Chapter 7

Study of Composite Ceramics for Combustion Engine

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Abstract

A wide variety of lasers have a growing number of applications in the fields of science, engineering, and medicine. This article provides a concise overview of the fundamental principles, operational aspects, and application areas pertaining to lasers for fuel ignition. The purpose of this article is the current relevance of lasers for fuel ignition, as well as how they function in combustion engines, their applications, benefits, and drawbacks. In essence, there are four different ways that laser light can initiate an ignition event. There are a few different names for these processes, including photochemical ignition, resonant breakdown, thermal initiation, and non-resonant breakdown. The non-resonant initiation of combustion technique is currently the method that is utilised the most frequently as a result of its ease of use and flexibility in terms of the laser wavelength that can be chosen. There are different types of ignition systems, conventional spark plugs can be replaced by lasers instead. The vehicles will continue to be powered by internal combustion engines for the foreseeable future. The continued use of internal combustion engine vehicles is responsible for a significant amount of pollution and has a negative impact on the environment. To mitigate this problem, advancements in combustion technology and treatment methods are required. The concept of the ignition process can be altered by the laser ignition system. When compared to a normal ignition system, it has many benefits.

Keywords: IC engine, modelling, analysis, nodes, electronic ignition system

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1. Introduction

The spark plug, which is a component of the spark mechanism (SI), is the component that is accountable for initiating the combustion of the air-fuel mixture that is contained within the combustion chamber. It is necessary for the mechanism to generate a voltage that is sufficiently high to light the electrodes of the spark plug. Electronic ignition systems have become more streamlined and reliable as a result of the development of electronic controls to initiate ignition and the use of distributor-less ignition systems [1]. These ignition methods, on the other hand, restrict the development of spark-ignition engines in the future. It is common practise to use lean air-fuel combination ignition in order to fulfil prime thermal efficiency requirements and stringent exhaust emission standards. On the other hand, lean combustion is related to slower rates of flame propagation and lower levels of power output. The power output of the engine can be raised by increasing the initial pressure in the cylinders through the use of turbocharging [2].

In order to keep the same plug electrode distance when the cylinder pressure was increased, a higher secondary coil voltage would be required. This would ultimately lead to severe electrode degradation over the course of time. Increasing the speed of flame propagation in lean air-fuel combinations by either utilising multi-point ignition or optimising the location of the ignition spot inside the combustion chamber. This can be accomplished by reducing the amount of oxygen in the mixture. An extremely conventional spark ignition engine's ignition spot never moves more than a short distance from the top of the combustion chamber and cannot be altered noticeably [3]. Traditional plug mechanisms suffer from these drawbacks, which can be circumvented by employing an ignition system that is dependable, high-energy, electrode-less, and flexible regarding the location of the spark. One such system is laser ignition.

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In the race to find a secondary ignition source for internal combustion engines, the laser is quickly emerging as a potential front-runner. A lens system will focus brief laser pulses with pulse durations of a few nanoseconds each in order to achieve ignition within the cylinder that is carrying a combustible air-fuel mixture. This will allow the ignition process to take place. Plasma is formed when combustible charge is subjected to an energy density that is greater than a certain threshold and causes it to break down. When the energy of the plasma spark is high enough, the mixture of air and fuel that is contained within the combustion chamber catches fire, which then kick starts the combustion process [4]. A localised input of energy in the form of heat or active chemical species (radicals) is required to start a flame and ignite a mixture of gaseous fuel and air.

This is the case whether the input is heat or radicals. This energy must be higher than a specific threshold, which is referred to as the minimum ignition energy. As a consequence of this, the most accurate physical representation of the ignition process is the injection of a specific minimum amount of energy (Emin) to raise the temperature of a circular zone of fuel-air mixture with a diameter of Lf to a temperature known as the adiabatically flame temperature. This temperature is reached by increasing the temperature of the zone until it reaches the adiabatic flame temperature.

According to the information provided in Ronny, a combustible gaseous mixture has the potential to interact with laser light in four distinct ways that could lead to its ignition. There are a few different names for these processes, including photochemical ignition, non-resonant breakdown, thermal initiation, and resonant breakdown [5]. During the process of thermal ignition, there is no electrical breakdown of the gas; rather, the K.E. of the target molecules is raised by irradiation in the form of translation, rotation, or vibration. This process can take place in any of three different ways. As a consequence of this, molecular connections are severed, and a natural

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process takes place, which ultimately results in ignition after an ignition delay that is typically quite significant [6-7]. This technique is suitable for use with fuel/oxidizer mixtures that absorb light at the laser wavelength in a significant manner. Due to the fact that energy is absorbed in the same direction that the laser is propagating, thermal ignition is not likely to be the most effective method to use when a more localised ignition of a gaseous or liquid mixture is desired. The ability of thermal ignition to absorb infrared light has led to its application in the burning of solid fuels.

1.1 Drawbacks of Conventional Ignition System

- A lack of gasoline spray and extreme heat
- Regular maintenance is necessary to get rid of carbon deposits, regular maintenance is necessary.
- Mixtures that are thinner or leaner cannot be burned or ignited easily.
- High pressure and temperature can cause electrode wear.
- The flame spread slowly.
- No multi-point gasoline ignition is possible.
- It is difficult to ignite without much turbulence.
- By adopting a laser igniting method, can get around all of the aforementioned problems.

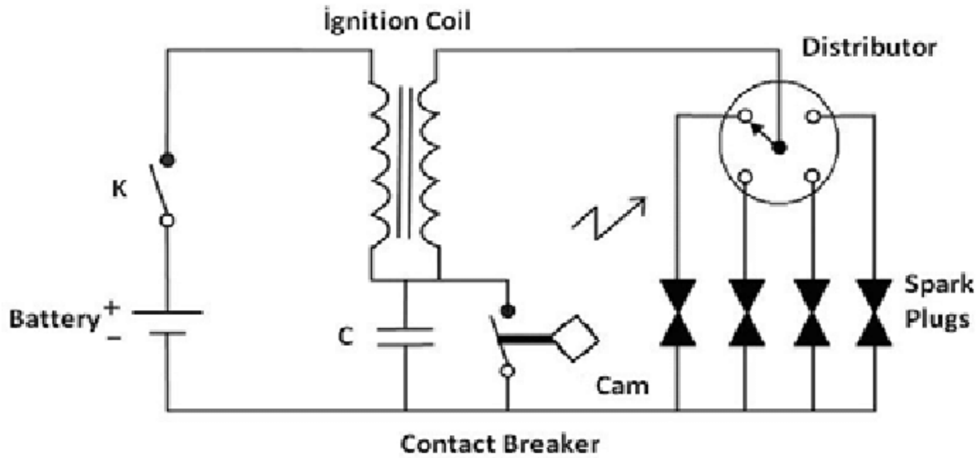

Figure. 1: Conventional Ignition System

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2. Laser Ignition System Working

The laser mechanism includes a laser transmitter that is powered by the car's battery, and this transmitter is connected to a fiber-optic cable. The laser ignites and produces enough energy (heat) to ignite the fuel when it is injected into the engine at the same time that fuel is being injected. The light is focused into a pinpoint by the lenses, which are made of sunlight. After going through the lens that converges light, the laser beams emerge from it more spread out. This makes the beam very powerful and, to some extent, able to start a fire. If necessary, the point of interest is modified where ignition is required.

The light beam's plasma produces the following two effects:

- High-energy photon emission Creating shock waves
- As can be seen from the flame's longitudinal propagation along the light beam, the high energy photons heat and ionise any charge that is present in the path of the ray.

The shock waves help the flame spread by carrying energy from the light beam outward.

3. Laser Ignition Types

In their most basic form, the energetic interactions that take place between a laser and a gas can be placed into one of the following four categories:

- The initial onset of thermal activity
- The result of non-resonance leading to failure
- Resonance failure

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3.1 Photochemical Mechanisms

3.1.1 Thermal start-up

In thermal initiation of ignition, there is no breakdown of the gas's electrical charge, and a shaft is used to increase mechanical energy in order to target molecules in translational, rotational, or vibration forms. Thermal initiation of ignition is a type of ignition.

3.1.2 Non-resonant failure

In order to ionise molecules during non-resonant breakdown ignition, multi-photon processes are necessary. This is due to the fact that the photon energy produced by sunlight is frequently undetectable or lies in the UV region of the spectrum.

3.1.3. Resonant analysis

The process of igniting a resonant breakdown laser begins with the non-resonant multi-photon dissociation of molecules, which is then followed by the resonant photoionization of the molecule fragments. 4. The various mechanisms involved in photochemistry: The ray shatters molecules, which results in the formation of radicals; however, this kind of ignition (the formation of highly reactive chemical species) does not directly cause things to become hotter. Following the fruitful completion of the preliminary tests of viability, the ignition system of the engine was modified to use lasers.

The standard plug on the engine was changed out for a window that was installed inside of a cylinder as part of the modification. Because the condition of the initial optical breakdown can vary from case to case, the positioning of the focusing lens within the mount will need to be adjusted to take these differences into account. In the

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beginning of the laser ignition experiment on the engine, an excimer laser was utilised; however, in the end, a q-switched Nd:YAG laser was utilised (see table 1).

Figure. 2: Laser system research engine

The excimer laser was replaced mostly due to the reality that it exhibits significant energy variations, particularly at extremely low pulse energies. During the trials, fuel/air ratios, ignition locations, and pulse energies are changed. The engine has been regularly run at different settings for several hours while being checked. As a baseline measurement, traditional plug igniting is ongoing in all laser ignition trials.

Table 1: Engine setup details

Size in cylinders	One	Single pump-source	Flash ligh
Quantity of valve	One	Wavelength	1064 or 532 nm
Type of Injector	Multi hole	Maximum pulse energy	1064 or 532 nm
Stroke Length	85 mm	Pulse duration	6 ns
Diameter	88 mm	Power Consume	1000 W
Displacement volume	517 cm^3	Beam	Dia. of 6 mm
Compression ratio	11.6	Type	Brilliant Quantel

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4. Results of Experiment

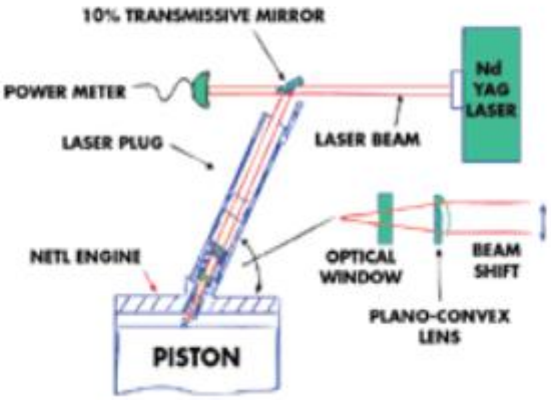

Figure.3: Diagram of a laser ignition controlled engine

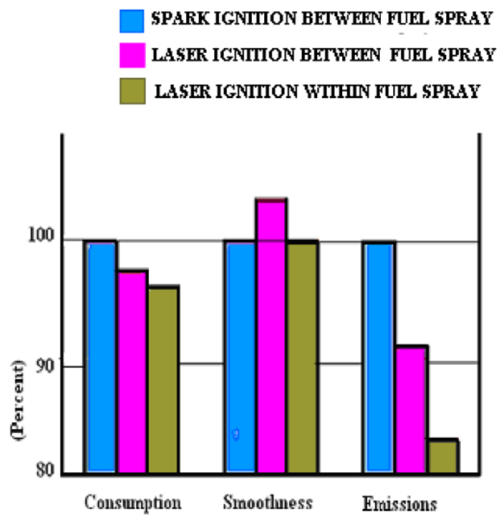

Figure.4: Laser ignition technology

The results of the experiment are depicted in a summary form in figure 3. The advantages that laser ignition has over the more conventional spark plug ignition are illustrated in figure 4. Laser ignition can save a significant amount of fuel when contrasted with the more traditional method of plug ignition. The decrease in emissions of exhaust is almost 20 percent. The utmost importance that the advantages

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of laser ignition be obtained while maintaining a level of engine smoothness that is nearly identical. In addition to this, a frequency-doubled Nd:YAG laser was utilised in order to look into the potential wavelength repercussions of the laser ignition process. There are no effects that are felt by other parties. The best results can also be obtained in terms of the amount of fuel that is used, and this is due to the fact that laser ignition within the fuel spray produces exhaust gases. As was mentioned earlier, traditional spark plugs will be quickly ruined by the fuel spray, which makes it impractical to use them in the first place. This limitation does not affect how a laser is ignited in any way.

5. Conclusion

It has been shown that a laser-induced method is effective when working with directly injected ICE. The ignition can be placed virtually anywhere within the chamber of combustion, including inside the fuel spray itself. The laser ignition method has a lot of potential given that it lowers the amount of fuel used and the amount of pollution produced. The cost of a laser ignition plug is currently quite high in comparison to the cost of a regular electrical device ignition, and the technology is not even close to being ready for widespread use. Nevertheless, there are many situations that occur in real life where using a laser to start a fire is more appealing due to the greater potential and benefits it offers.

References

[1] Prabhakaran, A et.al., "Analysis of the efficiency of an automotive alternator by replacing mild steel into aluminum as a material for rotor." Materials Today: Proceedings 37 (2021): 1269-1273.

[2] D. R. Lidde, ed., CRC Handbook of Chemistry and Physics, CRC Press, 2000

[3] J. Ma, D. Alexander, and D. Poulain, "Laser spark ignition and combustion Characteristics of methane-air mixtures," Combustion and Flame 112 (4), pp.492–506, 1998

[4] J. Syage, E. Fournier, R. Rianda, and R. Cohn, "Dynamics of flame propagation Using laser-induced spark initiation: Ignition energy measurements," Journal of Applied Physics 64 (3), pp. 1499–1507, 1988.

ISBN 978-819620981-0
9 788196 209810

[5] M.Gower, “Krf laser-induced breakdown of gases,” Opt. Commun. 36, No. 1, pp.43–45, 1981.

[6] M. Lavid, A. Poulos, and S. Gulati, “Infrared multi-photon ignition and Combustion enhancement of natural gas,” in SPIE Proc.: Laser Applications in Combustion and Combustion Diagnostics, 1862, pp. 33–44,1993.

[7] P. Ronney, “Laser versus conventional ignition of flames,” Opt. Eng. 33 (2), pp.510–521, 1994.

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