Descaling of Wellhead Production Tubing Using High Pressure Water Atomisers

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Abstract
Scale and corrosion formed in 'Tubing' pipes of the wellhead are the two production problems which can not only impact business profitability but, can also affect the safety and integrity of the asset. Managing corrosion and scale is critical and increasingly challenging in an engineering and operation fields. Scale deposition costs the petroleum industry, typically, $1,000,000 each year, depending on the size of the plant, and it is the leading cause in production decline worldwide.
This paper provides an overview of the design and analysis of the proposed simulated apparatus under *atmospheric pressure conditions*, using high pressure water atomisers spraying with high impact force, in determining the removal of the corresponding scale. Various tube samples were obtained from oil and gas fields which already had deposited scale, and they were examined under different conditions using the apparatus. Preliminarily results and analysis of the parametric effects of parameters , on chosen samples, in removing the typical Calcium Carbonate ($CaCO_3$) scale are given, for high pressure water atomisers (typically greater than 7 *MPa)* with high impact force (typically greater than 10 *MPa*) and coarse spray size of $350\mu m < D_{v0.5} < 2000\mu m$.

Introduction
Oil and natural gas, are accumulated in sedimentary rocks ,either alone or in combination with each other or with water. Figure 1 shows schematically a typical well with its corresponding related components. Exploration for oil and natural gas is risky, expensive and technically complex business. A typical cost of drilling/completing a commercial gas or oil well costs millions of dollars, when a well is drilled. Measurements must be taken for safety, environmental protection and resource management, including the use of appropriate equipment. Once commercial oil or gas zone is encountered, the well is completed by the following requirements and installations: The Casing, Well completion, Wellhead assembly, and Production formation treatment. There are various methods available for removing the scale such as chemical, mechanical or hydraulic, as previously reviewed [1-3 inclusive]. Scale is an assembly of deposits that perforate any of the casing, production tubing, down-hole pumps, and completion equipment (i.e. safety valve) and clogging well bore. Furthermore, scale can prevent fluid flowing due to the deposited scale along the water paths from reservoir to surface equipment. Most scale found in oil fields forms either by direct precipitation from the water, that occurs naturally in reservoir rocks, or as a result of a produced water becoming oversaturated, with scale components, when two or more incompatible waters meet down the hole. Whenever an oil or gas well produces water, or, water injection is used to enhance recovery, there is a possibility that scale could form, in some areas where entire regions are prone to a scale. Scale can develop in the formation pores, near the well bore, reducing the formation porosity and permeability. Scale such as *Calcium carbonate* (CaCO3) growth appears in production tubing ,safety valve and gas lift mandrels ,which can be dissolved with acids ,in most cases ,as other cases , the hydrocarbons protect scale from chemical dissolvers and accumulated as hard solid layers in production tubing ,sometimes block it completely and are less easily removed. High pressure water sprays technique proposed herewith is to remove scale, using minimum supply water and which does not affect the strength of the tubing of the wells and it is also environmentally friendly.

This investigation is mainly experimental, as previously described [1-3], is divided into two basic phases: Phase-1 involves volume of scale removal (VSR) tests under *atmospheric* pressure condition using a simulated down-hole production tube of oil/gas well and Phase-2 is the VSR tests under normal well *reservoir* pressure. Here the proposed simulated design of the Phase1 is only presented.

The main objectives of present work are: (a) to highlights the preliminarily results and analysis of the mathematical modelling, using ANSYS software, to establish and validate the required limits of impact force for a given water pressure as well as the required angle of sprays for maximum scale removal (b) to provide an overview of the design and analysis of the proposed simulated apparatus under atmospheric pressure

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Proceedings of the 21th ILASS - Europe Meeting 2007

conditions, using high pressure water atomisers spraying with high impact force, in determining the removal of the scale (typically Calcium Carbonate), and (c) to provide typical results and analysis of the parametric effects of parameters ,in removing these scales, for high pressure water atomisers (greater than 7 *MPa*) with high impact force (greater than 10 *MPa*) and coarse spray size of 350μm <$D_{v0.5}$<2000μm.

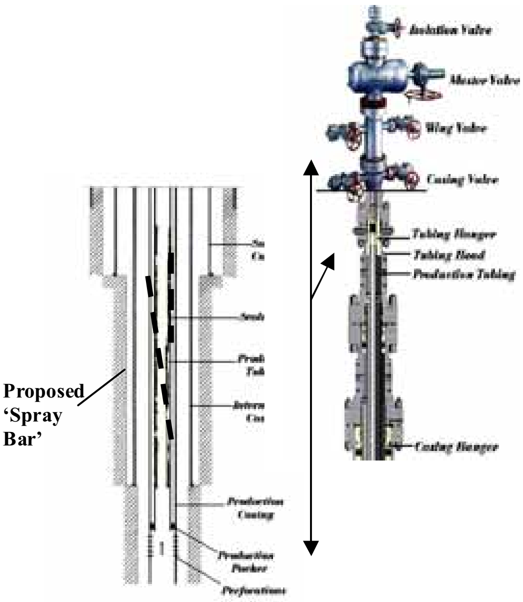


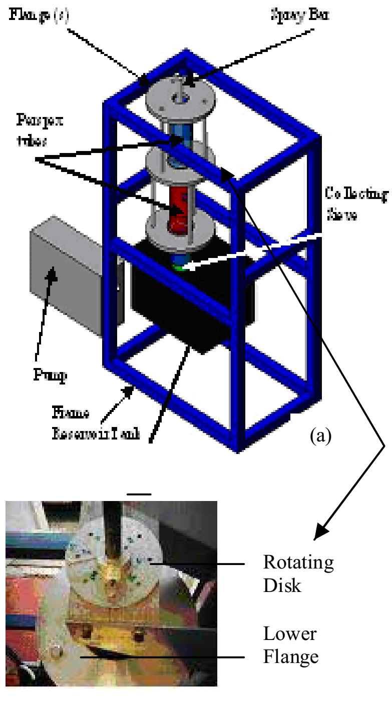
Figure 1 Typical Schematic illustration of a well for oil/gas production

Experimental Apparatus and Procedure

The details of the Volume Scale Removal (VSR) apparatus shown in the Figure 2(a) was described in the previous publications [1-3]. Here a brief description is provided. The apparatus is made from a transparent material called 'Perspex', which is a polymer with high mechanical resistance properties. Three pieces of Perspex tube are fixed together by means of flanges and aluminium 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. The only difference in the design of the apparatus, shown in Figure 2(a), compared with the one used in the previous works [1-3] is that of the Rotating Holder Disk shown in Figure 2(b). The disk ensures that the spray bar is always in the same height above the sample and also enables the automatic control of the spray bar at 90 degrees interval.

A Speck Kolben pump was used to deliver high pressure water to the "spray bar". Supply 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 (see also Figure 2). The pump has the following specifications [2]: 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 securely placed inside the top transparent tube. At the commencement of the experiment the 'spray bar' (or 'Spray head') was located centrally above the sample and was made to travel down, parallel to the centreline of tube, inside the sample, spraying onto the inner surface of the scale at a high pressure, as shown schematically in Figure 3. The corresponding scale removed was collected by two sieves with different mesh sizes. The collected scale was dried, weighed and analysed, thus enabling the removed volume of scale to be estimated over a period of time. The "spray bar" shown schematically in Figure 3 consists of a total of 23 atomisers, with 21 plugged, type 1/8 (NTP), to provide flexibility in using either single atomiser or a combination of them at any time. Flat spray atomiser used has the following specifications [2-3]: Spray angle: 60 degrees, Capacity: 0.5838 m^3/h, Atomiser type: high-pressure flat fan, Manufactured by: Lechler GmbH.



(b)

Figure 2 Schematic arrangement of Apparatus© (a) and rotating holder disk (b)

Results and Discussions

Modelling Considerations

It is important to characterise the sprays prior to the VSR tests, as briefly described previously in [1]. Detail and comprehensive results of spray characterization; however, relating to the performances of the atomisers will be provided in the future and separate publications.

The primary purpose of FE modelling using ANSYS was to gain understanding on the level of impact force that required for the sprays and its angle of attack upon impaction on the scale surface. A symmetrical cylindrical tube with deposited scale was used in the modelling. A quarter of the tube was thus modelled with 20mm length with its volume being divided by nine segments, although the actual production tubing is about 3600m. Figure 4 shows schematically the geometry that used for the static analysis (linear, elastic and isotropic). Two types of loading were applied: in the first application, uniform impact force of the sprays at a area of $3500 \mu m^2$ (Young's Modules) were applied at two different locations and in the second application point loads were used which were acted at different angles upon the impaction of sprays, relative to its centreline, onto the scale surface. It was not however possible, in the current study, to model the level of stress required between scale and the steel wall to remove the scale. The results did not converge at the increased pressure up to *13MPa*. Figure 5 shows schematically the areas that the pressure applied, with the upper most area (1) (see Figure 5(b) which was free to deform, where the sprays targeted first, with all other areas (2, 3 etc) being kept fixed, as the model assumed to be symmetrical and it were not to be free in any degrees of freedom (see Figure 5(c). A constant pressure applied to these areas varied from *7 MPa* to *13 MPa* by increments of *1 MPa*. Figure 6 shows an illustration where the first area meets the maximum Von Misses stress in the initial cracking/crushing than the second and subsequent areas. This means that, at a given time, the amount water used to remove the scales from the first area will be less compared to other areas. Figure 7 also shows the applied loads at different angle of attacks and at three different areas on the surface of scale.

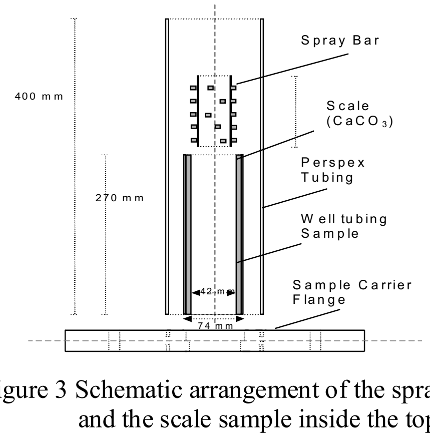


Figure 3 Schematic arrangement of the spray bar and the scale sample inside the top Perspex tube

The effects of changing the angle of attack from 45 to 120 degrees of the high-pressure water sprays on the scale at various locations of the tube were also analysed. Figure 8 and 9 also show the variation of maximum stress against applied pressure of the two areas. Figure 10 shows the first area, upper surface of the tube, the required angle of attack of sprays, relative to the centreline of the sprays, to remove the scale, found to be at 45 degrees. Whereas, for the subsequent areas the required angle to remove the scale found to be 90 degrees. This is similar to the previous findings reported in [1] and in the next Section.

Volume Scale Removal (VSR)

Calcium Carbonate (CaCO3) scale was removed from the sample (see Figure 11) using two and three atomizers with spray bar rotated at 90 degrees interval and kept at 12mm above the sample, similar to previous work reported [1-3]. The results of the two atomizers were also compared with previous published work which was at the wider spray angle (60degree) than present work of 15 degree.

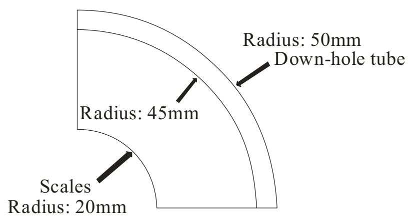


Figure 4 Geometric and dimensions of the tube for FE modelling

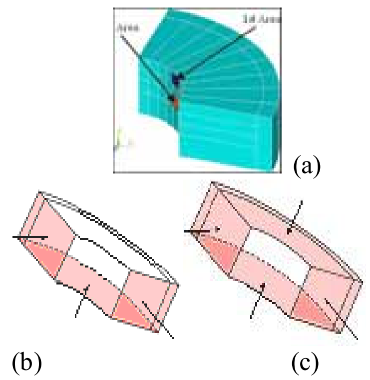


Figure 5 Application of pressure on two different areas (a), with lower areas fixed (b) and (c) all areas fixed except the middle area.

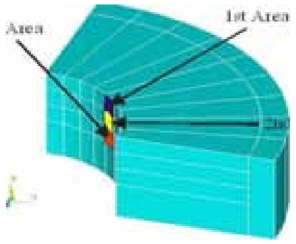


Figure 6 Illustration of the typical pressure of 7*MPa* to the first area

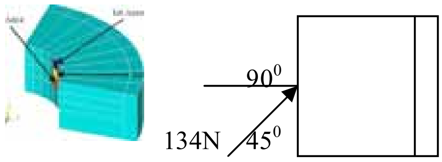


Figure 7 Typical illustration applied loads at different angle of attacks on three areas on the surface of scale

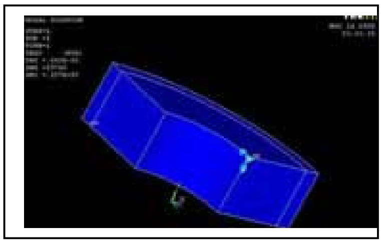


Figure 8 Illustrates typical maximum stress level when the angle attack varies from 45 to 120 degrees

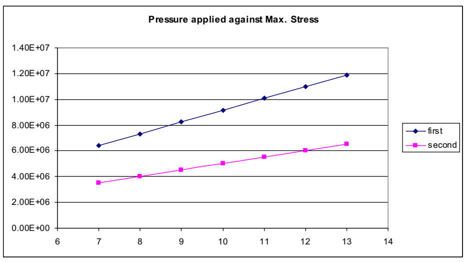


Figure 9 Typical variation of applied pressure with maximum stress

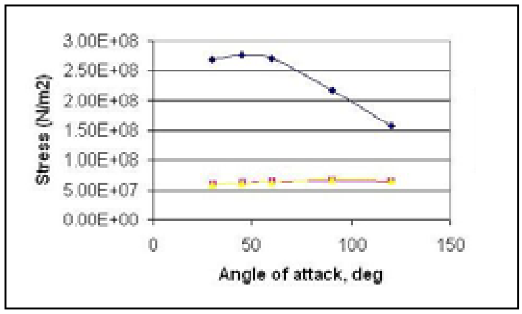


Figure 10 Typical variation of angle of attack with maximum stress on various areas

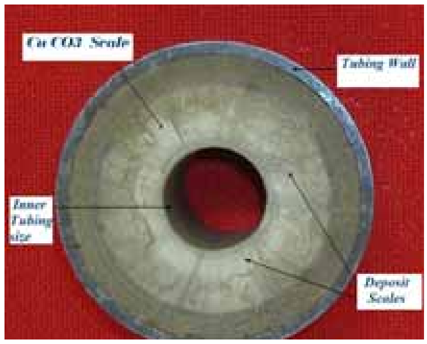


Figure 11 Sample of scale deposit in oil tubing from Libya

Figure 12 and 13 show the typical variation of VSR with respect to time for two and three atomizers respectively at 11*MPa*. As can be seen the total volume of scale is removed increases as the spraying time is increased. Figure 14 also typified the asymptotic variation of total scale removed as the pressure increases. These trends are similar to those found previously by Nasr et al [1-2]. The amount of VSR found to be 27% from the total VSR with two atomiser (2326m^3) as shown in Figure 14 and 73% with three atomizers equating to 6197cm^3. Figure 15 shows the fragmented scale removed with three atomisers.

Figure 16 also provides comparison of the findings of Elgamodi[2] with two atomizers with spray angle of 60 degree and the present results with 15 degree spraying angle. As can be seen significant level of scale removed at wider spray angle than 15degree. However, the angle of attack of 45 and 90 degrees have also found to have substantial effect on VSR which are closely compared with those predicted using FE modelling, as shown previously in Figures 9 and 10.

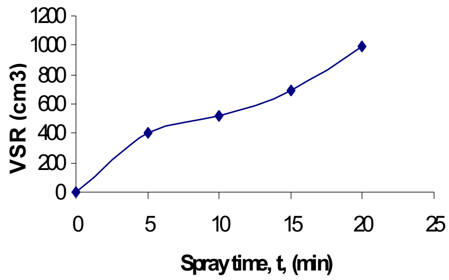


Figure 12 Typical variation of VSR with time using two atomisers at 11 *MPa*

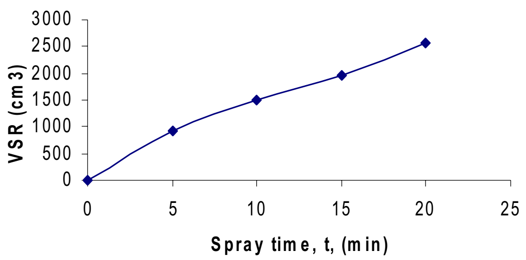


Figure 13 Typical variation of VSR with time using three atomisers at 11 *MPa*

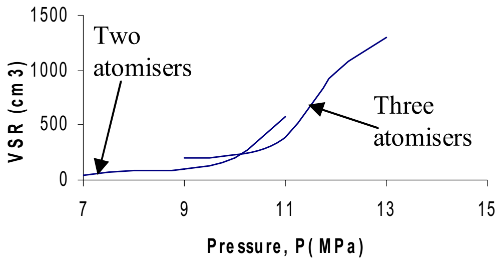


Figure 14 Typical VSR with pressure using two and three atomisers with the spray duration of 10 *min*

Conclusions and future works

At a pressure of 11MPa the first area of the impact shows a 55% more stress level than the second area (see Figure 7). This demonstrates that the first area of the impact could undergo crushing or cracking at a given pressure than other areas which requires less spray time in removing the hard scale. Furthermore, the FE analysis shows that the spray angle of 45 and 90 degrees are most effective in removing the volume of scale.

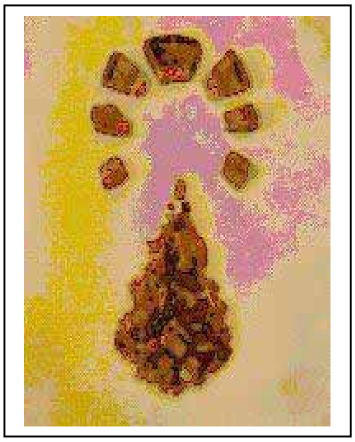


Figure 15 Fragmented scale removed with three atomisers (6197 cm^3)

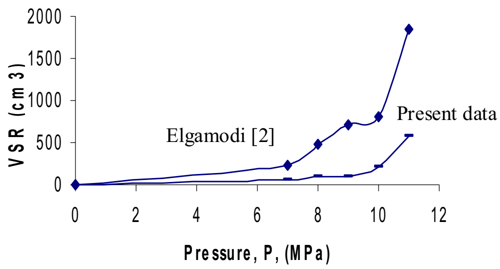


Figure 16 Comparison of VSR with pressure with two atomisers

VSR is increased by more than 45% when three atomizers used compared to two atomizers. Increasing the pressure can increase the volume of scale removed. It was also found that experimental results are closely compared with those estimated via mathematical modelling. Future work will report on increasing the number of atomizers to the level in complete removal of the scale and provide detail results for the characterization of the sprays, including realistic tests using pressure vessel.

REFERENCES

[1] Nasr, G. G. and Burby L.M., Descaling from downhole Tubing of Oil and Gas Wells Using High Pressure Water, ICLASS 06, Tokoyo, Japan, Sept. 06.
[2] Elgamodi, A., Descling of Down-Hole of Oil/Gas Wells by Using High Pressure Water Spray Atomisers, MSc Dissertation, and Sept. 2005.

[3] Nasr, G.G and Burby, M.L., Descaling from Down-hole Tubing of Oil and Gas Wells using High Pressure Water, Proceedings of the 20th ILASS-Europe, 2005.
[4] Nasr, G.G., Hilah, N., and Azzopardi, B., Scale Removal from Down-Hole Tubing of Oil and Gas, Utilising High Pressure Water Atomisers: a review, design simulation and analysis, Proc. 19th Annual Conference on Liquid Atomisation and Spray Systems (ILASS-Europe, 04), pp 564-569.
[5] Cabtree, M., Eslinger, D., Fletcher, P., Johnson, A., King, G., Fighting Scale Removal and Prevention, Oilfield Review, autumn 1999.
[6] Geothermal Training Programme, (Reports b 2001, Number 13), The United Nations University, Iceland.
[7] William C. Lyons. Standard Handbook of Petroleum & Natural Gas Engineering. Vol. I and II, Gulf Professional Publishing, 1996.
[8] Allen, T.O. & Roberts A.P. (1989) Production Operations Vol. I and II, Well Compilations, Workover and Stimulation. OGCI Inc., Technical Publications, Tulsa, Oklahoma.
[9] www.bjservices.com (acc. on 27/07/2006)
[10] www.Chemical.com (acc. On 09/05/2006) [11] www.Chlumberger.com (acc. on 14/06/2006)