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Analysis and Evaluation of Gravel Pack in Horizontal Wells

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Abstract **- In this research, gravel packing in horizontal wells are being analyzed to get the total pack efficiency of the gravel pack job. A model is developed for the gravel pack process using the basic laws of physics during the placement of the gravel in the horizontal well bore presuming some conditions are followed. The model developed is simulated using a Horizontal Gravel Pack SIMulator (HGPSIM), the results are now analyzed to determine the effectiveness and pack efficiency of the gravel pack job. The results gotten from the simulation process done in this research indicates that the settling effects of the slurry has to be considered when determining the pack efficiency of the gravel pack process. Some parameters where isolated, varied and analyzed to get the best gravel pack in terms of various injection rates to get their pack efficiencies. It was observed that low viscosity carrier fluid, low gravel concentration at low injection rates would give the most effective and efficient gravel pack process in horizontal wells. These results coincide with the general practices of gravel pack in horizontal wells.**

Keywords- **Gravel packing, horizontal wells, analysis, simulation, evaluation.**

I. INTRODUCTION

Sand production is undesirable during production of hydrocarbon as it can cause many different problems both topside and downhole. Sand production is typically present in formations producing from younger tertiary reservoir such as sands of Miocene and Pliocene ages. In order to control sand production, the method of Gravel packing has been used by the oil industry since the 1930's.

The application of gravel packing in horizontal wells has proven to be successful in some cases and had failed in other cases (Rune, 2015). Several authors have investigated the factors affecting gravel transportation and placement towards achieving an effective gravel pack and modeling the process. The models are derived most from several experimental measurements, which measures pack efficiency as a function of screen parameter, fluid and gravel properties, completion configuration (concentric/eccentric) and angle of inclination of the well bore.

Very few studies have been performed on the analysis and evaluation of gravel pack in horizontal wells. Production from horizontal wells can be very problematic if the rate of sand production is critical and this can be attributed to poor evaluation of gravel pack before and after installation. In order to determine the needed gravel pack size, a core sample from the formation and sand formation must be examined with a view to determine the median grain size diameter and grain size distribution (Saucier, 1974).

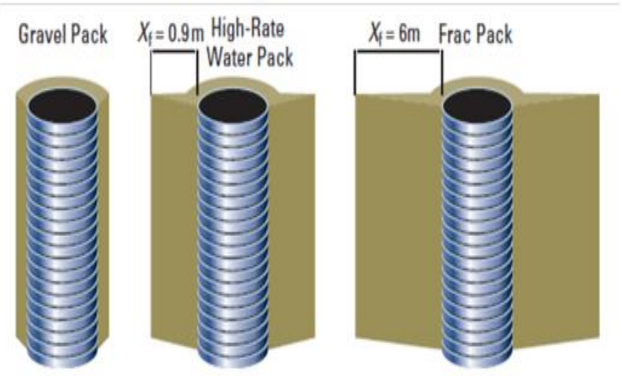

Fig.1. Relative Sand Face Areas for Gravel Packing, High-Rate Water Packing, and Frac Packing (SLB, 2007).

This study is basically concerned with the analyses and evaluation of gravel pack in horizontal wells using mathematical models and simulation soft wares such as HGPSIM. The design procedures of gravel pack systems is not the major goal of this research, however, a review of the design features of gravel pack will be considered. This study focuses on horizontal wells but for the purpose of data and results analysis and comparisons, gravel pack performance in vertical wells will be considered.

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II. METHODOLOGY

We started by creating a model to be simulated, the development of the gravel pack model for deep horizontal well is predicated on the fundamental laws of physics by solving for an overall conservation of forces during the placement of the gravel in the horizontal well bore. The horizontal well gravel pack simulator HGPSIM, which is a computer program developed to implement the solution method described. The data input module of the HGPSIM is shown in Fig. 2.1 through 2.4. The first data entry screen, Fig. 2.1, shows the project information screen where information about the project such as client name, location, project title and date is inputted. It's important to enter a reasonable value for the project title because this is used to name the simulation result output file that is generated at the end of the simulation run.

The second screen, Fig. 2.2, is the formation data input screen. Here information about the formation relevant to the gravel pack simulation process must be entered. These include the reservoir porosity, permeability, fracture gradient, reservoir pressure, etc in table 2.1. The third data entry screen is the shown in Fig. 2.3. This is the well data entry screen, and it's divided into two sections.

The vertical wellbore section where data pertaining to the vertical wellbore is entered and the horizontal wellbore section, for entering data about the horizontal wellbore to be gravel packed. Required data for the former include, vertical section total vertical depth (TVD), vertical section measured depth (MD), last casing size and open hole diameter. The data for the horizontal wellbore include, hole or casing diameter, screen outer and inner diameters, screen length, tell-tail diameter and length, wash pipe inner and outer diameters in table 2.2.

Finally, the fourth data entry screen is the treatment data screen shown in Fig. 2.4. This is where all data relating to the treatment carrier fluid, gravel, and slurry are entered. The injection pressure, rate and approximate volume to ascertain the approximate duration of the gravel pack job are also entered here.

Fig.2. Project initiation module.

Table I: Formation data for gravel pack simulation for WellOPD-23.

Formation Parameter	Value
Porosity	0.23
Fluid Compressibility	1.0
Permeability	32
Fracture Gradient	0.8
Overburden Gradient	0.7
Wellbore Skin	0.0
Reservoir Depth, ft	13200
Reservoir Temperature, °F	120
Reservoir Pressure, ft	2600

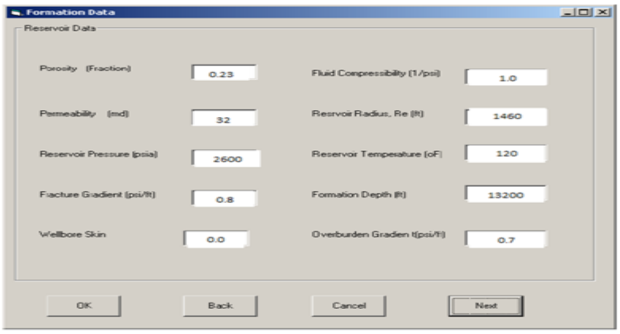

Fig.3. Input module for formation data.

Table II: Input data for well and screen.

Formation Parameter	Value
Porosity	0.23
Fluid Compressibility	1.0
Permeability	32
Fracture Gradient	0.8
Overburden Gradient	0.7
Wellbore Skin	0.0
Reservoir Depth, ft	13200
Reservoir Temperature, °F	120
Reservoir Pressure, ft	2600

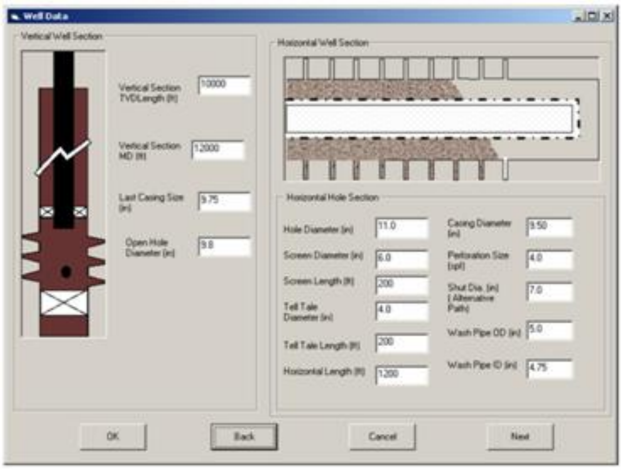

Fig.4.Input module for well and gravel data.

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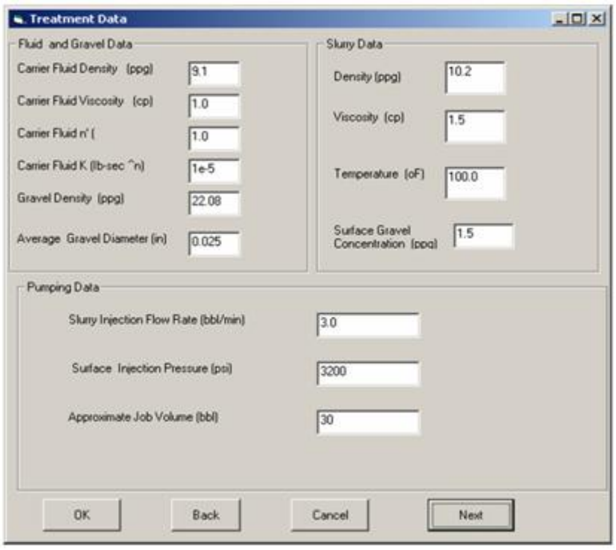

Fig.5. Gravel and Carry fluid input interface for HGPSIM.

III. RESULTS

Viscosity effect on horizontal gravel pack performance
The effect of carrier fluid viscosity on pack efficiency was studied by varying the viscosity between 1 and 51 cp, injection rate between 1 and 4 bpm and gravel concentration between 0.5 and 4.0 ppg.

The result of the simulation runs are presented in Figs. 3.1 and 3.2. These figures indicate that for the wide range of variables considered, viscosity has little effect on the pack efficiency obtained for both cases, with and without settling effect. The pack efficiency in both cases stayed above 80% over the entire range of input parameter considered. The low viscosity fluids at low gravel concentration have higher packing efficiencies which are more stable over the entire range of injection rate. This supports the usual practice in horizontal well gravel pack in which low gravel concentrations are used with the carrier fluid of mostly water or brine.

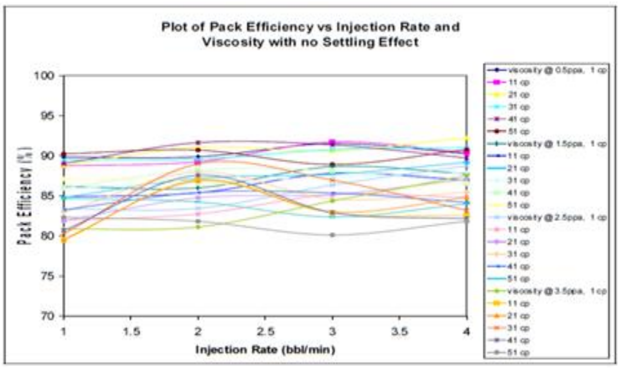

Fig.6. A plot of Gravel Pack Performance Efficiency vs Injection Rate and Viscosity with no Settling Effect.

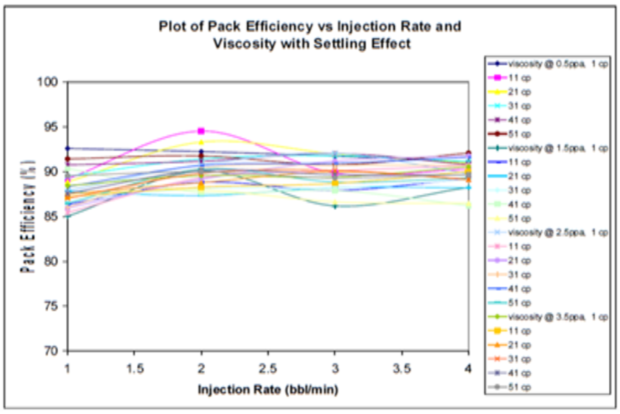

Fig.7. A plot of Gravel Pack Performance Efficiency vs Injection Rate and Viscosity with Settling Effect.

This effect was measured using the efficiency module of the HGPSIM software for settling and non-settling conditions. The effect of injection rate and gravel concentration on simulator estimated pack efficiency was studied by varying injection rate between 1 and 8 bpm while varying gravel concentration between 0.5 and 10 ppg. Two sets of simulation runs were done, with and without settling effect.

Fig. 3.3 shows the results of the runs without settling effect while Fig. 4.8 shows those with settling effect.Fig. 3.3 shows that at high injection rates of about 4 to 8 bpm, the model predicted pack efficiencies were very close for the entire range of gravel concentrations considered. At lower injection rate than 4 bpm, there are slight variations in the predicted pack efficiencies with the highest values predicted for the lowest gravel concentration. This is in agreement with the general acceptable practice for gravel packing horizontal wells and earlier experimental observations in the literature(Penberthy, Bickham, Nguyen, & Paulley, 1996).

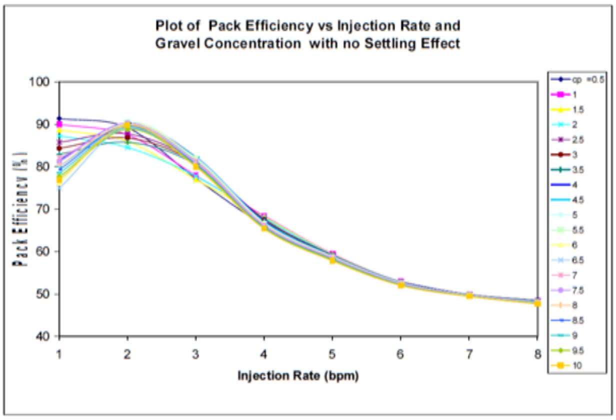

Fig.8. A plot of Pack Efficiency vs. Injection Rate and Gravel Concentration with no settling Effect.

With settling effect under consideration, the result is very different. Fig. 3.4 shows that the model predicted pack

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efficiency for these cases are consistently higher than the corresponding cases without settling effect throughout the range of injection rates and gravel concentration considered. This implies that available horizontal well gravel pack models that neglects settling effect consistently under predicts the pack efficiency obtained from gravel packing. Fig. 3.4 shows that at low injection rates between 1 to 2 bpm, low gravel concentrations predicted slightly higher pack efficiency. As injection rate increases, the pack efficiency obtainedfrom higher gravel concentration increases steadily while that from low concentrations decreases. The declines are however, oscillatory in nature.

This suggests that higher pack efficiency can be obtained at high injection rate and high gravel concentration. While these operating conditions are desirable in terms of good packing efficiency and lower job cost from lower pump time, such conditions are practically impossible because of the high friction pressure involved with pumping at such high concentration and high injection rate. High friction pressure is directly related to exorbitant pumping cost and possible failure of equipment’s in the wellbore. For these reasons, conditions are usually maintained at reasonably low injection rates and gravel concentrations in selecting the optimum operating conditions.

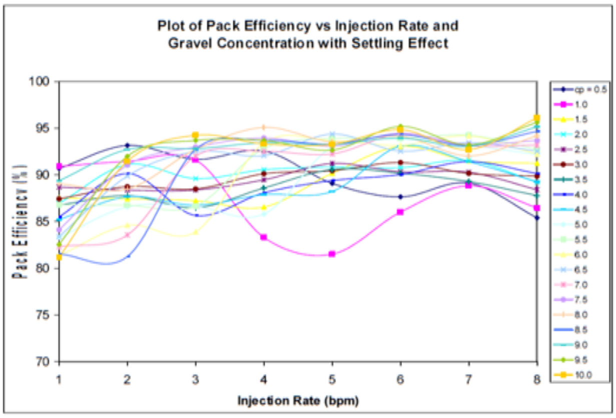

Fig.9. A plot of Pack Efficiency vs. Injection Rate and Gravel Concentration with settling Effect.

IV. DICUSSIONS

The results indicated that these effects vary depending on other variables in the system, including the wellbore geometry, formation properties and gravel pack job parameters thereby supporting the idea that settling effects has to be considered to determine the effect on the gravel pack result.

- The one dimensional model developed for the horizontal gravel pack performance is very much applicable to the function it is prescribe and offers a significant improvement in the studies of horizontal gravel pack performance.
- The low viscosity fluids at low gravel concentration have higher packing efficiencies which are more stable over the entire range of injection rate. This supports the usual practice in horizontal well gravel pack in which low gravel concentrations are used with the carrier fluid of mostly water or brine.
- That higher pack efficiency can be obtained at high injection rate and high gravel concentration.
- Without considering settling effect at high injection rates, the model predicted pack efficiencies were very close for the entire range of gravel concentrations considered. At lower injection rates, there are slight variations in the predicted pack efficiencies with the highest values predicted for the lowest gravel concentration. With settling effect under consideration, the model predicted pack efficiency for these cases are consistently higher than the corresponding cases without settling effect throughout the range of parameters considered.
- Carrier Fluid viscosity has little effect on the pack efficiency obtained for both cases, with and without settling effect. The pack efficiency in both cases stayed above 80% over the entire range of input parameter considered.

V. CONCLUSIONS

A one dimensional model was developed for a horizontal gravel system and analyzed using a gravel pack simulator called Horizontal Gravel Pack SIMulator (HGPSIM). The gravel pack efficiency and system pressure at any point in time and distance was determined and monitored as a function of the various job parameters. Comparison was be made between results obtained with and without considering the settling effects in the vertical section of the wellbore. For further studies the following areas can also be considered.

- The advancement of the model developed in these studies for 2 dimensional and three dimensional flow considerations in a horizontal well system.
- A shift of concentration towards vertical well systems and their gravel pack performance using a modification of the model presented in this study.
- The model can be extended to account for non-Newtonian fluids that can be used in gravel pack jobs and to predict amount of fluid lost to the formation and thus estimate amount of damage resulting from fluid loss to the formation.

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