EFFECTS OF POLYMER AND SURFACTANT COMPLEX WITH MICROBUBBLE ON THE FLOW ENHANCEMENT OF LIQUIDS IN PIPELINES

AKINDOYO EDWARD OLUWASOGA

DOCTOR OF PHILOSOPHY (CHEMICAL ENGINEERING)

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's full name	:	AKINDOYO EDWARD OLUWASOGA
Date of birth	:	24 MAY 1984
Title	:	EFFECTS OF POLYMER AND SURFACTANT COMPLEX WITH MICROBUBBLE ON THE FLOW ENHANCEMENT OF LIQUIDS IN PIPELINES
Academic Session	:	Semester II 2015/2016

I declare that this thesis is classified as:

- ☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)
- ☐ **RESTRICTED** (Contains restricted information as specified by the organization where research was done)
- ☑ **OPEN ACCESS** I agree that my thesis to be published as online open access (Full text)

I acknowledge that Universiti Malaysia Pahang reserve the right as follows:

1. The Thesis is the Property of Universiti Malaysia Pahang.
2. The Library of Universiti Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified By:

________________	________________
(Student's Signature)	(Signature of Supervisor)
A06333800	Ass. Prof. Dr. Hayder A. AbdulBari
New IC / Passport Number	Name of Supervisor
Date :	Date :

SUPERVISORS' DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy in Chemical Engineering.

(Supervisor's Signature)

Full Name : ASSOC. PROF. HAYDER A. ABDULBARI

Position : ASSOCIATE PROFESSOR

Date :

(Co-Supervisor's Signature)

Full Name :

Position :

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries, which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

____

(Author's Signature)

Name : AKINDOYO EDWARD OLUWASOGA

ID Number : PKC13002

Date : JULY 2016

TABLE OF CONTENTS

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

L	Pipe length
C	Concentration
m	Meter
D	Internal diameter
V	Viscosity
U	Velocity
ppm	Parts per million
F	Darcy friction factor
μ	Dynamic viscosity of fluid
ρ	Fluid density
Δp	Pressure loss
Wppm	Weight part per million
τ_w	Wall shear stress
g	Gram
µm	Micrometer
% DR	Percentage drag reduction
TEM	Transmission Electronic Microscopy

LIST OF ABBREVIATIONS

Re	Reynolds Number
DR	Drag Reduction
DRA	Drag Reduction Agent
PEO	Poly (ethylene oxide)
MW	Molecular weight
MWD	Molecular weight distribution
XG	Xanthan gum
RDA	Rotating Disk Apparatus
MDRA	Maximum drag reduction asymptote
CFD	Computational Fluid Dynamics
DNS	Direct numerical simulation
IUPAC	International Union of Pure and Applied Chemistry
ΔL	Length Difference
TAPS	Trans-Alaska Pipeline System
Wt.	Weight
^oC	Degree Celsius
CI	Effects of hydrodynamic interactions
H	Fiber resistance to extensional forces versus the fluid inertial forces
FFT	Force fully transformer

EFFECTS OF POLYMER AND SURFACTANT COMPLEX WITH MICROBUBBLES ON THE FLOW ENHANCEMENT OF LIQUIDS IN PIPELINES

AKINDOYO EDWARD OLUWASOGA

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Doctor of Philosophy in Chemical Engineering

Faculty of Chemical and Natural Resources Engineering
UNIVERSITI MALAYSIA PAHANG

JULY 2016

ABSTRACT

The major challenges confronting pipeline transportation of fluids are cost of transportation and energy dissipation. Such challenges are caused by the fluid turbulent flow. There are several attempted approaches to reduce the cost as well as the energy dissipated which have initially proven abortive. The main reason for this been that, there is no universal approach to reduce such turbulence as well as cost of liquid transportation. This turbulence flow, which leads to drag in the pipeline, has initially been attempted to reduce with active, passive and interactive means. However, safest practices, environmental consideration and less cost have prompted a continuous research in this area. Microbubbles, due to the environmental friendly nature and economic feasibility have as well been investigated by several researchers. However, the problem of coalescence is a major drawback to its general acceptance. This present work presents an approach to investigate and evaluate the effects of polymers, surfactant alone, complexes formed from these additives, each of these additives and their complexes with microbubbles. Such is aimed at changing the flow behavior in the pipeline. In this present work, Xanthan gum (XG), Polyacryl amide (PAM), Polyethylene Oxide (PEO), Hexadecyltrimethyl ammonium chloride (HTAC), Sodium dodecyl sulfate (SDS) were used as drag reducing agents (DRAs). These were tested in the Rotating Disk Apparatus (RDA) and also in the pipe. Rotating Disk apparatus was conducted to simulate external flows as well as mimic the high turbulence in the pipe. The pipeline loop was used to individually study the materials, their complexes as well as the combination of either of these with microbubbles. Materials were prepared in 50, 100, 200, 500, 700 and 1000ppm as the concentration and data were taken for their pressure drop across the sections of the pipe at varying flow rates. Such were used to evaluate drag reduction capability of these DRAs. From the result, it was observed that concentration played important roles in each of the materials investigated both in the RDA and pipeline. For the RDA, the best performance was obtained for Xanthan gum at 700ppm and a total drag reduction of about 53% was recorded while 47% and 43% for PAM and PEO at 1000ppm respectively. For the HTAC and the SDS, only 39 and 32 percent were recorded for each at 1000ppm. In the pipe, best performances were observed with the three dimensional complexes with microbubbles. Microbubbles alone gave 12% drag reduction, while microbubbles with three dimensional complex of XG 700ppm-HTAC 1000ppm-SP has the best drag reduction performance overall of about 87% drag reduction. Other complexes with microbubbles, such as XG 700ppm-SDS 1000ppm-SP, PAM 1000ppm-HTAC 1000ppm-SP, PEO 1000ppm-HTAC 1000ppm-SP, PAM 1000ppm-SDS 1000ppm-SP, PEO 1000ppm-SDS 1000ppm-SP only approximately 79%, 77%, 72%, 64% and 57% drag reduction respectively. However, when these complexes were investigated without microbubbles, they performed less as the following results were obtained: XG 700ppm-HTAC 1000ppm-SP, XG 700ppm-SDS 1000ppm-SP, PAM 1000ppm-HTAC 1000ppm-SP, PEO 1000ppm-HTAC 1000ppm-SP, PAM 1000ppm-SDS 1000ppm-SP, PEO 1000ppm-SDS 1000ppm-SP with 73, 62, 59, 58, 54, 51 drag reduction percentage respectively. From the observation for the pipe, it could be suggested that, the microbubbles played important role on the complexes compared to those obtained from without microbubbles or the RDA.

ABSTRAK

Cabaran utama yang dihadapi oleh pengangkutan saluran paip cecair adalah kos pengangkutan dan pembaziran tenaga. Cabaran ini adalah disebabkan adanya pergolakan aliran bendalir. Terdapat beberapa percubaan telah dilakukan untuk mengurangkan kos serta pembaziran tenaga di mana pada awalnya telah terbukti gagal. Sebab utama kegagalan ini adalah kerana tiada pendekatan yang universal serta kos pengangkutan cecair untuk mengurangkan pergolakan tersebut. Pada mulanya, percubaan untuk mengurangkan pergolakan aliran yang menyebabkan menyeret di dalam saluran paip ini telah dilakukan melalui cara aktif, pasif dan interaktif. Walau bagaimanapun, cara yang paling selamat dengan mempertimbangkan alam sekitar dan kos yang kurang telah mendorong kepada penyelidikan yang berterusan di dalam bidang ini. Beberapa penyelidik telah mengkaji tentang buih mikro kerana sifatnya yang mesra alam dan menjimatkan ekonomi. Namun begitu masalah penyatuan (coalescence) merupakan kelemahan utama kepada penerimaan umum. Penyelidikan ini menunjukkan satu pendekatan untuk mengkaji dan menilai kesan polimer, kesan "surfactant" itu sendiri, kompleks yang terbentuk antara bahan tambahan ini dan kompleks antara setiap bahan tambahan ini dengan buih mikro. Ini bertujuan untuk mengubah sifat aliran di dalam saluran paip. Xanthan gum (XG), Polyacryl amide (PAM), Polyethylene Oxide (PEO), Hexadecyltrimethylammonium chloride (HTAC), Sodium dodecyl sulfate (SDS) telah digunakan sebagai ejen pengurangan menyeret (DRAs) di dalam kajian ini. Ujian telah dilakukan di dalam Radas Disk Berputar (RDA) dan juga di dalam paip. RDA digunakan untuk mensimulasikan aliran luar dan bertindak sebagai tiruan terhadap pergolakan yang tinggi di dalam paip. Gelung saluran paip telah digunakan untuk mengkaji bahan-bahan dan kompleksnya, serta kombinasi salah satu daripadanya dengan buih mikro. Bahan-bahan disediakan dalam kepekatan 50, 100, 200, 500, 700 dan 1000ppm dan data penurunan tekanan di seluruh bahagian paip pada kadar aliran yang berbeza telah diambil. Datadata ini digunakan untuk menilai keupayaan pengurangan menyeret bagi ejen-ejen pengurangan menyeret ini. Keputusan menunjukkan kepekatan memainkan peranan penting untuk setiap bahan yang digunakan dalam kajian RDA dan saluran paip. Bagi RDA, Xanthan gum pada kepekatan 700ppm menunjukkan prestasi terbaik di mana jumlah pengurangan menyeret adalah sebanyak 53% manakala 47% dan 43% untuk PAM dan PEO pada kepekatan 1000ppm. Bagi HTAC dan SDS, hanya 39 dan 32 peratus dicatatkan bagi setiap bahan pada kepekatan 1000ppm. Bagi kajian di dalam paip, kombinasi antara tiga kompleks dimensi dengan buih mikro menunjukkan pencapaian yang baik. Buih mikro menunjukkan 12% pengurangan menyeret, manakala kombinasi buih mikro dengan tiga kompleks dimensi XG 700ppm-HTAC 1000ppm-SP menunjukkan pengurangan menyeret terbaik iaitu kira-kira 87%. Kombinasi kompleks lain dengan buih mikro seperti XG 700ppm-SDS 1000ppm-SP, PAM 1000ppm-HTAC 1000ppm-SP, PEO 1000ppm-HTAC 1000ppm-SP, PAM 1000ppm-SDS 1000ppm-SP dan PEO 1000ppm-SDS 1000ppm-SP menunjukkan pengurangan drag hanya kira-kira 79% , 77%, 72%, 64% dan 57%. Namun begitu, apabila kombinasi kompleks ini dikaji tanpa buih mikro, keputusan pencapaian yang didapati adalah berkurangan seperti berikut: XG 700ppm-HTAC 1000ppm-SP, XG 700ppm-SDS 1000ppm-SP, PAM 1000ppm-HTAC 1000ppm-SP, PEO 1000ppm-HTAC 1000ppm- SP, PAM 1000ppm-SDS 1000ppm-SP, PEO 1000ppm-SDS 1000ppm-SP dengan peratusan pengurangan drag sebanyak 73, 62, 59, 58, 54, 51. Cadangan yang boleh diberikan daripada pemerhatian untuk kajian di dalam paip adalah buih mikro memainkan peranan penting terhadap kompleks berbanding dengan kajian tanpa buih mikro atau kajian di dalam RDA.