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Laser Ignition and Optical Sensors for Enhanced Combustion

Avinash Malik

School of Engineering and Technology, Ansal University, Sector-55, Gurugram, India

Abstract: ***Sustainability with regard to efficient combustion stands strong on the complete and efficient combustion. Question arises how can we attain that complete efficient combustion first by changing our approach of conventional ignition system of spark ignition so we significantly need breakthrough in our ignition approaches. Laser ignition is promising example in attaining our efficient combustion state .Laser ignition yields extra ordinary advantages compared to the commonly used spark ignition as (1)by minimizing pollution residue (2)overall improve ignition efficiency (3) suitable for lean mixture of bio gas and methane to give enhanced performance (4) flexibility of sequential or multiple ignition which can contribute for enhanced ignition for lean mixture of bio gas, methane. Also by attaching optical sensors gives correct spot for incomplete combustion and gives enhanced efficiency. These two factors can be deciding factors in achieving overall enhanced efficiency of combustion and can be breakthrough in combustion process. As these two encompass the shot comings of conventional spark plug, restricted position. In this research paper we will discuss the enhanced efficiency of combustion process .Laser ignition and optical sensors seems promisable in attaining the enhanced efficiency of combustion engine. Laser plasma ignition and optical sensors holds strong point in achieving .Laser plasma ignition helps to burn lean mixture efficiently and gives enhance efficiency .Types are listed as (1)Thermal initiation (2)Non resonant Breakdown (3)Photo chemical ignition. By far non resonant is conventional to use for laser ignition gives freedom to selecting wavelength in ease of implementation. Absorption optical sensors are investigated as they are helpful in providing precise feedback to optimize combustion process and helpful in pollution control .Hence previous research discusses following types of sensors (1)Wavelength multiplexed TDL sensors(2)Diode laser sensor (3) Mid IR laser source sensor . These two breakthrough will help achieve the enhanced efficiency of lean mixture and very helpful in big turbines and give push to the use of lean mixture in big combustion engines.***

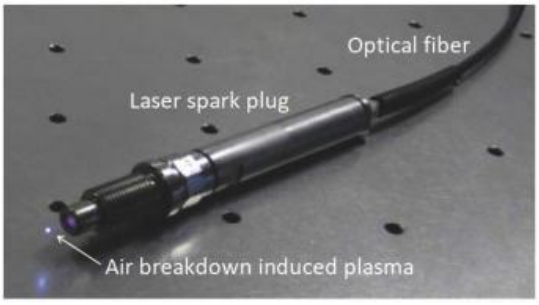
Keywords: Nd : YAG Laser .thermal initiation ,non resonant breakdown, resonant breakdown, photochemical mechanism

1. Introduction

The objective of this research paper has been the development in ignition methods and achieving maximum efficiency that can be achieved with two pragmatic approaches.

1.1 Using laser ignition

Ignition in combustion process plays a vital role whereas there is no breakthrough in the ignition process .There are many developments in types of conventional fuel such as CNG, LPG, DIESEL, H2Oetc. Laser ignition got edge over conventional ignition spark plug ignition as conventional spark plug ignition shows a lackadaisical approach with shortcomings in postioning of spark plug ,carbon deposits on spark plug, plug electrodes ,lean mixture such as CNG etc cannot burned completely .Ratio of fuel and air ahs to be in correct range ,NO x emissions .Hence considering all such points. Laser ignition holds strong ground with maximum efficiency and minimum pollution with CNG with its remarkably high knocking threshold and reduced NO x emission.



1.2 Using Smart sensors

Smart sensors hold potential to uplift the existing combustion process and helps in achieving enhanced efficiency. Smart optical sensors identify weal ignition spots and target the weak ignition spots to achieve enhanced efficiency. These sensors provide immediate feedback needed to optimize the combustion process .Hence previous research confirms that these sensors have ability to improve fuel economy.

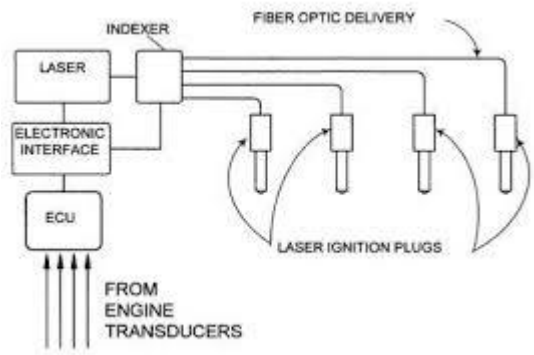
2. Background and Literature Review in I.C Engines

2.1 Ignition

Process of starting combustion by radical reactions until a self sustained flame achieved. Ignition process can be kick start by either compression/auto ignition or induced ignition. Ignition is a radical phenomena for achieving self sustaining flame.

2.2 Types of Ignition

Compression Ignition
Compression ignition self sustained flame is achieved by reaching certain levels of compression, temperature.



Induced Ignition

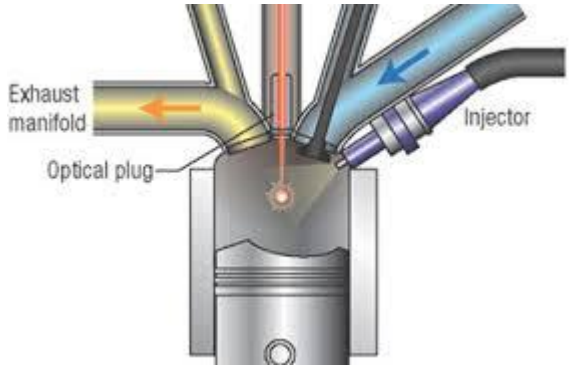
Induced ignition initiated by some external stimuli such as spark plug, laser or microwave for development of self sustaining flame.

2.3 Alternatives for Induced Ignition

From a certain long time, There is no pragmatic advancement in the induced ignition, other than spark ignited ignition. Whereas experiments shows laser ignition holds potential for better efficiency and reduced NO emissions around next 50-100 years pollution becomes a real concern .Therefore advancement in our approach and using new methods can be beneficial significantly in achieving .Smart sensors also both .Even the research of Stanford university investigates a sensor strategy that .showing smart optical sensors really impacted in achieving reduced green house by improving combustion efficiency.

2.4 Laser Ignition

Laser ignition depends on the process of initiating combustion by stimulis of intense and unidirectional beam of light .Laser light is monocromatic and unidirectional (one specific wavelength) Wavelength of energy depends on frequency by which electron drops to lower orbit .Laser ignition is a powerful short impulse beam is focused by a lens into a combustion chamber and near a focal point .Hot and bright plasma is generated.



Types of Laser

- Ruby
- Chemical
- Excimer
- Solid State
- Semiconductor
- Dye

Advantages of Laser Ignition Over Conventional Sparkplug

- Freedom of arbitrary positioning of the ignition.
- Precise ignition timing can be achieved.
- Easier feasibility of multipoint.
- Short combustion time and ignition time can be attained easily.
- Less exhausts of NO x emissions and HC.
- Fuel lean mixture possible.
- Allowing lower idle speed.
- Accurate ignition timing possible.
- No chance of erosion ,as in the case of conventional spark plugs.
- Quenching effects of spark plug electrodes was not at all present.
- Laser self cleaning property results in less polluting of oil and gives longeivity to engine.

Shortcoming of Conventional Spark Plug

- Restricted positioning of spark plug.
- Carbon deposits on the spark plug electrodes.
- Low flame propogation.
- Limitation to burning of leaner fuels example CNG,BIO FUEL,METHANE which require these fuel to be in correct range.
- Gas flow within the gas chamber can be distributed by the spark plug.
- At high temperature, possibility of degradation of spark plug.

3. Background and Literature Review on Smart Sensors

The Stanford research on investigates a sensor strategy that exploits the use of wavelength –multiplexing to combine the beams from multiple diode lasers into a single paths shown in figure. The optical absorption signal required in a practical combustion application like combustion engine or gas turbines is modeled using laboratory validated spectroscopic data. These models enables selection of the optimum molecular transitions from tens of thousands of potential experiments. The combination of process and spectroscopic modeling enables the design of smart absorption based sensor tailored to specific combustion.

Types of Sensors

Tunatble Diode Laser Absorption Sensor

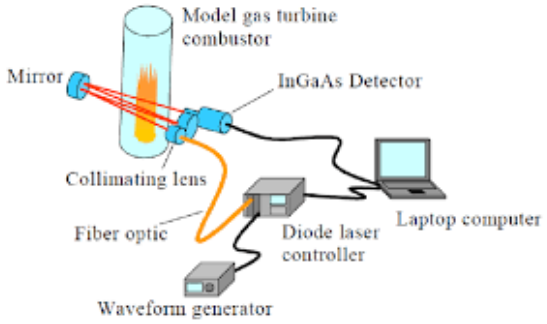
Tunable diode laser absorption sensor holds potential of increasing efficiency and reduced pollutant emissions .It is innovative combustion concept holds potential towards achieving improved overall efficiency and reduced NO x and CO emissions .As temperature is the key factor in combustion radical reactions .Given figure illustrates our concept of fully instrumental researched I.C engine where measurements of fuel ,air and temperature are made in the intake fold fuel ,air ,residual gas and temperature in cylinder and unburned fuel and pollutants in the exhaust manifold.

Wavelength Multiplexed TDL Sendor

This sensor based on absorption of light (naturally present in air and in re circulated exhaust gas) Previous experiments by university of Michigan and The combustion research facility at Scandia national laboratory. The astonishing result from these thriving demonstration shows great potential.

Diode Laser Sensor

Diode laser sensor using water vapour absorption developed for real time considering measurements of temperature in a severe stabilized combustor relevant to gas turbine engine. Using these sensors gas turbines can be operated in a correct range of fuel lean mixture. Future promising successful experiments is a new frontier in combustion control.

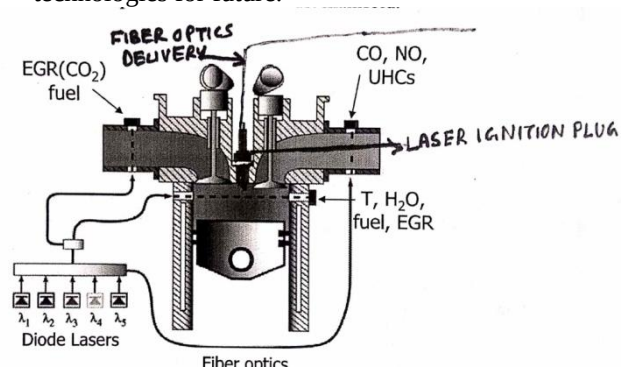


Mid Infrared Laser Source

Mid infrared laser to through quantitative sensing of hydrocarbon fuels .However injection of liquid fuel into the combustors produces a complex two phase mixture of fuel as a gaseous and liquid aerosol .Light scattering from fuel aerosol can make the gas phase measurement difficult .However during previous year collaborative support from AFOSO and ARO .Although the results are in preliminary but still they are very promising.

Advantages of Single Tunable Diode Laser Sensor

- Improves fuel economy.
- Reduced pollutant emissions (CO, NO).
- Increased turbine life because of freedom to operate at a lean fuel /air equivalence ratio.
- Prevent LBO (lean blow out) as it causes significantly safety hazards and reduced engine lifetime.
- Even reducing fossil fuels by 5% it would be an equivalent impact as a doubling of the use of renewable fuels.
- These sensors holds capability for active monitoring and control of combustion and energy conversion technologies for future.



Above diagram is a hypothetical representation of both laser ignition and optical laser sensors

4. Conclusion

Previous research projects shows that the laser ignition holds potential for best alternative of conventional spark plug ignition .Hence laser ignition seems to be the breakthrough in the ignition process .Even previous research paper on the sensors for improving overall efficiency and reduced emissions of CO and NO, hence it seems promising for future but there is no research done on the combination of both laser ignition and smart optical sensors .If the combination of both is only hypothetical achieved it manages to improve to give improvement it will cover up the cost of one time installation of laser .Since functioning of both on single combustion will give best results and will be suitable for lean mixture of CNG powered vehicles and big combustion turbines on lean mixture that not only improve fuel economy it also give a leap towards the pollution free ecosystem free of CO and NO x emissions.

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Author Profile

Avinash Malik received the B .Tech degree in Mechanical Engineering from Ansal University, Gurgaon.