THEORETICAL STUDY OF INJECTOR TESTING USING ELECTRIC INJECTOR TESTING TOOLS

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Abstract The development of technology, especially in the field of modern and sophisticated automotives, one of the technologies being developed is EFI (electronic fuel injection). EFI is a fuel spraying system whose performance is electrically controlled in order to obtain the value of the mixture of air and fuel that is in accordance with the needs of the combustion motor, so that optimal motor power can be obtained with minimal fuel use and has an environmentally friendly exhaust gas. The function and function of fuel injection system of the EFI system on the vehicle consists of three systems, especially the fuel system, the induction system and the electrical control system. The injector is an electromagnetic nozzle whose operation is controlled by the computer, the injector is equipped with a heat insulator on the inlet or on the cylinder line which is close to the input line. The way the injector works is as well as when the ECU sends its signal in the form of a solenoid coil then it must be converted into a magnet which will lift the nose to its upper position, so that the injector gate will open and the high pressure fuel supplied by the fuel pump can come out or spray gently. The electric injector is one of the only substances used to spray and atomize gasoline into the burner according to the Firing Order (FO) sequence.

Keywords: Fuel flow, injectors, fuel delivery system

INTRODUCTION

The injector is an electromagnetic nozzle which is controlled by a computer, the injector is equipped with a heat insulator at the inlet or on a cylinder line close to the inlet. The way the injector works is when the ECU sends a signal in the form of a current to the solenoid coil then the current is converted into a magnet which will lift the needle to the top position, so that the injector gate will open and the high pressure fuel supplied by the fuel pump can come out or spray gently. The electric injector is one of the tools used to spray and atomize gasoline into the combustion chamber according to the firing order (FO) sequence. If the injector experiences problems with fuel spraying and fogging it will result in reduced motor fuel power and the engine working efficiency does not work properly, this can be seen by using a tool that is already in the show room or the injector manufacturer.

From the above problems, why did the writer have the idea to improve spraying on the injector by using an electrical injector test to find out the results of spraying and burning gasoline fuel on the electrical injector, by using the test, then it is possible to determine the injector which has an adequate standard of spraying or standard. Testing the injectors is to find out which injectors still have spraying according to

standards and which are not in accordance with the standards. As well as being able to know the principles and workings of the injector.

Based on the background of the problems that have been discussed in the writing of this thesis. So the questions that arise are:

1. How to determine the efficiency of the injector against engine speed (rpm) and the duration of the injector valve opening time.
2. How to determine the damage to the injector.
3. How to compare data and display it.

METHODOLOGY

Experimental method is conducting tests and experiments directly on the fuel flow system trainer, to obtain the output data of the independent and dependent variables, it is necessary to collect data in accordance with how to provide input data to be used in the independent variables according to the research needs.

Variable used

The variables planned in the article include the independent variables and the dependent variable, as follows:

a. Independent variables are variables whose magnitude is determined by the researcher, including:
    1. Simulates the variation of rotation (rpm) controlled by speed control to influence the amount of fuel spray volume on the injector by the number of rpm turns (1000 rpm, 1500 rpm, 2000 rpm, 2500 rpm, 3000 rpm)
    2. Simulate the variation in the duration of fuel spraying time on the injector which is controlled by the speed duration that will be used the amount of the duration of the injector valve opening time, namely (0.002 seconds, 0.0025 seconds, 0.003 seconds, 0.0035 seconds, 0.004 seconds)
b. The dependent variable is the amount of fuel volume obtained from the simulated test results which can affect the volume of fuel sprayed by the injector, so the following results are obtained:
    1. Discharge of fuel sprayed by the injector.
    2. The volume of fuel that is sprayed by the injector.

Procedure of test

Ways to perform testing and data collection on the electric injector test equipment include:

1. Give the fuel pump an electric current.

2. Make sure the tank is filled with fuel.
3. Make sure all components are installed properly.
4. Set the speed rpm according to the desired variable.
5. Set the duration of the injector valve opening time as desired.
6. Check the position of the measuring cup so it doesn't deviate.
7. Make sure the measuring cup is empty.
8. Turn on the ignition along with the stopwatch to measure the test time.
9. Wait a few seconds for the fuel to flow steady.
10. After the specified time is over, turn off the contact at the same time as turning off the stopwatch.
11. Let stand for a few seconds so that the fuel foam in the measuring cup runs out.
12. Measure the volume of fuel that is in the measuring cup using a magnifying glass.
13. Record the volume results in a measuring cup on the test table.
14. The above steps are repeated with different variations of valve openings according to the variables to be tested.

Tool specification data

Injector specification data on Honda Civic type vehicles used in testing are as follows: (source: Honda Civic Maintenance book)

a. Fuel pressure on rail: 3 bar
b. Fuel discharge per minute: 180-190 cm3 / minute
c. Injector valve opening duration: 2.0 ms or 0.002 seconds

To calculate the number of injector injections in the 4 stroke motor combustion cycle, it can be calculated as follows:

Number of sprays per second= $\frac{n\,(rpm)}{t}$

Number of sprays per second = 16,6 times.

The calculation above is the length of time in the test used for 60 seconds and the specified rpm is 1000 rpm.

To calculate the number of Sprayings Simultaneously, namely every 1 time the crankshaft rotation occurs 1 time, the following results are obtained:

Number of sprays= 16.66 x 60 =1000 times

To calculate the number of spraying groups and individually in 2 times the crankshaft rotation occurs 1 time then it can be calculated as follows:

Number of sprays = 16,66 x 60 x ½

Number of sprays = 500 times

DATA PROCESSING

Data that obtained according to observations or tests will be processed to obtain the results of the relationship between the work efficiency value of

each injector to changes in engine speed (rpm) and the duration of opening the injector valve (s).

Injector test results

The procedure for testing the injector on a vehicle is in the vehicle maintenance and maintenance manual, for this type of Honda Civic vehicle specifications include:

a. Fuel volume 180-190 cm^3
b. Test time for 60 seconds
c. The difference in the volume of fuel for each injector should not be more than 10% or 18-19 cm^3.

To compare the condition of the injectors and determine the condition of the injectors that are still good and which are not suitable for use, it can be seen by giving current to each injector directly for 60 seconds to get the following results:

No	Injektor	Volume spesifikasi (cm3)	Volume hasil uji (cm3)	Waktu pengujian (detik)	Keterangan
1	1	180-190	184	60	baik
2	2		183		baik
3	3		185		baik
4	4		175		rusak

So it can be concluded that injector numbers 1,2 and 3 are still in the good category, while injector number 4 is damaged or is not suitable for use.

Calculation of the theoretical volume with simultaneous spraying.

a. The theoretical fuel discharge on the injectors can be obtained through the Honda Civic Vehicle Maintenance and Repair Specifications Manual as follows: (Source: Honda Civic Maintenance and Maintenance Manual)

$$Q = \frac{\text{Volume rata-rata } (cm^3)}{t\ (s)}$$

$$Q = \frac{(\frac{180+190}{2})\ (cm^3)}{60\ (s)}$$

$$Q = \frac{185\ (cm^3)}{60\ (s)}$$

$$Q = 3{,}083\ (cm^3/s)$$

$$Q = 0{,}003\ (m^3/s)$$

b. To calculate the volume of fuel sprayed by the injector, when the data is collected, the duration of the injector valve opening is 0.002 seconds, then it can be calculated as follows:

$$V_{penyemprotan}(cm^3) = Q(cm^3/s)\ \text{x}\ t\ (s)$$

$$V_{penyemprotan}(cm^3) = 3{,}083\ (cm^3/s)\ \text{x}\ 0{,}002\ (s)$$

$$V_{penyemprotan}(cm^3) = 0{,}00616\ (cm^3)$$

$$V_{penyemprotan}(cm^3) = 0{,}00000616\ (m^3)$$

c. The number of injectors spraying simultaneously at every 1 time the crankshaft rotation occurs 1 time, so the data collection carried out for 60 seconds is 1000 sprayings, so the theoretical total volume can be calculated as follows:

$$V_{teoritis} = 0{,}00616\ (cm^3)\ x\ 1000\ kali/60\ (s)$$

$$V_{teoritis} = 0{,}00616\ (cm^3)\ x\ 16{,}6$$

$$V_{teoritis} = 0{,}02656\ cm^3/1000$$

$$V_{teoritis} = 0{,}00002656\ (m^3)$$

d. In order to calculate the efficiency of the injector, the balance can be calculated as follows:

$$\eta_{injektor} = \frac{V_{pengujian}\ (cm^3)}{V_{teoritis}\ (cm^3)}\ x\ 100\ \%$$

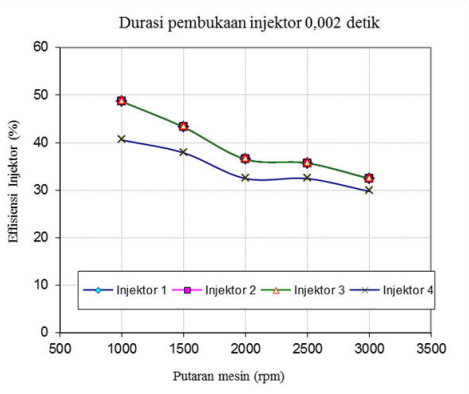
$$\eta_{injektor} = \frac{3\ (cm^3)}{6{,}16\ (cm^3)}\ x\ 100\ \%$$

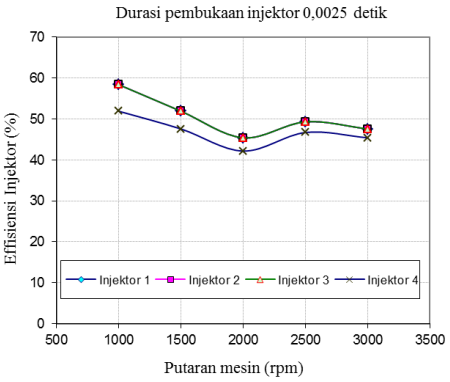
$$\eta_{injektor} = 48{,}65\ \%$$

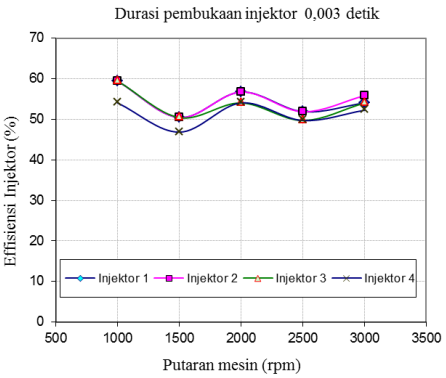
In the same way and the calculation example above, the calculation results are as follows:

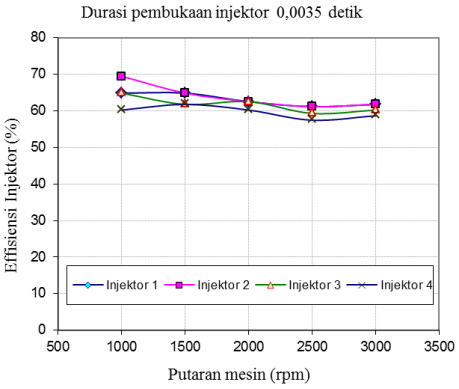
The relationship between engine speed (rpm) to fuel volume.

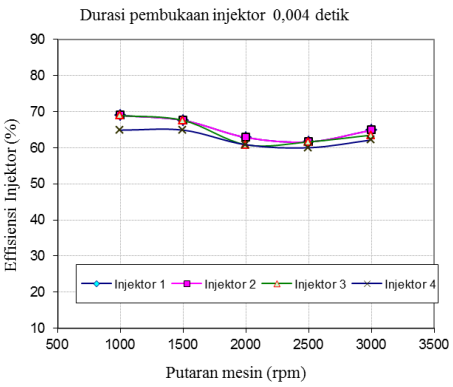
Figure 1: Graph of the relationship between efficiency and engine speed (rpm) at the duration of the injection of the injector 0.002 seconds

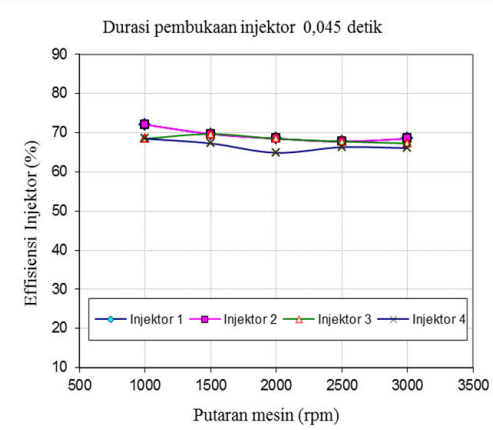


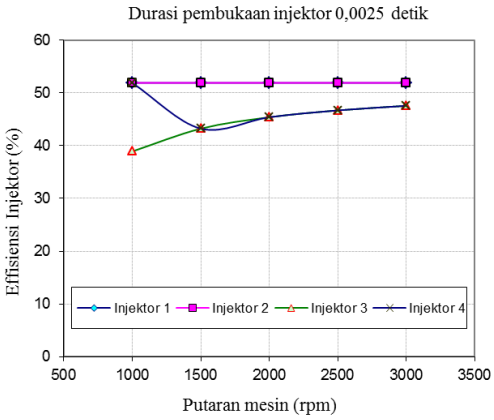












According to the picture in Figure 1, the duration of the injector valve opening is 0.002 seconds, the effect of engine rotation speed (rpm) is obtained, on the simultaneous spraying of the injectors at each injector resulting in the highest efficiency of 48.65% found in injectors 1,2 and 3 on engine speed of 1000 rpm, and the lowest efficiency of 29.37% is found in injector number 4 at 3000 rpm engine speed.

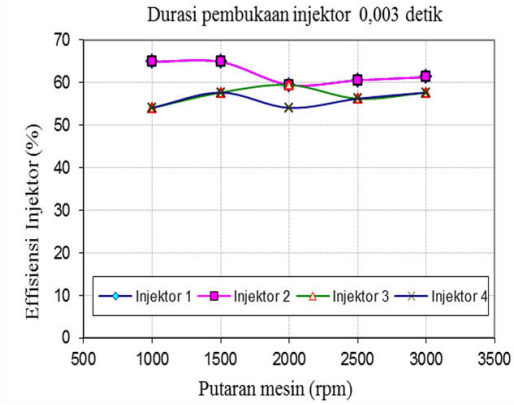
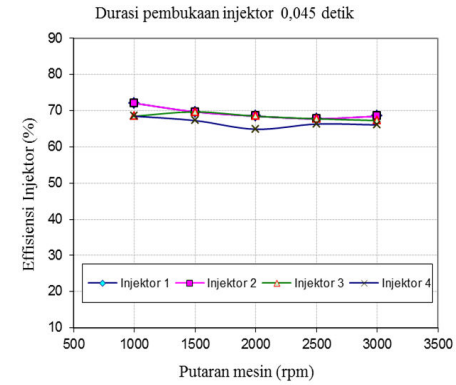
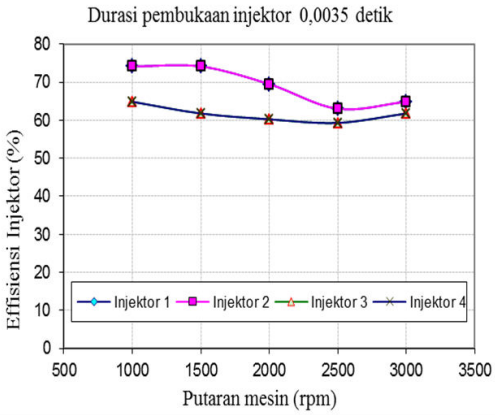
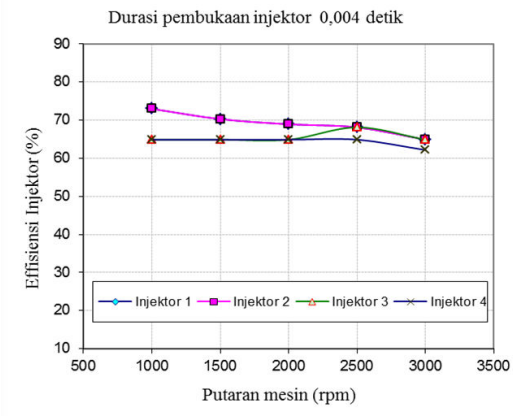
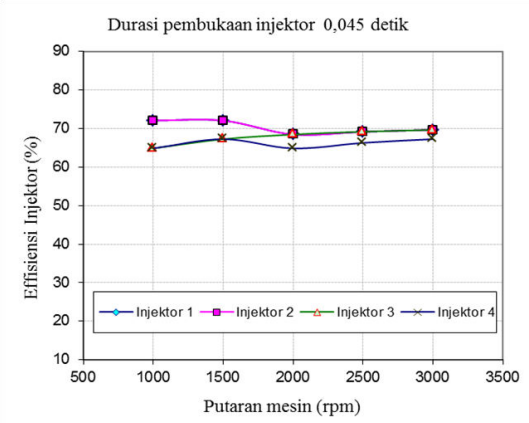


Figure 2: Graph of the relationship between efficiency and engine speed (rpm) at 0.0045 second injection duration.









According to the Figure 2 on the duration of the injector valve opening 0.0045 seconds, the effect of engine speed (rpm) on the injection efficiency of the injectors simultaneously results in the highest efficiency of 72.07% found in injectors number 1 and 2 on engine speed of 1000 rpm, and the lowest efficiency of 64.86% is found in injector number 4 at 2000 rpm engine speed.

b. Calculating the volume of fuel at each injector spraying as a group and individually with an injector valve opening time duration of 0.002 seconds can be calculated as follows:

$$V_{penyemprotan}(cm^3) = Q(cm^3/s) \text{ x } t \text{ (s)}$$

$$V_{penyemprotan}(cm^3) = 3{,}083\ (cm^3/s) \text{ x } 0{,}002 \text{ (s)}$$

$$V_{penyemprotan}(cm^3) = 0{,}00616\ (cm^3)$$

$$V_{penyemprotan}(cm^3) = 0{,}00000616\ (m^3)$$

c. Calculating the volume of fuel only when testing injectors in groups and individually for every 2 times the crankshaft rotation occurs 1 spray, then the number of injectors sprayed in 60 seconds is 500 times, so the theoretical total volume can be calculated as follows:

$$V_{teoritis} = 0{,}00616\ (cm^3) \text{ x } 500 \text{ kali } / \ 60$$

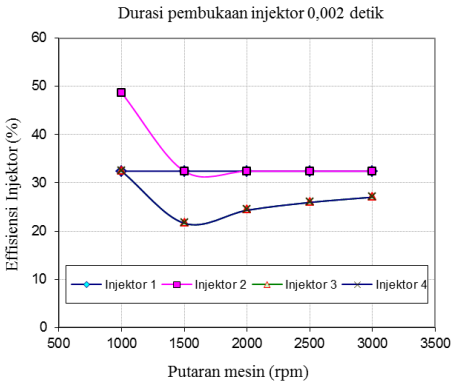
$$V_{teoritis} = 0{,}00616\ (cm^3) \text{ x } 8{,}33 \text{ kali}$$

$$V_{teoritis} = 0{,}05\ (cm^3) \ / \ 1000$$

$$V_{teoritis} = 0{,}00005131\ (m^3)$$

The graph of the calculation results and discussion of the calculation results of the data consists of the engine speed (rpm) and the duration of the injector opening time (ms) to the injector spraying volume.

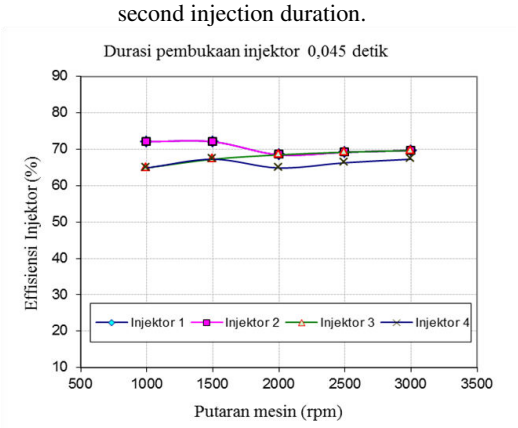
Figure 3 Graph of the relationship between efficiency and
engine speed (rpm) at the duration of the injection of the injector 0.002 seconds.



According to the Figure 3 on the duration of the injector valve opening 0.002 seconds, the effect of engine rotation speed (rpm) on the injector spraying efficiency in groups and individually on each injector produces the highest efficiency of 48.65% found in injector number 2 at engine speed. 1000 rpm, and the lowest efficiency of

21.62% is found in injectors number 3 and 4 at 2000 rpm engine speed.

Figure 4: Graph of the relationship between efficiency and engine speed (rpm) at 0.0045 second injection duration.



Based on the Figure 4, the duration of the injector valve opening is 0.045 seconds, the effect of engine rotation speed (rpm) on the injector spraying efficiency as a group and individually in each injector produces the highest efficiency of 72.07% found in injectors number 1 and 2 on engine speed of 1000 rpm and 1500 rpm, and the lowest efficiency of 64.86% is found in injectors number 3 and 4 at engine speed of 1000 rpm.

CONCLUSION

Based on the results of the calculation of the data above, it can be concluded the following conclusions:

a. Simultaneous spraying. The effect of changing engine speed (rpm) will result in decreased injector efficiency.
b. Spraying in groups and individually. The effect of changing engine speed (rpm) does not affect the efficiency of the injectors and the efficiency of the injectors is relatively constant.
c. The effect of changing the duration of spraying on the type of spraying simultaneously and individually will increase the value of the injector efficiency.
d. According to the test results, it was found that the injector number 1,2 and 3 were still in good condition and injector number 4 was declared damaged because the volume that was sprayed by the injector was less than the standardized volume of the Honda Civic injector.

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