dan tiada kemenurunan dilaporkan.

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