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# THE EFFECT OF BIOETHANOL AND PERTAMAX MIXTURES ON EXHAUST GAS EMISSIONS FROM A 4-STROKE ENGINE IN MOTORCYCLE MATIC

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## ABSTRACT

Bioethanol is an alternative fuel to substitute fossil oil. Bioethanol has several advantages in its use as a fuel in addition to its renewable nature, and bioethanol is also believed to reduce some motor vehicle emissions. The purpose and objective of this study were to determine the effect of a mixture of Bioethanol and Pertamax on gas emissions in a 4-stroke motor with variations in the fuel mixture and engine cycle. This test method is carried out with the measurement parameters of $CO$, $HC$, $CO_2$, and $O_2$. Tests on motor vehicles were carried out with variations of BP0 (0% Bioethanol) to BP100 (100% Bioethanol). The test results using a gas analyzer and analyzed using excel show that bioethanol cannot reduce exhaust gas emissions. Adding bioethanol fuel to Pertamax can also increase the fuel's octane number (RON) and specific gravity. From the available data, adding bioethanol can reduce HC emission levels by up to 4ppm at BP50 at 6000 rpm, increasing $CO_2$ emissions by 13.4% at BP50 at 7000 rpm with a compression ratio of 13:1. For the lowest $O_2$ emission level, it reaches 0.13%. At BP40 at 5000 rpm. $CO$ emission levels are still relatively small in various mixtures with a yield of 0.01%, but at BP0 and BP80 at 13:1 compression, emissions tend to increase every rpm.

**Keywords** Emissions; Bioethanol; Pertamax; Octane; Gas Analyzer
**Paper type** Research paper

## INTRODUCTION

Research in automotive technology is increasing rapidly, making many innovations by scientists to create a vehicle that is effective and efficient in terms of engine capacity and emissions produced. Even today, electric vehicles have emerged, which according to research, are very helpful in reducing the damage to nature caused by fossil fuels. However, the fact is that the waste from these batteries causes much unexpected natural damage. Developing a cleaner and more environmentally friendly fuel than battery waste from electric cars will be more effective in tackling the problem of environmental degradation [1]–[8].

Bioethanol is currently being developed as a substitute for fossil fuels. Using pure ethanol in gasoline engines will be very difficult because it needs to modify the engine. Ethanol is flammable at low temperatures, so pure ethanol is difficult at the initial point of ignition. Mixing gasoline with ethanol will facilitate starting at low temperatures. Changing the compression conditions of the engine to achieve bioethanol combustion is very necessary. Mixing ethanol with gasoline will produce gasohol. The composition of the mixture of ethanol and gasoline varies. The advantage of this mixture is that ethanol tends to increase the octane number and reduce CO2 emissions. Based on BPPT's B2TP research, gasohol with a bioethanol portion of up to 20% can be directly used in automotive engines without causing technical problems and is environmentally friendly [2], [6], [8], [9].

This research aimed to determine the effect of a mixture of Bioethanol and Pertamax on gas emissions in a 4-stroke motor with variations in the fuel mixture and engine cycle. The addition of bioethanol increased HC emissions by 30.65% for BE5 and 188.71% for BE10 at rpm variations and gear variations 35.54% for BE5 and 221.79% for BE10 (Ruri Octaviani, 2010). The addition of ethanol with a ratio of 10: 90 can increase thermal efficiency by 12.47%, and in exhaust emissions, there is an increase in the amount of CO2 and a decrease in CO compounds [6], [10], [11].

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## METHOD

Bioethanol production is carried out starting from the fermentation stage to distillation. Bioethanol fermentation based on molasses is mixed with water and then given yeast, urea fertilizer and NPK as a yeast catalyst to make bioethanol faster. Distillation is carried out using simple distillation but must maintain a temperature below 80 degrees Celsius. Test the motor with standard compression using a gas analyzer if the bioethanol is ready. Changing the compression is done if the test on a standard compression motor has been carried out.

The type of research used in this research is experimental research. Experimental research is a type of quantitative research used to determine the effect of the treatment variable (independent) on the outcome variable (dependent) under controlled conditions. In this case, it is intended that there are independent variables as treatment variables, with the dependent variable as the outcome variable and the control variable as a controlled condition. Quantitative research is based on the philosophy of positivism, this type of research is used to examine a particular population/sample, data collection using research instruments (measurements), and statistical/quantitative data analysis with the aim of testing and proving hypotheses. The data processing method is done with the help of Microsoft Excel software.

## DISCUSSION

This test method is carried out with the measurement parameters of *CO*, *HC*, $CO_2$, and $O_2$. Tests on motor vehicles were carried out with variations of BP0 (0% Bioethanol) to BP100 (100% Bioethanol) to Pertamax. Motor vehicle cycle variations start from 3000-9000 rpm. The results show in Tables 1-4.

ANOVA 2 way compares the mean difference between groups divided by two independent variables (called factors). So it is necessary to have two independent variables on the categorical data scale and one dependent variable on the quantitative/numeric data scale (interval or ratio).

TABLE I. *CO* GAS

| Mixed | RPM | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 |
| STD 0% | 0,68 | 0,44 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 |
| STD 10% | 0,61 | 0,05 | 0,01 | 0,01 | 0,01 | 0,02 | 0,02 |
| STD 20% | 0,67 | 0,07 | 0,01 | 0,02 | 0,01 | 0,01 | 0,01 |
| STD 30% | 0,72 | 0,05 | 0,01 | 0,01 | 0,02 | 0,01 | 0,03 |
| STD 40% | 0,59 | 0,04 | 0,01 | 0,01 | 0,02 | 0,01 | 0,01 |
| STD 50% | 0,63 | 0,06 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 |
| STD 60% | 0,59 | 0,1 | 0,01 | 0,01 | 0,01 | 0,04 | 0,01 |
| STD 70% | 0,33 | 0,09 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 |
| 13 0% | 0,16 | 0,1 | 0,06 | 0,12 | 0,57 | 0,3 | 3,46 |
| 13 10% | 0,4 | 0,14 | 0,1 | 0,06 | 0,14 | 0,3 | 2,17 |
| 13 20% | 0,09 | 0,15 | 0,09 | 0,19 | 0,2 | 0,05 | 2,23 |
| 13 30% | 0,21 | 0,13 | 0,13 | 0,06 | 0,17 | 0,05 | 0,31 |
| 13 40% | 0,07 | 0,05 | 0,04 | 0,02 | 0,03 | 0,5 | 0,03 |
| 13 50% | 0,01 | 0,01 | 0,01 | 0,02 | 0,02 | 0,01 | 0,02 |
| 13 60% | 0,02 | 0,02 | 0,02 | 0,02 | 0,02 | 0,04 | 0,02 |
| 13 70% | 0,04 | 0,03 | 0,01 | 0,01 | 0,01 | 0,02 | 0,02 |
| 13 80% | 0,05 | 0,03 | 0,41 | 0,33 | | | |

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TABLE II. ANOVA TABLE FOR STD WITH *CO* GAS

| *ANOVA* | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 0,037964 | 7 | 0,005423 | 1,206743 | 0,32039 | 2,23707 |
| Columns | 2,320811 | 6 | 0,386802 | 86,06492 | 5,51E-22 | 2,323994 |
| Error | 0,188761 | 42 | 0,004494 | | | |
| Total | 2,547536 | 55 | | | | |

TABLE III. ANOVA TABLE FOR COMPRESSION 13 WITH *CO* GAS

| *ANOVA* | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 3,198657 | 7 | 0,456951 | 1,794953 | 0,113727 | 2,23707 |
| Columns | 5,981318 | 6 | 0,996886 | 3,915878 | 0,003393 | 2,323994 |
| Error | 10,69217 | 42 | 0,254575 | | | |
| Total | 19,87214 | 55 | | | | |

TABLE IV. *HC* GAS

| Mixed | RPM | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 |
| STD 0% | 344 | 147 | 28 | 19 | 14 | 10 | 11 |
| STD 10% | 295 | 60 | 21 | 17 | 21 | 18 | 9 |
| STD 20% | 293 | 71 | 22 | 17 | 10 | 17 | 12 |
| STD 30% | 342 | 38 | 20 | 14 | 18 | 15 | 21 |
| STD 40% | 206 | 63 | 33 | 12 | 14 | 13 | 12 |
| STD 50% | 299 | 57 | 64 | 16 | 17 | 18 | 13 |
| STD 60% | 151 | 78 | 26 | 15 | 14 | 37 | 19 |
| STD 70% | 188 | 73 | 33 | 21 | 41 | 36 | 33 |
| 13 0% | 74 | 52 | 40 | 24 | 43 | 24 | 104 |
| 13 10% | 91 | 68 | 47 | 25 | 22 | 19 | 67 |
| 13 20% | 42 | 45 | 45 | 19 | 14 | 9 | 62 |
| 13 30% | 59 | 57 | 47 | 20 | 17 | 9 | 8 |
| 13 40% | 40 | 19 | 12 | 12 | 11 | 11 | 10 |
| 13 50% | 18 | 18 | 17 | 4 | 9 | 8 | 3 |
| 13 60% | 22 | 65 | 58 | 33 | 10 | 41 | 20 |
| 13 70% | 61 | 99 | 113 | 98 | 75 | 69 | 39 |
| 13 80% | 309 | 406 | 668 | 1361 | | | |

TABLE V. ANOVA TABLE FOR STD WITH *HC* GAS

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 5457,643 | 7 | 779,6633 | 0,770131 | 0,615425 | 2,23707 |
| Columns | 399820,4 | 6 | 66636,74 | 65,82202 | 9,1E-20 | 2,323994 |
| Error | 42519,86 | 42 | 1012,378 | | | |
| Total | 447797,9 | 55 | | | | |

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TABLE VI. ANOVA TABLE FOR COMPRESSION 13 WITH *HC* GAS

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 22548,86 | 7 | 3221,265 | 9,008197 | 9,72E-07 | 2,23707 |
| Columns | 7355,964 | 6 | 1225,994 | 3,428465 | 0,007608 | 2,323994 |
| Error | 15018,89 | 42 | 357,5927 | | | |
| Total | 44923,71 | 55 | | | | |

TABLE VII. $CO_2$ GAS

| Mixed | RPM | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 |
| STD 0% | 11,5 | 12 | 12,5 | 12,9 | 12,6 | 12,7 | 12,9 |
| STD 10% | 10,9 | 12,5 | 12,5 | 12,8 | 13 | 12,7 | 12,9 |
| STD 20% | 11 | 12,5 | 12 | 12,4 | 12,7 | 12,9 | 12,8 |
| STD 30% | 11,5 | 12,1 | 12,2 | 12,5 | 11,8 | 12,6 | 12 |
| STD 40% | 11,6 | 12,5 | 11,7 | 12,5 | 12,8 | 12,8 | 12,5 |
| STD 50% | 10,4 | 12,3 | 10,1 | 12 | 12,3 | 12,5 | 12,6 |
| STD 60% | 11,9 | 12,3 | 12,5 | 11,9 | 12,2 | 12,1 | 11,5 |
| STD 70% | 10 | 10,9 | 11,5 | 11,3 | 10,9 | 11,1 | 11,1 |
| 13 0% | 12,7 | 13 | 13,1 | 13 | 12,8 | 12,6 | 10,2 |
| 13 10% | 11,1 | 12,3 | 12,2 | 12,9 | 12,7 | 12,5 | 11,6 |
| 13 20% | 12,6 | 12,8 | 13,1 | 13,1 | 12,8 | 12,6 | 11,4 |
| 13 30% | 12,1 | 12,2 | 12,6 | 12,7 | 12,6 | 12,6 | 12,4 |
| 13 40% | 13,2 | 13,3 | 13,2 | 13 | 13 | 13,1 | 12,9 |
| 13 50% | 12,6 | 12,4 | 13 | 13,3 | 13,4 | 12,6 | 11,5 |
| 13 60% | 11,4 | 11,5 | 11,7 | 13 | 13 | 10 | 12,3 |
| 13 70% | 10,8 | 11,3 | 12,1 | 13 | 13,2 | 12,9 | 12,7 |
| 13 80% | 10 | 9,7 | 7,4 | 5,2 | | | |

TABLE VIII. ANOVA TABLE FOR STD WITH $CO_2$ GAS

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 12,28571 | 7 | 1,755102 | 9,067744 | 9E-07 | 2,23707 |
| Columns | 10,00214 | 6 | 1,667024 | 8,612688 | 4E-06 | 2,323994 |
| Error | 8,129286 | 42 | 0,193554 | | | |
| Total | 30,41714 | 55 | | | | |

TABLE IX. ANOVA TABLE FOR COMPRESSION 13 WITH $CO_2$ GAS

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 6,832679 | 7 | 0,976097 | 2,438273 | 0,034286 | 2,23707 |
| Columns | 8,549286 | 6 | 1,424881 | 3,559327 | 0,006114 | 2,323994 |
| Error | 16,81357 | 42 | 0,400323 | | | |
| Total | 32,19554 | 55 | | | | |

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TABLE X. $O_2$ GAS

| Mixed | RPM | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 |
| STD 0% | 1,74 | 1,1 | 0,55 | 0,24 | 0,2 | 0,2 | 0,16 |
| STD 10% | 2,92 | 0,6 | 0,52 | 0,41 | 0,19 | 0,17 | 0,19 |
| STD 20% | 2,8 | 0,43 | 1,37 | 0,36 | 0,2 | 0,21 | 0,2 |
| STD 30% | 1,7 | 1,13 | 0,69 | 0,42 | 2,05 | 0,28 | 1,13 |
| STD 40% | 1,52 | 0,36 | 0,53 | 0,36 | 0,58 | 0,22 | 0,71 |
| STD 50% | 3,52 | 0,89 | 1,56 | 1,09 | 0,85 | 0,69 | 0,56 |
| STD 60% | 1,38 | 0,75 | 0,45 | 1,54 | 1,13 | 1,05 | 2,45 |
| STD 70% | 4,19 | 2,44 | 1,53 | 2,42 | 2,66 | 2,81 | 2,82 |
| 13 0% | 0,35 | 0,37 | 0,21 | 0,15 | 0,2 | 0,21 | 1,27 |
| 13 10% | 2,36 | 1,34 | 1,31 | 0,37 | 0,35 | 0,25 | 1,21 |
| 13 20% | 0,81 | 0,46 | 0,18 | 0,15 | 0,52 | 1,02 | 1,07 |
| 13 30% | 1,51 | 1,41 | 0,95 | 0,82 | 0,5 | 1,44 | 0,38 |
| 13 40% | 0,24 | 0,15 | 0,13 | 0,17 | 0,19 | 0,17 | 0,22 |
| 13 50% | 0,21 | 1,34 | 0,63 | 0,16 | 0,21 | 1,17 | 1,96 |
| 13 60% | 2,43 | 2,25 | 2,01 | 0,39 | 0,27 | 4,4 | 1,31 |
| 13 70% | 3,68 | 2,79 | 1,72 | 0,16 | 0,16 | 0,32 | 0,65 |
| 13 80% | 4,5 | 5,66 | 9,1 | 11,97 | | | |

TABLE XI. ANOVA TABLE FOR STD WITH $O_2$ GAS

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 23,37262 | 7 | 3,338946 | 11,06614 | 7,82E-08 | 2,23707 |
| Columns | 17,35581 | 6 | 2,892635 | 9,586951 | 1,22E-06 | 2,323994 |
| Error | 12,6725 | 42 | 0,301726 | | | |
| Total | 53,40094 | 55 | | | | |

TABLE XII. ANOVA TABLE FOR COMPRESSION 13 WITH $O_2$ GAS

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 14,24039 | 7 | 2,034342 | 3,607864 | 0,003943 | 2,23707 |
| Columns | 9,753543 | 6 | 1,62559 | 2,882952 | 0,019156 | 2,323994 |
| Error | 23,68226 | 42 | 0,563863 | | | |
| Total | 47,67619 | 55 | | | | |

Data retrieval can only be carried out up to 80% at 6000 rpm because an error occurred in the engine, causing the engine to stop suddenly and the check engine on the indicator light to turn on. This is caused by incomplete combustion because the RON contained in the fuel used is too large, causing the fuel to be difficult to burn. The equation for a mixture of 20% Pertamax and 80% Bioethanol is as follows:

Known:
$0{,}2\ C_{10}H_{24} + 0{,}8\ C_2H_6O$
Such that:
$0{,}2 : 0{,}8 = 1 : 4$
So the combustion can be written:
$C_{10}H_{24} + 4C_2H_6O + O_2 \rightarrow CO_2 + H_2O$

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$C_{10}H_{24} + 4C_2H_4 + 4H_2O + O_2$ -> $CO_2 + H_2O$
$C_{10}H_{24} + C_8H_{16} + 4H_2O + O_2$ -> $CO_2 + H_2O$
Equalization:
$C_{18}H_{40} + 4H_2O + 38O_2$ -> $18CO_2 + 40H_2O + 4H_2O$
$C_{18}H_{40} + 4H_2O + 38O_2$ -> $18CO_2 + 44H_2O$
$C_{18}H_{48}O_4 + 38O_2$ $18CO_2 + 44H_2O$

- Ar C=12
- Ar H=1
- Ar O=16
- BM (Molecular Weight) air = 29 g/mol

For every 1 mole of oxygen, there will be 3,76 mol $N_2$

Asked: $m_a$, $m_b$, AFR
Solution:
$C_{18}H_{48}O_4 + 38O_2 + (38 . 3.76)\ N_2$ $18CO_2 + 44H_2O + (38 . 3.76)\ N_2$
$C_{18}H_{48}O_4 + 38O_2 + 142,88\ N_2$ $18CO_2 + 44H_2O + 142,88\ N_2$
$m_a$ = (koeficien $O_2 + N_2$) . 1 mol air . 29 g air/mol air
= (38 + 142,88) mol air . 29 g air/mol air
= 180,88 . 29 g air
= 5.245,52 g air
$m_f$ = 1 mol bb . ((18 . 12) + (48 . 1) + (4.16)) g bb/mol bb
= (216 + 48 + 64) g bb
= 328 g bb
AFR = $m_a$ / $m_f$
= 5.245,52 g udara/328 g bb
= 15,99 : 1 ≈ 16 : 1

It can be seen in the Compression Data above that in the 80% Bioethanol mixture at 6000 rpm, the HC level released by the motor is very high. This incomplete combustion causes a poor reading mixture and causes overheating, which prevents the motor from working correctly. It can be ascertained that the motor dies due to excess heat generated from incomplete combustion. Incomplete combustion is caused by changing the compression ratio without changing the ignition power (spark plug) and injector. The best exhaust emission levels were obtained by mixing Pertamax and bioethanol fuels. It can also reduce the use of petroleum.

## CONCLUSION

Based on the results of testing, retrieval, calculation and data processing, as well as data analysis conducted on exhaust emissions with fuel BP0 to BP100, the following conclusions are:

- The highest *CO* gas emission is found in a mixture of BP0 with compression of 13:1 at 9000 rpm. Moreover, the lowest *CO* gas is found in a mixture of BP0 to BP70 with standard compression at various rpm, namely 0.01%.
- The highest *HC* gas emission at a compression ratio of 13:1 was obtained in a BP80 mixture with 6000 rpm with a result of 1361 ppm. The lowest HC gas was obtained at a compression ratio of 13:1, a BP50 mixture with 6000 rpm yielding 4 ppm.
- The highest *HC* gas emission at the standard compression ratio of 11.6:1 is found in the BP0 mixture at 3000 rpm, with 344 ppm. The lowest *HC* gas at a standard compression ratio is found in a mixture of BP40 at 6000 rpm with 12 ppm.
- The highest $CO_2$ emission is found in the BP50 mixture, with a compression ratio of 13:1 at 7000 rpm with a yield of 13.4%. The lowest $CO_2$ gas is found in the BP80 mixture, with a compression ratio of 13:1 at 6000 rpm with a yield of 5.2%.
- The highest $O_2$ gas emission at a standard compression ratio of 11.6:1 was obtained in a BP70 mixture with 3000 rpm yielding 4.19%. The lowest O2 gas was obtained at the standard ratio of the BP0 mixture at 9000 rpm with a yield of 0.16%.
- The lightest $O_2$ gas emission at a compression ratio of 13:1 was obtained in a BP80 mixture with 6000 rpm yielding 11.9%. The lowest $O_2$ gas at a ratio of 13:1 is found in the BP40 mixture at 5000 rpm with a yield of 0.13%.
- The best mixture for standard compression is BP40 at 6000 engine cycle because the *HC* and *CO* gases produced tend to be the smallest. $CO_2$ and $O_2$ tend to be stable.

- The best mixture for 13:1 compression is BP50 at 6000 engine cycle because the *HC* and *CO* gases produced tend to be the smallest. 92 For $CO_2$ and $O_2$ tend to be stable.

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