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A Scientific Investigation into the Impact of CVT Roller Weight on Fuel Efficiency and Engine Performance in Motorcycles

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ABSTRACT

This research investigates the impact of Continuously Variable Transmission (CVT) roller weight on fuel consumption and engine performance in motorcycles. The study involved experimental testing of motorcycles fitted with rollers of varying weights (9 grams and 12 grams) to evaluate their effects on fuel consumption, and overall engine performance. This study concludes that the choice of CVT roller weight significantly affects both fuel consumption and engine performance, with potential implications for optimizing motorcycle efficiency based on user preferences and riding conditions. This study found that the 9-gram roller produced greater torque and power (7.85 Nm at 3,500 RPM, 8.45 hp at 6,500 RPM) than the 12-gram roller, but its fuel consumption was higher at low RPM (SFC 0.07 kg/hp.h at 1,500 RPM).

Keywords
Roller, continous variable transmission, fuel consumption, engine performance

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INTRODUCTION

Motorcycles are the most popular means of transportation for Indonesians. Statistical data shows that in 2022, Indonesia experienced a growth in the number of motorbikes, reaching 125,305,332 units, and they became the primary means of transportation for the Indonesian people [1]. More details can be seen in Table 1 below.

Table 1. Development of the number of vehicles categorized by type (units)

Type of Vehicle	2021	2022
Passenger Cars	16,413,348	17,168,862
Bus	237,566	243,450
Truck	5,299,361	5,544,173
Motorcycle	120,042,298	125,305,332
Total	141,992,573	148,261,817

* Source: Indonesia Statistics Center

By the increasing number of motorcycles every year, optimizing vehicle performance has become a significant concern, particularly for individuals who depend on motorcycles for daily use. Many individuals choose automatic motorcycles for their practicality in use and maintenance, as they feature automatic transmissions that do not require gear changes. While they offer several benefits, automatic motorcycles tend to consume more fuel and have heavier acceleration due to their high idle speed.

The high number of motorcycle owners underscores the necessity for technological innovation and advancements in engine and transmission systems to enhance driving comfort and efficiency [1][2][3][4]. A critical area of development that has garnered considerable demand is the transmission system, specifically Continuous Variable Transmission (CVT). CVT plays a crucial role in determining the vehicle's responsiveness and power under various road conditions [5][6].

Enhancing Continuous Variable Transmission (CVT) on a motorcycle is an effective method to improve power and torque, which are crucial factors influencing vehicle performance. CVT, an automatic transmission system that continuously regulates the ratio of engine to wheel rotation, has the potential to be optimized for better performance.

Many studies focus on achieving faster acceleration and better engine response, particularly for daily driving and track use. CVT modifications can address these needs effectively. Upgrading components like rollers, variations, and belts can enhance power transmission efficiency, boosting power and torque. These modifications involve more than just replacing parts; they require proper adjustments and tuning. A thorough understanding of how each CVT component interacts is essential to improve the entire transmission system's performance [7].

Studies have demonstrated that the use of racing CVT rollers has a considerable impact on the torque and power output of motorcycles. Research indicates that the weight of the roller is crucial in optimizing performance. For instance, a 150cc motorcycle outfitted with a 16g roller achieved a peak torque of 12.45 N/m at 6,800 RPM. Additionally, lighter rollers, such as 11g and 12g, also produced significant torque outcomes at varying RPM levels [8][9]. Another study on 110cc motorcycles revealed that lighter rollers increased acceleration and torque at lower RPM but sacrificed maximum power at higher RPM [10]. The roller mass and spring constant combination boosts torque and power but can increase wear and temperature in the CVT system [11].

The weight of rollers in a motorcycle's CVT (Continuously Variable Transmission) system significantly impacts its performance, particularly in terms of power, torque, and acceleration. Lighter rollers enhance acceleration and responsiveness, while heavier rollers can improve top speed and maintain control at higher RPMs. The choice of roller weight is crucial for optimizing the motorcycle's performance based on the rider's needs and the riding conditions.

Lighter rollers, such as 11 grams, have been shown to produce higher power and torque at lower RPMs, making them suitable for quick acceleration and responsive performance. For instance, a 110cc motorcycle achieved a power of 7.22 HP and torque of 8.57 Nm with 11-gram racing rollers [12]. Heavier rollers, like 13 grams, tend to generate maximum power and torque at higher RPMs, which can be beneficial for maintaining speed on highways. A 13-gram roller produced a power of 6.68 HP and torque of 7.94 Nm at higher RPMs [12][13].

The combination of roller weight and other CVT components, such as the primary fixed sheave angle, can affect acceleration and top speed. For example, a 13-gram roller with a modified sheave angle increased its top speed by 0.4 Kph [14]. Lighter rollers generally improve acceleration due to their ability to quickly change the effective gear ratio, enhancing the motorcycle's responsiveness [6].

The increase in motorcycle performance is associated with a change in fuel consumption. Enhanced acceleration due to lighter rollers frequently results in elevated engine RPMs during operation, which can increase instantaneous fuel consumption rates. However, when the CVT system is meticulously calibrated—considering roller mass, sheave angle geometry, and engine torque characteristics—it can facilitate more rapid transitions to optimal engine load conditions, potentially reducing fuel consumption during steady-state cruising. According to [4], modifications that maintain the engine within its maximum efficiency range can mitigate excessive fuel usage despite improved throttle response. Therefore, the overall impact on fuel economy is influenced not only by roller weight but also by the comprehensive integration and synchronization of CVT components. These findings highlight the significance of a system-level approach when tuning CVT parameters for both performance and fuel efficiency.

This highlights the need for careful consideration of roller specifications to strike a balance between performance and durability. Overall, these findings underscore the significance of roller weight in fine-tuning motorcycle performance and balancing torque and power for optimal efficiency [10][11]. This study seeks to identify roller weight that enhances vehicle performance and optimizes fuel consumption.

METHOD

This study investigates the impact of Continuously Variable Transmission (CVT) roller weights on fuel consumption and engine performance of automatic motorcycles. The method used in this research is experimental, which will see the difference between different treatments on the same object. The object of this research is a 2016 Honda Beat motorcycle with standard manufacturer specifications. The given treatment will vary the weight of the CVT roller used on the research object. Tests were carried out by comparing 9 grams and 12 grams of roller weights. A dynamometer measures engine power and torque, while fuel consumption is tracked with a burette and stopwatch, as depicted in Figure 1.

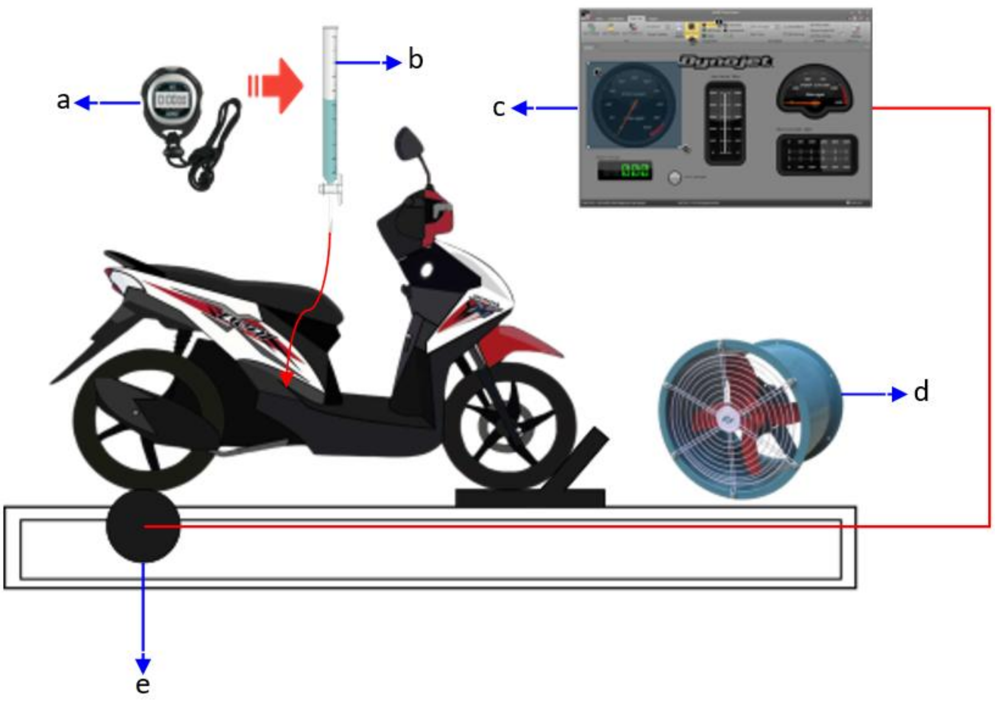

Figure 1. Test setup (a) Stopwatch, (b) Burette, (c) Driver panel dyno test, (d) Blower fan, (e) Roller dyno test

Figure 1 illustrates that the motorcycle was mounted on a dynamometer to assess engine power and torque. Additionally, a fuel gauge was installed to monitor fuel consumption throughout the testing process. To emulate real-world conditions, a fan was employed as an artificial cooler to simulate airflow experienced during motorcycle operation.

In the engine performance testing phase, the motorcycle was tested using two variations of CVT roller weights, 9 grams and 12 grams, which were installed alternately. Each configuration was tested to measure power and torque through a dynamometer. Fuel consumption testing was conducted by measuring the time required to consume 20 mL of fuel. The full-to-full method measures the change in fuel volume using a burette and records the time using a stopwatch. All data collected from both roller weight variations were then analyzed quantitatively. Comparisons were made to assess the impact of different roller weights on engine performance, including power, torque, and specific fuel consumption.

RESULT AND DISCUSSION

Power

The findings of this study are significant because they demonstrate how selecting the appropriate roller weight can optimize engine performance for different driving conditions. CVT rollers play a crucial role in determining engine power and acceleration response. This study investigates the impact of different roller weights on engine performance. Figure 2 investigates the relationship between roller masses specifically 12-gram and 9-gram rollers and their effects on power output and rotational speed (RPM).

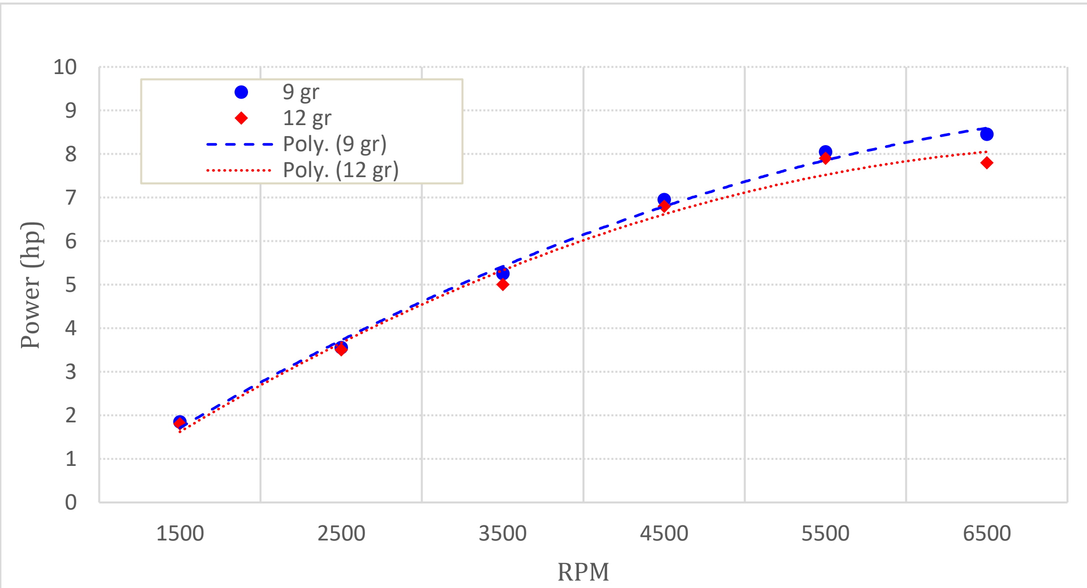

Figure 2. Comparison of power to RPM of 9-gram and 12-gram rollers

This study proves that CVT rollers affect engine power. With a 9-gram roller, power increases from 1.85 hp (1,500 RPM) to 8.45 hp (6,500 RPM). Meanwhile, a 12-gram roller produces lower power across the entire RPM range, from 1.8 hp (1,500 RPM) to 7.8 hp (6,500 RPM). The largest power difference reaches 0.65 hp at 6,500 RPM, while at other RPMs the difference ranges between 0.05-0.25 hp. Table 2 illustrates the detail. Analysis of the polynomial curve shows that the 9-gram roller produces a steeper power-RPM curve slope (+35% steeper at 3,500-5,500 RPM), indicating more aggressive acceleration response. Polynomial curve analysis is used to model the relationship between engine power and RPM, allowing for a detailed examination of how roller weight affects acceleration response.

Table 2. Data from the 9-gram and 12-gram roller power test

RPM	Power (hp)	
	9 gr	12 gr
1500	1.85	1.8
2500	3.55	3.5
3500	5.25	5
4500	6.95	6.8
5500	8.05	7.9
6500	8.45	7.8

In terms of performance characteristics, the 9-gram roller exhibits superiority at high RPM, with a power increase from 5.25 hp (3500 RPM) to 8.45 hp (6500 RPM). However, it requires a 3000 RPM increase to add 3.2 hp. Conversely, the 12-gram roller is more stable with a power increase from 5 hp (3500 RPM) to 7.8 hp (6500 RPM) over the same RPM range. This data reinforces that the lighter roller (9-gram) is suitable for quick acceleration, while the heavier roller (12-gram) excels in efficiency.

The practical implications are evident in theoretical fuel consumption: the 12-gram roller at 2500-4500 RPM only requires 3.5-6.8 hp to maintain a constant speed, while the 9-gram roller needs 3.55-6.95 hp under the same conditions. This difference of 0.15-0.25 hp indicates a potential fuel savings of ~4-7% for daily use. These findings provide a quantitative basis for selecting CVT rollers: 9-gram for performance (maximizing power of 8.45 hp) versus 12-gram for efficiency (reducing power by 0.65 hp at high RPM).

Torque

Through the analysis of the Torque vs RPM graph (Figure 3) and supporting data from empirical testing (Table 3), this study clearly demonstrated a significant relationship between variations in CVT roller weight and the torque characteristics of motorcycle engines. Table 3 shows the data obtained from torque testing for 9-gram and 12-gram rollers on automatic motorcycles.

Table 3. Data from the 9-gram and 12-gram roller torque test

RPM	Torque (Nm)	
	9 gr	12 gr
1500	6.48	6.3
2500	7.4	7.35
3500	7.85	7.5
4500	7.4	7.2
5500	6.85	6.75
6500	6.1	5.8

Test results indicate that the 9-gram roller produces a peak torque of 7.85 Nm at 3500 RPM, with a more aggressive curve profile compared to the 12-gram roller, which achieves a maximum torque of 7.5 Nm at the same RPM (a difference of 0.35 Nm or 4.5%). This difference is particularly evident in the 2000-4000 RPM range, where the 9-gram roller has a 15% larger area under the curve (AUC), indicating superior acceleration response with a 21.1% increase in torque from 1500-3500 RPM compared to 19% for the 12-gram roller.

Figure 3 illustrates the relationship between torque and RPM with variations in 9-gram and 12-gram rollers. A detailed analysis of the torque curve reveals several important patterns. Between 1500-3500 RPM, the 9-gram roller shows a 21.1% increase in torque (from 6.48 Nm to 7.85 Nm), while the 12-gram roller only experiences a 19% increase (from 6.3 Nm to 7.5 Nm). After reaching a peak at 3500 RPM, both configurations show a progressive decrease in torque, but with different characteristics. At 6500 RPM, the 9-gram roller maintains a torque of 6.1 Nm, while the 12-gram roller drops to 5.8 Nm (a difference of 0.3 Nm or 5.2%).

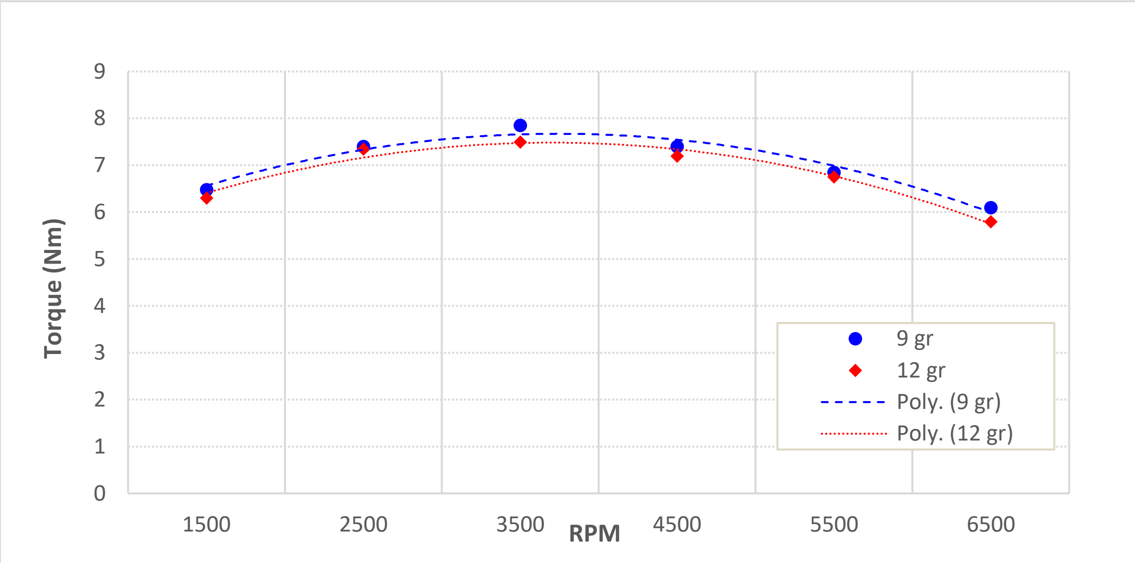

Figure 3. Comparison of power to RPM of 9-gram and 12-gram rollers

Comparison with previous power data shows a close correlation between torque characteristics and power output. At 3500 RPM, where torque peaks, the 9-gram roller produces 5.25 hp compared to 5.0 hp for the 12-gram roller. A similar pattern is observed across the entire RPM range, with the 9-gram roller consistently outperforming the 12-gram roller by 3-5% in power output, consistent with its advantage in torque production.

The technical implications of these findings indicate that the 9-gram roller is more suitable for applications requiring rapid acceleration, with a torque advantage of up to 4.7% at medium RPM. Meanwhile, the 12-gram roller exhibits more linear characteristics, with a more stable torque decline after 3500 RPM. The selection of roller weight must consider the trade-off between acceleration performance and operational stability.

Specific Fuel Consumption

Specific fuel consumption (SFC) is the amount of fuel used to produce one unit of power per hour. The SFC value is influenced by the degree of combustion completeness of the fuel and air mixture in the combustion chamber; more complete combustion will produce greater power. SFC is used to indicate how efficiently an engine uses fuel. Figure 4 presents the SFC graph of the research data calculation results after all data was collected for each variation of roller weight, 9-gram and 12-gram.

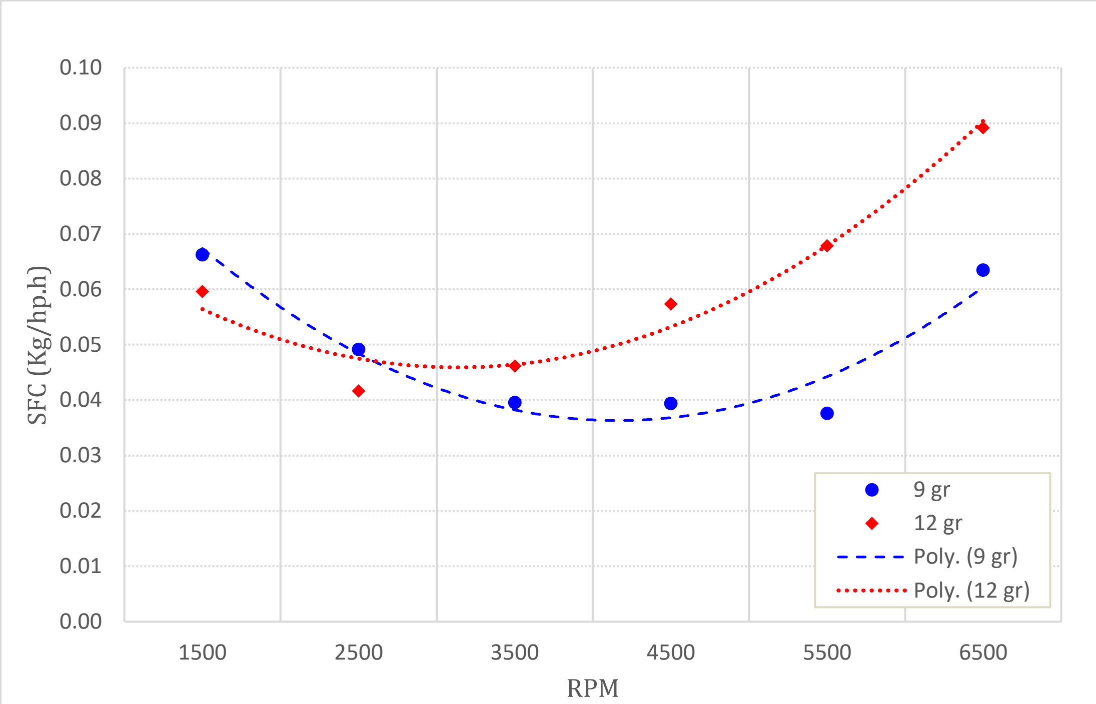

Figure 4. Comparison of SFC to RPM of 9-gram and 12-gram rollers

Figure 4 shows that specific fuel consumption (SFC) decreases as load increases because engine efficiency improves. At low loads, a lean fuel-air mixture results in higher fuel consumption per unit of power. With increased load and power, the engine shows higher fuel efficiency. After the load increases, the SFC graph generally decreases until it reaches a minimum point at a certain load. If the load continues to increase, the SFC value increases again to a certain point. The optimal SFC value is achieved when the BSFc is at its lowest point. An increase in the SFC value typically occurs because the amount of fuel being injected exceeds the air requirement, resulting in a rich mixture, which causes the combustion process to not operate optimally.

As shown in Figure 4, the shape of the SFC graph against load is parabolic facing upwards, where at low loads, SFC tends to have a high value. After the load is increased, the SFC graph tends to decrease until, at a specific load, the SFC value reaches a minimum. Then, as the load is increased, the SFC value will rise again to a certain point. The best SFC value is when the BSFC value is at its lowest.

Furthermore, Figure 4 illustrates the significant differences in Specific Fuel Consumption (SFC) patterns between the 9-gram and 12-gram roller configurations across the entire operational RPM range of 1500 to 6500 RPM. At 1500 RPM, the 12-gram roller shows better fuel efficiency, with an SFC of 0.06 kg/hp·h, compared to 0.07 kg/hp·h for the 9-gram roller, representing a 16.7% improvement. This efficiency advantage becomes even more pronounced at 2500 RPM, where the 12-gram roller achieves an SFC of 0.04 kg/hp·h, while the 9-gram roller has an SFC of 0.05 kg/hp·h, resulting in a 20% improvement.

The SFC characteristics show an interesting crossover point at 3500 RPM, where both configurations achieve comparable efficiency (0.04 kg/hp.h for 9-gram vs. 0.05 kg/hp.h for 12-gram). This aligns with our torque measurements, which show peak torque output at RPM (7.85 Nm for 9-gram vs. 7.5 Nm for the 12-gram roller). Beyond this point, the efficiency relationship changes dramatically—at 6500 RPM, the 9g configuration maintains 0.06 kg/hp.h while the 12-gram roller drops to 0.09 kg/hp.h (SFC 50% higher). The SFC calculation results can be seen in Table 4 below.

Table 4. Data of RPM against SFC for the 9-gram and 12-gram roller

RPM	SFC (kg/hp.h)	
	9 gr	12 gr
1500	0.07	0.06
2500	0.05	0.04
3500	0.04	0.05
4500	0.04	0.06
5500	0.04	0.07
6500	0.06	0.09

Based on the experimental results, this study successfully established a causal relationship between SFC characteristics, and the torque and power profiles analyzed previously. Comprehensive analysis indicates that changes in CVT roller weight result in a correlation between the three main parameters of engine performance.

The research findings reveal a complex dynamic relationship between power, torque, and SFC parameters in motorcycle CVT systems. The analysis shows that engine torque (τ) plays a key role in shaping the characteristics of the other two parameters, with a relationship that can be modeled mathematically as $P = \tau \times \omega$, where P represents output power and ω represents angular velocity (RPM). In the 9-gram roller configuration, peak torque of 7.85 Nm at 3500 RPM directly correlates with the optimal SFC point of 0.04 kg/hp.h, forming the system's maximum thermal efficiency zone. This pattern follows the basic principles of thermodynamics, where combustion efficiency reaches its optimum at a specific engine load. Conversely, the 12-gram roller exhibits significantly different characteristics—although it produces lower maximum torque (7.5 Nm at 3500 RPM), this configuration maintains a lower SFC of 0.04–0.05 kg/hp.h across the 1500–3500 RPM range, demonstrating superior volumetric efficiency under light to moderate operating conditions.

The relationship between these three parameters also shows an evident trade-off phenomenon in the high RPM range (4500-6500 RPM). The 9-gram roller maintains high power output (8.45 hp at 6500 RPM) with a gradual decrease in torque from 7.4 Nm (4500 RPM) to 6.1 Nm (6500 RPM), accompanied by a moderate increase in SFC from 0.04 to 0.06 kg/hp.h. Meanwhile, the 12-gram roller experiences more significant performance degradation with a torque decrease from 7.2 Nm to 5.8 Nm and a sharp increase in SFC from 0.06 to 0.09 kg/hp.h over the same RPM range. These experimental data confirm the fundamental theory of internal combustion engines that increasing engine speed beyond the optimal point leads to a decrease in thermal efficiency due to factors such as increased mechanical friction and suboptimal combustion time.

This study identified the optimal operating ranges that balance the three parameters: a 9-gram roller should operate between 3500 and 4500 RPM, while a 12-gram roller should function between 2500 and 3500 RPM. These findings highlight the significance of ECU mapping to ensure the engine remains within its efficient range. Additionally, they underscore the importance of systemic optimization, as adjustments to one parameter can impact the other two.

CONCLUSION AND RECOMMENDATION

Conclusion

Based on the results of a comprehensive analysis, this study concludes that variations in CVT roller weight have a significant effect on overall engine performance characteristics. Experimental data show that the 9-gram roller consistently produces higher torque and power output, with peak values reaching 7.85 Nm at 3500 RPM and 8.45 hp at 6500 RPM, but with relatively higher fuel consumption at low RPM ranges (SFC 0.07 kg/hp.h at 1500 RPM). Conversely, the 12-gram roller offers better fuel efficiency at low to medium RPM (SFC 0.04 kg/hp.h at 2500 RPM) with more stable operating characteristics, albeit at the expense of maximum performance. These findings reveal a clear trade-off between performance and efficiency aspects in selecting CVT roller weight.

Recommendation

For further development, it is necessary to analyze other factors or variables that affect fuel consumption with several other types of vehicles. In addition, it is necessary to develop an adaptive CVT system that can dynamically optimize the roller configuration based on vehicle operating conditions. Finally, further research is needed to investigate the combination of hybrid roller weights and their long-term effect on component wear.

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