



MODELLING BREAK TIME ON GRAVEL PACK FLUID AT DIFFERENT BREAKER CONCENTRATIONS AND TEMPERATURES

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ABSTRACT

The effect of gel breakers on 60lbs/Mgals gravel pack fluid at different temperatures and concentrations was investigated. Tests at temperatures of 190°F, 210°F and 230°F with high temperature (HT) breaker of concentrations 5.0gal/Mgal, 10gal/Mgal and 15gal/Mgal respectively were also investigated. The study revealed that break time is a function of temperature and concentration, at a higher temperature and concentration respectively, gel break is faster and vice-versa. Model coefficients were obtained using DATA FIT engineering software and results indicated that Exponential model described best the variation of break time with breaker concentration and temperature. Model which predicts break time at any breaker concentration and Bottom Hole Temperature was developed. The model equation at the different temperatures and concentrations is given by:

$$\text{BRT} = (-3097.9 \ln(T) + 17188) e^{-(0.00756e^{0.0129T})C_B}$$

Results calculated from the model equation showed a good agreement with experimental values with less than 10% deviation. This will help predict gel break time at different concentrations and temperatures thereby saving time and rigor associated with actual laboratory pilot test.

INTRODUCTION

Well stimulation techniques are applied on a regular basis to enhance productivity and maximize recovery in oil and gas wells. Among these techniques, matrix acidizing is probably the most widely performed job because of its relative low cost, compared to hydraulic fracturing [1]. The acidizing process leads to increased economic reserves, improving the ultimate recovery in both sandstone and carbonate reservoirs. Matrix acidizing consists of injecting an acid solution into the formation, at a pressure below the fracture pressure to dissolve some of the minerals present in the rock with the primary objective of removing damage near the wellbore, hence restoring the natural permeability and greatly improving well productivity [2]. Acidizing refers to the use of acid pumped into the oil-bearing formation to dissolve parts of the formation so that oil or gas can flow more easily to the well. That is, by dissolving acid soluble components within underground rock formations, or removing material at the wellbore face, the rate of flow of oil or gas out of production wells or the rate of flow of oil-displacing fluids into injection wells may be increased. Most acidizing treatments can be categorized as either [3]: (a) wellbore cleanout, (b) removal of damage from a sandstone formation by matrix acidizing, (c) improvement of production from carbonate formations by matrix acidizing, and (d) improvement of production from carbonate formations by fracture acidizing. A fundamental requirement for successful wellbore cleanout is that the material be acid soluble. If a well is plugged with an acid soluble scale such as carbonate scale, then acid can be very effective at removing the scale and restoring production. Acid will not dissolve paraffin deposits, which

are not acid soluble. Acid can be very effective at removing iron scales such as iron sulfide. With proper fluid selection, design, and execution, matrix acidizing can be applied successfully to stimulate high-temperature oil and gas wells and geothermal wells. These types of wells have some common features, but they also have significant differences (e.g., completions, mineralogy, formation fluids and formation flow) that influence stimulation designs and fluid choices.

Acidizing is used to increase production in many situations. The most important include: damage removal, completion and stimulation of horizontal wells, matrix acidizing, fracture acidizing and gel breaking [4,5,6].

The objective of this study was to examine the effect of temperature and concentration on break time on gravel pack fluid, develop a model equation to help predict gel break time at different concentrations and temperatures thereby saving time and rigor associated with actual laboratory pilot test.

Gravel packing/ fracturing fluids composition

Generally speaking, creating a fracture in a hydrocarbon-bearing formation requires a complex suite of materials. In the case of conventional fracturing treatments, four or five principal components are required: (1) a carrier fluid (usually water or brine), (2) a polymer, (3) a cross-linker, (4) a proppant, and (5) optionally a breaker. (Numerous other components are sometimes added, e.g. fluid loss agents, whose purpose is to control leak-off, or migration of the fluid into the fracture face.) The purpose of these fluids is to first create/extend the fracture, then once it is opened sufficiently, to deliver proppant into the fracture, which keeps the fracture from



closing once the pumping operation is completed. The carrier fluid is simply the means by which the proppant and breaker are carried into the formation. The fracturing fluid will also comprise a viscosifying polymer that is typically a solvatable polysaccharide. Suitable hydratable polymers include, for example, guar, hydroxypropyl guar, carboxymethyl guar, carboxymethylhydroxypropyl guar, hydroxyethyl cellulose, carboxymethylhydroxyethyl cellulose, hydroxypropyl cellulose, and xanthan. Other natural and synthetic polymers can be used as well. The purpose of the solvatable (or hydratable) polysaccharides is: (1) to provide viscosity to the fluid so that it can create/extend the fracture; and (2) to thicken the aqueous solution so that solid particles known as "proppant" can be suspended in the solution for delivery into the fracture. In many fracturing treatments, a cross-linking agent is added which further increases the viscosity of the solution by cross-linking the polymer. The borate ion has been used extensively as a cross-linking agent for hydrated guar gums and other galactomannans to form aqueous gels. The purpose of the proppant is to keep the newly fractured formation in that fractured state, i.e., from re-closing after the fracturing process is completed; thus, it is designed to keep the fracture open in other words to provide a permeable path (along the fracture) for the hydrocarbon to flow through the fracture and into the wellbore. More specifically, the proppant provides channels within the fracture through which the hydrocarbon can flow into the wellbore and therefore be withdrawn or "produced." Typical materials from which the proppant is made include sand (e.g. 20-40 mesh), bauxite, man-made intermediate-strength or high strength materials and glass beads. The proppant can also be coated with resin, which causes the resin particles to stick to one another, to help prevent proppant flowback in certain applications. Thus, the purpose of the fracturing fluid generally is two-fold: (1) to create or extend an existing fracture through high-pressure introduction into the geologic formation of interest; and (2) to simultaneously deliver the proppant into the fracture void space so that the proppant can create a permanent channel through which the hydrocarbon can flow to the wellbore [4,5,6].

The main industrial use of hydraulic fracturing is in stimulating production from oil and gas wells [7,8,9]. Hydraulic fracturing is also applied to stimulating groundwater wells, preconditioning rock for caving or inducing rock to cave in mining [10].

Fracturing fluid is the fluid used during a hydraulic fracture treatment of oil, gas or water wells. The fracturing fluid has two major functions (1) Open and extend the fracture; (2) Transport the proppant along the fracture length. Often an oil- or gas-bearing formation may contain large quantities of oil or gas, but have a poor flow rate due to low permeability, or from damage or clogging of the formation during drilling [11]. This is particularly true for tight sands, oil shales and coalbed methane. Hydraulic fracturing is a technique used to create fractures that extend from the well bore into rock or coal formations. These fractures allow the oil or gas to flow

more easily from the rock pores, where the oil or gas is trapped, to the production well [12,13].

MATERIALS AND METHODS

The basic composition of the gel among others include: Water as the base fluid, bactericide, gelling agent, Iron- control additive, pH buffers, breakers and surfactants. The formulation depends on job targets and formation geometry. The basic tests and test procedures for gravel pack and fracturing fluids are summarized below:

Hydration test

- i. The biocides were added to the mix water while blending at low speed.
- ii. Iron control and pH adjuster was added to bring down the pH~ 2-3.
- iii. The salt (KCl) was added.
- iv. The required amount of buffer was added to raise the pH to between 7 and 8.
- v. The gelling agent was added to the brine solution at high blender speed and blended for about 10mins.
- vi. The gel was circulated at low speed for about 30mins to allow full hydration of the gel.
- vii. The apparent viscosity of the gel was measured.
- viii. The mixture was poured into 8-oz bottles and placed in a preheated water bath at Bottom Hole Temperature (BHT) to determine the break time.

pH determination

pH adjusters are usually implored to adjust the pH of Gravel Packing fluids. pH strips were used for a quick pH check.

Apparent viscosity

The apparent viscosity of gels was determined using the Fann 35 Viscometer. A direct viscosity reading in centipoises (cp) was obtained by taken the 300rpm reading of VG meters with F1 spring, B1 bob and R1 rotor.

Break test

The required amount of breaker was mixed with gel in an 8-oz bottle and placed in a preheated water bath at the Bottom Hole Temperature (BHT) to determine the break time.



Table-1. Gel formulation for 60 lbs/Mgal.

#	Chemical	Concentration
1.	Fresh water (Mix water)	1000gal/Mgal
2.	Biocide-1 (short time)	0.15lb/gal
3.	Biocide-2 (long time)	0.15lb/Mgal
4.	Gelling agent	60lb/Mgal
5.	Iron reducing agent	8lbs/Mgal
6.	pH adjuster	20lbs/Mgal
7.	KCL (Clay stabilizer)	3%
8.	Gel breaker	0; 5; 10; 15gal/Mgal

RESULTS AND DISCUSSIONS

pH of fresh water was 5
 pH after adding Iron reducing agent was 3
 pH after adding pH adjuster was 7
 Apparent viscosity of 60lb/Mgal hydrated gel was 40cp

Table-2. Effect of temperature on the break time at breaker concentration of 5gpt at 300rpm (cp).

Time (minutes)	0	30	90	120	180	210	270	300	360	390	420	450	510	540	600
190°F	40	34	30	29	28	27	26	26	25	24	22	20	16	14	10
210°F	40	34	30	29	27	25	18	15	10						
230°F	40	32	28	24	10										

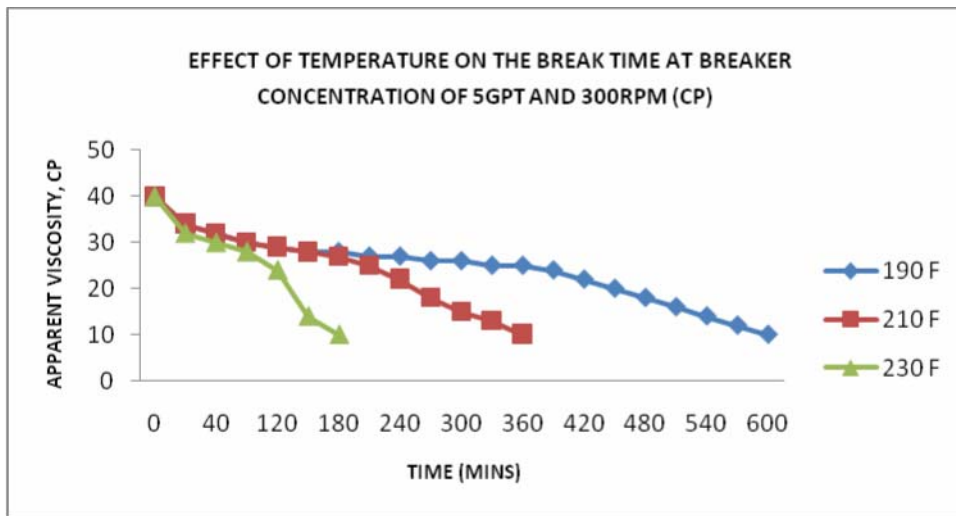


Figure-1. Effect of temperature on the break time at breaker concentration of 5gpt at 300rpm (cp).

Table-3. Effect of temperature on the break time and breaker concentration of 10gpt at 300rpm (cp).

Time (minutes)	0	30	60	90	120	150	180	210	240	270	300	330	360
190°F	40	34	32	30	29	28	27	25	22	18	14	12	10
210°F	40	33	31	29	28	22	14	10					
230°F	40	32	10										

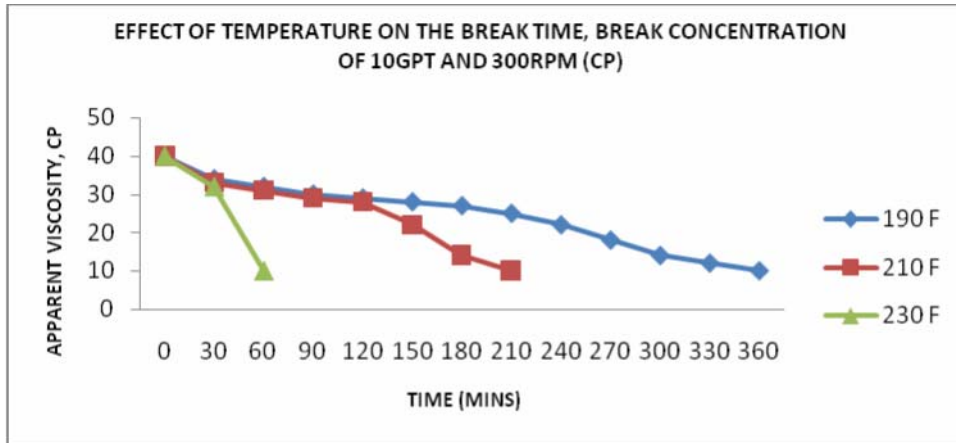


Figure-2. Effect of temperature on the break time and breaker concentration of 10gpt at 300rpm (cp).

Table-4. Effect of temperature on the break time and breaker concentration of 15gpt at 300rpm (cp).

Time (minutes)	0	30	60	90	120	150	180	210	240
190°F	40	34	31	28	25	20	16	13	10
210°F	40	30	22	14	10				
230°F	40	32	8						

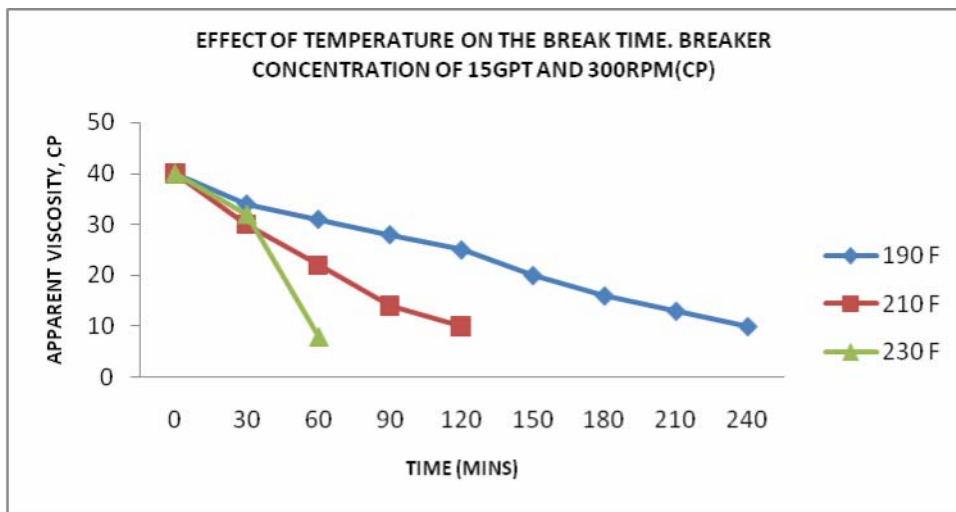


Figure-3. Effect of temperature on the break time and breaker concentration of 15gpt at 300rpm (cp).

Table-5. Effect of temperature and concentration on break time.

Breaker concentration (gal/1000gal)	190°F	210°F	230°F
5	600mins	360mins	180mins
10	360mins	210mins	60mins
15	240mins	120mins	40mins



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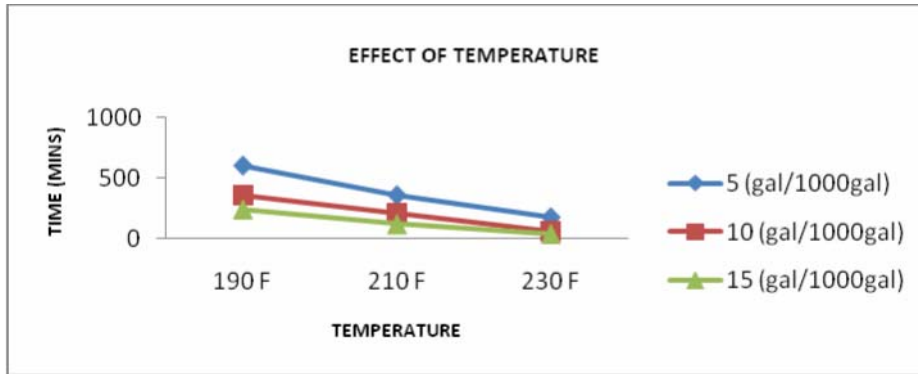


Figure-4. Effect of temperature and concentration on break time.

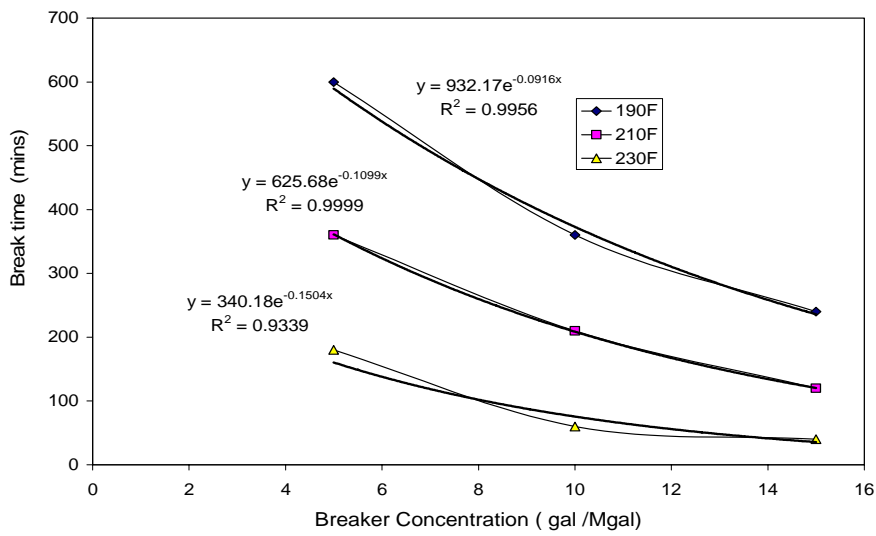


Figure-5. Effect of breaker concentration and temperature on break time.

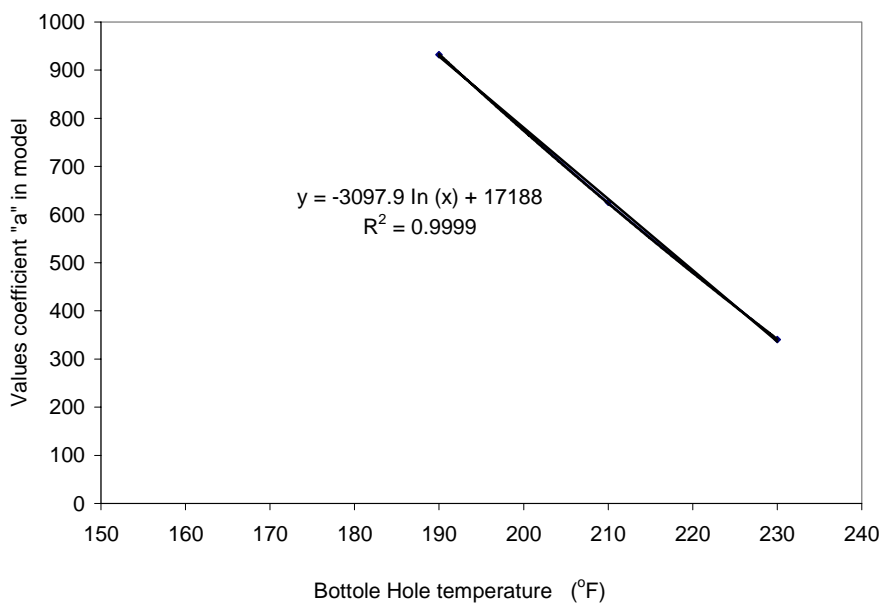


Figure-6. Plot of "a" vs. temperature.

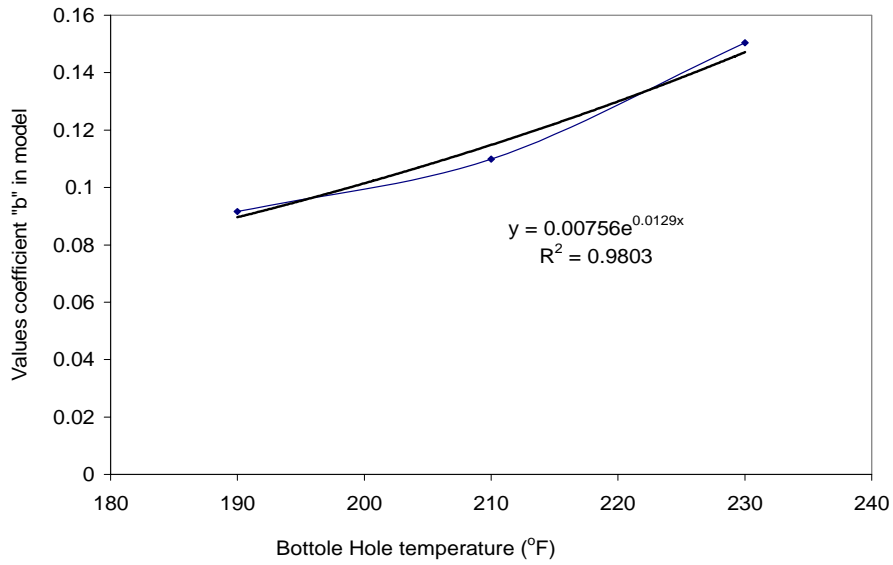


Figure-7. Plot of “b” vs. temperature.

Table-6. Comparison of experimental and model break time at 190°F.

Concentration	Model break time	Experimental break time
5	599.5574mins	600mins
10	385.1515mins	360mins
15	247.4186mins	240mins
20	158.94mins	Not determined

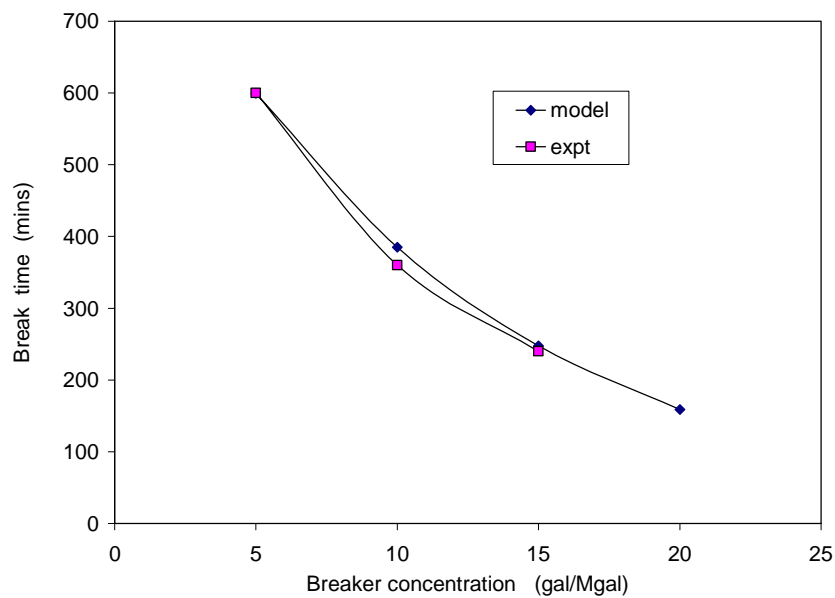


Figure-8. Comparison of experimental and model break time at 190°F.



Table-7. Comparison of model and experimental break time at 210°F.

Concentration	Model break time	Experimental break time
5	351.2423mins	360mins
10	197.9424mins	210mins
15	111.5504mins	120mins
20	62.86416mins	Not determined

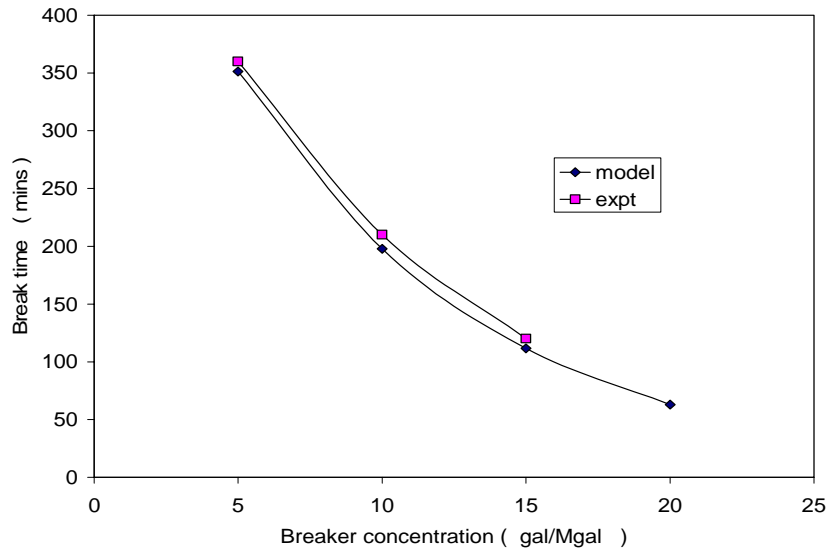


Figure-9. Comparison of model and experimental break time at 210°F.

Table-8. Comparison of model and experimental break time at 230°F.

Concentration	Model break time	Experimental break time
5	160.9643mins	180mins
10	75.88225mins	60mins
15	35.77262mins	40mins
20	16.86403mins	Not determined

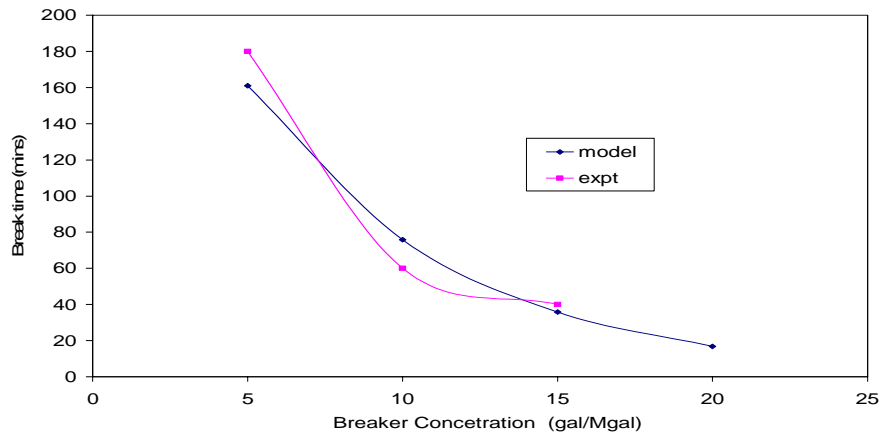


Figure-10. Comparison of model and experimental break time at 210°F.



DISCUSSIONS

The Gel hydration is pH sensitive and the various chemicals must follow a sequence to ensure proper gel hydration. Before adding the salt, the water must be brought down to a pH of (2-3). This is to ensure that the iron in the water does not precipitate as well as to avoid the formation of fish eyes when the salt is added. After dissolving the salt, the mixture must be raised to a pH of 7-8. The gelling material (HEC) hydrated in basic medium.

The gel was considered broken when viscosity of 10cp or less is obtained for 300rpm dial reading of Fann Viscometer. The gel break is a function of temperature and concentration of the breaker. Test with lower temperature and breaker concentrations respectively had longer break time than test at higher temperature and concentration of breaker (Tables, 4-5).

In the development of the model equations, all possible models (logarithmic, Power, linear, exponential etc models) were tested based on high multiple correlation coefficient R^2 and exponential model described best the variation of break time with Breaker concentration and temperature. The Break time was then assumed to vary exponentially with breaker concentration as shown in the experimental work in Figure-6.

So that

$$\text{Break time (BRT)} = ae^{-bC_B} \quad (1)$$

Where a and b are constants and C_B is the breaker concentration, BR is the break time.

The constants a and b are assumed to be functions of temperature (BHT). The constants a and b were regressed against the temperature by multiple regression analysis using m Microsoft excel programme. First the breaker concentration was regressed against the break time at different temperature (BHT) to obtain three equations: as shown in Figure-6. The coefficients of the equations in Figure-6 were now regressed against Bottom hole temperature to obtain the relationship between constants a, b and temperature (BHT) in equation 1, as shown in equations 2 and 3

$$a = -3097.9 \ln(T) + 17188 \quad R^2 = 0.9999 \quad (2)$$

$$b = 0.00756 e^{0.0129T} \quad R^2 = 0.9803 \quad (3)$$

Where T is the Bottom hole temperature in °F

The relationship between coefficients a and b in equation 1 and bottom hole temperature are also presented in Figures 6 and 7. Hence the combination of equations 1, 2 and 3 gives the new Ademiluyi - Ogbonna model,

Break time (BRT) (mins) =

$$(-3097.9 \ln(T) + 17188) e^{-(0.00756 e^{0.0129T}) C_B} \quad (4)$$

This can be used to predict the break time at any breaker concentration and at Bottom hole temperature BHT for HT breakers.

CONCLUSIONS

Results calculated from the model equation showed a good agreement with experimental values with less than 10% deviation. This will help predict gel break time at different concentrations and temperatures thereby saving time and rigour associated with actual laboratory pilot test.

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