ANALYSIS OF SMART CONTROL INTERFACE IN PRESSURIZED LIQUID INJECTION SYSTEMS FOR COMPETITIVE TECHNICAL SOLUTIONS

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Abstract: In the recent decades, the intake port fuel injection equipment have been updated and calibrated for multiple types of systems in combustion engines and industrial applications. For increasing performances of injection and to improve dynamic output when changing inertia mass it must be thoroughly researched and electronically managed. Further developments made in the injection system field increase the potential of internal combustion engines. These improvements are to be realized in order to control the emissions and fuel consumption as the final objective. Computational Fluid Dynamics (CFD) and electronic control is yet to be studied and applied for reaching the higher hydraulic control and management of the power machine. Controlling the real operation as well as symptomatic phases is close related to quantifying the amount of fuel, coolant and fuel temperatures and timings for ignition and injection, creating thus the opportunity to outline the optimal poles for electronic intervention in the hydraulic injection system. A rally car like Mitsubishi Lancer has a worldwide impact, which makes that any improvement in hydraulic (fuel) and gaseous mixture formation and ignition (burning) efficiency a good step forward and a basic protocol in energy saving and pollution control for reaching complex market requirements. Complex industrial hydraulic systems and injection processes for internal combustion generators for electric power-plants are also working in a similar protocol methodology and impacting the environment in a much extended manner, thus influencing the society development and life in general.

Keywords: Automotive, diagnostics, electronic fuel injection system, hydraulic

1. Introduction

Managing engine’s digital evaluation and all the functions of fuel injection procedures in electronic management of the operation highlights the optimal regime definition with the main characteristics which facilitates fuel saving and increased efficiency a given working condition. The present paper presents an applied research with high tech equipment regarding electronic control of hydraulic processes of injection and flammable fluid mixture ignition in operation for Mitsubishi rally engine. The analysed hydraulic system is an electronically controlled model, which was detailed monitored regarding the fuel injection duty and fluid mixture ignition characteristics. Using modern technologies were made some innovative achievements in scientific research and engineering, being thus brought to light innovative components and features in electronic control and management. The contribution of latest software applications in fluid fuel injection management and in engine’s operation control offers new possibilities in electronic module calibration and definition. The present research paper use the Engine Control System (ECS) for outlining the fluid dynamic performances of more than twelve operating scenarios or crankshaft speed regimes on the Mitsubishi Lancer EVO9 rally car, at different air pressures measured inside the intake manifold. Also were experimentally determined the fuel injection duty and ignition advances. A post processing study of result was conducted. Were analysed the trend lines and system variables. They were drawn to outline the rally ICE’s (internal combustion engine) operational markers and to design the optimal area with corresponding air intake pressure, better fluid burn rate and controlled pollution risk factors. Air pressure at the intake manifold determines the initial status of air-fuel mixture formation and for lambda coefficient. Prior to air intake stroke there is a gasoline spray in
the port fuel injection (PFI) system. Fuel injection duty expresses the operational sequence time in relation with a base parameter in the engine working process. Ignition advance is adapted to the hydraulic-fuel charge, as well as engine load and speed so it is analysed. In this work we introduce a model for estimating fuel injection duty on the basis of ignition advance value, engine speed, manifold pressure, as well as the air pressure in the intake manifold on the basis of the same parameters. Applied research results were collected through computation and experimental testing. Some features and improvement possibilities are pointed out. After studying the actual values and drawing at least ten operational characteristics in order to trace the trend lines, than the final conclusive ideas consisting in optimal regime and practical conditions are stated and discussed. There are shown the incremental steps between reference operational points of hydraulic injection system with electronic control module and the ignition advance defined for Mitsubishi engine. Optimizing the engine's hydraulic injection process with electronic management application, as well as proper trend-line estimation and ignition advance control in working conditions, is facilitated by engineering evaluation regarding fluid mechanics. These improvements of engine’s hydraulic system controlled with electronic management capabilities are closely created and influenced with software applications in a cluster type environment (which has electromechanical and software components for regulation). The adequate calibration and proper definition of fuel injection duty (as well as mixture formation and ignition) require advanced engineering methods applied in controlling and testing the fuel injection and ignition systems. Digital evaluation and Computational Fluid Dynamics (CFD) contribute to injection optimization and combustion improvement [1-5]. Electronic management of injectors and ignition system operation lead to the power output increase. By designing engine operational strategies, the efficiency is improved in some regimes [4-9]. Fuel injection system with port valve spray is designed from multiple parts, that consist from a sensor group, digital control unit and actuator components. With digital testing management and research of the injection system, consisting of particular operational parameters, system variables, electronic devices and signal mapping indicators [5-8] are used to evaluate the applied digital management strategy model for particular motor-load charge.

The primordial target or aim of the present work is to define and express the correlation in the hydraulics, mechanics and digital control between the fuel injection duty, manifold pressure, ignition advance and the engine speed, throttle position etc. Digital mapping of the engine's behavior to track the tendency of the phenomena is useful for researching the topic. Specific objectives of the present study are as follows: investigation of values recorded for fuel injector duty, air intake pressure in the manifold, ECU auxiliary duty and ignition advance versus crankshaft speed, throttle position and manifold pressure.

2. Research methodology

For realising the research (concerning digital control of the fluid in the manifold and fuel injection hydraulic performances of the supply system applied to the Mitsubishi Evo rally powertrain operated in motor-sport competition which has been investigated) there was implemented in the first place a hardware package with devices and applications. This package facilitated the application of the research methodology. The later one is based on analyse and practical determinations and testing, as well as trend-line evaluation. Tracking the actual values and the methodology protocol, regarding input/output parameters, is realized in a practical endeavour of inspecting and investigating the Mitsubishi Evo power-train with diagnostic equipment (figure 1).

The injectors assembly and other operated components (such as spark plugs) are instrumented by the digital control equipment (DCE). DCE records and use the sensor data from input devices, process all the acquired information and then creates the corresponding decisions to actuate the injectors’ opening and fuel pressure regulator.
Fig. 1. Structural design of electronic management system for hydraulic injection in the powertrain’s control

The research method, based on the connections and exploitation of the TeleMATriX devices (figure 1), achieving the goals of the specific documentation and practical measurements on the Mitsubishi rally vehicle facilitates the interpretation and post-processing of the actual values determined after multiple rewinding of tests and use of digital applications is also versatile.

Fig. 2. Structural assembly of management system for hydro-mechanical components in the vehicle’s spark ignited engine

1-initial state of equipment; 1a-OBD interface package; 1b-transmission and receiver package; 2-detailed components of the transmitting and reception package; 2a-communication interface; 2b-wire interface connector; 3-actual OBD interface; 3a-instruction manual; 4-16 pin connection rack; 4a-documentation.
2.1 The study at specific temperature value for engine and air intake

The engine and powertrain is prepared and properly calibrated for testing before starting the applied determination during the experimental research (figure 3). The indicator/pointer on display graph is placed at 24:12:10 minutes from start.

![Fig. 3. Display capture in ECM with engine (crankshaft) speed variation and engine’s fluid temperatures](image)

Engine scanning and data processing are aimed also toward the investigation of air intake manifold pressure, throttle position, fuel injection duty and ignition advance angle versus time.

![Fig. 4. Data capture with ECM regarding air intake manifold pressure and ignition advance angle before top dead center (BTDC)](image)

2.2 The study of mathematical models

The main important aspect that is studied and outlined for a comprehensive approach is the model determination of injection duty related to engine’s speed, as a percent from total mass of sprayed fuel when vehicle is fully charged and develops maximum speed, as it is expressed by relation (1):

\[ F_{id} = 7 \times 10^6 \times n^2 - 0.0128x + 8.5398, \% \]  

(1)

The other significant aspect, which must be analyzed in this paper regarding the hydraulic control in motor-sport powertrain, consists in the ignition advance vs. engine speed (n), as it follows:

\[ F_{ia} = 0.0101n - 0.167, ^\circ BTDC. \]  

(2)
3. Research results

The evaluated powertrain is started up and made ready to use when beginning the practical determinations in experimental testing (figure 5). Ignition advance and fuel injection duty are some of the first acquired values.

![Graphs](image)

**Fig. 5.** Ignition advance (a), fuel injection duty (b), manifold pressure (c) and aux 3 duty ECU (d) vs. engine speed

![Graphs](image)

**Fig. 6.** Results of fuel injection duty (a), air pressure in the intake manifold (b) versus ignition advance

![Graphs](image)

**Fig. 7.** Aux 3 Duty ECU (a) and ignition advance (b) versus fuel injection duty
The applied testing was realized on a Mitsubishi Lancer with technical specs given in the table 1.

By using the TeleMATriX engine’s parameters are collected and
Table 1: Powertrain technical specs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Actual Value</th>
<th>Unit of measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Platform</td>
<td>CT9A</td>
<td>-</td>
</tr>
<tr>
<td>Powertrain – Spark Ignited Engine</td>
<td>2.0 L 4G63T I4 Turbo-supercharged</td>
<td>-</td>
</tr>
<tr>
<td>Manual Rally Transmission</td>
<td>6-speed mechanic</td>
<td>Gear ratios</td>
</tr>
<tr>
<td>Wheelbase distance (front-rear)</td>
<td>2625 mm</td>
<td>mm</td>
</tr>
<tr>
<td>Total Length</td>
<td>4490 mm</td>
<td>mm</td>
</tr>
<tr>
<td>Total Width</td>
<td>1770 mm</td>
<td>mm</td>
</tr>
<tr>
<td>Total Height</td>
<td>1450 mm</td>
<td>mm</td>
</tr>
<tr>
<td>Total authorized Weight</td>
<td>1350 kg</td>
<td>kg</td>
</tr>
</tbody>
</table>

By inspecting the values and trend-lines of the recorded parameters there are made some interpretations and conclusions.

4. Conclusions

In the present engineering research, were studied the actual values from numerous hydraulic or fluid channels, with electronic control. These values and all hydraulic measurements in fuel supply and combustion control versus the engine speed, injection duty, spark advance angle and intake manifold pressure are monitored and evaluated.

The highest ignition advance (at 22.5°BTDC) was recorded for the 2200 rpm engine speed recorded at crankshaft with 15% fuel injection duty, while the lowest spark ignition advance was 14.9°BTDC found for 1500 rpm.

The peak manifold pressure (at 102 kPa) was found for the 2200 rpm and 65% Aux 3 duty ECU, while the lowest intake air manifold pressure was found for the 1850 rpm.

The minimal fuel injection duty was recorded for the 15°BTDC ignition advance angle, while the maximum fuel injection duty 13.9% was stored at 19.5°BTDC ignition advance. The minimal manifold pressure 88 kPa was recorded for the 18.5°BTDC ignition advance angle, while the maximum manifold pressure 102 kPa was stored at 19.5°BTDC ignition advance.

This research paper elaborated the tests and value recording methodology. Monitoring the fuel system and its specific parameters is realized with diagnostic equipment by continuous measurements. Computer power was used to calculate the probability and determine trend-line of fluid mechanics and ignition advance phenomenology.

An innovative protocol to optimize the gasoline fuel injection systems for competition high demanding regimes in Mitsubishi powertrains may be highlighted through the present research results. The application of TeleMATriX equipment as an electronic On Board Diagnostic solution for optimized correlation between ignition advance angle and manifold intake pressure and charge instead of the conventional measurements could bring some advances in remote repair control and maintenance. This creates a possibility for improving operation and combustion process, thus leading to a better level of performances and exploitation in specific scenarios.

The applied study and recorded results revealed that the optimal performance and admissible results in operational regime (located for this particular stage at 17-18°BTDC ignition advance angle) provides a lower fuel quantity sprayed in the engine and an average engine speed range (1700-1900 rpm). At 2200 rpm the ignition advance increases toward the 23°BTDC, and thus leads to higher fluid quantities introduced in the engine. Determining the optimal operational model with
the lowest repetitions of applied tests and measurements throughout the investigation of mathematical relations, trend-lines and the corresponding values would also be implemented in engine electronic control unit by specific intervention as particular sequences in the future studies.

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