Characterization of Two Fluid Nozzles for NOx Control Applications

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Summary

Emergency power stations and refineries often use the Selective Catalytic Reduction (SCR) method of cleaning up NOx from the exhaust of their stationary diesel or natural gas engines. In an SCR system a reducing agent is injected into the exhaust gas stream where it mixes with the exhaust before passing through a bed of catalyst. Anhydrous ammonia, aqueous ammonia or a urea solution is used as the reducing agent.

Current methods rely on using single fluid injectors to deliver the urea solution. While this method has yielded some success, it has presented a series of problems that include nozzles clogging and non-optimal performance due to an uneven spray distribution. Today, it is believed that two fluid nozzles would be better suited due to larger inlet passages and their ability to provide better control of drop size and flow distribution within the exhaust system. There are no standard methods in use for selecting and optimizing two fluid spray nozzles for NOx applications.

This paper will propose a method that will include an analysis of the critical elements of atomizer design and testing. This will include nozzle design considerations to reduce clogging and optimization of spray and drop size distribution. This method will also evaluate the effects of “normal” operating parameters such as fluid flow rate, atomization pressure, and exhaust gas velocity on spray uniformity and drop size.

PERFORMANCE REQUIREMENTS

For operational purposes a 7:1 turn down ratio is preferred. This provides the operation of the facility with a range of flexibility. The nozzles must also be able to operate in an atomizing air pressure range of 40-60 psi and a urea injection pressure in the range of the atomizing air pressure in order to produce a finely atomized spray while maintaining a safe environment and low systems costs.

The nozzles must provide a tight drop size distribution, and a $D_{V0.5}$ in the range of 40 - 50 µm to insure that the reducing agent will evaporate in the exhaust gas stream. The nozzles must feature a low spray trajectory that would insure no wall wetting and large free passages to reduce clogging.

INSTRUMENTATION AND PROCEDURE

Drop size data was collected at a constant spray height of 18 inches. The nozzles were placed in a wind tunnel to simulate the exhaust gas velocity of a stationary diesel or natural gas engine. Typical air velocity profiles of the wind tunnel were recorded at 1500 and 2500 cfm along the horizontal center axis of the test section.

Drop size data was collected using a TSI Phase Doppler Particle Analyzer (PDPA-2D). A drop size measurement range of 0.5µm – 189.2µm was used and was sufficient to ensure the full range of droplet sizes could be measured. The $D_{V0.5}$ diameters were used to evaluate the drop size data.

TEST NOZZLES

Two types of Spraying Systems Co. nozzles were used in this test, a 1/4J+SU11 nozzle (low flow) and an FM0.25 FloMax™ nozzle (high flow). Both nozzles are classified as internal mix two fluid atomizers. Water was used for all tests as its physical characteristics (*i.e.* density, viscosity, surface tension) are reasonably close to those of Urea.

RESULTS

FLOW RATE

The nozzle flow rate increased with an increase in liquid pressure. This trend is expected as the increase in liquid pressure increases the velocity of the liquid through the nozzle orifice and hence increases the flow rate.

EFFECT OF LIQUID FLOW RATE

The effects of liquid flow rate on $D_{v0.5}$ were evaluated at air pressures of 30, 40 and 60 psi. $D_{v0.5}$ increased with an increase in liquid flow at a constant air pressure. Normally, one would expect the $D_{v0.5}$ to decrease with an increase in flow rate, this would be the case since the increase in flow rate is normally accompanied by an increase in liquid pressure. In the case of two-fluid nozzles, the increase in liquid pressure at a constant air pressure negated the effects of the increase in liquid pressure and as a result the drop size would increase with an increase in atomizing air pressure.

EFFECT OF ATOMIZING AIR PRESSURE

The effects of atomizing air pressure on $D_{v0.5}$ were also evaluated at the air pressures of 30, 40 and 60 psi, and liquid flow rates of 0.5 – 3.5 gph (low flow) and 9 – 25 gph (high flow). $D_{v0.5}$ decreased with an increase in air pressure. This increase in air pressure results in imparting a larger velocity to the liquid stream, which results in a breakup of the stream into finer pieces and thus reducing the drop size.

EFFECT OF VOLUMETRIC AIR FLOW

Both nozzles were tested at volumetric airflows of 0, 1500 and 2500 ft/min. For all conditions, $D_{v0.5}$ decreased with an increase in volumetric airflow**.** The data supports previous research that attributes this effect to various droplet breakup regimes, bag breakup at low volumetric airflow rates, and boundary layer breakup at high volumetric airflow rates.

CONCLUSIONS

A method for selecting and optimizing two fluid spray nozzles for NOx applications was presented in this work. Based on this work the following conclusions can be drawn:

1. An increase in liquid flow rate at a constant pressure increased the drop size.

2. An increase in atomizing air pressure reduced the drop size.

3. An increase in volumetric airflow also reduced the drop size.

This data suggests that in order to optimize the drop size, one must consider the atomizing air pressure as the primary control mechanism. The extent of this effect and its relevance to the NO_x control applications are determined by other factors such as exhaust temperature, exhaust gas composition and the effects of how the reducing agent sprays interact with the exhaust gas stream, also referred to as spray mixing. These factors were not within the scope of this study.