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The Effect of Exhaust Manifold Diameter Variation on Engine Performance of 1300 cc Gasoline Engine

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A B S T R A C T

One of the critical components responsible for channeling combustion gases from the engine to the exhaust is the exhaust manifold. Changes in the configuration and diameter of the exhaust manifold have an impact on engine performance. This study aims to understand how changes in exhaust manifold configuration and diameter affect torque and BMEP in a 1300 cc gasoline engine through an experimental approach that includes quantitative research methods. The experiment utilized 4-2-1 configuration exhaust manifolds with diameters of 32, 35, and 38 mm. Data collection of torque and BMEP was done using a dynamometer which was then processed into a graph and analyzed using anova. The highest torque value of 1300 cc gasoline engine is found on exhaust manifold with 38 mm diameter variation with torque value of 108.06 Nm, and the highest BMEP value is 1046.18 kPa. It can be concluded that the larger the diameter of the exhaust manifold, the combustion airflow coming out of the engine becomes more optimal, smoother, and there is no back pressure on the engine.

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INTRODUCTION

In the automotive sector, improving engine performance is one of the main priorities in developing vehicle technology. The 1300 cc gasoline engine is one of the popular car engine variants in Indonesia, and has a significant role in meeting the transportation needs of the community. Engine performance in this car is a major concern in an effort to improve the overall quality of motorized vehicles. Optimal engine performance will ensure adequate fuel efficiency and thrust.

One component that can affect engine performance is the exhaust manifold. The exhaust manifold plays an important role in directing exhaust gases from the engine cylinders to the exhaust system. An optimal exhaust manifold configuration and diameter can improve the efficiency of exhaust gas removal from the engine, thus having a direct influence on engine performance.

The replacement of exhaust manifold configuration and diameter is expected to improve engine performance and is expected to determine the performance and quality of exhaust emissions when replacing the exhaust manifold configuration and diameter. The effect of replacing the exhaust manifold with an increase in engine power and torque, Understanding this is very important because it can help in the optimization process to improve the performance of the vehicle or engine produced. Optimization is finding the best conditions to get the best results. (Nasution & Suhadi, 2020). Therefore, it is necessary to conduct further research, in order to determine the effect of replacing the exhaust manifold.

The results of the research conducted are expected to provide further information or insight into the effect of replacing the exhaust manifold exhaust manifold configuration and diameter on a 1300 cc gasoline engine.

LITERATURE REVIEW

Fuel Motor

According to Asrianto (2018), a combustion motor is a variant of a drive engine that is popular and widely used. This machine functions by converting heat energy from the combustion process into mechanical energy. In a gasoline combustion engine, the combustion process occurs in the engine, where the combustion gas functions as a working fluid simultaneously.

Torque

Torque is a parameter that shows the ability of a machine to do work, a form of energy. Torque is calculated by multiplying the force by the distance (Mulyono, et al, 2014). To calculate the torque produced is formulated by the following equation:

$$\mathbf{T} = \frac{\boldsymbol{P} . \mathbf{60}}{\mathbf{2} . \pi . \boldsymbol{n}}$$

T = Torque / Nm
P = Power / Watt
n = Engine rotation / rpm

BMEP

BMEP (Brake Mean Effective Pressure) is a constant pressure that occurs on the piston during the working stroke which will produce net work every cycle which is the same as the actual conditions (Winoko, 2017). BMEP or average pressure can increase along with changes in engine volume. The BMEP formula is (Winoko, 2023):

$$\text{Bhp} : \frac{2.\pi.n.T}{1000} \text{ kW}$$

dan

$$\text{BMEP} : \frac{Bhp.\ z}{A.\ L.n.\ i} \text{ Kpa}$$

Description:
Bhp : kW
BMEP: KPa
L : Stroke length (m) n: Engine speed (rpm)
A : Cross-sectional area (m2) i: Number of pistons
Z : Number of crankshaft revolutions for 4 stroke: 2 and for 2 stroke: 1

Muffler or Exhaust System

The function of a muffler or exhaust system is not only limited to the diversion of residual combustion products. The muffler is also part of the exhaust step in the overall process. Inside the muffler, flow instability (turbulence) is maintained continuously. With the use of a muffler, the conversion of the turbulent exhaust gas flow produces a thrust force that pushes the piston towards the lowest position (TMB). Although the engine can operate without a muffler, the risk is high as it may generate minor turbulence. Once the fuel is burned, the turbulence vortex effect is broken as it is discharged too quickly through the exhaust port and will mix with the outside air. There are two variations of mufflers, namely the exhaust chamber used in standard mufflers, effective at low RPMs, and the free flow muffler that works on engines with high RPMs. The free flow exhaust releases exhaust gases quickly and reduces turbulence, so it is known as a free exhaust system, and is widely used in racing exhaust variants.

RON 92 Fuel

According to Winarno (2011), Pertamax, also known as RON 92 fuel, has been the main product of Pertamina since 1999. With an RON 92 (Research Octane Number), Pertamax is a type of fuel without added lead and is equipped with the latest additives designed to clean the combustion chamber and fuel injector port from carbon impurities. Recommended for gasoline vehicles with high compression ratios, Pertamax is one of the products of petroleum processing that has undergone various improvements by Pertamina to become one of the most environmentally friendly types of high-octane fuel. With the latest formulation using high-quality raw materials, Pertamax improves vehicle engine efficiency and performance, reduces the risk of engine knock, produces lower emissions, and saves fuel consumption. Pertamax is considered highly environmentally friendly with a minimum specific gravity of 715 kg/mL at 15 degrees Celsius.

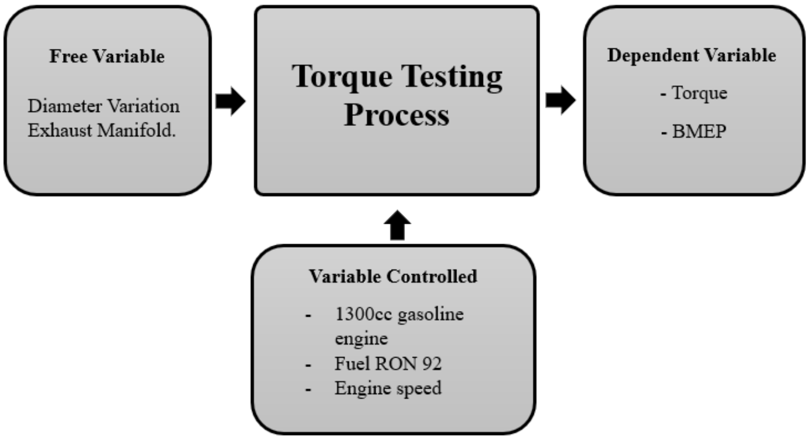


Image 1. Research Conceptual Framewor

METHODOLOGY

This research uses an experimental approach, which is a method of collecting data by observing the object of research directly during a certain period and systematically recording the things observed. The experimental method requires research conducted in the field because the necessary data is obtained through direct and careful observation. The data collected in this research is quantitative, in the form of numbers that will be recorded and collected for comparison and further analysis.

This research is a type of experimental research divided into three phases. The first phase is the preparation phase, which includes determining the configuration and diameter of the exhaust manifold and providing the necessary equipment and materials. The second phase is the testing of power, torque, and exhaust emission quality, which involves using a dynamometer and gas analysis. The third phase is the data analysis of the test results.

The data processing approach applied in this study involves the transformation of data derived from the average test results for each exhaust manifold category in tabular form into graphical form on Microsoft Excel software. After that, the data displayed on the graph will be analyzed using the comparative analysis method (specific comparative) and anova to determine the effect of the independent variable on the dependent variable. The hypothesis that can be formulated is that there is a difference in the replacement of exhaust manifold diameter variations on the performance and exhaust emissions of 1300 cc gasoline engines.

RESEARCH RESULTS

This test was conducted to determine the amount of torque (Nm), Brake Mean Effective Pressure / BMEP (kPa), and exhaust emissions affected by each of the specified variables. This research used a 1300 cc gasoline engine using a standard exhaust manifold and exhaust manifold diameter variations with pipe diameter variations of 32 mm, 35 mm, and 38 mm. This test was conducted with dynotest for 3 times, then the results were averaged. The results of testing torque (Nm), Brake Mean Effective Pressure / BMEP (kPa), and testing using a gas analyzer to determine exhaust emissions. The results of the research conducted are shown in the tables below.Table Testing Results

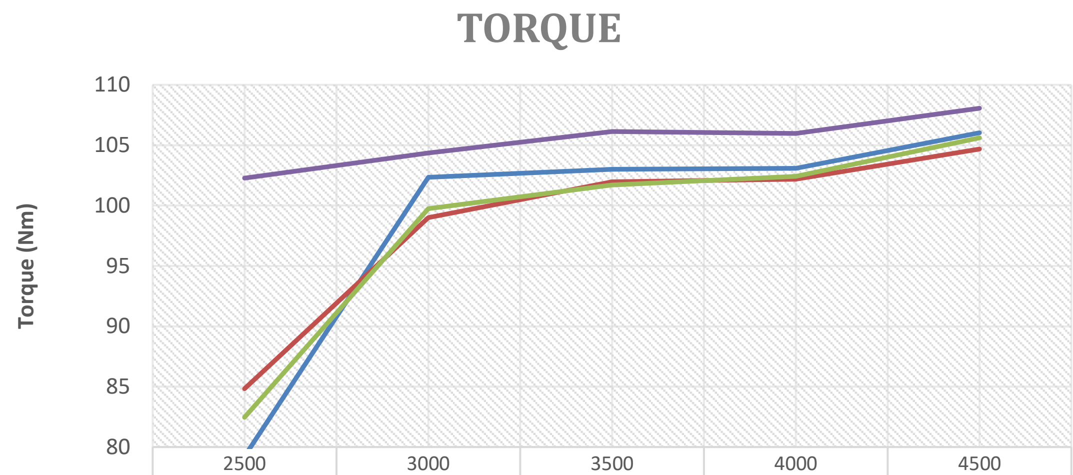
Day/Date : March 15, 2024 At : 13.30
Temperature : 29℃ Fuel : Ron 92

		Engine Rotation (Rpm)	Toque (Nm)			
			1	2	3	Average
DIAMETER *EXHAUST MANIFOLD*	standard / 30mm	1500	0	0	0	0
		2000	0	0	0	0
		2500	81,74	80,74	75,21	79,23
		3000	102,6	102,52	101,88	102,3333333
		3500	103,19	103,23	102,62	103,0133333
		4000	103,15	103,17	102,9	103,0733333
		4500	106,08	106,13	105,88	106,03
	32mm	1500	0	0	0	0
		2000	0	0	0	0
		2500	88,41	86,14	79,93	84,82666667
		3000	98,76	98,73	99,54	99,01
		3500	101,72	101,5	102,72	101,98
		4000	101,97	101,71	102,84	102,1733333
		4500	104,46	104,14	105,44	104,68
	35mm	1500	0	0	0	0
		2000	0	0	0	0
		2500	84,5	89,83	73,05	82,46
		3000	99,59	99,61	100	99,73333333
		3500	101,43	101,36	102,35	101,7133333
		4000	102,04	102,08	103,15	102,4233333
		4500	105,21	105,28	106,33	105,6066667
	38mm	1500	0	0	0	0
		2000	0	0	0	0
		2500	102,43	102,23	102,16	102,2733333
		3000	104,78	103,31	104,95	104,3466667
		3500	106,44	104,96	107	106,1333333
		4000	106,4	105,14	106,36	105,9666667
		4500	108,5	107,18	108,5	108,06

Table BMEP Calculation Result

		Engine Rotation (Rpm)	BMEP (kPa)			
			1	2	3	Average
DIAMETER *EXHAUST MANIFOLD*	standard / 30mm	1500	0	0	0	0
		2000	0	0	0	0
		2500	791,3549267	781,6735598	728,1356011	767,0546959
		3000	993,3082392	992,5337299	986,3376551	990,7265414
		3500	999,0202457	999,4075003	993,5018666	997,3098709
		4000	998,632991	998,8266183	996,2126493	997,8907529
		4500	1026,999396	1027,483464	1025,063123	1026,515328
	32mm	1500	0	0	0	0
		2000	0	0	0	0
		2500	855,9296436	833,9529408	773,8316526	821,238079
		3000	956,1317905	955,8413495	963,6832567	958,5521322
		3500	984,7886364	982,6587357	994,4700033	987,3057918
		4000	987,2089781	984,6918227	995,6317673	989,1775227
		4500	1011,315582	1008,217544	1020,803321	1013,445482
	35mm	1500	0	0	0	0
		2000	0	0	0	0
		2500	818,0754992	869,6771845	707,2238487	798,3255108
		3000	964,167325	964,3609523	968,1366854	965,5549876
		3500	981,98104	981,3033443	990,8878975	984,724094
		4000	987,8866738	988,2739285	998,632991	991,5978644
		4500	1018,576607	1019,254302	1029,419738	1022,416882
	38mm	1500	0	0	0	0
		2000	0	0	0	0
		2500	991,6624069	989,7261335	989,0484378	990,1456594
		3000	1014,413619	1000,18201	1016,059451	1010,21836
		3500	1030,484688	1016,156265	1035,906253	1027,515735
		4000	1030,097433	1017,898911	1029,710179	1025,902174
		4500	1050,428304	1037,648899	1050,428304	1046,168502

DISCUSSION



	2500	3000	3500	4000	4500
STD	79,23	102,3333333	103,0133333	103,0733333	106,03
32MM	84,82666667	99,01	101,98	102,1733333	104,68
35MM	82,46	99,73333333	101,7133333	102,4233333	105,6066667
38MM	102,2733333	104,3466667	106,1333333	105,9666667	108,06

RPM

Graphics Torque

Based on the results of the research that has been done, it is known that when the engine speed is 2500 the resulting torque is relatively low, because the engine condition has not produced maximum torque. After that the torque rises from 3000 rpm to 4500 rpm engine speed, because the engine condition can produce maximum torque.

The table and graph above show that the torque generated by the exhaust manifold with a diameter of 38 mm is compared to the exhaust manifold diameter of 35 mm, 32 mm, and standard diameter. The most power generated by the 38 mm exhaust manifold variation is at 4500 rpm. In this case, the exhaust manifold with a diameter of 38 mm produces a torque of 108.06 N.m. Then, followed by the 35 mm diameter variation produces a torque of 105.6 N.m, the 32 mm diameter variation produces a torque of 104.68 N.m, and the standard exhaust manifold with a resulting torque of 106.2 N.m.

The resulting torque is the highest value difference between the exhaust manifold diameter 38 mm with a standard exhaust manifold with a difference in torque increase of 2 N.m. In the standard exhaust manifold with exhaust manifold diameter 35 mm there is a decrease in torque of 1 Hp, and in the standard exhaust manifold with exhaust manifold diameter 32 mm there is a decrease in torque of 2.2 Hp.

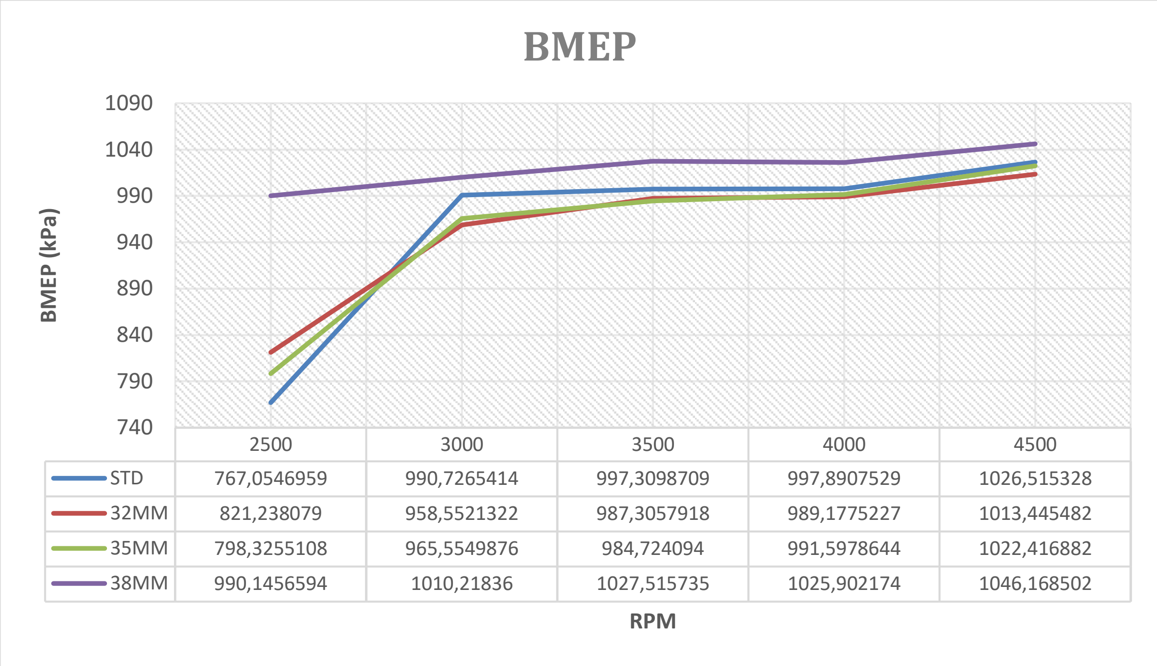
The exhaust manifold with a diameter of 38 mm has a torque with a greater value due to more optimal exhaust gas flow due to a wider miner area, and reduced back pressure towards the combustion chamber due to the absence of a catalyst in the exhaust manifold.

ANOVA

Source of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
RPM	174992,1	6	29165,35	7350,658	3,35652E-79	2,265567
d-Ex Manif	372,6168	3	124,2056	31,30403	5,13407E-12	2,769431
Interactior	720,76	18	40,04222	10,092	1,01864E-11	1,791158
Within	222,1923	56	3,967719			
Total	176307,7	83				

Torque Anova Table

In this analysis using alpha (error rate) of 0.05, the alpha value is the maximum value of the alternative hypothesis error accepted. From the table above it can be concluded that engine rotation has an effect on torque, where the value of P-Value = 3.35652E-79 or 0.00000 which means less than the specified alpha value (P-Value < α) and the value of F = 7350.658 is greater than the value of F crit = 2.265567 so that the H0 hypothesis is not accepted or rejected and the H1 hypothesis is accepted. From the table above, it is known that exhaust manifold variations have a significant effect on torque, where the value of P-value = 5.13407E-12 or 0.00000 which means less than the alpha value specified (P-Value < α) and the value of F = 31.30403 is greater than the value of F crit = 2.769431 so that the hypothesis H0 is not accepted or rejected and hypothesis H1 is accepted. From the table above, it is known that the interaction between rpm and exhaust manifold variations has a significant effect on torque, where the value of P-value = 1.01864E-11 or 0.00000 which means less than the alpha value specified (P-Value < α) and the value of F = 10.092 is greater than the value of F crit = 1.791158, so the hypothesis H0 is not accepted or rejected and hypothesis H1 is accepted.



Graphics BMEP

From the BMEP test, it will be produced as in graph 2. BMEP refers to the amount of torque produced by the engine. At the time of engine rotation 2500 BMEP produced is relatively low, because the engine condition has not produced maximum torque. After that the power rises from 3000 rpm to 4500 rpm engine speed, because the engine condition can produce maximum torque along with the increase in BMEP.

The table and graph above show that the BMEP generated by the exhaust manifold with a diameter of 38 mm compared to the exhaust manifold diameter of 35 mm, 32 mm, and standard diameter. The most power generated by the 38 mm exhaust manifold variation is at 4500 rpm. In this case, the exhaust manifold with a diameter of 38 mm produces a BMEP of 1046.168 kPa. Furthermore, the 35 mm diameter variation produces BMEP of 1022.41 kPa, 32 mm diameter produces BMEP of 1013.445 kPa, and the standard exhaust manifold produces BMEP of 1026.515 kPa.

ANOVA

Source of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	16401809	6	2733635	7350,658	3,36E-79	2,265567
Columns	34924,95	3	11641,65	31,30403	5,13E-12	2,769431
Interactio	67556,02	18	3753,112	10,092	1,02E-11	1,791158
Within	20825,83	56	371,8898			
Total	16525116	83				

BMEP Anova Table

In this analysis using alpha (error rate) of 0.05, the alpha value is the maximum value of the alternative hypothesis error accepted. From the table above it can be concluded that engine rotation has an effect on BMEP, where the value of P-Value = 3.36E-79 or 0.00000 which means less than the specified alpha value (P-Value < α) and the value of F = 7350.658 is greater than the value of F crit = 2.265567 so that the H0 hypothesis is not accepted or rejected and the H1 hypothesis is accepted. From the table above, it is known that exhaust manifold variation has a significant effect on BMEP, where the value of P-value = 5.13E-12 or 0.00000 which means less than the alpha value specified (P-Value < α) and the value of F = 31.30403 is greater than the value of F crit = 2.769431 so that the hypothesis H0 is not accepted or rejected and hypothesis H1 is accepted. From the table above, it is known that the interaction between rpm and exhaust manifold variation has a significant effect on BMEP, where the value of P-value = 1.02E-11 or 0.00000 which means less than the alpha value specified (P-Value < α) and the value of F = 10.092 is greater than the value of F crit = 1.791158 then the hypothesis H0 is not accepted or rejected and hypothesis H1 is accepted.

CONCLUSIONS AND RECOMMENDATIONS

Variations in exhaust manifold diameter have a significant effect on torque and BMEP in a 1300 cc gasoline engine. The larger the exhaust manifold diameter, the greater the torque produced. The highest torque was achieved on the exhaust manifold with a 38mm diameter of 108.06 Nm at 4500 rpm, followed by 35mm (105.60 Nm), 32mm (104.68 Nm), and standard 30mm (106.03 Nm). In addition, the effect on BMEP also showed the same pattern, where the highest BMEP was produced by the 38mm diameter exhaust manifold at 1046.18 kPa at 4500 rpm, followed by the 35mm diameter (1022.41 kPa), 32mm (1013.44 kPa), and standard 30mm (1026.51 kPa). Thus, an increase in exhaust manifold diameter generally increases torque and BMEP in 1300 cc gasoline engines.

ADVANCED RESEARCH

From the research or testing that has been done, there are suggestions to be considered for researchers who want to research on the next exhaust manifold, among others:

1. Make sure or do the service first on the vehicle that will be used for research.
2. This research used the 4-2-1 configuration form for further research, there is a need for innovation and new ideas for other forms of exhaust manifolds.

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