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The Safer Future Ignition ‘Laser Ignition’

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Abstract— **For more than 150 years, spark plugs have powered internal combustion engines. Automakers are now one step closer to being able to replace this long-standing technology with laser igniters, which will enable cleaner, more efficient, and more economical vehicles. The technique of laser ignition has reached a high degree of maturity. It allows the improvement of performance of large MW gas engines: higher ignition pressures, capability for ignition of leanest mixtures, lower NOx content in the exhaust, higher efficiency. Conventional spark plugs pose a barrier to improving fuel economy and reducing emissions of nitrogen oxides (NOx), a key component of smog. Engines make NOx as a byproduct of combustion. If engines ran leaner -- burnt more air and less fuel -- they would produce significantly smaller NOx emissions. Laser igniters 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.**

Keywords:- *Laser Igniter, Spark Plug, NOx Emissions, Fuel Efficiency.*

I INTRODUCTION

Since very long time, 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. 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 TYPES OF LASER IGNITION SYSTEM

[1]. Thermal initiation:

In thermal initiation of ignition, there is no electrical breakdown of the gas and a laser beam is used to raise the kinetic energy of target molecules in translational, rotational, or vibration forms. Consequently, molecular bonds are broken and chemical reaction occur leading to ignition with typically long ignition delay times. This method is suitable for fuel/oxidizer mixtures with strong absorption at the laser wavelength. However, if in a gaseous or liquid mixtures is an objective, thermal ignition is unlikely a preferred choice due to energy absorption along the laser propagation direction. Conversely, this is an ideal method for homogeneous or distributed ignition of combustible gases or liquids. Thermal ignition method has been used successfully for solid fuels due to their absorption ability at infrared wavelengths.

[2]. Non-resonant breakdown:

In no resonant breakdown ignition method, because typically the light photon energy is invisible or UV range of spectrum, multi photon processes are required for molecular ionization. This is due to the lower photon energy in this range of wavelengths in comparison to the molecular ionization energy. The electrons thus freed will absorb more energy to boost their kinetic energy (KE), facilitating further molecular ionization through collision with other molecules. This process shortly leads to an electron avalanche and ends with gas breakdown and ignition. By far, the most commonly used technique is the non resonant initiation of ignition primarily because of the freedom in selection of the laser wavelength and ease of implementation.

[3]. Resonant breakdown:

The resonant breakdown laser ignition process involves, first, a non resonant multi photon dissociation of molecules resulting to freed atoms, followed by a resonant photo ionization of these atoms. This process generates sufficient electrons needed for gas breakdown. Theoretically, less input energy is required due to the resonant nature of this method.

[4]. Photochemical mechanisms:

In photochemical ignition approach, very little direct heating takes place and the Laser beam brings about molecular dissociation leading to formation of radicals, if the production rate of the radicals produced by this approach is higher than the recombination rate (i.e., neutralizing the radicals), then the number of these highly active species will reach a threshold value, leading to an ignition event. This number augmentation scenario is named as chain-branching in chemical terms.

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III TYPES OF LASER

There are different types of laser which can be used:-
1. Ruby laser
2. Chemical lasers
3. Excimer lasers
4. Solid-state lasers
5. Semiconductor lasers
6. Dye lasers

IV 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 gaga watts per square centimeter with short pulses of more than10 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.

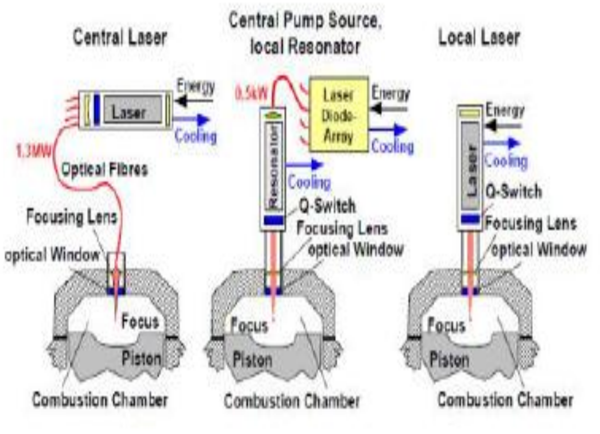

Figure 1 Overhead Laser System Attachments

Made from two bonded yttrium-aluminum-gallium segments, the laser igniter is just 9 millimeters wide and11 millimeters long. It has two beams, which can producea 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. Concept Carynthian Tech Research Villach / AVL Graz, Austria, based on transversally diode-pumped Q-switched Nd: YAG laser.

Figure 2 Difference between spark plug and laser plug

V LITERATURE REVIEW OR SURVEY

A. Laser Ignition Process :

Laser induced spark ignition begins with the initial seed electrons produced from impurities in the gas mixture (e.g. Dust, aerosolorsoot particles). It is very unlikely that the initial electrons are produced by multi photon ionization because the intensities in the focus (1012 W/cm2) are too low to ionize gas molecules via this process, which requires intensities of more than 1014 W/cm2. The laser energy is deposited in a few nanoseconds on impurities lead to formation of free electron. Electrons liberated by this means collide with other molecules and ionize them, leading to an electron avalanche which produces the shock wave and that leads to breakdown of the gas. In the first milliseconds an ignition delay can be observed which has duration between 5 – 100 ms depending on the mixture. Combustion can last between 100 ms up to several seconds again depending on the gas mixture, initial pressure, pulse energy, plasma size, position of the plasma in the combustion bomb and initial temperature. Location of ignition point in the combustion chamber can be optimized in laser ignition by changing the focal length of the converging lens. Flame kernel can be moved away from the combustion chamber walls thus the heat transfer losses through the cylinder walls can be reduced thereby enhancing the overall efficiency for the process.

The generated plasma due to heat which is produce by shock wave is sufficiently strong to ignite the fuel. The wavelength of laser depend upon the absorption properties of the laser and the minimum energy required depends upon the number of photons required for producing electron avalanche.

B. Comparison between LI and SI system :

Spark ignition system :

Less intense spark, Restrictions while choosing the ignition location, Leaner mixtures cannot be burned, Spark plug ignite the charge in a fixed position, so they can't cope with a stratified charge, Flame propagation is slow, Multi point fuel ignition is not feasible, NOX emission-Ratio between fuel and air has to be within the correct range. It causes more noxe mission.

Laser ignition system :

More intense spark, Free choice of the ignition location within the combustion chamber, Leaner fuel can burn effectively, Laser ignition system could cope with a stratified charge, Flame propagation is relatively fast resulting in shorter combustion time, Easier possibility of multipoint ignition, nox emission-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. Less nox emission.

Additional advantages of LI :

Absence of quenching effects by the spark plug electrodes, 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.

C. Effects on Engine Performance:

The experimental result shows that fuel consumption and emissions levels are less with the laser ignition system. This parameter increases the efficiency of the engine with laser ignition system. Smoothness in engine is more with laser ignition system than spark ignition system.

As compression ratio and compression flame velocity must be increase. Combustion should be minimum. The use of optic additional possibilities to generate sever different points in the combustion chamber approach is the use of diffractive lenses.

Minimum Ignition Energy for Combustion:

The minimum energy require for the ignition of the charge present in the combustion chamber is called as minimum ignition energy.

The experimental result show energy for laser and spark is lean and rich mixture respectively.

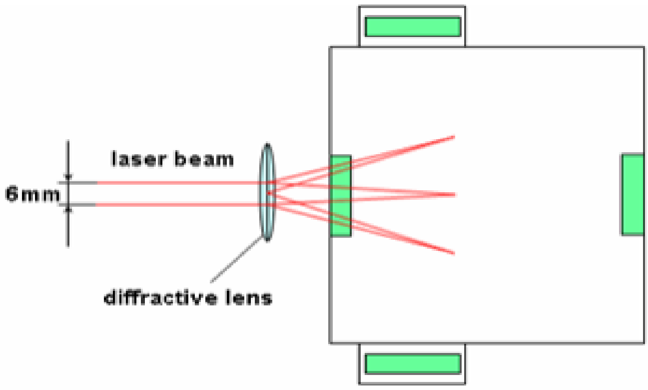

Figure 3 Optical Triplication Of Foci

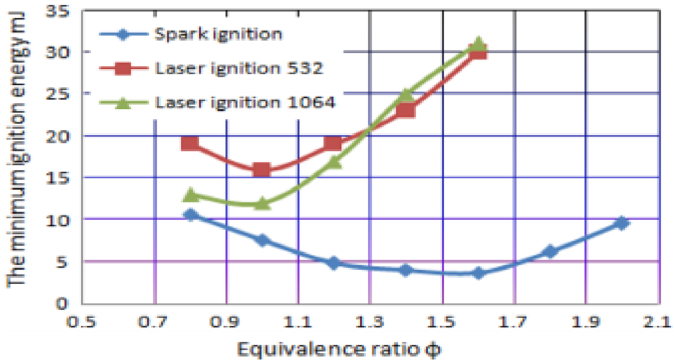

Figure 4 Minimum Ignition Energy W.R.T. Equivalence Ratio

D. Effects on Exhaust Gases: NOx gases emission in engine : Experimentally calculated flame front of a Laser ignition after 29°CA in operation at Lambda(k) (relative air-fuel ratio) 2.05. In this manner, the spark duration (90 %) can be reduced approximately to less than half (NOX level 30 ppm).

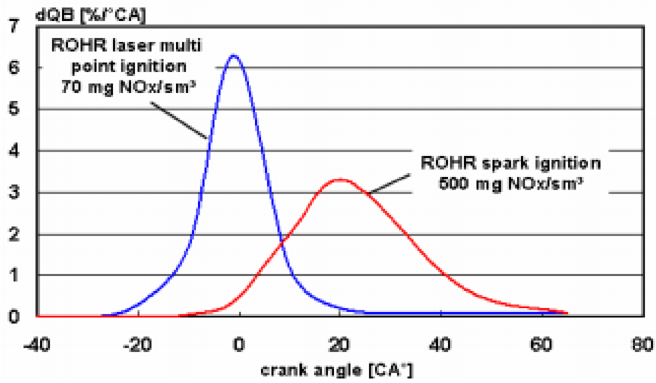

Figure 5 Variation In Nox Emission With Crank Angle

CO gases emission in engine :

The experimental results shows comparative mass emission carbon monoxide (BSCO) for laser ignition and spark w.r.t. K for different ignition timings. Spark ignition often operates on stoichiometric or slightly richer most of the time in entire engine operating range. CO emission from spark ignition engines are therefore significant. Monoxide emissions are a direct function of lambda.

Performance Requirements For Laser Igniters

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

Mechanical - Laser and mounting must be hardened against shock and vibration

Enviromental - Laser should perform over a large temperature range

Peak Power - Laser should provide megawatts raw beam output

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

Life Time - 150 million shots – good, 600 million shots - better

Disadvantages of Conventional Ignition System

1. Location of spark plug is not flexible as it requires shielding of plug from immense heat and fuel.
2. Spray and spark plug location cannot be chosen optimally.
3. Spark plug electrodes can disturb the gas flow within the combustion chamber
4. It is not possible to ignite inside the fuel spray
5. It requires frequent maintenance to remove carbon deposits.

Advantages of Using Laser Ignition System

1. The lifetime of laser ignitor is much more as compared to the conventional ignition system.
2. Laser ignition system can burn leaner mixture more efficiently.
3. Precise timing is possible in laser ignition system.
4. Reduced fuel consumption rate.
5. Free choice of the ignition location within the combustion chamber.

VI CONCLUSION

Laser ignition system allows almost free choice of the ignition location within the combustion chamber, even inside the fuel spray. Laser ignition system helps in significant reduction in consumption of fuel and also in nox emission.

Laser ignition system requires less energy requirement as compared to conventional ignition system with lean and rich air fuel mixture. Laser ignition is nonintrusive in nature; high energy can be rapidly deposited, has limited heat losses, and is capable of multipoint ignition of combustible charges. Although the laser will need to fire more than50 times per second to produce 3000 RPM, it will require less power than current spark plugs.

Experiments were performed on a single cylinder research engine comparing two different ignition systems including: conventional capacitance discharge spark ignition, free space laser ignition, and Several benefits were observed with laser ignition including the following:

Extension of the lean misfire limit by about 10 percent at BMEPS of 10 and 15 Bar.

Increase of the overall burn rate, and

Improved combustion stability at all comparable test points.

The improved combustion, combined with optimization of engine intake air pressure and ignition timing, was found to result in,

A reduction of BSNOx emissions by about 70 percent for a given efficiency, or An increase in brake thermal efficiencies up to 3 percentage points, while maintaining BSNOx emissions constant.

Considering all of the perceived benefits of laser ignition, the ongoing efforts aimed to develop an LIS for use with a multi cylinder engine.

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