International Journal of Mechanical Engineering and Applications
2015; 3(1-3): 9-17
Published online January 08, 2015 (http://www.sciencepublishinggroup.com/j/ijmea)
doi: 10.11648/j.ijmea.s.2015030103.12
ISSN: 2330-023X (Print); ISSN: 2330-0248 (Online)

A study on the performance improvement in the type VE conventional fuel distributor system

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To cite this article:
Tran Anh Tuan, Ly Vinh Dat. A Study on the Performance Improvement in the Type VE Conventional Fuel Distributor System. *International Journal of Mechanical Engineering and Applications*. Special Issue: Transportation Engineering Technology.
Vol. 3, No. 1-3, 2015, pp. 9-17. doi: 10.11648/j.ijmea.s.2015030103.12

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

(*) The VE in the name of the Bosch pump used in the VW diesels and many other small diesel engines system for “Verteiler”, which is German for distributor or divider.

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;

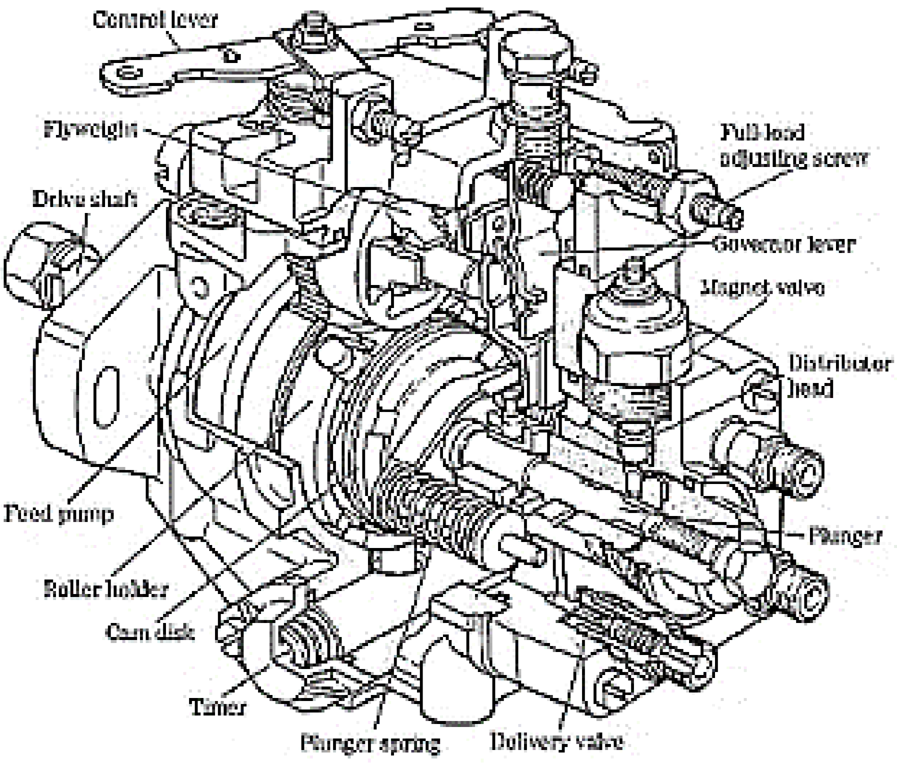

Figure 1. *The composition of high-pressure pumps VE*

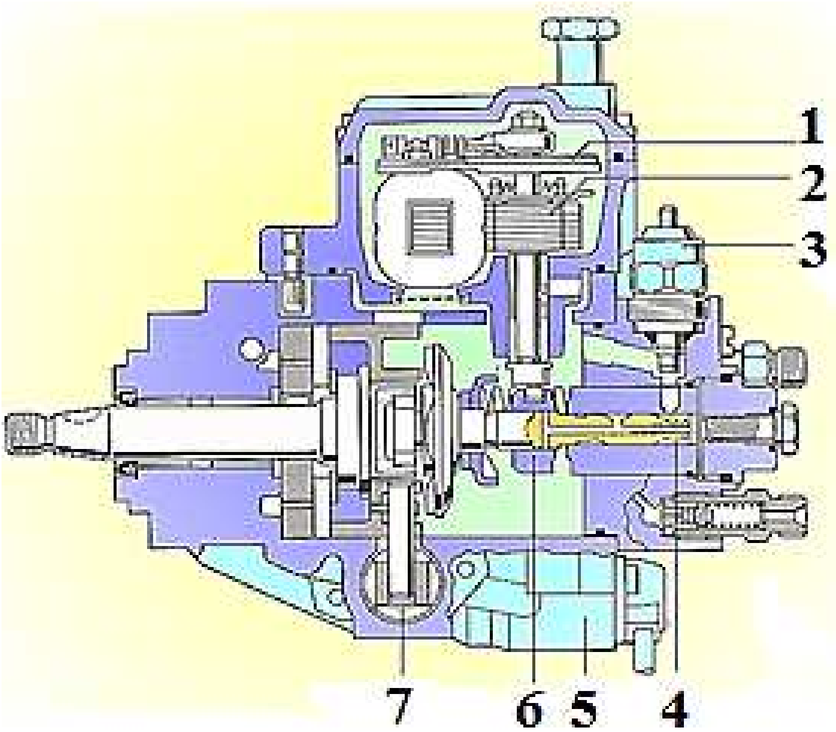

Figure 2. *The composition of high-pressure pumps VE-EDC*

1. Potentiometer for control-collar position;2. Quantity adjuster; 3. Electric cut-off valve; 4. Plunger; 5. Solenoid valve for start of injection; 6. Control Collar; 7. Timing device

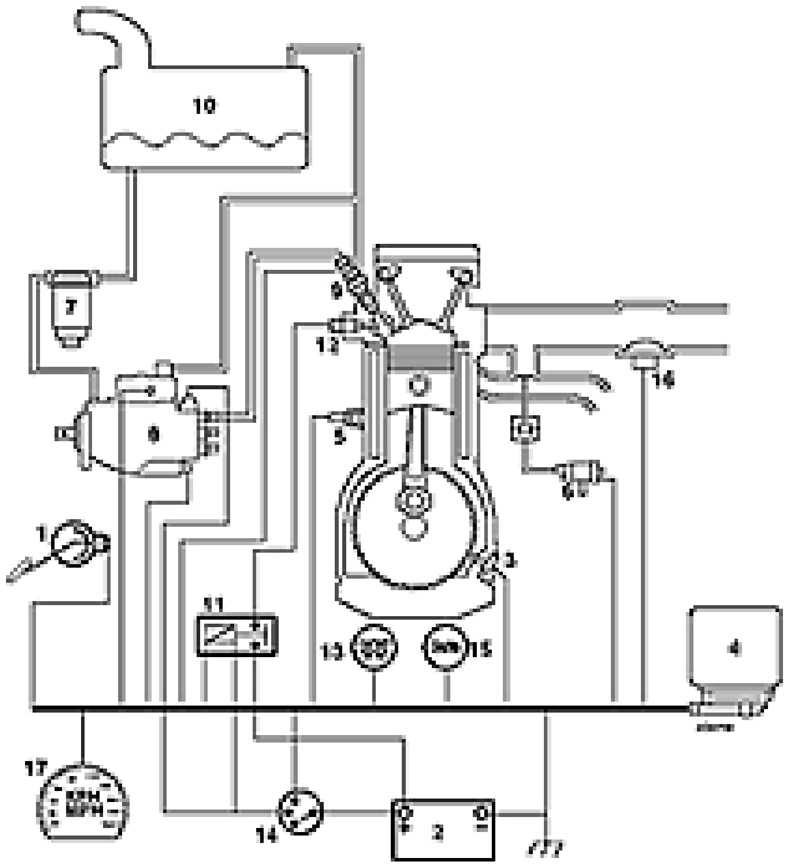

Figure 3. *The system pump VE with EDC of Bosch.*

1. Accelerator position (APP) sensor; 2. Battery; 3. Crankshaft position (CKP) sensor; 4. EDC control unit; 5. Engine coolant temperature (ECT) sensor 6. Exhaust gas recirculation (EGR) solenoid; 7. Fuel filter; 8. Fuel injection pump; 9. Fuel injector (with needle lift sensor) ; 10. Fuel tank; 11. Glow plug relay; 12. Glow plug; 13. Glow plug warning lamp; 14. Ignition switch; 15. Malfunction indicator lamp (MIL); 16. Mass air flow (MAF) sensor; 17. Vehicle speed sensor (VSS).

- 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).

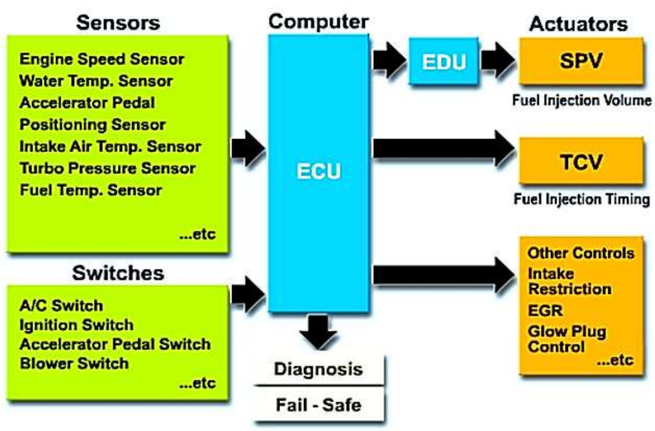

Figure 4. *Diagram of SCV Valve, TCV Valve and Diesel injector on Hyundai H100 experimental engine*

* Engine's net power N_e:

$$N_e = \frac{p_e.n.V_h.i}{30.\tau}, kW \tag{1}$$

where:

p_e *- net useful pressure (MPa);*

n = crankshaft's round per minute (rpm);
V_h *= cylinder's working volume (liter);*
i = numbers of cylinders;
τ *= numbers of strokes.*
* Engine's torque M_e:

$$M_e = \frac{N_e}{\omega} = \frac{N_e.60}{2.\pi.n} = \frac{9{,}55.N_e}{n}, (\text{kG.m}) \quad (2)$$

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 1. *The technical features of the Hyundai H100 engine*

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

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).

Figure 5. *VE-EDC Fuel delivery system installed on Hyundai engine.*

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.

Figure 6. *Designing and installing the sensors on Hyundai engine.*

Figure 7. *Crank shaft position sensor (Ne)*

Figure 8. *Engine coolant temperature (ECT) sensor.*

3. Testing and Evaluating

3.1. Testing and Evaluating the Engine Productivity Performance

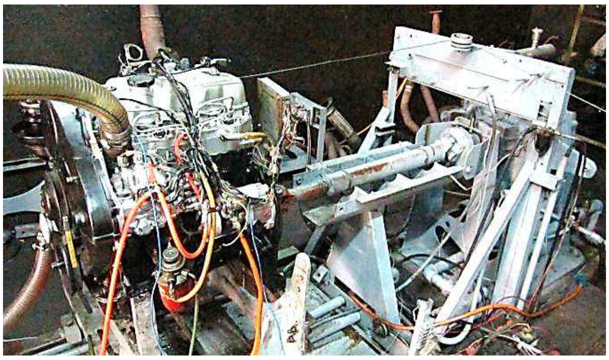

Figure 9. *Diesel VE-EDC fuel delivery system model installed on experimental engine.*

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.*

n_e (rpm)	N_{e1} (kW)	N_{e2} (kW)	Diesel injection volume (ml/min)		Note
			m_{f1}	m_{f2}	
1200	7,4	7,4	52	47	Testing time: 1 minute
1400	10,3	10,3	60	49	
1600	13,2	14,7	68	60	
1800	16,9	18,4	80	72	
2000	20,6	22,1	95	85	
2200	23,5	25,7	112	99	
2500	27,2	29,4	135	120	
2800	29,4	33,1	The sample is not collected with the high speed range.		
3000	30,9	36,1			
3400	35,3	39,7			
3600	37,5	41,9			
3800	37,5	43,4			
4000	39,1	45,6			

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).

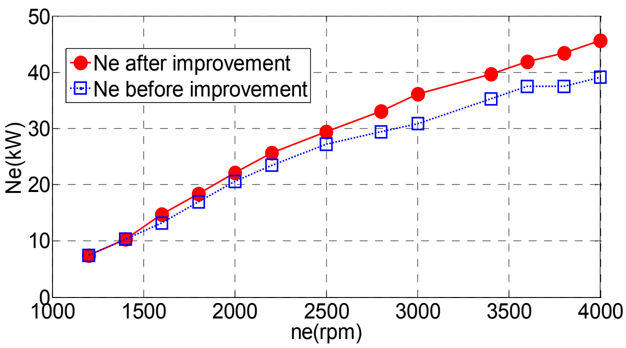

Figure 10. *Diagram of Engine power before and after improvement.*

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).

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

n_e (rpm)	M_{e1} (kG.m)	M_{e2} (kG.m)	Note
1200	6,1	6,1	Testing time: 1 min
1400	7,3	7,3	
1600	8,1	8,9	
1800	9,2	10,1	
2000	10,1	10,9	
2200	10,8	11,7	
2500	10,5	11,4	
2800	10,2	11,1	
3000	9,8	10,7	
3400	9,5	10,1	
3600	8,9	9,8	
3800	8,3	9,2	
4000	7,7	8,6	

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.

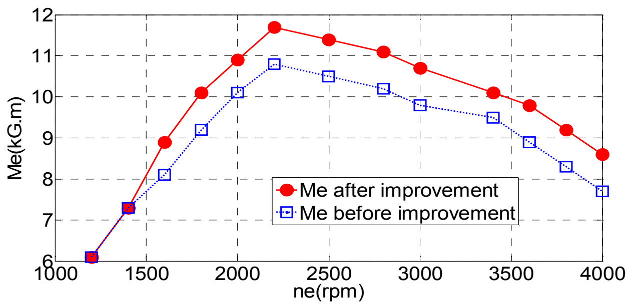

Figure 11. *The diagram of the engine torque before and after the improvement.*

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

Figure 12. *Electronic balance ViBRA.*

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

(Fig. 12).

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.

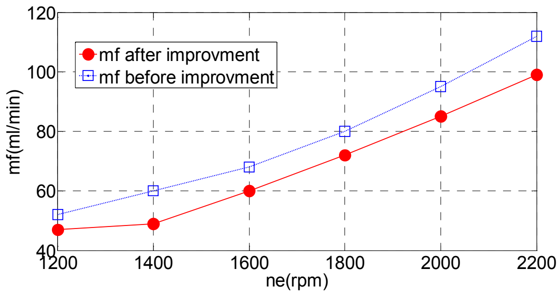

Figure 13. *Diagram of Diesel injection of engine before and after improvement.*

The graph above indicates the amount of Diesel being injected to the VE-EDC engine from which the huge of the fuel consumption is noted to be reduced from 10% to 30% compared to the ones as the conventional VE (Fig. 13) is used. By adopting the sensor input signal and the ECU processor, the computation time of injection and the amount of fuel injection are more accurate.

Specific density of oil: γ=0,82 ÷ 0,86. Choosing γ=0,85 [8].

We have the converted formula from m_f to G_{nl} as follow:

$$G_{nl} = \frac{\frac{g_{nl}}{1000}.0,85}{60} \text{(kg/h)} \quad (3)$$

Therefore, the fuel consumption is calculated and the data conversion table (Table 4) as below:

$$g_e = \frac{G_{nl}}{N_e}.10^3 \text{ (g/kW.h)} \quad (4)$$

Table 4. *The experimental specifications of the fuel consumption rate before and after the improvement*

g_{e1}	1,01	0,83	0,72	0,67	0,65	0,67	0,69
g_{e2}	0,89	0,67	0,58	0,55	0,56	0,57	0,58

g_{e1}, g_{e2}: the fuel consumption rate before and after the improvement, (g/kW.h)

The comparison results are as the following (Fig. 14):

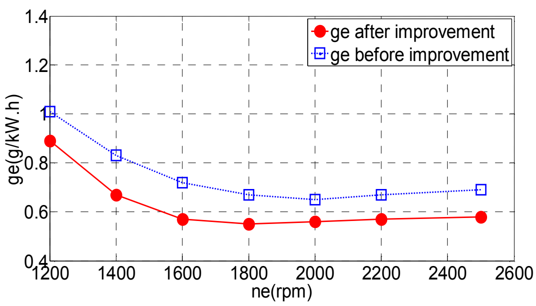

Figure 14. *The diagram of fuel consumption rate comparison before and after the improvement.*

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).

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

n_e (rpm)	HC_t (ppm)	HC_s (ppm)	CO_t (%vol)	CO_s (%vol)	Note
1200	21	18	0.18	0.13	Testing time; 1 minute
1400	21	20	0.19	0.13	
1600	18.5	17.5	0.22	0.14	
1800	20	16.5	0.25	0.18	
2000	18.8	17.5	0.6	0.4	
2200	17	15	0.7	0.48	

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: $-50^0C \div 120^0C$;
- 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)

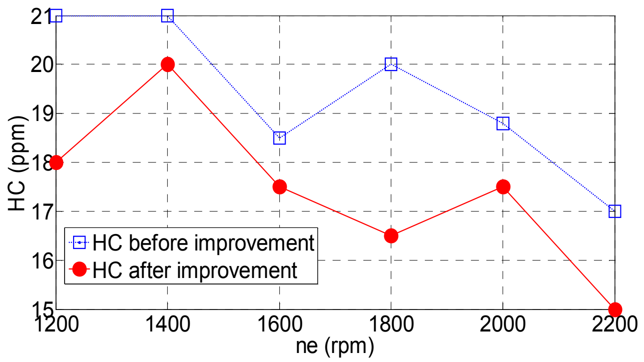

Figure 16. *The diagram of the HC level of the engine before and after the improvement.*

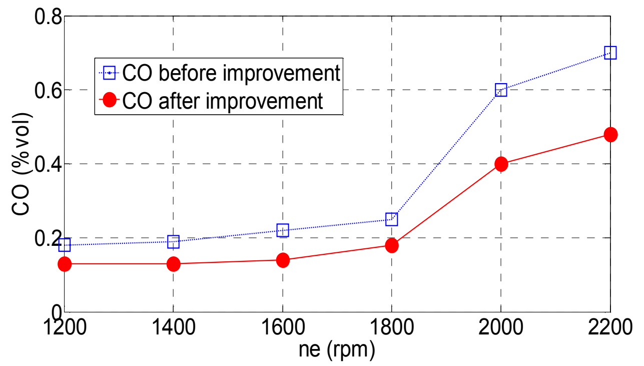

Figure 17. *Diagram of CO level of engine before and after improvement.*

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.

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Biography

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