Indonesian Journal of Advanced Research (IJAR)
Vol. 3, No. 7, 2024: 1127 – 1140

Improving the Performance of a 4-Stroke Motorcycle with Variation Diameter and Mass Piston

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A R T I C L E I N F O

Keywords: Motorcycles, Diameter, Mass, Piston, Performance

Received : 5, May
Revised : 28, June
Accepted: 25, July

A B S T R A C T

The purpose of this study was to determine the effect of variations in piston diameter and piston mass on the performance of a 4-stroke motorcycle. The method used is an experimental method with a quantitative approach. Data collection was carried out using the dynotest method, burret and stopwatch. The samples of this study are 3 types of pistons with different diameters where the piston mass varies to test the performance of a 4-stroke motorcycle including Torque, SFC (Specific Fuel Consumption) and BMEP (Break Mean Effective Pressure). The results of this study show that the p-value of the variation of piston diameter and mass is smaller than alpha p-value < alpha (0.05) which indicates that the variation of piston diameter and mass affects the performance of 4-stroke motorcycles.

DOI prefik: https://doi.org/10.55927/ijar.v3i7.9914
ISSN-E: 2986-0768
https://journal.formosapublisher.org/index.php/ijar

INTRODUCTION

Technological development continues to advance and does not lag behind in the field of transportation technology, both in personal vehicles and in transportation vehicles. In our beloved country, one of the most popular vehicles is a motorcycle. Motorcycles themselves are a type of vehicle that has developed and grown very quickly. Nowadays, vehicles definitely have the latest versions and models in their development, not to mention spare parts that have been modified to become developments in the automotive industry, especially motorcycles. Modifications to vehicles have several goals, one of which is to improve the performance of the motorcycle than before (Jatnika & Mudasir, 2021).

Currently, many modifications are made to motorcycles, one of the most common and well-known is the change in diameter and weight of the piston. Studies on changes in piston diameter and piston weight have been done for several reasons, the first of which was to improve vehicle performance by reducing compression pressure in the combustion chamber (Prianda & Syofii, 2018). (Prianda & Syofii, 2018)cylinder block, which creates a gap between the piston and the cylinder and causes the motorcycle's compression to leak (Hariyadi & Maftukhin, 2016). If there is wear and tear in the inner diameter of the cylinder block, this part needs to be enlarged or restored to its original state. And if the inner diameter of the cylinder block is increased, automatically the piston diameter also needs to be increased according to the increased inner diameter of the cylinder block

Of the numerous studies that have been conducted before, this has never been investigated on a 4-stroke motorcycle engine. with variations in oversized piston diameters of 0.25 mm and 0.75 mm and combined with piston weight, so researchers will conduct further research under the title ***"Improving the performance of 4-stroke motorcycle with variaton diameter and mass piston".***

LITERATURE REVIEW

Combustion engine

An internal combustion engine is a type of heat engine that converts thermal energy into mechanical energy. Mechanical energy is obtained through the combustion that takes place in the combustion chamber. This produces mechanical energy in the form of translational motion of the piston (connecting rods), which is then converted into rotational motion of the crankshaft, which is transmitted to the transmission system and then to the drive wheels. Mechanical energy is obtained through the combustion process in the combustion chamber (Ghaly & Winoko, 2019).

Pistons

The piston is part of an engine component that moves back and forth to transfer the force of the expanding gas in the cylinder to the crankshaft via the piston rod and connecting rod (Nurfaiz et al., 2023)

Torque

Torque or twisting torque is the work produced by the movement of the crankshaft as a result of the movement of the piston in the power stroke. The pressure of the combustion process creates a force on the piston surface so that the piston moves from top dead center to bottom dead center (Jatnika & Mudasir, 2021). The formula to calculate torque is as follows (Pratama, n.d.) :

$$\mathbf{T} = \frac{2.\pi.n}{60.000\ .\ \mathrm{Ne}} \ldots\ldots\ldots\ldots\ldots (1)$$

Information :

Ne	:	Power (kW)	N	:	Engine Rotation (Rpm)
T	:	Torque (Nm)	Π	:	Phi (22,7 / 3,14)

According to (Milano et al., 2019) increasing the piston diameter and changing the piston weight increases the frictional force between the piston and the cylinder wall, so that a higher torque is required to compensate.

H1: Differences in piston diameter and mass affect the torque.

Power

Power is the ability of an internal combustion engine to produce energy by converting thermal energy into rotational energy (Muchlisinalahuddin et al., 2022). The formula for calculating power is as follows (Wijayanti & Irwan, 2014) :

$$\mathbf{Ne} = \frac{2.\pi.n.T}{60.000} \ldots\ldots\ldots\ldots\ldots (2)$$

Information :

Ne	:	Power (kW)	N	:	Putaran mesin (Rpm)
T	:	Torque (Nm)	Π	:	Phi (22,7 / 3,14)

Spesific Fuel Consumption

Spesific Fuel consumption is an engine operating parameter that indicates the mass of fuel required by the engine per unit of time (Kusmanto & Winoko, 2019). The following formula to calculate SFC is (Priatama et al., 2020) :

$$\mathbf{Sfc} = \frac{mf}{Ne} \ldots\ldots\ldots\ldots\ldots (3)$$

Keterangan **:**

Sfc	:	Spesific Fuel Consumption (Kg/HP.Jam)
Mf	:	Flow Rate (Kg.Jam)
Ne	:	Power (HP)

According to (Kumala et al., 2018) increasing the piston diameter increases the compression ratio, which in turn increases the thermal efficiency and reduces fuel consumption. In addition, different piston mass affects the inertia of the crankshaft mechanism, which in turn affects the consumption of the supplied fuel.

H2: Variations in piston diameter and mass affect the SFC.

BMEP (Break Mean Effective Pressure)

BMEP (*Brake Mean Effective Pressure*) is a constant pressure exerted on the piston during the power stroke, capable of producing a net work in each cycle that corresponds to the actual conditions (Agus Winoko & Syahirin, 2021). The following formula to determine BMEP is as follows (Winoko & Wijaya, 2023) :

$$\textbf{BMEP} : \frac{Bhp.\ z}{A.\ L.n.\ i} \ldots\ldots\ldots\ldots\ldots \ (4)$$

Keterangan :

Bhp	:	kW	L	:	Stroke (m)
BMEP	:	Kpa	n	:	Engine rotation (rpm)
A	:	Cross sectional area (m^2)	i	:	Number of pistons
Z	:	Number of crankshaft revolutions, for 4 stroke : 2 and 2 stroke : 1			

The BMEP or average pressure can increase with changes in engine volume. According to (Susilo et al., 2020) when the piston diameter increases, the stroke volume increases and the stroke volume then tends to increase the BMEP. Apart from that, changes in piston mass also generate higher pressure through the stroke force, which can increase the BMEP.

H3: Variations in piston diameter and mass affect the BMEP.

Conceptual Framework

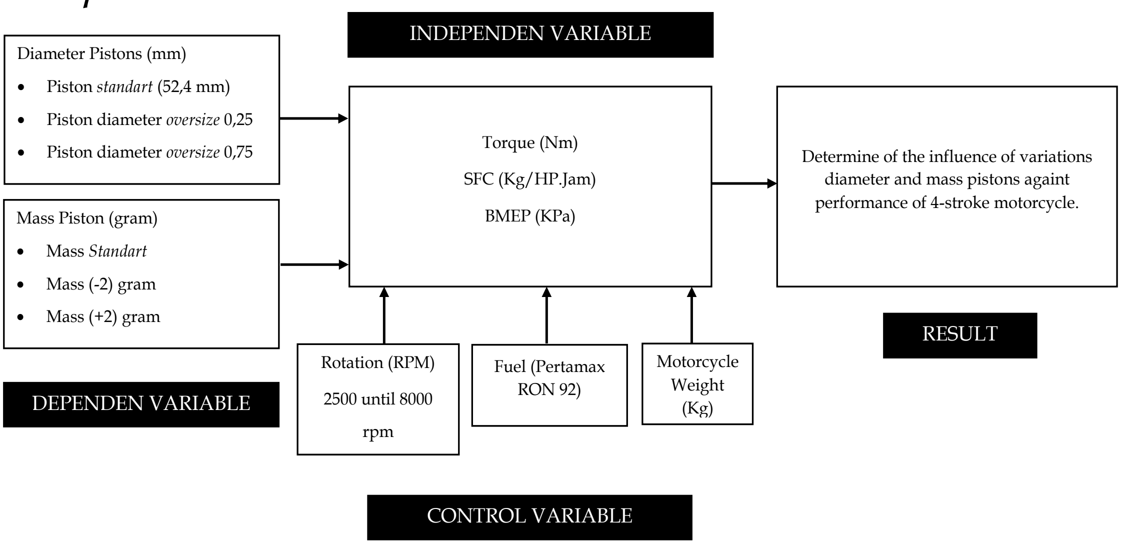

Figure 1. Conceptual Framework

METHODOLOGY

This investigation was conducted at 57 Mapant Garage, Madiun and Nabata Racing Craft, Magetan. This investigation was conducted from February to April 2024 .

The method used is the experimental method. Experiments were carried out by varying the size of the piston diameter with the determined piston weight to determine the effects on the engine performance including torque, specific fuel consumption (SFC) and BMEP (Brake Mean Effective Pressure). Experiments were carried out with variations of the standard piston diameter of 52.4 mm, oversized piston diameters 0.25 mm (52.65 mm), oversize piston diameter 0.75 mm (53.15 mm) with standard piston mass, mass (-2) and (+2) grams using a Dynotest tool to test performance and using a burret and stop watch to test fuel consumption. The analysis method used was a *Two-Way Anova* using *Ms.Excel* application to test the hypothesis put forward.

In analyzing the tested data, the following steps are followed: The data resulting from the average test results for each type of piston are converted into tabular form. Then, the tabular data are converted into graphical form in MS Excel software. Then, the data processed into graphs are analyzed using *Two Way Anova Ms. Excel* method, with systematic explanations in simple sentences that are easy to understand and read.

RESEARCH RESULTS

In this study, the total number or number of pairs of variations of the independent variables, namely the variables diameter and piston weight, was 9 variations. The results of the nine variations are shown in tabular form for each dependent variable. After that, the table is converted into a graph of the relationship between the independent variable and the dependent variable. And after that, the results from the table are analyzed using the *Two Way Anova* method Ms.Excel to determine whether there is an influence of the independent variable on the dependent variable or not.

Table 1. Table of Torque Test Results

Torque Test Results (Nm)									
Engine Rotation (RPM)	Diameter *Standart*			Diameter *Oversize* 0,25			Diameter *Oversize* 0,75		
	110 gram	108 gram	106 gram	110 gram	108 gram	106 gram	110 gram	108 gram	106 gram
2500	6,47	7,07	7,96	7,45	7,92	7,98	8,71	8,82	9,58
3000	8,77	9,13	9,62	9,9	10,23	10,34	11,14	11,34	11,94
3500	9,5	9,78	10,03	10,67	10,97	11,1	11,85	12,11	12,62
4000	9,44	9,74	9,94	10,69	10,97	11,21	11,92	12,12	12,57
4500	9,29	9,6	9,78	10,59	10,82	11,05	11,88	12,01	12,48
5000	9,32	9,46	9,66	10,5	10,7	10,93	11,84	11,89	12,36
5500	9,17	9,29	9,51	10,36	10,53	10,73	11,68	11,69	12,14
6000	8,93	9,02	9,23	10,1	10,26	10,43	11,36	11,39	11,77
6500	8,61	8,64	8,82	9,69	9,84	10	10,87	10,95	11,26

7000	8,17	8,16	8,22	9,16	9,28	9,41	10,27	10,36	10,59
7500	7,59	7,6	7,63	8,51	8,57	8,66	9,58	9,63	9,76
8000	6,88	6,93	6,88	7,73	7,78	7,79	8,79	8,77	8,81

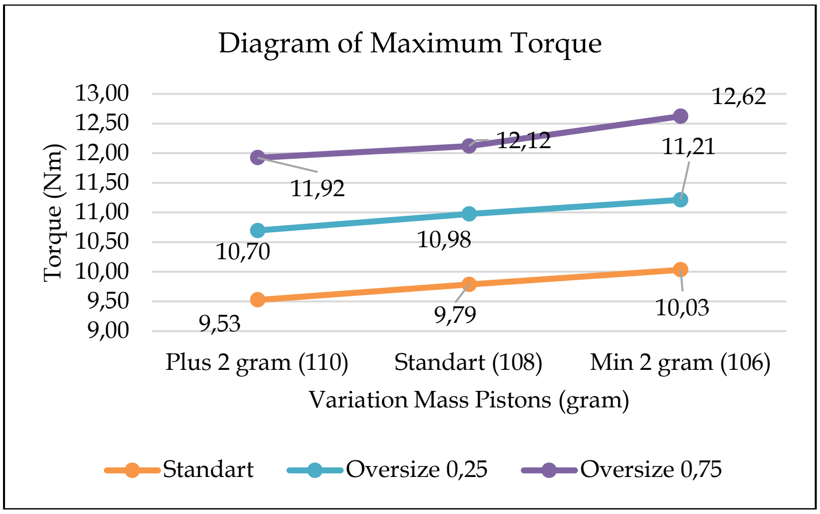

Figure 2. Diagram of Maximum Torque

It can be seen that starting from the standard piston diameter (52.4), without adding or subtracting the piston mass (108), the maximum torque is obtained at 9.78 Nm at 35,000 rpm, then if the piston mass is increased by 2 grams (110), the maximum torque is obtained at 9.525 Nm at 3500 rpm and if the piston mass is decreased by 2 grams (106), the maximum torque is obtained at 10.03 Nm at 3500 rpm.

Oversized piston diameter of 0.25 (52.65), if you do not add or subtract the piston mass (108) you get the highest torque at 10.97 Nm at 4000 rpm, then if you add 2 grams to the piston mass (110) you get the highest torque at 10.69 Nm at 4000 rpm and if you reduce the piston mass by 2 grams (106) you get the highest torque at 11.21 Nm at 4000 rpm.

Third, with an oversized piston diameter of 0.75 (53.15), you get the highest torque at 12.12 Nm at 4000 rpm if you do not add or subtract the piston mass (108), the highest torque at 11.92 Nm at 4000 rpm if you then add 2 grams to the piston weight (110), and the highest torque at 12.62 Nm at 3500 rpm if you reduce the piston mass by 2 grams (106).

Table 2. Table of Two-Way Anova Torque

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Diameter	707,346	2	20,2098	162,1628	0,00000	1,4778
Mass	10,2601	2	5,13009	41,16352	0,00000	3,0376
Interaction	13,2923	4	0,18989	1,523672	0,01168	1,3585
Within	26,9194	99	0,12462			
Total	757,818	107				

In the table of the two-way anova test it can be seen that for diameter variations the value of F (162.16282) is greater than the F-crit value (1.47781) with a *p*- value < alpha (0.05), namely 0.00000. And for mass variations the value of F (41.163522) is greater than the F-crit value (3.03766) with a *p*-value < alpha (0.05), namely 0.00000.

Table 3. Table of SFC Test Results

SFC Test Results (Kg/hp.hour)									
Engine Rotation (RPM)	Diameter *Standart*			Diameter *Oversize* 0,25			Diameter *Oversize* 0,75		
	110 gram	108 gram	106 gram	110 gram	108 gram	106 gram	110 gram	108 gram	106 gram
2500	0,0075	0,0063	0,0049	0,0111	0,0087	0,0083	0,0142	0,0129	0,0109
3000	0,0054	0,0045	0,0038	0,0080	0,0062	0,0057	0,0100	0,0090	0,0080
3500	0,0047	0,0040	0,0037	0,0054	0,0055	0,0048	0,0086	0,0078	0,0069
4000	0,0047	0,0041	0,0038	0,0065	0,0053	0,0044	0,0079	0,0073	0,0066
4500	0,0046	0,0041	0,0038	0,0068	0,0052	0,0043	0,0076	0,0071	0,0063
5000	0,0045	0,0042	0,0039	0,0066	0,0051	0,0042	0,0073	0,0068	0,0061
5500	0,0046	0,0043	0,0041	0,0064	0,0051	0,0045	0,0070	0,0067	0,0060
6000	0,0049	0,0045	0,0042	0,0063	0,0053	0,0046	0,0070	0,0066	0,0061
6500	0,0051	0,0046	0,0043	0,0063	0,0054	0,0049	0,0071	0,0066	0,0062
7000	0,0053	0,0049	0,0046	0,0065	0,0058	0,0054	0,0073	0,0069	0,0064
7500	0,0056	0,0051	0,0049	0,0067	0,0062	0,0059	0,0077	0,0072	0,0068
8000	0,0061	0,0056	0,0054	0,0073	0,0068	0,0064	0,0082	0,0077	0,0073

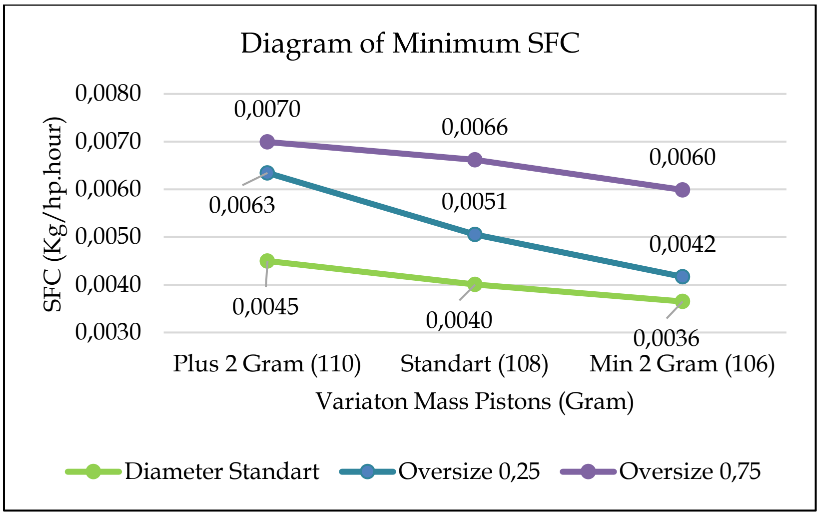

Figure 3. Diagram of Minimum SFC

SFC (*Spesific Fuel Consumption*) test results for each engine revolution for each variable variation from 2500 rpm to 8000 rpm. Starting from the standard piston diameter (52.4) you get the lowest SFC (*specific fuel consumption*) of 0.0040 kg/hp.hour at 3500 rpm if you do not add or subtract the piston mass (108), and if you increase the piston mass by 2 grams (110) you get the lowest SFC (*specific* *fuel consumption*) of 0.0045 Kg/hp.hour at 5000 rpm and if you reduce the piston mass by 2 grams (106) you get the lowest SFC (*Specific Fuel Consumption*) of 0.0036 Kg/hp.hour at 3500 rpm.

Oversized piston diameter of 0.25 (52.65), without adding or removing the piston mass (108) you get the lowest SFC (*Specific Fuel Consumption*) of 0.0051 Kg/hp.hour at 5500 rpm, then if you increase the piston mass by 2 grams (110) you get the lowest SFC (*Specific Fuel Consumption*) at 0.0063 Kg/hp.hour at 6000 rpm and if you reduce the piston mass by 2 grams (106) you get the lowest SFC (*specific fuel consumption*) of 0.0042 Kg/hp.hour at 5000 rpm.

Thirdly, with an oversized piston diameter of 0.75 (53.15), if you do not add or subtract the piston mass (108), you get the lowest SFC (*Specific Fuel Consumption*) of 0.0066 Kg/hp.hour at 6000 rpm, then if you add 2 grams (110) of piston mass you get the lowest SFC (*Specific Fuel Consumption*) at 0.0070 Kg/hp.hour at 6000 rpm and if you reduce the mass a piston of 2 grams (106) gets the lowest SFC (*Specific Fuel Consumption*) at 0.0060 Kg/hp.hour at 5500 rpm.

Table 4. Table of Two-Way Anova SFC

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Diameter	0,00016	2	7,8E-05	46,175	0,00000	3,0882
Mass	0,00003	2	1,6E-05	9,8393	0,00012	3,0882
Interaction	0,00000	4	5,5E-07	0,3302	0,85709	2,4635
Within	0,00017	99	1,6E-06			
Total	0,00036	107				

In the table of the Two-Way Anova test, it can be seen that for diameter, the value of F (46.1754) is greater than the F-crit value (3.0882) with a *p*- value < alpha (0.05), namely 0.00000. And for mass, the value of F (9.8393) is greater than the F-crit value (3.0882) with a *p*- value < alpha (0.05), namely 0.00012.

Table 5. Table of BMEP Test Results

Hasil Pengujian BMEP (KPa)									
Engine Rotation (RPM)	Diameter *Standart*			Diameter *Oversize* 0,25			Diameter *Oversize* 0,75		
	110 gram	108 gram	106 gram	110 gram	108 gram	106 gram	110 gram	108 gram	106 gram
2500	651,5	711,5	801,1	743,0	790,2	795,8	852,0	862,8	937,1
3000	883,3	919,5	968,5	987,2	1019,8	1031,1	1090,1	1109,9	1168,6
3500	958,6	984,9	1009	1063,7	1093,9	1106,9	1159,2	1184,9	1234,8
4000	950,1	980,6	1000	1066,3	1094,2	1117,8	1166,4	1185,6	1230,3
4500	935,0	966,2	984,9	1056,0	1079,3	1102,2	1162,8	1174,8	1221,3
5000	938,7	952,1	972,9	1047,2	1066,7	1089,6	1158,2	1163,4	1209,1
5500	923,2	935,3	957,1	1033,1	1050,4	1070,0	1143,2	1144,2	1187,9
6000	899,4	908,1	929,3	1006,9	1023,1	1040,4	1111,6	1114,2	1151,7
6500	867,2	869,5	887,7	966,3	980,9	997,2	1064,0	1071,1	1101,5

7000	822,2	821,6	827,9	913,8	925,4	938,7	1005,3	1014,1	1036,6
7500	764,5	764,9	768,6	849,0	854,7	863,6	937,1	942,0	955,4
8000	692,4	698,1	693,1	771,3	776,2	776,9	859,9	858,2	862,1

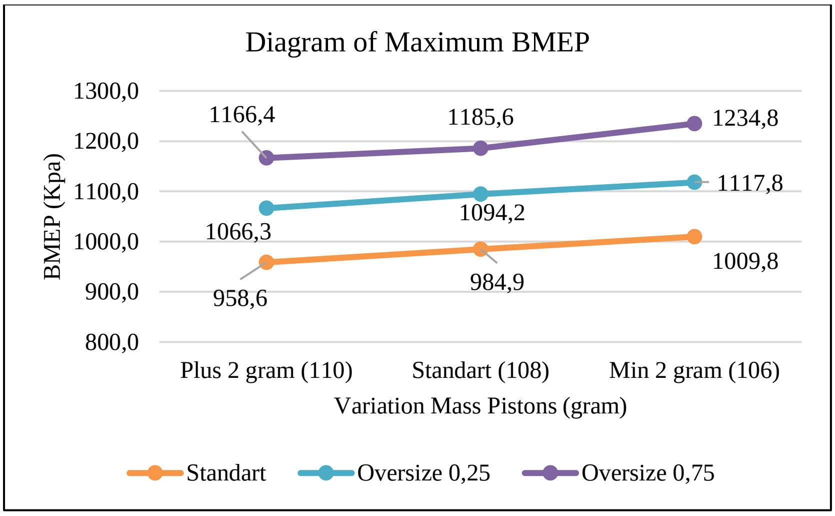

Figure 4. Diagram of Maximum BMEP

The BMEP *(Break Mean Effective Pressure)* test results for each engine revolution for each variable variation from 2500 rpm to 8000 rpm. Starting from the standard piston diameter (52.4) you get the highest BMEP *(Break Mean Effective Pressure)* at 984.9 KPa at 3500 rpm, if you do not add or subtract any piston mass (108) you get the highest BMEP *(Break Mean Effective Pressure)* at 958.6 KPa at 3500 rpm, if you then add 2 grams to the piston mass (110) you get the highest BMEP *(Break Mean Effective Pressure)* at 1009.7 KPa at around 3500 rpm and if the piston mass is reduced by 2 grams (106).

An *oversized* piston diameter of 0.25 (52.65) results in the highest BMEP *(Break Mean Effective Pressure)* at 1094.2 KPa at 4000 rpm when no piston mass is added or subtracted (108) adding 2 grams of piston mass (110) results in the highest BMEP *(Break Mean Effective Pressure)* at 1066.3 KPa at 4000 rpm and reducing the piston mass by 2 grams (106) results in the highest BMEP *(Break Mean Effective Pressure)* at 1117.8 KPa at 4000 rpm.

Oversized piston diameter of 0.75 (53.15), if without adding or subtracting the piston mass (108) a BMEP *(Break Mean Effective Pressure)* is achieved at 1185.6 KPa at 4000 rpm, then if you add 2 grams of piston mass (110) you get the highest BMEP *(Break Mean Effective Pressure)* at 1166.4 KPa at 4000 rpm and if you reduce the piston mass by 2 grams (106) you get the highest BMEP *(Break Mean Effective Pressure)* at 1234.8 KPa at 3500 rpm.

Table 6. Table of Two-Way Anova BMEP

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Diameter	6062301,3	2	173208,60	472,5570	0,00000	1,47781
Mass	96210,235	2	48105,117	131,2429	0,00000	3,03766
Interaction	50643,488	4	723,47840	1,973832	0,00010	1,35853
Within	79171,513	99	366,53478			
Total	6288326,5	107				

From the above table with Two-Way Anova test, it is observed that for variations in piston diameter, value of F (472.5570) is greater than F-crit value (1.47781) with *p*-value < alpha (0.05), namely 0.00000. And for variations in piston mass, value of F (131.2429) is greater than F-crit value (3.03766) with *p*-value < alpha (0.05), namely 0.00000.

DISCUSSION

Torque

Of all the above piston diameter and weight variations, oversized piston diameter variations experience an increase in torque as compared to standard diameter variations even though the mass of the piston used is the same. This is because increasing the size or oversizing the piston causes the cross section of the piston to increase so the volume of the cylinder also increases which increases the compression ratio so the percentage of the perfect air-fuel mixture that enters the combustion chamber and is burned there also increases so the resulting explosion becomes larger. The larger it is, the more it increases the thrust force on the piston head and then accelerates the up and down motion of the piston which is connected to the connecting rod and crankshaft.

Moreover, in all the above mentioned variations in piston diameter and mass, when the piston mass is varied, it experiences additional mass, it results in a decrease in torque, whereas when the mass is reduced, the torque increases due to variations in the standard mass, even though the diameter of the piston used is the same. This is because when the weight is increased, the mass of the piston increases, which results in more inertia. When the inertia is large, more force is required to move it as it is from the resting state, which reduces the torque produced, whereas when the weight is reduced, the mass of the piston decreases, which also results in lesser inertia. When the inertia becomes less, the force produced during combustion is more and can produce more torque. Apart from this, when the piston weight is low, the frictional force is less, which helps minimize the energy loss in the form of heat, so there is enough energy available to produce the torque.

SFC (Specific Fuel Consumption)

It can be seen that oversized piston diameters lead to an increase in SFC (*Specific Fuel Consumption*) compared to the standard diameter variation , although the mass of the piston used is the same. This is because oversizing the piston leads to an increase in the piston cross section, so the cylinder volume also increases and, in accordance with the cylinder volume, more fuel enters the combustion chamber.

Moreover, for all the variations in piston diameter and mass listed above, for variations in piston mass, increase in weight will result in increase in SFC *(Specific Fuel Consumption)*, whereas for decrease in mass, SFC *(Specific Fuel Consumption*) will decrease due to variations in standard mass even if the piston diameter is different or same. This is because with added mass, the mass of the piston increases which increases the moment of inertia. When the moment of inertia increases, the energy required to move and stop the piston also increases and the higher the energy, the higher the fuel consumption required. On the other hand, when the mass is reduced, the mass of the piston decreases which results in decrease in moment of inertia. When the moment of inertia decreases, the energy required to move and stop the piston also becomes less and the less the energy, the less the fuel consumption required.

BMEP (Break Mean Effective Pressure)

Oversized piston diameter variations result in higher BMEP compared to standard diameter variations even though the mass of the piston used is the same. This is because increasing or oversizing the piston results in an increase in the piston cross-section, so the cylinder volume also increases and the compression ratio increases, which can lead to an increase in pressure and temperature. As pressure and temperature increase, a larger thrust force is generated during the power stroke. The larger piston and larger thrust force can produce a higher BMEP.

Furthermore, for all the variations in piston diameter and mass listed above, for variations in piston mass which experience an increase in mass, the BMEP will decrease, whereas for variations in the standard mass, the torque will increase even though the diameter of the piston used is the same. Because for an increase in mass, the mass of the piston also increases, resulting in greater inertia. With great inertia, more energy is required to move it as it is coming from rest, so the resulting BMEP will decrease, while for a reduction in mass, the mass of the piston will decrease, also resulting in lesser inertia. With lesser inertia, less energy is required during the power stroke, and more energy is produced from combustion, which can be harnessed during the power stroke to increase the BMEP.

Two-Way Anova

In the two-way anova test with an alpha value of 0.05, this value is the error value used, assuming that the alternative hypothesis is accepted if the P-value is less than 0.05 and the value of F is greater than F-crit, whereas the alternative hypothesis is rejected if the P-value is greater than 0.05 and the value of F is less than F-crit.

From the results of the obtained two-way ANOVA table, firstly, the results for torque show a value of F > F crit and *p*-value < alpha (0.05), so the requirements for accepting the alternative hypothesis or H1 are met, which means that variations in piston diameter and mass have an impact on torque.

Secondly, SFC shows that both piston diameter and mass show the results F > F crit and *p*-value < alpha (0.05), so the requirements for accepting the alternative hypothesis or H2 are met, which means that variations in piston diameter and mass have an impact on SFC. Thirdly, BMEP shows that both piston diameter and weight show the results F > F crit and *p*-value < alpha (0.05), so the requirements for accepting the alternative hypothesis or H3 are met, which means that variations in piston diameter and mass have an impact on BMEP.

CONCLUSSIONS

From the results obtained with reference to the standard diameter size and standard mass, it shows that the highest torque is obtained in the variation of *oversize* piston diameter 0.75 with piston mass reduced by 2 grams, which is up 2.84 Nm, then the SFC shows the lowest results obtained in the variation of standard piston diameter with piston mass reduced by 2 grams, which is down 0.0004 Kg/HP.Jam, and the BMEP shows the highest results obtained in the variation of *oversize* piston diameter 0.75 with piston mass reduced by 2 grams, which is up 249.9 KPa. This shows that the larger the *oversize* diameter and weight reduction of the piston carried out, the higher the torque and BMEP will be with the lower the SFC consumed. Conversely, if the smaller the diameter size and weight gain of the piston, the torque and BMEP will be lower with the SFC consumed also getting higher.

In the two-way anova test that has been carried out, it shows that both the results on torque, SFC and BMEP F value > F crit and the value of the p-value <0.05, so that these results have met the requirements of the Null Hypothesis (H0) is rejected and the Alternative Hypothesis is accepted. Therefore, the variation of piston diameter and mass affects the performance of a 4 stroke motorcycle which includes torque, SFC and BMEP.

RECOMMENDATIONS

Based on these studies, the following suggestions can be made:

1. Since any change or modification involves risks, the use of oversized diameters and changes in piston mass are not recommended for everyday use, as they have several disadvantages. Among them, although they can improve engine performance, they also cause the engine to knock or strike more quickly, resulting in losses for the user.
2. The use of pistons with an oversized diameter and mass is recommended when you want to improve performance, even for competitions or racing. In addition, it can be used as a solution to improve the condition of the engine due to excessive engine use.

ADVANCED RESEARCH

They carry out further investigations with oversized piston diameters above the variations mentioned above, as well as a series of reductions and increases in piston mass outside the sizes investigated, so that the results obtained are maximized.

ACKNOWLEDGMENT
The researchers would like to thank:
1. Fellow Bengkel 57 Mapant as a research location.
2. Nabata Racing Craft serves as a testing ground.
3. Friends from 4B Automotive Electronic Engineering, State Polytechnic of Malang who helped in completing this research.

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