Scientific Research and Essays Vol. 6(14), pp. 3058-3064, 18 July, 2011
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE11.755
ISSN 1992-2248 ©2011 Academic Journals

Full Length Research Paper

Effect of chitosan solution in turbulent drag reduction in aqueous media flow

Hayder A. A. Bari*, N. K. Mohamad, N. Mohd and A. H. Nour

Faculty of Chemical and Natural Resources Engineering, University Malaysia Pahang, Kuantan 2500, Malaysia.

Accepted July 3, 2011

Nowadays, the exploration of drag reductions by using natural resources has become popular because of its high efficiency in providing positive results and low cost comparing with other proposed technologies. This paper focuses on applying the chitosans, the polypeptide in aquatic live and the chitin, in a flowing liquid to improve the systems in plummeting drag reductions. As natural fluid resource, water is used as the reference flowing fluids for drag reduction with fixed volume. By employing different types of acid with various proportionate volumes of chitosan, it demonstrates positive results of decreasing drag. In addition, when the concentrations of the additive solutions are increased, the drag reduction process appears more effected. Finally, the most incredible results are convinced to be obtained in forms of 80.842% drag reductions from the chitosan solutions prepared with hydrochloride acids.

Key words: Drag reduction, chitosans solutions, water.

INTRODUCTION

The pumping power is the product of the flow volumetric flow rate of the pressure drop. Although this effect has been known for almost half a century, the fluid dynamics community still has not been able to clearly identify the physical mechanism that causes this drag reduction. The drag reduction is caused exclusively by the actively controlled transverse motion has being discovered by Barrett et al. (1999). The addition of a minute amount of polymers to a turbulent pipe or channel flow can result in a large reduction of the frictional drag. Direct force and power measurements on a streamlined, fish-like, flexible-hull vehicle with turbulence stimulation, show that the drag on the actively swimming body is smaller than the drag on the same body towed straight and rigid.

The drag reducing agent (DRA) is shear degradable and loses its effectiveness after having circulated through the pump more than two or three times and is effective in reducing pressure gradients in both full pipe oil and water flows by up to 50%. 5 ppm is nearly as effective as 75 ppm in full pipe flow pressure gradient reduction. Toonder (1995) said that apart from the obvious practical applications, it is interesting from a fundamental fluid dynamics point of view as well, since the study of polymeric drag reduction may give insight in turbulence itself. Diamond et al. (1992) have surveyed the existing experimental and theoretical understanding of drag reduction by polymer additives, and have presented a new continuum model (polymer hydrodynamics - PHD) of turbulent polymer solutions. Several natural extensions of and directions for further development of this model are apparent. Additionally, the friction factors in full pipe oil flow are lower than those predicted by the Blasius equation (Robert, 1997). It is important to note that each production field and water injection system has its own characteristics and hence the performance of drag reducing agents will vary from field to field. It is always recommended to conduct an in depth evaluation of drag reducing agents to a particular application before final implementation (Jennifer, 2003). Toms (1948) stated that the addition of small concentrations of high molecular weight polymer solvent can significantly reduce frictional pressure drop in turbulent flows leading to maintain the flow energy resulting increment in pipeline capacities. Since then, extensive research was done on all kinds of additives such as high molecular weight polymers (Mowla and Naderi, 2005), surfactants (Hayder et al., 2008; Andrej

*Corresponding author. E-mail: ahmedras_76@yahoo.com.

and Lucija, 2010; Ge et al., 2008; Li et al., 2008), and suspended solid (Moghaddam and Toll, 2006; Paul et al., 2009). The mechanism of polymer reduction process within boundary layer effect is still doubt, but supporting experimental evidences have been given by Shetty and Solomon (2009) and Dubief et al. (2004). Roy and Larson (2005) cited that high extensional stress in dilute polymer solution have been reported in earliest explanations on drag reduction mechanism including a "viscous" mechanism.

Chitosan is produced commercially by deacetylation of chitin, which is the structural element in the exoskeleton of crustaceans (crabs, shrimp, etc.) and cell walls of fungi. The degree of deacetylation (%DD) can be determined by NMR spectroscopy, and the %DD in commercial chitosans is in the range 60 to 100%. On average, the molecular weight of commercially produced chitosan is between 3800 to 20,000 Daltons. A mathematical equation was developed, based on macroscopic balances, to compute efflux time for the case of gravity draining of a Newtonian liquid from a large cylindrical tank through an exit pipe located at the center of the bottom of the tank, the flow in the pipe line being turbulent. The equation was fine-tuned with the experimental data and an empirical equation for friction factor was proposed. The proposed equation will be of use in arriving at the minimum time required for draining the tank. The effect of addition of water-soluble polymer, polyacrylamide, on drag reduction was investigated for the cases of partly laminar (when draining through the cylindrical tank), partly turbulent (while draining through the exit pipe), gravity driven once through flows and % reduction in efflux time was reported. The concentration of polymer on drag reduction was also established from the experimental data (Subbarao et al., 2010).

In the present study graft copolymer of chitosan with acrylamide has been synthesized in the presence of nitrogen using ceric ammonium nitrate, nitric acid redox system with UV irradiation. The synthesis copolymer subjected to various analytical techniques such as Fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC) and scanning electron microscopy (SEM) to confirm the formation of copolymer. The cross linkage between chitosan and polyacrylamide was analyzed and proven with FTIR and DSC. The SEM results showed the formation and strong chemical interaction between chitosan and polyacrylamide. The prepared graft copolymer was subjected to industrial dye effluent and result revealed that the copolymer prepared is excellent in removing all the polluted ions including heavy metals (Ansar et al., 2011).

METHODOLOGY

In solid powder phase, the chitosan powder is sieved by using stackable shaker to attain average particle size of 200 to 250 µm and from that, 25 g of chitosan powder are mixed with 500 ml of distilled water and will stirred until completely mixed while influence with heat during the process. As the solution becomes homogenous, it then should to be cooled down at room temperature. The chitosan solutions then mixed with acetic acid 100% glacial solutions with different amounts in order to produce several of chitosan concentration. The acetic acid then gradually added into the solutions to with ratio of 6% and mix continuously with speed 850 rpm. This solution stirring period prepared with different speed of mixing process; (850 rpm) for 7 h, (1100 rpm) for 10 h; (1500 rpm) for 15 h. After completely stirred with the desired condition the solution becomes high viscosity then it needs to be mixed with water before injecting to the flow systems a night before.

The main purpose of this work is to study the effect of different concentration of chitosan solution on the drag reduction performance. The experimental works was first carried out in the 0.5 inch pipe diameter and using a constant pipe length measurement which is 1.0 m. The active solution initially need to be diluted with water and left aside for approximately 24 h before it can be introduce to the solvent in order to make sure the solution will perfectly soluble in water. The pressure drop data before the addition of additives which is the pressure drop reading of raw water flow are need to be recorded first before the chitosan solution are pour into reservoir tank. There are 4 variable of chitosan concentration varied from 100 to 700 ppm (weight basis) and this solution are transferred into the reservoir tank and allowed to be well-mixed with the solvent which is water. For every additives concentration, the pressure drop value can be read at the moment of pump were started and the solution has begun to flows across the test section. The reading are made at five different value of flow rate (0.2, 0.4, 0.6, 0.8, and 1.0 m^3/h) which controlled by adjusting the valves at the pipe and at the bypass section.

Figure 1, shows the flow system that will be used in this investigation further. The system is consisted of reservoir tank, pipes, valves, pumps, and drain funnel. The main reservoir tank was joined by two pipes that connected to the centrifugal pumps. The first exit pipe was connected to 6 hp pump which is the main centrifugal pump that delivers water across the testing section pipes. The other pipe is connected to the other pump which pumps the solvent back to the main reservoir tank. These system designs are completely closed loop system build and consists of three transparent polyvinyl chloride pipe that has different size of inside diameter (0.5, 1.0 and 1.5 inch) that passed by the system. The flow pattern of solution can be observe by looking at the visible pipe wall and ease to controlling flow. Flow piping system started from the main reservoir tank and pumped until it reach the connection that split the pipe into three sections with different pipe diameter and testing section. the testing section used in this investigation are 1.0 m length and located 50 times of pipe diameter in order to ensure the that the turbulent flow are fully develop before the testing section point. To measure the pressure drop across the test section and in order to examine the efficiency of active solution prepared, a moveable differential pressure manometer with reading range from 0.00 to 0.025 bar were used. The Ultra-flux Portable Flow Meter Minisonic P are used to measure the flow rate of water in the pipeline and the flow of water can be controlled by adjusting the valve opening of the desired pipe diameter. The solvent that has flow across the pipeline system that reach reservoir tank 2 will be pump back to the main reservoir tank and this process is continuously.

RESULTS AND DISCUSSION

The percent of drag reduction are plotted function of Reynold's number with varied polymer concentration as

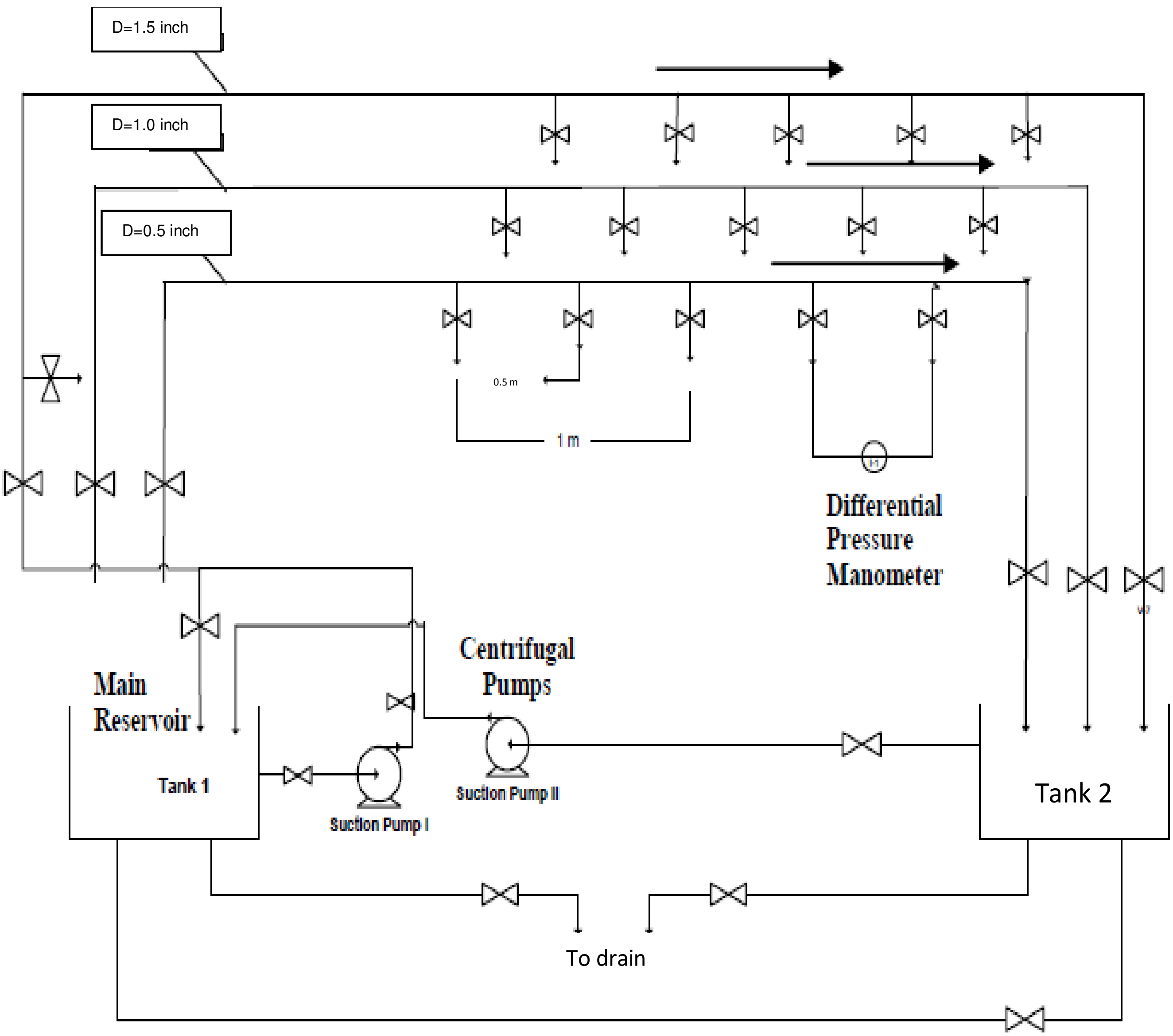

Figure 1.A schematic diagram of experimental rig.

shown in Figures 2 to 4. It is observed from the graph that addition of small amount of polymer concentration, leads to reduce frictional force between water molecule and pipe wall at the same flow condition. As it is noted by Tom (1948) publication, by the addition of small amount of polymer solution into turbulent Newtonian fluid flow can result a significantly effect in drag reduction in comparison to the pure solvent. The graph's trend shows an increasing of drag reduction percentage as increase of chitosan concentration for each pipe diameter but there is a critical concentration above which no more drag reduction can be obtain. Figure 3 show that the %Dr decreases after reaching a maximum point of drag reduction at 80.42% in 0.025 m pipe diameter. By scrutinize the pattern of graph, we can proposed that the optimum concentration of chitosan drag reducing agent in water flowing system were at 300 ppm concentration where as high as 80.42% of drag reduction obtained compared to pure solvent at Reynolds number range from 6000 to 30000.

In another embodiment of the present invention, another constraint that limits the drag reduction performance is the values of superficial velocity of the water flow in the pipeline system. From Figures 2 to 3, the percentage of drag reduction is plotted versus Reynolds number for strike flow regime in various pipe diameters. It is observed that the percentage of drag reduction increase as increase of Reynolds number and drastically diminished after reaching MDR at high mean velocity profile which from range NRe of 30000 to 70000. So, it can be said that the effective superficial velocity in 0.025 m pipe diameter is at the point where maximum

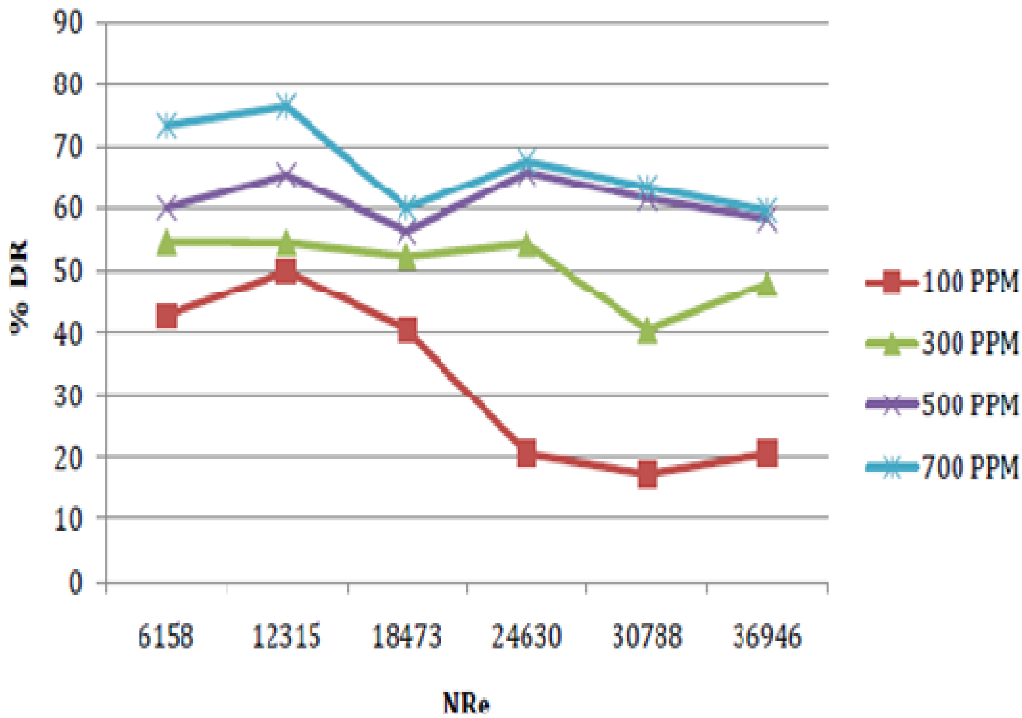

Figure 2. Figure 2. Effect of Reynolds number on chitosan concentration dissolved in water flowing through 0.0127 m diameter pipe for 6% acetic acid proportion.

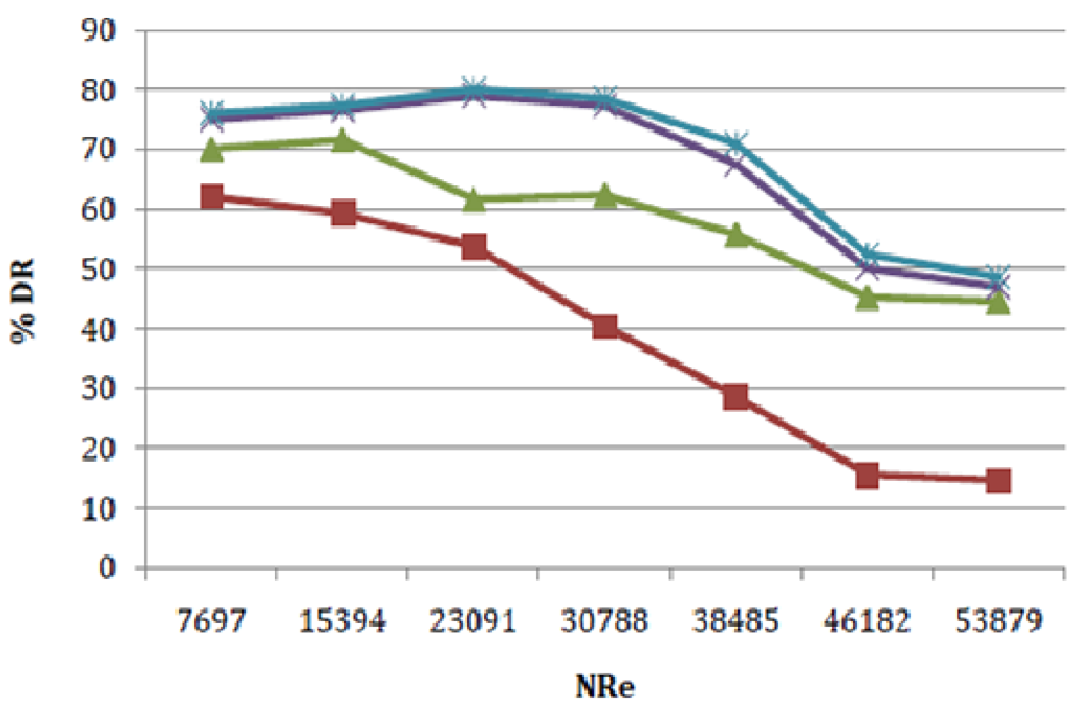

Figure 3 Figure 3. Effect of Reynolds number on chitosan concentration dissolved in water flowing through 0.025 m diameter pipe for 6% acetic acid proportion.

drag reduction (MDR) are shown which are at 0.5 m^3/h. Kang and Jepson (1999, 2000) works has observed that increasing of drag reduction are led by decreasing superficial velocities which is shown in the Figures 2 to 3

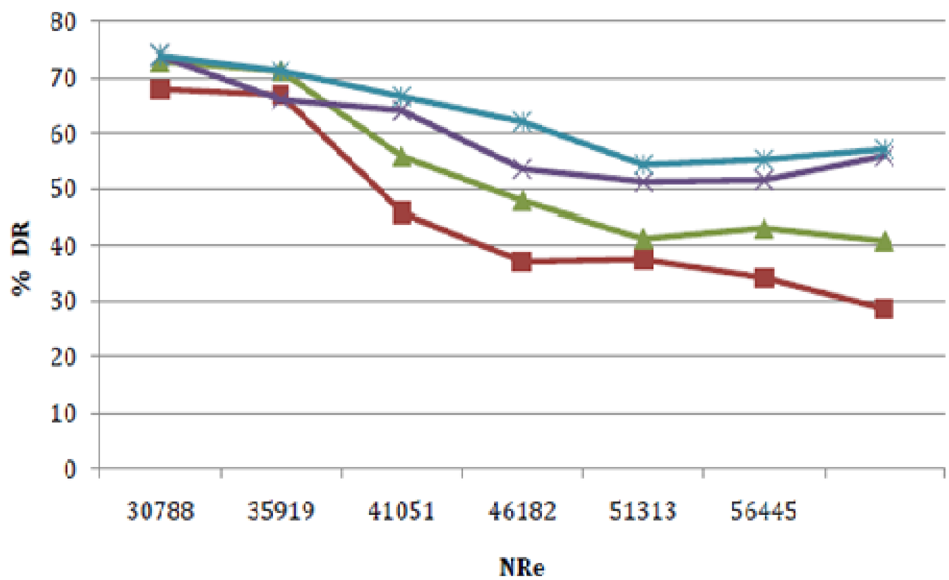

Figure 4. Figure 4. Effect of Reynolds number on chitosan concentration dissolved in water flowing through 0.0382 m diameter pipe for 6% acetic acid proportion.

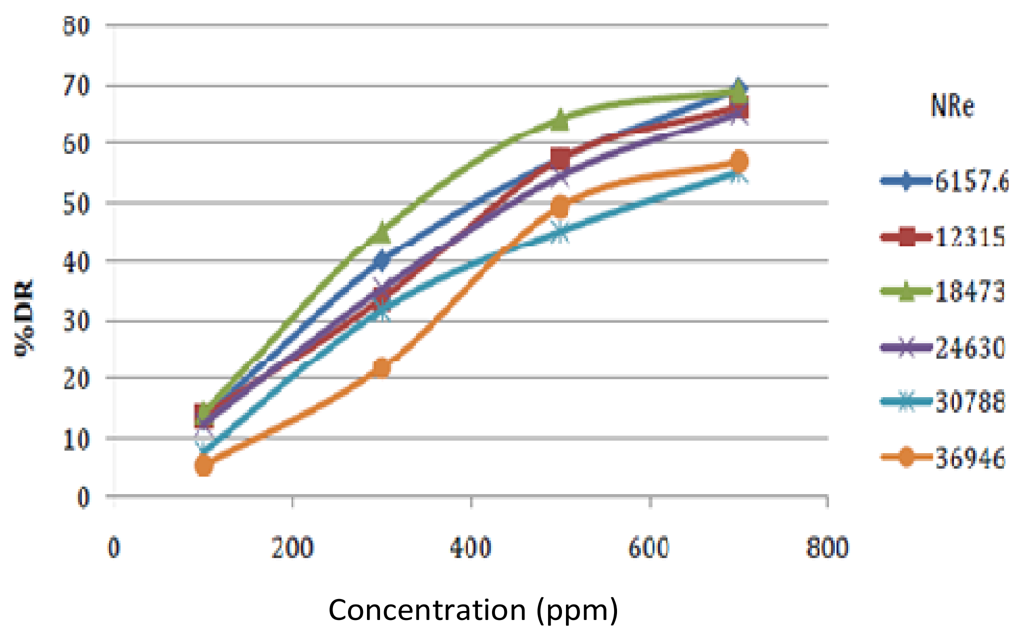

Figure 5. Figure 5. Drag reduction profile relationship for 0.0127 m pipe diameter for different chitosan concentration.

with directly proportional relation of velocities and Reynolds number. Explain on the mechanism, by increasing the velocity of the water flowing system will lead to the extended large eddies in the viscous sub layer region into the buffer layer. The expended large eddies produce increased stream wise irregular velocity primarily in the buffer layer. Based on the Lumley's hypothesis, eddies expanded before will be liable for the extensional viscosity and that high extensional viscosity will damp the small intensity eddies. The stress in the buffer layer will delay the reduction in the mean profile slope that will thicken the buffer layer resulting from the decreased of small eddies intensity. Since the molecules are not extended the viscous sub layer, the active agents in the solution are not affected so, the polymer drag reducer will not effective.

From Figures 5 to 7, percentage of the drag reduction is plotted versus the polymer concentration for each pipe

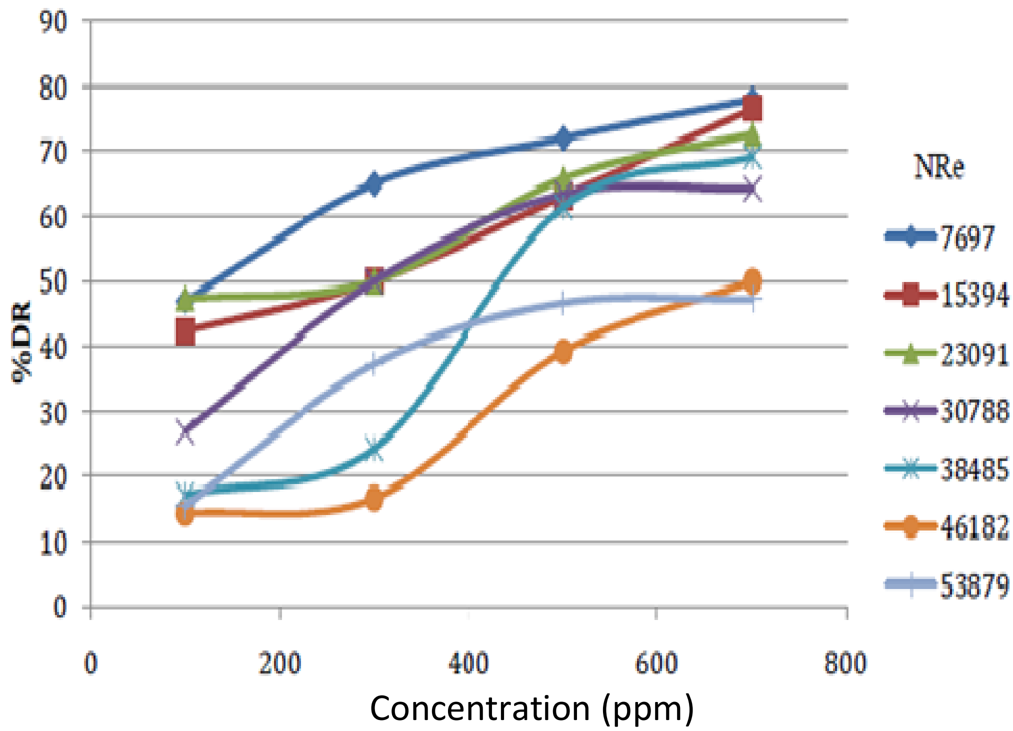

Figure 6. Drag reduction profile relationship for 0.0254 m pipe diameter for different chitosan concentration.

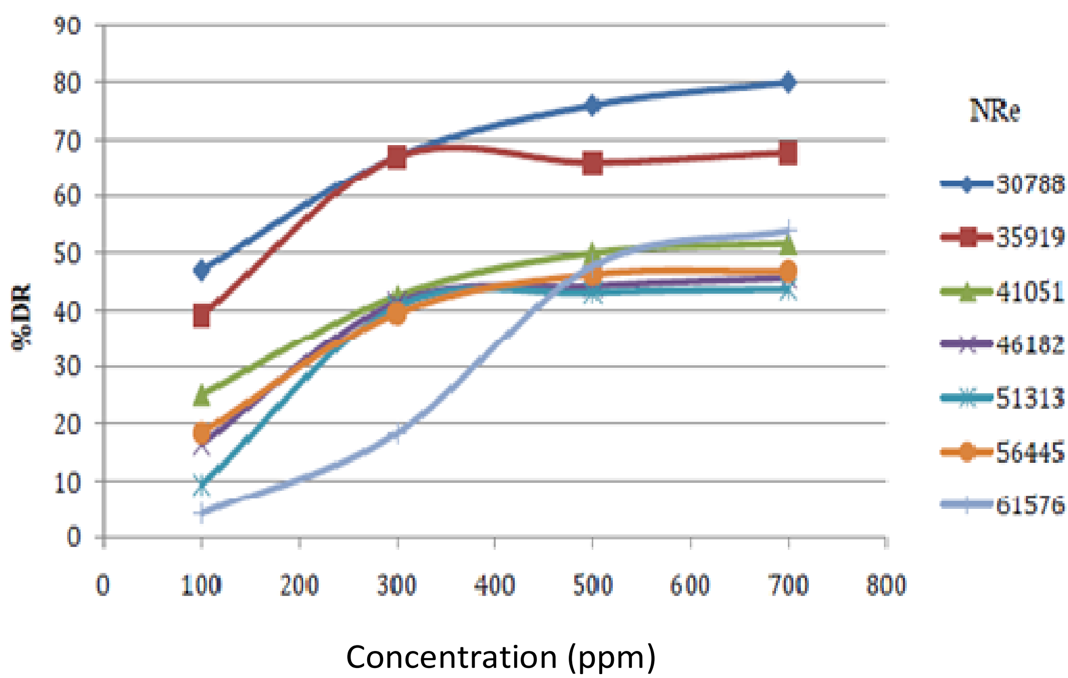

Figure 7. Drag Reduction profile relationship for 0.0381 m pipe diameter for different Chitosan concentration.

diameter. The maximum drag reduction value recorded is still 80.42% which are at 0.00254 m pipe diameter which is in range of 15000 to 32000 Reynolds number. This data confirmed the statement of Ferrante and Elghobashi

(2005), which says that the polymer drag reducer are only effective in turbulent flow and they are enhanced by the degree of turbulence. Indeed the decreasing of pipe diameter, this will result in higher turbulences and that represent the greater effect of polymer DRA. As the pipe diameter increases, the shear stress of the fluid are decrease and a higher drag reduction will be obtain at low concentrations. Though, with the increase of Reynolds number and shear stress, roughness of the pipe will increases the turbulences of the flow and suppresses the better performance of drag reduction. So, by controlling these three effects which are increase of pipe roughness, decrease of pipe diameter and increase Reynolds number, we can control the rate of pressure loss during pipeline transportation (Ferrante and Elghobashi, 2005).

Conclusions

This paper examined the effects of different concentrations of chitosan solutions on the drag reduction performance. By increasing the concentration of chitosan solution, the percentage of drag reduction in the pipeline is increased although there is a critical concentration where no more reduction is obtained. DRA becomes ineffective when the flow is laminar as it plays with the appearance of turbulence in the system and becomes more pronounced with the increasing number of Reynolds and the increasing roughness of pipe. But in smaller diameter size, DRA is more effective, although decreasing the pipe diameter results in higher degree of turbulence. Moreover, chitosan solution is tremendously cheaper while offering comparable performance in reducing drags, compared to other commercial drag reducing agents. More importantly, a high level of 80.42% of maximum drag reductions is achieved before no more reductions can be obtained as it approaches concentration limits

ACKNOWLEDGEMENT

This project is registered under the Malaysia Patent office (Patent No. PI20091830). The authors sincerely acknowledge University Malaysia Pahang for their laboratory and managerial supports.

REFFERENCES

Andrej K, Lucija CL (2010). Drag reducing surfactants for district heating. Appl. Thermal Eng., 30: 833-838.

Ansar Ali Z, Jayachandran Venkatesan, Se Kwon Kim, Sudha PN (2011). Beneficial Effect of Chitosan-G-Polyacrylamide Copolymer in Removal of Heavy Metals from Industrial Dye Effluents. Int. J. Environ. Sci., 1(5): 820-833.

Barrett DS, Triantafyllou1y MS, Yue1 DKP, Grosenbaugh MA, Wolfgang MJ (1999). Drag reduction in fish-like locomotion. J. Fluid Mech, 392: 183-212.

Diamond P, Harvey J, Katz J, Nelson D, Steinhardt P (1992). Drag Reduction by Polymer Additives. The MITRE Corporation, Colshire Drive McLean, Virginia 22102-3481 (703): 883-6997.

Ge W, Kesselman E, Talmon Y, Hart DJ, Zakin JL (2008). Effects of chemical structures of para-halobenzoates on micelle nanostructure, drag reduction and rheological behaviors of dilute CTAC solutions. J. Non-Newtonian Fluid Mech., 154:1-12.

Hayder A A Bari , Suali E, Hassan Z (2008). Glycolic acid ethoxylate lauryl ether performances as drag reducing agent in aqueous media flow in pipelines. J. App. Sci., 8: 4410-4415.

Toms BA (1948). Some observations on the flow of linear polymer solutions through straight pipe at large Reynolds numbers. Proceeding of the international congress on rheology, Scheveningen. The Netherlands. 2: 135-141.

Toonder JMJd, (1995). Drag Reduction by Polymer Additives in a Turbulent Pipe Flow: Laboratory and Numerical Experiments. Thesis Technische Universiteit Delft in Dutch. ISBN 90-9008990-X NUGI p. 841.

Jennifer N (2003). Optimizing production using drag reducing agents in water injection wells. Offshore Eng., pp. 1-3.

Li FC, Kawaguchi Y, Yu B, Wei JJ, Hishida K (2008). Experimental study of drag reduction mechanism for a dilute surfactant solution flow. International Journal of Heat and Mass Transfer. 51: 835-843.

Moghaddam MD, Toll S (2006). Fibre suspension rheology: effect of concentration, aspect ratio and fibre size. Rheol Acta., 45: 315-320.

Mowla D, Naderi A (2006). Experimental study of drag reduction by a polymeric additive in slug two-phase flow of crude oil and air in horizontal pipes. Chem. Eng. Sci., 61: 1549-1554.

Paul J K , James AO, Mark MD (2009). Fiber suspension flow in a tapered channel: The effect of flow/fiber coupling. Int. J. Multiphase Flow., 35: 676-688.

Robert M, Vancko J, (1997). Effect Of a Drag Reducing Agent on Pressure Drop and Flow Regime Transitions in Multiphase Horizontal Low Pressure Pipelines. Faculty of the Fritz J. and Delores H. Russ, College of Engineering and Technology, Ohio University.

Roy A, Larson RG (2005). A mean flow model for polymer and fiber turbulent drag reduction. App. Rheol. J., 15: 370-389.

Shetty AM , Solomon MJ (2009). Aggregation in dilute solutions of high molar mass poly(ethylene) oxide and its effect on polymer turbulent drag reduction. Polymer, 50: 261: 270.

Subbarao ChV, King P, Bhaskara Sarma C, Prasad VSRK (2010). Drag Reduction by Polymer Additives in Gravity Driven Flow. Inter. J. App. Eng. Res. Dindigul, 1(3): 452-468.