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A PATH FOR HORIZING YOUR INNOVATIVE WORK

LASER ASSISTED IGNITION SYSTEM FOR IC ENGINES

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Abstract: Now-a-days internal combustion engines are playing the vital roles in day-to-day life. Hence study of ignition in IC Engines is very important. In general, a well-defined ignition location and ignition time is of great importance for an IC engine. Spark plugs are well suited for such tasks but suffer from disadvantages, like erosion of electrodes & inflexible or un-optimal location of spark plug. Over the conventional ignition systems, ignition of combustible materials by means of high power laser pulses could be beneficial. Because the thermodynamic requirements of a high compression ratio and a high power density are fulfilled well by laser ignition. This paper outlines progress made in recent research on laser ignited IC engines, discusses the potential advantages and control opportunities and considers the challenges faced. In technical appliances such as internal combustion engines, reliable ignition is necessary for adequate system performance. Ignition strongly affects the formation of pollutants and the extent of fuel combustion. Laser ignition system can be a reliable way to achieve this.

Keywords: Laser ignition, Thermal initiation, Non resonant breakdown, Resonant breakdown, Photochemical mechanism.

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INTRODUCTION

It is widely accepted that the IC engine will continue to be the main vehicle power plant over the next two decades, before significant displacement by alternative technologies takes place. Hence, as the global mobilization of people and goods increases, advances in combustion and after-treatment are needed to reduce the environmental impact of the continued use of IC engine vehicles. To meet environmental legislation requirements, automotive manufacturers continue to address two critical aspects of engine performance: fuel economy and exhaust gas emissions. New engines are developed with advanced combustion mechanisms to meet future goals on performance, fuel economy and emissions. The spark plug has remained largely unchanged since its invention, yet its poor ability to ignite highly dilute air-fuel mixtures which limits the potential for improving combustion efficiency. SI also restricts engine design, since the spark position is fixed by the cylinder head location of the plug, and the protruding electrode disturbs the cylinder geometry and may quench the combustion flame kernel. 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.

STUDY OF IGNITION IN IC ENGINES:

What is ignition?

Ignition can be defined as 'the relatively rapid combination of hydrogen & carbon in the fuel with the oxygen in the air resulting liberation of energy in the form of heat'
Types of ignition:

A. Compression Ignition (CI) or Auto Ignition: At certain values of temperature and pressure a mixture will ignite spontaneously, this is known as the auto ignition or compression ignition.

B. **Induced Ignition**

A process where a mixture, which would not ignite by it, is ignited locally by an ignition source (i.e. Electric spark plug, pulsed laser, and microwave ignition source) is called induced ignition. In induced ignition, energy is deposited, leading to a temperature rise in a small volume of the mixture, where auto ignition takes place or the energy is used for the generation of radicals. In both cases subsequent flame propagation occurs and sets the mixture on fire.

CONVENTIONAL SPARKING PLUG IGNITION:

Conventional spark plug ignition has been used for many years. For ignition of a fuel-air mixture the fuel-air mixture is compressed and at the right moment a high voltage is applied to the electrodes of the spark plug. hence spark is produced between the electrodes of the spark plug which initiates the combustion.

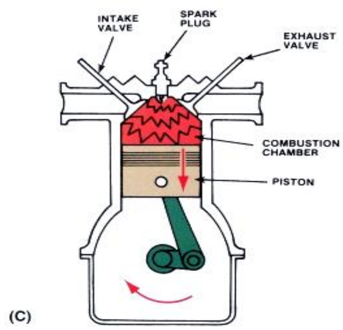

Fig. : 1 conventional sparking plug ignition

INTRODUCTION TO LASER:

Laser stands for **"Light amplification by stimulated emission of radiations"** Lasers provide intense and unidirectional beam of light. Laser light is monochromatic (one specific wavelength). Wavelength of light is determined by amount of energy released when electron drops to lower orbit. Light is coherent; all the photons have same wave fronts that launch to unison. Laser light has tight beam and is strong and concentrated. To make these three properties occur takes something called "Stimulated Emission", in which photon emission is organized.

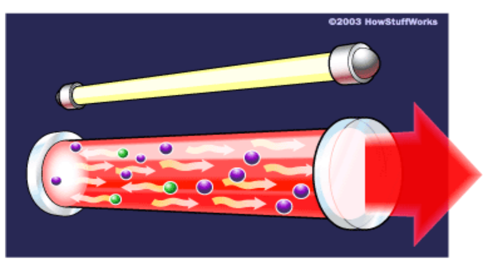

Fig.:2 Laser

Types of lasers

1. Ruby laser

2. Chemical lasers
3. Excimer lasers
4. Solid-state lasers
5. Semiconductor lasers
6. Dye lasers

LASER ASSISTED IGNITION SYSTEMS:

It is the process of starting combustion by the stimulus of a laser light source. LI uses an optical breakdown of gas molecules caused by an intense laser pulse to ignite gas mixtures. The beam of a powerful short pulse laser is focused by a lens into a combustion chamber and near the focal spot and hot and bright plasma is generated.

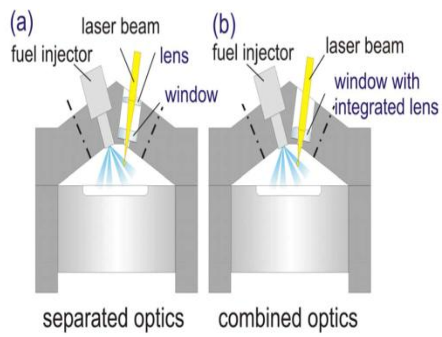

Fig.3: laser assisted ignition systems

The process begins with multi-photon ionization of few gas molecules which releases electrons that readily absorb more photons via the inverse bremsstrahlung process to increase their kinetic energy. Electrons liberated by this means collide with other molecules and ionize them, leading to an electron avalanche, and breakdown of the gas. Multiphoton absorption processes are usually essential for the initial stage of breakdown because the available photon energy at visible and near IR wavelengths is much smaller than the ionization energy. For very short pulse duration (few picoseconds) the multiphoton processes alone must provide breakdown, since there is insufficient time for electron-molecule collision to occur. Thus this avalanche of electrons and resultant ions collide with each other producing immense heat hence creating plasma which 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 the electron avalanche.

Types of Laser Ignition

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 vibrational 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 nonresonant breakdown ignition method, because typically the light photon energy is invisible or UV range of spectrum, multiphoton 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 nonresonant 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 nonresonant multiphoton 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 (i.e., highly reactive chemical species), 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 (radical) number augmentation scenario is named as chain-branching in chemicalterms.

How Laser Ignition Works

The laser ignition system has a laser transmitter with a fiber-optic cable powered by the car's battery. It shoots the laser beam to a focusing lens that would consume a much smaller space than current spark plugs. The lenses focus the beams into an intense pinpoint of light, and when the fuel is injected into the engine, the laser is fired and produces enough energy (heat) to ignite the fuel.

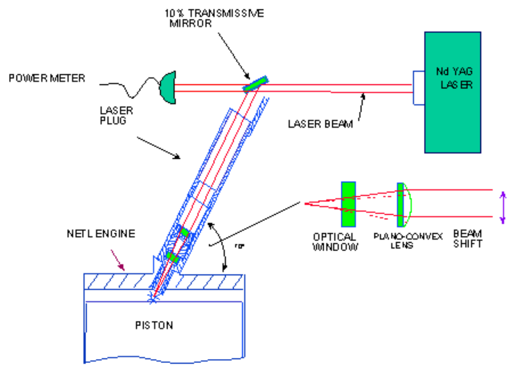

Fig:Laser ignition arrangement

WHY LASER ASSISTED IGNITION SYSTEMS ?

Drawbacks of Conventional Ignition System

1. Location of spark plug is not flexible.
2. Ignition location cannot be chosen optimally.
3. Spark plug electrodes can disturb the gas flow within the combustion chamber.
4. It requires frequent maintenance to remove carbon deposits.
5. Leaner mixtures cannot be burned.
6. Degradation of electrodes at high pressure and temperature.
7. Flame propagation is slow.
8. Multi point fuel ignition is not feasible.
9. Higher turbulence levels are required.

10. Erosion of spark plug electrodes.

Advantages of laser ignition system

1. Laser ignites the leaner mixtures, thus NOx emission is reduced.
2. Lasers are monochromatic, so it will be much easier to ignite natural gases which is otherwise difficult.
3. Laser spark plug ignition system requires less power than traditional spark plugs.
4. Lasers can be focused and split into multiple beams to give multiple ignition points, which means it can give a far better chance of ignition.
5. The laser also produces more stable combustion so you need to put less fuel into the cylinder, therefore increasing efficiency.
6. Optical wire and laser setup is much smaller than the current spark plug model, allowing for different design opportunities.
7. Lasers can reflect back from inside the cylinders relaying information such as fuel type and level of ignition creating optimum performance.
8. Laser use will reduce erosion.

CHALLENGES IN LASER ASSISTED IGNITION SYSTEMS:

- It is costly
- Delivering the beam through free space and channeling it into the combustion chamber through the optical fiber is quite difficult.
- The engine vibration increases the divergence of the output beam and reduces the beam mode quality.
- Bending the fiber is also problematical.

High density of laser energy can cause long term degradation and therefore loss of ignition.

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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