GSJ: Volume 7, Issue 5, May 2019
ISSN 2320-9186

Global Scientific JOURNALS

GSJ: Volume 7, Issue 5, May 2019, Online: ISSN 2320-9186
www.globalscientificjournal.com

`EFFECTS OF GUM ARABIC ON THE RHEOLOGICAL PROPERTIES OF POLYACYLAMIDE

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Abstract

Graft copolymer of Polyacrylamide/Gum Arabic has been successfully synthesized with the aim of modifying the mechanical and rheological properties of polyacrylamide. This was done by preparing solution of different concentrations of acrylamide and gum Arabic and solution polymerization reaction was performed in a reaction vessel. The graft copolymer was characterized in terms of percentage graft level, shear rates and viscosity determination using the ubbelohde viscometer. The results obtained indicate that gum Arabic has a marked effect on the mechanical stability of polyacrylamide by improving the back bone rigidity and hence improvement on shear sensitivity behavior.

Keyword: *Polyacrylamide, Gum Arabic, Polymerization,Viscosity,Concentration*

GSJ: Volume 7, Issue 5, May 2019
ISSN 2320-9186

Introduction

Prior to 1980, oil based mud drilling fluids were used in eighty-five percent of all wells drilled, specialty chemical usage like polymer was limited. However, as drilling ventured into more hostile environment, deep offshore, horizontal, inclinated drilling better performing products were required[1,2].Spearheading many of the changes were environmental concerns regarding disposal of oil based mud especially offshore drilling. Additionally, fine clay formation damage potential has resulted in a trend towards polymer mud (water base mud), in this area polyacrylamide (PAM) has clearly taken the lead.

As a result of increasing environment concern in drilling all over the world, there is the need to produce new environmentally acceptable polymer mud which can match the stability of the oil based mud, as well as meeting the many other requirement and challenges for drilling efficiency and quality[3-5].

Polyacrylamide molecule is a flexible chain structure sometimes knows as random coil in polymer chemistry [6]. There is essentially no permanent secondary structure in polyacrylamide which affords it some degree of rigidity in the way that helical structure acts in xanthan. The most striking feature concerning the mechanical stability of polymer commonly used in the oil industry operation is that xanthan appears to be extremely shear stable and polyacrylamide appears to be very sensitive to shear degradation[6-10].Among hydrocolloids, gum Arabic is unique because of its very high solubility in water. It can form solutions of up to 50% concentration whereas most gum are limited to solubilities of less than 5%[7]. This property makes it very useful in applications where low viscosities are required. This work is aimed at improving the mechanical stability of polyacrylamide by using Gum Arabic to stiffen the backbone.

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ISSN 2320-9186

Materials and Methods

Gum Arabic was obtained from Asalgy, Nigeria Limited, Kano, Nigeria. Acrylamide (AM) and other reagents used were of analytical grade, supplied by Sigma –Aldrich, Germany.

Preparation of Samples

Five different concentrations of the acrylamide were prepared by dissolving 0.1, 0.5, 1.0, 2.0, 5.0g, of acrylamide (AM), in distilled water and stirred using the Hamilton beach scovie auto stirrer.

Gum Arabic of 0.1, 0.5, 1.0, 2.0 and 5.0g were also dissolved in distilled water respectively, filtered using press filter, and after which the acrylamide prepared earlier were introduced while stirring. The solution was allowed to stay 3hrs before further test.

Graft Polymerization

The grafting reaction was carried out by solution polymerization system in an adiabatic condition under nitrogen atmosphere in a flask equipped with a nitrogen inlet immersed in a water bath. Solutions of gum Arabic (GA) of varied concentrations (0.1, 0.5, 1.0, 2.0 and 5.0%) were prepared by dissolving the required molar concentration of GA in distilled water. In a typical reaction, 0.1% was immersed in 30 ml solution of GA (0.1-5.0%) for a particular time (30-120 mins) followed by addition of a mixture of potassium persulphate and sodium metabisulphate, on heating to 50-70^{0}C, the reaction mixture was stirred. A continuous supply of nitrogen was maintained throughout the reaction period. The temperature was increased to 80-90^{0}C with vigorous agitation[11].

Characterization of GA-g-PAM Copolymers

The graft copolymer was characterized in terms of percentage graft level, and viscosity determination using ubbelohde viscometer.

Results and Discussion

Variation of concentration with viscosity

Table 1 and 2 indicate the observed differences between the rheological behavior of polyacrylamide alone and polyacrylamide/gum Arabic based on their molecular structre. Rheological relationship has also helped to improve certain polymer properties, specifically viscosity.

Tables 1: variation of polyacrylamide concentration with viscosity,(Zero concentration of Gum Arabic)

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ISSN 2320-9186

%Concentration of polyacrylamide	t(s)	to(s)	n_r	$n_{sp} = n_r - 1$
0.1	38.6	34.4	1.15	0.15
0.5	42.8	34.4	1.24	0.24
1.0	48.8	34.4	1.42	0.42
2.0	53.7	34.4	1.56	0.56
5.0	57.6	34.4	1.67	0.67

Table 2: Variation of Gum Arabic (GA) of Different Concentrations with Viscosity,(Using a Constant 5.0% Concentration of Polyacrylamide)

% concentration of GA	t(s)	t_o(s)	n_r	$n_{sp} = n_r - 1$
0.1	39.16	34.4	1.138	0.138
0.5	195.8	34.4	5.690	4.690
1.0	381.6	34.4	11.090	10.090
2.0	743.2	34.4	21.60	20.60
5.0	2177.6	34.4	63.30	62.30

The effects of Gum Arabic (GA) on Polyacrylamide can be seen from table 2, it is observed that at different concentrations of Gum Arabic (GA) to a fixed concentration of Polyacrylamide (5.0%), there is an increase in viscosity, which could be explained based on the molecular structure or rheological behavior of the resulting polymer GA-g-Polyacrylamide [12-14]. The flexible backbone coil of the polyacrylamide molecule has been stiffened, which manifested itself with the increased viscosity as shown in table 2. The viscosity of the solution containing gum Arabic has increased tremendously as compared to that without Gum Arabic as a result of the grafting..

Table 3: Variation of Gum Arabic Concentration with Viscosity, Using a Constant Concentration of 1.0% Polyacrylamide.

%Concentration Of GA	t(s)	to(s)	n_r	$n_{sp} = n_r - 1$
0.1	50.9	34.4	1.48	0.48
0.5	42.7	34.4	1.24	0.24
1.0	51.0	34.4	1.48	0.48
2.0	59.7	34.4	1.74	0.74
5.0	92.0	34.4	2.67	1.67

Variation of concentration with Shear rate.

Table 4: Variation of concentrations with shear rates and viscosity.

Samples	% Concentration of GA	% Concentration of	Shear rates (S^{-1})x10^3	Specific viscosity(n_{sp})

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		polycrylamide		
A	5.0	0.1	26	0.14
B	5.0	0.5	5	4.69
C	5.0	1.0	3	10.0
D	5.0	2.0	1	20.60
E	5.0	5.0	0.5	62.30
F	1.0	5.0	20	0.48
G	1.0	5.0	23	0.24
H	1.0	5.0	20	0.48
I	1.0	5.0	17	0.74
J	1.0	5.0	11	1.67
K	-	0.1	25	0.15
L	-	0.5	23	0.24
M	-	1.0	20	0.42
N	-	2.0	19	0.56
0	-	5.0	17	0.67

Shear rate values were considerably high for the copolymer with decreasing gum Arabic concentration as compared to shear rate values of polymer solution with zero gum Arabic. Specifically, the least shear rate values have been observed with 5%/5% of polyacrylamide/gum Arabic graft copolymer due to high viscosity. This is shown in sample E of Table 4 above.

Graft Level Determination

The percentage graft, P_g was calculated from the relationship:

% Pg = (W_2-W_1/W_1) x 100……………….1

Where, W_1 and W_2 are the weights of the acrylamide and the grafted polyacrylamide in solution respectively[11].

From table 5, it can be seen that hundred percent graft level was observed in sample E, having 5% concentration of GA, but in sample J, where the gum Arabic concentration is reduced to 1.0% at the same acrylamide concentration as in sample E, the graft level reduces to 82.6% showing that the Gum Arabic has a marked effect as regards the grafting into polyacrylamide as evidenced in sample E with 100% graft level.

Table 5: Variation of graft level with gum Arabic concentration

Samples	W_1(g)	W_2(g)	%Pg	%Concentration of Acrylamide	% conc. of GA
A	105	140.1	33.4	0.1	5.0
B	105	145.5	38.6	0.5	5.0
C	105	151.0	43.8	1.0	5.0
D	105	187.0	78.1	2.0	5.0
E	105	210.0	100.0	5.0	5.0
F	101	135.2	33.9	0.1	1.0

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ISSN 2320-9186

G	101	135.1	34.8	0.5	1.0
H	101	142.3	40.9	1.0	1.0
I	101	151.2	49.7	2.0	1.0
J	101	184.4	82.6	5.0	1.0

It was observed that as the viscosity increases, it takes a high shear rate to shear the copolymer compared to that required to shear the polymer alone and this is possible due to the grafting effect, resulting in the rigidity or stiffening of the copolymer backbone structure[15-17].

Conclusion

The shear degradation of polyacrylamide is associated with its viscoelastic behaviour in elongational flow; the elastic response, leads to high elongation viscosities and high elongation stress, hence as the polymer is given some degree of backbone rigidity as demonstrated in this work, the molecules appear less susceptible to mechanical degradation. The grafting exercise has been encouraging with appreciable results as shown in Table 5. There has been significant stiffening of the flexible backbone coil of polyacrylamide molecule by Gum Arabic which is manifest in rheological properties, viscosity and shear rate of the graft copolymer solution.

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ISSN 2320-9186

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