Analysis of Influence of Extension in The MAF (Mass Air Flow) Sensor on Power and Consumption of Fuel in The Engine Model (B401RA)

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Abstract. MAF is an electronic component in the form of a sensor that is used to transfer mass flow determined by the ECM to determine the fuel injected. Based on Technical Research on 8/3/2016 engine knocks occur during acceleration in the vehicle with the model code (B401RA) because the detection of air entering the detection area of the MAF sensor is less than optimal, thereby increasing fuel injection volume and ignition time in the cylinder, causing knock to the machine because the ignition time is too fast. Therefore, improvements made to the MAF sensor by changing the size of the MAF sensor, from the standard size (30 x 10 mm) to the size (32 x 22 mm). By enlarging the outer appearance of the MAF will expect not to occur ignition earlier so that replacing the fuel is more suitable according to engine needs. From the research results obtained, MAF sensor modification can increase Power by 5.56 kW and reduce fuel consumption by 0.00009 kg / kW-hour at 6000 Rpm. While on average there is an increase in each engine speed for Power of 3.24 kW and consumption of fuel consumption of 0.00009 kg / kW-hour.

Keywords: Electronic MAF sensor, power, and fuel consumption.

1. Introduction

The fuel system is a very rapid development system, one of the developments in the air induction system, wherein conventional vehicles to regulate the amount of air entering the combustion chamber a carburetor system used, and for vehicles with type of Electronic Fuel Injection (E.F.I.) already using sensors and Engine Control Module (E.C.M.) as sensor regulator.

Mixing air and fuel using a carburetor is not as perfect as using an air induction system. Air mixing using the Air Induction System is better because it is supported by sensors that support one of them, namely the Mass Air Flow (M.A.F.) sensor (Syamsul Rizal, 2013). M.A.F. sensor used type L E.F.I. the engine that serves to measure the mass flow of air entering the engine and control the air-fuel ratio because of its fast response, wide range and high reliability (Elsevier B.V., 2006). M.A.F. sensors that have been scanned by heat film sensors will be better than linear dynamic models, and convenient for dynamic correction of non-linear sensors. Also, this model can used by other models. Ken ju Xu, Hao Ren, Wang Xiao-Fen, Qin Teng (2006).

Produces analytical redundancy, which has two signals from the same variable, one provided by the observer, and sensors provide others. The FDI system allows I.C. machine operation without interruption, after a M.A.F. sensor total failure, by replacing the damaged signal to the excellent value given by the observer. Ethical values injected into the engine control unit (E.C.U.). The results of the experiment showed effectiveness proposed system. (Elsevier,2018).

The solution to overcoming knocking on the engine is by regulating air intake and fogging into the right cylinder and the right time. Ahmad Kholil1, Darwin Rio Budi Syaka1, Andreas Edi Widyartono, (2014).

TPS sensor voltage that occurs, the more volt that occurs will eat power will be higher, whereas, at ISC, this sensor affects the value of CO and HC on exhaust emissions. Therefore it can be set between TPS and ISC to obtain the right power and emissions(cecep deni mulyadi,2013)

E.C.M. requires M.A.F. sensors to find out how much volume of air entering the engine to calculate the engine load. This usually used to determine how much fuel will inject, when the combustion occurs in the cylinder and when the transmission gearshift is carried out (Toyota Motor Sales, U.S.A.).

From the results of research conducted at P.T.XX, the compiler gets information through the Technical Research published on March 8, 2017, sourced from P.T.XX, Product Quality Improvement Dept. Regarding improvement research conducted on M.A.F. sensors in vehicles with a model code (B401RA), the authors are interested in analyzing and studying the effect of changes in the cross-sectional area made on the M.A.F. sensor components. The purpose of this analysis is:

e-ISSN 2721-0952

1) can find out the MAF sensor inspection procedure on the vehicle with the model code (B401RA).
2) It can determine the effect of voltage on the MAF sensor on air mass flow in vehicles with the model code (B401RA).
3) It can determine the effect of air mass flow through the MAF sensor on engine torque on a vehicle with a model code (B401RA).

2. Research Method

Research Flow Chart of MAF sensors shown in figure 1.

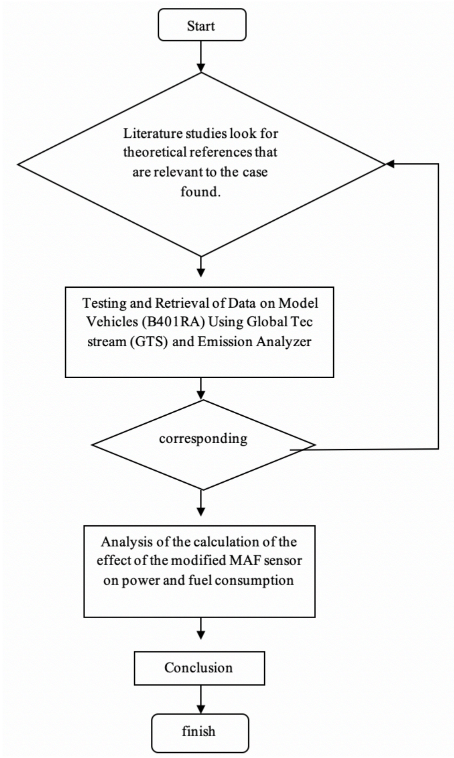

FIGURE 1. Lift force on a simplified RX 450 rocket fins structure

The data found in this research process, includes data obtained from the calculation results and data obtained from the DVD Repair Manual (B40 #), 2016, in the form of specifications for the engine in the vehicle model (B401RA). Vehicle Engine Model Specifications Data (B401RA):

- Type: 4 stroke petrol engine
- Step volume: 1197 cc
- Number of Cylinders: 4 in a row
- Number of Valves: 16 pieces
- Diameter (B) x Step (S): 72.5 mm 72.5 mm
- Max Output: 63kW @ 6000 RPM
- Max Torque: 108N.m @ 4400 RPM
- Fuel System: Sequential Port Fuel Injection (SFI)
- Compression Ratio: 11.5: 1

The data obtained is then processed into equations, then the calculation data is made of several tables and graphs. The thermistor measures the temperature of the incoming air. So hot wire maintained at a constant temperature with a thermistor through an electronic controller circuit. An increase in temperature due to the incoming airflow will cause the hot wire to lose heat quickly, and the electronic controller circuit by itself will be compensated by sending more current via a hot wire.

e-ISSN 2721-0952

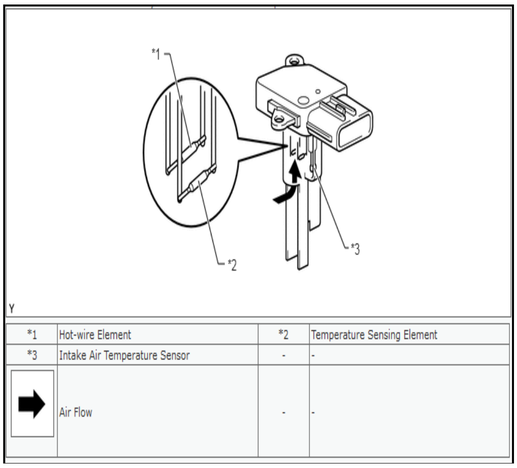

FIGURE 4. MAF Sensors on Vehicle Models (B401RA)

3. Data Analysis and Research Results

Facilitates the calculation in the thermodynamic process, the idealization of certain conditions is first carried out. Where the process that occurs in the actual situation will be different from the process that occurs ideally. Where the idealization process is as follows:

1) The air contained in the cylinder is considered a working fluid and is an ideal gas with constant heat.
2) The compression and effort steps are assumed to be isentropic processes.
3) The combustion process is assumed to be the process of entering heat.
4) At the end of the business step, where the piston position is at the bottom dead point, so the temperature and pressure in the cylinder decrease until it reaches atmospheric pressure and temperature.
5) The pressure in the cylinder is constant during the exhaust step and the suction step.

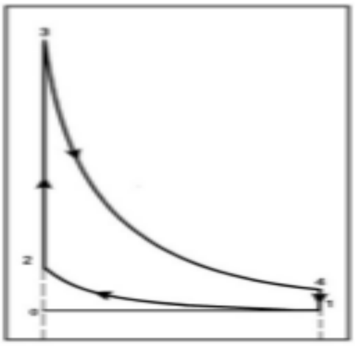

FIGURE 5. P - V diagram of the ideal Otto Cycle

The thermodynamic process that occurs in the otto cycle using MAF sensor modification in the vehicle model (B401RA) can be reviewed as follows.

State I (Process 0-1)

Suction step, where the piston moves from the top dead point to the bottom dead point, the inlet valve opens and the exhaust valve closes, the mixture of air and fuel enters the cylinder. Constant pressure and incoming air equal atmospheric pressure. Air entering the cylinder is assumed to have a pressure of 1.03 atm or 104.3647 kPa at an air temperature of 29 ° C or equal to 302 K, then:

Step Volume

Is the overall volume produced from the piston step.

$$VL = \frac{\pi}{4} . B^2 . S . Z \text{ (cc)} \quad (1)$$

Where :
VL = step volume (cc), π = 3.14, B = cylinder diameter (cm), S = piston step (cm), Z = number of cylinders
The 4 cylinder capacity is 1197 cc, so the stroke volume for one cylinder is.

Remaining Volume
The remaining volume is the same as the combustion chamber volume. Wherewith the compression ratio of 11.5: 1 and the step volume of 0,00029925 m^3, the residual volume is:

Where :
RC = compression ratio
VL = step volume (m^3)
Vc = residual volume (m^3)
Vc = (0,00029925 m^3) / (11.5-1) = 0.0000285 m^3

Volume at Point 1
That is the result of the sum of the step volume with the remaining volume

V_1 = (VL + Vc) m^3

Where :
VL = step volume (m^3)
Vc = residual volume (m^3)
V_1 = volume at point 1 (m^3)

Mass Mixed Fuel and Air
To find the mass of the fuel mixture, the following equation can be used:

$$mcamp = (P1 . V_1) / (R . T1) \quad (2)$$

Where :
mcamp = mass of fuel and air mixture (kg)
P1 = pressure at point 1 (atmospheric pressure) (kPa)
V_1 = volume at point 1 (m^3)
R = universal gas constant (kJ / kg-K)
T1 = temperature at point 1 (K)

It is known that the results of the study found that:
AFR (Air Fuel Ratio) of vehicles using MAF sensor modification = 15.50: 1
It is assumed that the residual combustion gas residue = 2%

$$mcamp\ total = mud + mbb + mb \quad (3)$$

Where :
mud = air mass (kg)
mbb = massa of fuel (kg)
mb = massa of waste (kg)

State II (Processes 1-2)
Isentropic compression step, where both valves close, and the mixture of air and fuel is compressed.

The pressure at Point 2
After the mixture of fuel and air is compressed by the piston. As a result, the pressure in the cylinder rises to (P2).

$$P2 = P1 (rc)^k \quad (4)$$

Where :
P2 = pressure at point 2 (kPa)
P1 = pressure at point 1 (kPa)
rc = compression ratio
^{k} = specific heat ratio

The temperature at Point 2

The mixture of fuel and air compressed or compressed by the piston, also causes the temperature in the cylinder to rise to (T2).

$$T2 = T1\,(rc)^{k-1} \quad (5)$$

Where :
T2 = temperature at point 2 (K)

Volume at Point 2

$$V2 = \frac{V_1}{rc}$$

Where :
V2 = volume at point 2 (m³)
V2 = Vc (m³)

Work absorbed during the isentropic compression step

$$W_{1-2} = \frac{(mcamp\ total\ .R.(T2 - T1))}{(1-k)} \quad (6)$$

Where :
W_{1-2} = work cycle 1-2 (kJ)

State III (Processes 2-3)

In this 1-2 process, the step is adding or entering heat.

Incoming heat:
The fuel used in this study is Pertamax with a heating value of 46000 kJ / kg and it is assumed that complete combustion ηc = 1.

$$Qin = mbb\ .\ QHV\ .\ \eta c \quad (7)$$

Where :
Qin = heat in (kJ)
QHV = heating value of fuel (kJ / kg)
ηc = combustion efficiency

Temperature at Point 3

Using the mathematical equation Qin = total mcamp. C_v (T3-T2), the temperature is T3. can be known :

$$T3 = \frac{(Qin + (total\ mcamp\ .C_v\ .T2)}{(mcamp\ total\ .C_v)} \quad (8)$$

Where :
T3 = temperature at point 3 (K)
C_v = specific heat at constant volume (kJ / kg)

The heat entering the power process is ideal

$$Qin = mcamp\ total\ .C_v\ (T3-T2) \quad (9)$$

Where :
Qin = heat input (kJ)
C_v = specific heat at constant volume

(kJ / kg-K)

Volume at Point 3
From the P-V diagram, the ideal otto cycle can be seen that V3 is equal to V2. Then,
V3 = V2

The pressure at point 3
As the constant volume increases, so does the pressure in the cylinder.

$$P3 = P2\left(\frac{T3}{T2}\right) \tag{10}$$

Where :
P3 = pressure at point 3 (kPa)
T3 = temperature at point 3 (K)

State IV (Process 3-4)
Isentropic effort or expansion step, where due to an explosion from the combustion of a mixture of fuel and air, the piston moves from the top dead point to the bottom dead point, so that it can move the crankshaft and can produce power. And in this business step, both valves are still closing.

The temperature at Point 4
After the piston reaches the bottom dead point many heats are removed from the cylinder, so the temperature of the working fluid will decrease to T4.

$$T4 = T3\left(\frac{1}{rc}\right)^{k-1} \tag{11}$$

Where :
T4 = temperature at point 4 (K)

The pressure at point 4
Likewise with the pressure in the cylinder, decreased to P4.

$$P4 = P3\left(\frac{1}{rc}\right)^{k} \tag{12}$$

Where :
P4 = pressure at point 4 (kPa)

Volume at Point 4

$$V4 = \frac{(\text{mcamp total} \,.R.T4)}{P4}$$

Where :
V4 = volume at point 4 (m^3)
R = universal gas constant (kJ / kg-K)

Work that is produced at the business stage or isentropic power is:

$$W_{3-4} = \frac{(\text{mcamp total} \,.R.(T4-T3))}{((1-k))} \tag{13}$$

Where :
W_{3-4} = effort generated on (process (kJ)

The heat that comes out at the ideal power process

$$Qout = \text{mcamp total} \,.C_v\,(T4\text{-}T1) \tag{14}$$

Where :
Qout = heat out (kJ)

Net work (nett) for one cycle

$$Wcycel = Qin - Qout \quad (15)$$

Where :

Wcycel = net effort each cycle (kJ)

Qin = incoming heat (kJ)
Qout = heat out (kJ)

Analysis of Engine Performance Parameters

Engine Power

Is the power generated in the engine cylinder due to combustion in the cylinder? The amount of engine power at 4000 rpm can be calculated using the equation:

$\dot{W}$ = cycle x N

Where :
$\dot{W}$ = engine power (kW)
N = engine speed per minute (RPM)

Specific Fuel Consumption (SFC)
Indirectly the specific fuel consumption is an indicator of efficiency in generating power from burning fuel, so the specific fuel consumption at 4000 rpm engine speed can be obtained as follows:

$$sfc = \frac{\dot{m}bb}{\dot{W}}$$

Where :
sfc = specific fuel consumption (kg / kW-hour)
$\dot{m}$bb = fuel flow rate (kg / s)

The results of the calculation of engine power parameters and specific fuel consumption for engines using MAF sensor modifications will be made tables and graphs and will be compared with engines that use standard MAF sensors.

TABLE 3. The amount of airflow mass detected by the MAF sensor and ignition point degrees

Engine Speed (RPM)	Air Flow Rate (gm/s)		Ignition Degree (deg)	
	Standart	Modification	Standart	Modification
1000	2,4	4,18	13,5	12
2000	3,73	5,57	35	26,5
3000	6,82	9,73	31,5	30
4000	9,96	16,76	28	25,5
5000	16,18	21,65	17	22
6000	29,26	36,43	6,5	3,5

The amount of air mass flow detected by the MAF sensor, can also affect the ignition point, here are the data obtained through testing using Global Techstream (GTS).From Table 4 it can be seen that at engine speed 4000 rpm, the ignition degree point using a standard MAF sensor is 28 deg, while for engines that use a modified MAF sensor that is 25.5 deg, so it can be seen that the ignition point is slowed and can avoid knocking.To make it easier in the comparison process, then some of the tables above will be formed into one table, as follows.

TABLE 5. Parameters of airflow rate power, and specific fuel consumption

Engine speed (RPM)	Air Flow Rate (gm/s) Standart	Air Flow Rate (gm/s) Modification	increase (%)	POWER (kW) Standart	POWER (kW) Modification	increase (%)	SFC (kg/kW-hour) Standart	SFC (kg/kW-hour) Modification	decrease (%)
1000	2,4	4,18	74,1667	10,5	11,43	8,85714	0,2512	0,251	-0,0705
2000	3,73	5,57	49,3298	21,01	22,86	8,80533	0,25106	0,2511	0,00717
3000	6,82	9,73	42,6686	31,52	34,3	8,8198	0,25104	0,251	-0,0359
4000	9,96	16,76	68,2731	42,02	45,73	8,82913	0,25109	0,251	-0,0442
5000	16,18	21,65	33,8072	52,53	57,16	8,81401	0,25105	0,251	-0,0307
6000	29,26	36,43	24,5044	63,04	68,6	8,8198	0,25104	0,251	-0,0359

From the graph and table above, it appears that for a 4000 rpm engine speed, the power generated by the engine using a modified MAF sensor is 45.73 (kW). In contrast, a machine that uses a standard MAF sensor produces a power of 42.02 (kW), so an increase of 4.63 (kW). For engine power parameters that power increases with increasing engine speed. Then the fuel consumption for the engine using the modified MAF sensor is 0.250981 kg / kW-hour, while for the engine that use the standard MAF sensor, the fuel consumption is 0.251092 kg / kW-hour, resulting in a decrease in fuel consumption by 0,000111 kg / kW-hour. On average, it can be said that the use of MAF sensor modification on model vehicles (B401RA) with the same engine specifications will increase engine power at each rpm by an average of 8.8% and a decrease in specific fuel consumption by an average of 0.035 %. This increase in engine power and the efficiency of using specific fuel consumption is due to the cross-sectional area of the modified MAF sensor compared to the cross-sectional area of the standard MAF sensor because the larger cross-sectional area of the MAF sensor modification allows air through the detection area (hot wire will be more, causing the MAF sensor to detect more air entering the intake manifold and subsequently the MAF sensor sends a signal to the ECU for injection of the fuel volume and ignition timing tailored to the needs.

4. Conclusions

1) Generally for all engine speeds tested then:
    a. Airflow rate increases by an average of 4.32 gm/sec when using a modified MAF sensor.
    b. An average of 1.64 deg slows the degree of ignition. When using MAF sensor modification.
    c. Engine power increases an average of 3.24 kW when using a modified MAF sensor.
    d. Fuel consumption also increased by an average of 0.00009 kg / kW-hour when using a modified MAF sensor.
2) From the calculation, analysis results obtained that the use of MAF sensor modification will increase engine power and decrease specific fuel consumption when compared with the use of standard MAF sensors for the same engine specifications.

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