

Research of CFR SI Engine and Dacia single cylinder SI engine equipped with LASER and Classical Spark Plug

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Abstract. Latest investigation has shown that laser ignition offers many potential benefits compared to the classical spark plug ignition due to the improvement of the performance of internal combustion engines. This paper aims to show the progress made in recent research on laser ignited internal combustion engines and also discusses the advantages and control opportunities, while considering the challenges faced and the prospects for its future implementation. It has been demonstrated that laser ignition can be used to improve the control of the engine in areas such as improved combustion stability, reductions in emissions, lower idle speed and leaner operation. Moreover, laser ignition not only that is non-invasive, but it also has a great flexibility in terms of the ignition position. Therefore, it allows the possibility of multi-point ignition. On the other hand, spark plugs offer limited possibilities for optimising engine efficiency, as their fixed position within a cylinder and the protrusion of electrodes disturbs the cylinder geometry and can also quench the flame kernel. As a result, this paper explores several results of the recent research focusing on: indicated, mediated pressures and their wave dispersion .

1. Introduction

A potentially better technological solution for gasoline injection compression Ignition engines, however, continues to depend on fuel Cetane Number, which should not be in excess of CN15[1] causing longer Ignition delays. In other words, faster Ignition and combustion over very lean mixtures, have considerable benefits concerning fuel efficiency and emissions, due to the extremely high-power Ignition sources such as LASER Ignition and offer several advantages in comparison with classical Spark Plug Ignition [2,3]. This type of Ignition was tested initially in 1978, when a single-cylinder research engine was ignited by a CO2 LASER [5].

In 2008, advanced Q-switched Nd:YAG LASERs were used to ignite a four-cylinder engine [4] but T. Taira et al. [5] made public the first gasoline engine ignited only by LASER. Following the research, Nd:YAG/Cr4+:YAG LASERs which were either side pumped [7] or longitudinally pumped and that delivered one beam [7] or multi-beam output [7] proved to be feasible for engines.

The following main advantages of LASER ignition are:

- a choice of arbitrary positioning of the ignition plasma in the combustion cylinder
- absence of quenching effects by the spark plug electrodes
- ignition of leaner mixtures than with the spark plug => lower combustion temperatures
=> less NOx emissions

- 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 [6,7]
- shorter ignition delay time and shorter combustion time [4,7]
- fuel-lean ignition possible

The disadvantages of LASER ignition are:

- high system costs
- concept proven, but no commercial system available yet.

Current research is focusing on the improvement of reliability and miniaturization of LASER Ignition (LI) systems [7], also on the influence of delivered energy on a single point [7].

3. Experimental investigation

Experimental investigations were carried out in a research laboratory of the University POLITEHNICA of Bucharest. The experimental research was developed on an experimental single cylinder SI engine, equipped with LASER Ignition on two engines. The Dacia Single Cylinder SI Engine, operating regime was 2800 rev/min, 90 % load and the CFR Octane Rating Unit Engine, operating regime was 900/min. Both experimental engines were single-cylinder and were mounted on test beds adequately instrumented. The LASER spark plug used in the experiments was provided by INFLPR, Laboratory of Solid-State Quantum Electronics, Magurele, Romania. A photo of the LASER spark is shown in figure 1.



Figure. 1. A photo of a LASER spark plug is shown in comparison with a classical spark plug.

The plasma induced in air by optical breakdown is visible.

(Courtesy of INFLPR, Laboratory of Solid-State Quantum Electronics, Magurele, Romania)

4. Results and discussion

As the graphs show, the dispersal of curves is higher in the case of the classical spark plug at narrow and wide β angles and increases in the case of the LASER spark plug up to a value of $\beta=364^\circ\text{CAD}$. Detail A in figure 2, shows that the maximum values reached by the curves are 363°CAD for the classical spark plug and 364°CAD for the LASER spark plug. Detail B highlights the fact that at an $\beta=357.7^\circ\text{CAD}$, the curve of the LASER spark plug is above that of the classical spark plug.

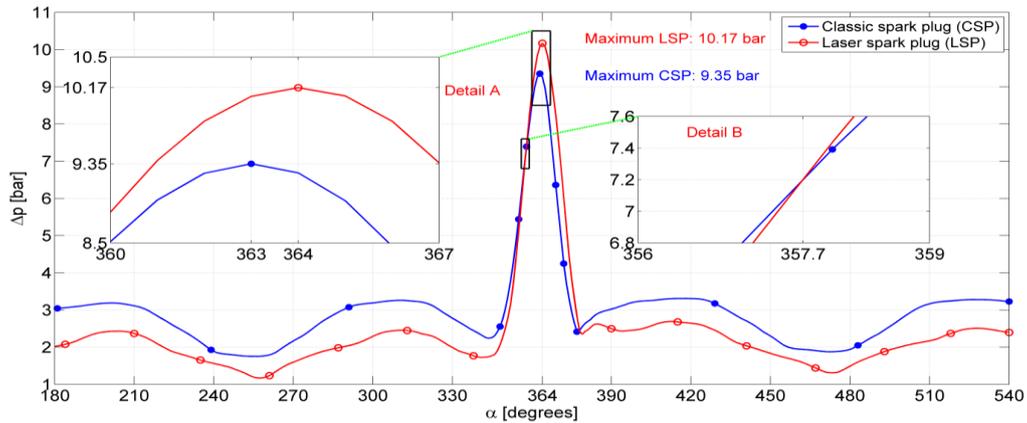


Figure 2. Dispersion of the cycle pressure curves for the classic spark plug and laser spark plug, $\beta = 28.5^\circ\text{CAD}$, $\lambda = 1.1$

Thus, figure 3, presents the pressure curves indicated for the $\lambda=0.9$ classical spark plug case while figure 3b for the LASER spark plug, for all the 50 measured cycles; figure 3c presents the distances between the external outlines of the curves, at each crankshaft rotation angle. As figure 8c, shows, cyclic dispersion is higher for narrow angles in the case of classical spark plugs and higher for wider angles in the case of LASER spark plugs. Moreover, the classical spark plug registers the maximum value (33.1 bar). In exchange, figure 4, shows that in the case of $\lambda=1.0$, cyclic LASER spark plugs have a higher cyclic dispersion in the case of narrow angles while classical spark plugs have a higher cyclic dispersion in the case of wider angles. Furthermore, LASER spark plug register the maximum value (32.2 bar).

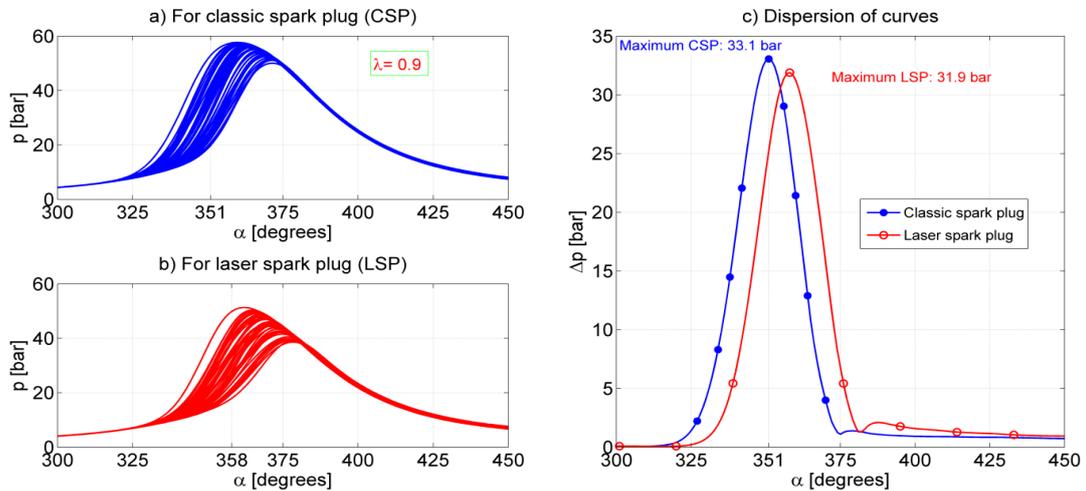


Figure 3. The indicated pressures and the dispersion of their curves (details), Dacia monocillium, for: 50 cycles; $n = 2800 \text{ rpm}$; $\kappa = 90\%$; $\lambda = 0.9$

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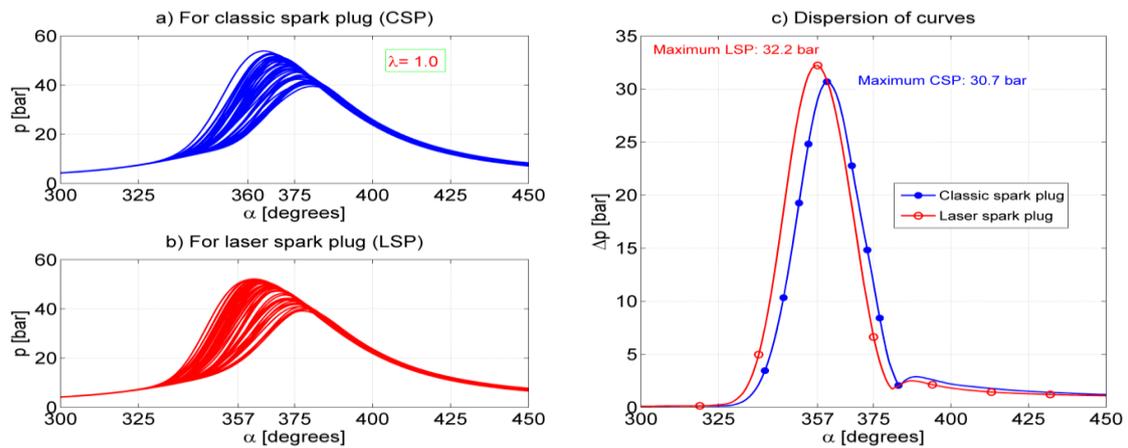


Figure 4. The indicated pressures and the dispersion of their curves (details), Dacia monocillium, for: 50 cycles; $n = 2800$ rpm; $\kappa = 90\%$; $\lambda = 1.0$

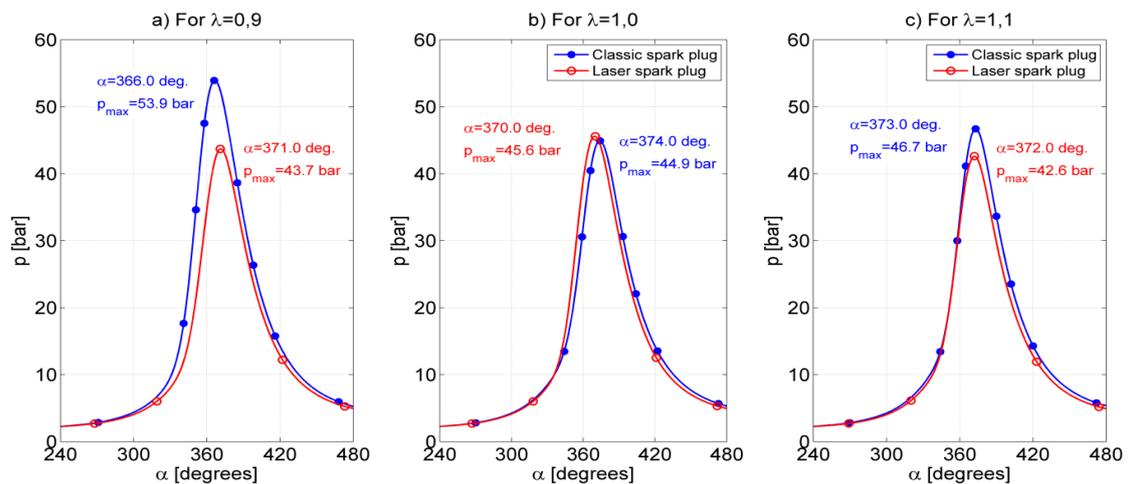


Figure 5. The indicated pressure for the Dacia single-cylinder curve for: 50 cycles; $n = 2800$ rpm; $\kappa = 90\%$; $\lambda = [0.9; 1.0; 1.1]$

For example, figure 5, indicates the median pressure curves for the Dacia mono-cylinder engine, for three values of the excess air coefficient λ . The graphs also show the maximum pressure values p_{max} , as well as the rotation angle β related to them. Also noticeable in figure 5, in the case of the stoichiometric mix ($\lambda = 1.0$), the maximum pressure values indicated are the closest to the two types of spark plugs (44.9 bar and 45.6 bar respectively). Also, for this excess air coefficient value the maximum pressure value is obtained in the case of the LASER spark plug. In regard to the above however, it should be specified that operation based only on the median pressure of cycles represents a simplification which actually conceals the real phenomenon. For this reason, a live study should operate with all the indicated pressure curves, with the concept of uncertainty, the algorithms related to the uncertainty theory and highlighting the non-linear phenomena which accompany cyclic dispersion.

5. Conclusions

The experimental results obtained from the LASER spark plug used in the spark Ignition engine compared to the classic Ignition system have led to several important conclusions presented as follows:

- research carried out utilizing all the experimental data (the study presents only a part of it) confirms the well-known fact that cyclic dispersion, performance levels and pollutant emissions are influenced by the Ignition advance and the quality of the air-fuel mix (through the excess air coefficient) resulting in the need to quantify them by resorting to dispersion analysis, information analysis and sensitivity analysis.
- a comparative study of the two types of spark plugs, as close as possible to the real phenomenon, should target not only the median diagram but also all the curves of the indicated diagram which involves resorting to the uncertainty concept as well as highlighting the non-linear phenomena that accompany cyclic dispersion by means of bi-spectral analysis in frequency, analysis in time-frequency, the chaos theory, etc.

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