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Experimental Analysis of the Effects of Intake Manifold Length and Angle Variations on Torque and Power in 110 cc Fuel Injected Motorcycles

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ABSTRACT

The performance of small displacement motorcycle engines is significantly influenced by the design of the intake manifold, particularly its geometric characteristics such as length and bend angle. This study examines the effects of intake manifold geometry variations on the performance of a 110 cc fuel injected motorcycle engine. Nine configurations were tested, combining three intake lengths (3 cm, 9 cm, and 12 cm) and three bend angles (0°, 20°, and 40°). A dynamometer was used to measure engine output in terms of torque and power. Results indicate that manifold geometry strongly affects engine performance. The best torque value, 23.40 Nm, was achieved with the 12 cm and 20° configuration, while the highest power output of 9.0 HP came from the 12 cm and 40° configuration. ANOVA confirmed statistically significant effects of both variables ($p < 0.05$). Unlike previous studies that typically isolate one geometric factor, this research fills a gap by evaluating length and angle together. These findings provide practical insights for optimizing intake manifold design in small fuel injected engines, improving both power and efficiency.

INTRODUCTION

The performance of an internal combustion engine depends heavily on the volumetric efficiency of the air–fuel mixture entering the combustion chamber. Among the components that play a critical role in this process, the intake manifold functions as a conduit that guides the airflow from the throttle body into the engine cylinders. Its design significantly affects the airflow dynamics, including velocity, pressure, and turbulence, which are essential parameters that determine how effectively the air–fuel mixture is delivered into the combustion chamber. The intake manifold must be carefully designed to match the engine's operating conditions, as poor airflow can result in inefficient combustion, reduced power output, and increased fuel consumption. For small displacement engines, such as those found in 110 cc motorcycles, any improvement in intake efficiency can have a noticeable impact on performance. Since these motorcycles are typically used in daily transportation and often operate at varying speeds and loads, optimizing intake efficiency across a wide RPM range is especially important. This makes the geometry of the intake manifold a crucial focus in engine design and research.

One of the most influential geometric aspects of an intake manifold is its length. The length of the intake runner affects the timing and momentum of the air entering the cylinder, which is closely related to a phenomenon known as intake resonance. At certain engine speeds, the pressure waves created by the opening and closing of the intake valves can be timed such that they assist in pushing more air into the cylinder—a process called "ram effect." A longer intake runner tends to enhance low end torque by promoting better cylinder filling at lower RPMs due to slower airflow velocities and stronger pressure wave tuning. Conversely, shorter runners are typically associated with higher power output at elevated engine speeds, where the engine benefits from reduced resistance to high velocity airflow. The ideal intake runner length, therefore, must be tailored to the target operating range of the engine. However, in fixed manifold designs, compromises must be made, and the choice of length can determine whether an engine favors torque or horsepower. Understanding this trade off is essential for achieving desired performance characteristics.

In addition to length, the bend angle of the intake manifold also plays a significant role in shaping airflow characteristics. A sharp bend or an excessive angle can disrupt the smooth flow of air, causing turbulence and pressure loss, which can negatively affect engine breathing. On the other hand, a moderate bend can promote air swirl and improve mixing, potentially enhancing combustion efficiency. Several studies have investigated the effects of manifold curvature and bending angles, showing varied results depending on engine configuration, valve timing, and intake port design. For example, a smoother, more gradual bend typically maintains higher airflow velocity and reduces losses, while aggressive angles can lead to flow separation and eddies. The interaction between airflow velocity and bend angle becomes even more complex in engines with small displacement, where any minor change can cause significant fluctuations in output. Therefore, evaluating the angle of the intake runner alongside its length is necessary to obtain a holistic understanding of airflow optimization. Despite the known individual impacts of length and angle, few studies examine both factors simultaneously.

Research in this domain has shown promising findings, yet many remain context specific and fragmented. For instance, Fajarudin and Wibowo (2016) conducted experiments involving internally threaded short manifolds and observed improvements in both power and torque. Their work showed that manipulating internal flow through turbulence enhancing structures could aid combustion. Similarly, Saputro and Roziqin (2021) experimented with an IM2 intake manifold design (110°/88), reporting gains in peak power and torque. These findings support the view that minor geometric changes in the manifold can lead to measurable performance gains, especially when tailored to engine characteristics. Hasnur et al. (2024) extended this research by comparing long and short manifolds, confirming that longer intake lengths favor torque generation at lower RPMs while shorter ones support power at higher RPMs. Additionally, Ali et al. (2025), using 1D Ricardo Wave simulations, reported that a 70° intake bend improves torque at high engine speeds due to smoother airflow dynamics. However, these studies tend to isolate one variable at a time—either length or angle—without considering their combined effects.

Most existing studies prioritize simplified models or single variable experiments that may not reflect the complex interactions that occur in actual engine operation. For instance, analyzing length without accounting for the bend angle may overlook the compounded turbulence created when both parameters are adjusted. Similarly, simulations, while useful for visualizing flow fields and predicting performance trends, often require validation through experimental data to ensure real world applicability. Furthermore, many investigations focus on larger engines or generalized automotive applications, limiting their relevance to small motorcycles. The behavior of intake air in small displacement engines, such as the widely used 110 cc models, can differ considerably due to higher engine speeds, reduced intake cross sectional area, and simplified engine architecture. As a result, there is a pressing need for experimental research that examines both length and angle in a real engine environment. Bridging this gap can provide actionable design recommendations for manufacturers and tuners.

The importance of this research is amplified by the popularity and widespread use of 110 cc motorcycles, especially in countries with dense urban populations and high reliance on fuel efficient transport. These motorcycles are valued for their balance between power, affordability, and fuel economy, making them a staple in both rural and urban mobility. In such applications, engine responsiveness at low to mid RPM becomes critical for usability, especially in stop and go traffic or when climbing inclines. As consumers increasingly demand vehicles that are both economical and perform well under various load conditions, manufacturers are pushed to enhance engine performance without sacrificing efficiency. Improving intake manifold geometry is one of the few non intrusive ways to meet this demand, as it does not require changes to engine displacement or combustion chamber volume. Hence, identifying the optimal combination of manifold length and angle may offer a cost effective solution for performance enhancement. This presents a valuable opportunity for innovation in engine design for small displacement motorcycles.

Furthermore, as fuel injection systems replace carburetors in modern motorcycles, the sensitivity of intake geometry to performance becomes more pronounced. Fuel injection allows for precise control of air–fuel ratios, making intake air dynamics even more critical. Unlike carbureted systems, which often tolerate slight irregularities in airflow, fuel injected engines respond more distinctly to changes in intake manifold design. A well designed manifold can ensure uniform airflow distribution, reduce pressure drop, and support better atomization and combustion. In contrast, poor design may create inconsistencies in engine response, reduced power, and increased emissions. Since 110 cc motorcycles increasingly adopt fuel injection technology, intake manifold optimization becomes a necessary step in engine development. The shift from mechanical to electronic fuel delivery highlights the importance of integrating geometric considerations with modern fuel system dynamics.

Considering these factors, a comprehensive investigation into the combined effects of intake manifold length and angle on engine performance is both timely and necessary. While individual aspects of intake design have been explored, their synergistic influence remains poorly understood in small displacement engines. By focusing on a 110 cc fuel injected motorcycle engine and conducting controlled experimental testing with nine manifold configurations, this study aims to fill a critical research gap. The use of varying lengths (3 cm, 9 cm, 12 cm) and angles (0°, 20°, 40°) enables a matrix of analysis that reflects realistic design variations used in the industry. Measurements of torque and power across these configurations, analyzed statistically using ANOVA, will help determine which combinations produce the most favorable outcomes. The findings are expected to provide technical guidelines for intake manifold design, both for original equipment manufacturers and performance tuners.

In summary, the optimization of intake manifold geometry represents a valuable strategy for improving the performance of small displacement, fuel injected motorcycle engines. By addressing the gap in existing literature regarding the combined effects of length and angle, this study aims to contribute meaningful insights to the field of engine design. The outcomes of this research could influence future engineering practices, enabling better balance between power, torque, and efficiency in motorcycle applications. Moreover, as urban transportation evolves and environmental considerations become more prominent, enhancing the mechanical efficiency of small engines becomes increasingly important. Intake manifold optimization offers a low cost yet effective pathway toward these goals. This study, therefore, serves both academic and practical interests, aligning scientific understanding with real world applications. The following sections will detail the experimental procedures, data analysis, and interpretation of findings resulting from this investigation.

RESEARCH METHODS

1. Type of Research

This study employs an experimental quantitative research design, aimed at evaluating the influence of intake manifold geometry—specifically variations in length and bend angle—on engine performance. The research focuses on two dependent variables: engine torque and power. By systematically varying the physical geometry of the intake manifold and measuring its impact under controlled conditions, the study seeks to establish causal relationships between manifold configuration and engine output characteristics.

2. Experimental Design

A full factorial experimental design was used to examine the effects of two independent variables: manifold length and bend angle. The manifold lengths tested were 3 cm, 9 cm (standard), and 12 cm, while the bend angles evaluated were 0° (standard), 20°, and 40°. These combinations resulted in a total of nine distinct intake manifold configurations. Each configuration was fabricated and installed on the same engine, and its performance was measured under consistent operating conditions.

Figure 1. Intake Manifold Variations

3. Test Object and Engine Specification

The test subject was a 2016 Suzuki Address FI, a 110 cc gasoline powered motorcycle with an electronic fuel injection system. This model was selected due to its widespread use in Indonesia and its representative engine characteristics for small displacement motorcycles. The engine was maintained in standard condition throughout the testing process, without modifications to ignition timing, fuel mapping, or internal components, ensuring that performance changes were solely due to the intake manifold variation.

Figure 2. Suzuki Address FI 2016

4. Instruments and Equipment

The testing was carried out in a controlled laboratory environment using a chassis dynamometer to measure the engine's power and torque for each intake manifold variation. Each configuration was tested under specific engine speed conditions and consistent ambient parameters to ensure reliable and comparable results. Torque and power outputs were recorded directly from the dynamometer, with measurements expressed in Newton-meters (Nm) for torque and horsepower (HP) for power.

Figure 3. Dynotes

5. Data Collection Procedure

The testing procedure was conducted in a controlled laboratory environment. Each intake manifold variation was installed on the test engine sequentially, and the engine was run to stabilize temperature before data collection. Torque and power values were recorded directly from the dynamometer software and tabulated for statistical analysis.

6. Data Analysis Technique

The collected data were analyzed using descriptive statistics to summarize mean performance values, and one way Analysis of Variance (ANOVA) to determine the statistical significance of intake manifold length and angle on torque and power. ANOVA was selected because it enables the comparison of means across multiple treatment groups and can identify which variables have a significant influence on engine performance ($p < 0.05$). Microsoft Excel and SPSS were used for data tabulation and analysis.

7. Research Flow

The research flow diagram below illustrates the step-by-step methodology followed in this study, from problem identification to data analysis and conclusion formulation.

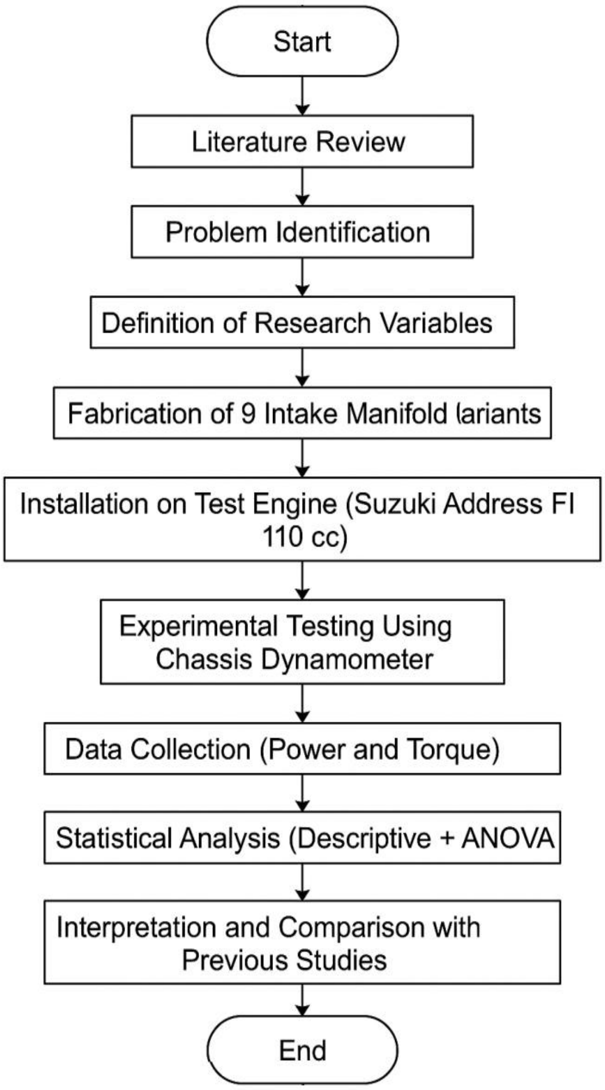

Figure 4. Flowchart of the Study

RESULTS AND DISCUSSION

1. Overview of Findings

The experimental results demonstrate that variations in intake manifold geometry—specifically the length and bend angle—have a significant impact on engine performance in terms of torque and power output. Across the nine tested configurations, each representing a unique combination of intake manifold length (3 cm, 9 cm, and 12 cm) and bend angle (0°, 20°, and 40°), there were clear differences in performance metrics. The highest torque value of 23.40 Nm was achieved by variation 6 (12 cm length, 20° angle), while the maximum power of 9.0 HP was recorded by variation 9 (12 cm, 40°). Conversely, the standard configuration (9 cm, 0°) produced the lowest performance, with only 8.2 HP and 18.63 Nm. These variations confirm that intake manifold geometry directly affects airflow characteristics and volumetric efficiency, which in turn influence combustion effectiveness and overall output.

2. Power Output Across Variations

Table 1. Power Output for Each Intake Manifold Configuration

Variation	Length (cm)	Angle (°)	Power (HP)	Vehicle Speed (km/h)
1	9	0	8.2	81.3
2	3	0	8.7	88.1
3	12	0	8.8	81.1
4	9	20	8.6	88.2
5	3	20	8.8	74.7
6	12	20	8.9	30.7
7	9	40	8.7	79.2
8	3	40	8.7	87.4
9	12	40	9.0	49.3

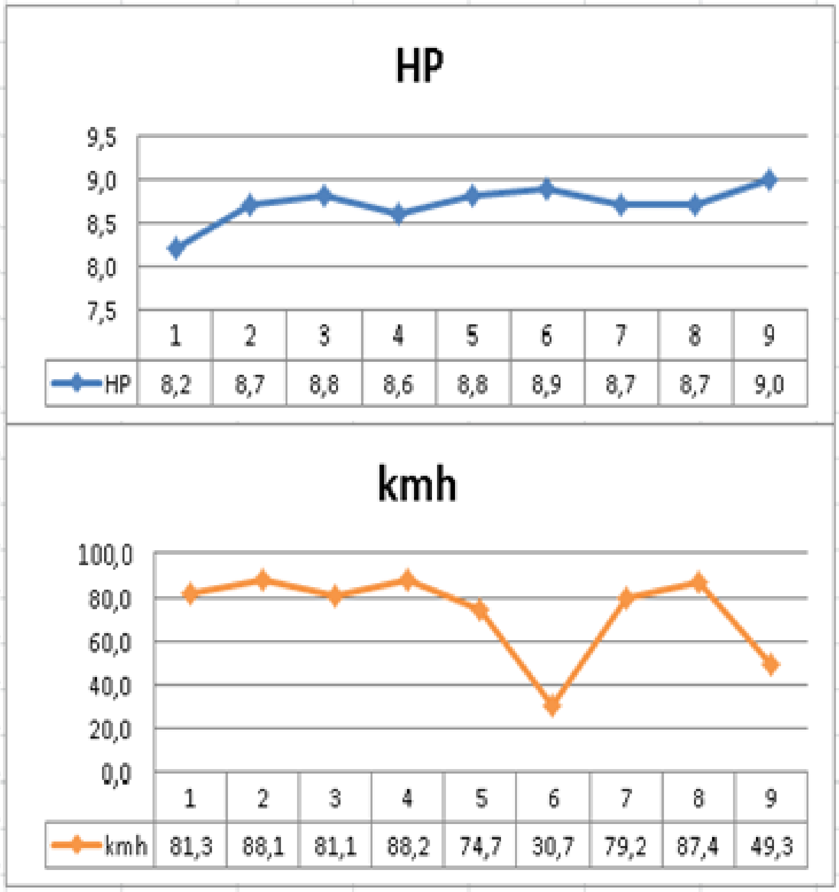

Figure 5. Flowchart of Power Output

As shown in Table 1 and Figure 5, variation 9 recorded the highest power output. This supports the hypothesis that shorter, more direct airflow paths and higher intake angles at appropriate lengths can improve power at higher RPMs due to enhanced dynamic flow momentum. Meanwhile, variation 6, with only slightly less power, demonstrated a superior balance when both power and torque were considered.

3. Torque Output Across Variations

Table 2. Torque Output for Each Intake Manifold Configuration

Variation	Length (cm)	Angle (°)	Torque (Nm)	Vehicle Speed (km/h)
1	9	0	18.63	20.6
2	3	0	20.31	21.6
3	12	0	22.47	24.2
4	9	20	21.16	22.8
5	3	20	21.65	23.7
6	12	20	23.4	24.0
7	9	40	20.61	23.0
8	3	40	22.48	23.5
9	12	40	22.83	23.8

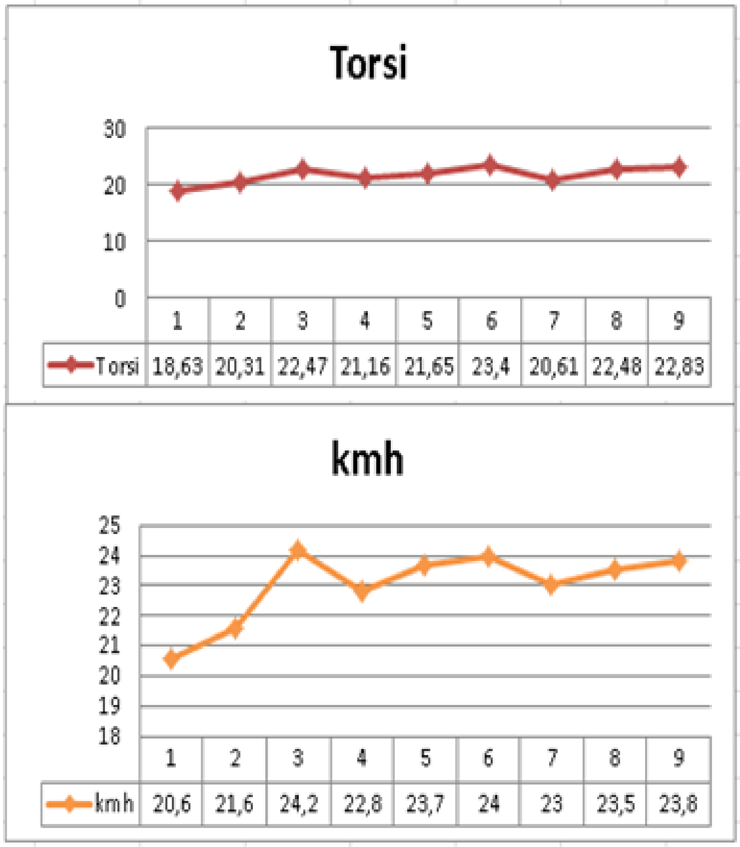

Figure 6. Flowchart of Torque Output

In Table 2 and Figure 6, variation 6 exhibited the highest torque value. This indicates that a longer intake manifold with a moderate bend angle enhances the ram effect and maximizes air fuel mixture volume entering the cylinder at mid range engine speeds. Such findings are consistent with Bayas (2016), who reported that longer intake runners promote better torque due to improved resonance at lower RPM.

4. Statistical Validation using ANOVA

The results of single factor ANOVA testing on both power and torque confirmed the statistical significance of intake geometry:

- Power output: $F = 98.05$, $P = 2.82 \times 10^{-12}$
- Torque output: $F = 241.31$, $P = 1.28 \times 10^{-16}$

Both p values are < 0.05, indicating that intake manifold length and angle significantly influence engine performance. This supports the conclusion that optimizing these two parameters together, rather than in isolation, yields better mechanical output.

5. Interpretation and Comparison with Previous Studies

The increased torque with longer intake lengths, as seen in variation 6, is attributed to the ram effect and air pressure harmonics that assist cylinder filling during the intake stroke. This aligns with Hasnur et al. (2024), who demonstrated that longer intake runners improve torque at lower RPM. Likewise, moderate bend angles such as 20° appear to enhance airflow without inducing excessive turbulence or pressure drop, in line with Sunaryo and Gunawan (2021).

In contrast, sharper angles (40°) can induce turbulent flow and resistance, but when paired with optimal length (12 cm), as in variation 9, they contribute to high power due to better volumetric efficiency at higher RPMs. This finding is consistent with Ali et al. (2025), who showed that specific bend angles optimize high speed engine breathing.

These results also support Fajarudin and Wibowo (2016), who reported that short manifolds with internal modifications improve engine performance. However, the current study suggests that for 110 cc fuel injected engines, a longer intake (12 cm) with a moderate bend (20°) is more effective, particularly for combined torque and power optimization.

6. Summary of Optimal Configuration

While variation 9 (12 cm, 40°) produced the highest peak power, variation 6 (12 cm, 20°) achieved the most balanced performance with the highest torque and near maximum power. This combination supports practical usability in real world riding conditions, where both power and torque are necessary across varying speeds.

CONCLUSION

This study investigated the effects of intake manifold geometry—specifically variations in length and bend angle—on the performance of a 110 cc fuel injected motorcycle engine. The results demonstrated that both the length and angle of the intake manifold significantly influence engine torque and power. Among the nine variations tested, the configuration with a length of 12 cm and a 20° bend angle (variation 6) produced the highest torque of 23.40 Nm, while the configuration with a length of 12 cm and a 40° bend angle (variation 9) achieved the maximum power of 9.0 HP. Although variation 9 showed the highest power, variation 6 provided the best balance between torque and power, making it the most optimal configuration overall for practical applications.

The findings of this study can be generalized to support the importance of intake manifold design optimization in small displacement, fuel injected engines, particularly for improving real world performance such as acceleration and load response. The results offer valuable guidance for motorcycle manufacturers and engine tuners in selecting intake geometries that enhance engine output without the need for complex engine modifications. For theoretical development, the study reinforces airflow dynamics theory related to resonance effects and flow turbulence as influenced by manifold geometry. Future research is encouraged to explore the impact of intake manifold variations on fuel efficiency, emission characteristics, and engine durability. In addition, incorporating numerical simulations such as CFD and extending experimental testing to other engine types would strengthen the applicability and depth of the current findings.

REFERENCES

Ali, M. H. A., Razlan, Z. M., Bakar, S. A., Eswanto, Maruyama, N., Mohamad, M. S., Ramasamy, G., Murali, R., Ishak, A. A., & Rani, M. F. H. (2025). Impact of Intake Manifold Geometry on Power and Torque: A Simulation Based Study. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 128(1), 169–180. https://doi.org/10.37934/arfmts.128.1.169180

Bari, S., Hossain, S. N., & Saad, I. (2020). A review on improving airflow characteristics inside the combustion chamber of CI engines to improve the performance with higher viscous biofuels. Fuel, 264(February). https://doi.org/10.1016/j.fuel.2019.116769

Bayas, A. W. P. N. P. J. J. (2016). a Review Paper on Effect of Intake Manifold Geometry on Performance of Ic Engine. Ijariie, 2(2).

Cahyo, B. D., & Irawan, B. (2024). Manufacture and Analysis Performance of Injection Device System 4 Stroke Engine Againts Emissions. Asian Journal Science and Engineering, 2(2), 101. https://doi.org/10.51278/ajse.v2i2.963

Erlangga, Z. T. (2018). Pengaruh Perubahan Intake Manifold Terhadap Performa Mesin Sepeda Motor Honda Supra X 125 CC. 269–274.

Firdaus, A., Besi, N. P., Mesin, T., Sriwijaya, U., Mesin, T., Islam, U., & Raden, N. (2020). PENGARUH DESAIN INTAKE MANIFOLD MOTOR CB125 DUA SILINDER TERHADAP EMISI GAS BUANG MENGGUNAKAN CFD. November, 18–19.

Guo, S., Huang, S., & Chi, M. (2018). Optimized design of engine intake manifold based on 3D scanner of reverse engineering. Eurasip Journal on Image and Video Processing, 2018(1), 0–12. https://doi.org/10.1186/s13640-018-0304-8

Hasnur, P., Kuala, B., & Buana, U. M. (2024). page 159-170. 6(2), 159–170. https://doi.org/10.20527/jtamrotary.v7i

Najib, M. S. A., Harly, M., & Paryono, P. (2023). Pengaruh Panjang Intake Runner Pada Honda 4 Stroke 200 Cc Terhadap Akselerasi. Jurnal Teknik Otomotif : Kajian Keilmuan Dan Pengajaran, 7(1), 59. https://doi.org/10.17977/um074v7i12023p59-66

Nastiti, Y. A., R, N. H., & Nurdinda, R. (2022). Review of Air Intake System Development for Internal Combustion Engine. Jurnal Serambi Engineering, 7(4), 4110–4117. https://doi.org/10.32672/jse.v7i4.4958

Rizki Fajarudin, Agus Wibowo, & A. F. (2016). Analisa Modifikasi Intake Manifold Terhadap Kinerja Mesin Sepeda Motor 4 Tak 110cc. Universitas Pancasakti, Tegal, 12 no 1(April 2016), 36.

Rohman, F., & Adiwibowo, P. H. (2017). Modifikasi Intake Manifold Dengan Variasi Sudut Putar Terhadap Emisi Gas Buang Honda Supra X Tahun 2002. Jurnal Pendidikan Teknik Mesin, 6(01), 122–128. https://jurnalmahasiswa.unesa.ac.id/index.php/15/article/view/21303

Rokhman, K. N., Sumarli, S., & Paryono, P. (2021). Pengaruh Modifikasi Ukuran Lubang Intake Manifold Terhadap Konsumsi Bahan Bakar Dan Performansi Kendaraan Sepeda Motor Honda 4 Tak 125Cc. Jurnal Teknik Otomotif : Kajian Keilmuan Dan Pengajaran, 5(2), 7. https://doi.org/10.17977/um074v5i22021p7-12

Saputro, W. A., & Roziqin, A. (2021). Modifikasi Panjang Intake Manifold Terhadap Performa Dan Konsumsi Bahan Bakar Mesin Tipe K03. Automotive Science and Education Journal, 9(1), 25–30. http://journal.unnes.ac.id/sju/index.php/asej

Shin, J., Kim, D., Son, Y., & Park, S. (2022). Effect of intake manifold geometry on cylinder-to-cylinder variation and tumble enhancement in gasoline direct injection engine. Scientific Reports, 12(1), 1–24. https://doi.org/10.1038/s41598-022-24079-8

Sunaryo, S., & Gunawan, L. Van. (2021). PENGARUH SUDUT INTAKE MANIFOLD TERHADAP PENINGKATAN DAYA, TORSI DAN KECEPATAN AKSELERASI PADA SEPEDA MOTOR. Device, 11(2), 58–66. https://doi.org/10.32699/device.v11i2.2243

Suparta, I. N., Suarta, I. M., Rahtika, I. P. G. S., & Sunu, P. W. (2021). Perbandingan konsumsi bahan bakar pada sistem injeksi dan sistem karburator. Journal of Applied Mechanical Engineering and Green Technology, 2(3), 108–113. https://doi.org/10.31940/jametech.v2i3.108-113

Syahrullah, L. O. I., & Sinaga, N. (2016). Optimization and prediction of motorcycle injection system performance with feed-forward back-propagation method Artificial Neural Network (ANN). American Journal of Engineering and Applied Sciences, 9(2), 222–235. https://doi.org/10.3844/ajeassp.2016.222.235

Wahono, B., Setiawan, A., & Lim, O. (2021). Effect of the intake port flow direction on the stability and characteristics of the in-cylinder flow field of a small motorcycle engine. Applied Energy, 288(April 2020), 116659. https://doi.org/10.1016/j.apenergy.2021.116659

Wibowo, S. B., & Siswantoro, S. (2015). Analisis Unjuk Kerja Mesin Sepeda Motor 4 Tak Dengan Penambahan Turbulator Pada Intake Manifold. Jurnal Rekayasa Mesin, 10(2), 39–48.