Advanced EDM Technology

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AA EDM Corporation Research & Development information

Ways of nozzle geometry optimization for new injection systems, fulfilling future emission limits EURO 5&6

One important aspect in the development of new combustion systems is the design of the injection system especially the shape and geometry of the nozzle. The paper describes the correlation between the microstructure of spray holes, spray characteristics, atomization and combustion.
Therefore the stability of special high quality processing of spray holes is the key of successful injection technology in general, fulfilling EURO 5 and EURO 6.

AA EDM Corporation spends many hours analyzing, reviewing and providing research & development for the fuel injection nozzles. The fuel-injection process is critical to attaining high fuel efficiency and low emissions in modern engines. Accurate control of fuel injection parameters such as vehicle timing, delivery, flow rate, pressure, spray geometry, are all important. Perfect or as close to perfect sized spray orifices is important due to it being the most effective means to influence fuel and air mixing and to achieve both clean burning and high efficiency within the engine.

Today advanced technologies especially for manufacturing nozzle spray holes are required. These are for example the **electro discharge machining (EDM)** and the hydrogrinding (EH/HE) process. At present these technologies are mostly developed and economical for this field of application. Newer technologies such as **the laser machining** for spray hole manufacturing are not expected earlier than in five years for mass production. The nearly perfect processing stability of the mentioned technologies allows to produce specified, flow optimized spray holes for high quality nozzles, fulfilling future emission limits.
With the knowledge of the combination and adjustment of the specific processing parameters there are possibilities to bring spray holes into line with the engine manufacturers combustion requirements for specified engine applications. For example a low nitrogen oxides and low soot combustion for the marine engine application needs an injection system (conventional or modern common-rail) with nozzles **produced by EDM advanced technology.**

Final tuning of the engine is a trial-and-error procedure since the physics of spray atomization and its influence on combustion, pollutant formation and fuel efficiency are being better understood. A deeper understanding of the injection process and spray atomization are needed to enable new strategies for clean and efficient combustion.

AA EDM Corporation has worked with many other sources to assist in the spray direction, orifice diameter and change in taper angle for the good of their customers. **We understand, the more accurate our holes, the better quality fuel nozzles become.** The more accurate spray direction

along with the amount released, the better engine manufactures understand what is needed to adjust for the best efficiency of the engine.

Fuel Injection and Spray Research

Diesel engines are significantly more fuel-efficient than their gasoline counterparts, so wider adoption of diesels in the world would decrease the world's dependency on the petroleum. However, diesels emit much higher levels of pollutants, especially particulate matter and NOx (nitrogen oxides). These emissions have prevented more manufacturers from introducing diesel passenger cars.

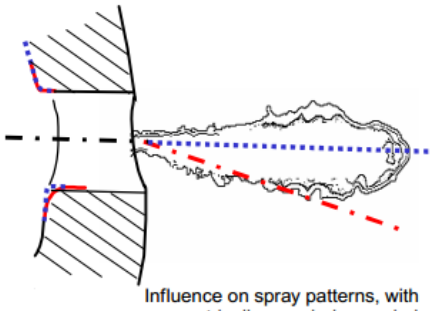
The flow through the spray holes depends on a few important characteristics, for example:
- The ratio of spray hole length / diameter, rate of taper and spray hole inlet rounding geometry
- Boundary layer / surface condition (micro geometry: roughness)
- Flow creeping / detachment
- Reynolds number

This characteristics determine the main spray patterns as there are for example:
- Cone angle
- Penetration and impulse
- Droplets size and distribution

Electro Discharge Machining (EDM) is a thermal process to remove conductive material electrically by means of rapid and repetitive spark discharges between the shaped tool and the work piece in a medium of dielectric fluid.
The shaped tool defines the area in which spark erosion would occur thus determining the shape of the resulting cavity or hole depending on Z- and W axis movement in the work piece. Accurate machining and closer tolerances are possible because the spark gap can be as small as 10 **m** m.
The surface finish in this instance can be in the order of 1 **m** m (Ra-value). Special methods were developed by AA EDM Corporation inc. to meet the specific requirements , leading to optimal atomization and combustion results.
The Electro Discharge Machining (EDM) is the most advanced technology for manufacturing orifices, e.g. spray holes from 0.1 mm diameter up 0.7mm.

INFLUENCES ON ENGINE OPERATIONPARAMETERS

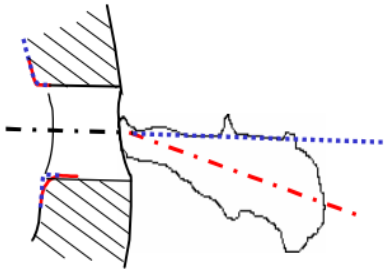
The cause of using this technologies for spray hole manufacturing is an efficient combustion as a basis for less emissions (soot and nitrogen oxides) as well as a fewer fuel consumption as shown on the figures.



Influence on spray patterns, with symmetrically rounded spray hole

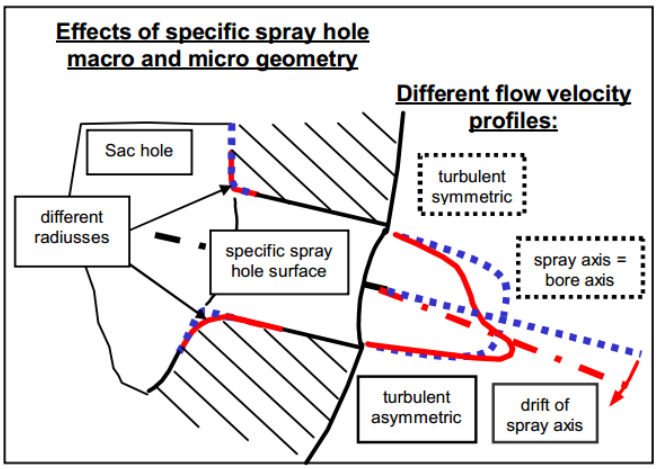
INFLUENCES ON FLOW PATTERNS

With the described spray hole manufacturing technologies and the controllable processing parameters it is possible to adjust different specified hole geometric conditions.
The effects of different specified macro and micro geometry are very significant on flow patterns.
On figure 1 you can see two examples of differently shaped spray holes. A symmetric rounded hole with constant radiuses at the circumference (adjusted by the hydrogrinding process, see pointed lines) with a specified surface roughness (adjusted by specified CNC-EDM parameters) causes perfect flow patterns. This



Influence on spray patterns with asymmetrically rounded spray hole

means a turbulent symmetric high velocity flow profile with a straight streaming out in line with the bore axis.
A non well shaped sprayhole (e.g. in this case different radiuses at the circumference) causes a different asymmetric flow velocity profile and a deflection of the flow with in sum lower velocity.
Figure ..— Correlation between geometric sprayhole and flow parameters



Conclusion of optimized spray holes flow characteristics:

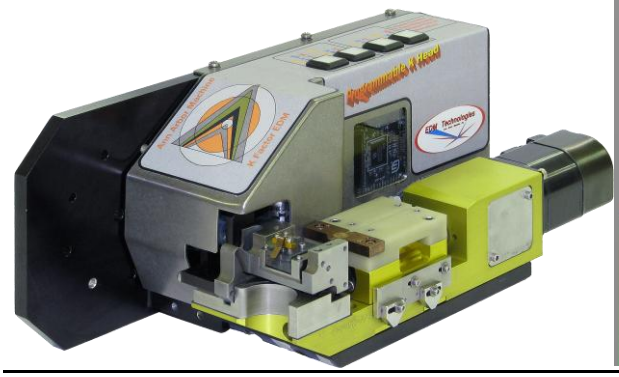
· Identical penetration, spray angle and flow rates between each sprayhole and each nozzle
· Ideal flow conditions, flow acceleration and optimal use of the sprayhole cross-section
· Homogeneous, symmetric flow velocity profile. Lower smoke index, reduction more than 75% in specified parts of the engine performance map compared with no EDM and no hydrogrinded spray holes
· Obvious improvement of the NOx /BSFC/SN – trade off behaviour
· Higher engine efficiency and fuel savings
· Long useful life, allows high TBO periods (up to 7500-10000h),

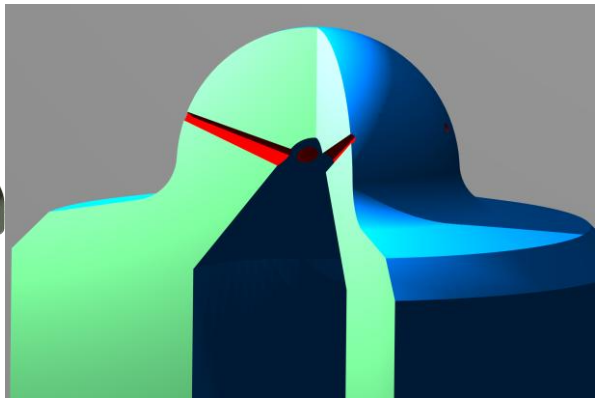
AA EDM Corporation is doing our best to work with various OEM manufactures to assist in the best flow achievable by the diesel nozzles being produced on our machines. Our research is exploring ways to reduce pollution formation in the engine by using clean combustion strategies. A key component to the development of clean combustion is controlling the fuel spray and fuel/air mixing.

AA EDM Corporation research of diesel sprays has led to the understanding that quantitative measurements of the mass distribution within fuel sprays have been obtained with very precise time resolution. In addition, the density of the fuel can be calculated at any position and time within the spray. This result proved for the first time that sprays from modern diesel injectors are atomized only a few millimeters from the nozzle.

Spray structure is important since it determines how the fuel and air mix together in the engine combustion chamber. A spray that poorly atomizes fuel will lead to fuel-rich regions in the cylinder, while a spray that is overly dispersed will lead to a mixture that is too lean. At both of these extremes, combustion either cannot take place, burns inefficiently or it generates high levels of emissions. A spray that distributes the fuel optimally will lead to engine combustion that is clean and efficient.

AA EDM Corporation developed the Reverse Taper EDM head, patented technology, for improved microholes for diesel injectors.





Our particular expertise is in giving the customer the exact hole geometry they require. In the past the holes in the injector had too much standard taper – i.e. the entrance hole diameter was larger than the exit. With our generator technology we were able to make the straight holes with no taper that our customers needed. Now the need is for reverse taper – where the entrance hole diameter is less than the exit diameter. Our generator technology is able to provide small reverse tapers and using our reverse taper EDM head we are capable of making reverse taper holes with K-factors up to 8 with straight sides (cone shaped) – not trumpet shaped holes.

We hope that with our assistance, our research will assist in understanding how various factors such as injector design, fuel pressure, cylinder pressure, temperature, will affect the fuel distribution, and how these variables might be manipulated to develop clean, efficient engines.

SOME OF OUR CUSTOMERS:

CATERPILLAR
MAGELLAN AEROSPACE CORPORATION
HI-TEK
sun hydraulics CORPORATION
YANMAR
STS SANDERS TOOLS & SUPPLIES SANDERS TECHNICAL SERVICES
Cummins
GE
Westport INNOVATIONS INC.
BOSCH Invented for life