HIGH PRESSURE OVERLAPPING FLAT SPRAYS NOZZLES

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Abstract

Descaling of oil and gas well pipes has proved to be a major problem to oil and gas companies, as scale formation significantly reduces well productivity and costs the industry millions of pounds a year. Current scale removal methods involve the use of chemicals, which can be harmful to the environment and mechanical methods, which can affect the integrity of the pipe.

The use of high pressure overlapping sprays provides a potential solution to this problem and one that has significant advantages over traditional methods. The overall aims of this paper is to investigate the characteristics of a novel, overlapping fan spray nozzle arrangement and examine its affect on scale removal for potential use in oil and gas pipe descaling applications.

Introduction

Most scale found in oilfields form 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].

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 Figure 1.

Scaling causes a large number of costly operations such as perforation, re drilling, stimulation and other remedial actions. It is estimated that the productivity of oil wells in the USA has declined significantly because of scale of formation of the well tubing. It is likely that many wells or even reservoirs are abandoned permanently because of scaling (Griffin, 1954). [2]

Scale removal

Over time, scale formation within the pipework reduces the cross-sectional area of the pipe and causes the pressure drop of the well to increase, thus reducing the production rate of oil. When the reservoir pressure drops, traditional techniques such as injecting water into reservoir, or gas lift are used to try and increase the pressure of the well. The worse case scenario is the total blockage of the production tubing, in which case the pipe has to be removed and replaced. This has happened in the North Sea [6] where the production fell from 30000 Barrel Per Day (BPD) to zero in 24 hours. Scale problems in wells. Also been reported from Brazil, Canada, Angola, Western Siberia and Saudi Arabia [3][4][5][6].

The precipitated mineral growth, form crystals that stick in the surface of the pipe, forming scale. The scale in the oil/gas production pipe is similar to that of scale to be found in domestic appliances, such as, plumbing pipes or in the base of a kettle. The most common types of scale found in the oil/gas wells are; Calcium sulphate ($CaSO_4$), Calcium Carbonate ($CaCO_3$), Barium Sulphate ($BaSo_4$), Strontium Sulphate ($SrSo_4$). Figure 2 shows typical scale build-up within a sample of well tubing.

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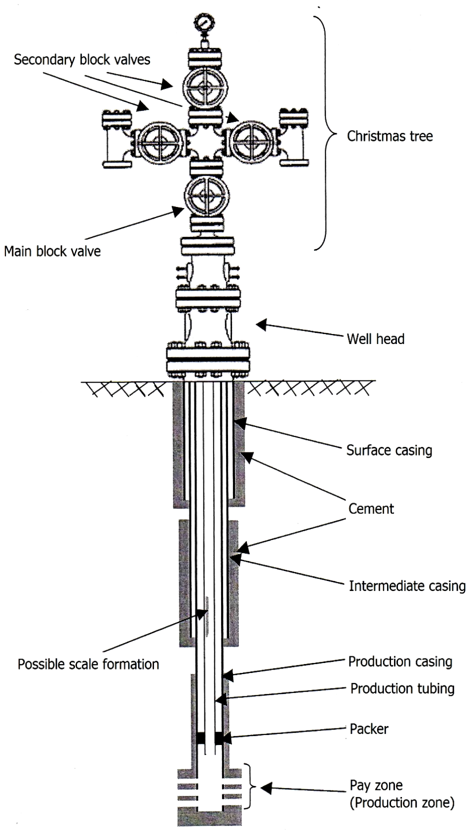

Figure 1: Typical oil well installation with scale deposit

Figure 2: Cross sectional of wax deposit in production tubing.

Until recently, ways to treat the problem were limited and sometimes ineffective. When scale forms, a fast, effective removal technique is needed. Currently available scale-removal methods involve both chemical and mechanical approaches, each with its own niche depending on the location of the scale within the extraction path and the physical properties of the individual types of scale. Figure 2 shows scale deposition in a production tubing of oil well.

Chemical scale removal is often the first and lowest cost approach, especially when the scale is not easily accessible or exists where conventional mechanical removal methods are ineffective or expensive to deploy. Most mineral scales cannot be dissolved using chemical means, while some others such as Calcium Carbonate, can be broken up with acids. However, occasionally tar like or waxy liners of hydrocarbons shelter scale from such chemical dissolvment. There are also environmental concerns associated with using chemical methods.

Mechanical solutions to remove scale deposits offer a wide array of tools and techniques applicable in wellbore tubulars. 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 damage of the well bore itself. However, the use of high pressure water sprays avoid the pitfalls of both chemical and mechanical methods, and this project proposes to appraoch the problem in this way

New Scale Removal Method

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 high pressure sprays from damaging the structural integrity of the pipe.

A scale-removal method must therefore be fast, non-damaging to the wellbore tubing, environmentally friendly and effective in preventing re-precipitation of scale. The advantages of high pressure spray are:

- environmentally friendly;
- sufficient impact force to remove the scale;
- a minimum of liquid to be supplied;
- cost effective technique to deploy;
- precise control of impact force to avoid damage to the integrity of the well tubing.

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, spray for scale removal has not been developed for removing hard-scale within a pipe in a controlled way to prevent damage to the interior of a pipe. [6]

The purpose of this investigation is to cerate a new novel technique to address the problem and lay the foundations for a methodology for dealing in situ with a problem that currently requires either aggressive chemicals or expensive mechanical methods.

Apparatus and Procedures

Descaling experiments were conducted for two different scale samples in order to calculate the amount removed, with one, two and three overlapping fan sprays when set at the optimum position for scale removal. Figure 3 is a schematic of the experimental rig which consists of the following components: high-pressure pump (A), hydraulic tubing (B), spray header (C), overlapping flat spray nozzles (D), spray angle (E), well tubing sample (F), base-clamp (G), water collection bench (H), water return hose (I), water tank (J) and vertical adjustment for the nozzles (K).

The first scale sample was candle wax, this was used to determine the most effective nozzle orientation for scale removal, such as spraying distance (25, 50 and 75mm) and orientation of the nozzles relative to the sample (30, 45, 60 and 90°) over a five minute spray duration and at a water supply pressure of 90bar.
The second sample was an oil sample (wax scale) from Zelten oilfield in Libya (Sirte Oil Company, Libya). From an understanding of the optimum position of the nozzles relative to the scale for maximum scale removal, these settings were employed on the sample in order to measure the amount of scale removed over five minute spray duration and a water supply pressure of 90 bar. Figure 4 shows the wax scales were removed during the experiment.

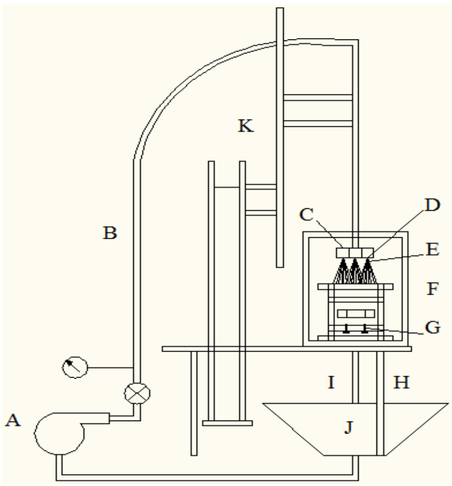

Figure 3: Experiment Rig

Figure 4: Wax scales removed from oil sample

Results

Candle Wax

Figures 5, 6 and 7 are examples of the wax plates that were used for testing one, two and three fan spray nozzles at varying nozzle heights (25, 50 and 75mm) and orientation (30, 40, 60 and 90°) relative to the wax sample. The amount of scale removed over a five minute spray duration at 90bar water supply pressure are shown in Tables 1, 2 and 3. Form the Tables it is apparent that three nozzles, at a height of 75mm and 45˚ relative to the wax sample produces maximum wax removal.

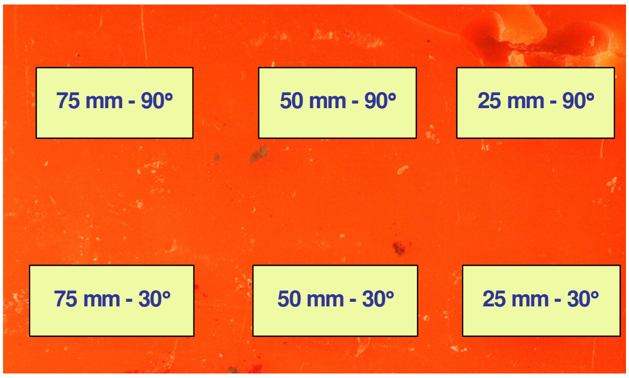

Figure 5: Wax plate for one nozzle

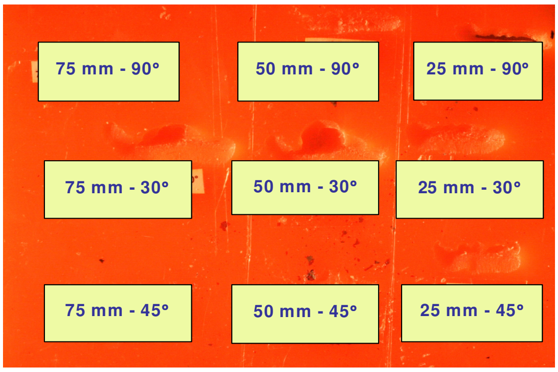

Figure 6: Wax plate for two nozzles

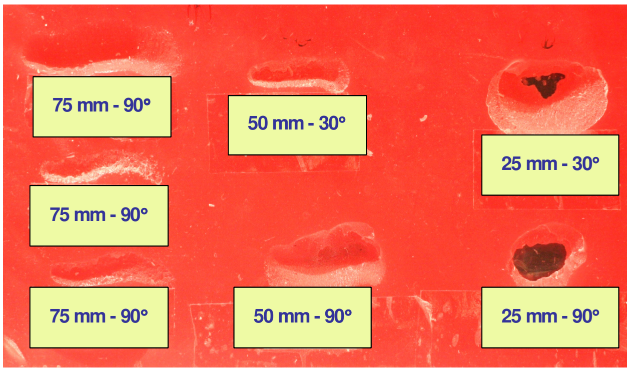

Figure 7: Wax plate for three nozzles

Oil Well Sample

Four fan nozzles were setup to produce maximum scale removal. This orientation was derived from the wax removal tests, which was found to be: three nozzles, a spray height of 75mm and spray angle of 45˚. The nozzles were sprayed over a five minute spray duration and 13.5g of scale was removed, as shown in Fig.4.

Discussion

The results show that for three nozzles there is an exponential rise in the amount of scale removed. Scale removed also increases with height as shown for the 75mm distance case, this is probably due to a greater footprint area, whilst the distance is not too great so as to reduce the impact force of the spray.

The orientation of the nozzles appear to be of primary importance in scale removal, at 90˚ the scale is impacted face on and a hole approximately the size of the spray foot print area is produced, this is probably more suitable for hard scales where a sudden impact will shatter the scale off the surface. With the nozzles at 60˚ the angle is too shallow and the sheet of water skims of the surface and removes very little scale. It is found that an angle of 45˚ promotes maximum scale removal as the sheet of water shears off layers of the wax and would be beneficial for soft scales.

From the optimum spraying distance and orientation it was possible to remove scale from an actual well pipe sample, even at the relatively low pressure of 90bar, this is encouraging as at this pressure there is no danger of damaging the integrity of the production tubing.

Table 1: Volume removal for one nozzles

Height (mm) \ θ	Q (ml)			
	30°	45°	60°	90°
25	0.5	0	0	5
50	0.5	0	0	0.5
75	0.5	0	0	0

Table 2: Volume removal for two nozzles

Height (mm) \ θ	Q (ml)			
	30°	45°	60°	90°
25	3	4	2	2
50	2	5	0	3
75	3	7	0	1

Table 3: Volume removal for three nozzles

Height (mm) \ θ	Q (ml)			
	30°	45°	60°	90°
25	2	1	0	4
50	3	0.5	0	1
75	3	0	0	0

Conclusions and Future Work

Scale formation is one of the problems facing oil and gas production wells. A high-Pressure overlapping water fan spray was used to remove formation scale from an oil production tubing sample. This was achieved after an initial investigation into determining the most suitable nozzle distance and orientation for maximum scale removal.

Future work will involve characterising the structure of the spray using PDA at distances of 25, 50 and 75mm downstream, to investigate the rate of descaling over a range of increasing pressures and to simulate the spray under well conditions at high ambient pressures.

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