

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

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(CHEMICAL ENGINEERING)
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PERFORMANCE INVESTIGATION OF WATER-SOLUBLE ADDITIVES FOR
DRAG REDUCTION AGENT IN PIPELINES

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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

SUPERVISORS' DECLARATION	i
STUDENT'S DECLARATION	ii
ACKNOWLEDGEMENTS	iv
ABSTRACT	v
ABSTRAK	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF SYMBOLS	xx
LIST OF ABBREVIATIONS	xxi
CHAPTER 1 INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	3
1.3 Research objectives	4
1.4 Scope of Study	4
1.5 Study Contribution	5
1.6 Overview of Study	6
CHAPTER 2 LITERATURE REVIEW	7
2.1 Introduction	7
2.2 Drag Reduction	8
2.3 Drag Reduction Agents (DRA)	12
2.3.1 Polymer DRA	13
2.3.2 Suspended Solid DRA	20
2.3.3 Surfactant DRA	23
2.3.4 Polymer-Surfactant Complexes DRA	26
2.4 Drag Reduction Mechanism	30

2.5	Drag Reduction Applications	34
2.6	Summary	35
CHAPTER 3 MATERIALS AND METHODS		36
3.1	Introduction	36
3.2	Materials	37
3.3	Experimental Phases	40
	3.3.1 Rotating Disk Apparatus Test	40
	3.3.2 Pipeline Test system	44
3.4	Transmission Electronic Microscopy (TEM)	50
3.5	Experimental Procedures	50
CHAPTER 4 RESULTS AND DISCUSSION		52
4.1	Introduction	52
4.2	Rotating Disk Apparatus (RDA)	52
	4.2.1 Effect of Reynolds Number (Re)	53
	4.2.2 Effect of Additives Concentrations	70
4.3	Transmission Electron Microscopy Analysis	80
4.4	Pipe Loop	86
	4.4.1 Effect of Reynolds Number	86
	4.4.2 Effect of Concentration	98
	4.4.3 Effect of Testing section Length	104
	4.4.4 Additives Stability	112
4.5	Mathematical Correlation	118
CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS		123
5.1	Conclusions	123
5.2	Recommendation for Future Work	125
REFERENCES		126

APPENDICES	137
A Amount of Additive Soluble in Transporting Liquids	137
B Calculation of Flow Rate, Velocity and Reynold Number	139
C Result of Rotating Disk Apparatus	140
D Percentage Drag Reduction by Polymeric Additive Drag Reduction Performance by Transporting Liquid	158
E Steps for Statistical Correlation Estimation	162
F List of Publications	166

LIST OF TABLES

Table No.	Title	Page
3.1	The specifications of the chemical material	38
3.2	Conversion of rpm to Re.	42
3.3	Amount of additive soluble in 1.2 L transporting water.	137
3.4	Amount of additive soluble in 30 L transporting water.	138
3.5	Flow rate, Velocity and Reynold number.	139
4.1	The correlation parameter for different condition from experimental data.	120
4.2	Reynold number vs Torque by 50 ppm Poly (acrylamide-co-diallyl-dimethylammonium chloride)P(AAm-co-DADMAC)-Sodium Oleate in water solution.	140
4.3	Reynold number vs Torque by 500 ppm Poly (acrylamide-co-diallyl-dimethylammonium chloride)P(AAm-co-DADMAC)-Sodium Oleate in water solution.	141
4.4	Reynold number vs Torque by 1000 ppm Poly (acrylamide-co-diallyl-dimethylammonium chloride)P(AAm-co-DADMAC)-Sodium Oleate in water solution.	142
4.5	Reynold number vs Torque by 50 ppm Poly (acrylamide-co-diallyl-dimethylammonium chloride)P(AAm-co-DADMAC)-Tween 20 in water solution.	143
4.6	Reynold number vs Torque by 500 ppm Poly (acrylamide-co-diallyl-dimethylammonium chloride)P(AAm-co-DADMAC)-Tween 20 in water solution.	144
4.7	Reynold number vs Torque by 1000 ppm Poly (acrylamide-co-diallyl-dimethylammonium chloride)P(AAm-co-DADMAC)-Tween 20 in water solution.	145
4.8	Reynold number vs Torque by 50 ppm Hydroxypropyl cellulose (HPC)-Sodium Oleate in water solution.	146
4.9	Reynold number vs Torque by 500 ppm Hydroxypropyl cellulose (HPC)-Sodium Oleate in water solution.	147
4.10	Reynold number vs Torque by 1000 ppm Hydroxypropyl cellulose (HPC)-Sodium Oleate in water solution.	148

4.11	Reynold number vs Torque by 50 ppm Hydroxypropyl cellulose (HPC) - Tween 20 in water solution.	149
4.12	Reynold number vs Torque by 500 ppm Hydroxypropyl cellulose (HPC) - Tween 20 in water solution.	150
4.13	Reynold number vs Torque by 1000 ppm Hydroxypropyl cellulose (HPC) - Tween 20 in water solution.	151
4.14	Reynold number vs Torque by 50 ppm Poly (diallyldimethylammonium chloride) PDADMAC -Sodium Oleate in water solution.	152
4.15	Reynold number vs Torque by 500 ppm Poly (diallyldimethylammonium chloride) PDADMAC -Sodium Oleate in water solution.	153
4.16	Reynold number vs Torque by 1000 ppm Poly (diallyldimethylammonium chloride) PDADMAC -Sodium Oleate in water solution.	154
4.17	Reynold number vs Torque by 50 ppm Poly (diallyldimethylammonium chloride) PDADMAC - Tween 20 in water solution.	155
4.18	Reynold number vs Torque by 500 ppm Poly (diallyldimethylammonium chloride) PDADMAC - Tween 20 in water solution.	156
4.19	Reynold number vs Torque by 1000 ppm Poly (diallyldimethylammonium chloride) PDADMAC - Tween 20 in water solution.	157
4.20	Percentage of drag reduction by PAA in transporting water via 0.025 m ID pipe.	158
4.21	Percentage of drag reduction by Sodium Oleate in transporting water via 0.025 m ID pipe.	159
4.22	Percentage of drag reduction by PAA-Sodium Oleate complex in transporting water via 0.025 m ID pipe.	160
4.23	Percentage of drag reduction by PAA-Sodium Oleate complex in transporting water via 0.025 m ID pipe.	161

LIST OF FIGURES

Figure No.	Title	Page
2.1	The effect of (CDRs) or drag reduction agents (DRAs) on pressure drop reduction in pipelines.	13
2.2	Differences between additions of 42 ppm polyethylene oxide (PEO) at two different times. A and B: Water without PEO at 0.63seconds and 0.8 seconds C and D: Water with PEO at 0.63 seconds and 0.8 seconds.	14
2.3	Illustration of cross linked polymer.	15
2.4	Illustration of surfactant structures and clusters and critical micelle concentration formation.	24
2.5	Plot of the surface tension as a function of the logarithm of the CR concentrations (\blacktriangle), pure CTAB (\circ), and CTAB in the presence of 0.05mM CR (\bullet) at 25 °C.	28
2.6	Ink injection to demonstrate polymer suppression.	31
2.7	Illustration of eddies cancellation.	32
2.8	Illustration on mechanism of drag reduction by addition of polymer additive.	33
3.1	Graphical image of an RDA for drag reduction measurement: (1) speed controller, (2) thermocouple, (3) motor, (4) solution container, (5) water jacket, (6) water-circulating system, (7) thermometer, and (8) PC.	43
3.2	Rotating Disk Apparatus rig.	43
3.3	Schematic diagram of the pipe loop flow.	48
3.4	Experimental Rig Closed Loop Circulation System	49
3.5	Flowchart of the entire experimental work.	51
4.1	The effect of the Reynold number on the PAA solutions at different concentrations.	54

4.2	The effect of the Reynold number on the drag reduction and flow behavior of the HPC polymer with different concentrations.	55
4.3	The effect of the P(AAm-co-DADMAC) polymer on the torque readings with different Reynold number.	55
4.4	The effect of the PDADMAC polymer on the torque readings at different Reynold number.	56
4.5	A comparison between the torque of PAA, HPC, P (AAm-co-DADMAC) and PDADMAC at 50 ppm to torque of water as a function in Reynold number.	57
4.6	A comparison between the torque of PAA, HPC, P (AAm-co-DADMAC) and PDADMAC at 700 ppm to torque of water as a function in Reynold number.	58
4.7	A comparison between the torque of PAA, HPC, P (AAm-co-DADMAC) and PDADMAC at 1000 ppm to torque of water as a function in Reynold number.	58
4.8	Compares the torque of sodium oleate and tween 20 at 50 ppm to the torque of water as a function in Reynold number.	59
4.9	Compares the torque of sodium oleate and tween 20 at 700 ppm to the torque of water as a function in Reynold number.	60
4.10	Compares the torque of sodium oleate and tween 20 at 1000 ppm to the torque of water as a function in Reynold number.	60
4.11	The effect of the Reynold number on the torque reading for all the investigated polymers and their complexes with Sodium Oleate at 50 ppm.	62
4.12	The effect of the Reynold number on the torque reading for all the investigated polymers and their complexes with Sodium Oleate at 700 ppm.	62
4.13	The effect of the Reynold number on the torque reading for all the investigated polymers and their complexes with Sodium Oleate at 1000 ppm.	63
4.14	The effect of the Reynold number on the torque reading for all the investigated polymers and their complexes with tween 20 at 50 ppm.	64

4.15	The effect of the Reynold number on the torque reading for all the investigated polymers and their complexes with tween 20 at 700 ppm.	64
4.16	The effect of the Reynold number on the torque reading for all the investigated polymers and their complexes with tween 20 at 1000 ppm.	65
4.17	The effect of Sodium oleate concentration on the complex flow behavior with 50 ppm PAA polymer.	66
4.18	The effect of Sodium oleate concentration on the complex flow behavior with 500 ppm PAA polymer.	67
4.19	The effect of Sodium oleate concentration on the complex flow behavior with 1000 ppm PAA polymer.	67
4.20	The effect of Tween 20 concentration on the complex flow behavior with 50 ppm PAA polymer.	68
4.21	The effect of Tween 20 concentration on the complex flow behavior with 500 ppm PAA polymer.	69
4.22	The effect of Tween 20 concentration on the complex flow behavior with 1000 ppm PAA polymer.	69
4.23	The effect of the polymers concentrations on the torque readings at $Re = 163330$.	71
4.24	The effect of the polymers concentrations on the torque readings at $Re = 326660$.	71
4.25	The effect of the polymers concentrations on the torque readings at $Re = 816650$.	72
4.26	The effect of surfactant concentration on the torque readings at $Re = 163330$.	73
4.27	The effect of surfactant concentration on the torque readings at $Re = 326660$.	73
4.28	The effect of surfactant concentration on the torque readings at $Re = 979980$.	74
4.29	The effect of the addition concentrations on the torque readings of polymers and polymer-Sodium Oleate mixtures at $Re = 163330$.	76

4.30	The effect of the addition concentrations on the torque readings of polymers and polymer- Sodium Oleate mixtures at $Re = 326660$.	76
4.31	The effect of the addition concentrations on the torque readings of polymers and polymer- Sodium Oleate mixtures at $Re = 816650$.	77
4.32	The effect of the addition concentrations on the torque readings of polymers and polymer- Tween 20 mixtures at $Re = 163330$.	78
4.33	The effect of the addition concentrations on the torque readings of polymers and polymer- Tween 20 mixtures at $Re = 326660$.	79
4.34	The effect of the addition concentrations on the torque readings of polymers and polymer- Tween 20 mixtures at $Re = 816650$.	79
4.35	TEM picture of the PAA-Sodium Oleate complex at 500-500 ppm concentrations.	81
4.36	TEM picture of the PAA-Sodium Oleate complex at 1000-1000 ppm concentrations.	82
4.37	TEM picture of the PAA-Sodium Oleate complex at 1000-1000 ppm concentrations.	82
4.38	TEM picture of the HPC-Sodium Oleate complex at 1000-1000 ppm concentrations.	83
4.39	TEM picture of the HPC-Sodium Oleate complex at 1000-1000 ppm concentrations.	83
4.40	TEM pictures of the PAA-Tween 20 complex formed at 1000-1000 ppm concentration.	84
4.41	TEM pictures of the PAA-Tween 20 complex formed at 1000-1000 ppm concentration.	84
4.42	TEM pictures of the PDADMAC-Sodium Oleate complex formed at 1000-1000 ppm concentration.	85
4.43	TEM pictures of the PDADMAC-Sodium Oleate complex formed at 1000-1000 ppm concentration.	85
4.44	Explains the effect of Reynolds number on the drag reduction at different concentrations of PAA and $L = 4$ m.	87

4.45	Explains the effect of Reynolds number on the drag reduction at different concentrations of PAA and $L = 1$ m.	88
4.46	Explains the effect of Reynolds number on the drag reduction at different concentrations of PAA and $L = 3$ m.	88
4.47	The %Dr-Re relation for the sodium oleate at different concentration and 4 m sections length.	89
4.48	The %Dr-Re relation for the sodium oleate at different concentration and 1 m sections length.	90
4.49	The %Dr-Re relation for the sodium oleate at different concentration and 2 m sections length.	90
4.50	The %Dr-Re relation for the sodium oleate at different concentration and 3 m sections length.	91
4.51	The effect of the Re on the %Dr for PAA- Sodium Oleate complexes formed at the same concentrations and $L = 4$ m.	91
4.52	The effect of the Re on the %Dr for PAA- Sodium Oleate complexes formed at the same concentrations and $L = 1$ m.	92
4.53	The effect of the Re on the %Dr for PAA- Sodium Oleate complexes formed at the same concentrations and $L = 2$ m.	92
4.54	The effect of the Re on the %Dr for PAA- Sodium Oleate complexes formed at the same concentrations and $L = 3$ m.	93
4.55	Compares the effect of the Re on the %Dr for PAA, Sodium Oleate and PAA- Sodium Oleate complex at 1000 ppm and $L = 4$ m.	94
4.56	compares the effect of the Re on the %Dr for PAA, Sodium Oleate and PAA- Sodium Oleate complex at 1000 ppm and $L = 1$ m.	95
4.57	Compares the effect of the Re on the %Dr for PAA, Sodium Oleate and PAA- Sodium Oleate complex at 70 ppm and $L = 4$ m.	95
4.58	The effect of adding different concentrations of sodium oleate to 50 ppm PAA on the drag reduction as a function of Reynolds number at $L = 4$ m.	96

4.59	The effect of adding different concentrations of sodium oleate to 500 ppm PAA on the drag reduction as a function of Reynolds number at $L = 4$ m.	97
4.60	The effect of adding different concentrations of sodium oleate to 1000 ppm PAA on the drag reduction as a function of Reynolds number at $L = 4$ m.	98
4.61	Explains the effect of PAA concentration on the drag reduction at different Reynolds number and $L = 4$ m.	99
4.62	Explains the effect of PAA concentration on the drag reduction at different Reynolds number and $L = 1$ m.	99
4.63	Explains the effect of PAA concentration on the drag reduction at different Reynolds number and $L = 3$ m.	100
4.64	The effect of Sodium Oleate concentration on the drag reduction at different Reynolds number and $L = 4$ m.	101
4.65	The effect of Sodium Oleate concentration on the drag reduction at different Reynolds number and $L = 3$ m.	101
4.66	The effect of Sodium Oleate concentration on the drag reduction at different Reynolds number and $L = 1$ m.	102
4.67	Compares the effect of the concentration on the %Dr for PAA, Sodium Oleate and PAA- Sodium Oleate complexes at $Re = 42462$ and $L = 4$ m.	102
4.68	Compares the effect of the concentration on the %Dr for PAA, Sodium Oleate and PAA- Sodium Oleate complexes at $Re = 48124$ and $L = 4$ m.	103
4.69	Compares the effect of the concentration on the %Dr for PAA, Sodium Oleate and PAA- Sodium Oleate complexes at $Re = 66524$ and $L = 1$ m.	103
4.70	Length vs. % DR of PAA at $Re = 66524$ and different polymer concentration.	104
4.71	Length vs. % DR of PAA at $Re = 56616$ and different polymer concentration.	104
4.72	Length vs. % DR of sodium oleate at $Re = 66524$ and different surfactant concentration.	106
4.73	Length vs. % DR of sodium oleate at $Re = 56616$ and different surfactant concentration.	107

4.74	Length vs. % DR of sodium oleate at $Re = 42462$ and different surfactant concentration.	107
4.75	Length vs. % DR of PAA-sodium oleate complexes at $Re = 66524$ and different concentrations.	108
4.76	Length vs. % DR of PAA-sodium oleate complexes at $Re = 70770$ and different concentrations.	109
4.77	Length vs. % DR of PAA-sodium oleate complexes at $Re = 56616$ and different concentrations.	109
4.78	Length vs. % DR of PAA, sodium oleate and PAA-sodium oleate complexes at 700 ppm and $Re = 66524$.	110
4.79	Length vs. % DR of PAA, sodium oleate and PAA-sodium oleate complexes at 1000 ppm and $Re = 42462$.	111
4.80	Length vs. % DR of PAA, sodium oleate and PAA-sodium oleate complexes at 1000 ppm and $Re = 70770$.	112
4.81	Time vs. ΔP of PAA at $Re = 70770$, $L = 3$ m and different concentrations.	113
4.82	Time vs. ΔP of PAA at $Re = 66524$, $L = 4$ m and different concentrations.	114
4.83	Time vs. ΔP of Sodium Oleate at $Re = 70770$, $L = 3$ m and different concentrations.	115
4.84	Compares the (ΔP) values of water, PAA, sodium oleate and PAA-sodium oleate complexes at $Re = 70770$, $L = 3$ m as a function of the time.	116
4.85	Compares the (ΔP) values of water, PAA, sodium oleate and PAA-sodium oleate complexes at $Re = 56616$, $L = 3$ m as a function of the time.	117
4.86	The effect of the degradation on the polymer after a period of time comparing the other complexes at $Re = 66524$, $L = 4$ m as a function of time.	118
4.87	Observed versus predicted values for statistical correlation of water with PAA solution.	121
4.88	Observed versus predicted values for statistical correlation of water with Sodium oleate solution.	121

4.89	Observed versus predicted values for statistical correlation of water with PAA- Sodium oleate complex.	122
4.90	Observed versus predicted values for statistical correlation all experimental values.	122

LIST OF SYMBOLS

m	Meter
Ppm	Part per million
ρ	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
$^{\circ}C$	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 menahan 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 $Re = 816650$, 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 $Re = 816650$, kebanyakan bahan tambahan surfaktan menunjukkan prestasi pengurangan seretan dengan maksimum % DR masing-masing pada 16% dan 12% untuk natrium oleat dan Tween 20 surfaktan. Kompleks dicipta daripada bahan tambahan polimer dan surfaktan awal menunjukkan peningkatan prestasi yang ketara pada pengurangan seretan dan rintangan kepada daya ricih. Rintangan PAA dipertingkatkan ke 66% apabila diuji pada 500 ppm kalium oleat dan $Re = 489990$. Rintangan PAA dipertingkatkan secara besar sebanyak 203% apabila diuji pada 500 ppm natrium oleat dan $Re = 914648$. 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 kementerian dilaporkan.

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