FLOW ENHANCEMENT IN MICROCHANNELS USING OKRA, ALOE VERA AND HIBISCUS MUCILAGES

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MASTER

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SUPERVISOR'S 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 Master of Science in Chemical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at University Malaysia Pahang or any other institutions.

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LIST OF SYMBOLS

Subscripts

a	after drag reducing additive addition
b	before drag reducing additive addition

LIST OF ABBREVIATION

%DR	Percentage of drag reduction
%FI	Percentage of flow rate increment
APG1214	Alkyl Polyglycoside
CMC	Carboxymethylcellulose
DI water	Deionized water
DR	Drag reduction
DRA	Drag reducing additives
DSC	Differential Scanning Calorimeter
F	Flow rate
FTIR	Fourier Transform Infrared
HF	Hydrogen fluoride
HNO_3	Nitric acid
ID	Inner diameter
IR laser	Infrared laser
KOH	Potassium hydroxide
MEMS	Microelectromechanical systems
NaAMPS	Sodium 2-acrylamido-2-methylpropane sulphonic acid
PA	Polyamide
PAM	Polyacrylamide
Poly(AM-co-AA)	Poly(acrylamide-co-acrylic acid)
PCI	Percutaneous coronary intervention
PDMS	Polydimethylsiloxane
PEG	Polyethylene glycol
PEO	Polyethylene oxide
PiB	Polyisobutylene
PIV	Particle Image Velocimetry
PMMA	Polymethyl methacrylate
ppm	Parts per million
Re	Reynolds number
RIE	Reactive-ion etching
SDS	Sodium Doedecyl Suplhate
SEM	Scanning Electron Microscope
Tg	Glass transition temperature
XG	Xanthan gum
μ-PIV	Micro Particle Image Velocimetry

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ABSTRAK

Bahan tambahan pengurangan seretan polimer semula jadi yang diekstrak daripada sumber semula jadi mulai menarik perhatian dan minat penyelidik dalam usaha untuk menggantikan polimer tiruan yang sedia ada. Kajian ini bertujuan untuk mengkaji kemungkinan polimer semula jadi yang diekstrak daripada sumber tumbuh-tumbuhan dalam meningkatkan aliran cecair dalam mikrosaluran. Perkembangan teknologi *microfluidics* sebagai kaedah yang dapat menjimatkan kos dan dipercayai boleh menguji fenomena teori-teori berkaitan dengan bidang kejuruteraan dan perubatan menyebabkan mikrosaluran telah digunakan untuk menggantikan kaedah konvensional dengan penggunaan paip di mana mikrosaluran dapat mengurangkan penggunaan bahan kimia dan reagen. Polimer diekstrak daripada bendi, lidah buaya dan daun bunga raya menggunakan kaedah pengekstrakan air. Kepekatan lender yang berbeza telah disediakan berdasarkan asas berat / berat dengan menambah Air *deionized*. Empat *microchannels* yang mempunyai ketebalan kira-kira 200 mikron dengan lokasi tersumbat yang berbeza mensimulasikan saiz sebenar saluran jantung manusia telah direka dan difabrikasi dengan menggunakan kaedah *xurographical* dan kemudian dibentuk dengan *polydimethylsiloxane* (PDMS). Eksperimen ini dijalankan menggunakan sistem *microfluidic* yang dihubungkan dengan mikrosaluran yang direka. Prestasi peningkatan aliran dengan menggunakan kepekatan bahan tambahan yang terdiri daripada 100 hingga 500 ppm telah dinilaikan dengan merekod kadar aliran yang berpadanan dengan tekanan operasi (50 hingga 500 mbar). Kelakuan aliran aliran cecair dengan bahan tambahan diperhatikan dengan menggunakan sistem *micro-particle image velocimetry* (μ-PIV). Polimer semulajadi yang dikaji dalam kajian ini mempunyai ciri-ciri pengurangan seretan. Hubungan tidak linear diperolehi antara kepekatan bahan tambahan dan peratusan kenaikan kadar aliran (%FI) daripada kerja ini. Meningkatkan kepekatan polimer akan meningkatkan %FI sehingga had yang dipanggil kepekatan kritikal di mana di luar titik ini, peningkatkan kepekatan mempunyai kesan negatif kepada pengurangan seretan. Daripada keputusan eksperimen, lendir bunga raya memberikan prestasi pengurangan seretan tertinggi dengan mencapai %FI lebih tinggi dalam kebanyakan kes kerana lendir bunga raya mempunyai komposisi kumpulan polisakarida yang tertinggi. Dalam kebanyakan kes, peningkatan tekanan operasi mengakibatkan pengurangan %FI. Kenaikan aliran maksimum sehingga 63.48% telah dicapai dengan menggunakan 300 ppm lendir bunga raya pada tekanan operasi 50 mbar. Dari data yang diperolehi daripada sistem μ-PIV, kelajuan lebih tinggi diperhatikan apabila cecair itu memasuki kawasan yang sempit. Halaju kekal tinggi apabila cecair keluar dari bahagian separa tersumbat tersebut. Data daripada sistem μ-PIV bersetuju dengan keputusan eksperimen di mana penambahan bahan tambahan meningkat aliran dalam saluran mikro itu. Keputusan eksperimen juga mengesahkan potensi penggunaan bahan tambahan ini dalam bidang perubatan untuk meningkatkan aliran darah di dalam aliran darah separa tersumbat yang boleh menjadi rawatan alternatif untuk penyakit kardiovaskular. Ini adalah dicadangkan untuk menyiasat polimer semula jadi yang baru dan meneroka kemungkinan polimer untuk membubarkan atau mengakis kolesterol yang menyebabkan penyempitan saluran darah.

ABSTRACT

Natural polymeric drag reducing additives (DRA) extracted or obtained from natural resources started to gain attention and interest from researchers in an attempt to replace the existing artificial DRA. The present work aims to study the feasibility of the natural polymer extracted from plant sources in enhancing the liquid flow in microchannels. Due to the development of microfluidics technology as an economical and reliable method for testing different theoretical phenomena related to engineering fields and medical fields, microchannel was utilized replacing the conventional method by using pipes which can reduce the usage of the chemical and reagents significantly. Polymers were extracted from okra, aloe vera and hibiscus leaves using water extraction method. Different mucilage solution concentration was prepared by weight/weight basis after extraction by adding deionized water which acted as working fluid. Four microchannels which have a thickness about 200 µm with different clogging area simulating the human heart vessel size were fabricated using xurographical approach and then molded with polydimethylsiloxane (PDMS). The experiment was conducted using an open-loop microfluidic system which connected to the costum made microchannels. The flow enhancement performance of different concentration of the additives ranging from 100 to 500 ppm was evaluated by recording the flow rate corresponding to the operating pressure (50 to 500 mbar). The flow behavior of the liquid flow with the addition of the additives was observed by utilizing micro-particle image velocimetry (µ-PIV) systems. It is important to highlight that the examined natural polymers have drag reduction properties. A non-linear relationship was obtained from this work between the concentration of the additives and percentage of flow rate increment (%FI). Increasing the polymer concentration increases the %FI until a limit which so-called critical concentration where beyond this point continuous increasing the concentration have an adverse effect on drag reduction. From the experimental results, hibiscus mucilage gives highest drag reduction performance by achieving higher %FI as hibiscus mucilage contained the highest composition of polysaccharides group. In most of the cases, increasing of the operating pressure resulted in the decreasing of %FI. Maximum flow increment up to 63.48% was achieved using 300 ppm of hibiscus mucilage at the operating pressure of 50 mbar. From the data obtained from µ-PIV systems, higher velocity was observed when the liquid was entering the narrowed area of the microchannel. The velocity remained high when the liquid exiting the semi-clogged part. The data from µ-PIV systems agreed with the experimental results where the addition of the additives increased the flow in the microchannel. The experimental results validate the potential use of these additives in medical fields to enhance the blood flow in semi-clogged blood streams which can be an alternative treatment for cardiovascular diseases. It was recommended that more new natural polymeric DRA should be investigated and explored the possibility of these polymers to dissolve or corrode the cholesterol which cause narrowing of the blood vessels.

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