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LLNL-TR-741111

Laser Drilling Development Trial Final Report CRADA No. TSB-1538-98

M. R. Hermann, R. R. Hebbar

November 3, 2017

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Laser Drilling Development Trial

Final Report
CRADA No. TSB-1538-98
Date Technical Work Ended: December 4, 1998

Date: June 18, 2001 Revision: 3

A. Parties

This project was a relationship between the Lawrence Livermore National Laboratory (LLNL) and Cummins Engine Company, Inc.

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Lawrence Livermore National Laboratory
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B. Project Scope

This project performed various laser drilling tests to demonstrate femtosecond laser drilling of fuel injector nozzles with minimal recast, minimal heat affected zone and no collateral damage.

LLNL had extensive experience in ultra short-pulse laser systems and developed specialized hardware (and software) for these applications. This expertise was useful to industry when combined with its expertise in engine performance and marketplace understanding. LLNL utilized its expertise with advanced pulse-pulse laser systems that it developed to perform laser drilling tests of fuel injector nozzles for diesel engines.

Cummins provided its expertise in engine performance and its real world knowledge of the requirements of the engine marketplace.

The combination of these two areas of expertise kept this cutting edge research and development focused on practical solutions to implementing more effective engine and fuel performance for a commercial product.

C. Technical Accomplishments

This project performed various laser drilling tests to demonstrate femtosecond laser drilling of fuel injector nozzles with minimal recast, minimal heat affected zone and no collateral damage.

There were two phases to this project.

In Phase I, we:

- Demonstrated femtosecond laser drilling on Cummins-supplied test plates
- Evaluated the cut quality and measurement of drilling rates
- Examined methods of elimination of back wall damage

In Phase II, we:

- Designed and fabricated a phase plate to convert gaussian beams to supergaussian. Drilled shaped beam/shaped holes in the test plates using imaging geometry
- Demonstrated drilling double-coupons (plates) with acceptable hole quality and minimal backwall damage, but with tapered holes
- Drilled Cummins-supplied injectors

D. Expected Economic Impact

This process will require further development before making any economic impact. It has the potential of being able to manufacture smaller injector holes that will lead to reduced vehicle emissions.

D.1 Specific Benefits

LLNL was producing a femtosecond laser for the Y-12 plant to perform laser cutting of parts as part of the nation's Stockpile Stewardship effort.

The Oak Ridge Y-12 Plant ordered a 12 watt Femtosecond Laser Cutting System (FLCS) from LLNL.

This production system was utilized for disarmament and refurbishment of nuclear warheads (Stockpile Modernization). The same laser and control technology will be used in this project thereby increasing the base used for reliability and maintainability analysis. This is especially important since the Y-12 system has a requirement of zero part kill.

This project also increased the understanding of the femtosecond laser material removal process and extended its use to new materials.

E. Partner Contribution

Cummins provided its expertise in engine performance and its real world knowledge of the requirements of the engine marketplace.

Cummins provided samples for testing and also aided in evaluation of laser drilled components.

Based on expertise in diesel engine performance, Cummins determined the following requirements for applying laser drilling to drilling of injector spray holes:

1. Holes must be relatively taper free
2. The laser beam must be stopped within 1 mm from exit of hole to avoid inner wall damage
3. A high machining rate is needed to justify and offset the laser system cost compared to EDM
4. Holes need to be free of "recast"/heat-affected-zone/white layer from the laser drilling

From the evaluation of the results of this project, Cummins verified that conditions 2 and 4 (above) were successfully achieved. However, since conditions 1 and 3 (above) were not achieved, it is not viable to apply this technology to spray hole drilling.

F. Documents/Reference List

1.*Viewgraph presentation – "Short-pulse laser machining for fuel injector applications," at Cummins, May 13, 1999
2.*Memo – "Parallel walls in holes," Dec. 18, 1998
3.*Memo – "Hole drilling with 405 nm light," Oct. 5, 1999
4.*Memo – "Short-pulse laser drilled holes," July 29, 1999
5.*Memo – "Fuel injector hole summary," July 5, 1999
6.*Memo – "Cummins CRADA," Nov. 12, 1998
7.*Memo – "Drilling of injectors," Sept. 7, 1999

* Protected CRADA Information

Reports

There were no published reports generated under this CRADA.

Patent/Copyright Activity

There were no patents or copyrights generated under this CRADA.

Subject Inventions

There were no subject inventions in this CRADA.

Background Intellectual Property

LLNL
IL-10179
IL-10244
IL-9983: Patent pending
IL-9775: Patent pending
IL-9566A: Patent pending
IL-9566B: Patent pending
IL-10126: Patent pending

No licensing of BIP has been initiated.

G. Acknowledgement

Participant's signature of the final report indicates the following:

1) The Participant has reviewed the final report and concurs with the statements made therein.
2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
3) The Participant certifies that all reports either completed or in process are listed and all subject inventions and the associated intellectual property protection measures generated by his/her respective company and attributable to the project have been disclosed and included in Section E or are included on a list attached to this report.
4) The Participant certifies that if tangible personal property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
5) The Participant certifies that proprietary information has been returned or destroyed by LLNL.

RRHebbar 7/13/01

Raja R. Hebbar — Date
Cummins Engine, Inc.

Mark R. Hermann 7/31/01

Mark R. Hermann — Date
Lawrence Livermore National Laboratory

Attachment I – Final Abstract

Laser Drilling Development Trial

Final Abstract (Attachment I)
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C. Benefit to Industry

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E. Project Dates

June 4, 1998 – December 4, 1998