PERFORMANCE OF COCOA HUSK MUCILAGE AS A DRAG REDUCTION AGENT IN PIPES

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Thesis submitted in fulfillment of the requirements for the award of the degree of
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We certify that the thesis is entitled “Performance of cocoa husk mucilage as a drag reduction agent in pipes” written by Hamad Khudhair Mohammed. We have examined the final copy of this thesis and that in our opinion; it is fully adequate in terms of scope and quality for the awarding the degree of Masters of Chemical Engineering. We herewith recommend that it be accepted in fulfillment of the requirements for the degree of Masters of Chemical Engineering.

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion this thesis is satisfactory in terms of scope and quality for the award of the degree of Master of Chemical Engineering.

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Date: June 2011

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.

Signature :
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To all the hearts that pray for me, and to all whom supported me.

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LIST OF SYMBOLS

C	Concentration
% FI	Percentage flow increase
ΔP	Pressure drop
D	Diameter
D1	Main tank drain
D2	Collecting tank drain
F	Fanning friction factor
F1	Ultrasonic flow meter
Fp	Friction factor of the drag reduced flow
*F*s	Friction factor of the tap water
KKM 22	Cocoa clone.
Le	Length required for a fully developed velocity profile
Lp	Length of the pipe
P1	Section pipe one
P2	Section pipe two
P3	Section pipe three
P4	Pressure gauge
p1	Main pipe
p2	Bypass pipe
p3	0.0127 m pipe
p4	0.0254 m pipe
p5	0.0381 m pipe

p6	Circulation pipe
ppm	Part per million
PU1	Main pump
PU2	Recirculation pump
Q	Mass flow rate
Q	Volumetric flow Rate
R	Pipe radius
R	Radius at measuring position
Re	Reynolds number
Sc	Schmidt number
St	Stanton number
T1	Main tank
T2	Collecting tank
t1, t2, t3, t4, t5	Testing point
U	Streamwise velocity fluctuation
U	Velocity
U_{av}	Mean fluid velocity
U_m	Bulk mean velocity
V	Wall-normal velocity fluctuation
ν	Kinematics viscosity
v1	Pump valve
v2	Bypass valve
v3, v4, v5	Pipe valve
v6	Circulation valve

Wt	Weight
Θ	Temperature fluctuation
M	Dynamic viscosity
P	Density
Tw	Wall shear stress

LIST OF ABBREVIATIONS

AM	Acrylamide
AMPDAPS	3-((2-acrylamido-2-methylpropyl)dimethylammonio)- 1-Propanesulfonat
AMPTAC	2-acrylamido-2-methylpropyl)trimethylammoniumch loride
CMC	Critical micellization concentration
CMT	Critical Micellization temperature
CWM	Coal water mixture
DNS	Direct numerical simulation
DR	Drag reduction
DRA	Drag reduction agent
DRPs	Drag reduction polymers
LDA	Laser Doppler anemometry
LDV	Laser-Doppler-velocimetry
LEBU	Large eddy breakup
LIE	Laser induced fluorescence
LMM	Like mucilage molecules
MOL	Main oil line
NaAMPS	Sodium 2-acrylamido-2-methylpropanesulfonate
ODEAO	Oleyldihydroxyethylamineoxide
PAAM	Polyacrylamide
PEO	Polyethylene oxide
PIB	Polyisobutylene
PIV	Particle image velocimetry
PNVF	Poly(N-vinylformamide)

PVAC	Polyvinylacetate
SIS	Shear induced structure
TME	Trimethylolethane
TTAA	tris (2-hydroxyethyl) tallowalkyl ammonium acetate
TTAB	n- etradecyltrimethylammoniumbromide

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ABSTRACT

Energy loss during transport of fluids in an industry is one of the problems to be resolved. This research worked on the possibility of using cocoa husk mucilage as a drag reducing agent to replace synthetic polymers used by the industry today. A closed loop liquid circulation system was used to carry out the experimental work. The major variables investigated in the present work to study the effectiveness of the new drag reducer are pipe size (0.0127 m, 0.0254 m, 0.0381 m), liquid flow rate (0.5-8 m^3/hr), additives concentration (100 ppm, 200 ppm and 300 ppm) and testing section length (0.5 m, 1 m, 1.5 m and 2.0 m). The extraction of the mucilage achieved by mixing 75 % ethanol and 25 % acetone for one hour and further extracted by autoclave for half an hour at 150 °c and 0.25 Mpa. Generally, the drag reduction effectiveness of the cocoa husk mucilage was proven in the present work, with a maximum percentage drag reduction value of 54.55% for the solution flowing in 0.0254 m I.D. pipe and at testing section length of 0.5 m, concentration 300 ppm and at 4 m^3/hr flow rate. The cocoa bean husk mucilage concentration and the solution flow rate, showed a great effect on profile of drag reduction in the pipe. As concentration of cocoa bean husk mucilage increases, drag reduction increases in all conditions of experimental research. Besides, drag reduction is also increased by increasing flow rate until a maximum drag reduction is reached where degradation happens. The effect of pipe diameter on the percentage of drag reduction was not completely stable, generally, the 0.0254 m I.D. pipe showed the best and the most stable performance of the new mucilage as drag reducing agent. Increasing the testing section length led to the reduction in the cocoa husk mucilage effectiveness as a drag reducer due to continues effect of shear force on the mucilage molecules with length. A numerical empirical expression was developed depending on the experimental data. The numerical model major equation was $f = a\,(Re)^b$. Several solutions and models were introduced for each case of drag reduction in the present work depending on the experimental system investigated. As a conclusion; a new environmental friendly drag reducing agent is successfully introduced and its effectiveness in improving the flow was proven experimentally.

ABSTRAK

Kehilangan tenaga semasa pengangkutan bendalir dalam industri yang merupakan salah satu masalah yang perlu diselesaikan. Penggunaan lendiran sekam koko sebagai ejen mengurangkan geseran bagi menggantikan bahan polimer sintetik yang digunakan oleh industri hari ini. Pembinaan sistem perpaipan tertutup disediakan khas bagi menguji keberkesanan bahan tambah yang baru dari segi kadar pengurangan geseran. Parameter utama yang dikaji di dalam penyelidikan ini adalah, keberkesanan bahan tambah, saiz paip (0.0127 m, 0.0254 m, 0.0381 m), kadar aliran bendalir (0.5-8 m^3/hr), kepekatan bahan tambah (100 ppm, 200 ppm dan 300 ppm) dan juga panjang paip yang diuji (0.5 m, 1.0 m, 1.5 m, dan 2.0 m). Ekstrak bendalir (bahan tambah) diperoleh dengan mencampurkan 75% ethanol dan 25% aseton untuk sejam, dan diteruskan dengan pengekstrakan menggunakan "autoclave" selama setengah jam pada suhu 150^{o}C dan 0.25 Mpa. Keberkesanan pengurangan geseran setelah menggunakan lendiran kulit koko telah berjaya dibuktikan di dalam kajian ini, dengan rekod pengurangan geseran tertinggi pada bendalir yang mengalir dalam paip 0.0254 m iaitu 54.55% pada ukuran panjang 0.5 m, kepekatan lendir 300 ppm dan kelajuan aliran pada 4 m^3/hr. Kepekatan lendiran kulit koko dan juga kelajuan aliran bendalir menunjukkan kesan terbesar kepada gambaran kejadian pengurangan geseran di dalam paip. Apabila kepekatan meningkat, pengurangan geseran pada semua keadaan di dalam aspek kajian turut meningkat. Malahan, pengurangan geseran turut direkod berlaku dengan peningkatan kelajuan aliran sehingga paras maksimum pengurangan geseran iaitu degan berlakunya penguraian lendiran. Kesan diameter paip kepda peratusan pengurangan geseran tidak begitu stabil. Umumnya direkodkan diameter 0.0254 m I.D mempunyai bacaan yang paling stabil dan menunjukkan prestasi yang terbaik. Apabila jarak ujikaji ditingkatkan akan menyebabkan pengurangan dalam prestasi lendiran kulit koko sebagai pelincir kerana kesan daya ricih terhadap molekul bendalir dengan panjang paip. Persamaan utama secara model numerikal dijana bagi menunjukkan kaitan antara parameter iaitu $f = a (Re)^b$. Beberapa penyelesaian dan model turut diperkenalkan dalam setiap ujikaji pengurangan geseran ini. Kesimpulannya, satu pelincir mesra alam dengan jayanya diperkenalkan dan dibuktikan ia dapat meningkatkan prestasi secara eksperimen.

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