# Sand consolidation by chemical treatment using indigenously developed chemicals

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## ABSTRACT

Sand production with reservoir fluid is a well known problem in many parts of the world. Sand production in a well causes restricted production or complete loss of production due to sanding of well bore. There are several methods of sand control but most of the technologies require heavy hardware and tools thus making the cost of new well very high. Chemical sand consolidation can be an alternative to traditional techniques for poorly consolidated formations.

The present studies are carried out to develop a suitable sand control technique for weakly consolidated oil/gas reservoirs using indigenously developed chemicals. The concept is based on the fact that water soluble polymers/chemicals have a strong tendency to adsorb on the surface of rock, thus binding the loose sand. However, the permeability of the formation is maintained by injecting oil soon after injection of chemicals. In order to develop this technology, a laboratory study was carried out to evaluate the chemicals for sand consolidation under static and dynamic conditions. Both the above studies were carried out on a 20/40 sand and using different combinations of chemicals and catalyst. The treated plug was kept at 80 0C for gelation. The compressive strength of sand pack prepared under static condition was found to be around 239 psi, which is satisfactory for field implementation.

The studies in dynamic condition (simulating reservoir condition) was carried out in steel sand pack holder, filled with 20/40 sand having 3.6 cm diameter and 15.2 cm length. The chemicals were flowed through the sand by gravity followed by oil again to keep the flow path open during gelation at 80 0C. the results of study indicated that a gel solution with 7% catalyst and volume equivalent to about 6% of sand volume could give desired sand consolidation with retention of permeability about 790 md at injection point from initial permeability of 72 Darcy of loose sand.

**Keywords**

permeability, porosity, sand consolidation, frac pack

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## Introduction

Production of formation sand with reservoir fluid is common phenomenon in many heavy oil and gas fields/wells. Sand production in a well can cause restricted production or complete loss of production due to sanding of the well bore. If production rates are high enough to carry produced sand to the surface, severe erosion of both surface and sub surface equipment may occur. It is a big challenge for an engineer to control/stop the sand production while maintaining the production of a well. There are several methods of sand control used in the petroleum industry, like gravel packing, wire wrapped screens, frac-and-pack, chemical consolidation and expandable screens etc. The sand production is due to the start of degradation of rock with the erosion of cement of the rock during production from a highly permeable reservoir. The erosion of the cement accelerated with time and degradation of rock leads to production of sand grains at surface together with sand accumulation in the well.

Gravel Pack is widely accepted technology in major oil companies across the well. However, drawback of Gravel Pack technology is that it reduces productivity index, besides placement of Gravel Pack in work-over is also difficult. High skin and cost of installation is another major drawback. In terms of permeability recovery, frac-pack, stress frac, propped fracturing and use of resin coated sand are useful. The drawback of the systems is tip screen-out during installation, directional control (in inclined wells), fracture containment control, proppant flow back on production etc. Other methods are selective perforating, oriented perforating, production rate control etc but they have their own limitations. Chemical treatment is one of the options which can consolidate the loose sand and can be an alternative to the traditional techniques.

The principal of sand consolidation technology is the formations of polymeric films on the sand grains which acts as cementing material around the wellbore and thus stop erosion process of the rock. Such film required to be strong enough to resist harsh hydrodynamic conditions of oil/gas flow through pore channels. In order to prove this idea, a laboratory study was undertaken to evaluate the chemical for sand consolidation. A chemical named FURAMID-500 supplied by M/s Nova Transfer Pvt. Ltd. has been studied in the laboratory.

## Properties Of Chemical

FURAMID - 500 is a thermosetting resin and for better gelation control a catalyst is used namely CALAYST - HP. FURAMID - 500 is a liquid based resin having pH around 8. The product is soluble in water. CATALYST -HP is a chemical in powder form. It accelerates the gelation rate of FURAMID - 500 and also provides additional strength to the cured product. The chemical is having following features.

- High salinity ( 2 - 3% NaCl) and hardness tolerance.
- Gel formation process controllable in all possible range of reservoir temperature (75 - 120°C).
- Low viscosity capable of achieving deep penetration.
- Capable of consolidating loose sands and still allowing flow of oil/gas/water.
- Gelation time can be controlled from few hours to even days by altering the concentration of catalyst.
- Excellent thermal stability of cured gels.

**A. Thermosetting of Chemical**

To study the thermosetting of the supplied chemicals, samples with different ratio of chemical and catalyst were prepared in the laboratory and kept at different temperature to record the setting time before carrying out consolidation studies on sand. The results of study are presented in the following table-1.

**Table-1,** Thermosetting studies of Chemical

| Conc. of catalyst added in FURAMID-500 | Setting time of Chemical (Hrs.) | | |
|---|---|---|---|
| | Set-1 (Room Temp) | Set-2 (60 $^0$C) | Set-3 (80 $^0$C) |
| 5% | 12 | 10 | - |
| 6% | 10 | 9 | 8 |
| 7% | 8 | 7 | 6 |

## Experimental Details

**A. Sand Consolidation Studies in Static Condition**

A known quantity of sand (20/40) taken in beaker and the mixture of chemical (Furamid-500) made by adding catalyst in the proportion of 6% to chemical volume was added. The volume of chemical –catalyst mixture was equivalent to about 6% to sand volume. The above sand chemical ratio (6% chemical) was arrived after conducting several experiments with different sand chemical ratios. The sand and chemical mixture was mixed and made a homogeneous mixture. Chemicals mixed sand was filled in a rubber sleeve and was kept in the oven at 80 $^0$C. After 6 hours wait-in period the sleeve was taken out for observation. It was found that the consolidation of sand had initiated. Then it was again kept in oven for overnight and consolidated sand plug was removed from oven. It was observed that the sand particles were intact in the form of sand plug. The picture of consolidated sand plug is placed in fig-1.

**Fig-1,** Sand Plug prepared in static condition

**B. Compressive Strength**

The compressive strength of consolidated sand plug was measured in cement laboratory at IDT. To find out compressive strength of the consolidated sand, a cubical mould of 5.1 cm as per the requirement of cement lab, was prepared (fig-2) by using the above method. The mould was kept in the oven at 80 $^0$C for about 24 hrs. The cubical block of consolidated sand was kept in a hydraulic press and the force was applied to test its compressive strength. It broke at 239 psi. The breaking point has been taken as compressive strength of the consolidated sand. The plot of load verses relative time is placed as plate-1. The consolidated sand having strength to break at 239 psi is sufficient to provide well bore stability and stop the sand cut.

**Fig-2,** Sand Cube for compressive strength

## Sand Consolidation Studies in Dynamic Condition

Major challenges were faced to setup the experiment in laboratory for conducting sand consolidation studies in dynamic condition. Many set of experiments were carried out using different sand pack holder like PVC pipe and GI pipe and observed some shortcoming in the sand pack holder while conducting experiments. To overcome all the observed problems, a different steel sand pack holder having smooth inner surface was got fabricated for the study. The sand pack holders were got fabricated and improved subsequently as per the experience gained during the experimentation. Finally a pack holder having 3.6 cm diameter and 15.2 cm length having inlet and outlet NPT connections as shown in fig.-3 was found suitable for conducting experiments.

The experiment was designed such that the flow of fluid through the sand pack (20/40 sand) prepared in sand pack holder was made by gravity. The rate of flow was measured by using stop watch and the volume of flowing fluid in unit time was calculated by storing the flowing fluid in measuring cylinders. Double transparency sheet with grease in between the sheet was placed inside the wall of pack holder to make the inner surface of pack holder smooth enough to remove the sand plug from the pack.

**Fig-3**, Steel Sand Pack Holder

A known quantity of sand (20/40) was filled in the pipe from top end. To reduce the permeability of the pack and to make the sand pack compact, it was pressed by slow hammering. During flow studies, first water was flowed through sand pack by flowing water from a water container placed about 3 ft above the pack holder to provide a hydrostatic column. After water saturation, the absolute permeability of the sand pack with water was observed about 72 Darcy. This time the sand pack was better compacted as the permeability of pack has come down to 72 Darcy from 100 Darcy observed during initial experiments. After water saturation diesel was flowed to create oil water saturation to represent as reservoir rock. About 100 ml of gel with 6% of catalyst followed by diesel to retain matrix permeability was flowed through the sand pack. All the flow was gravitational and the sand pack was kept horizontal to allow slow movement of fluid through sand pack. The sand pack holder having treated sand pack was kept inside the oven at 80 $^0$C. After gelation for about 72 hrs the plug was removed very easily and a perfect sand consolidation was observed (Fig.-4).

## Permeability and Porosity of Consolidated Sand Plug

The permeability of consolidated sand pack was determined at Petro-physical Laboratory of KDMIPE. Two plugs samples were cut from consolidated sand plug for determination of porosity and permeability. Sample-1 is taken from the point of injection of gel where as sample-2 was taken from out let point of plug. The results of experiment are shown in table -3.

**Table -2:** Porosity and Permeability of sand plug after consolidation

| Sample no | Length inch | Porosity | Permeability, md |
|---|---|---|---|
| Sample-1 | 1 | 27.7% | 790 |
| Sample-2 | 1 | 30% | 1067 |

## Observations

- This experiment was quite successful and desired sand consolidation was achieved by chemical treatment.
- It is observed that sand consolidation was more at the injection point having permeability 790 md in sample-1 taken from injection point where as plug sample-2, taken at out let point has shown the permeability of 1067 md. This may be due to dilution effect from water saturation initially existing in sand plug and as the chemical front moved into the sand pack it went on getting diluted.
- This procedure along with chemicals used is suitable for implementation in fields as it would give sand consolidation near wellbore and also retain permeability to allow the well to produce without sand cut after treatment.

## Conclusions

- Carried out four experiments at various conditions and many lessons learned during experimentations. Thus each experiment was improved from previous experiment.
- From studies, it emerges that the sand consolidation using resin based chemical is effective and can offer the desired result.
- Chemical Furamid-500 used is quite suitable to consolidate loose sand at reservoir temperature.
- The chemical is hydrophilic and environment friendly.
- Sand consolidation is more effective if more time is given at 80 $^0$C for curing.
- Sand consolidation is more at the injection point as permeability was 790 md observed in sand plug taken from injection point where as plug taken at distance shown the permeability 1067 md. This may be due to dilution effect from interstitial water saturation as the chemical front move into the formation.

The volume of chemicals to be injected may be planned according to the requirement of consolidation deep in to the formation from well bore.

## References

[1] A. Zaitoun and N. Kohler, "Improved Polymer Treatment for Water Control in Producing Wells", JPT, 862-867, July 1991.

[2] A. Zaitoun, N. Kohler, D. Bossie-Codreanu and K. Denys, "Water Shutoff by Relative Permeability Modifiers: Lesson from several Field Applications", SPE 56740 presented at the 1999 SPE Annual Conference, Houston, TX, October 3-6.

[3] F. Haavind, S. S. Bekkelund, A. Moen, H. K. Kotlar, J. S. Andrews and T. Haland, "Experience With Chemical sand Consolidation as Remedial sand Control Option on the Heldrun Field" paper SPE 112397 presented at the 2008 SPE formation damage Symposium, Lafayette, 13-15 Februry.

[4] H. K. Kotlar, F. Haavind and O. Torsaeter, "A new Concept of Chemical Sand Consolidation: From Research Idea to Field Application, SPE 95723, 2005

## Annexure:

**Properties of FURAMID-500**

FURAMID-500 is thermosetting resin and for better gelation control a catalyst is used namely CALAYST-HP, FURAMID-500 is a liquid based resin having Ph AROUND 8. The product is soluble in water. CATALYST-HP is a chemical in powder form. It accelerates the gelation rate for FURAMID-500 and also provides additional strength to the cured product.

**Key features of FURAMID-500**

High salinity (2-3% NaCl) and hardness tolerance
Gel formation process controllable in all possible range of reservoir temperature (75-120$^0$C)
Low viscosity capable of achieving deep penetration
Capable of consolidating loose sands and still allowing flow of oil/gas/water.
Gelation time can be controlled from few hours to even days
Excellent thermal stability of cured gels.

**PRELIMINARY LABORATORY STUDIES**

**Gelation rate:**

FURAMID-500 gel times are controlled by temperature and catalyst concentration. In lab some preliminary gelation studies were carried out chagning the concentration of catalyst-HP from 0.1@ to 10% by keeping same composition and concenttation of FURAMID-500 as supplied. Gelation time from 2hrs to 48hrs was achieved at 80$^0$C. The gel strength is sirectly dependent upon the concentration of CATALYST HP. Similar studies were also carried out a 120$^0$C at 5kgs. Pressure gel time was obtained from 1 to 8hrs by varying the catalyst concentration.

**Investigation as follows**

FURAMID-500 with Hardner HP

**Table - 1**

| **RESIN** | **FURAMID-500** | | |
|---|---|---|---|
| Catalyst | **Catalyst HP** | | |
| Catalyst % | 5% | 6% | 7% |
| Curing time (min) Set-1 | 465 | 410 | 330 |
| Curing time Min) Set-2 | 475 | 435 | 375 |

**Viscosity Measurement:** Viscosity measurement of the resins has been done by using viscometer model – RV-1 witht the following parameters:
Temperature -30$^0$C, Shear rate -10 & 20/S
Viscosity of the resin samples are produced in the following table:

**Table: 2**

| **Shear Rate** | **FURAMID-500** |
|---|---|
| 10 | 82 cps |
| 20 | 77 cps |

**Compressive Strength:**
Specimen samples were prepared from the cured material and cut to a length of 2cm before palcing on the instrument.

Results of the compressive strength are given below:

**Table: 3**

| **Sample** | **Av.Compr.Strength of 3 identical samples in lb/sq.cm** |
|---|---|
| Conc of Catalyst | |
| 5% | 7600 |
| 6% | 7750 |
| 7% | 7930 |