PROJECT AND ADAPTATION OF TORCH-IGNITION SYSTEM IN AN OTTO CYCLE ENGINE

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Abstract. *The work evaluates as the adaptation of a torch-ignition system* in *an Otto cycle engine alters the acting curves and also its level of emissions in relation to the engine with original ignition system. For this, based on the literature, three prechamber combustion geometries are projected, built and adapted to a FIAT 1581cm^3, 4 cylinder, 16 valves engine modified previously for operation in one cylinder end development ECU. After accomplishment of the tests it was verified losses in performance and gain in the emissions of CO and CO_2 as presented in the literature.*

Keywords: *Otto cycle engine, torch ignition system, combustion prechamber.*

1. Introduction

The internal combustion engine are in development since they were created, but at the present time, this development becomes more important, due to the perspectives of shortage of petroleum, introduction to the use of new fuels and environmental legislations more and more rigorous.

The great growth of the use of the internal combustion engine that use liquid fuels of fossil origin is directly related with the fall of the quality of the atmospheric air. Due to this fact, specific legislations were created to regulate the maximum index of gaseous transport emissions progressively. Then, the world scientific community stays in search of new technologies, in order to promote reduction of the index of emissions of pollutant gases, of the consumption of fuel and improvement of the performance. This way the torch-ignition system can contribute to reach these objectives [5] [11].

The torch-ignition system consists of the ignition of the mixture air/fuel through coming fire jets of a cavity or combustion prechamber physically separate from the main chamber. This system can present charge stratification or to use the same mixture present in the main chamber for feeding of the combustion prechamber. The system with charge stratification, in other words, with mixture enriched close to the spark plug, the fuel or mixture air/fuel is supplied to the combustion prechamber by a system of auxiliary feeding, as shown in the Fig. 1[6].

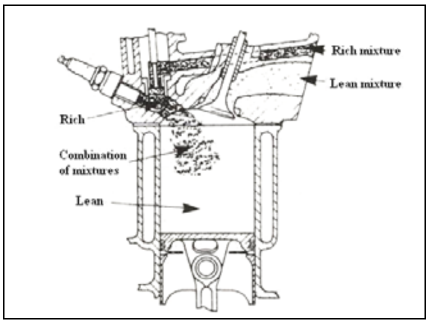

Figure 1- Torch-ignition system with charge stratification

The torch-ignition system without load stratification (Fig. 2), called torch cell, it uses a cavity or combustion prechamber to begin the process of it burns the mixture air/fuel. The function of the prechamber is to create a more turbulent area than in the main chamber. The fire jets generated possess high energy and enough superficial area to begin the combustion process in the main chamber for several types of fuels, besides the one of difficult ignition for the spark plug. This way there is improvement of the combustion, could happen profit of performance and, mainly, reduction of the pollutant gases emissions [7].

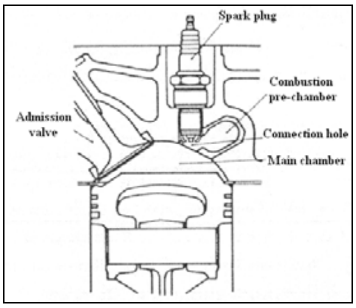

Figure 2 – Torch-ignition system without charge stratification

Systems of this type have been developed with combustion prechamber volumes that vary from 1 to 20 percent of the main chamber. The flow produced during the time of compression inside of the combustion chamber, the location of the spark plug, the number and size of the holes of connection of the pre-chamber with the main chamber have fundamental importance in the project of this ignition system [6] [7].

2. Objective

To evaluate the performance parameters and pollutant gases emissions of internal combustion engine of the Otto cycle working with torch-ignition system without load stratification.

3. Methodology

Basically the proposed methodology involves the choice and preparation of the engine, definition of the geometries of the combustion prechamber, conception, project and construction of the combustion prechamber, adaptation of the torch-ignition system, preparation of the engine to operate with development ECU, and obtaining of the performance and emissions gaseous curves.

The engine, for the installation of the torch-ignition system, should make possible the cooling of the combustion prechamber to avoid the appearance of the phenomenon of the detonation. For this was selected FIAT 1581cm^3, 4 cylinder, 16 valves engine, modified for operation in one cylinder.

For the definition of the three configurations of combustion pre-chambers, in agreement with the consulted literature, such parameters were analyzed as volume, geometry, diameter and number of interconnection holes with the main chamber, positioning angle in relation to the top of the piston and the direction of the flow in relation to the admission and exhaustion valves. The volumes of the three configurations are the same ones and equal to 1,97 cm^3. This value represents 4,14% of the total volume of the main chamber. The three configurations of the torch-ignition system are show in Fig. 3.

The configuration 1 it presents four individual passages starting from the top and the interconnection holes with inclination to address the flow for the admission and exhaustion valves with objective of taking advantage of the inertia of the gases, to favor the wash of the prechamber and also to avoid the flow of gases in combustion directly in the top of the piston. It possesses geometry practically cylindrical and diameter of the interconnection holes of 3 mm [4] [9] [7].

The configuration 2 presents a central passage of larger diameter (6 mm) and 4 interconnection holes with the main chamber addressed for the admission and exhaustion valves to take advantage of the inertia of the gases, to favor the wash and also to avoid the flow of gases directly in combustion in the top of the piston, as the configuration 1 [7] [15].

In the configuration 3, the central passage of diameter 6 mm, it makes the interconnection directly with the main chamber. Therefore, the flow of gases in combustion is going directly to the encounter of the top of the piston, generating larger turbulence [10] [12].

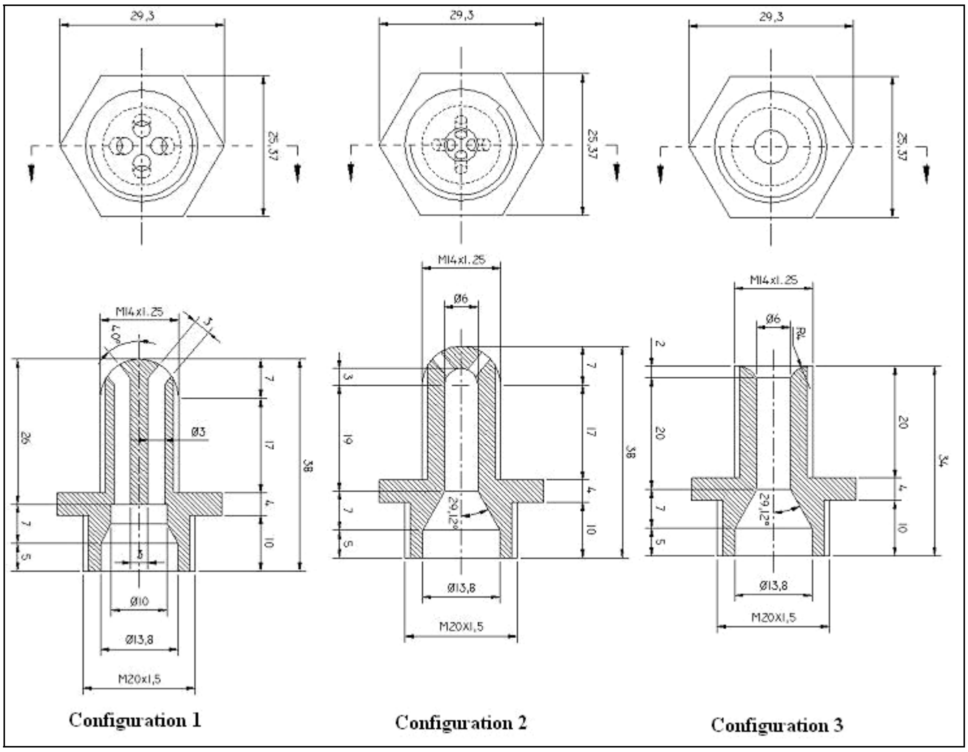

Figure 3 – Configurations of the torch-ignition system

As the combustion prechamber is adapted at the place of the spark plug, becomes necessary the development of a component to accommodate of the spark plug and the combustion prechambers. This component coupled to the configuration 3 is shown in the Fig. 4.

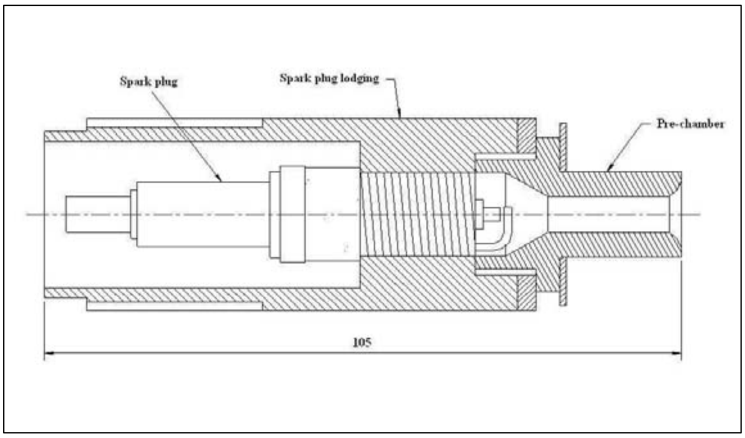

Figure 4 - Entirety for adaptation of the torch-ignition system

For use of development ECU they were made modifications in the electric part. With the elimination of the original system, a new electrical system was manufactured to interconnect sensor to the new ECU of command. This ECU was used with objective of obtaining the largest possible torque for the speeds engine. The final configuration of the adaptation of the torch-ignition system is presented in the Fig. 5.

Figure 5 – Torch-ignition system adapted to the engine

Concluded the adaptation, dynamometric tests were executed, according to Brazilian Norm NBR ISO 1585 [1], at full load and using the three configurations of the torch-ignition system and the original ignition system.

4. Results

The presented results refer to the performance parameters and emissions of pollutant gases.

a) Analysis of the performance parameters.

The Figure 6 presents the torque values of the engine using original ignition system with original ECU and development ECU. It is observed a gain of torque with the use of the development ECU. Due to this fact, all of the tests with the torch-ignition system were made using this development ECU to obtain maximum torque.

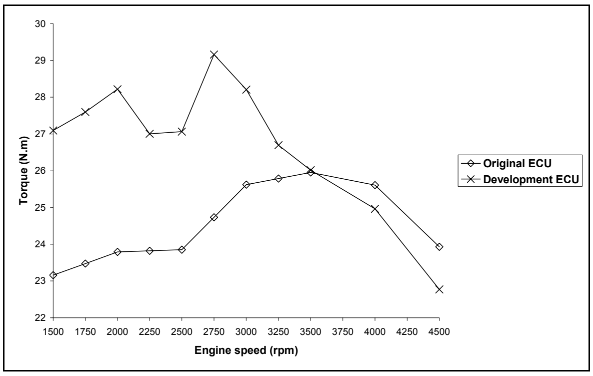

Figure 6 – Variation of the torque for the type of ECU used

The torque values obtained for the three configurations are shown in Fig. 7. Is observed, except for the configuration 2, than all the curves present same tendency of behavior and the engine using the original ignition system reaches the largest torque, although using development ECU. This variation was already expected due to the increase of the heat transfer area and the decrease of the compression ratio implemented by the torch-ignition system [2] [3].

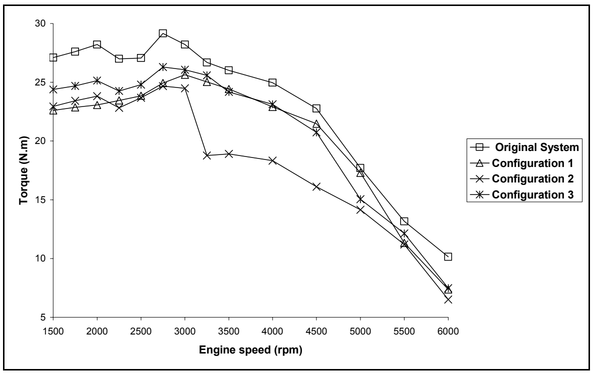

Figure 7 – Variation of the torque for the type of ignition system used

The Fig. 8 shows the curve of specific consumption of fuel for the same speed engine. A same tendency of behavior is observed in all the curves. However the engine using the original ignition system presents smaller specific consumption in practically all of the rotations, being this more evident fact in the maximum rotation.

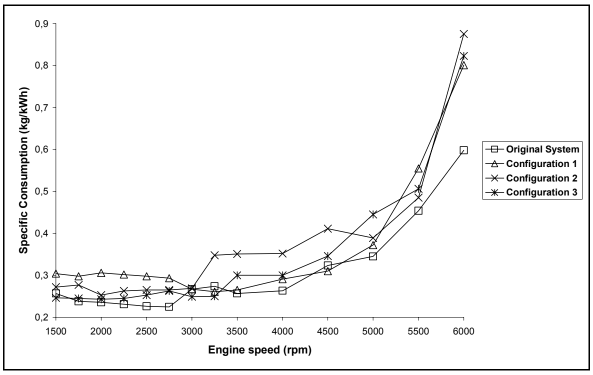

Figure 8 – Variation of the specific consumption for the ignition system used

It can be to conclude that the engine using torch-ignition system didn't obtain gain of performance, as foreseen in the literature. This fact can be attributed to the increase of the heat transfer area and the decrease of the volumetric compression reason implemented by the torch-ignition system and also for the lack of an efficient system of cooling of the combustion prechambers and main chamber.

b) Analysis of the gaseous emissions

CO Emissions

The Fig. 9 presents the indexes of CO emissions in the four analyzed cases.

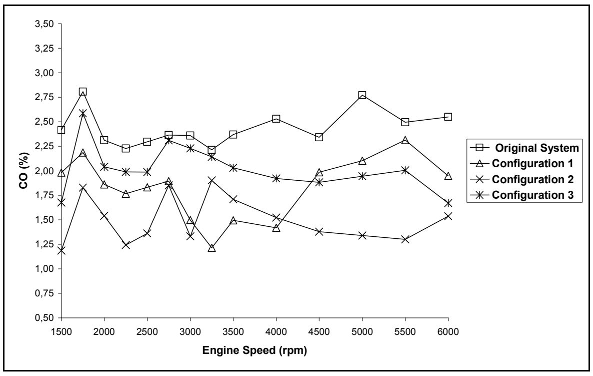

Figure 9 – Variation of the indexes of CO emissions

The Fig. 9 display that the index of CO emissions for the engine equipped with the torch-ignition system is smaller for all of the analyzed rotations. The configuration 2 presents larger reduction in this index, being about 52% smaller than presented by the engine with original ignition system in the rotation of 5000 rpm. For maximum rotation, the index presents reduction of 13% for configuration 1, 35% for configuration 3 and 40% for configuration 2 in relation to the engine equipped with original ignition system, indicating improvement in the combustion.

CO_2 Emissions

The Fig. 10 presents the indexes of CO_2 emissions. It is verified that all of the configurations of the torch-ignition system present index of CO_2 emissions larger than obtained them with the use of the original ignition system, confirming the fall in the indexes of CO emissions.

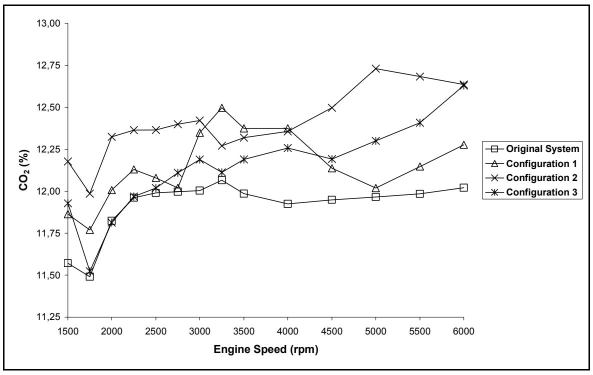

Figure 10 – Variation of the indexes of CO_2 emissions

HC Emissions

The Fig. 11 presents the indexes obtained of HC emissions. It is observed that the index of HC present same tendency of behavior for all of the ignition systems, and the maximum torque rotation, is the point where the largest elevation happens. Therefore this is a characteristic of the used engine.

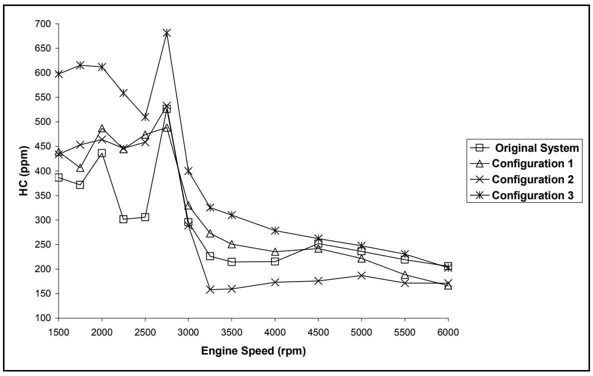

Figure 11 – Variation of the indexes of HC emissions

NO_x Emissions

The Fig. 12 presents the indexes of NOx emissions. The indexes, for the engine using torch-ignition system are larger in practically all of the rotations, if compared with the original ignition system. These values indicate high temperature in the prechamber and in the main combustion chamber. Therefore a system of more efficient cooling should be projected.

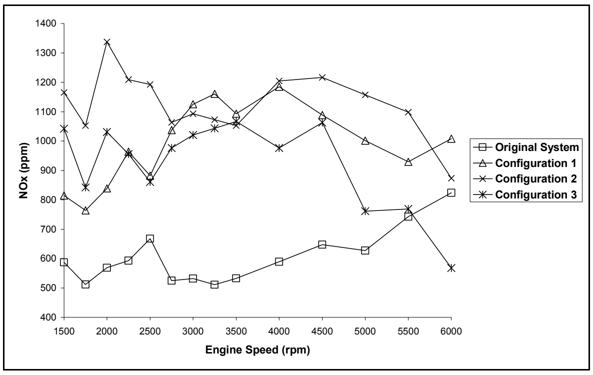

Figure12 – Variation of the indexes of NO_x emissions

5. Conclusions

The obtained results allow concluding:

a) The torch-ignition system presented fall in the performance parameters in relation to the original ignition system. In agreement with the literature the heat transfer area increased by the combustion prechamber and the presence of residual gases diluting the fresh mixture inside the same, it provokes performance losses. It should also be emphasized that the compression ratio was altered with the addition of the volume of the pre-chamber in the main combustion chamber. These facts can explain the largest torque reached by the original configuration of the engine, about 10,9% larger in relation to the configuration 3, 13,8% in relation to the configuration 1 and 18,15% in relation to configuration 2.

b) The specific consumption of fuel presents same tendency of behavior for all of the rehearsed configurations of the engine. There isn't a configuration that presents great gain in relation to the original ignition system.

c) The index of CO emissions for the torch-ignition system is smaller, in all of the rotations, when compared with the original ignition system, indicating more efficient combustion due to the turbulence generation.

d) All of the configurations of the torch-ignition system have indexes of CO_2 emissions superior to the obtained with the use of the original ignition system confirming fall in the indexes of CO emissions.

e) There is not a configuration of the torch-ignition system that it introduces gain one in relation to the other, except for the emissions of HC, where the configuration 3 presents larger levels of emissions clearly.

f) The largest value found for the index of HC emissions is in the maximum torque rotation for the entire ignition systems rehearsed, confirms an engine characteristic.

g) The index of NOx emissions, for torch-ignition system is larger of the obtained with original ignition system. The high index of NOx indicates high temperature in the prechamber and in the main chamber of combustion being necessary the project of a more efficient system to promote the cooling.

6. References

[1] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. (RJ) NBR-ISO 1585: veículos rodoviários: código de ensaio de motores: potência líquida efetiva. Rio de Janeiro, 1996
[2] ADAMS, T. G. *Torch Ignition for combustion control of lean mixtures*. Paper SAE 790440, 19 p., 1979.
[3] DATE, T.; YAGI, S.; ISHIZUA, A.; FUJJI, I. *Research and development ao Honda CVCC engine*. Paper SAE 740605, 1974.
[4]FAVRAT, D. e ROETHLISBERGER, R. P. *Investigation of the prechamber geometrical configuration of a natural gas spark ignition engine for cogeration.* International Journal of Thermal Sciences, p. 223-237, Abril, 2002.
[5] GANESAN, V. *Internal combustion engines*. New York. McGraw-Hill International, 1995.
[6] GARRET, T. K. *Automotive fuels and fuel systems*. London. Pentech Press Limited, Vol 1, 1996.
[7] HEYWOOD, J. B. *Internal conbustion engine fundamentals.* New York. McGraw-Hill International, 1988.

[8] JEANDEL, D.; BUFFAT, M.; MAO, Y. *Simulation of the turbulent flow inside the combustion chamber of a reciprocating engine with a finite element method*. ASME – The American Society of Mechanical Engineers, 69131, 1996.
[9] KATAOAKA, K.; HIRAKO, Y. *Combustion process in a divided chamber spark ignition engine*. Bolletin JSME, Vol. 25, Nº 210, 1982.
[10] NAKAZOMO, T.; NATSUME, Y. *Effect of prechamber on lean burn gas engine*. JSME International Journal, Vol. 37, 1994.
[11] OBERT, Edward F. *Motores de combustão interna*. Trad. por Fernando Luiz Carraro. Porto Alegre.Globo, 1971.
[12] RYU, H.; CHTSU, A.; ASANUMA, T. *Effect or torch jet direction on combustion and performance of a prechamber spark-ignition engine*. Paper SAE 870167, 1987.
[13] SÁ, Denis Cley Cândido de. *Análise de um sistema de ignição por lança-chamas adaptado a um motor do ciclo otto*. Belo Horizonte. Dissertação de Mestrado. Universidade Federal de Minas Gerais, 2001.
[14] SANDA, S.; KONISH, M.; NAKAMURA, N.; ONO, E.; BAIKA, T. *Effects of a prechamber on* NO_x *formation process in the SI engine*. Paper SAE 790389, 1979.
[15] TAYLOR, C.F. *Análise dos motores de combustão interna*. São Paulo, Edgard Blucher, Vol 1, 1971.

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