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THE CHARACTERISATION OF OVERLAPPING FLAT SPRAYS FOR DESCALING OIL AND GAS WELLS

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ABSTRACT

Scale deposition and blockages is one of the most common production problems in oil and gas fields. The scale formed in the well bore is predominately due to the accumulation of calcium carbonate. This growth of scale in the pipe can significantly decrease well productivity, and can also affect the safety and integrity of the asset. Thus, managing scale deposition is highly essential to the productivity of the well.

The three most common types of scale to form in oil wells are calcite, the calcium sulfates and barite. Calcite crystals are consists mostly of calcium carbonate ($CaCO_3$), but often contain up to 20% of iron or magnesium carbonate. The problems caused by each scale can be dramatic and immediate, for example, petroleum companies may spend in excess of £2,000,000 annually to remediate scale related problems in the North Sea alone and attributes about 20% of its well losses to scale removal and scale inhibition treatment.

It has been proposed to use high-pressure water atomizers to remove wellhead scale as a cost effective and environmentally friendly method. This paper investigates the characteristics of a novel, overlapping, flat fan spray nozzle arrangement and examines its effect on scale removal for use in oil and gas fields. The use high pressure water spray, through a carefully selected atomizer, has significant advantages over the chemical and mechanical techniques as there is no requirement for a drilling or rig work-over. In the application of high pressure spray for removing down-hole scale, a Coiled tubing unit is all that is required for the operation with the spray-head connected to the tubing. Various samples from oil and gas wells, with scale deposition have also been used in the study to analyse operational effectiveness of the spray.

Introduction

The build-up of scale inside wellbores is one problem faced by oil and Gas production companies resulting in millions of dollars of production downtime every year. New understanding of scale accumulation is allowing production engineers to predict when scale formation will occur, so that adverse operating conditions can be prevented with new inhibitor techniques. Most scale found in fields forms either by direct precipitation from water that occurs naturally in reservoir rocks, or as result of produced water becoming oversaturated with scale components when two incompatible waters meet down-hole.[1] Whenever an oil or gas well produces water, or water injection is used to enhance recovery, there is the possibility that scale forms.

Scale problems have been identified as the leading cause in production decline Worldwide. Scale is an assemblage of hard, inorganic crystals that cake perforations, casing, production tubing, valves, pumps and down-hole completion equipment which result in the clogging of the wellbore and preventing fluid flow, as shown in Fig.1

Scale formation

Scaling is the precipitation of dense, adherent material on metal surfaces and other materials, as shown in Fig. 2. Scale formation at oil producing well screens eventually results in lower oil yields and well failure. In addition, the problem of scale in water flooding occurs all the way from the water injection facilities to the producing well. In general, there are six important regions where scaling can occur during and after injection operations [3]: (i) in the injector wellbore, (ii) near the injection-well bottom-hole, (iii), in the reservoir between the injector and the producer, (iv) at the skin of the producer well, (v) in the producer well-bore,(vi) at the surface facilities.

Scale is produced when groundwater dissolves rocks and minerals releasing calcium and magnesium ions, which in turn produces hard water, which is then deposited as a scale in the bore of the pipe. Water injection to enhance oil recovery can also result in scale deposits. Excessive scaling results in a thick lining on the internal surface of the pipe, which result in reduced production rates, equipment failure, costly down time, and increased production costs. The direct cost of removing scale from one well can be as high as $2.5M, and the cost of deferred production even higher.

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Current Scale Removal Technology

Until recently, ways to treat the problem were limited and sometimes ineffective. When scale forms, a fast, effective removal technique is required. Scale-removal methods involve both chemical and mechanical approaches, each with its own niche depending on the location of the scale and its physical properties. The hydraulic method using pressurized water was first introduced in an elementary form and in the last forty years, hydraulic de-scaling has gained much relevance as standard method for most applications [5].

Scale removal methods, both chemical and mechanical, each have their own niche depending on the location of the scale and the oil chemistry of the reservoir [2]. Chemical scale removal is often the first and lowest cost approach, especially when scale is not easily accessible or exists where conventional mechanical removal methods are ineffective or expensive to deploy. Most mineral scales cannot be dissolved, while some others, such as Calcium Carbonate ($CaCO_3$) can be with acids, however occasionally a tar like or waxy liners of hydrocarbons shelter scale from chemical dissolvent's. There are also the environmental concerns associated with using chemical methods.

Mechanical solutions to remove scale deposits offer a wide array of tools and techniques applicable in wellbore tubing. Like chemical techniques, most mechanical approaches have a limited range of applicability, and selecting the correct method depends on the well and the scale deposit. Mechanical approaches, though varied, are among the most successful methods of scale removal, but often can lead to the damaging of the well bore itself.

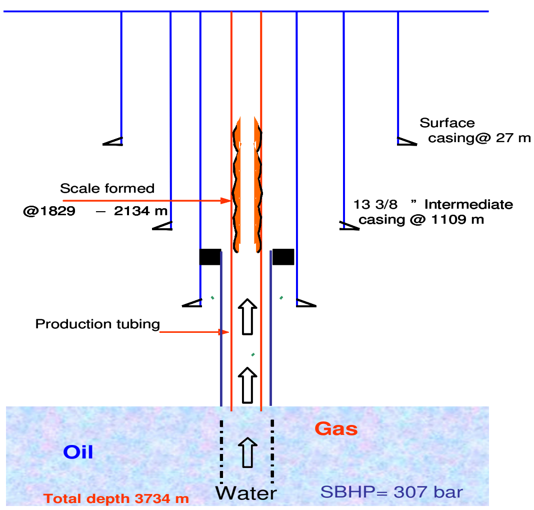

Figure 1. Scale formation in the wellhead.

Figure 2. Scale formation in the production tubing.

Proposed Scale Removal Method

A scale-removal method must therefore be quick, non-damaging to the wellbore tubing, environmentally friendly and effective in preventing re-precipitation of scale. The scale removal technique proposed herewith is one such method. A high pressure spray will be utilized, which will:

- Have sufficient impact force to remove the scale;
- Precise control of impact force to avoid damage to the integrity of the well tubing;
- Use a minimum supply of liquid;
- Cost effective technique to deploy;
- Environmentally friendly;
- Scale growth inhibitors can also be added to the spray to reduce the rate of scale build-up.

The use of sprays for the removal of scale and for cutting through material has been well documented and has become the approved method in a number of industrial applications. However, a spray removal method has not been developed for removing hard-scale within in a pipe in a controlled way to prevent damage to the interior of a pipe [6].

High pressure spraying is one of the most effective processes for particle removal and there are many applications of this technology being used within other industries. However there is very little published information on the utilization of flat overlapping sprays within pipe bores and the prevention of the high pressure sprays from damaging the structural integrity of the pipe. The research will involve developing an understanding of the breakup mechanisms (supply pressures and impact force) for typical scales encountered in well bores. This will allow a methodology to be developed which will optimize the spraying process in order to achieve efficient de-scaling with regard to water usage and time.

This investigation proposes a new and novel technique to address the problem and lay the foundations for a methodology for dealing with a problem in situ that currently requires either aggressive chemicals or expensive mechanical methods. The study entails using high pressure water atomizers (> 10*MPa*) to remove the scale build up in oil and gas wells, as shown in Fig. 3

Experimental Apparatus and Procedures

The Volume Scale Removal (VSR) apparatus is shown in the Fig. 4, which includes: pump (1), unloader valve (2), safety valve (3), gauge pressure (4), three nozzles spray head (5), tubing sample (6), water reservoir (7), and water tank (8)Three pieces of Perspex tube are fixed together by means of flanges and aluminum bars. The top Perspex tube contains the scale sample tubular with the middle one carrying sieves. The bottom tube fixed below the bench is for collecting the water to the reservoir tank.

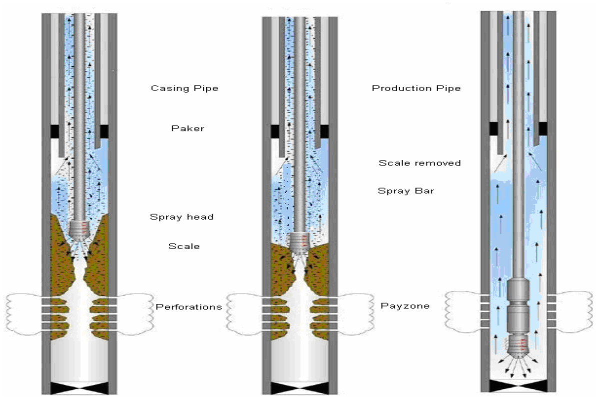

Figure 3. Down-hole spray treatment. [4]

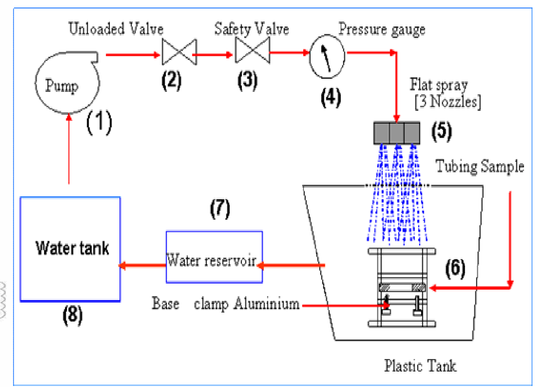

Figure 4. Schematic diagram of the test apparatus.

A Speck Kolben pump was used to deliver high-pressure water to the "spray bar", which is inserted into the oil well tube sample. Water was continuously re-circulated around the system after being filtered, before entering the receiving tank mounted below the outlet of the bottom Perspex tube. The pump had the following specifications, Manufacturer: Speck Kolben Pump Ltd. Type NO25/50-120, Flow rate: 48.7*l/min*, Maximum Working Pressure: 120 bar (12*MPa*).

Each sample was placed securely inside the transparent tube. The scale removed after spraying was collected in a sieve, which was mounted below the sample. The collected scale was dried, weighed and analyzed, thus enabling the removed volume of scale to be measured over a period.

Nozzle Characteristics

To achieve the hydraulic effect of de-scaling, a flow of water is required, which has a suitable combination of values of parameters to increase the impact i.e. pressure, flow rate and the footprint area of the spray [5]. The selection of spray parameters will allow the de-scaling process to be optimized, thus improving scale removal and associated energy cost. This has turned hydraulic scale removal from being a simple question of high pressure to a developing a science on de-scaling systems.

Result and Discussion

Mass flux /Droplet size

Mass flux tests were carried out using a patternator, measuring the radial distribution of the spray produced by the three overlapping nozzle design, as shown in Fig. 5. The patternator consisted of 24 collection holes, each 8 mm in diameter. Water that collected in these holes passes through a drain hole into measuring receptacles located under the patternator. The overlapping spray was observed to have a foot print length of 60 mm and a subsequent foot print area of approximately 180 mm^2, as shown in Fig. 6. The flux measurement for the three atomizers was measured at different heights (10mm, 20mm and 30mm) and is shown in Figs. 6, 7 & 8. At all three heights the footprint area and volume flux remain similar.

The droplet size distribution through the spray was investigated using the Malvern size analyzer; the measured liquid particle sizes were between 350 µm $<D_{0.5}<$200µm. The effect of droplet size on scale removal will be reported in details in a future publication.

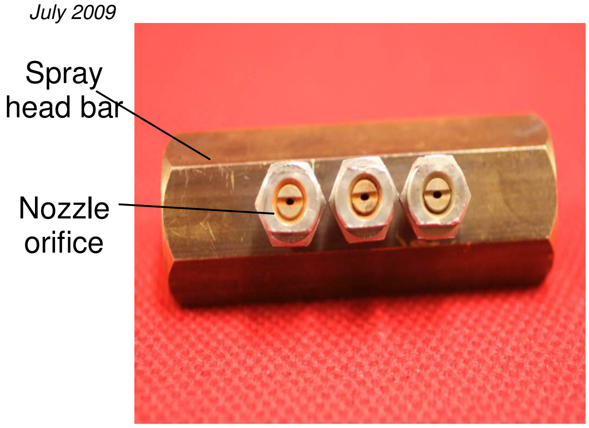

Figure 5. Proposed nozzles Design

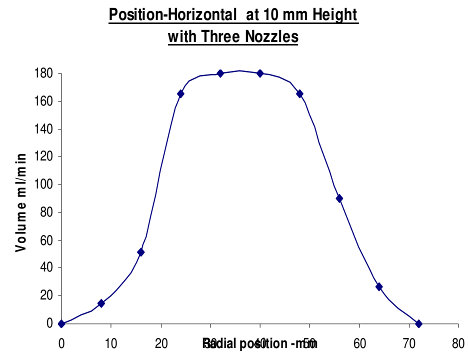

Figure 6. Volume Mass flux at 100 bar

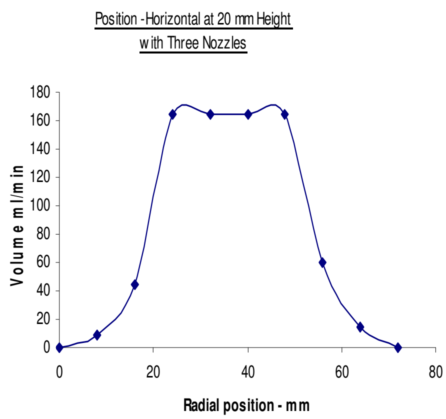

Figure7. Volume Mass flux at 100 bar

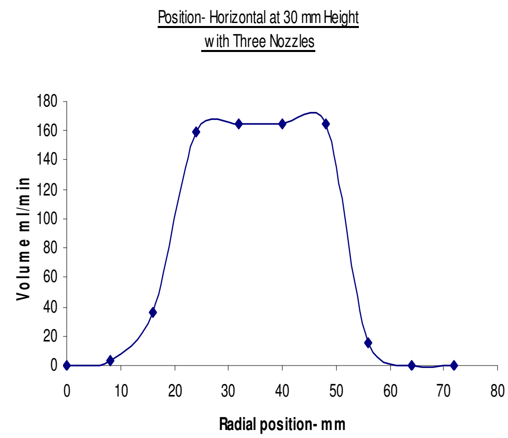

Figure 8. Volume Mass flux at 100 bar

Spray Impact Force

The spray impact force at the wall of the oil tubing is a very important parameter during scale removal, as it relates directly to the force required for removing the scale deposit,and this depends upon the hardness of the scale. It is also improtant that the impact force of the spray is less than that which would cause damage to the oil tube wall.

The impact force was measured across the spray using a force transducer. It was found that at a pressure of less than 19MPa, the hard scale can be removed, Fig. 9 shows the scale removed by three nozzles. The pressure required to shear-off the scale may be signicantly less than that obtained using the test sample. In situ the precitated salt in the well bore exist in the form of a paste which when brought in contact with air solidifies and becomes hardened.The technique here, adopted for removal of hard scales from inner surfaces of tubular bores in oil and gas well relies heavly on the use of high pressure water atomizer (Nozzles) with high impact forces (11Mpa), that is capable of producing coarse droplet of between (350 µm <$D_{0.5}$<200µm) [6]. The result shown in Fig. 10 and Fig. 11 plot impact force across the spray .

Figure 9. Scale removed by using three nozzles

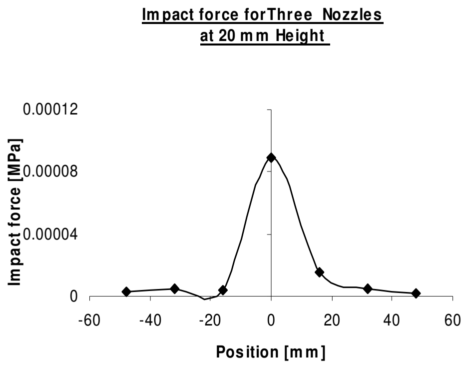

Figure 10. Impact force across the spray at 30 mm height and 100 bar.

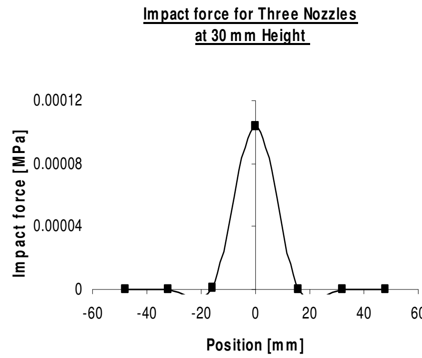

Figure 11. Impact force across the spray at 30 mm height and 100 bar.

Volume Scale Removed

Previous experimental work on scale removal used relatively differents pressures (50, 60 & 70 bar respectively) for 5, 10 & 15 minutes with very little scale collected. This research utilises three overlapping sprays for scale removal at pressure (80, 100 & 110 bar) and the amount of VSR removed is shown in Table 1.

Table 1. Volume Scale Removed over time for three overlapping nozzles.

Pressure (bar)	Spray Time (min)	Height of spray (mm)	Tem p (C°)	Initial weight of sample (gms)	Final weight of sample (gms)	Weight of scale removed (cm^3)	Vol. of scale removed (cm^3)
100	5	70	22	320	319.18	0.82	344.544
100	10	70	25	320	318.54	1.46	515.90
100	15	70	27	320	355	5	1766.78

Table 1 is a typical example of one of the tables obtained for the three nozzles overlapped spray operating at a pressure of 10MPa for 5, 10 & 15 minutes spray time.

The maximum weight of scale sheared off was 5 grams at 110 bar pressure with the overlapping spray by using three nozzles. Following the trend of these results, there is the need to carry out a hardness test by crushing a sample of scale of a known cross-sectional area under a pre-determined load (load) to obtain the shear stress at failure. The value of the maximum yield stress determined as this point now becomes the force that will be needed to shear off the scale. It is therefore possible to compare the values of the Impact force (fluid forces) for each of the test run with the force (Mechanical forces) applied to the scale sample at failure on compression. From the values of the volume flux measurement obtained, the maximum flow rate of 31 l/min for 80 bar pressure and 34 l/min for 110 bar were recorded for the 30mm and 20mm spray height respectively.

The Volume flux measurements enable us to have an understanding of the spray patternation (liquid size distribution) of the fluid at high pressure by using a suitable atomizer (Flat fan nozzles) while the Impact force measurement helps us to accurately calculate the shearing Force required to remove the scale sample from the oil-well production tubing. The maximum weight of scale removed from the experiments using the 3-nozzles overlapped spray was 5 grams at a pressure of 110 bar and at spraying height of 30mm for 15 minutes. Fig.12 and Fig. 13 indicate the Volume Scale Removal (VSR) against spray bar position for the different pressures and time. Result obtained from this shows that the amount of scale removed increases with an increase in time and pressure.

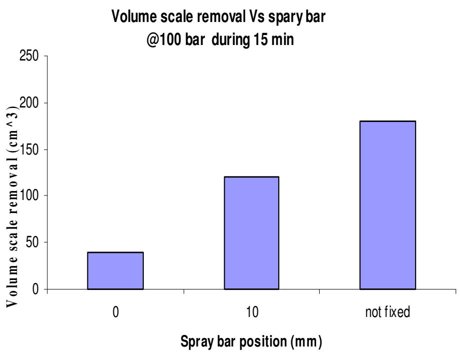

Figure 12. VSR at 100 bar pressure.

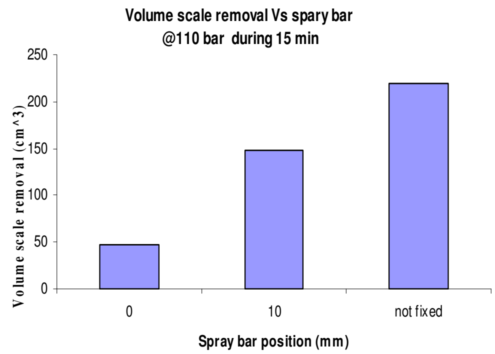

Figure 13. VSR at 110 bar pressure.

Conclusions

The use of high-pressure water sprays for descaling oil tubing are an attractive alternative to mechanical and chemical methods, as they are easy to assemble and operate, environmentally friendly and do not cause damage to the production tubing.

Results of this investigation illustrate that it is difficult to remove scale at low pressure. It was however noticed that greater amount of scale had been removed by each set of nozzle (two, three for overlapped spray). The characteristics of the overlapping, flat fan spray nozzle arrangement examined and its effect on scale removal were studied. Comparative analysis shows the volume of scale can be removed at high pressures at different spray times and nozzle positions. Future works will include the characterization of the sprays and the use of 6 nozzle sets, including the use high-pressure vessel, thus simulating the realistic conditions.

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