Characterising High Pressure Overlapping Sprays Using Phase Doppler Anemometry (PDA)

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Abstract

The high pressure overlapping flat spray atomiser are used for removing scale deposition and the blockage that normally experienced in the well bore of oil and gas production tubing. This method provides significant advantages over current scale removal methods that involve the use of chemicals or other harmful substances which are impediment to the environment and can also affect the integrity of the pipe.

This paper reports on characterising the overlapping sprays using Phase-Doppler Anemometry (PDA) at various radial positions across the spray and distance downstream of the atomiser. The results also provides information on the optimum downstream distances which are required in order to achieve the highest impact force for removing the corresponding scale from the production tubing.

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Introduction

One of the most common production problems in oil and gas fields is scale deposition, Scale blockages formed in the wellbores decrease significantly the output of the production wells. Scale is experienced in almost all the oil and gas fields around the world. The flow rate in an oil/gas production fields depends on the reservoir pressure energy and the drop of the pressure in the well due to the flow area available, flow restrictions, and the header that has to be overcome, which depends on the well depth. Experience in the oil industry has indicated that many oil wells have suffered flow restriction because of scale deposition within the oil producing formation matrix and the down-hole equipment, generally in primary, secondary and tertiary oil recovery operation as well as scale deposits in the surface production equipment. 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].

Previous experience shows that in de-scaling process, apart from the injection pressure and droplet sizes, particularly in steel making, impact force is a significant parameter in removing hard surface scale, this has an a significant influence on the spray patternation, even though the condition of the surface may quite different [8].

Current scale removal methods involve the use of chemical, which can be harmful to the environment. The use of high pressure overlapping sprays provides a potential insight to the problem. This will be corrected by characterising the overlapping flat spray by using Phase Doppler Anemometry (PDA) with regards to velocity, SMD, liquid volume flux, and the size of the droplets.

The overall aim of this paper is to develop an understanding of the descaling process using high pressure overlapping sprays. PDA of the spray structure will be validated by experimental data which will be utilised in optimisation of the spray for descaling at both atmospheric and oil/gas rig conditions.

Apparatus and Procedures

The experimental apparatus was designed to investigate the structure of one, two and three overlapping flat fan spray atomisers (manufactured by Lechler Ltd.) at high pressure and at three different downstream distances using water to obtain the following data:

- Velocity profiles of overlapping flat fan spray atomisers.
- Sauter Mean Diameter (SMD)
- Liquid volume flux of the drops

Figure 1 shows side view of the mounting arrangement of the PDA optics to obtain the axial velocity component for the flat spray and spray droplets. The laser and the receiver are mounted on two arms that are capable of being moved to various axial distances from the face of flat fan spray atomiser. To obtain radial positions throughout the spray the mounting trolley is traversed horizontally relative to the beams with the transmission optics fixed.

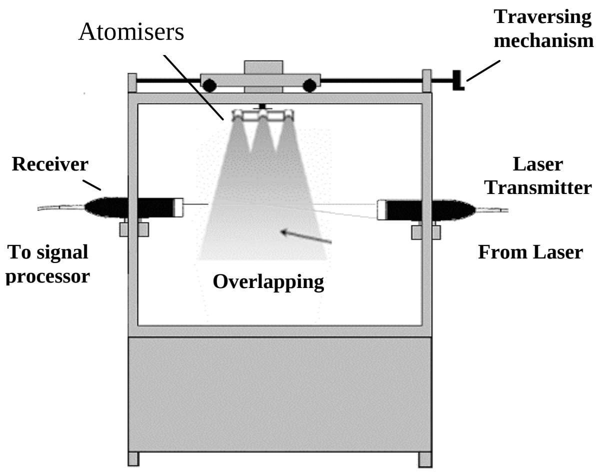

Figure1: Plan view of the mounting arrangment for the PDA optics

During the experimental setup both the transmitting and receiving optics were optimised for data acquisition. The only setting that can be adjusted on the transmitting optics is the power level of the laser. For duration of all the tests carried out, the maximum power setting was used which can have the effect of increasing the measuring volume.

The focal length of the receiver was 310mm. Decreasing the focal length of the receiver increases the sensitivity of the optics allowing the receiver to measure smaller particles. However there are trade-offs with reducing the focal length such as reducing the size of the measurement volume and reducing the maximum droplet diameter that can be measured. The set focal length of 310mm was suitable for measuring the range of particles in the experiments.

Figure 2 shows the schematic diagram of the radial positions used for measuring the velocity, SMD and liquid volume flux of the drops using PDA.

The PDA experiment used 1, 2 and 3 atomisers as shown qualitatively in Figures 3-5 respectively. The measured downstream distances show the three different distances which are (25, 50 and 75 mm).

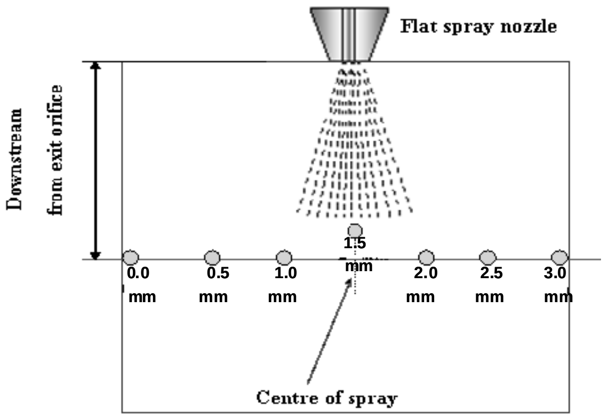

Figure2: Schematic diagram of the radial positions.

Results and Discussion

Using the radial measurement positions shown in Figure 2, Microsoft Excel software was used to produce ‘radial plots for the atomiser. Figures 6-8 show the velocity profiles for one, two and three overlapping flat fan spray atomisers. The radial plots are the direct measurements with no interpolation between positions which permit the variations of drop size and drop velocity to be presented graphically at different downstream distances 25, 50 and 75 mm from the exit of the orifice of the flat spray atomiser.

Figures 6-8 show the distribution of mean drop velocity for different atomisers that are reasonably axis symmetric, providing confirmation of the validity of the PDA method with regards to the corresponding spray patternation. The atomiser has its highest drop velocity near the centreline. There is also expected clear trend showing the reduction in the velocity of the drops as the downstream distance increases.

Figures 9-11 also show the PDA measurements for SMD for different atomisers at various supply pressures (3.7, 4.8 and 6MPa respectively) at three different downstream positions (25, 50 and 75 mm). The increase in drop diameter as the downstream distances increase can also be seen in Figures 9-11. The drop size distribution through the spray was found to be between 350µm<SMD<200 µm. Moreover, as one moves downstream, the distribution of SMD becomes somewhat homogenous across the spray, after an initial region where the smaller drops are concentrated towards the central region of the spray.

Liquid volume flux was also measured at different radial positions across of the spray as shown previously in Figures 3-5. The regions where maximum liquid flux appears are also shown in these images.

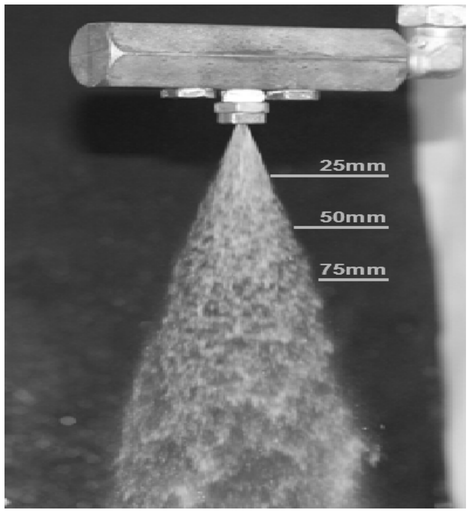

Figure3: Image of spray with one atomiser

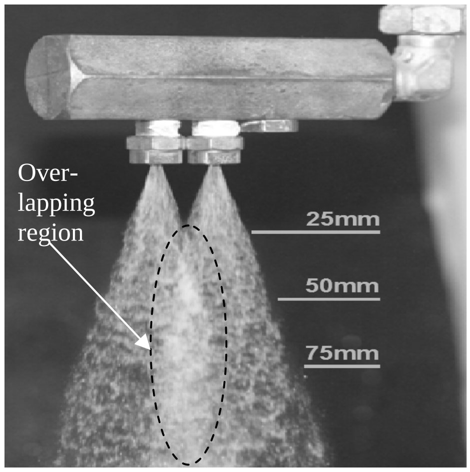

Figure4: Image of spray with two atomisers

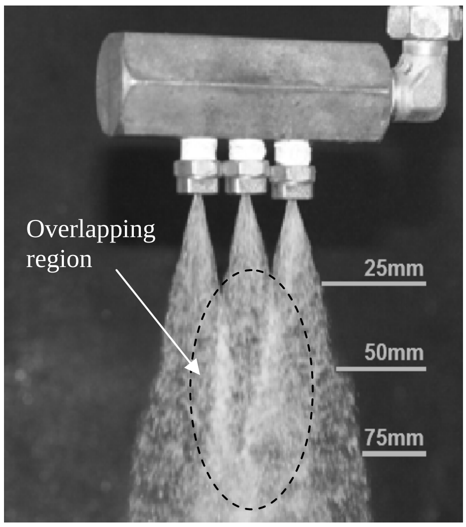

Figure5: Image of spray with three atomisers

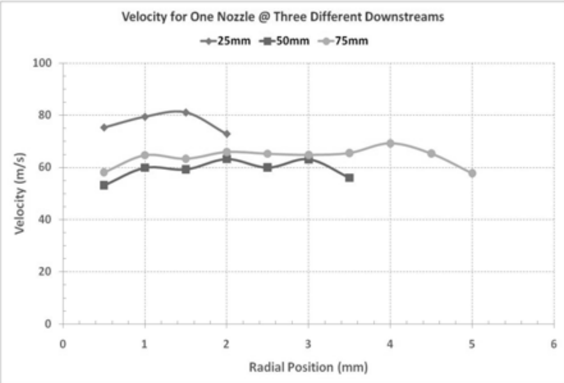

Figure6: Velocity comparison for one spray atomiser at three different downstream positions

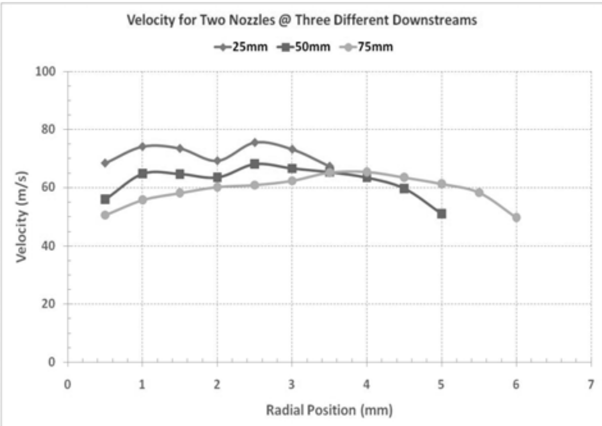

Figure7: Velocity comparison for two spray atomisers at three different downstream positions

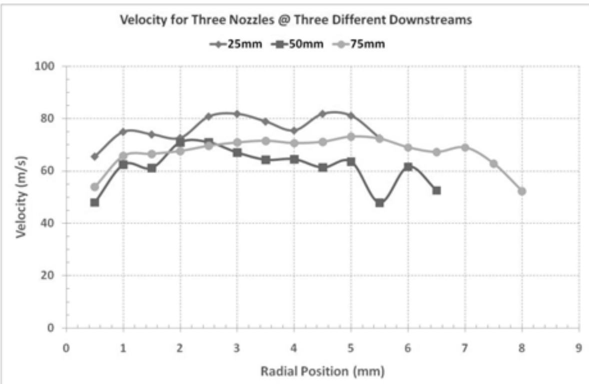

Figure8: Velocity comparison for three spray atomisers at three different downstream positions

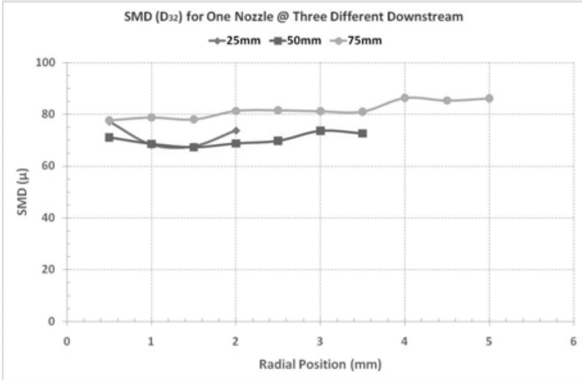

Figure9: SMD comparison for one spray atomiser at three different downstream positions

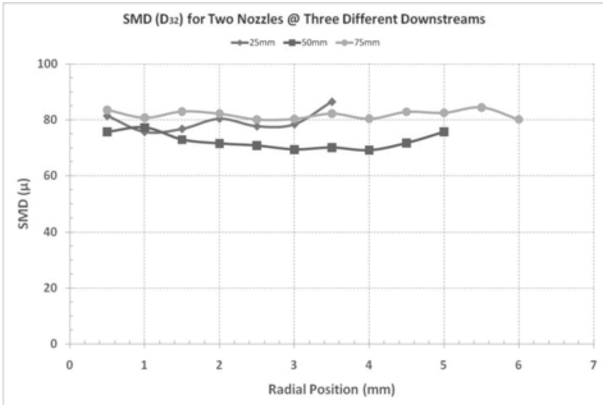

Figure10: SMD comparison for two spray atomisers at three different downstream positions

Figures 12-17 also typified graphically the liquid volume flux at different downstream distances (25mm, 50mm, and 75mm). The maximum liquid volume flux at the respective radial positions across the spray can also be seen on these figures.

The expected difficulties in taking PDA measurements in dense spray became, particularly apparent as the measurement taken at different downstream distances. There are regions that a number of droplets may occupy the measuring volume at the same time, leading to unprocessable data gathering, due to low validation rates. To reduce the occurrence of “multiple occupancy” and increase the light intensity, the size of the measuring volume were reduced. By decreasing the control volume this will also reduce the number of fringes, therefore the amount of light scattered by each droplet will be smaller, resulting in a weaker burst signal which may cause the equipment to have difficulty in processing the signal to determine the Doppler frequency. Nevertheless each test run was repeated three times to ensure the accuracy of the obtained data.

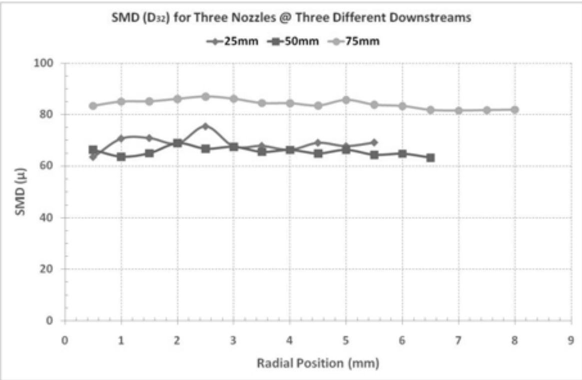

Figure11: SMD comparison for three spray atomisers at three different downstream positions

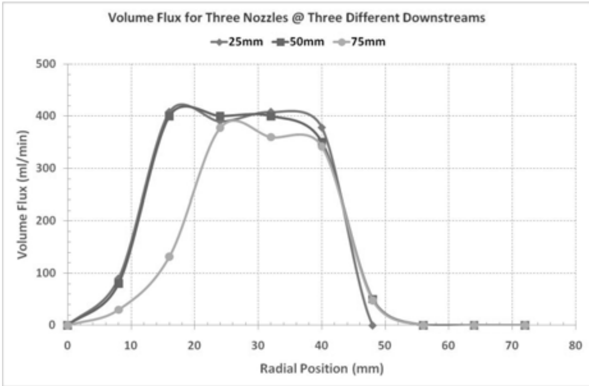

Figure14: Volume flux comparison for 3 spray atomisers at three different downstream positions

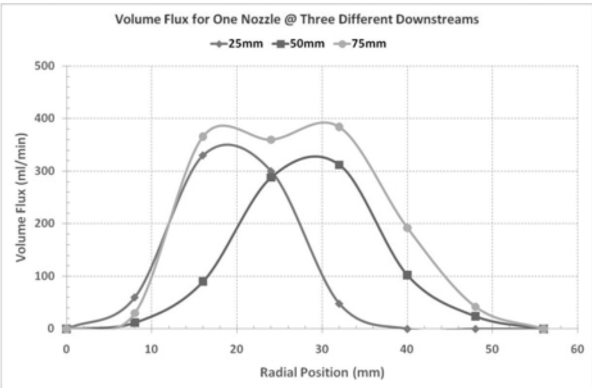

Figure12: Volume Flux comparison for 1 spray atomiser at three different downstream postions

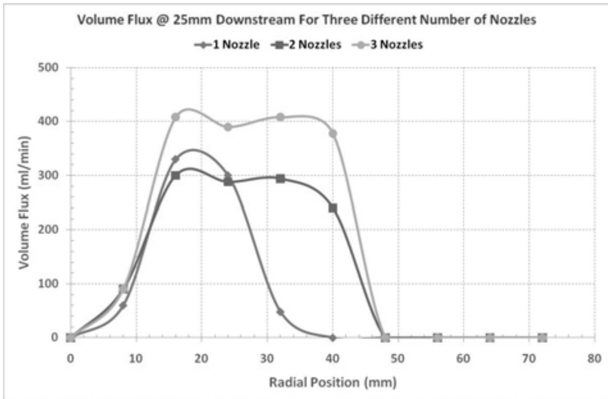

Figure15: Volume Flux comparison at 25mm downstream for three different number of spray atomisers

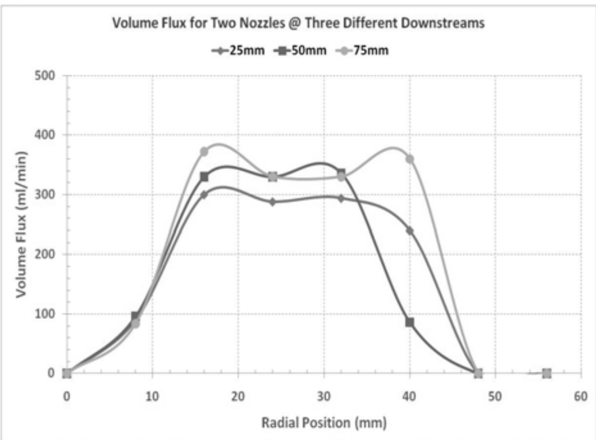

Figure13: Volume Flux comparison for 2 spray atomisers at three different downstream positions

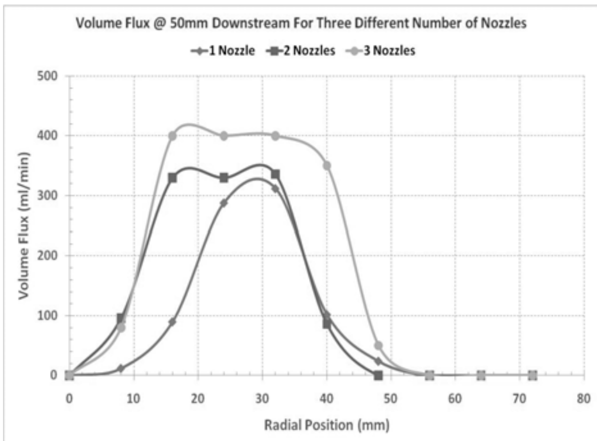

Figure16: Volume Flux comparison at 50mm downstream for three different number of spray atomisers

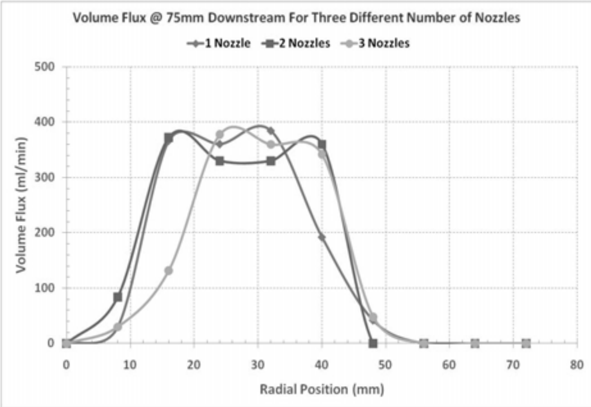

Figure17: Volume Flux comparison at 75mm downstream for three different number of spray atomisers

Conclusions and Future Work

The processing of the PDA data from radial positions across the spray and at different downstream distances provided basic understanding with regards to main spray properties (i.e. drop velocity, SMD and drop liquid volume flux) and thus the spray patternation across a single radial plane. The examination of the experimental findings shows that the structure of the spray is closely axis-symmetric and there is relative uniformity across the spray, with regards to velocity and SMD, although drop volume flux across the spray could vary, particularly in the overlapping regions. The atomiser tends to have a maximum velocity along the centreline and as expected this is the region of lowest SMD.

Future work will include further measurement with an increase in the number of atomisers and the use of Computational Fluid Dynamics (CFD) to further validate the experimental results.

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