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Analysis of 45 Micron Air Filter's Effect on Car Engine's Performance (Matic 1500cc) by Using Dynamometer-Bench Test Data Research

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Abstract. There are many racing air filter products on the market with air filter fold gap of 45 microns. However, there has been no research proves that an air filter with 45 microns' fold gap can increase the performance of a car engine. Based on this, the author is interested in conducting an experimental test analysis of the car engine air filter by modifying the factory standard air filter which has fold gap of 25 microns into an air filter that has fold gap of 45 microns. This study aims to prove whether a 45-micron air filter can increase the performance of a car engine in the form of torque, power, fuel consumption, and mechanical efficiency. The study is conducted by using dynamometer. Analysis of research data uses descriptive statistics with data presentation in the form of tables and graphs. The results of this study indicates that the effect of a 45-micron air filter on a car engine performance is proven to improve car engine performance compared to factory standard air filters with details: torque in car engine increases by 3.05%, power in car engine increases by 1.78%, the specific fuel consumption of the car engine is 1% more efficient, and the mechanical efficiency of the car engine is increased by 0.02%. Based on the research that has been done, it is necessary to do further research regarding the effect of the 45 micron racing air filter on the service life of the piston and valve in the car engine.

Keywords: air filter; engine performance; torque; power; fuel consumption

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1. Introduction

The public's need for private vehicles for 4-wheeled cars is increasing from year to year, especially from 2017 to 2019 the car population in Indonesia has increased by 5% [5].

There are many options circulating in the community to improve vehicle engine performance by modifying the manufacturer's standard vehicles such as Digital Tuning, Exhaust Set modifications, air filter modifications, and so on. All of these options have the same goal, which is to improve the performance of the car engine. Of the many choices, one of the modifications that the public considers the most affordable is the replacement of the air filter from the manufacturer's standard to a racing air filter [20]. The racing air filter manufacturers also produce air filters with a density size of 45 microns, while for standard factory sizes, air filters have a density size of 25 microns [20].

There is no research that proves whether the design of this racing air filter has a significant effect on the performance of a car engine. Based on this, the authors are interested in conducting an experimental test analysis of the car engine air filter by modifying the factory standard air filter which has a density of 25 microns into an air filter that has a density of 45 microns.

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Therefore, the author wants to conduct a study entitled "Analysis of the Effect of a 45 Micron Air Filter on the Performance of a 1500cc Car Engine Using a Dynamometer Test Data". The aims of this research are as follows:

a. Testing a racing air filter with a density design of 45 microns using an engine dynamometer.
b. Analysing the effect of a 45 micron air filter on the performance of a 1500cc automatic car engine by comparing it to a 25 micron factory standard air filter.

2. Methodology

2.1 Flow Chart

The stages of completion in this study were carried out in accordance with the flowchart, the following is an image of the research flowchart:

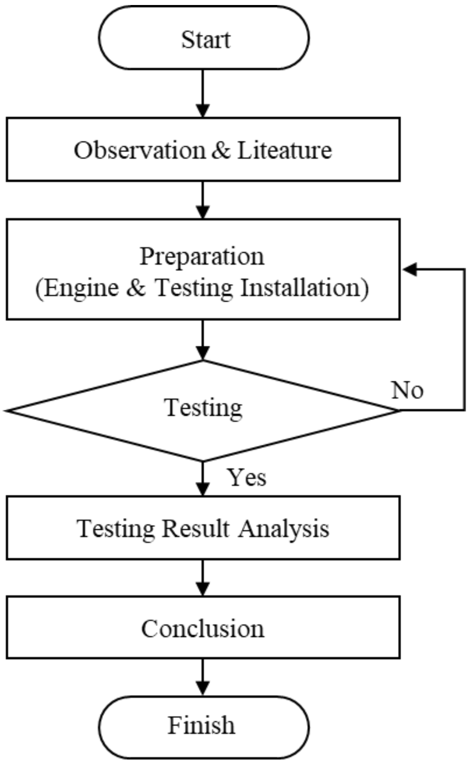


Figure 1. Flowchart

2.2 Observation and Literature

In compiling the final project report, the author uses preparation by collecting data contained in the guidelines or literature related to the material analysed in the discussion of this report.

a. Air filter

Automotive air filter is one of the disposable components in the combustion engine which functions to filter the air before it enters the combustion chamber [1]. This air filter functions to filter dirt and dust from the air so that it gives the opportunity for cleaner and more air to enter the combustion chamber. Filtration with an air filter is intended to prevent the entry of dust and other particles into the cylinder along with the air. Carrying dirt/dust into the cylinder will cause the combustion process to be incomplete, cause crust on the combustion chamber and cylinder wall, detonation in the engine which results in decreased engine power, increased air pollution and increased noise. In addition, the flow of air entering the combustion chamber will affect the homogeneity of mixing air and fuel in the combustion chamber which will affect combustion performance. Because it functions as a filter, this air filter must be clean of dirt. If a lot of dirt is attached, it will block the incoming air so that it will cause incomplete combustion and waste fuel. There are several types of air filters that are often used, namely paper air filters, foam air filters, and cloth air filters.

b. Engine performance

The performance or performance of a motorized vehicle engine can be determined by analysing the parameters in the form of power, torque, specific fuel consumption, average effective pressure, and efficiency of the engine. These parameters become practical guidelines for measuring the performance of a motorized vehicle engine.

In general, the engine power will be directly proportional to the piston area, while the torque will be directly proportional to the stroke volume. A vehicle engine is usually operated continuously, therefore the fuel consumption of the vehicle's engine and also the efficiency of the vehicle's engine is very important to assess the performance of the vehicle's engine [4].

- Torque (T)

The rotary compressive force on the rotating part is called torque, the motor is driven by torque coming from the crankshaft.

$$T = F \ x \ r \ (N.m) \tag{1}$$

Which are:
$F = \ Force \ (N)$
r = length

The length of rotation (r) is equal to the distance from the crankshaft to the crank pin, this means half of the piston stroke. The force (F) contained in the player is equal to the compression pressure produced by the combustion gases which will push the piston down, therefore the torque (T) changes according to the magnitude of the force (F), as long as the length r remains the same. The magnitude of the force (F), changes according to changes in engine speed. This means that the magnitude of the force is affected by combustion efficiency, as well as torque. At a certain speed the engine torque becomes maximum. This is called the maximum torque. An increase in engine speed will not increase torque if the engine torque has reached its maximum point.

- Power (N)

Power is the speed at which work is done. In this study, 2 different powers will be used, namely input power/piston power and output power/shaft power. The input power/piston power is the power that occurs in the engine combustion chamber and is received directly by the piston surface [13]. The input power/piston power can be obtained from the following formula:

$$N_{piston} = \frac{P_e \ x \ V_d \ x \ RPM}{60} \ (Watt) \tag{2}$$

Which are:
P_e = Mean effective pressure (Pa)
RPM = Rotation per minute
V_d = Total step volume (m^3), 1500cc machine = $1497 \ x \ 10^{-6} \ m^3$

While the output power/shaft power is the power that is read by the dynamometer on the test panel obtained from the crankshaft [13]. The output power/shaft power can be calculated by the following formula:

$$N_{shaft} = \frac{2\pi \ x \ RPM \ x \ T}{60} \ (Watt) \tag{3}$$

Which are:
RPM = Rotation per minute
T = Torque (Nm)

- Mean Effective Pressure (P_e)

The mean effective pressure is defined as the effective pressure of the working fluid against the piston along its stroke to produce work per cycle. This mean effective pressure is needed to further calculate the piston power [4].

$$P_e = 2\pi n_c \frac{T}{V_d}\ (Pa) \quad (4)$$

Which are:
P_e = Mean effective pressure (Pa)
n_c = Steps per revolution (4 stroke machine, n_c= 2)
T = Torque (N.m)
V_d = Total step volume (m^3) → 1500cc machine = $1497\ x\ 10^{-6}\ m^3$

- Mechanical Efficiency (η_m)

Mechanical efficiency states the ratio between the shaft power produced and the fuel power required for a certain period of time.

$$\mu_m = \frac{N_{shaft}}{N_{piston}} \quad (5)$$

Which are:
N_{shaft} = Shaft power which is read by dynamometer (Watt)
N_{piston} = Piston power which is calculated on by equation 2 (Watt)

2.3 Machine Preparation and Test Installation

At this preparatory stage, a complete car engine will be installed into the dynamometer unit set by installing the mechanical parts of the car that are connected to the engine such as transmission, alternator, oil cooler, engine belt, various hoses (water, gas, fuel, etc.) , dynamo, fill the radiator water, connect the engine to the fuel tank, and so on. In addition to connecting the mechanical parts, another important part during the preparation stage is the installation of all car engine wires and the installation of the ECU (Engine Control Unit). Before the engine is ready to start, it must be ensured beforehand that all cables to the battery are installed and the transmission is in neutral. After confirming that everything is installed according to standard, the operator will press the start button on the display panel and the engine will start as in a car condition which is indicated by the engine fan spinning and engine oil flowing at a certain value. Illustration of the test installation can be seen in Figure 2.

Figure 2. Engine Dynamometer Installation

2.4 Testing

This research was conducted with several stages of testing using a dynamometer with a description of the testing stages carried out as follows:

a. Warming Up

The purpose of this stage is to ensure that there are no water, gas, and oil leaks, and no abnormal sounds in the engine or other abnormalities for safety reasons before proceeding to the next testing stage. The engine will be rotated at a constant speed / idle 800 Rpm with a neutral transmission position.

b. Break-in Running
This stage aims to give time and make sure the car engine is used to the dynamometer environment that has just been installed or is often referred to as the adjustment period. Break-in running is done by manually setting the combination of Rpm and torque variables within the time specified by the manufacturer's standard. By conditioning the engine speed at a certain Rpm, it is hoped that all engine functions can be observed for normality, such as oil flow, wind, water, ignition, air flow, and most importantly ensure that all engine rotations can run more smoothly when the next stage is the performance test. . With a smoother engine rotation, theoretically it will produce lower friction, so that the recording performance will be better. This break-in running is executed with a total time of 1 hour of work.

c. Performance Testing
This stage is the core stage of the car engine performance testing process. After break-in running, the car engine condition is considered to be in accordance with the actual conditions when the car is running. From this stage, it is determined that the independent variable is the engine rotation speed (Rpm). While the dependent variables are torque (Nm), fuel consumption (gr/kWh), and power (kW). The independent variables of engine speed (Rpm) that will be recorded are 1200, 1600, 2000, 2400, 2800, 3200, 3600, 4000, 4200, 4400, 4800, 5200, 5600, 6000, and the highest is 6200 Rpm. Before running the above test pattern, the operator must upload the independent and bound variable commands to the ECU, so that data reading and processing can be done automatically by the checker panel. After all the independent variables are executed, then the data is downloaded from the checker panel for evaluation. After all dependent variable data is obtained, the next step will be to shut down the engine by cooling down the engine, turning off the engine, removing radiator water, removing all mechanical parts and wires, as well as ensuring the shutdown safety conditions are in accordance with predetermined procedures. Testing completed.

2.5 Analysis of Test Results
In analysing the data, the author performs calculations related to engine performance. This activity is intended so that the machine can be compared.

2.6 Conclusion
After testing and analysing the data, the next step is to make conclusions and suggestions from the results of the analysis on testing standard air filters and 45 micron air filters using a dynamometer

3. Result and Discussion
3.1 Comparison of Test Result Data
After testing the machine using a dynamometer test equipment, the comparison of the test results data is obtained as shown in the following pictures. As seen in Figure 3, the average percentage of engine torque with an air filter of 45 microns is slightly higher than a standard air filter with a value of 3.05%. At each engine rpm the torque value achieved by the engine with a 45 micron air filter is almost always above the engine with a standard air filter, except after passing 5600 rpm the engine torque value with a 45 micron air filter decreases significantly. Both engine torques reach their maximum point when the engine rotates at a speed of 4000rpm, the torque value of the engine with a 45 micron air filter is 142.3 Nm while the engine with a standard air filter is 139.5 Nm, meaning the engine torque is at 4000rpm with an air filter of 45 microns 2% greater compared to engines with standard air filters. The author's hypothesis, with an air filter density of 45 microns which is more tenuous than a standard air filter, causes an increase in engine torque due to more air entering so that combustion is more complete. The graph of the engine torque test with a standard air filter and 45 microns is in accordance with the Performance Engine Curve theory, which forms a linear line that increases with increasing rpm and forms a slight downward curve.

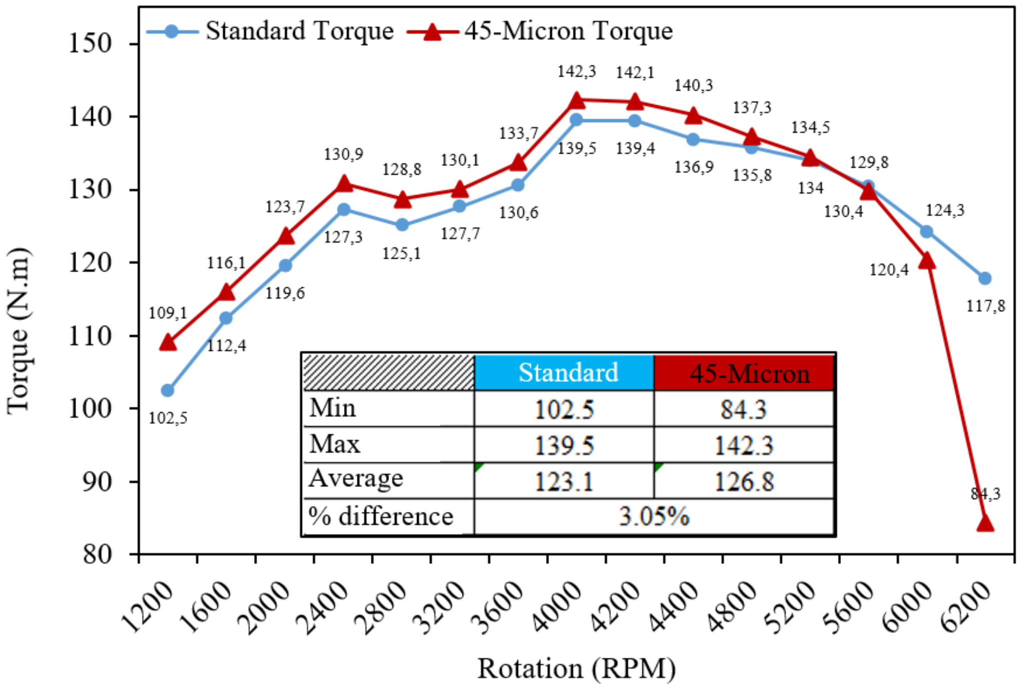


Figure 3. Engine Torque Comparison Chart from Standard vs 45 Micron Air Filters

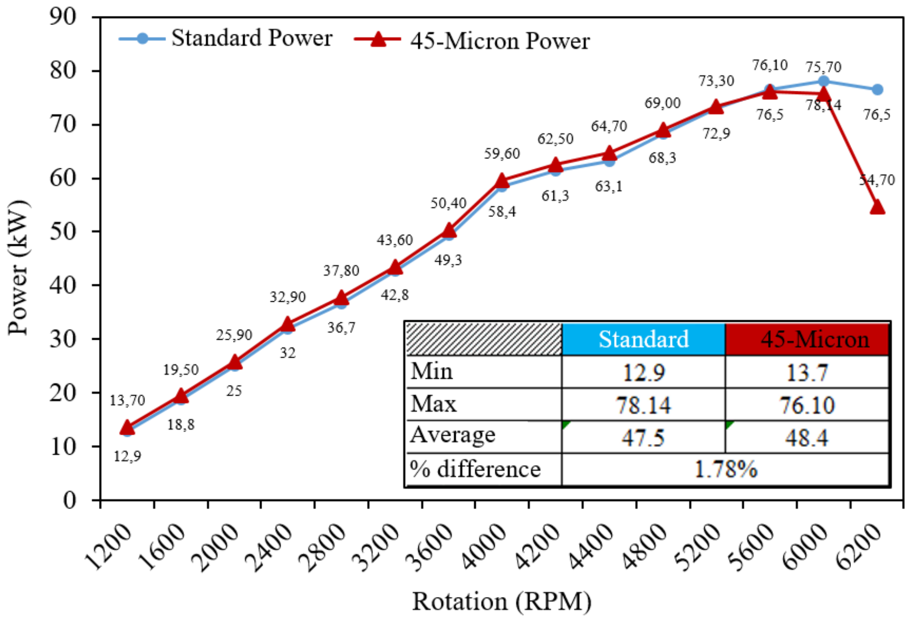


Figure 4. Engine Power Comparison Chart from Standard vs 45 Micron Air Filters

As seen in Figure 4, the average percentage of engine power with a 45 micron air filter is slightly higher than a standard air filter with a value of 1.78%. At each rpm of the engine the shaft power value achieved by the engine with an air filter of 45 microns is almost always above the engine with a standard air filter, except after passing through rpm of 5600 the value of the shaft power of the engine with an air filter of 45 microns begins to decrease slowly, even after rpm of 6000 it decreases significantly. The engine shaft power with a 45 micron air filter reaches its maximum point when the engine rotates at a speed of 5600rpm with a value of 76.1 kW, while the engine shaft power with a standard air filter reaches its maximum point when the engine rotates at a speed of 6000rpm with a value of 78.14 kW. The author's hypothesis, with an air filter density of 45 microns which is more tenuous than a standard air filter, causes an increase in engine power because the air enters more smoothly so that combustion is more complete.

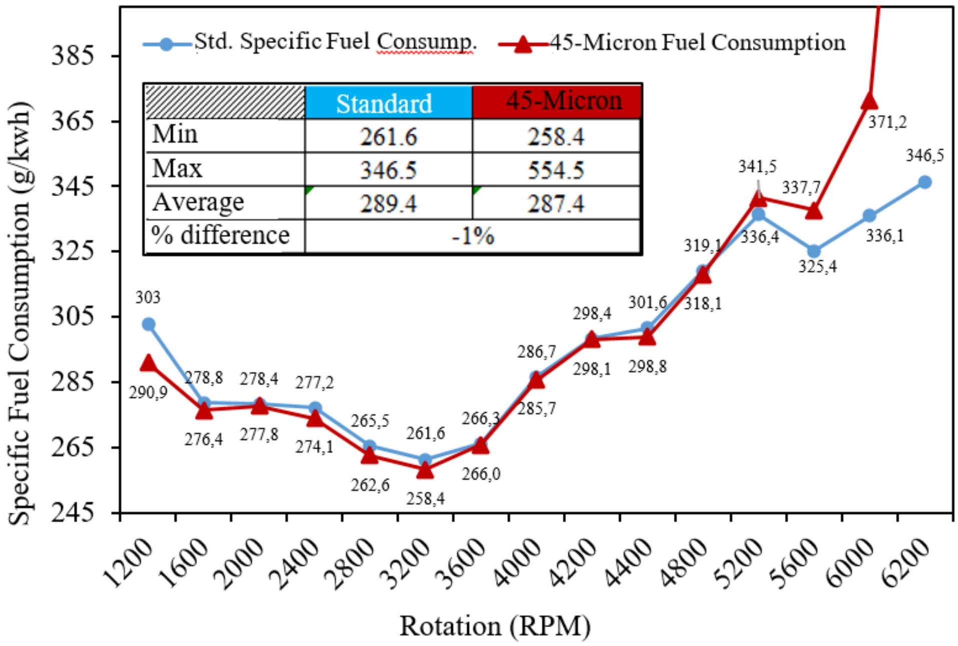


Figure 5. Engine Fuel Consumption Comparison Chart from Standard vs 45 Micron Air Filters

As seen in Figure 5, the percentage of engine fuel consumption with an air filter of 45 microns is slightly more efficient than a standard air filter with a value of 1%. At each engine rpm the specific fuel consumption value achieved by an engine with a 45 micron air filter is almost always below that of an engine with a standard air filter, except after passing 4800 rpm the engine specific fuel consumption value with an air filter of 45 microns begins to rise slowly, even after 6000 rpm rose significantly. Both engine-specific fuel consumption reaches the most efficient point when the engine rotates at a speed of 3200rpm, the value of engine-specific fuel consumption with a 45 micron air filter is 258.4 g/kWh while the engine with a standard air filter is 261.6 g/kWh. , meaning that the specific fuel consumption of the engine at 3200rpm with a 45 micron air filter is 1.2% more efficient than the engine with a standard air filter. The author's hypothesis, with an air filter density of 45 microns which is more tenuous than a standard air filter, causes fuel consumption to be more efficient because the incoming air is smoother so that combustion is more complete.

3.2 Calculation of Test Results

From the data generated by the dynamometer test, we can perform calculations and perform analysis to compare the results of engine testing with standard air filters and engines with 45 micron air filters.

a. Calculation of Mean Effective Pressure

The mean effective pressure is defined as the effective pressure of the working fluid against the piston along its stroke to produce work per cycle. This mean effective pressure is needed to further calculate the piston power. The following is an example of calculating the average effective pressure (Pe) of an engine with a standard air filter at 1200 RPM using equation 4.

$$P_e = 2\pi n_c \frac{T}{V_d} \text{ (Pa)} \tag{4}$$

$$P_e = 2\pi(2)\frac{102{,}5}{1497 \times 10^{-6}}$$

$$P_e = 860.77 \text{ (kPa)}$$

Which are:

P_e = Mean effective pressure (Pa)

n_c = Steps per revolution (4 stroke machine, n_c= 2)

T = Torque (N.m)

V_d = Total step volume (m^3) → 1500cc machine = 1497 x 10^{-6} m^3

The results of the calculation of the average effective pressure then obtained graphic data from the machine using a standard air filter and a 45 micron air filter as shown in Figure 6.

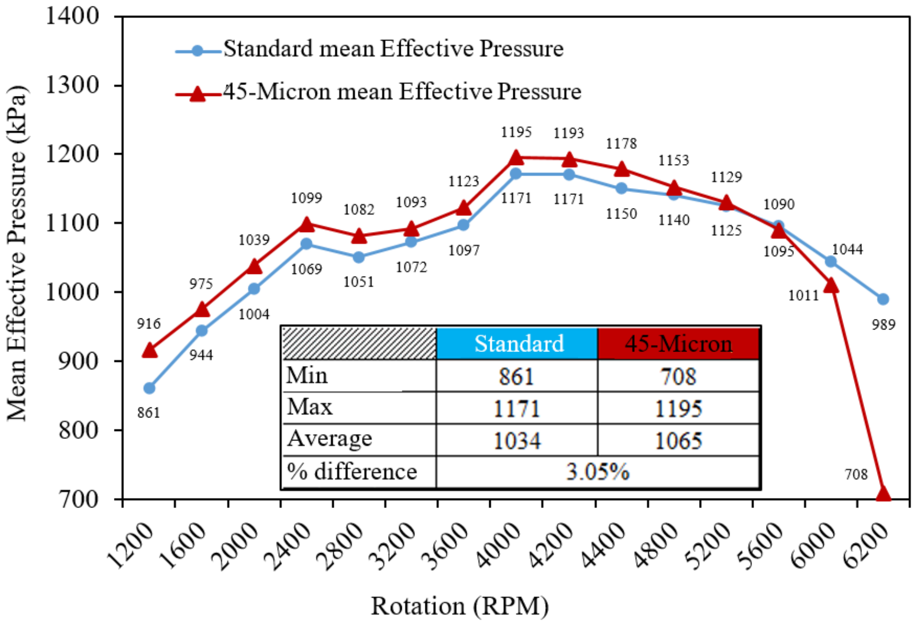


Figure 6. Engine Mean Effective Pressure Chart from Standard vs 45 Micron Air Filters

b. Calculation of Indicated Power (Piston's Power)

Piston power or indicated power is the power that arises in a flat combustion chamber received by the piston. This piston power is needed to further calculate the mechanical efficiency. The following is an example of calculating the piston power of an engine with a standard air filter at 1200 RPM using equation (2).

$$N_{piston} = \frac{P_e \text{ x } V_d \text{ x } RPM}{60} \text{ (Watt)} \quad (2)$$

$$N_{piston} = \frac{860.77 \text{ x } 1497 \text{ x } 10^{-6} \text{ x } 1200}{60}$$

$$N_{piston} = 25 \text{ (Watt)}$$

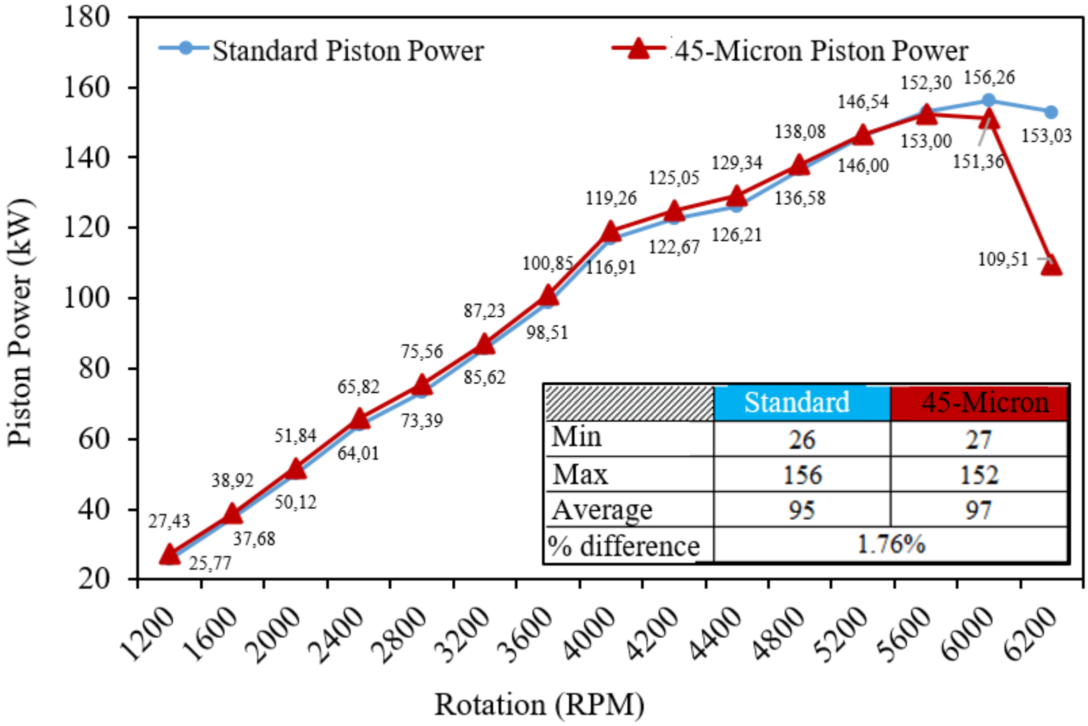
Which are:

P_e = Mean effective pressure (Pa)

RPM = Rotation per minute

V_d = Total step volume (m^3), 1500cc machine = 1497 x 10^{-6} m^3

The results the calculation of the piston power (indicated power), the graph data obtained from the engine using a standard air filter and a 45 micron air filter as shown in Figure 7.



	Standard	45-Micron
Min	26	27
Max	156	152
Average	95	97
% difference	1.76%	

Figure 7. Piston Power (Indicated Power) Calculation Results Graph

c. Calculation of Mechanical Efficiency (η_m)

Mechanical efficiency states the ratio between the shaft power produced and the fuel power required for a certain period of time. The following is an example of calculating the mechanical efficiency (η_m) of an engine with a standard air filter at 1200 RPM using equation (5).

$$\mu_m = \frac{N_{shaft}}{N_{piston}} \tag{5}$$

$$\mu_m = \frac{12.9}{25.77}$$

$$\mu_m = 50.06\%$$

Which are:

N_{shaft} = Shaft power which is read by dynamometer (Watt)

N_{piston} = Piston power which is calculated on by equation 2 (Watt)

The results the calculation of the mechanical efficiency, the graph data obtained from the engine using a standard air filter and a 45 micron air filter as shown in Figure 8.

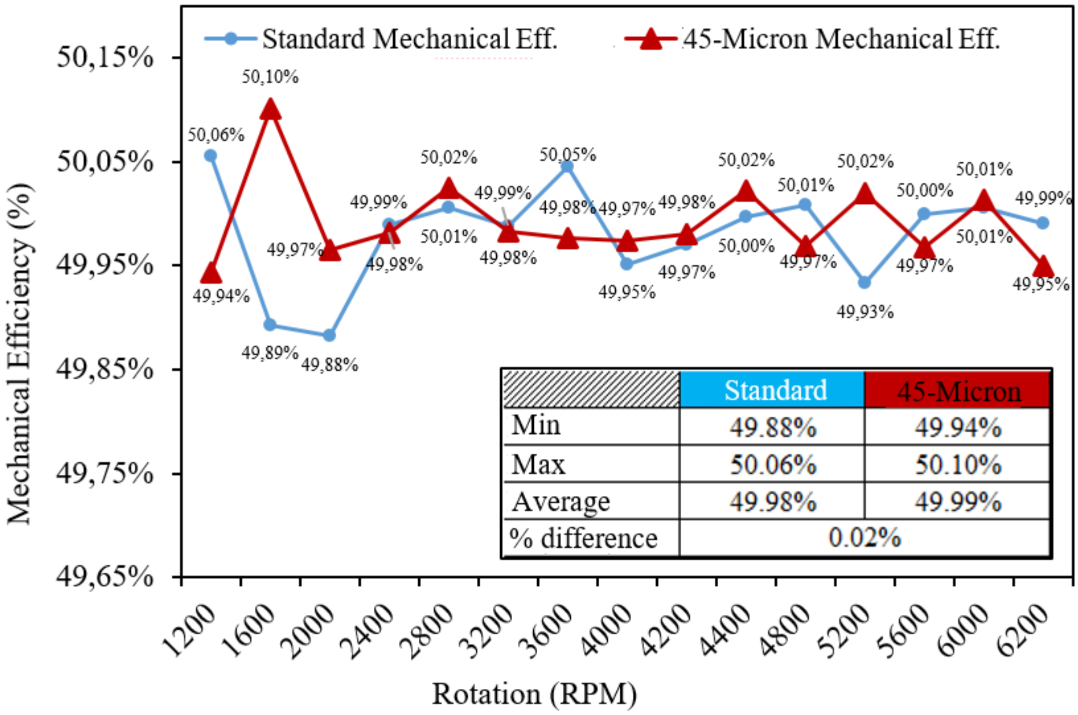


Figure 8. Mechanical Efficiency Calculation Results Graph

As a result, overall engine performance is increased by using a 45 micron air filter compared to using a standard air filter. The author's hypothesis regarding this is because the 45 micron air filter is more tenuous than the standard type (25 micron) air filter, so that more air intake or air enters the combustion chamber every 1 combustion. This causes more complete combustion to increase engine performance.

4. Conclusions

Based on the results of the research entitled Analysis of the Effect of 45 Micron Air Filter on the Performance of a 1500cc Matic Car Engine Using Test Data of a Dynamometer Tool, we can summarize that torque on the car engine increased by 3.05%, power on the car engine increased by 1.78%, the specific fuel consumption of the car engine is 1% more efficient, the mechanical efficiency of the car engine is increased by 0.02%. The performance of a car engine using a 45 micron racing air filter is indeed higher than the performance of a car engine using a factory standard air filter. However, this increase is not significant, it is even proven that the mechanical efficiency of the car engine only increases by 0.02%.

Acknowledgments

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