

Effect of Polymer Type and Mixing of Polymers on Drag Reduction in Turbulent Pipe Flow

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Abstract

The paper reports on studies on effect of the type of polymer on drag reduction. The study conducted through circular pipe using Carboxy Methyl Cellulose (CMC), Xanthan gum (XG) and their mixing in equal ratios as additives in pipe of diameter 0.0381m. The study covered range of parameters like concentration, mean velocity and angle of inclination of pipe. The maximum drag reduction observed was about 58%, 46% and 46% for the three polymers respectively. It is found that the drag reduction for the mixture is close to the drag reduction for XG polymer. The SPSS program has been used for correlate the data that have been obtained. The drag reduction percentage is correlated in terms of Reynolds number Re , additive concentration C (ppm) and angle of inclination of pipe δ (deg), and the relations obtained is mentioned.

Key Words:- Drag Reduction; polymers; Carboxy Methyl Cellulose; Xanthan Gum; Turbulent Flow.

الخلاصة

البحث يتناول دراسة تأثير نوع البوليمر على تقليل الاعاقة. الدراسة اجريت خلال انبوب دائري باستخدام كاربوكسي مثيل سليولوز الصوديوم، صمغ الكزانثان وخليطيهما بنسب متساوية كاضافات في انبوب قطره 0.0381م. الدراسة اخذت بنظر الاعتبار تأثير عدد من العوامل مثل التركيز ورقم رينولدز وزاوية ميلان الانبوب. اعظم تقليل اعاقه كان تقريبا 58%، 46% و 46% للبوليمرات الثلاثة على التوالي. وجد بان نسبة تقليل الاعاقه للخليط قريبة من نسبة تقليل الاعاقه لبوليمر (XG). برنامج SPSS استخدم لايجاد علاقات تصحيحية للاضافات الثلاثة. نسبة تقليل الاعاقه وجدت بدلالة رقم رينولدز والتركيز بالاضافة الى زاوية ميلان الانبوب والتي ستذكر فيما بعد.

الكلمات المفتاحية : - الحد من السحب، البوليمرات، كاربوكسي مثيل سليولوز، صمغ زنتان؛ الجريان المضطرب.

Nomenclature

	<i>Meaning</i>	<i>Units</i>
Δp	Pressure Drop For Water With Additives	N/m^2
Δp_0	Pressure Drop For Pure Water	N/m^2
∇p	Pressure gradient	N/m^3
A	Pipe Cross-Sectional Area	m^2
C_F	Friction Factor	---
D	Diameter of pipe	m
$DR\%$	Drag Reduction Percentage	---
Q	Volumetric Flow Rate	m^3/s
Re	Reynolds Number	----
U	Mean Water Velocity	m/s

Greek Letters

δ	Angle of Pipe Inclination	Deg.
ρ	Density of Water	kg/m^3
ρ_e	Effective Density of Solution	kg/m^3
ε	Dissipation Rate of Turbulent Kinetic Energy	m^2/s^3
μ	Water Dynamic Viscosity	$kg/m.s$
μ_e	Solution Dynamic Viscosity	$kg/m.s$
μ_t	Turbulent Dynamic Viscosity	$kg/m.s$
μ_{ef}	Effective Turbulent Viscosity	$kg/m.s$
τ	Shear Stress	N/m^2

1. Introduction

It has been known for over fifty years that adding a small quantity of polymer can lead to a reduction in friction of turbulent pipe flow. This phenomenon has been classified as a drag reduction (DR). The first publication on this subject is credited to Toms, for which the DR effect is sometimes referred to as the Toms's effect (1948).

Drag reduction has a broad range of important applications; including transportation of oil, wastewater treatment, firefighting, transport of solids in water, heating and cooling loops, hydraulic and jet machinery, refined products and non-potable water, transportation industries for designing the optimal operation of oil pipelines. The use of drag reducing additives to enhance flow in petroleum pipelines has received the greatest attention due to its great commercial success in reducing cost and energy consumption. and also biomedical applications, where there are several studies with ongoing tests in rats looking to see if drag reducers can help with blood flow. There is also currently much research in using biocompatible polyelectrolytes for implant coatings, for controlled drug release.

Most studies have showed that polymer with a linear structure and high molecular weight, above 500, 000 (g/gmole), can be good drag reducers (Den Toonder *et.al.*, 1997).

(Warholic *et.al.*, 1999) presented his experimental evidence of drag reduction of polymer solutions and suggested that the Reynolds shear stress can be considered negligible near the maximum drag reduction. (Kim, 2003) studied the pseudo plastic behavior of CMC polymer as a drag reducer in straight pipes. He used power law model for laminar flow and extended this model to non-Newtonian turbulent flow.

P. Venkata Rao and Ch. Ravikishore (2013) made experimental work with an equipment consisted of diameters (0.52, 0.50 and 0.45m) of the stainless steel conical tanks. A mild steel pipe of 0.006 diameter (d) was fitted at the centre of the bottom of the tank, served as an exit pipe. A Gate valve (GV) was provided at the bottom most point of the exit pipe, served as control valve for draining of liquid from the tank. Polymer addition to the vessel show significant reduction in % drag reduction. i.e.,

draining of tank contents was found to be relatively faster when polymer solutions were added and also for PAM concentration of 30ppm, draining of tank solution with minimum efflux time was observed and in the presence of polymer solution, % of drag reduction was found certainly by a minimum of 18% and maximum of 26 % on an average.. He found also that The efflux time was increased with the increase in length of the exit pipe, exit pipe diameter and the tank diameter and decreases with the decrease in height of liquid in the tank.

Şerife Zeybek Vural and Göknur Bayram (2014) studied the drag reduction in fully developed turbulent pipe flow with 4 concentrations (200 to 500 wppm or mg/kg) of low molecular weight sodium carboxymethylcellulose (CMC) in aqueous solutions was investigated experimentally. Maximum drag reduction achieved was 22% using 500 wppm CMC solution. Two impacts of increasing CMC concentration on the flow field were observed. The first effect was the decrease in the mean velocity gradient, especially near the wall, with increasing polymer amount, which in turn gave rise to a lower friction factor or pressure drop. Furthermore, smaller eddy viscosities were obtained in the flow. The second impact of polymer addition was on the velocity fluctuation or turbulent intensity variation along the radial distribution. Presence of the polymer suppressed the velocity fluctuations near the wall while the intensity in the turbulent core region became stronger than in the case of lower or no polymer addition.

Various studies have shown that degradation is a complex process which depends on many factors like chemical, thermal, and mechanical variables. The mechanism is likely to be the scission of molecular entanglements or breaking of individual molecular chains (Liberatore and Baik, 2004). Thus, the first question that should be determined about the issue is what factors cause the degradation, especially the mechanical degradation. Until now, some researches (Kalashnikov, 2002) have indicated that polymer molecular weight, molecular weight distribution, temperature, solvent solubility, polymer concentration, turbulent intensity, preparation and storage methods, entrance or end effects, and flow geometry may influence polymer degradation in turbulent flows.

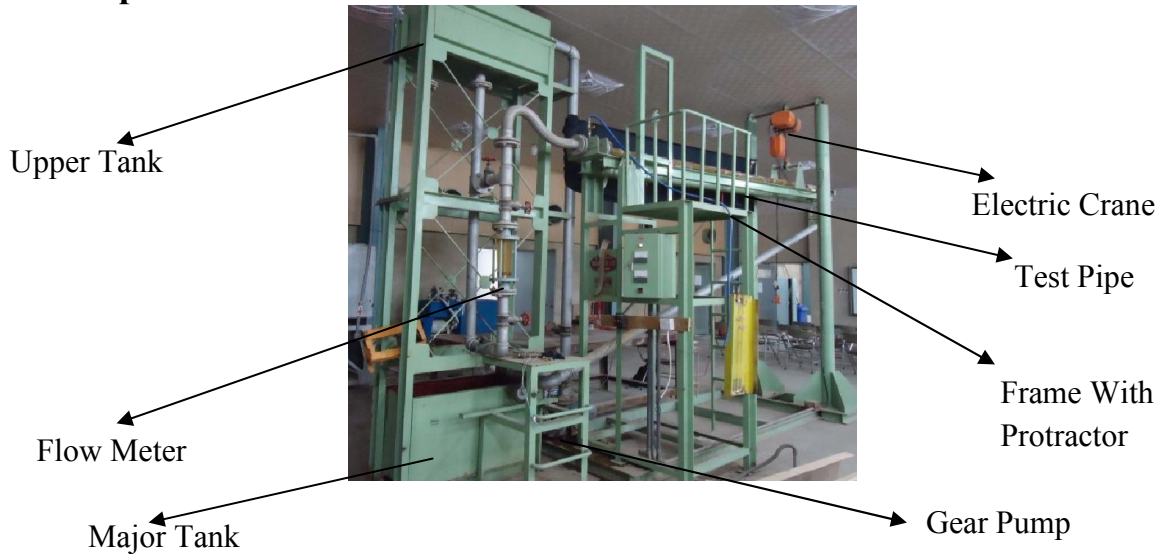
The objective of this research is to study drag-reducing ability of available drag reduction materials using two types of polymers (CMC and XG) and their mixing in equal ratios. Three parameters which affect drag reduction ability are taken into consideration during the experimental work such as mean water velocity, additive concentration and pipe inclination. Also, the degradation for both polymers has been studied.

Most of the reported studies on drag DR suffer from various issues two of which are listed below.

- a. Several studies were done under extreme range of concentrations which are not applicable in practical situations (very low or very high concentration of drag reducers).
- b. The angle of inclination of pipes was not taken into consideration. In most studies the pipes are taken horizontal.

So these two parameters will be taken into consideration.

2.Experimental work



Figure(1) :The test rig.

The test rig consists of the following parts:

- 1-Test pipe
- 2-Flow meter (rotameter)
- 3-Major tank (fluid tank)
- 4-Gear pump
- 5-Minor tank
- 6-Sensors with interface system
- 7-Frame with protractor
- 8-Electric crane

The test pipe is made of glass with 4m long ,38.1mm internal diameter and a circular cross section area. There are four pressure sensors connected with pipe for measuring pressure. It is fixed by steel frame to support and hold it firmly .the pipe and frame are connected with protractor for determination the angle of inclination of the pipe .The flow meter is rotameter F.M.91426 type used for water flow rate measuring at 20 C° with range of (20-200 L/min).A liquid tank of 300L capacity, with length of 1m ,width of 0.5m and height of 0.6m is used to store the water for recirculation flow in the pipe .The pump used is Hitachi Ltd type with power of 3.7KW ,voltage of 380V, head of 20m and with maximum flow rate of 0.4m³/min. the pump delivers the water from the major tank(lower tank) to the upper tank. The main purpose of having such elevated tank is to provide uniform stream flow for water and get ride off the pulse created by the pump which will affect the measurement taken because of the non uniformity .The electric crane is used to change the angle of inclination of test pipe.

2.1.Preparation of Additive Solution

The following procedure represent the steps to make the required preparation for the solution:

- 1- Weighting the powder required for each additive by a sensitive balance.
- 2- To obtain half liter of solution at the 5% concentration in a separate container, we add 25 g of additive to 475 g of water. Then the mixture will be stirred in a magnetic stirrer for 2 hours to get uniform solution.

- 3- The solution allowed to stand for 24 hours at room temperature prior to its usage, and then carefully transferred to the test apparatus, care should be taken also to avoid degradation of additive during mixing and transfer.
- 4- The desired additive concentration is obtained by mixing the mother solution with the water in the reservoir according to the following equation:

Quantity added of mother

$$\text{Solution} = \frac{\text{fluid mass in the tank} \times \text{desired concentration}}{\text{concentration of mother solution}} \quad (1)$$

For example to obtain 50 ppm by weight:

$$\text{Volume added from mother solution} = \frac{100000 \times 0.000050}{0.05} = 100 \text{ cm}^3$$

2.2. Experimental Procedure

Firstly we must calculate the amount of mother solution required for each concentration from the equation that has been mentioned above.

After that it will be mixed with the water in the major tank. In order to obtain flow data against which the various predictive methods could be tested, experiments were carried out in pipe whose nominal diameter 38.1 mm with three angles of inclination which are (0, 3 and 6 degrees) and with eight values for flow rates which are (60, 80, 100 and 120, 140, 160, 180 and 200 L/min). The additive solution concentration tested where (50, 70, 100 and 120 ppm). The tank will be filled with enough quantity of water and operating the pump, the valve is opened to the required flow rate. The fluid is allowed to flow through the pipe and wait for 5 minute until steady state will be attend. Then connect the four pressure taps with sensors and with the interface and personal computer to recording the pressure of the four points. The same procedure is repeated in order to obtain more data at various flow rates, angles of inclination and various concentrations of additives.

2.3. Determination of Flow Parameters

Reynolds number for turbulent flow is given by :

$$\text{Re} = \frac{\rho U D}{\mu} \quad (2)$$

Where:

ρ : water density (kg/m^3).

U : mean velocity of water inside the pipe (m/s).

D : pipe diameter (m).

μ : water dynamic viscosity (Pa. s).

The mean velocity can be calculated from the flow rate from the equation:

$$U = \frac{Q}{A} \quad (3)$$

$$\text{Where } A = \frac{\pi}{4} \times D^2 \quad (4)$$

Where:

A : cross-sectional area of pipe (m^2)

Pressure gradient has been found from the equation:

$$\nabla p = \frac{\Delta p}{L} \quad (5)$$

Friction factor can be found from the equation:

$$C_F = \frac{\tau}{\frac{1}{2} \rho D^2} \quad (6)$$

Where :

$$\tau = \frac{D}{4} \times \frac{\Delta P}{L} \quad (7)$$

Where:

C_F : friction factor

τ : shear stress (N/m²)

ΔP : pressure drop (Pa)

L: length between pressure taps (m)

Drag reduction percent can be found for the equation:

$$DR\% = \frac{C_{F0} - C_F}{C_{F0}} \quad (8)$$

or

$$DR\% = \frac{\Delta p_0 - \Delta p}{\Delta p_0} \quad (9)$$

Where:

DR%: Drag reduction percentage.

C_{F0} : friction factor for pure water .

C_F : friction factor at any additive concentration

Δp_0 : Pressure drop for pure water (Pa).

Δp : Pressure drop for water with additive (Pa).

The range of variables in the present study and the several drag reducing polymers that have been reported in literature are maintained in table 1.

Table(1): Range of variables.

S. No	Variable	Maximum	Minimum
1	Mean velocity(m/s)	0.877	2.924
2	Reynolds number	33418	111394
3	Polymer concentration (ppm)	50	120
4	Angle of inclination of pipe (°)	0	6

3. Results and discussion

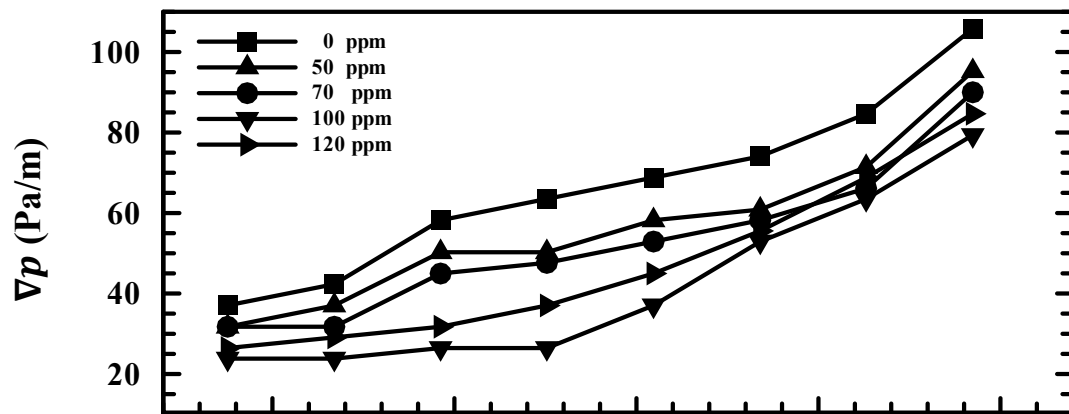
The purpose of our experimental work was drag reducing ability of available drag reduction materials in order to determine the suitable shear stress of the formulation, determination of friction factor, the effect of flow velocity, additive concentration and angle of inclination of pipe on pressure gradient.

Two types of polymers have been used which are CMC and XG polymers and their mixture which consists of equal mass ratio. Four concentrations are used for the two polymers and their mixing. The results of this study have been presented in figures below which will be discussed in detail.

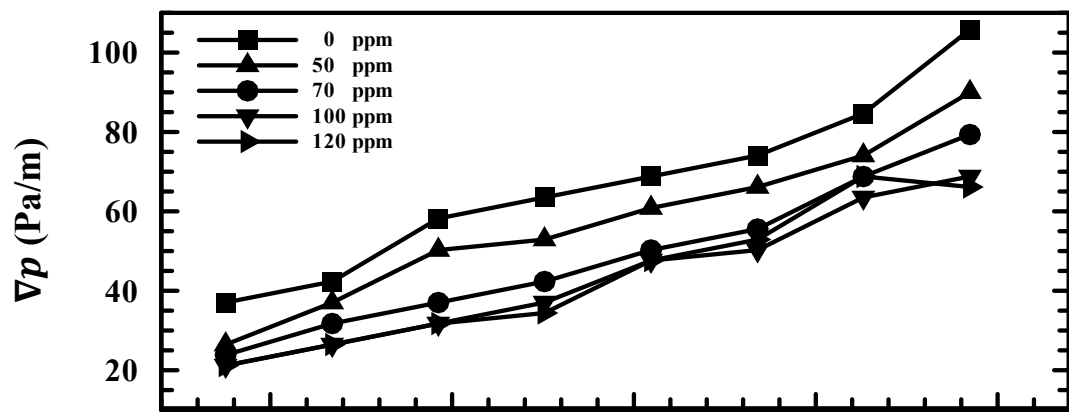
Carboxy Methyl Cellulose (CMC) and Xanthan gum (XG) have been used which have a molecular weight of 0.7×10^6 and 1×10^6 g/mol respectively. Figure (2) explains the effect of mean water velocity on the pressure gradient for various concentrations of additives for pipe of 4m length. It is observed from the figure that the pressure gradient increases with increasing velocity of water until reach maximum increase at velocity 2.924 m/s due to high inertia force for the same angle and concentration. Increase of polymer concentration leads to decrease in pressure gradient due to damping of near wall vortices and sustain turbulence by imparting energy into the stream wise velocity component in the very near wall region.

It can be noticed from figure (2-a) that the difference between pressure gradient for pure water and 50 ppm CMC concentration is greater than other differences between other concentrations for same velocity due to larger difference in concentration. The pressure gradient for different concentrations at velocity 0.877 m/s is convergent then starts to diverge until velocity 1.462 m/s then converges until reach maximum convergence at the velocity 2.34 m/s. Maximum decrease in pressure gradient occurs when polymer concentration is 100 ppm. The pressure gradient for 120 ppm is greater than 100 ppm, this may return to increase in solution viscosity as discussed by (Goren and Norbury, 1967).

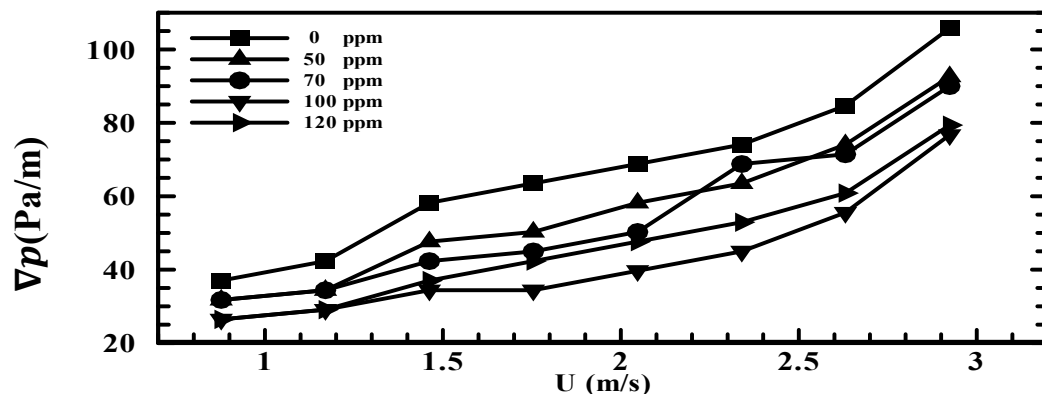
Figure (2-b) likes figure (2-a) for the most behaviors of pressure gradient with velocity, but there are some differences, where it can be seen that the difference in pressure gradient for 50 ppm and 70 ppm XG concentration is larger than that of figure (2-b). It also can be noted that the pressure gradient for concentrations from 70-120 ppm is very convergent for different velocities. The pressure gradient for 100 ppm and 120 ppm is equal in most velocities. These differences are due to dynamic action of the polymer in the flow.



(a)



(b)



(c)

Fig.(2): Variation of pressure gradient (Pa/m) with mean velocity (m/s) at $\delta=0^\circ$ for different concentrations (ppm) of a) CMC. b) XG. c) mixing of CMC and XG.

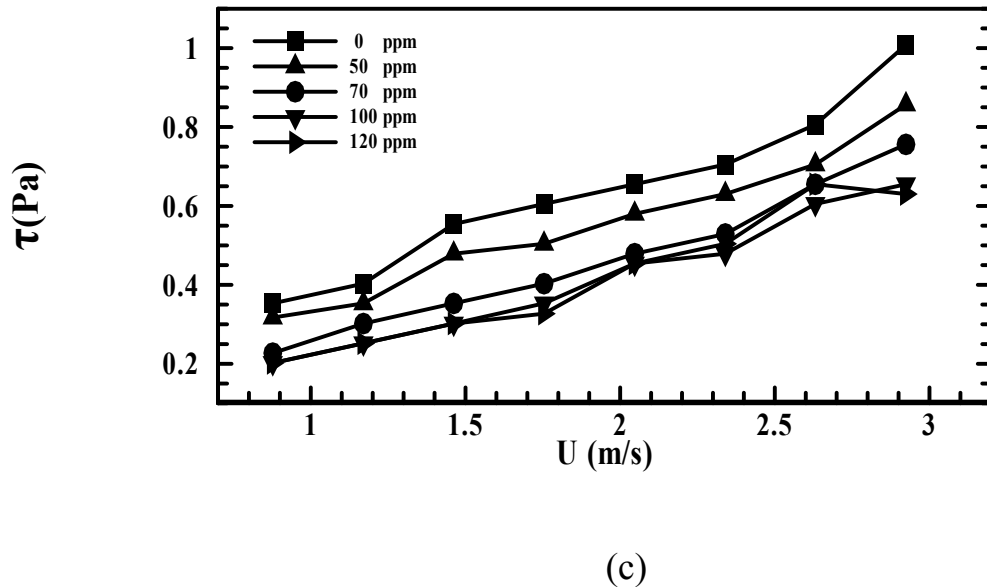
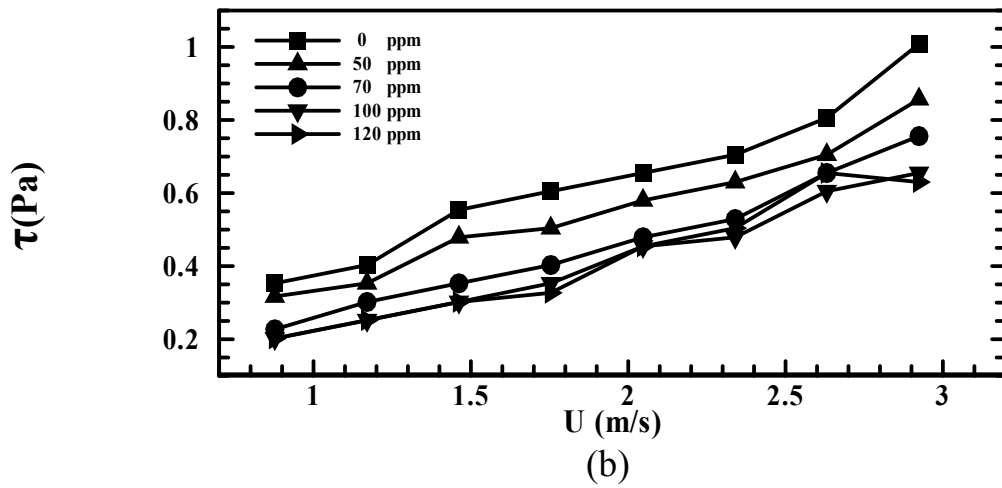
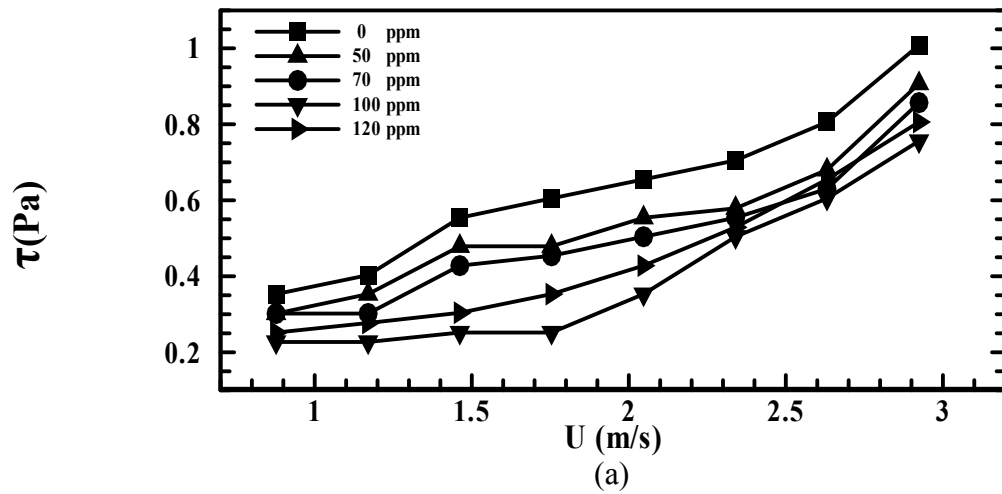


Fig.(3): Variation of shear stress(Pa) with mean velocity (m/s) at $\delta=0^\circ$ for different concentrations (ppm) of a) CMC. b) XG. c) mixing of CMC and XG.

It can be noted from figure (2-c) that the curves of 50 and 70 ppm is convergent due to small difference in concentration, moreover the curves 100 and 120 ppm are also convergent due to attaining maximum drag reduction between these concentrations. Also it is seen that the minimum difference in pressure gradient for pure water and the four concentrations is at the velocity 0.877 m/s, while maximum difference is at the velocity 2.047 m/s where its value is 23.82 Pa/m.

Figure (3) presents the effect of mean velocity on wall shear stress for different additive concentrations. It is observed from the figure that the wall shear stress increases with increase in velocity for Newtonian and non-Newtonian flow due to suppression of more eddies which make great contact of water particles with each other that leads to high shear stress. It is noted from figure (3-a) that the difference in shear stress for the four concentrations start from minimum value which is 0.0755 Pa at velocity 0.877 m/s then increases until reaches maximum value which is 0.2268 Pa at the velocity 1.462 m/s then decreases until reaches the minimum value at the velocity 2.34 m/s then increases after that. It can be seen from figure (3-b) that the difference in shear stress between the concentrations 50 and 70 ppm is higher than other differences between other concentrations. This due to types of polymer and dynamic action of it, but the difference in shear stress of XG like CMC in the behavior but differs in values, where it can be noted that the difference in shear stress for the four concentrations starts from the value 0.05 Pa at velocity 0.877 m/s then increases until reaches maximum value of 0.1765 Pa at the velocity 1.462 m/s, then increases in a fluctuated behavior until reaches the value of 0.2267 Pa at the velocity 2.924 m/s. It can be noted from figure (3-c) that the difference in shear stress for the pure water and the other concentrations start from minimum value, then increases until reaches maximum value at the velocity 1.754 m/s, then decreases after that.

Figure (4) presents the effect of additive concentration on the drag reduction at different solution velocities. It is observed from the figure that drag reduction increases as additive concentration increases. This increase is probably due to increasing the number of additive molecules which cause the damping of more turbulent eddies until reaches maximum value at certain concentration which is called saturation concentration which is for the used polymers about 100-120 ppm concentration. The decrease in drag reduction after the saturation concentration is caused by increase in solution viscosity as shown by (Goren and Norbury, 1967). The increase in velocity causes increase in drag reduction until reaches the velocity 1.754 m/s that is called critical velocity, then decreases after that.

It can be noted from figure (4-a) that the maximum drag reduction which is at 100 ppm increases from 43.75% at the velocity 1.17 m/s to 58.33% at velocity 1.754 m/s, then decreases to 28.57% at the velocity 2.34 m/s. Also the maximum drag reduction in figure (4-b) occurs at the same velocity where the drag reduction increases from 16.67% at the concentration 50 ppm then increases until reaches the maximum value that is 45.83% at the concentration 120 ppm. Also in figure (4-c) the drag reduction for the velocity 1.754 m/s starts from the value 20.83% at 50 ppm concentration then increases until maximum value that is 45.83% at 100 ppm concentration, then decreases after that.

Figure (5) explains the effect of Reynolds number on drag reduction for different additive concentrations. It is noted that drag reduction increases with increasing the Reynolds number until reaches a critical value which is about 66000. After this critical value drag reduction falls off due to the increase in turbulence which

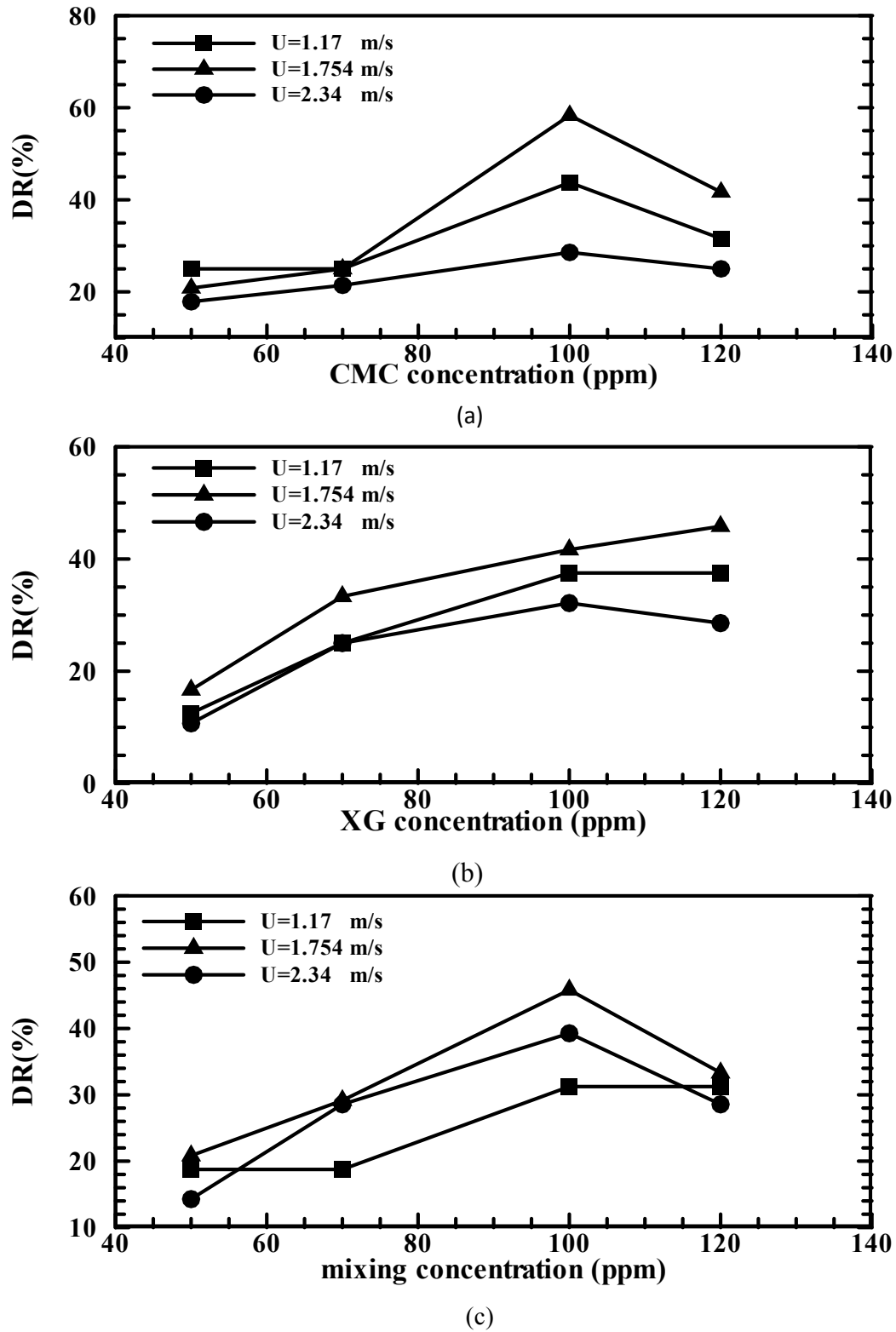


Fig.(4): Variation of drag reduction(%) with concentration (ppm)for different velocities at $\delta=0^\circ$ for a) CMC. b) XG. c) mixing of CMC and XG.

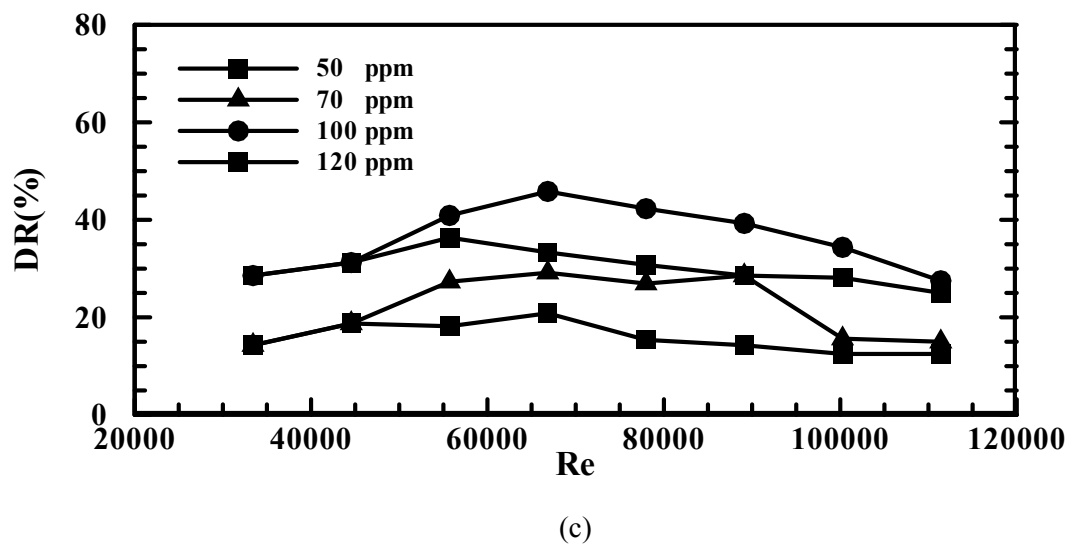
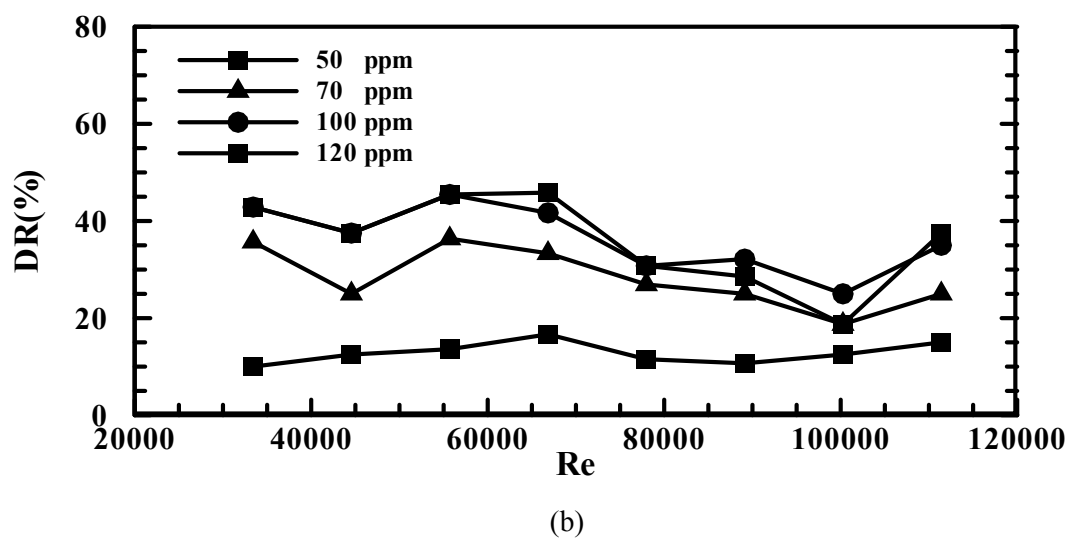
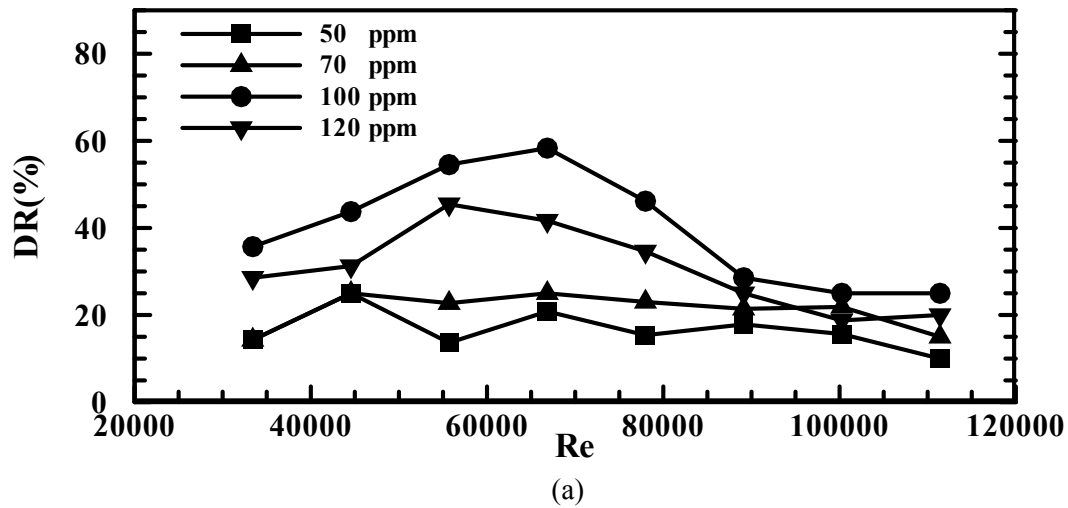


Fig.(5): Variation of drag reduction(%) with Reynolds number at $\delta=0^\circ$ for different concentrations (ppm) of a) CMC. b) XG. c) mixing of CMC and XG.

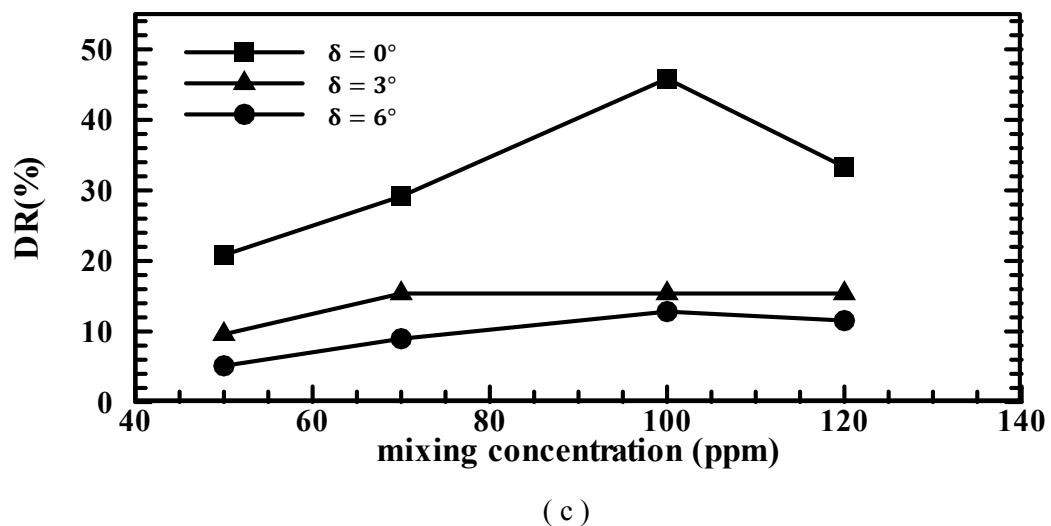
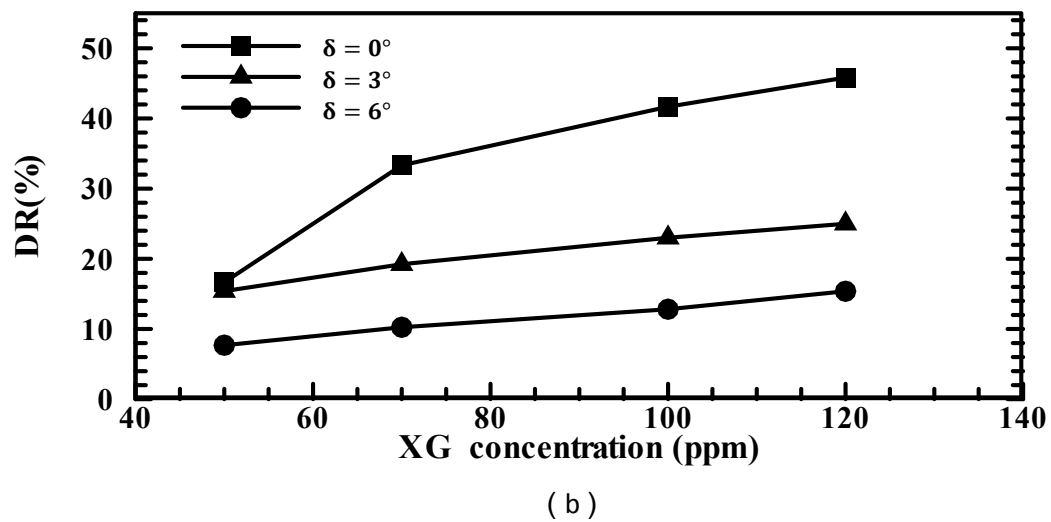
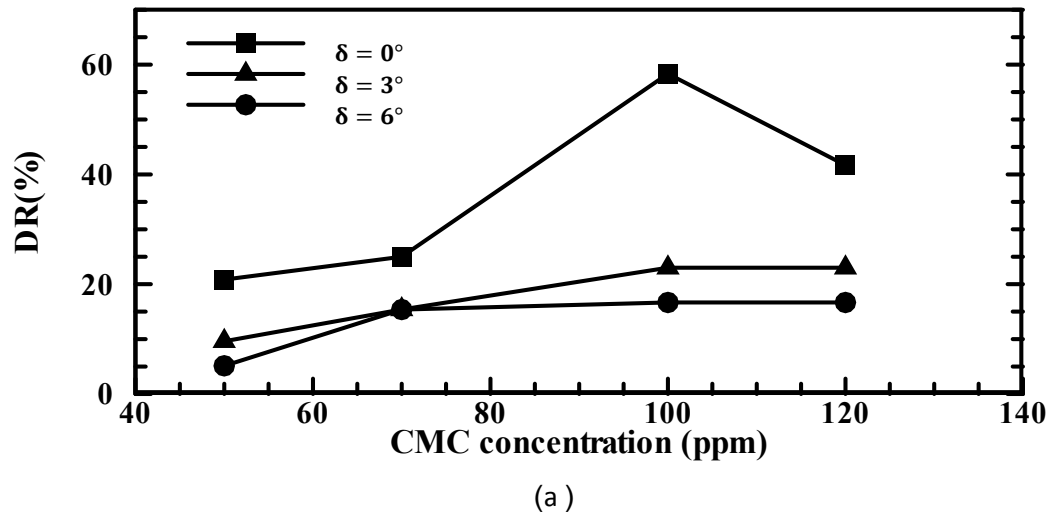


Fig.(6): Variation of drag reduction(%) with concentration (ppm)for different values of δ at $Re=66836$ for a) CMC. b) XG. c) mixing of CMC and XG.

causes permanent degradation in the chains of polymers. It can be noted from figure (5-a) that maximum drag reduction occurs at 100 ppm concentration and velocity 1.754 m/s where its value is 58.33%. Also it can be seen that the maximum difference in drag reduction between the four concentrations has a value of 37.5 and occurs at the velocity 1.754 m/s, while minimum value occurs at the velocity 2.047 m/s and its value is 9.38%.

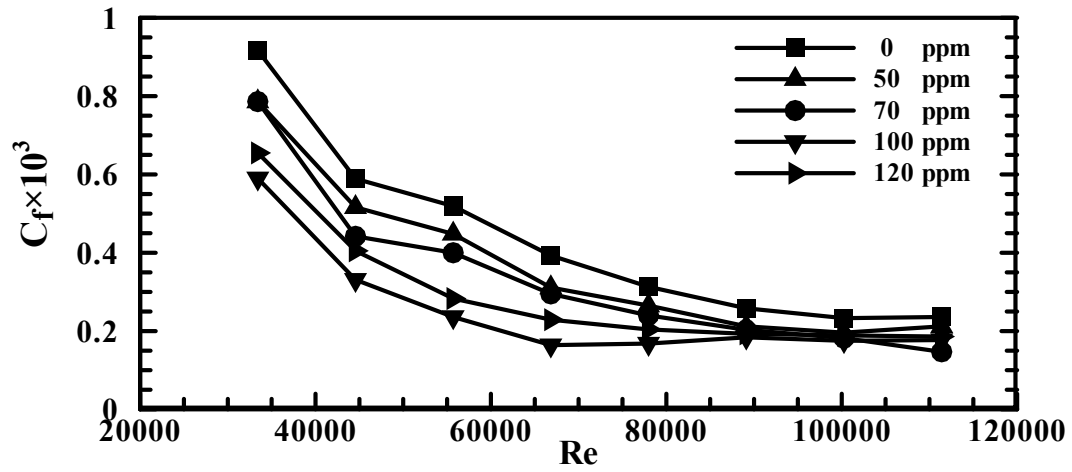
Figure (5-b) shows the maximum drag reduction transmits from 100 ppm to 120 ppm XG concentration, while for certain concentration it is noted that maximum drag reduction occurs at Reynolds number (55697 to 66836). It is observed that the maximum difference in drag reduction for the four concentrations occurs that is 32.7% at the start, while minimum difference in drag reduction that is 12.5% occurs at $Re=100255$. It is noted from the figure that the difference in drag reduction between 50 and 70 ppm XG concentration is very large, while the difference between other concentrations is small, this may return to dynamic behavior of the polymer. Also figure (5-c) explains the maximum drag reduction for certain concentration occurs at $Re=66836$. Also it is observed that the difference in drag reduction for 50 and 70 ppm concentration start from 0% at the range of Reynolds number (33418 to 44557), then increases until reaches maximum value that is 14.3% at $Re=89115$, then decreases after that.

Figure (6) shows the effect of additive concentration on the drag reduction at different angles of inclination. It is noticed from the figure that increasing angle leads to decrease in drag reduction due to high increase in pressure drop in the direction of flow due to additional force from tangential component of solution weight. It can be

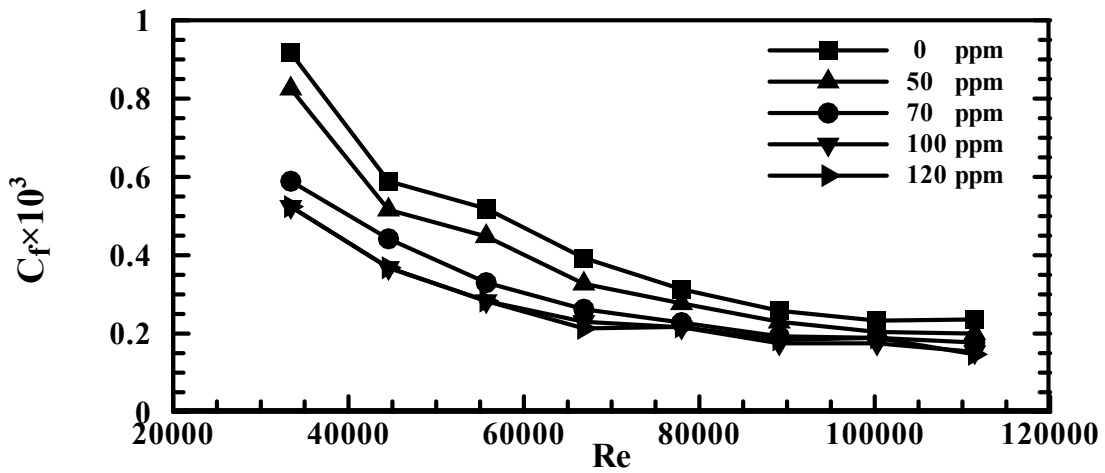
noticed from figure (6-a) that maximum drag reduction is at 100 ppm CMC concentration. Also the difference in drag reduction between the angles 0° and 3° is higher than the difference between 3° and 6° , also the drag reduction for angles 3° and 6° is 15.4% for 70 ppm CMC concentration this may return to behavior of polymer and its dynamic action. Maximum drag reduction for 0° is 58.33%, while for 3° is 23% and 16.67% for 6° .

It can be observed from figure (6-b) that maximum drag reduction is at 120 ppm XG concentrations for all angles, where its value is 45.83% at 0° , 25% at 3° and 15.38% at 6° . Also the difference in drag reduction at 120 ppm concentration between the angles 0° and 3° is 20.83%, while its value is 9.62% between the angles 3° and 6° , also the difference in drag reduction for 0° and 3° is 1.27% at 50 ppm concentration. The causes of these behaviors is discussed in figure (6-a). Figure (6-c) explains the maximum drag reduction is at 100 ppm mixing concentration for all angles, where it has a value of 45.83% at 0° , 15.38% at 3° and 12.82% at 6° . Also the difference in drag reduction at 100 ppm concentration between the angles 0° and 3° is 30.45%, while its value is 2.56% between the angles 3° and 6° .

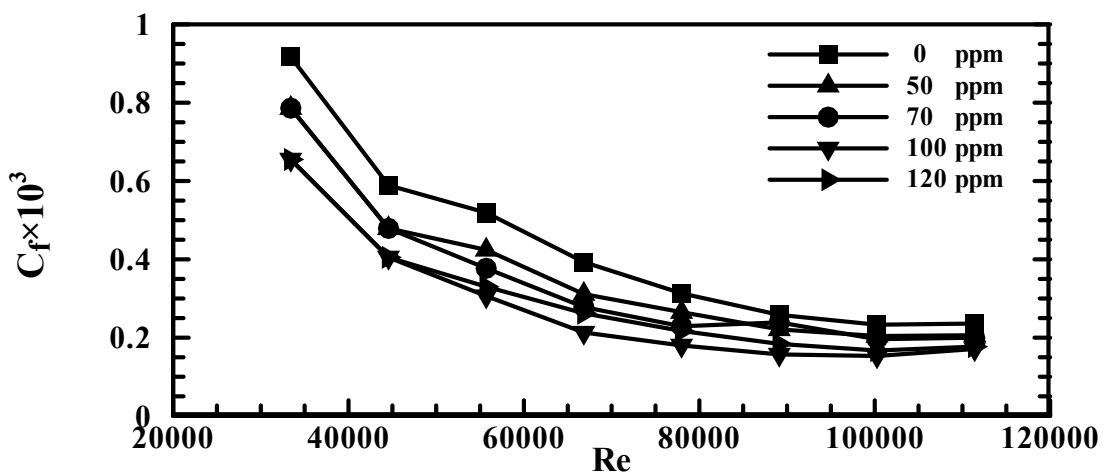
Figure (7) shows the effect of Reynolds number on friction factor for different concentrations of polymers. It is noticed that friction factor decreases with increase in Reynolds number for Newtonian and non-Newtonian fluid flow, also increase in concentration causes decrease in friction factor due to slide of layers near the wall on each other. Figure (7-a) shows the difference in friction factor for Newtonian and different concentrations starts from the value 0.327×10^{-3} then decreases to the minimum value which is 0.047×10^{-3} at $Re=111394$. While from figure (7-b) it can be noted that the difference in friction factor for Newtonian and for concentrations starts from the value 0.393×10^{-3} at $Re=33418$ then decreases until reaches the minimum value which is 0.058×10^{-3} at $Re=100255$, then increases after that. Also figure (7-c) expresses the difference in friction factor for pure water and the four concentrations



(a)



(b)



(c)

Fig.(7): Variation of friction factor with Reynolds number at $\delta=0^\circ$ for different concentrations (ppm) of a) CMC. b) XG. c) mixing of CMC and XG.

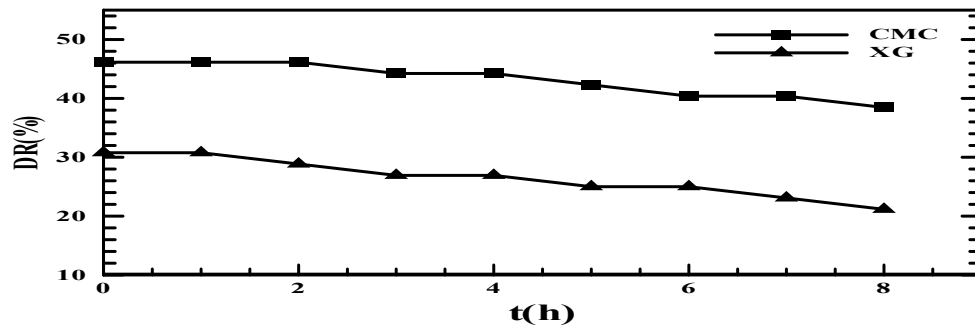


Fig.(8): Degradation of CMC and XG polymers with time at $Re=77976$ and $\delta=0^\circ$.

starts from the value 0.262×10^{-3} then decreases until reaches maximum decrease which is 0.058×10^{-3} at $Re=111394$.

Figure (8) explains the effect of time on the degradation of the two polymers. It can be noted that the degradation of XG is higher than the degradation of CMC due to its larger molecular weight. From the figure we can note that the value of drag reduction begins at a value 46.15% then the degradation starts after the second hour of recirculation, where the drag reduction decreases until reaches decreases to the value 38.5% at the eighth hour.

The drag reduction for XG polymer starts from the value 30.8% before the recirculation and remains the same at the first hour then suffers from degradation at the second hour where the drag reduction begins to decrease until reaches to the value 21.2% at the eighth hour. From the figure we can see that CMC resists degradation more than XG polymer where the degradation of CMC starts from the third hour, while the XG polymer suffers from degradation at the second hour.

4. Drag Reduction Mathematical Correlation

The obtained data of experimental work for all parameters that have been concluded in our study are used for developing an empirical correlation for drag reduction percentage. The SPSS program has been used for correlate the data that have been obtained. The drag reduction percentage is correlated in terms of Reynolds number Re , additive concentration C (ppm) and angle of inclination of pipe δ ($^\circ$). The power law that is $Dr\% = C_1 \times (Re - C_2)^{n_1} \times (C - C_3)^{n_2} \times (\delta + C_4)^{n_3}$ is used to correlate the experimental results because it is the only relation that gave the higher maximum correlation coefficient for all additives. The values of C_2, C_3 and C_4 are evaluated by try and error until the optimum maximum correlation coefficient is obtained, While the constants C_1, n_1, n_2 and n_3 are found by the program according to the input data for each type of polymer. The obtained empirical relations can be expressed as follows:

1- CMC polymer :

$$DR\% = 58.116 Re^{-0.144} (C-47)^{0.253} (\delta+1)^{-0.516}.$$

With maximum correlation coefficient 0.827.

2- XG polymer:

$$DR\% = 8 \times 10^8 Re^{-0.174} (C-49)^{0.206} (\delta+35)^{-6.657}.$$

With maximum correlation coefficient 0.912.

3- Mixing Of XG And CMC Polymer:

$$DR\% = 48.896 (Re-33415)^{0.021} (C-45)^{0.281} (\delta+4)^{-1.292}.$$

With maximum correlation coefficient 0.921.

Where $33418 < Re < 89115$, $50 < C < 120$ and $0^\circ < \delta < 6^\circ$.

5. Conclusions

It can be concluded from the above results the following:

- 1-One of the difficulties faced at working in this field is the inability to reproduce the same results of other researchers. This will make the comparison of the obtained experimental data very difficult. The following Reasons are suggested.
 - a-Degradation of polymer solution between the time of its manufacturing and its use in the laboratory.
 - b-Difference of polymer molecular weight and impurities from different manufacturers.
 - c-Difference in the age of polymeric solution or the waiting time from preparation to the time of laboratory test.
- 2-The small amount of dilute polymer solutions required to reach maximum drag reduction.
- 3-Maximum drag reduction occurs at about 100 ppm concentration and at about $Re=66000$ for both polymers and their mixing in our experimental condition.
- 4- Drag reduction for CMC polymer is higher than drag reduction for XG polymer and their mixing. Due to degradation of XG polymer due to high turbulence, which causes the chains of XG to be degraded quickly.
- 5-Drag reduction decreases as angle of inclination of pipe increases. Where the angle influences drag reduction considerably.
- 6-Degradation depends on the structure of the molecules ,molecular weight, preparation method, solution concentration, storage conditions and the flow system setup.
- 7- CMC resists degradation higher than XG polymer. Because the large molecular weight of XG.
- 8-Degradation for most polymers occurs quickly with time due to its large molecular weight.

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