

Effect of Different Gums on Rheological Properties of Slurry

Yogita Weikey¹, S L Sinha¹ & S. K. Dewangan¹

¹Mechanical Engineering Department,
National Institute of Technology, Raipur, C.G, 492010, India

E-mail:- yweikey.phd2015.me@nitrr.ac.in, slsinha.mech@nitrr.ac.in,
skdewangan.amech@nitrr.ac.in

Abstract. This paper presents the effect of different natural gums on water- bentonite slurry, which is used as based fluid in water based drilling fluid. The gums used are Babul gum (*Acacia nilotica*), Dhawda gum (*Anogeissus latifolia*), Katira gum (*Cochlospermum religiosum*) and Semal gum (*Bombax ceiba*). For present investigation, samples have been prepared by varying concentration of gums. The variation of shear stress and shear rate has been plotted and on the basis of this behaviour of fluids has been explained. The value of k and n are calculated by using Power law. R^2 values are also calculated to support the choice of gum selection.

1. Introduction

In recent years natural gum has come out as a rich source of industrial raw material and has been the subject of exhaustive research over synthetic material. So there is a need for continues research for effective gums that could meet the need of drilling fluid operation. Gums are broadly used in industries for various purposes such as a stabilizer, a thickener, as emulsifier and as encapsulating in the food industry and to a lesser extent in textiles, ceramics, lithography, cosmetic and pharmaceutical industry (Verbeken *et al.*, 2003). The addition of gums has favourable effect on rheological properties of various water- based drilling fluids, which is a slurry formulated by the combination of water, bentonite and some additives. Some gums like Guar gum and Xanthan gum are used to control the rheological property and filtrate loss required in water-based drilling fluids. In water based drilling fluid bentonite is as major drilling fluid additive (Abdou *et al.*, 2013; Vipulanandan and Mohammed, 2014). The main function of the bentonite is to increase the viscosity of the mud and to reduce the fluid loss to the formation. But bentonite is unable to provide satisfactory rheological properties at low concentration. Therefore, other additives like polymer are added to enhance the properties of drilling fluid to meet the need of operation. The rheology and filtration properties of drilling fluids with the water-soluble polymers change significantly under severe operating conditions (Vermolen, 2011). Polymer are classified as natural polymer like Tamarind gum (Mahto *et al.*, 2004), Xanthan gum (Ochoa *et al.*, 2004), tragacanth gum (Mahto & Sharma, 2005) or carboxy methyl cellulose [CMC] (Benchabane *et al.*, 2008); modified-natural like polyanionic cellulose [PAC] (Plank, 1992); synthetic polymer like partially hydrolyzed polyacrylamide [HPAM] (Nasr-El-Din, 1991). Water soluble polymers are added in order to perform very specific functions, like fluid-loss control,



rheology modification, shale stabilization, lubrication, etc. (Yan, 2006). This paper investigates the effect of four different natural gums (which are natural polymers) on water-bentonite slurry by using MCR-102 rheometer. Fluids can be classified as Newtonian or non-Newtonian. Almost all the drilling fluids show non-Newtonian behaviour. In order to accomplish the effect of non-Newtonian behaviour of water-bentonite slurry, calculation requires a rheological model. Power-law model has been used to determine the value of k and n . The rheological behaviour of four gums with water-bentonite slurry has been investigated. The gums used are Babul gum, Dhawda gum, Katira gum and Semal gum. These gum trees are found throughout the India. Gum Arabic (Babul gum) is used to enhance the emulsions viscosity and stability (Makri & Doxastakis, 2006); improve consistency and shelf-life of puree, Stabilize water-in-oil-in-water emulsions (Su *et al.*, 2008). Gum ghatti (dhawda gum) is reported as an emulsifier and stabilizer in beverages, butter containing table syrups, petroleum and in non-petroleum waxes to form liquid and wax paste emulsions and flavour fixative for specific applications (Krystal colloid).

2. Material-Source

In the present investigation, the effect of rheological properties of bentonite water slurry has been studied with different concentration of four gums. The gums used are Babul gum (*Acacia nilotica*), Dhawda gum (*Anogeissus latifolia*), Katira gum (*Cochlospermum religiosum*) and Semal gum (*Bombax ceiba*).



Babul gum



Babul tree

Figure 1: Showing babul gum and tree

(Source: from Wikipedia and Google search dated 07/09/2016)

Babul is a moderate sized, almost evergreen tree is found throughout the drier parts of India (figure 1). The gum exudes mostly in the month of March-May. The gum obtained from *Acacia nilotica* is known as "Indian gum arabic". The gum is tasteless and almost completely soluble in water (50g/100ml). The darker samples contain tannin and are much less soluble, and leave behind a gelatinous residue. It contains 13% of moisture and on ignition; it leaves behind 1.8% of ash (CaO, 52.2% and MgO, 19.7%). Its molecular weight is 2.3×10^6 . The gum contains galactose, L-arabinose, L-rhamnose, and four aldobiouronic acids. The viscosity of 30 percent of *A. Nilotica* at shear rate of 9.6 Sec^{-1} was found to be 120 cps Viscosity of both the gums decreases as the shear rate increases. Therefore it is termed as psuedoplastic material. It has been found that gum arabica shows high value of ionic conductivity after swelling which may be due to release of ions during swelling.



Dhawda gum



Dhawda tree

Figure 2: Showing dhawda gum and tree

(Source: from Wikipedia and Google search dated 07/09/2016)

Dhawda gum also known as Indian gum and is exudates from *Anogeissus latifolia* tree (figure 2). The tree is characteristic of the dry, deciduous forests and is common almost throughout India. It contains moisture 15.8%, pentosan 26.3%, methyl pentosan 7.6%, galactan 16.4%, N 0.99%, ash 3.0% and riboflavin 68.92 μ g/g. It is a calcium and magnesium salt of an acidic polysaccharide composed of L-arabinose, D-galactose, D-mannose, D-xylose and D-glucuronic acid in a molar ratio of 10:6:2:1:2. It forms viscous dispersions in water when a concentration is 5% or more. The dispersions are thixotropic and non-Newtonian in behaviour. It has good emulsifying properties.



Katira gum



Katira tree

Figure 3: Showing katira gum and tree

(Source: from Wikipedia and Google search dated 07/09/2016)

Katira gum also known as Indian tragacanth is the dried exudates from the tree *Sterculia urens* (figure 3). The tree *Sterculia urens* is common in India in the tropical deciduous forests mostly in dry and rocky areas. The best quality gum is collected during April-June. It is partially acetylated complex polysaccharide. It contains approximately 80% acetyl groups and around 37% uronic acid residues with acid number varying from 17.4 to 22.7. Its molecular weight is 9.5×10^6 . It forms viscous mucilage at low concentrations and the swelling behaviour is caused by the presence of acetyl groups. Chemical deacetylation through an alkali treatment results in a water-soluble gum. It shows strong wet-adhesive properties at concentrations of 20 to 50% in water. Katira gum is more readily soluble in water. Mucilage of Katira gum becomes thinner on aging; whereas that of tragacanth becomes thicker.

**Figure 4:** Showing semal gum and tree

(Source: from Wikipedia and Google search dated 07/09/2016)

Semal gum is exuded from semal tree as it is known in Hindi is taxonomically known as *Bombax ceiba* belonging to family *Bombacaceae* of the class *Magnoliopsida* (figure 4). It grows in warm climatic conditions across the India. Gum exudates obtained from the bark is dried and sold as 'semal-gum' or 'mocharas'. The dried gum is light brown in colour resembling the galls, and gradually becomes opaque and dark brown. It also contains 8 to 9 % minerals and catechol tannin. It also contains tannic acid and Gallic acid. It contains starch 71.2 %, glucose 8.2 %, proteins 1.2 %, fatty acids and cellulose.

3. Experimental Procedure

The samples are prepared by adding Babul gum, Dhawda gum, Katira gum and Semal gum to water bentonite solution by varying concentration. Compositions of the prepared samples are given in Table 1.

Table 1: Composition of the Sample

Sample	Additives	Quantity	Fluid Weight (gm)	Sample	Additives	Quantity	Fluid Weight (gm)
1.	Bentonite babul gum water	5gm 15mg	35	11.	Bentonite katira gum water	5gm 15mg	35
2.	Bentonite babul gum water	5gm 30mg	35	12.	Bentonite katira gum water	5gm 30mg	35
3.	Bentonite babul gum water	5gm 45mg	35	13.	Bentonite katira gum water	5gm 45mg	35
4.	Bentonite babul gum water	5gm 60mg	35	14.	Bentonite katira gum water	5gm 60mg	35
5.	Bentonite babul gum water	5gm 75mg	35	15.	Bentonite katira gum water	5gm 75mg	35
6.	Bentonite dhawda gum water	5gm 15mg	35	16.	Bentonite semal gum water	5gm 15mg	35
7.	Bentonite dhawda gum water	5gm 30mg	35	17.	Bentonite semal gum water	5gm 30mg	35

8.	Bentonite dhawda gum water	5gm 45mg	35	18.	Bentonite semal gum water	5gm 45mg	35
9.	Bentonite dhawda gum water	5gm 60mg	35	19.	Bentonite semal gum water	5gm 60mg	35
10.	Bentonite dhawda gum water	5gm 75mg	35	20.	Bentonite semal gum water	5gm 75mg	35

The rheological properties of sample have been measured by using modular compact Rheometer (MCR-102 Anton Paar GmbH, Germany). The samples of gums (35 ml) were filled the container having the test volume of 40 ml. Stirrer type four-bladed vane geometry ST22-4V-40 are coupled with the measuring head and correctly brought down into the cylindrical cup by 10 mm from the surface level. For every test, the filled specimen glass (35ml) and spindle has been temperature equilibrated for around 10 min. At that point, the sample has been subjected to shear with ramped from 1/s to 100/s with fixed measuring point length for a period of 3 min. The consistency curves have been plotted and fitted with power law model at a temperature of 303K. All the rheological estimations are performed in thrice using Rheo-Plus software package for the accuracy of the results. It is difficult to predict the flow behaviour of gum due to its complex structure but most gums exhibit non-Newtonian behaviour, therefore non-Newtonian models are considered for the flow designs and heat stability studies. The experimental data are fitted to non-Newtonian rheological model, which is discussed in following section.

Power Law Model: (Skelland, 1967). It states the relation as $\tau = K\dot{\gamma}^n$, (1)

Where, K and n are consistency and flow behaviour indexes, respectively. Parameter constraints are $K > 0$ and $0 < n < 1$. The value of K is uniform for a particular drilling fluid and the value of n is constant for a particular drilling fluid.

For Newtonian fluid, shear rate is proportional to the shear stress i.e. viscosity has a constant value. Water, glycerine and oil are examples of Newtonian fluids. For pseudo-plastic fluids, these fluids have no yield point; origin of the curve passes through the origin. Slurry of long chain polymers are examples of typical pseudo-plastics fluids. Bingham-plastic fluids will not flow until a shear stress is applied which is greater than the yield to start movement. When fluid starts to flow the curve becomes linear, and the slope is called the plastic viscosity. Oil well drilling fluids, cement slurries, etc. are examples of Bingham-plastic fluids.

4. Result and discussion

In this study, water-bentonite slurry has been used as a base fluid to perform the experiment. The rheological parameters of four gums have been analyzed with solid concentration of 15, 30, 45, 60 and 75 mg at a temperature of 303K. The experiment has been performed on the rheometer (MCR-102) by using concentric cylinder measuring system with stirrer type measuring system so that it could relate to the actual condition of drilling system. Shear stress measurement has been done by setting shear rate. Value of shear rate has been varied from 1 to 100 s⁻¹. Shear stress and shear rate curves are plotted at different concentration of gums and compared. Power law model has been used to determine the flow qualities of different gum. Usually the non-Newtonian behaviour of drilling slurry is characterized by using Bingham plastic and Power law rheological models. Both of these are two parameter models and resultant model equations are simple. Out of these two, for lower shear rate

usually Power law model preferred (Kok, 2009). Considering this, in the present investigation, rheological data obtained from experiment has been fitted using Power law model.

Moreover, behaviour of fluids has been explained by calculating the value of k and n by using Power law. The coefficient of determination (R^2) has been calculated for particular concentration to support the decision of gum selection.

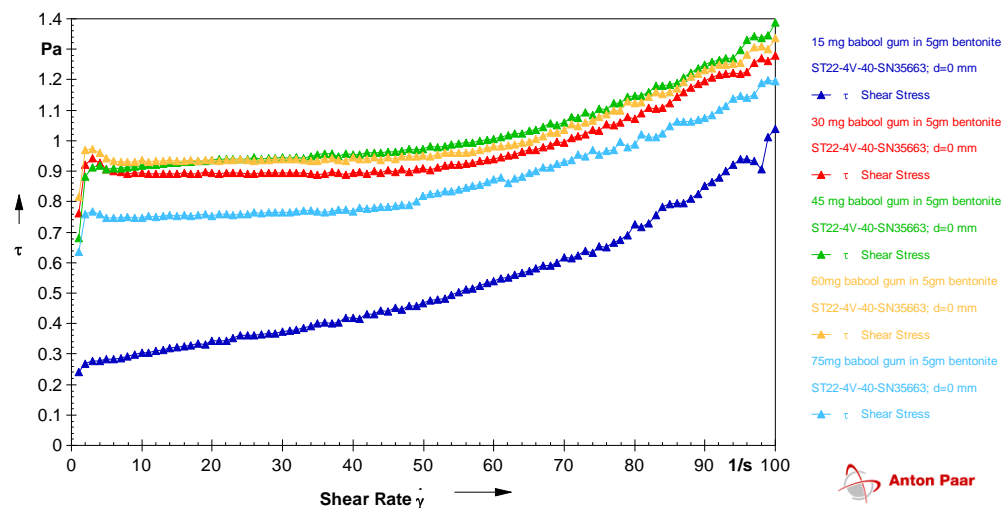


Figure 5: Variation of shear rate vs shear stress at different concentrations for babul gum

Figure 5 shows variation of shear rate and shear stress with different concentration of babul gum. Samples have been prepared by adding different concentrations (15mg, 30mg, 45mg, 60mg and 75mg) of babul gum in water-bentonite slurry. The value of shear stress is calculated by varying shear rate from 1 to 100 s^{-1} . With increase in shear rate, there is increase shear stress. It can be seen that with increase in concentration of babul gum the value of shear stress increases up to 45mg and then it starts decreasing. It can be found that after reaching maximum shear stress of 1.4 Pa at 45 mg, after that by adding more concentration of babul gum to the slurry it starts decreasing. The higher concentration of babul gum in slurry decreases the value of shear stress.

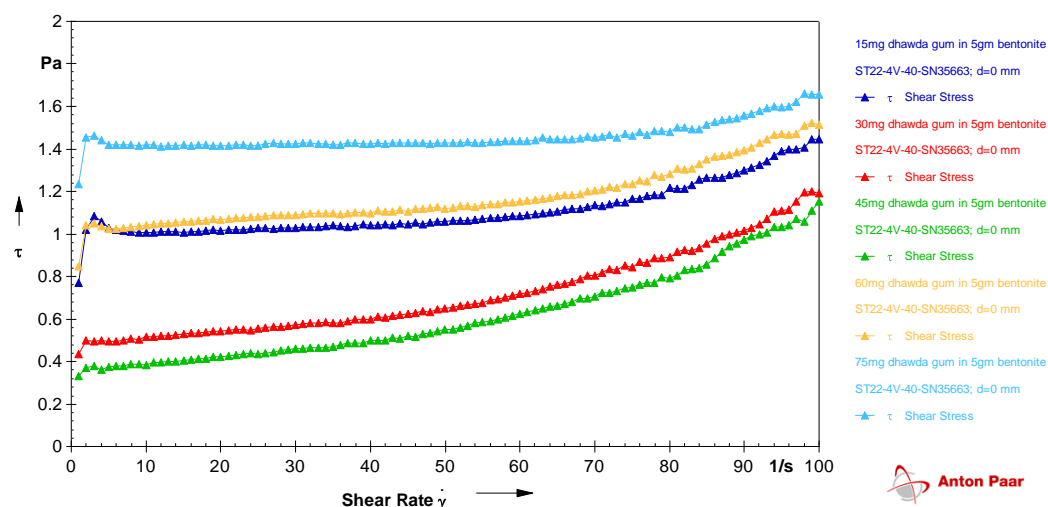


Figure 6: Variation of shear rate vs shear stress at different concentrations for dhawda gum

Figure 6 shows variation of shear rate and shear stress for dhawda gum. Samples have been prepared by adding different concentrations of dhawda gum to the water-bentonite slurry. From the graph, it can be seen that with increase in concentration of dhawda gum the value of shear stress decreases up to 45mg and at higher concentration (60mg), it starts increasing. It is observed that after reaching minimum value of 0.3Pa at 45 mg, it starts increasing. That means at higher concentration the value of shear stress is high. The gum ghatti has an excellent emulsification property due to its protenious molecular components, which binds to oil and which is probably better than gum Arabic (Ido *et al.*, 2008).

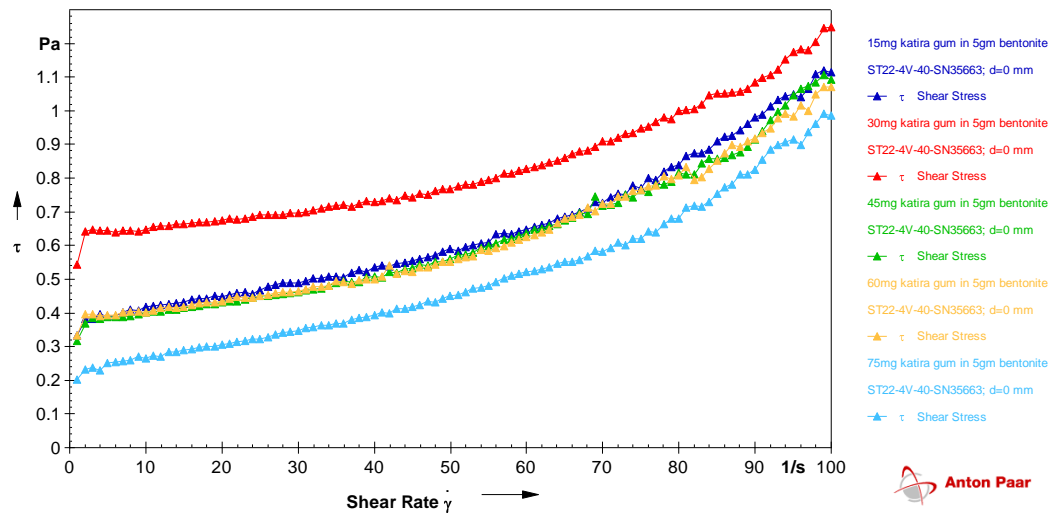


Figure 7: Variation of shear rate vs shear stress at different concentrations for katira gum

Figure 7 shows shear rate versus shear stress plot for different concentration of katira gum. The value of shear stress is calculated by varying shear rate (1 to 100s^{-1}). With increase in shear rate, there is an increase in the value of shear stress. From the plot, with increase in the concentration of katira gum the value of shear stress increases up to 30 mg concentration and then it starts decreasing for higher concentration. It can be found that after reaching maximum value of 1.25 Pa at 30 mg, it starts decreasing at higher concentration of katira gum. The higher concentration of katira gum decreases the value of shear stress.

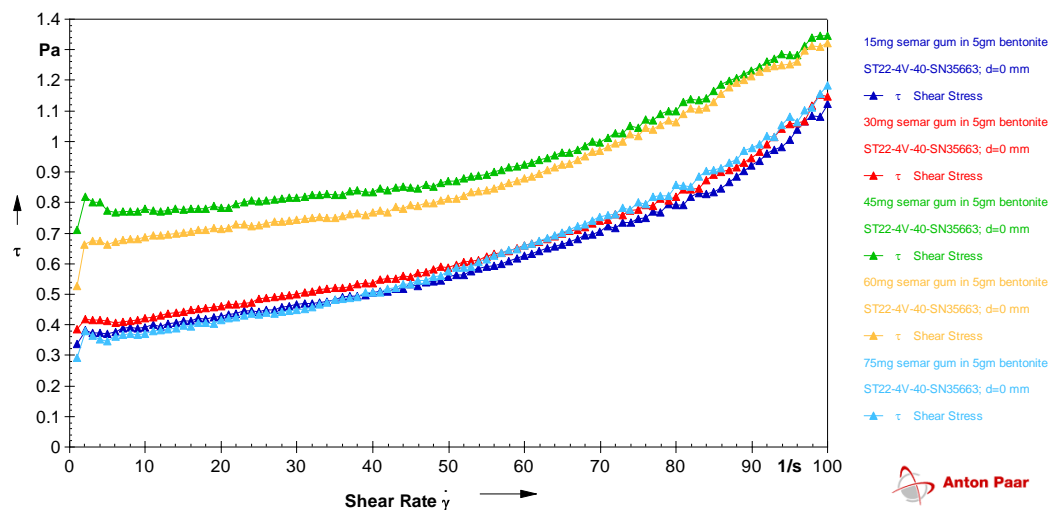


Figure 8: Variation of shear rate vs shear stress at different concentrations for semal gum

Figure 8 shows variation of shear rate and shear stress of different concentration of semal gum. From the graph, with increase in shear rate and concentration, shear stress increases. It can be seen that with increase in concentration of semal gum the value of shear stress increases up to 45mg concentration and after reaching maximum value of 1.3 Pa at 45 mg concentration, it starts decreasing. At higher concentration of gum, the value of shear stress decreases.

From the graph 5 to 8, it can be concluded that at the higher concentration of gums the value of shear stress decreases in case of babul, katira and semal where as in case of dhawda gum it increases. Gum ghatti (dhawda gum) solutions exhibited pseudoplastic behaviour, which became more prevalent with increasing concentrations (Kaur *et al.*, 2009).

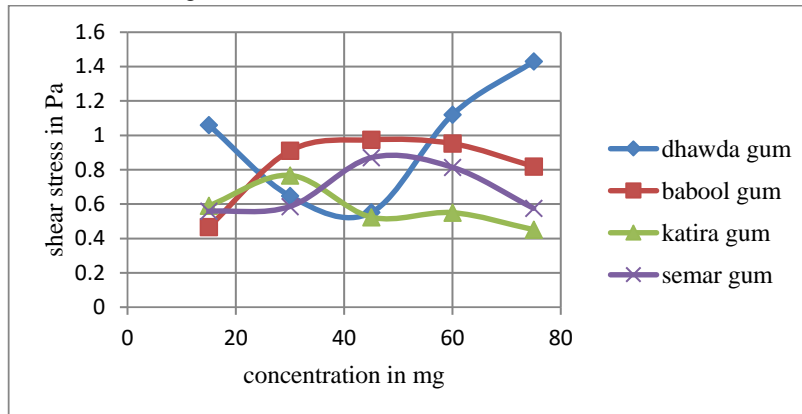


Figure 9: Variation of shear stress vs concentration of different gums at 50 sec⁻¹ shear rate

Variation of shear stress and concentration for four gums at 50 s⁻¹ shear rate. From the figure 9, it is cleared that dhawda gum has the highest value of shear stress of 1.4Pa and katira gum has lowest value of shear stress of 0.4Pa. The highest and lowest values are getting at same concentration of 75 mg.

Table 2: Rheological data of gums

Sample	Composition	Rheological data		
		k	n	μ
1	Bentonite =5gm Babul gum =15mg	0.418	0.355	0.24
5	Bentonite =5gm Babul gum =75mg	0.775	0.120	0.634
6	Bentonite =5gm Dhawda gum =15mg	0.917	0.082	0.768
10	Bentonite =5gm Dhawda gum =75mg	1.124	0.029	1.23
11	Bentonite =5gm Katira gum =15mg	0.509	0.292	0.335
15	Bentonite =5gm Katira gum =75mg	0.382	0.396	0.203
16	Bentonite =5gm Semal gum =15mg	0.528	0.272	0.386
20	Bentonite =5gm Semal gum =75mg	0.471	0.333	0.293

Table 2 shows the value of flow consistency index (k), flow behavior index (n) and viscosity (μ) for different samples. From the table, dhawda gum has the highest value of viscosity $\mu=1.23$ Pa-sec and katira gum has the lowest value of $\mu=0.203$ Pa-sec. For all the samples, the value of n is less than one, according to Power law if $n < 1$ then its mean that the viscosity decreases with increasing shear rate. This behaviour is caused by deformation of fluid structures at a higher shear rate and this causes a decrease in viscosity. Therefore, the gums are showing shear thinning behaviour. For better hole cleaning, the drilling fluids should be shear thinning (Mahto & Sharma, 2005).

Also, R^2 values are calculated for particular concentration of different gums to support the decision of gum selection. R^2 values for the different gums at particular concentration are tabulated in Table 3. Figure 10 showing the equation of best fit, plotted between concentration and shear stress of gum at 50 sec^{-1} . On comparing it can be seen that among four gums babul gum and katira gum have the maximum value of R^2 . Therefore it can be concluded that babul gum and katira gum have best fit equation.

Table 3: R^2 value for different gums

Gum	Babul gum	Dhawda gum	Katira gum	Semal gum
R^2	0.991	0.955	0.991	0.908

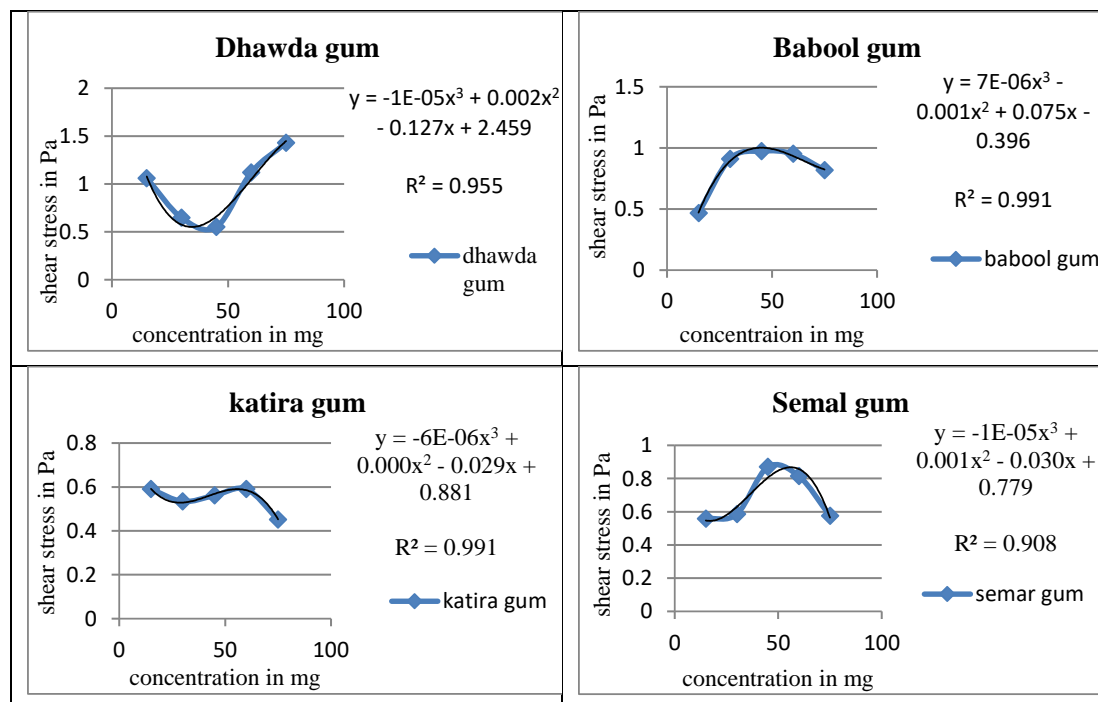


Figure 10: Showing the equation of best fit

5. Conclusion

In the present work the rheological effect of the addition of various natural gums on water-bentonite slurry has been carried out using MCR-102 rheological measurement apparatus. Four gums namely babul, dhawda, katira and semal gum have been used for the purpose of experimental investigation. Following conclusions can be drawn based on the investigation;

- Consistency curves have been drawn for effect of various gums from figure 5 to 8. From these graphs it can be concluded that dhawda gum has contributed the highest value of viscosity as compared to other gums, in the water- bentonite slurry. Afterwards babul, semal and katira contribute in the enrichment of the viscosity of the slurry considered in the descending order.

- b. The value of flow consistency index (k), flow behaviour index (n) and viscosity (μ) for different samples have been calculated. From table 2 the value of n is less than one for all the samples, which means viscosity decreases with increase in shear rate. Therefore, the gums are showing shear thinning behaviour. R^2 value has been calculated (table 3) from which babul gum and katira gum are having the maximum value of R^2 and showing the best fit equation. It can be used as rough indicator.
- c. From the consistency plot (figure 5 to 8) with increase in concentration of dhawda gum, the value of shear stress increases. Where as in case of babul, katira and semal the value shear stress decreases.
- d. The Gums affect the rheological parameters of water-bentonite slurry as their amounts vary. The selection of optimum gums amount in the fluid directly affects the quality of the fluid.

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