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Laser Ignition System – An Overview

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Abstract: -

Internal Combustion engines play an important role in today's automotive industry. Besides this the combustion process is of great importance in various applications. Thus, study of this combustion process is of great importance as it also has various side-effects. Combustion leads to the release of pollutants into the environment. And taking into consideration, the sustainability of the environment various researchers is working towards better technologies that might reduce pollution and also increase the efficiency of engines. Laser Ignition system is one such technology that can be an alternative to the conventional spark ignition system. The process of starting radical reaction until a self-sustaining flame has developed is called as ignition. Ignition can affect the release of pollutants and the fuel conversion rate. Although spark plugs are well suited for ignition they suffer from disadvantages like erosion of the electrodes, limited positioning possibilities, etc. This paper aims towards providing an overview of the current state of development in the Laser Ignition technology and the various advantages that it provides over the conventional.

Keywords: - Overview of laser ignition system, spark plug ignition, combustion

Introduction: -

Internal combustion engines have a widespread use in transportation and energy production. Even a nominal improvement in them can significantly affect their impact on the environment. In combustion engines, adequate engine performance demands reliable ignition. It is also necessary to reduce fuel consumption and emission of pollutants into the environment. Direct injected fuel engines have a great potential at doing this. However, the existing spark ignition system has a great disadvantage as the location of ignition cannot be appropriately

chosen. As an alternative to this, Laser ignition can not only overcome the disadvantages of spark ignition but also provide us with other major advantages like high compression ratio and power density.

Literature Review: -

Aspects of experimental investigations of laser plug ignition use at spark ignition engine by Bogdan Done (2017) – This research paper provides with the experimental investigation on laser plug ignition and the results thus obtained. The results are in the forms are two plots on the same graphs where the two plots are of spark plug ignition system and laser plug ignition system. This helps us at comparing both these technologies at once and derive our results of which technology is better.

Spark Plug Ignition: -

An electrical spark plug is basically made up of two electrodes separated by a small distance in between. If a high voltage is applied, an electrical breakthrough occurs. This conventional ignition method has been in use for several years. However, it has disadvantages like:

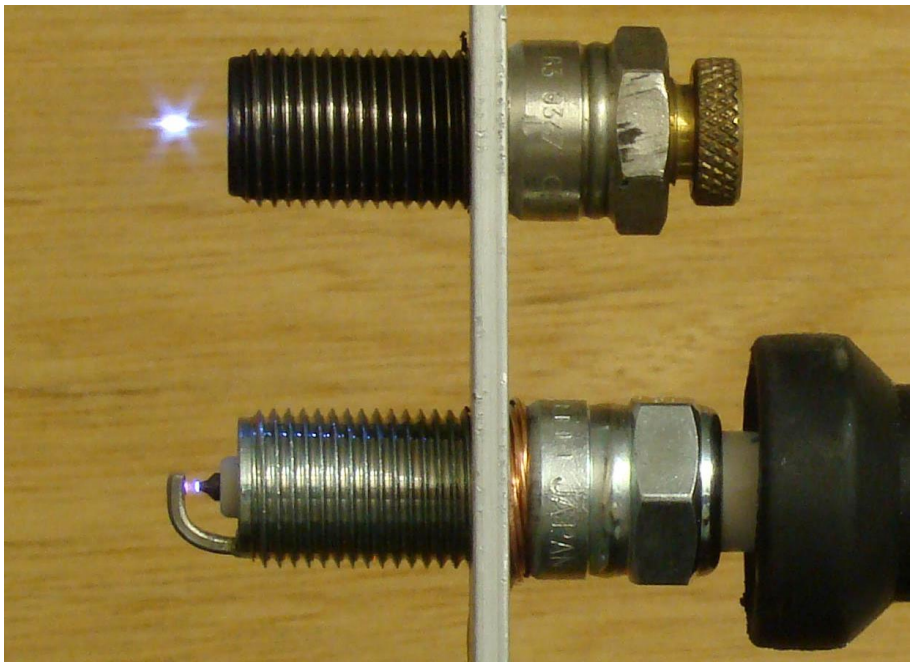
1. No freedom of spark plug location (it needs to be kept away from high temperatures)
2. The electrodes can disturb the flow of gas in the combustion chamber
3. Over a period of time, these electrodes erode and degrade
4. Fuel ignition position is restricted
5. It cannot be ignited inside the fuel spray
6. High frequency of maintenance is required to keep the carbon deposits in check

Laser Ignition: -

Laser ignition, or laser plug ignition, or laser-induced ignition is the ignition where the combustion is brought about by the stimulus of a laser light source. Lasers provide intense, unidirectional, monochromatic beam of light. As the beam is intense optical breakdown of gas molecule occurs leading to the ignition. A lens is used leading to the generation of hot and bright plasma at the focal point. Energy interaction of a laser and gas can

be classified into four categories viz. thermal initiation, non-resonant breakdown, resonant breakdown and photochemical mechanisms.

As intensive laser beam produces optical breakdown in air, the intensity requirements lie in the range of 10^10 to 10^11 W/cm^2. At this intensity gas molecules at the proximity of focal point of the lens ionize and disassociate generating hot plasma. This plasma can be used for the purpose of ignition of fuel-gas mixtures. If we compare the field strength of the field between electrodes of a spark plug and that of a laser pulse, it becomes possible to know approximately the intensity of laser required to get the optical breakdown. It has been observed that at high pressure the laser ignition is favored for ignition process.



Top – Laser Ignition system, Bottom – Spark Plug Ignition system

(Image credit : ourautoexpert.com)

Experiments and Results: -

The experimental research was developed on an experimental single cylinder SI engine, equipped with Laser Plug Ignition. The engine operating regime was 2800 rev/min, 90 % load. The experimental single cylinder engine was mounted on the test bed adequately instrumented; its schema being presented in Figure 1.

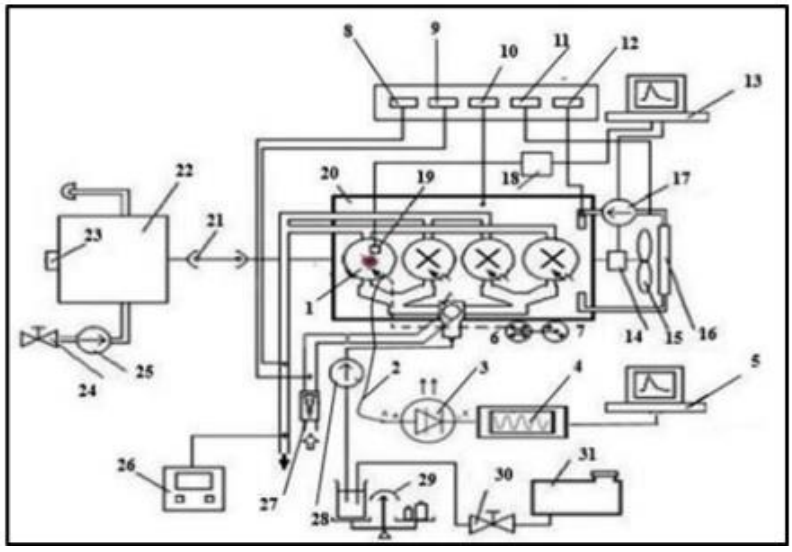
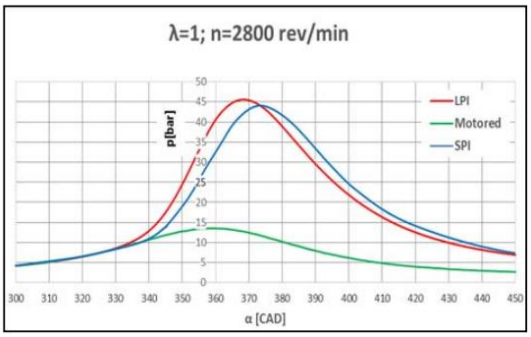
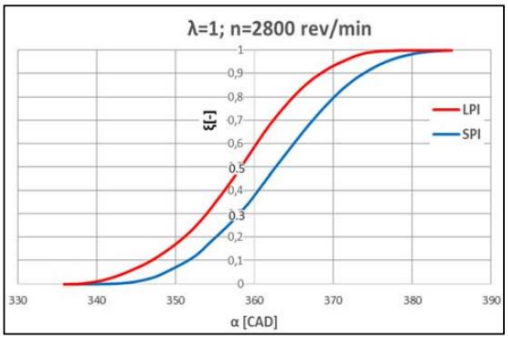


Fig. 1. Experimental test bed schema. 1-laser plug ignition, 2-optical fibre, 3-laser diode, 4-laser power supply, 5-PC with soft laser, 6,7-the ensemble breaker distributor (cam with one corner), 8-inlet air temperature measurement indicator, 9- exhaust gas temperature measurement indicator, 10-engine oil temperature measurement indicator, 11- engine oil pressure measurement indicator, 12-cooling liquid temperature measurement indicator, 13- PC equipped with AVL acquisition board, 14-crank angle encoder, 15-cooling fan, 16-cooler,17-engine water pump, 18- Kistler charge amplifier , 19-piezoelectric Kistler pressure transducer, 20-spark plug ignition, 21- coupling, 22-Schönebeck B4 hydraulic dynamometer, 23-mechanical snuff speed, 24-air flow meter, 25-hydraulic dynamometer water pump, 26-AVL DiCom Analyzer 4000, 27-air flow meter, 28-gasoline fuel pump, 29-gravimetric fuel flow meter, 30-gasoline consumption tap, 31-tank.

Provided below are some graphs obtained from experimentation.





Some conclusions to be derived from these graphs are:

The initial phase ends approximately 4 degrees earlier for laser ignition in comparison to the spark ignition. Similarly, the heat release rate for laser ignition starts sooner. The main influence of laser ignition is reflected on the combustion process which starts earlier and ends earlier compared to the combustion phenomenology registered for the classic ignition system.

Advantages of Laser Ignition: -

1. The spark is more intense
2. Ignition location can be chosen freely
3. Combustion time is short as flame propagation is comparatively faster
4. Multipoint ignition is also possible
5. Less NOx emission if provided with the proper requirements
6. The ignition can be precisely timed

Conclusion: -

Laser plug ignition system shows significant reductions in fuel consumptions as well as reduction in the emission of exhaust gases in comparison to spark plug ignition system, thus proving to be a major advantage. Also, there is no significant difference in the ignition for different wavelengths of the laser. It also facilitates deposition of high amount of energy quickly, less amount of heat loss and multipoint ignition is possible. It shows better minimum ignition energy requirement than electric spark systems. Although laser ignition has a lot of advantages over the spark ignition, it is quite expensive to be of large-scale application. However further research and development in this technology will definitely provide us with a better alternative to the spark plug ignition system.

Acknowledgements and References: -

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