# Fabrication of Micro-orifices

## Developing Advanced Injector Nozzles to Reduce Diesel Engine Emissions

Nicholaos G. Demas, Energy Systems Division

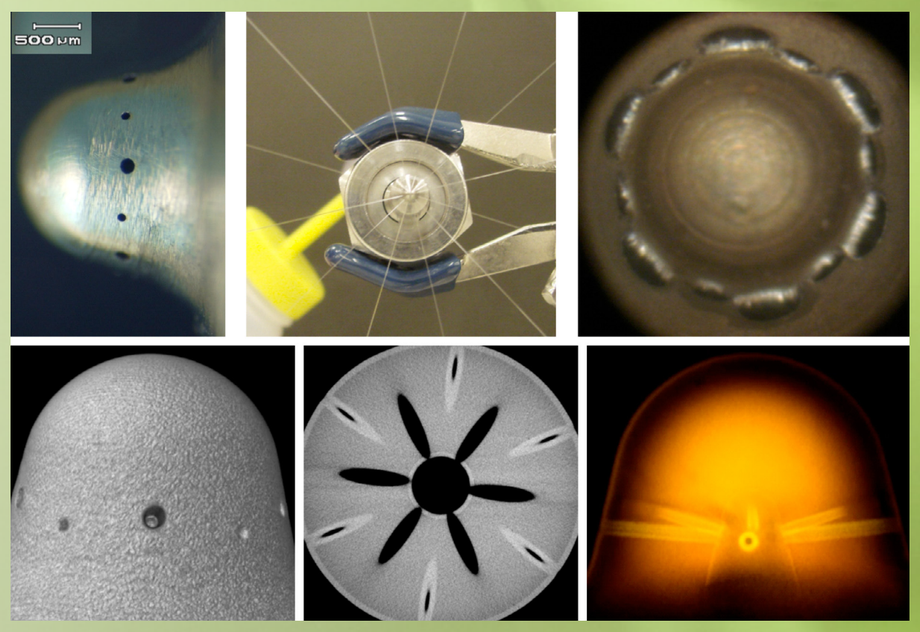
## Opportunity

In 2007, EPA regulations mandated significant reductions in diesel engine emissions. To meet this requirement, diesel engines must be redesigned to reduce in-cylinder soot production. In a test cylinder, experimental injectors with orifice diameters of 50 µm have shown increased fuel atomization efficiency, which results in promising reductions of soot and nitrogen oxides ($NO_x$) emissions.

Although 100 µm-diameter orifices can be economically mass produced by electrical discharge machining (EDM), further reductions in hole size are accompanied by unacceptable fabrication error rates. There is a need for economical and efficient ways to fabricate nozzles with orifice diameters of 50 µm.

## Solution

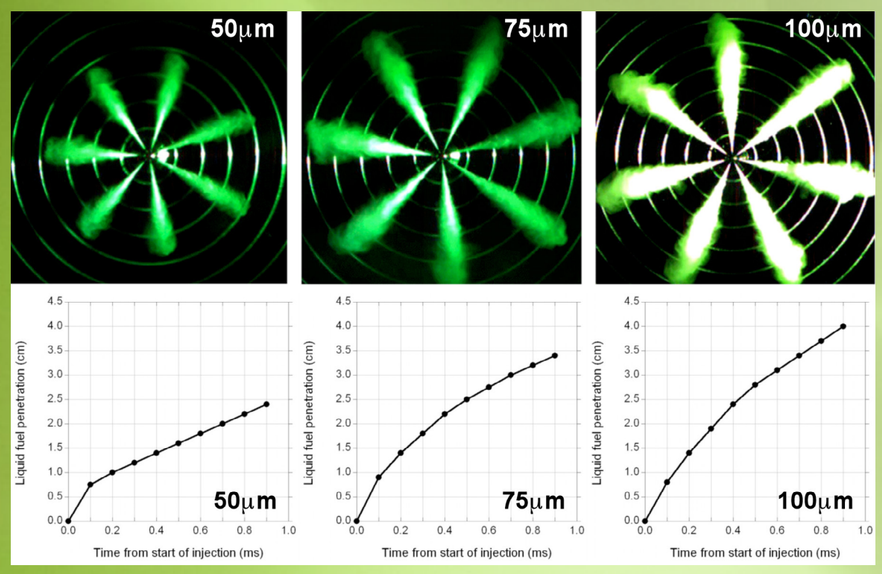
Argonne researchers are working to reduce the orifice diameter by coating its interior with electroless nickel (EN) plating. This method can be used to deposit a wide variety of alloys, offering the possibility of tailoring surface chemistry to reduce or eliminate deposit formation. The plated surface is also corrosion-resistant, smoother, and results in a higher discharge coefficient of the plated orifices.




Clockwise from top left: Microscope image of multi-orifice nozzle; spray test; microscope image of the interior; snapshot during 3-D X-ray rendering; 2-D X-ray slice showing two sets of holes; and X-ray image showing through the nozzle.

## What We've Achieved

Multi-orifice nozzles with different diameters have been fabricated. Argonne researchers used high-speed imaging to characterize the spray properties of EN-coated nozzles. X-ray phase contrast imaging has been used for a nondestructive examination of the coating integrity and uniformity of thin EN layers applied to the interiors of diesel injectors. Researchers also demonstrated the successful adhesion of EN coatings to the orifices using a micro-indentation technique at the coating/substrate interface.




Laser images of fuel spray tests.

## Benefits

Argonne's work is leading to the development of fuel injector nozzles that demonstrate enhanced spray properties and reduced deposit formation. This improvement in fuel atomization efficiency for diesel engines will result in a reduction of harmful emissions.

## Future Work

- Simulate cavitation erosion and evaluate the impact of different alloy compositions and treatment on erosion.
- Extract specimens from actual nozzles and test according to an ASTM standard developed for cavitation erosion
- Demonstrate the EN plating process for large batches of nozzles
- Characterize spray properties and flow characteristics of multi-orifice, EN-coated nozzles by high-speed laser imaging
- Evaluate EN-plated nozzles under actual engine testing conditions

This work is funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Program. Collaborators include Robert Bosch GmbH, Imagineering Finishing Technologies, Leer Technologies Inc., and C&A Tool Engineering Inc.