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An Equipment for Directly Cleaning Out Fuel Injectors of Internal Combustion Engine

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Abstract: This paper presents the results of research, design, and manufacture a new equipment for directly cleaning out fuel injectors of internal combustion engine which can be used on electronic fuel injection of gasoline engines. The equipment combined with new proposed cleaning solution will shorten engine maintenance time without disassembling the injectors out of the engines, and no need to use brackets (no need to disassemble the injectors out of the engine). The equipment operates safely and accurately, providing a very high efficiency. This new device is firstly manufactured in Vietnam, incorporates resent new advanced technologies in electrical - electronic engineering and information technology, contributes to reduce pollution emissions, and can be applied to EURO 2 standard gasoline and diesel engines mounted on passenger cars. The research results can be applied immediately in manufacture with low cost, suit domestic technological capabilities, reduce maintenance time of fuel injection system for internal combustion engine.

Keywords: Direct Cleaning Equipment, Fuel Injectors, Internal Combustion Engines

1. Introduction

Equipment which can directly clean out fuel injectors of internal combustion engines is very helpful to shorten engine maintenance time. Normally, every 20.000 km each injector should be rinsed to help burn fuel completely, reduce emissions of pollution …[1], [2], [3], [4]. Until now, integrated rinsing equipments on gasoline and diesel engines are not produced in Vietnam, as well as cleaning solution for gasoline engines is not commercialized. This condition is very good and suited for our study. Compared with imported equipments, this device will save a lot of money. Products of this research can be applied widely, useful in the automotive sector in Vietnam.

Research contents are:

- Design and manufacture an equipment to clean the injectors directly on the internal combustion engine [2], [3], [4], [5], [6].
- Research and evaluate selected fuel-chemical mixture compared to cleaning solution available in the market.
- Experiment on many types of gasoline engines to evaluate the equipment and propose its applications.

2. Design and Manufacture the Equipment

2.1. Design of Equipment's Hardware

Energy source: Energy source is 12 V DC battery in the car to supply for the entire system (Figure 1.). Control circuit of gasoline pump or diesel pump are protected by fuses and relays (Figure 2.).

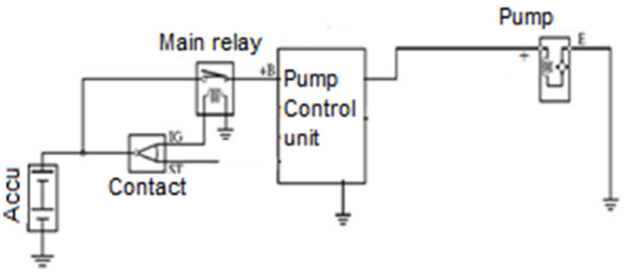


Figure 1. *Schematic diagram of pump control circuit*

Fuel pumps: Fuel pumps are driven by 12V electric motors,

with permanent. Fuel pressure provided by pump reaches from 2,5 kG/cm^2 to 3,1 kG/cm^2 for gasoline engines, and from 3 kG/cm^2 to 6 kG/cm^2 for diesel engines [3].

2.2. Design and Programming Control Circuit

Supply circuit includes two parts: microcontroller supply circuit for microcontroller, LCD, LED ... and power supply circuit for activating relays and running the motors.

Power supply source requirements include:

- 3,3V DC power supply source for microcontroller, LED;
- 5V DC power supply source for LCD and other components;
- 12V DC power supply source to active relays, run electric motors. This source uses common grounding circuit.

Design include:

-.Calculate the total current consumption of 5V supply source. Power consumption of the components using 5V supply source VDC is shown in Table 1;

Table 1. *Power consumption of the components using 5V supply source VDC*

Component	Electricity consump./ea. (mA)	Quantity	Total electricity consumption (mA)
Micro controller STM32F103RCT6	150	1	150
Opto (LED)	15	2	30
Single LED	10	5	50
LCD 16 x 4	30	1	30
Transistor	50	3	150
Opto (Transistor)	50	2	100
Other	130	1	130
			640

-Fuse protects short circuit, over-current;

-D1 prevents circuit damage due to reverse plug in the input DC power;

Capacitors are used for power filter;

LED1 indicates power supply.

Power supply source is 12V DC to enable the relays and electric motors.

Microcontroller STM32F103RTC6 is used. It uses 8MHz external quartz, low Reset circuit.

LCD circuits use 16 x 4 characters LCD to display the function menu for the controller as shown in Figures 2 and 3. This LCD is connected to PORT C of the microcontroller as shown in the diagram in Figure 2. This LCD is controlled by 4-bit data method.

Buttons are used for connection to PORT B of the microcontroller. These buttons are used for the installation mode of the controller (REST, DC1, DC2, START, STOP, UP, DOWN) are shown in Figures 3 and 5.

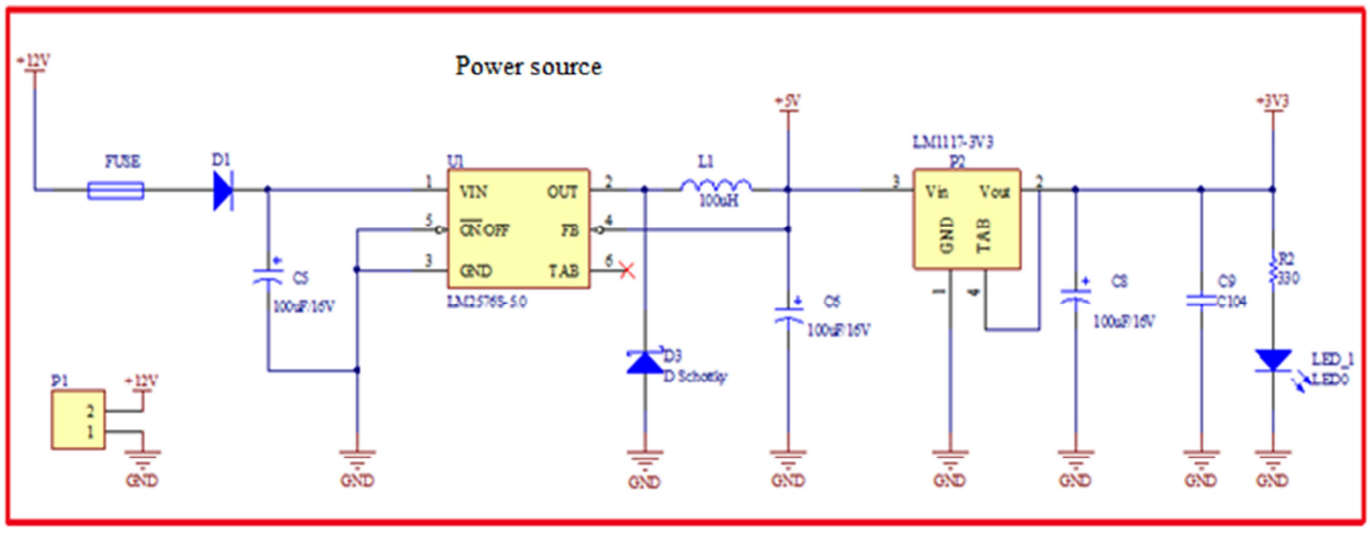


Figure 2. *Schematic diagram of supply circuit for contronler*

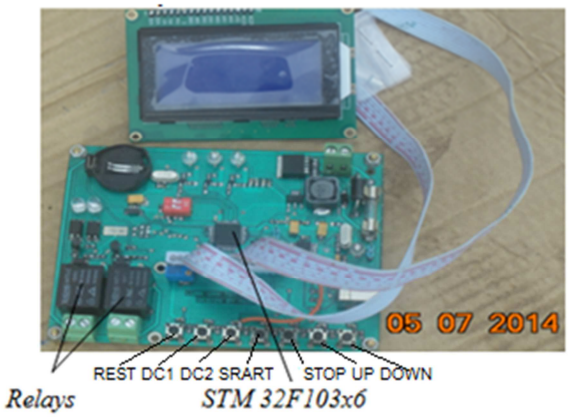


Figure 3. *LCD circuit*

Figures 5 and 6 display front and back views of a new equipment for directly cleaning of fuel injectors on the ICE.

Figure 4 shows the screen display of equipment's LCD circuit.

Figure 4. *Screen display of LCD circuit*

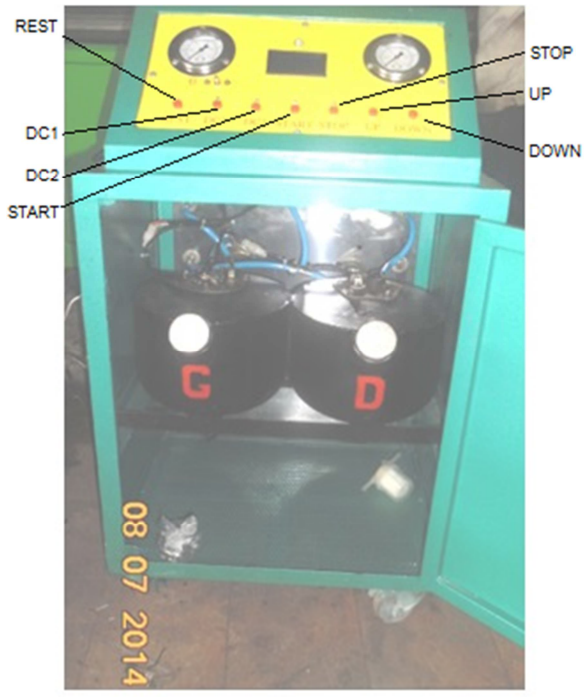


Figure 5. *Front view of equipment*

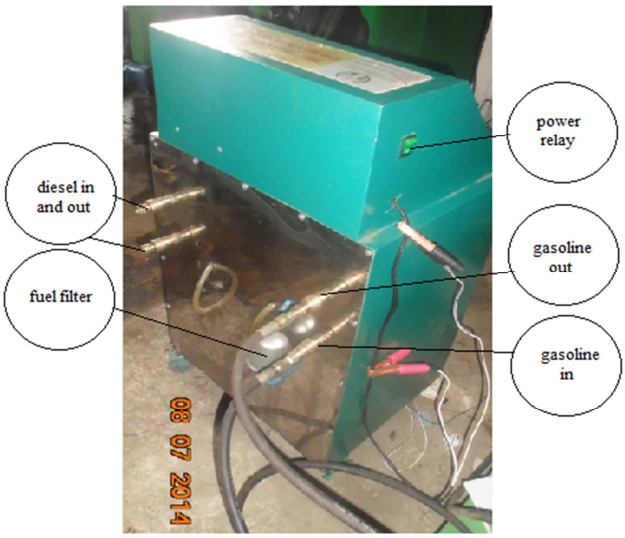


Figure 6. *Back view of equipment*

2.3. Select the Cleaning Solution

We have realized experiments a new equipment for EFI on the gasoline engines in order to evaluate its effect. Besides all cleaning solutions for injectors available on the market such as "FUEL INJECTION" (USA product), we studied and found two types of chemical: Toluene, Acetone. After doing many times we obtain the best solution when blended them with gasoline at spesified rate which can be used to rinse the injectors directly with high efficiency.

2.3.1. Chemical Composition of Acetone

$$CH_3\text{-}CO\text{-}CH_3 + H_2 \text{ --> } CH_3\text{-}CH(OH)\text{-}CH_3$$

Acetone is difficult to oxidize. However, it can be oxidized by potassium permanganate solution heated with sulfuric acid to create a mixture of carboxylic acids.

Reaction in hydrocacbon radical:

$$CH_3\text{-}CO\text{-}CH_3 + Br_2 \text{ -->} CH_3\text{-}CO\text{-}CH_2Br + HBr$$

The reaction occurs when using bromine anhydrous and heated acetic acid as catalyst.

2.3.2 Chemical composition of Toluene

Properties of Toluene is shown in Table 2.

Price of acetone and toluene:

30.000 VND/500ml Acetone;

30.000 VND/500ml Toluen.

After many tests on the 4-cylinder fuel injection engine, results show that we can blend gasoline with Acetone and Toluene in proportion as shown in Table 3. This is the most reasonable rate to clean injectors. After 25 minutes rinse, the fuel burn completely and meet Euro 2 standards of emissions.

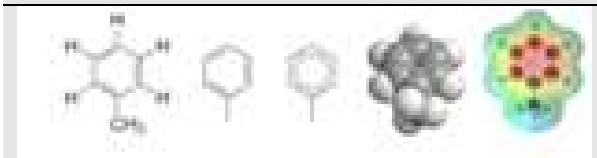
3. Experimental Results

The flow chart of the control circuit is shown in Figure 8.

After making the cleaning injector equipment and cleaning

solution of toluene - acetone, the experimental evaluation have been conducted to compare with cleaning solution in the market. Experiment was conducted on a variety of gasoline engines to check the soot deposit on the spark plugs, combined with emissions tester HESHBON - HG.520 to measure exhaust emissions. The process is carried out in the Key lab on Internal Combustion Engine of HCM University of Technology, Road Vehicle Register Station 5001S, and Tran Dai Nghia University.

Table 2. *Composition of Toluene*

Toluene	
	
General	
Name	Metylbenzen Penylmetan
Other name	Toluene Toluol
Chemical formula	C_7H_8
Mol	92,14 g/mol
Appearance	Colorless liquid
Properties	
Density, state	0,8669 g/cm^3, liquid
Solubility in water	0,053 g/100ml (20-25^{o}C)
Solubility in etanol	Completely miscible
Feature	Flammable

3.1. Emissions Tester *HESHBON-Model HG 520 (Figure 7).*

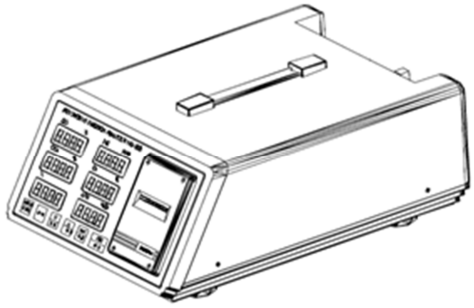


Figure 7. *Emissions tester HG 520*

The Emissions tester HESHBON-Model HG 520 is shown in the Figure7.

3.2. Test the Cleaning Injectors Equipment on Light Truck SYM 2010

Table 3. *Percentage of cleaning injector solution*

No.	**Fuel**	**Qty.**	**Clean Time**	**Eng. speed (rpm)**	**Note**
1	Gasoline	1 liter			Mixed before
2	Acetone	30 ml	25 min.	900-1100	pouring into the
3	Toluene	35ml			cleaning equip.

Tests were done on the SYM car at Key lab on Internal Combustion Engine of HCM University of Technology, using the cleaning injector equipment and emission tester HESBON to measure engine exhaust emissions.

Using solution as shown in Table 3. to rinse SYM engine who injected fuel in the manifold.

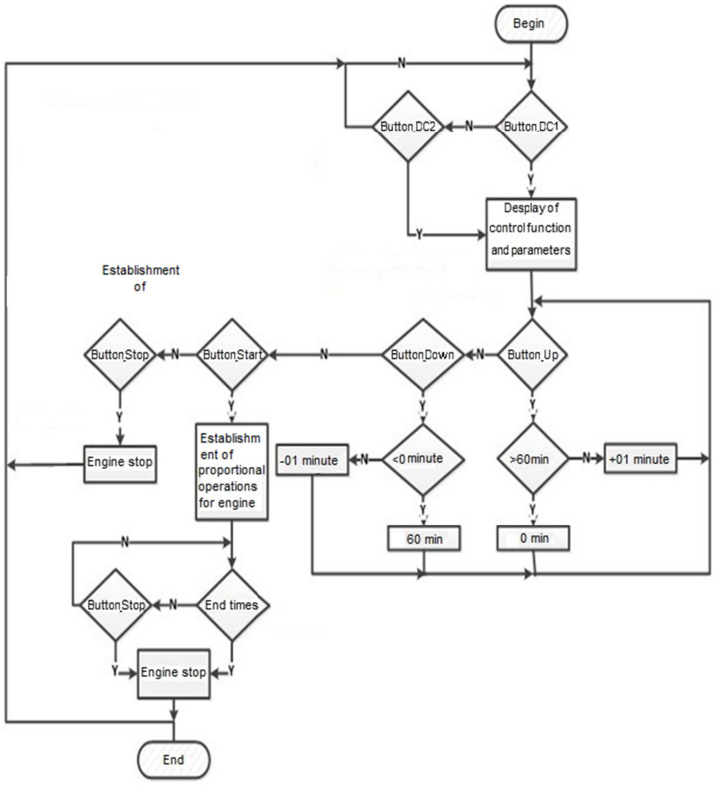


Figure 8*. Flow chart of control circuit*

Results of exhaust emissions measuring *(Figures 9, 10.)*

Figure 9*. Exhaust gas composition before rinsing injector*

Figure 10. *Exhaust gas composition after rinsing injector with new equipment and new solution*

Test results on real spark plug

After using the new equipment and new cleaning injectorsolution, there is no carbon deposit on the spark plug (bronze color on the spark plug, Figure 11.). Soot on top of the spark plug was clean, combustion process was better.

Figure 11*. Soot on top of the spark plug afterrinsing injector*

3.3. Test the cleaning injector solution on TOYOTA- D4 engine, model 1997

Tests were done at Minh Hung automotive company (Tran Dai Nghia University), using emission tester HESBON – HG 520. Two TOYOTA D4 engines with the same specifications and status were used in the tests. The first engine was rinsed with FUEL INJECTION solution, the second engine with new solution came from this research.

Cleaning solution FUEL INJECTION (USA) *(Figure 12.)*

Ingredients blended with gasoline as indicated in Table 4, the price of 60.000 VND /(330ml).

Figure 12. *Fuel Injection Solution*

Table 4. *Percentage of cleaning injector solution*

Chemistry	Mixing ratio	Time	Eng. speed (rpm)
Fuel Injection	30ml/5l gasoline	Run until out of fuel	900-1100

Results of Exhaust Emissions Measuring *(Figures 13, 14.)*

Figure 13. *Exhaust gas composition after rinsing injector with Fuel Injection solution*

Figure 14. *Exhaust gas composition after rinsing injector with new solution*

Test results on real spark plug *(Figure 15.)*

After testing, the soot layer on spark plug of D4 engine which was rinsed by new solution is reduced significantly compared with the other which was rinsed by Fuel Injection solution. Pay attention that D4 engine is gasoline direct injection (DI) engine, the λ coefficient is relatively poor, and the exhaust emissions after rinsing is reduced, burn fuel more completely.

a) before clean *b) after clean*

Figure 15. *Soot on the spark plug before and after cleaning by new equipment and new Solution*

To easily recognize the efficiency of the new equipment and new solution, we can see data in Table 5.

Table 5. *Exhaust emissions measuring*

Tested engine	Composition	CO	HC + NO_x
TOYOTA D4 -1997	After using FUEL INJECTION solution	1,65	0,516
	After using new solution	1,45	0,470
SYM -2010	Before cleaning	0,04	0,197
	After cleaning with new solution	0,03	0,188

4. Conclusions

The results of research, an experimental equipment is to produce for cleaning out fuel injectors of internal combustion engine with low cost, and really useful in automotive sector in Vietnam. The following specific conclusions can be state:

- The new equipment works very stable.

-The new cleaning solution has high efficiency in reducing CO, HC, NO_x, fuel burning completely, reducing soot layer on spark plug.

- Significant fuel savings.

- Model the process of mixing and burning of more fuel type; and analyse the soot layer in gasoline engine combustion chamber.

- Complete and early commercialize research results of equipment and solution for gasoline engines in real auto repair in Vietnam. This device is also useful for training in technical schools.

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Biographies

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