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Paper

SELECTING THE MOST EFFECTIVE WATERBLAST PRESSURE AND FLOW FOR A GIVEN STANDOFF DISTANCE

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ABSTRACT

When selecting equipment and pumps for a waterblast cleaning job, many contractors now have the ability to choose from a range of pressures and flow rates for a particular task. As the equipment type and method of approach is selected, a working standoff distance can be determined. Based upon previous tests of jet deterioration with standoff distance, a prediction can be made as to which combination of available pressure and flow will have the greatest impact at the surface to be cleaned. The purpose of this research is to determine how to best predict the relative performance of equal power systems at a given standoff distance to aid in the selection of the most effective operating pressure and flow rate.

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1. INTRODUCTION

When selecting a waterblast system configuration to achieve effective cleaning or material removal for a given standoff distance, it is useful to have a mathematical estimation of the impact resulting at the surface to be cleaned. This allows comparison of various pressures and flows that may be available based on existing pump selection, and aids in specifying the system requirements to obtain the desired results.

As an example, a contractor has two equal power pumps, one capable of 80 lpm (21 gpm) at 138 MPa (20,000 psi), and the other 160 lpm (42 gpm) at 69 MPa (10,000 psi). If this flow is divided into two jets, typical of a balanced waterblasting tool, the respective orifice sizes would be 1.4 mm (.053 in.) and 2.2 (.088 in.) diameter. Which system will produce the most effective impact at the surface to be cleaned, if the application will require a standoff distance of 800 mm (31.5 in.)?

A method of estimating the relative performance can be based on charts of known jet performance deterioration that occurs with increasing standoff distance; such a chart is shown in Figure 1. The jet deterioration is known to be proportional to the orifice diameter, in the ratio of standoff distance divided by orifice diameter. For the example above, this ratio would be 600 orifice diameters at the higher pressure, and 360 orifice diameters at the lower pressure. By taking the percentage deterioration from the chart at these two ratios, one could potentially predict the relative performance of the two systems.

The purpose of these tests was to determine if applying the percentage deterioration from the chart to the initial jet pressure would be comparable in performance to the same jet at this percentage lower pressure at a minimal standoff distance. This information could then also be applied in the prediction of actual performance relative to properties necessary to clean or remove a material, such as threshold pressure.

2. TEST METHOD

Blocks of machineable wax were traversed across in one pass by a single jet orifice with good upstream conditions produced by a straight rigid lance. Performance was measured by depth of cut produced. Tests were conducted first with increasing standoff distance and a fixed pressure supplied to the nozzle to determine the actual performance deterioration due to standoff distance. These tests were conducted at 248 MPa, 138 MPa, and 69 MPa (36,000 psi, 20,000 psi and 10,000 psi), at flow rates corresponding to powers of 50, 85 and 125 kW (70, 115 and 170 hp). The next series of tests were conducted at a standoff distance of 50 times the orifice diameter, and the pressure supplied to the same nozzle was reduced by the percentage according to the chart in Figure 1, at points corresponding to 250 diameters, 75 percent; 500 diameters, 60 percent; and 800 diameters, 46 percent.

Additional tests at a standoff distance of 50 diameters with reduced pressures were performed to determine the effect of constant flow rate and constant power, where the orifice size was increased to achieve either flow or power equivalent to the higher supply pressure condition.

3. RESULTS

3.1 Constant Orifice Diameter with Reduced Pressure

The results for the three pressure ranges tested are shown in Figures 2, 3 and 4, averaged for the powers tested. The curves show the actual performance as produced by deterioration due to standoff distance, and the performance of tests with the same nozzle orifice at comparably reduced pressures supplied to the nozzle. The results for 138 and 69 MPa (20,000 and 10,000 psi) show the same shape of curve but an effective performance about 25 percent less than that of the actual performance curve.

The results at 248 MPa (36,000 psi) do not show the same matching trend; this is likely due to the different orifice design used in these tests. The predicting curve used (Figure 1) was produced from results of a typical tapered carbide orifice, as was used for these tests at 138 and 69 MPa, while the tests at 248 MPa used a sapphire orifice. It is expected that this design shape would require a different deterioration curve for performance estimation.

3.2 Constant Flow Rate and Constant Power with Reduced Pressure

Since reducing the pressure supplied to a fixed orifice size results in reducing both the flow rate and the power, a series of tests was performed to determine if this accounted for the 25 percent difference. First, the orifice size used for the comparative tests was increased to produce an equal flow rate at the reduced pressure, and then increased to produce an equal power at the reduced pressure. The results of these tests are shown in Figure 5, relative to the actual deterioration curve. The slight increase in orifice size to produce equal flow rate did not show significant change, while the increase to equal power did bring the comparative curve closer, to within 15 percent of the actual deterioration curve.

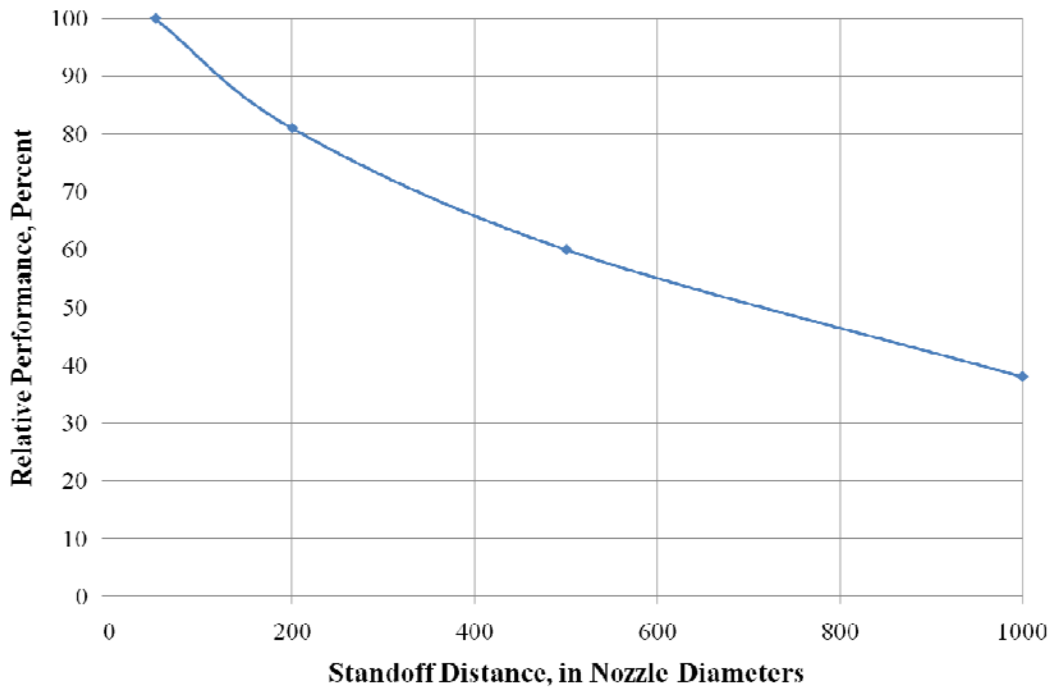
4. CONCLUSIONS

The results of these tests showed that there is a practical correlation between jet deterioration due to standoff distance and an estimation of performance based on a comparatively reduced pressure. When evaluating two systems of equal power, an estimation based on performance with increasing standoff distance would allow a relative comparison, as long as an appropriate deterioration curve based on orifice type was used. It should also be noted that these deterioration curves will vary due to the effect of turbulent upstream conditions, as shown in Figure 6.

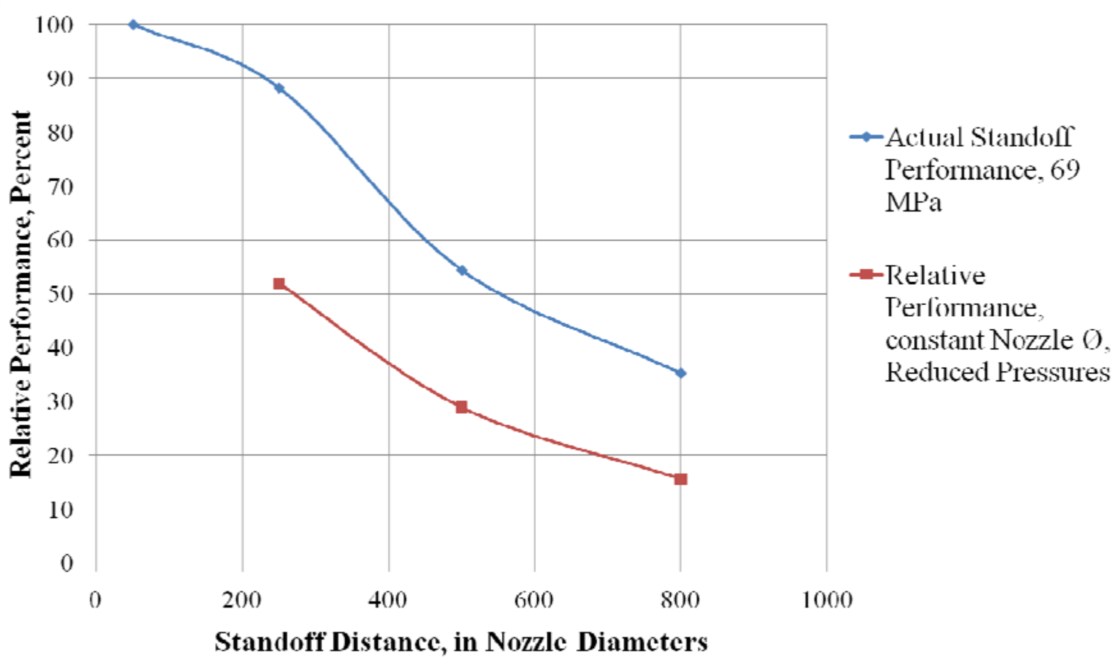
When the tests were performed using the same orifice size at reduced pressures, the results showed a 25 percent less effective performance; Figure 7 illustrates the results of adding this factor of 25 percent to the pressure, by shifting the comparative data points. It appears that if the estimated impact pressure value were increased by this factor, this method of prediction could be used to estimate effective impact relative to pressure, and allow evaluation of the ability to remove a material with a known threshold pressure at a given standoff distance.

The tests performed of increasing the orifice size to hold either the flow rate or the power constant showed some improvement toward the actual deterioration. However, since this still did not match the actual performance, and unless the perfect match is found, it would be simplest to base the prediction on decrease of pressure through the same nozzle and make the adjustment of 25 percent if desired.

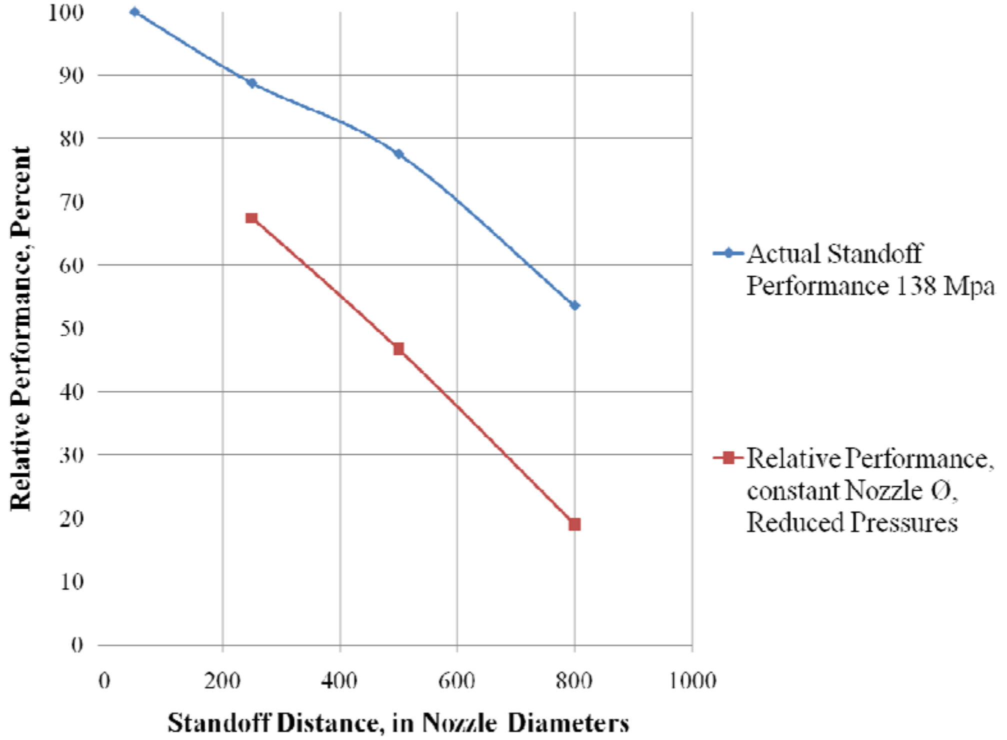
Applying these findings to the example of the introduction, it would show that the 69 MPa (10,000 psi) system would produce a comparative impact of 59.5 MPa (8,625 psi), while the 138 MPa (20,000 psi) system would result in a comparative impact of 95 MPa (13,750 psi). By this type of comparison, it is the typical result to have the higher pressure system showing the greatest impact, with the difference narrowing with increasing standoff distance, and with this, the effect of the mass of the water must become more dominant. Finally, when comparing various systems of different pressure and flow capabilities, consideration must always be taken for how any given material responds to flow rate as well as to pressure.



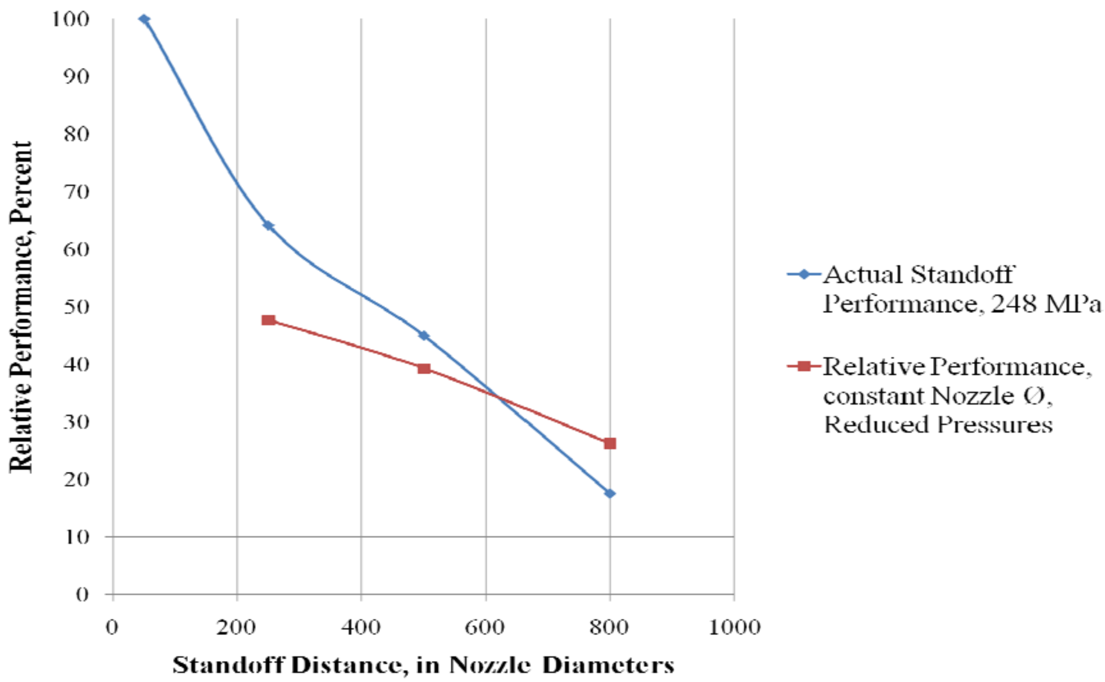
Relative Performance vs. Standoff Distance
Tapered Carbide Nozzle with Good Upstream Conditions
Figure 1.



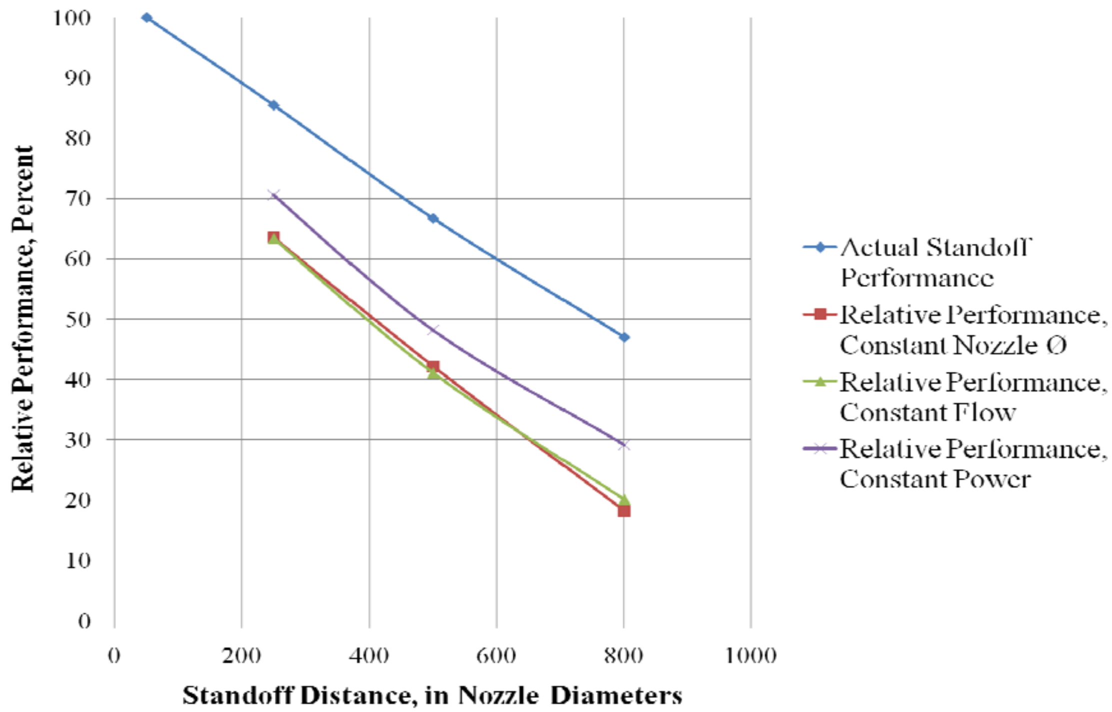
Reduced Pressure Performance vs. Actual Standoff Distance Performance
69 MPa (10,000 psi)
Figure 2.



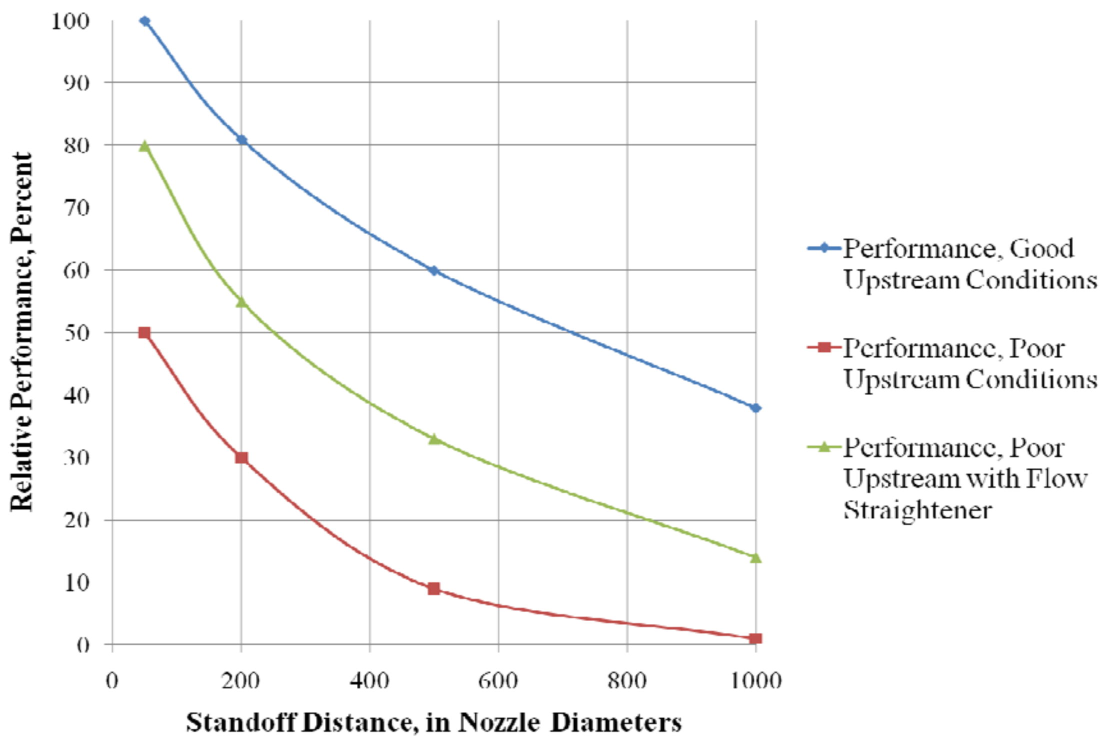
Reduced Pressure Performance vs. Actual Standoff Distance Performance
138 MPa (20,000 psi)
Figure 3.



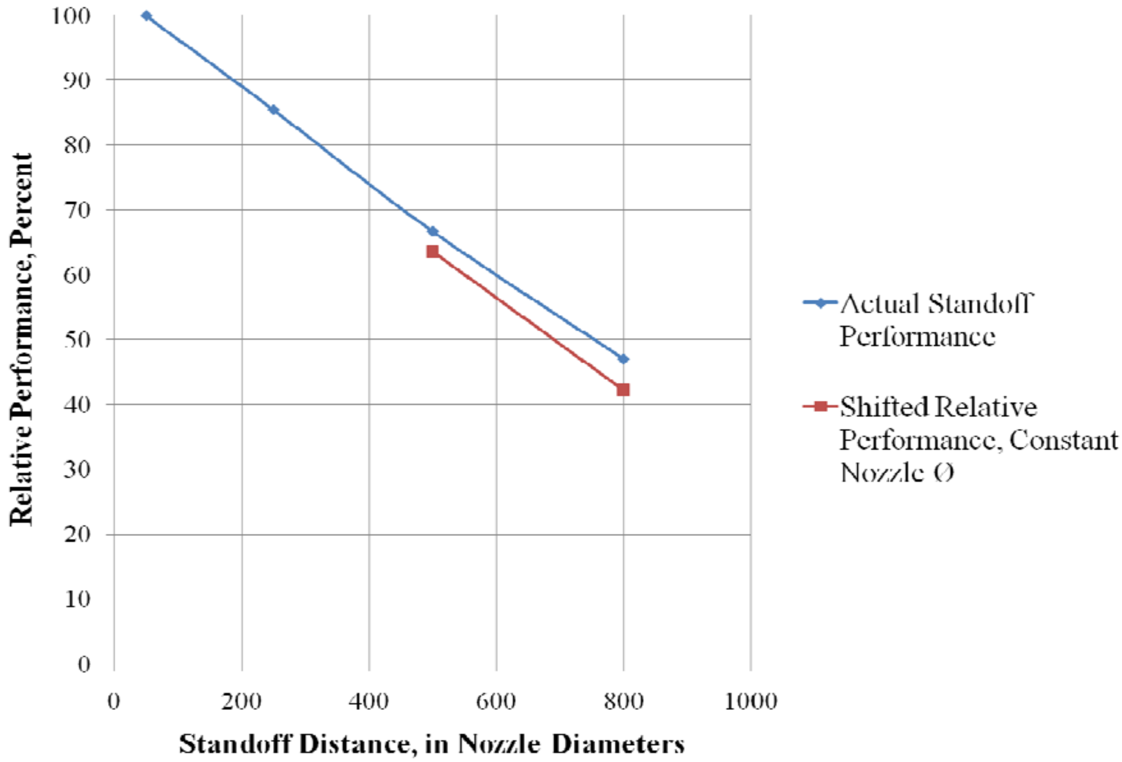
Reduced Pressure Performance vs. Actual Standoff Distance Performance
248 MPa (36,000 psi)
Figure 4.



Reduced Pressure Performances vs. Actual Standoff Distance Performance
Average of 69 MPa and 138 MPa
Figure 5.



Effect of Upstream Conditions on Performance of a Tapered Carbide Nozzle
Figure 6.



Reduced Pressure Performance Adjusted vs. Actual Standoff Distance Performance
Average of 69 MPa and 138 MPa
Figure 7.