Enhancing Engine Performance and Environmental Sustainability Through Innovative Exhaust Design

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Abstract. This research investigates and demonstrates the potential benefits of material innovation and exhaust design in enhancing vehicle performance and being more environmentally friendly. The pursuit of optimal vehicle efficiency has driven the exploration of alternative materials. Galvanized materials have emerged as a significant factor, highlighting the potential for increased agility and fuel efficiency. With this material, the new exhaust design results in an extraordinary weight reduction of 3.2 kg compared to the original exhaust at 6.450 kg. Additionally, the new exhaust design has yielded significant improvements in performance metrics. The peak power output of the original exhaust is 12.4 HP at 7336 RPM, increasing to 13.3 HP at 7695 RPM, showing a power increase of 7%. The maximum torque of the original exhaust is 12.99 N.m at 6186 RPM, increasing to 13.81 N.m at 5501 RPM, showing a torque increase of 6%. The power-to-weight ratio calculation shows a substantial shift in efficiency, with the original exhaust having a value of 0.09 HP/Kg and the new, more efficient exhaust having 0.10 HP/Kg, an efficiency increase of 11%. Furthermore, the noise produced by the original exhaust at a maximum of 8000 RPM is 90.2 dB, while the new exhaust at a maximum of 8000 RPM is 88 dB. From these results, it can be concluded that the new exhaust design enhances motorcycle efficiency and is more environmentally friendly.

1 Introduction

The field of automotive engineering has witnessed increasing emphasis on exhaust systems, as these components are essential for efficient combustion and optimal vehicle performance[1, 2]. The interplay between air, fuel, engine combustion, and exhaust gas expulsion is a crucial aspect of vehicular operations[3]. This study investigates the complex connection between engine performance, exhaust system design, and the pursuit of optimization in the automotive industry[4].

In the present age of rapid technological advancements and varying consumer expectations, the role of exhaust systems, commonly referred to as mufflers, has expanded

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beyond their primary functional purpose[5]. Initially designed to direct and release exhaust gases, the exhaust system has evolved into a platform for innovation, addressing not only engine efficiency but also aesthetic and auditory aspects[6]. This study delves into the complex nature of exhaust systems, including their historical development, essential functionalities, and continuous quest for enhancements through customization.

The automotive industry is striving to exceed the performance and durability standards set for vehicles[7]. Enthusiasts frequently seek to improve the speed, power, and appearance of vehicles[8]. However, significant modifications to engines are not always necessary. One area in which enhancements can be made without altering the engine is the exhaust system. This component embodies a combination of engineering advancements and the pursuit of automotive excellence.

This study undertakes an extensive analysis of previous research, such as that of Kosasih and Rachman (2019), to delve into the intricacies of exhaust system modifications[9]. By examining the difficulties, advancements, and consequences of designing aftermarket exhaust systems, this research offers a more profound understanding of how enthusiasts endeavor to redefine the boundaries of automotive performance[10, 11]. Furthermore, this article elucidates the intricate equilibrium between high-quality materials, sound engineering techniques, and pursuit of optimal exhaust notes[12].

As the automotive industry advances towards sustainable transportation and enhanced driving experiences, exhaust systems exemplify the indomitable spirit of innovation[13]. This study examines the potential advantages of material innovation and exhaust design in enhancing vehicle performance and environmental friendliness[14, 15]. The investigation of alternative materials, particularly galvanized materials, has emerged as a crucial factor indicating potential increases in agility and fuel efficiency. Additionally, this study delves into the evolution of vehicular soundscapes, the craftsmanship of exhaust system modifications, and the unwavering pursuit of vehicular perfection within the automotive community.

2 Experimental Details

2.1 Material

The new exhaust design utilizes stainless-steel pipes and galvanized plates, contributing to an overall lighter exhaust weight. The chamber design was meticulously engineered to deliver superior performance compared to the built-in motorcycle exhaust. This improved performance was achieved while maintaining comparable noise levels and even reducing the noise output within specific RPM ranges.

2.2 Dynotest

DYNOTEST represents a testing method to evaluate the performance of both car and motorcycle engines, focusing on power and torque measurements. Torque, in this context, refers to the engine's capacity to initiate movement from a stationary position to motion for both cars and motorcycles.

2.3 Noise Level Testing

In accordance with Article 285 of Law No. 22 of 2009 and Minister of Environment Regulation No. 7 of 2009 concerning traffic and road transportation, as well as the noise threshold for new motor vehicle types. Motorcycles are categorized according to their noise threshold levels, based on the cylinder capacity of the engine:

1. Motorcycles with engines of up to 80cc had a noise threshold of 77 dB.
2. Motorcycles with engines ranging from 80cc to 175cc have a noise threshold of 80.
3. Motorcycles with engines exceeding 175cc had a noise threshold of 83 dB.

These legal regulations are designed to ensure that motor vehicles, particularly motorcycles, do not exceed permissible noise levels while operating on the road. The thresholds are categorized based on engine capacity, acknowledging the varying noise emissions associated with different engine sizes. This noise level testing framework aligns with broader efforts to maintain environmental originals and preserve the tranquility of urban and residential areas while promoting responsible road usage.

2.4 Exhaust System Weight Measurement

The weight of an exhaust system is a critical factor that influences various aspects of the vehicle performance and efficiency. Beyond its primary role in facilitating the expulsion of exhaust gases, a well-designed exhaust system aims to minimize unnecessary weight, thereby improving vehicle dynamics and fuel efficiency. The impact of exhaust system weight is multifaceted and far-reaching.

First, reduced exhaust system weight positively affects vehicle performance by enhancing acceleration and handling capabilities. The decreased weight can lead to a significant improvement in the power-to-weight ratio, which is a key determinant of the overall performance potential of a vehicle. A lighter exhaust system reduces the unsprung weight of the vehicle, allowing for a quicker response and more agile handling.

In addition, a lighter exhaust system influences the vehicle's center of gravity, resulting in enhanced stability and improved cornering abilities. This is particularly crucial in sports and performance-oriented vehicles, in which driving dynamics and responsiveness are paramount. By lowering the overall weight and altering the weight distribution, the exhaust system design can contribute to a more balanced and engaging driving experience, enabling the vehicle to respond better to driver inputs and navigate turns and maneuvers with greater precision and control.

Furthermore, the reduced weight of the exhaust system positively affects the fuel efficiency by decreasing the overall vehicle mass. This in turn leads to improved acceleration, reduced fuel consumption, and enhanced overall energy efficiency, all of which are crucial considerations in the pursuit of sustainable and environmentally friendly transportation solutions. Therefore, the optimization of exhaust system weight represents a multifaceted approach to enhancing vehicle performance, handling, and environmental friendliness.

3 Results and discussion

3.1 Dynotest

Below is a tabulated representation of the results obtained from the Dynotest for the exhaust system:

Table 1. Dynotest results

No.	Exhaust	Power		Torque	
		Max power (HP)	RPM	Max Torque (N.m)	RPM
1.	Original	12,4	7336	12,99	6186
2.	New Design	13,3	7695	13,81	5501

The performance data presented in the table offer a detailed comparison between the original and new exhaust system designs. The maximum power and torque values provide quantitative evidence of the improvements achieved through the new design. The accompanying RPM figures indicate the engine speeds at which these peak performance metrics were measured, thereby shedding light on the operating characteristics of the two exhaust systems. This comparative analysis allows for a deeper understanding of how the new design, with its innovative use of materials and engineering, enhances the overall performance capabilities of the vehicle. The results demonstrate tangible benefits in terms of power delivery and torque output, which are crucial factors in determining a vehicle's acceleration, responsiveness, and overall driving dynamics. These detailed performance data serve as a valuable foundation for further exploration of the design trade-offs and potential of the new exhaust system to deliver a more engaging and efficient driving experience..

3.2 Noise Level Testing

Here are the test results for noise levels of the original and new design exhaust systems presented in Table 2 and 3 :

Table 2. Test Results for Noise Levels of Original Exhaust System.

Number	RPM	NOISE- LEVEL TEST RESULT
1	Idle / 1000 rpm	65 DB Meter
2	3000 rpm	72 DB Meter
3	4000 rpm	76,8 DB Meter
4	6000 rpm	82,5 DB Meter
5	8000 rpm	90,2 DB Meter

Table 3. Test Results for Noise Levels of New design Exhaust System

Number	RPM	NOISE- LEVEL TEST RESULT
1	Idle / 1000 rpm	65 DB Meter
2	3000 rpm	74 DB Meter
3	4000 rpm	78 DB Meter
4	6000 rpm	86 DB Meter
5	8000 rpm	88 DB Meter

Based on the analysis of the noise-level test results, several key findings can be observed. For the RPM range of 1000 to 6000, the new exhaust system design exhibited noise levels comparable to those of the original factory-installed exhaust. This indicates that the new design effectively maintains a similar acoustic profile within the typical operating RPM range. However, the data revealed a noteworthy improvement at a higher engine speed of 8000 RPM. At this elevated RPM, the new exhaust system demonstrated significantly lower noise levels than the original exhaust. This suggests that the refined design and engineering of the new exhaust system have enabled superior noise reduction capabilities, particularly in the upper RPM spectrum, contributing to a quieter operation.

3.3 Exhaust System Weight Measurement Results

The weight testing results revealed significant improvements in the new exhaust system design compared to the original design. The original exhaust system weighed 6.450 kg. In contrast, the new design exhaust system weighed only 3.250 kg, representing a substantial reduction in the overall weight of over 3 kg. This considerable decrease in exhaust system weight can have far-reaching implications for vehicle performance, handling, and fuel efficiency. A lighter exhaust system means less unsprung weight, which enhances the acceleration, responsiveness, and agility.

Based on the reduction in the exhaust system weight, the calculated power-to-weight ratio indicates an efficiency improvement of 11%. This percentage increase demonstrates the enhanced efficiency provided by the newly designed exhaust system compared to the original exhaust system. Thus, the efficiency of the engine increases because of the increase in power and weight reduction of the motorcycle. The increase in the efficiency was 11%. This implies that the required fuel is also reduced, which indirectly reduces the emissions released into air. In other words, the exhaust with this new design is more environmentally friendly in terms of emissions released into the air and more environmentally friendly in terms of noise pollution produced where the test results show that this exhaust is 2.2 dB quieter than the default exhaust at 8000RPM.

4. Conclusions

This study aimed to explore and showcase the potential advantages of material innovation and exhaust design in improving vehicle performance and promoting environmental sustainability. Based on the condected test, the peak power output of the original exhaust is 12.4 HP at 7336 RPM, increasing to 13.3 HP at 7695 RPM, showing a power increase of 7%.

The maximum torque of the original exhaust was 12.99 N.m at 6186 RPM, increasing to 13.81 N.m at 5501 RPM, showing a torque increase of 6%. The power to weight ratio calculation shows a substantial shift in efficiency, with the original exhaust having a value of 0.09 HP/Kg and the new, more efficient exhaust having 0.10 HP/Kg, an efficiency increase of 11%. Furthermore, the noise produced by the original exhaust at a maximum of 8000 RPM was 90.2 dB, while the new exhaust at a maximum of 8000 RPM was 88 dB. From these results, it can be concluded that the new exhaust design enhances the motorcycle efficiency and is more environmentally friendly.

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