International Journal on Emerging Technologies **5**(1): 107-109(2014)

ISSN No. (Online) : 2249-3255

An Introduction to Laser Igniters: Revolution in Internal Combustion Engines

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(Received 19 March, 2014 Accepted 25 April, 2014)

ABSTRACT: In this paper it is shown that, internal combustion engines are likely to remain in widespread use for some time yet, but it's possible that most iconic of engine parts, the spark plug will be replaced by laser igniters or laser spark plugs. Researchers from Japan's National Institutes of Natural Sciences (NINS) are creating laser igniters that could one day replace spark plugs in automobile engines. Not only would these lasers allow for better performance and fuel economy, but cars using them would also create less harmful emissions.

Key words: Laser igniters, Spark plug, Internal Combustion Engines, fuel efficiencies, Gas Laser, engines emissions

I. INTRODUCTION

For more than 150 years, spark plugs have powered internal combustion engines. Located at the top of each engine cylinder, spark plugs send a high-voltage electrical spark across a gap between their two metal electrodes. That spark ignites the compressed air-fuel mixture in the cylinder, causing a controlled mini-explosion that pushes the piston down. One byproduct of the process is toxic nitrogen oxides (NOx), which pollute the air causing smog and acid rain. Engines would produce less NOx if they burnt more air and less fuel, but they would require the plugs to produce higher-energy sparks in order to do so. While this is technically possible, the voltages involved would burn out the electrodes quite quickly. Laser igniters on the other hand, could ignite leaner mixtures without self-destructing because they don't have electrodes. The operation of internal combustion engines with lean gas-air mixtures, laser igniters results in increase of fuel efficiencies and reduce green-house gas emissions by significant amounts.

II. LIMITATIONS OF SPARK PLUG

Spark plugs only ignite the area of the air-fuel mixture closest to them (the top), with much of the heat of the explosion being absorbed by the metal cylinder walls before it can reach down to the piston. The fuel inside the combustion chamber is not burnt completely by the conventional spark plug.

Spark plug burn the air-fuel mixture which is slightly on richer side than air-fuel mixture, we can use in laser igniters. Spark plugs can ignite leaner fuel mixtures, but only by increasing spark energy. Unfortunately, these high voltages erode spark plug electrodes so fast, the solution is not economical.

III. LASER IGNITERS

A new laser system invented by Japanese researchers could displace the venerable design of spark plugs, which has stood virtually unchanged for the past 150 years. Lasers, by contrast, could focus their beams into the middle of the column, from which point the explosion would expand more symmetrically – and reportedly up to three times faster than one triggered by a spark plug. Additionally, engine timing could be improved, as lasers can pulse within nanoseconds, while spark plugs require milliseconds.

In order to cause the desired combustion, a laser would have to be able to focus light to approximately 100 giga-watts per square centimeter with short pulses of more than 10 milli-joules each. Previously, that sort of performance could only be achieved by large, inefficient, relatively unstable lasers. The Japanese researchers, however, have created a small, robust and efficient laser that can do the job. They did so by heating ceramic powders, fusing them into optically-transparent solids, then embedding them with metal ions in order to tune their properties.

Made from two bonded yttrium-aluminum-gallium segments, the laser igniter is just 9 millimeters wide and 11 millimeters long. It has two beams, which can produce a faster, more uniform explosion than one by igniting the air-fuel column in two locations at once – the team is even looking at producing a laser with three beams. While it cannot cause combustion with just one pulse, it can do so using several 800-picosecond-long pulses.

IV. LASER IGNITION & ITS ADVANTAGES

Laser ignition, or laser-induced ignition, is the process of starting combustion by the stimulus of a laser light source. Basically, energetic interactions of a laser with a gas may be classified into one of the following four schemes as listed below:

(i) Thermal breakdown
(ii) Non-resonant breakdown
(iii) Resonant breakdown
(iv) Photochemical mechanisms

The main advantages of laser ignitions are given below:

- A choice of arbitrary positioning of the ignition plasma in the combustion cylinder
- Absence of quenching effects by the spark plug electrodes
- Ignition of leaner mixtures than with the spark plug; lower combustion temperatures and less Nox emissions
- No erosion effects as in the case of the spark plugs, lifetime of a laser ignition System expected to be significantly longer than that of a spark plug
- High load/ignition pressures possible, increase in efficiency\
- Precise ignition timing possible
- Exact regulation of the ignition energy deposited in the ignition plasma
- Easier possibility of multipoint ignition
- Shorter ignition delay time and shorter combustion time

V. PERFORMANCE REQUIRMENTS FOR LASER IGNITERS

There are certain performance requirements which a practical laser spark plug should posses, are listed below:

(i) Mechanical - Laser and mounting must be hardened against shock and vibration

(ii) Enviromental - Laser should perform over a large temperature range

(iii) Peak Power - Laser should provide megawatts raw beam output

(iv) Average Power - 1-laser per cylinder requires 10Hz for 1200rpm engine operation

(v) Life Time - 100 million shots – good, 500 million shots - better

VI. PRESENT SCENERIO

Lasers promise less pollution and greater fuel efficiency, but making small, powerful lasers has, until now, proven hard. To ignite combustion, a laser must focus light to approximately 100 giga-watts per square centimeter with short pulses of more than 10 milli-joules each.

In the past, lasers that could meet those requirements were limited to basic research because they were big, inefficient, and unstable. Nor could they be located away from the engine, because their powerful beams would destroy any optical fibers that delivered light to the cylinders. This problem overcame by making composite lasers from ceramic powders. In this the powders is heated and fuse into optically transparent solids and embeds metal ions in them to tune their properties. Ceramics are easier to tune optically than conventional crystals. They are also much stronger, more durable, and thermally conductive, so they can dissipate the heat from an engine without breaking down.

Researchers from Japan's National Institutes of Natural Sciences (NINS) are creating laser igniters that could one day replace spark plugs in automobile engines. The team from Japan built its laser from two yttrium-aluminum-gallium (YAG) segments, one doped with neodymium, the other with chromium. They bonded the two sections together to form a powerful laser only 9 millimeters in diameter and 11 millimeters long (a bit less than half an inch).

The composite generates two laser beams that can ignite fuel in two separate locations at the same time. This would produce a flame wall that grows faster and more uniformly than one lit by a single laser.

The laser is not strong enough to light the leanest fuel mixtures with a single pulse. By using several 800-picosecond-long pulses, however, they can inject enough energy to ignite the mixture completely.

A commercial automotive engine will require 60 Hz (or pulse trains per second), The team has already tested the new dual-beam laser at 100 Hz. The team is also at work on a three-beam laser that will enable even faster and more uniform combustion.

The laser-ignition system, although highly promising, is not yet being installed into actual automobiles made in a factory. Scientist team from Japan is, however, working with a large spark-plug company and with DENSO Corporation, a member of the Toyota Group.

VII. CONCLUSION

In this paper, it is described that how a revolutionary change has come after the positive research work on laser igniters which can replace the conventional spark plug in near future very soon. This replacement of conventional spark plugs to laser igniters will be a milestone in automobile industry. Laser igniters will be able to combust the fuel with lean air-fuel mixture as compare to conventional spark plug, which helps to lower down the Nox emission and gives better fuel efficiency.

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