Abstract: The emission and the noise in the Diesel engines are the main factors causing the environment pollution. To overcome the disadvantage, the Electronic Diesel Control system (EDC) has been equipped with modern Diesel engines. This paper will analyze the installation and the conversion of the VE(*) conventional fuel system to the VE-EDC in Hyundai H100 1T25. The application of the VE - EDC in the traditional Diesel engine brings some advantages in the performance, the efficiency, the emission and the fuel consumption thanking to the exact control of the fuel flow and the injection timing which are respectively controlled with the spill control valves and the timing control valves. The results show that the engine performance is significantly increased (about 5 ÷10 % for the torque and 10 ÷15 % for the power); the fuel consumption is also reduced about 10 ÷30 % as the VE - EDC is used for the conventional Diesel engine. In additional, there is also the achievement in the improvement of the emission in engine: the reduction of CO is about 40 ÷50 %; of HC is about 5÷20 % and so on.

Keywords: Accelerator Position (APP) Sensor, Suction Control Valve (SCV), Timing Control Valve (TCV), Electronic Diesel Control (EDC)

1. Introduction

The introduction of EDC is about the possibility of the EDC for implementing its new functions totally, so that recently the diesel engine can be able to comply with the increasing demands on the comfort, the dynamic response fuel economy and the environmental compatibility. In addition, the Electronic control unit (ECU) enables the diagnosis and the communication between the ECUs in the vehicle.

There are various scientific projects on creating, researching and improving diesel engines. With some announced domestic researches, the authors have focused on the principles, the compositions and the action cycle of the combustible diesel engine system; in order to manufacture speed control set for the diesel engine as the high pressure pump is used and the improvements in using dual fuel on the diesel engine [1], [2], [3].

In some international study reports, the topics are usually on evaluating the diesel engine exhaust emission, analyzing the engine efficiency as the VE-EDC fuel sup-plying system is used [7].

Apparently, there are not any researches on transferring the VE (*) mechanical supplying system into the VE-EDC electronic system, to assess the efficiency in improving the Diesel engine.

This research is about replacing the VE mechanical fuel delivery system (Fig. 1) with the VE-EDC system (Fig. 2) on Hyundai H100 for improving the productivity and the engine torque. Besides, another purpose is to identify the fuel consuming level and to deal with the environment pollution issue on diesel engine.

This study focuses on:

- Researching, improving and installing the VE-EDC fuel delivery system with sensors inputs, the electronic diesel injection delivery system consisting of the VE-EDC high
pressure pump, the Suction Controlling Valve (SCV), the Timing Control Valve (TCV), the Electronic Control Unit (ECU), sensing inputs are installed on Hyundai H100 engine (Fig. 3), replacing for the old engine;

**Figure 1.** The composition of high-pressure pumps VE

**Figure 2.** The composition of high-pressure pumps VE-EDC


- Manufacturing the Diesel VE-EDC fuel supplying system model;
- Testing the engine, evaluating the experimental results including the productivity, the fuel consumption rate and the components of the exhaust after improving the engine [9].

2. Theoretical Fundamental

2.1. General Issues about the Productivity and the Exhaust Components of the Experimental Hyundai H100 Engine

The action process of the Diesel VE-EDC fuel delivery system on the experimental engine is based on the sensing inputs: Crankshaft position sensor (Ne), Accelerator Position Sensor (APP), Engine coolant temperature (ECT) sensor, Mass air flow (MAF) sensor, Thermal Heat Air (THA) [6].

ECU is designed for collecting the inputs, calculating and releasing the outputs which control the SCV (Suction control valve) and TCV (Timing control valve) to be compatible with every engine action mode (Fig 4).

\[
N_e = \frac{p_e \pi \cdot V_h \cdot t}{30 \cdot \pi}, \text{kW}
\]

where:
- \(p_e\) - net useful pressure (MPa);
\[ n = \text{crankshaft's round per minute (rpm)}; \]
\[ V_h = \text{cylinder's working volume (liter)}; \]
\[ i = \text{numbers of cylinders}; \]
\[ \tau = \text{numbers of strokes}. \]

*Engine’s torque \( M_e \):
\[
M_e = \frac{N_e}{\omega} = \frac{N_e 60}{2 \pi n} = \frac{9.55 N_e}{n}, \text{(kG.m)} \tag{2}
\]

In the exhaust air, the concentration of oxide-carbon (CO), hydro-carbons (HC) and oxide-nitro (NO\(_X\)) are checked. NO\(_X\) is emitted in productivity enhancing condition, especially as the car is sped up. The CO emission is the result of the action of the fuel delivery system. The acceleration and the cold boot have caused the increase of the CO emission. The HC component is generated by the incomplete combustion of the fuel exhaustion. This happens as the engine is working at idle or in braking status [5].

2.2. Researching and Installing the Diesel VE-EDC Fuel Delivery System on Hyundai H100 1T25

<table>
<thead>
<tr>
<th>Engine type</th>
<th>Turbo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore * stroke(mm)</td>
<td>91,1 x 100</td>
</tr>
<tr>
<td>Engine displacement (cm(^3))</td>
<td>2,476</td>
</tr>
<tr>
<td>Maximum power (kW/rpm)</td>
<td>58/4000</td>
</tr>
<tr>
<td>Maximum torque (kG.m/rpm)</td>
<td>17/2200</td>
</tr>
<tr>
<td>Compression Ratio ( \varepsilon )</td>
<td>22:1</td>
</tr>
<tr>
<td>Fuel consumption rate (g/kW.h)</td>
<td>285</td>
</tr>
<tr>
<td>Injection opening pressure (kG/cm(^2))</td>
<td>320</td>
</tr>
</tbody>
</table>

The Hyundai H100 engine is the small size, 4-strokes diesel having 4 aligned cylinders, with its basic specifications as follows [4] (see Table 1):

Keeping the old engine structure, after removing the old fuel delivery system (the high pressure pump, the mechanical speed control), the VE-EDC system is designed and installed on the Hyundai engine (Fig. 5).

The electro-magnetic sensors identifies the position and the speed of the crankshaft which is mounted on the engine body through getting the signal from the flywheel gear. Manifold assemblies are designed and re-fitted to fit the sensors, such as TPS, hypertension, MAF, THF ... injectors in the combustion chamber is kept the same as the position of the old injectors (Fig. 6, 7, 8).

The layout of main sensors on experimental model engine.

1 - MAF sensor; 2 - APP sensor; 3- THA sensor.

\[ \text{Figure 6. Designing and installing the sensors on Hyundai engine.} \]
3. Testing and Evaluating

3.1. Testing and Evaluating the Engine Productivity Performance

The experimental engine is tested the pull operation by hydraulic loading (Fig. 9) which is installed at the factory Z751-Department of National Defense.

Specifications try pedestal base engine:
- Brand: Clayton hydraulic testing machine 300 kG.m.
- Maximum Capacity Test: 300 (kG.m) ± 1;
- Maximum torque strength test: 120 (kG.m) ± 1;
- Rated speed: 6000 (rpm) ± 10;
- Remote load: Hydraulics;
- Throttle Control Engineering.

- Parameter display:
  - Digital:
    + Speed;
    + Power;
    + Torque.
  - Electronics:
    + Water temperature;
    + Water pressure;
    + Temperature viscosity;
    + Viscous pressure.

The equipment is tested in the test and the measurement Combine Enterprise Z-751 - Department of Defense. Alternatively operating the engine with the speed range...
1200rpm to 4000rpm, the tested results are collected as the following (Table 2).

The experimental results are presented on the figure 10. Below are the graph parameters.

### Table 2. The experimental parameters of the engine power before and after the improvement.

<table>
<thead>
<tr>
<th>n, (rpm)</th>
<th>$N_{e1}$ (kW)</th>
<th>$N_{e2}$ (kW)</th>
<th>Diesel injection volume (ml/min)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>7.4</td>
<td>7.4</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td>10.3</td>
<td>10.3</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>13.2</td>
<td>14.7</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td>16.9</td>
<td>18.4</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>20.6</td>
<td>22.1</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>2200</td>
<td>23.5</td>
<td>25.7</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>2500</td>
<td>27.2</td>
<td>29.4</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>2800</td>
<td>29.4</td>
<td>33.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>30.9</td>
<td>36.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3400</td>
<td>35.3</td>
<td>39.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3600</td>
<td>37.5</td>
<td>41.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3800</td>
<td>37.5</td>
<td>43.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td>39.1</td>
<td>45.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where:
- $Me1$, $Me2$: The engine torque before and after the improvement (kG.m/rpm);
- $Ne1$, $Ne2$: The engine power before and after the improvement (kW);
- $mf1$, $mf2$: The volumetric Diesel injection before and after the improvement (ml/min).

The sample is not collected with the high speed range.

### Figure 10. Diagram of Engine power before and after improvement.

In the lower rpm range, there is no significant difference in the engine power, but as the load test is conducted with the high-speed range, the productivity curve of the engine used with VE-EDC is higher than the one with the normal VE. After the improvement, the productivity is more stable and increased 10% -15% pursuant to the engine speed.

Similarly, for the parameters of the moment, we have comparable data table as follows (Table 3).

The experimental results are presented in figures 11.

As being seen from the graph, the torque found to increase 5%-10% and more stable compared to itself before improvement.

### Table 3. The experimental specifications of the engine torque before and after the improvement.

<table>
<thead>
<tr>
<th>n, (rpm)</th>
<th>$M_{e1}$ (kG.m)</th>
<th>$M_{e2}$ (kG.m)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>6.1</td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td>7.3</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>8.1</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td>9.2</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>10.1</td>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td>2200</td>
<td>10.8</td>
<td>11.7</td>
<td></td>
</tr>
<tr>
<td>2500</td>
<td>10.5</td>
<td>11.4</td>
<td></td>
</tr>
<tr>
<td>2800</td>
<td>10.2</td>
<td>11.1</td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>9.8</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>3400</td>
<td>9.5</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>3600</td>
<td>8.9</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>3800</td>
<td>8.3</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td>7.7</td>
<td>8.6</td>
<td></td>
</tr>
</tbody>
</table>

Testing time: 1 min

### Figure 11. The diagram of the engine torque before and after the improvement.

#### 3.2. Experimenting and Evaluating the Fuel Consumption and the Emission Level of HC and CO

Based on the process of the productivity of the engine before and after the improvement, the Diesel injection is measured by the VIBRA scale and shows the following result.

### Figure 12. Electronic balance VIBRA.
Specifications try pedestal base engine:
- Brand: VIBRA electronic scales;
- Manufacturer: Shinno Denshi
- Product Code: DJ 6000 TW;
- Sensitivity Display: 0.01 (g).

Experimental results are presented on the figure 13.

The engines after the improvement have the significantly lower $g_e$ despite the same injection pressure, which proves the better oil injection optimization.

After the improvement, the Engine remarkably decreases at the average speed, it is clear that $g_e$ is actively controlled with the very low regular speed zone of the engine as the cars are operated on the roads (1400 - 2000 rpm), which shows the great fuel saving capacity. This confirms the role of the computer – driven in making it easy to optimize the engine performance in accordance with business demand.

Installing the NHT-6 emission measurement equipment (Fig. 15), running the engine with the speed from 1200rpm to 2200rpm, collecting the experimental data on the HC and CO concentration. It takes 1 minute for the data collection process to be taken place in every case (Table 5).

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### Table 5. The experimental figures of HC and CO of the engine before and after the improvement.

<table>
<thead>
<tr>
<th>$n_e$ (rpm)</th>
<th>$HC_t$ (ppm)</th>
<th>$HC_s$ (ppm)</th>
<th>$CO_t$ (%vol)</th>
<th>$CO_s$ (%vol)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>21</td>
<td>18</td>
<td>0.18</td>
<td>0.13</td>
<td>Testing</td>
</tr>
<tr>
<td></td>
<td>1400</td>
<td>20</td>
<td>0.19</td>
<td>0.13</td>
<td>time;</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>18.5</td>
<td>0.22</td>
<td>0.14</td>
<td>1 minute</td>
</tr>
<tr>
<td></td>
<td>1800</td>
<td>20</td>
<td>0.25</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>18.8</td>
<td>0.6</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2200</td>
<td>17</td>
<td>0.7</td>
<td>0.48</td>
<td></td>
</tr>
</tbody>
</table>

### Figure 15. The NHT-6 emission measurement equipment.

Specifications try pedestal base engine:
- Brand: Nanhua - China
- Measuring range:
  - Opacity exhaust + (N): 0 ÷ 99.99%;
  - Light absorption coefficient: 0 ÷ 16.0m$^{-1}$;
  - Oil Temperature: −50°C ÷ 120°C;
- The analysis:
  - Opacity (N): 0.1%;
  - Light element in the testing room: 0.01m$^{-1}$;
- Accuracy:
  - Opacity exhaust (not edited): ± 2.0% (abs.);
  - The machine running speed (voltage): ± 1.0% (rel.);
  - Oil Temperature deviation: ± 2 (abs.);
- The measured effective optical length: 215mm;
- The average length of the optical measurement: 430mm;
- The length of the sample probe: 2.5m;
- Power consumption: 200W;
- Power supply: AC220V ± 10% 50Hz ± 1Hz;
- Overall machine weight: 6.5kg.
Experimental results are shown on table 5. Referencing the diagram as follow (Fig. 16 and 17)

Figure 16. The diagram of the HC level of the engine before and after the improvement.

Figure 17. Diagram of CO level of engine before and after improvement.

The concentrations of HC and CO levels in the tested at the following enhancements are always lower than the original. This clearly shows the high efficiency as the VE conventional system is replaced by the VE-EDC fuel delivery system.

4. Conclusion
This study focuses on replacing the VE mechanical fuel system with the VE-EDC computerized fuel controlling system on the Hyundai H100 engine. The implementation of VE-EC has brought many advantage advantages in improving the productivity performance, the fuel consumption and the exhaust level on the Diesel engine. The conclusion of research is as follows:
+ $M_e$ increases from 5% to 10% against before improvement;
+ $N_e$ increases from 10% to 15%;
+ $g_e$ decreases from 12% to 24%;
+ CO decreases from 40% to 50% and HC decreases from 5% to 20%.
This is the first step in the researching, improving and gradually replacing the VE mechanical system with the VE-EDC electric controlled system. Based on the experimental results, it is shown that the research on the feasibility of using VE-EDC on the Diesel engine and it is highly deserved for the more investment and perfectivity, especially the controlling technology to find the solution for the energy resources and the environment pollution.

Article is the result of the Master thesis [11] and has been presented in [10].

Acknowledgement
This study is a part of the Master thesis [11] of Tran Anh Tuan under supervision of Dr. Ly Vinh Dat from the University of Technology and Education Ho Chi Minh City.

References


Biography

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