1 INTRODUCTION

1.1 Background

It has become a well-known situation that finding sustainable solutions to prevent turbulent flow tends to occur during high cardiac output and reduction of local vessel diameter which resulting in a localized increase in blood flow velocity (Richard, 2011). In the late 1940s, Toms has observed that nanomolar concentrations of long-chain flexible polymer molecules can drastically reduce turbulent friction in flowing fluids. Tom's phenomenon has been useful in various industrial and engineering applications including firefighting, transportation of crude oil through pipelines, and drag reduction on ship and submarines (Marhefka et al., 2006).

Although turbulent flows are not present in much of the vascular system, a minute concentration of the polymer drag reducing additives (DRAs) injected into the system can enhance the blood flow and reduce vascular resistance without affecting the blood viscosity (Marhefka et al., 2006; Bessa et al, 2011). Elucidation of the observation mechanism for DRA functions on blood circulation is extremely significant for the future medical applications (J. Marhefka et al., 2006). The feasibility of the DRAs in enhancing the blood flow in semi-clogged blood streams has been proved to have the potential as an alternative treatment of hypertension and cardiovascular disease (Unthank et al., 1992; Kameneva et al., 2004; Pacella et al., 2006; Marascalco, 2009). Since then, it is not surprising that researches started to use nanomolar concentrations of water soluble polymers to increase the flow of blood in the semi-clogged blood streams.

In most of the experimental work, animal testing were widely used by researchers to test the effectiveness of the DRA towards DR performance (Kameneva et al., 2004). However, animal testing does not follow the ethics dictate that values each life in this world. In order to solve problems occurred using animals, microfluidic devices start to be considered and used in order to replace animal testing.

In last two decades, microfluidics technology started to gain great interest in chemical engineering as well as in biomedical field. This device has the range of cross-section between 10 μ and 3 mm. The advantages of the microfluidics including lower amount of chemicals usage during process which reduce the emission of hazardous or toxic chemicals to the environment. The further advantages of these devices are extremely short response time and small equipment size (Bajus, 2012).

1.2 Motivation

Cardiovascular disease is the leading global cause of death in United States and across the world (Friedewald, 2002). According to the source from 2015 Heart Disease and Stroke statistics Update which is compiled annually by American Heart Association, there are accounting for 17.3 million Americans deaths per year. Meanwhile, the number is expected to grow to more than 23.6 million by 2030. It was about 85.6 million Americans are living with cardiovascular disease. Mortality statistics showed that about 2,150 Americans die each day from these diseases (Association, 2015). Therefore, treatment for semi-clogged heart blood vessel is extremely important for millions of patients suffering from cardiovascular disease, stroke and other illnesses. Most of the standard therapies available today for cardiovascular diseases treatment are being developed using tissue engineering and regenerative medicine methods (Marhefka, 2007). The costs of these treatments are enormous. Thus, the development of the novel methods to enhance the blood flow in semi-clogged blood vessels, which is major cause of cardiovascular disease, is essential. In this study, microfluidics technology and drag reduction technique were introduced to enhance the flow of blood in order to solve the problem caused by cardiovascular disease.

1.3 Problem Statement

Cost saving and environmental safety is the most essential concern in any fields. Micro scale is an alternative method to reduce the cost of chemicals due to the small amount of chemicals usage. The waste of chemicals can greatly reduce by introducing micro scale devices as the quantity of waste is one-tenth to one-thousandth of that formerly produced. Besides, a smaller quantity of chemicals used, usually in parts per million (ppm), exposes lesser amount of flammable, explosive, toxic, carcinogenic, and teratogenic material (Williamson & Masters, 2011). Furthermore, micro scale experiments can be carried out more rapidly than macro scale experiments. The time to prepare sample and conduct experiment also reduce significantly (Rivet et al., 2011; Hung & Lee, 2007).

For medical applications, due to the ethics dictate that value each life in this world, micro-channels started to be considered by researchers in order to solve problems on animal testing. Micro-channels are not only applicable in chemistry but also in medical fields including smart drug delivery (Weibel & Whitesides, 2006; Zhao, 2013). Therefore, in term of cost, safety and ethical values, microfluidic devices should be considered for this experiment work.

Synthetic polymeric additives are used for drag reduction researches where the introductions of a minute of these polymers were observed to increase the blood flow and reduce vascular resistance since several decades ago (Bessa et al, 2011). However, these synthetic polymer additives are not suitable to be injected or consumed by human due to the possibility of side effects for human health as they are toxic and non-biodegradable. In addition, it had been claimed that natural polymeric additives were more resistance to degradation compare to synthetic polymer in the presence of red blood cell where mechanical degradation is a serious drawback in medical applications that will cause the polymer to lose the properties of DRA (Joie N. Marhefka et al., 2006). Thus, it is essential to discover new natural polymer additives to replace synthetic polymers to enhance the blood flow.

1.4 Objectives

The objectives of this research are to fabricate micro-channels of different geometry using soft lithography method and to investigate the performance of soluble polymeric drag reducing additives in enhancing the flow of liquid in costumed made micro-channel under different conditions by varying parameters such as concentration, operating pressure and geometry of micro-channel. Besides, the flow behavior of the liquid flow in the micro-channel was also evaluated using µ-PIV system.

1.5 Scopes

The scopes of this research are:

i) Fabrication of micro-channel using soft lithography method.

ii) Elucidate the effect of concentration on DR performance in reducing the drag in fluid flow. The concentration of 20ppm, 50ppm, 100ppm, 150ppm, 200ppm, 300ppm, 400ppm and 500ppm are used in this study.

iii) Investigate the effect of length and width on the percentage of flow increment. It is proposed to use channel length of 70mm, 60mm, 50mm and 40mm and width of 500µm, 300µm and 200µm in the purpose above.

iv) The flow behavior of the liquid flow in the 500 µm width of micro-channel was evaluated using µ-PIV system.