USES AND RESULTS OF A LIQUID FRICTION REDUCER IN ACIDIZING TREATMENTS

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INTRODUCTION

The concept of using chemical additives to reduce drag or friction of fluids flowing in turbulence has been a well-known phenomenon for many years. It has been the subject of several papers both in and outside the petroleum industry.[1-7] There are many stimulation treatments now being performed which would be virtually impossible were it not for friction-reducing chemicals present in the stimulation fluids. Even small-volume acid washes done through small-diameter tubing or coiled tubing units utilize friction-reducing chemicals. Friction reducers, used in small quantities, can provide reduced surface treating pressures, higher injection rates, and lower hydraulic horsepower requirements.

Historically, powdered-type friction reducers have been used in the petroleum industry for most aqueous fracturing treatments. The common polymers used to reduce friction on a large scale are guar gum, derivatives of cellulose, and synthetic polymers such as polyethylene oxides and polyacrylamides. Synthetic polymers generally provide higher friction reduction at lower concentrations than do the natural polymers and cellulose materials.

Advances in polymerization techniques have made possible the development of polymers in liquid form. Now, synthetic friction-reducing polymers, similar to those previously used as solids, can be obtained in liquid form making handling and mixing less difficult. Liquids do not have a tendency to lump when added to aqueous fluids as do dry powders. When lumps form, they are not easily dispersed and can reduce the material available for lowering friction pressure. Also, the addition of liquid systems to treating fluids can be uniformly controlled.

Using proper guidelines, it is possible to select a polymer system which provides good friction reduction, is stable in concentrated acid solutions for extended periods of time, and is compatible with most acid additives.

This paper compares the properties of a liquid acid friction-reducing agent with several commonly used powdered materials. Some guidelines for selecting an acid friction reducer and laboratory testing of friction reducers are discussed. Successful field results using a liquid friction reducer in acid are also described.

EXPERIMENTAL

Materials

The friction-reducing chemicals used in this investigation consisted of a variety of synthetic and other water-soluble polymeric materials. The polymers investigated were natural gum (NG), derivatized natural gum (DNG) and two cellulose derivatives (CD-1 and CD-2) commonly used as water gelling agents by the petroleum industry. The synthetic polymers investigated consisted of various polyacrylamide products and polyethylene oxide materials. These are identified as PAM and PEO, respectively. The liquid acid friction reducer is identified in this paper as LAFR.

All of the powdered friction reducers were pre-wet with absolute methanol to prevent lumps from forming when the friction reducer was added to the aqueous fluid.

The acid solutions used for friction tests were dilutions of 20° Be technical grade muriatic acid and contained 0.3% corrosion inhibitor.

Equipment

The device used to measure friction pressure reduction in various fluids is illustrated in Fig. 1. The closed-loop pipeline is essentially the same as described by T.C. Buechley, et. al.,[1] with some minor variations as outlined below. The apparatus will be referred to as an FR meter.

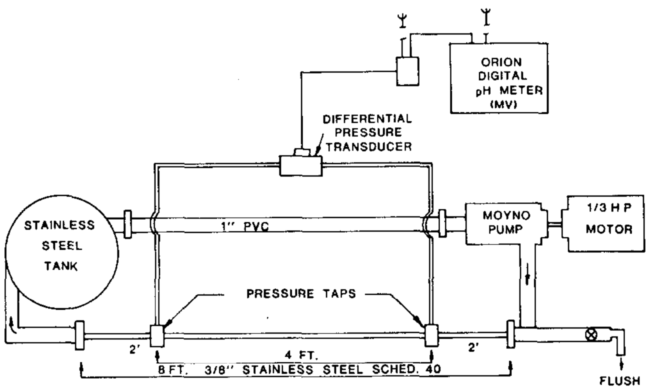

FIG. 1 — FR METER

Since the application of this particular FR meter was primarily for testing friction reducers in acid solutions, it was constructed entirely of stainless steel and PVC to make it less susceptible to acid corrosion. The FR meter consists of an 18-liter stainless steel mixing tank from which fluid is circulated through a 1-in. diameter PVC line into an 8-ft by 3/8-in. schedule 40 stainless steel pipe and back into the tank by a progressing cavity Moyno pump powered by a 1/3-hp motor. The approximate flow rate through the 3/8-in. pipe was 13.7 gpm, giving a mean linear fluid velocity of 23.3 fps. Two pressure taps were drilled 4-ft apart into the 3/8-in. stainless steel pipe. This allowed a 2-ft entrance and exit distance. Provision was made for cleaning the system, once a test had been completed.

During normal evaluations of various friction reducers, the pressure drop across the 4-ft section of 3/8-in. pipe was detected by a Viatran Differential Pressure Transducer Model 209. A regulated 12 volt excitation voltage was applied to the transducer and the millivolt output measured as a function of pressure. The present system utilizes an Orion Digital Meter to read out pressure in millivolts. An electronic x-y plotter can also be used to monitor the transducer output.

One of the parameters for selecting a friction reducer is its ability to withstand high-energy mechanical shear. Thus, a mixer which imparts high energy to the test fluid was used in the mixing tub of the FR meter. The mixer consists of a single-phase, 1/4-hp motor which turns a large emulsion-type stirrer at approximately 11,300 rpm. Generally, the high-energy mixer is not started until the fluid has circulated through the loop for several minutes.

Procedure

The procedure used to evaluate and compare various friction reducers is outlined below.

1. The FR meter was filled with 14 liters of base fluid, the pump turned on, and the pressure drop across the 4-ft section of 3/8-in. stainless steel pipe noted. Since the pressure is measured by a millivolt readout system, the millivolt reading of the base fluid was noted.
2. The friction reducer was then added to the base fluid and the millivolt (MV_t) readings taken at periods of 1, 5, 10 and 15 minutes as the solution circulated through the loop.
3. The high-energy mixer was then turned on to impart shear to the system. The millivolt (MV_t) readings were taken at 16, 20, 25 and 30 minutes as the solution continued to circulate through the loop.
4. The solution was then removed and the FR meter thoroughly cleaned before making another test.

This procedure was altered to evaluate the liquid acid friction reducer. The high-energy mixer was used to help hydrate the liquid friction reducer. In these evaluations the high-energy mixer was started prior to adding the liquid friction reducer and left on for one minute. After one minute the procedure was the same as that shown above. This procedure would be analogous to adding the liquid friction reducer through a blender tub and using the centrifugal blender pump to impart shear to the treating solution.

In this paper, friction pressure reduction is expressed as percent reduction (PFR) calculated as follows:

$$PFR = \left[\frac{MV_{(\text{base fluid})} - MV_t}{MV_{(\text{base fluid})}}\right] \times 100$$

It should be pointed out that the values for friction reduction given are valid only for the test conditions given. It has been shown that friction pressure reduction will vary with both pipe diameter and fluid velocity.[4,7] It has been further observed in the field, that uncontrollable variations in pipe roughness, base fluid properties, ambient temperatures and mixing procedures often lead to differences between laboratory and field determination values.[7]

RESULTS AND DISCUSSION

The data illustrated in Tables 1 and 2 show a comparison between several types of friction reducers in fresh water and in 15% HCl.

TABLE 1 — EFFICIENCY OF FRICTION REDUCERS IN FRESH WATER

FR Material	Conc. Lbs/1000 Gal	Percent Friction Reduction Fresh Water — No Shear 1 Min	No Shear 15 Min	Shear 15 Min
NG	5	45.0	59.8	57.7
DNG	5	44.5	59.0	56.6
CD-1	5	33.9	41.0	44.0
CD-2	5	44.3	42.5	37.6
PAM 1	5	67.9	64.7	54.9
PAM 2	5	52.0	50.6	34.1
PAM 3	5	66.7	66.7	62.9
PEO	5	67.1	39.0	22.8
LAFR	5*	60.6	53.5	40.9

*This material was added at 2 gals/1000, an equivalent of approximately 5 lbs/1000.

A comparison of the information shown in Table 1 and Table 2 indicates distinct differences between various types of friction reducers. While these tests may be considered more stringent than most field applications warrant, the tests are valuable for selecting a friction reducer to be used under the most extreme acid pumping conditions. It is shown that the gum polymers, cellulose derivatives, PAM 1, and PEO may be good friction reducers for fresh-water applications, but they should not be used in acid because of their poor response in acidic solutions. Friction tests conducted on materials labeled PAM 2, PAM 3, and LAFR show the results of a concerted effort to chemically change polyacrylamide to the extent that it is more stable in acid solutions. Any of these three materials would be good friction reducers for fresh water and acidic fluids according to the above tests.

TABLE 2 — EFFICIENCY OF FRICTION REDUCERS IN 15% HCl

FR Material	Conc. Lbs/1000 Gal	Percent Friction Reduction — No Shear 1 Min	No Shear 15 Min	Shear 15 Min
NG	5	51.8	21.5	14.2
DNG	5	50.7	16.2	13.9
CD-1	5	36.4	32.9	27.9
CD-2	5	3.6	5.0	16.5
PAM 1	5	44.8	18.8	12.7
PAM 2	5	63.0	57.4	38.9
PAM 3	5	60.7	49.6	37.0
PEO	5	62.4	33.5	15.3
LAFR	5*	54.9	50.3	40.8

*This material was added at 2 gal/1000, an equivalent of approximately 5 lbs/1000.

Several additional tests also may be conducted on these friction reducers to select the best acid friction reducer. For example, an acid friction reducer should maintain its friction-reducing properties even after prolonged exposure to acid. Acid stability is tested by mixing the friction reducer in acid and allowing it to stand for several hours before placing the mixture in the FR meter. The results of tests on two materials, PAM 3 and LAFR, show that there was approximately 15% loss in friction-reducing properties after 24 hours contact in 28% HCl.

A friction reducer should be compatible with other additives used in the particular treating fluid. It is important from a formation damage standpoint that no precipitated material be forced into the formation matrix. Acid solutions normally contain corrosion inhibitors plus one or more other types of additives used for a variety of reasons. The addition of a friction reducer may cause a precipitate to form due to incompatibilities with these additives. Compatibility tests can be as simple as mixing the treating solution in a beaker and visually checking for precipitates, or the solution can be tested on the FR meter. Incompatibilities between the friction reducer and additives will often show up as a decrease in friction-reducing properties of the solution as shown in Table 3. These data show the compatibilities of PAM 3 and LAFR with a commonly used cationic surfactant in 15% HCl.

All of the above tests were designed to help select the best friction reducer for acid solutions.

There are several points that must be considered

TABLE 3 — FRICTION TESTS IN 15% HCl: COMPATIBILITY OF PAM 3 AND LAFR WITH A CATIONIC SURFACTANT

FR Material	Conc. Lbs/1000 Gal	Surfactant Conc. Gal/1000 Gal	Percent Friction Reduction No Shear 1 Min	No Shear 15 Min	Shear 15 Min
PAM 3	5	None	60.7	49.6	37.0
PAM 3	5	5	55.4	~40.0	----
LAFR	5*	None	54.9	50.3	40.8
LAFR	5*	5	----	52.4	41.7

*This material was added at 2 gal/1000, an equivalent of approximately 5 lbs/1000.

when selecting a friction reducer for acid solutions. That is, good friction reduction provided by a material should not be the sole factor for selecting the proper friction reducer for acid solutions. An attempt should be made to maximize all aspects of a friction reducer's performance before using it in field applications. The points listed below should be considered in selecting an acid friction reducer.

1. The material should provide good friction reduction in 15% and concentrated HCl under field-use conditions.
2. During a fracturing treatment, displacement times are relatively short. Therefore, it is necessary to have a material which, when added continuously to the fluid stream, hydrates or solvates very quickly. The material should develop at least 80% of its friction-reducing capabilities in 45 seconds or less.
3. Fluids are subjected to very high shear during a high-rate treatment. Therefore, the material should be as shear-stable as possible. It has been observed that acid solutions tend to have an adverse effect on shear stability.
4. Many materials used as friction reducers tend to degrade rather quickly in acid solutions, particularly in concentrated acids. From the standpoint of premixing a friction reducer in acid, it is necessary that the material be stable in acid solutions for several hours.
5. Most acid solutions contain a variety of ionically charged corrosion inhibitors, nonemulsifiers, etc. Thus, the friction reducer must be compatible with these acid additives. Such compatibility tests should be determined in the laboratory.
6. Finally, the material should be selected on the basis of ease of handling in the field. The easier it is to handle, the more uniformly the friction reducer can be added.

FIELD TESTS

The data shown in Table 4 illustrate the use of LAFR as a friction reducer in various types of acid treatments.

TABLE 4 — FIELD TESTS USING LAFR FRICTION REDUCER

Treatment No.	Type Treatment	Volume Treatment	Tubing Size (in.) O.D.	Rate (BPM)	Observed Friction Reduction
1	HF-HCl 2% NH_4Cl	4,000 4,000	2 7/8	6-9 9	62.3% 59.1%
2	Acetic-15% HCl	8,000	--	8	70.0%
3	7½% HCl	1,500	2 7/8	3	66%
4	20% HCl (17,900')	20,000	2 7/8 - 5	15	50.0%
5	15% HCl	5,700	--	3.5	76.1%
6	15% HCl	3,000	2 7/8	6 3/4	71%
7	HF-HCl (coiled tubing 14,000')	1,500	3/4	1/2	79.8%

All calculations of percent friction reduction were made by taking the wellhead treating pressure (P_w) minus instantaneous shut-in pressure (P_i) and comparing the resulting pressure (P_f) to the known friction pressure for fresh water at a given rate.[8]

$$P_f = P_w - P_i$$

$$PFR = \left[\frac{P_{f(water)} - P_{f(treating\ sol.)}}{P_{f(water)}}\right] \times 100$$

The field tests shown in Table 4 indicate that LAFR is an effective friction reducer for acid solutions. The observed friction reduction under actual field conditions ranged from a low of 50% to 79.8% for a small coiled-tubing job. The tubing sizes ranged from 3/4-in. OD to 5-in. in diameter. The acid solutions included HF-HCl mixtures, HCl, and acetic-15% HCl. Twenty percent HCl was the strongest acid in which the material was field-tested. The pump rate during these various treatments ranged from 0.5 BPM to 15 BPM.

During the above treatments, several observations were made concerning the use of a liquid friction reducer for acid. It was found that the liquid friction reducers are much easier to handle under field conditions than are the powdered-type friction reducers. The liquids can be added more uniformly than powders without forming lumps of friction reducer in the treating solution. It was further observed that the liquid LAFR could be used as a premixed additive or it could be added continuously during treatment. This gives the friction reducer much greater versatility when trying to design an acid treatment for even the most adverse conditions.

CONCLUSIONS

1. It has been shown by laboratory tests that LAFR is a friction reducer which provides good friction reduction in acid solutions; it is stable in acid for extended periods of time, and is compatible with most acid additives.

2. Field tests indicate LAFR is an effective friction reducer for various acid solutions and can be used either premixed or added, continuously, depending on requirements of the job.

3. Guidelines have been proposed for properly selecting a friction reducer for acid solutions.

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