The Effect of the Ignition Dwell Time at Constant Speed for CNGDI Engine

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Abstract: The different of combustion characteristics of natural gas, gasoline and diesel in direct injection internal combustion engine requires different combinations of engine parameters to optimize the engine performance. Natural gas combustion requires a longer ignition delay time than most hydrocarbons, and has higher minimum ignition energy than gasoline. This is due to the strength of the carbon-hydrogen covalent bond in methane than contributes 90% in the natural gas. Therefore, the natural gas requires a high-voltage ignition system to ignite the air-fuel in the combustion chamber. This paper describes one important characteristics of ignition system, which is a dwell time, that influence the performance of compressed natural gas direct injection (CNGDI) engine. The affect of dwell time is discussed and analyse at a constant speed.

Key words: CNGDI, direct injection, dwell time, smart ignition system.

INTRODUCTION

CNGDI spark ignition engine in replacement of gasoline engine is a new engine development, which could bring hopes to natural gas vehicles. A sensible short-term solution to resolve the puzzle for bi-fuel engine is to use a conversion kit, which requires two engine management system or sometimes-called master-slave system. Although, the conversion kits are available, the number of conversion vehicles until present day are not encouraging enough especially in Malaysia. These are due to the feedbacks that conversions vehicles are lack of power, engine cranking difficulties in the morning, bulky storage tank and very limited refuelling stations available. Conversion of originally gasoline or diesel based engine however, gives lower fuel conversion efficiency and higher hydrocarbon emission. For that reason, a dedicated direct injection natural gas engine system will be an alternative solution to resolve the problems.

The prospective of CNGDI with the spark ignition engine has not been detailed by many researchers worldwide. Most of works presented were simulation and single cylinder engine analysis (Haeng, M.C. and Bang, Q.He., 2007;Aslam, M.U., 2006). Therefore, there are needs to investigate the prospective of CNGDI spark ignition engine that could contribute to the knowledge of CNGDI engine.

It is known that gasoline octane number is in the range of 98-100 and the CNG is 120, hence as octane number increases by 10 the compression ratio can be increased by 5. High compression ratio engine creates high thermal energy and eventually produces a better engine performance as discussed above (Heywood, J.B., 1988).

Nasrullah (2005) has provided a basic initiative and background information for designing suitable timeline algorithms for laser ignited leaner direct injected CNG engine. He has determined the electrical and physical characteristic of the electric spark ignition of single cylinder premixed petrol and CNG. The premixed petrol and CNG mixtures were tested for variation of current and voltage characteristic of the spark with engine speed. The current magnitude of discharge circuit was found to vary linearly over a wide range of speed.

The application of high-voltage ignition system inside the engine is to provide stable ignition characteristics with positive effects on the stability of the combustion process from cycle to cycle variations has also been reported by Azimah (2007). The experiment was conducted on single cylinder CNGDI engine. Her research concluded that for optimum ignition setting the ignition advance is between 20 and 21.3 degrees BTDC which results in a typical ignition dwell at 2.77 ms. Meanwhile, the quantity of air pressure and fuel is within ratio 14:1 to 16:8 which is depends upon the engine design.
**Problem Statement and Objective:**

The difficulty to ignite the natural gas with low voltage comes from the effect of the carbon bonding that presents in the natural gas. There is around 90% of methane inside the natural gas with one carbon atom and four hydrogen atoms attached together unlike gasoline. Therefore, it requires very high spark energy from ignition system to ignite the mixture in the cylinder. A standard spark plug uses for gasoline system would not give enough energy to fully combust the mixture. CNGDI system requires a dedicated ignition system with a specific dwell time. Dwell time is the interval of spark ignition to ignite. The dwell period on an engine with electronic ignition is controlled by the current limiting circuit within the amplifier. The dwell is determined by the time it takes to build up approximately 8 amps. This paper describes the best dwell time for CNGDI engine with a constant engine speed.

**Methodology:**

The dwell time is the interval of spark ignition to occur. The current switches on, as the dwell period starts and rises until the requisite 8 amps is achieved within the primary circuit, at which point the current is maintained until it is released at the point of ignition as shown in Figure 1.

The dwell period on an engine with electronic ignition is controlled by the current limiting circuit within the amplifier. The dwell is determined by the time it takes to build up approximately 8 amps. The induced voltage is produced by a process called magnetic inductance. The coil oscillation period should display a minimum number of 4 to 5 peaks (both upper and lower). A loss of peaks would indicate that the coil needs substituting for another of comparable values. The ‘correct’ time that the injector physically opens is validated according to the specifications given by manufacturer. The waveform for current and voltage is splinted into two areas as illustrated in Figure 2. The first part of the waveform is responsible for the electromagnetic force lifting the pintle is approximately 1.3 msec. This is often referred to as the solenoid reaction time. The remaining 0.5 ms is the actual time the injector is fully open. This, when taken as a comparison against the injector voltage duration (blue trace), is different to the 1.8 ms shown.

![Fig. 1: Dwell time](image)

**Experimental Setup:**

Table 1, shows the CNGDI engine under test specification. The CNGDI engine has been tested at 3000 rpm at wide open throttle has been chosen during the analysis. The dynamometer being used is an eddy current typed rated 10,000 rpm and 500 Nm.

The engine dynamometer control is calibrated from CP Engineering, United Kingdom. The dwell time is the interval of spark ignition to ignite.

The lowest duration is 2 milliseconds and the maximum is 6 milliseconds. The range is specifically designed for this particular spark plug to fully optimise the combustion of CNG in the cylinder. The spark plug has individual coil that produces 40kV at 14 Vdc of battery voltage. The output energy is 103 mJ ± 7% with reference dwell at 5ms.
Table 1: CNGDI Engine specification

<table>
<thead>
<tr>
<th>Engine parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore × Stroke (mm)</td>
<td>78 × 84</td>
</tr>
<tr>
<td>Connecting rod length (mm)</td>
<td>131</td>
</tr>
<tr>
<td>Displacement (cm³)</td>
<td>1596 (4 Cylinders – Inline)</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>14:1</td>
</tr>
<tr>
<td>Crank radius (mm)</td>
<td>44</td>
</tr>
<tr>
<td>Intake valve open (° CA)</td>
<td>12° before TDC</td>
</tr>
<tr>
<td>Intake valve close (° CA)</td>
<td>48° after BDC</td>
</tr>
<tr>
<td>Exhaust valve open (° CA)</td>
<td>45° before BDC</td>
</tr>
<tr>
<td>Exhaust valve close (° CA)</td>
<td>10° after TDC</td>
</tr>
<tr>
<td>Fuel Pressure (bar)</td>
<td>20</td>
</tr>
<tr>
<td>Valve Train</td>
<td>DOHC 16V &amp; 4 cylinders in-line</td>
</tr>
</tbody>
</table>

**Result:**

The dwell time of 3 to 5 milliseconds produced high and stable power and torque and it an arc. However, a longer dwell time may not promise to produce the best engine performance as illustrated in Figure 3. Any value from 3-5 milliseconds will produce good engine performance. At this interval, an average torque is 109.05 Nm and the average power is 34.14 KWatt. The difference of engine performance at different dwell time can be explained with the cylinder pressure. The cylinder pressure for these values is illustrated in Figure 4 (a) and exemplified in Figure 4 (b). The maximum cylinder pressure is 70.5 bar at 5 seconds.

![Injector current vs injector voltage](image)

**Fig. 2:** Injector current vs injector voltage

![Torque, power vs. dwell time](image)

**Fig. 3:** Torque, power vs. dwell time
Fig. 4: (a) Pressure at different dwell time (b) Zoom-out

**Conclusion:**

In summary, the best dwell time for CNGDI engine lies between 3-5 milliseconds. Within these values the performance of engine increased which can be concluded that the a complete combustion occurred. This can be verified with gas analyser. However, the range may varies with regards to load, engine speed as well as injection timing.

**REFERENCE**


