

Application Note No. 125

Cutting Injection Nozzles with SYNOVA Laser MicroJet®

Description of Product

All forms of fuel injection are designed to achieve the delivery of a correct fuel/air mix into an internal combustion engine for the most fuel efficient burn. They do this by forcing the fuel under pressure through nozzles (injectors) that break up or atomise the fuel into a fine spray. This spray when mixed in the correct ratio with the air drawn into the engine (or forced into the engine by a turbo or supercharger) burns very completely creating maximum power and minimum emissions. Fuel injection not only provides power improvements over the rpm range of an engine, it can also provide improved fuel economy.

A nozzle is a mechanical device or orifice designed to control the characteristics of a fluid flow as it exits (or enters) an enclosed chamber or pipe. It is often a pipe or tube of varying cross sectional area, and can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them.



View of Injection Nozzle

Description of Material

One of the materials most commonly used to manufacture injection nozzles is AISI 440C a high grade Chromium martensitic Stainless Steel used for components which require extreme hardness and severe wear resistance coupled with excellent corrosion resistance. Typical composition, besides Iron, is by %, 16-18 Cr, 0.95-1.20 C, 1.0 Mn, 1.0 Si, 0.040 P, 0.030 S, 0.75 Mo.

Description of Manufacturing Task

Manufacturing of injection nozzles requires the forming of one or more small high precision holes in the head of the nozzle to provide a calibrated flow of the fuel into the combustion chamber. The holes can range in diameter from 50 to 250 μm , with a required precision of ± 1 to 2 μm .

Description of Conventional Manufacturing Process and Problems

The main processes presently used to make injection nozzle parts is Electrical Discharge Machining (or EDM), a machining method primarily used for hard metals or those that would be impossible to machine with traditional techniques. EDM is a non-traditional method of removing material by a series of rapidly recurring electric arcing discharges between an electrode (the cutting tool) and the work piece, without touching it. Consecutive sparks produce a series of micro-craters on the work piece (and the electrode) and remove material along the cutting path by melting and vaporisation; the resulting debris must then be removed by a constant flow of de-ionised water. This method necessitates constant replacement of the electrodes or, in the case of wire EDM machining, constant replacement of the wire by feeding from a spool.

Water Jet-Guided Laser Technique

In 1993, scientists working at the Institute for Applied Optics at the Swiss Federal Institute of Technology in Lausanne, succeeded in creating a water jet-guided laser, referred to as the Laser-MicroJet® (LMJ) by its inventors.

The laser beam is focused into a nozzle while passing through a pressurized water chamber. The geometry of the chamber and nozzle are critical to coupling the energy-rich laser beam in the water jet.

The low-pressure water jet emitted from the nozzle guides the laser beam by means of total internal reflection at the transition zone between water and air, in a manner similar to conventional glass fibre optics. The water jet can thus be referred to as a fluid optical wave-guide of variable length.

Because a pulsed laser is used, the continuous water jet is able to re-cool the cut immediately, resulting in only a very slight depth of thermal penetration. The results are very narrow, parallel wall, burr-free kerfs, with negligible thermal damage. The water simultaneously washes any contaminants and ablated material away, removing the requirement for any post processing cleaning steps.

Laser MicroJet® Solution

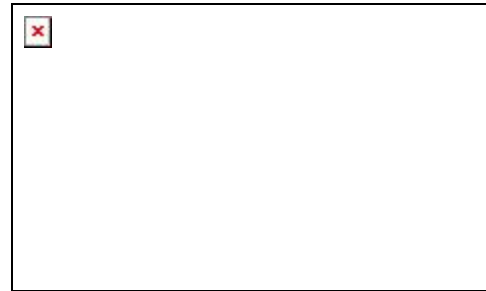
Injection nozzle drilling with the Laser MicroJet®

The LMJ is ideally suited to the micromachining of these parts, especially when excellent edge quality is required.

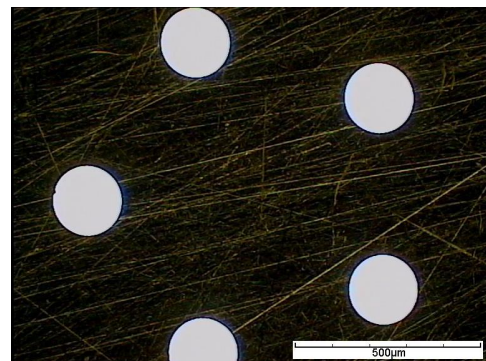
Due to the cooling effect provided by the water jet between laser pulses, the cut edges are immediately cooled and the material does not suffer from thermal effects and, as the force applied by the water jet is so low, mechanical damage is also avoided.

The example shown in the image at right is for test sample drilled for demonstration purposes. The material is AISI 440C Stainless Steel with a thickness of 160 µm and the holes are ~ 200 µm in diameter and were cut in ~ 2.5 s/hole.

The highly magnified view shows the excellent edge quality of the finished product obtained with the LMJ, demonstrating its capabilities for micromachining precise holes in hard materials.



Principle and cutting with the water jet-guided laser



Magnified view of Injection Nozzle holes



Highly magnified back surface view of Injection Nozzle hole



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Customer Benefits

Customers can obtain the following advantages when using Laser MicroJet® technology:

- ▶ High speed cutting
- ▶ Excellent cutting and grooving quality with narrow and parallel-cut walls, and smooth and straight edges
- ▶ No burrs or depositions maintaining a very smooth surface
- ▶ No mechanical damage: water exerts very low (<0.1N) forces on the work piece
- ▶ No heating of the parts or thermal deformation
- ▶ No contamination or re-deposition
- ▶ Constant results
- ▶ Very flexible, can produce complex 2D shapes
- ▶ Very low running costs; no tool wear
- ▶ Higher throughput and productivity with improved return on investment (ROI)
- ▶ Environmentally friendly process as only DI water is required, ablated materials are removed with the water for later filtering and disposal

Outcome of the benefits

Because of the significant advantages over other manufacturing methods, in particular, the negligible thermal and mechanical stress, as well as the burr and contaminant free parts produced, the Laser-MicroJet® process is proving to be the ideal method for the micromachining of components such as Injection Nozzles.

Laser MicroJet®¹ Cutting System for Injection Nozzles

Synova offers a state-of-the-art, clean-room compatible machine; the LCS 300 laser cutting system illustrated at right, designed and optimised for applications such as cutting Injection Nozzle holes.

The system has a precision of $\pm 3 \mu\text{m}$, a repeatability of $1 \mu\text{m}$ and a usable working area of 300 mm x 300 mm with a maximum axis speed of 1000 mm/s. The system is equipped with a CCD camera and fast image treatment software, allowing automatic alignment and inspection. The operator interface is a flat colour touch panel screen, and the machine software is based on Windows 2000®².

The LCS 300 can be connected to a LAN network for data transmission and remote diagnostic services. Adapted CAM software can convert all DXF data, quickly and economically, with no special knowledge or training requirements.

Options include water chillers, alternative laser sources (i.e. UV), water treatment system, 2D-reference scales and transformers. The CE and S2 certified Synova machines are field-proven and are in use in 24/7 production environments.

A smaller model, the LCS 150 with a working area of 150 mm x 150 mm, is also available.



LCS 300 Laser Cutting System

¹ Laser MicroJet® is an internationally protected trademark of Synova S.A., Ecublens, Switzerland.

² Windows 2000® is a trademark of Microsoft Corp., USA.