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Analysis of CVT Spring Variation's Effect on Honda Beat Deluxe Motorcycle Performance

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Abstract. *Automatic motorcycles are popular due to their efficiency and flexibility in urban areas. CVT spring modifications are often done to improve performance. This research tested the effect of 1000 RPM (standard), 1500 RPM, and 2000 RPM CVT springs on a Beat Deluxe using a dynotest, observing torque, power, fuel consumption, CVT wear, and engine temperature on 68 kg and 134 kg riders. The results showed that at 3000 RPM, the highest torque was achieved by the 2000 RPM spring (14.04 Nm for 68 kg, 12.84 Nm for 134 kg). The highest power at 4000 RPM was also by the 2000 RPM spring (6.6 HP for 68 kg, 5.9 HP for 134 kg) but with the highest fuel consumption (0.021 l/km for 68 kg, 0.030 l/km for 134 kg). The 1500 RPM spring showed a moderate performance increase with wear and temperature between the 1000 RPM and 2000 RPM springs. The 1000 RPM spring produced the lowest temperature (76.5 ℃), followed by 1500 RPM (79.7 ℃) and 2000 RPM (84.1 ℃), indicating a correlation between spring stiffness and operating temperature.*

Keywords - *CVT Spring, Torque, Power, Fuel Consumption, Component Wear.*

INTRODUCTION

Two-wheeled vehicles, especially motorcycles, have become a popular choice in society due to their fuel efficiency and flexibility in reaching various locations. Besides being a means of personal transportation, motorcycles also play an important role in the commercial sector and are a source of income for some people. Automatic scooters, with their automatic transmission system, offer higher riding comfort in urban areas compared to manual motorcycles, allowing riders to focus more on the road without the hassle of manually shifting gears [1]. This advantage makes automatic scooters highly suitable for use in heavy traffic conditions often found in urban areas.

However, behind this convenience, the need for more optimal performance for daily activities is becoming increasingly pressing. Many automatic scooter riders feel dissatisfied with the acceleration and engine power of standard engines when riding on city streets or facing inclines [2]. To address this need, engine performance modifications, particularly to the Continuously Variable Transmission (CVT) system, have become a popular choice. One common modification is replacing the CVT spring with higher specifications, for example, from the standard 1000 RPM spring to an aftermarket 1500 RPM or 2000 RPM spring [3].

Although CVT spring modifications are widely performed, it is important to remember that selecting the wrong spring specifications can lead to negative consequences. Without careful calculation and understanding, using an unsuitable CVT spring can result in undesirable impacts such as accelerated wear of CVT components (e.g., V-belt, rollers, and slider piece), suboptimal engine performance, or even damage to other engine components [4]. This phenomenon highlights an urgent need for accurate empirical data to guide riders and mechanics in making modification decisions [5].

Therefore, the primary intent and purpose of this research is to systematically investigate and deeply analyze the specific impact of varying CVT spring stiffness levels (1000 RPM, 1500 RPM, and 2000 RPM) on various performance aspects of the Honda Beat Deluxe motorcycle [6]. This study aims to measure and compare the changes in torque and power produced, analyze the influence of spring variations on fuel consumption rates under different load conditions, and evaluate the wear patterns on vital CVT components. Furthermore, this research will also investigate the impact of CVT spring variations on engine operational temperature [7].

Through a quantitative approach and controlled testing, this research strives to generate valid and accurate empirical data. This data is expected to serve as a strong scientific basis for riders, mechanics, and even manufacturers to make more informed decisions regarding CVT spring configurations [8]. The ultimate goal is to achieve an optimal balance between desired performance enhancement, component durability, and fuel efficiency, thereby contributing to the development of more responsible and sustainable motorcycle modification practices [9].

METHOD

This section presents in detail the research design and procedures used, with the primary goal of ensuring the transparency and replicability of this study. The research methodology is systematically designed so that readers, particularly other researchers, can follow each step identically to validate or expand upon the findings presented herein [10]. This process begins with a clear topic identification and a well-defined formulation of the research problem, which are essential for understanding the core issue regarding the influence of CVT spring variations on the performance of a Honda Beat Deluxe motorcycle. The research objectives and study limitations are explicitly established in this initial phase to focus the investigation. Subsequently, a comprehensive literature review is conducted to gather relevant information and references from various reliable sources, including scientific journals and current publications [11].

The testing preparation phase (Experimental Preparation) is a crucial step that guarantees the readiness of all components for accurate and replicable experimentation. In this stage, all necessary equipment and materials are meticulously prepared. The main equipment used in the testing includes: (a) one unit of a standard Honda Beat Deluxe motorcycle that has been verified to be in optimal operational condition, (b) one set of adequate specialized tools or wrenches for precise disassembly and assembly of CVT components, (c) one unit of an on-wheel chassis Dynotest machine that has been calibrated according to industry standards to ensure measurement accuracy, and (d) three variations of CVT springs to be tested, namely the standard spring (1000 RPM), the racing spring (1500 RPM), and the racing spring (2000 RPM), all of which are confirmed to be in new condition and meet manufacturer specifications [12]. The testing process is shown in Figure 1.

Figure 1. Beat Deluxe motorbike process on the dynotest machine

The testing implementation (Experimental Implementation) is carried out methodically using an on-wheel chassis Dynotest machine. Each CVT spring (1000 RPM, 1500 RPM, and 2000 RPM) is tested sequentially and separately on the same Beat Deluxe motorcycle. To ensure data consistency and comparability between tests, each spring variation is tested after the motorcycle engine has reached a completely cold condition (engine temperature close to ambient temperature, for example, after being left to cool for at least 30 minutes). This cooling procedure is crucial to eliminate residual heat effects from previous tests that could influence the results. Important performance data such as torque (in Newton meters, Nm), power (in Horsepower, HP), and engine speed (in Revolutions Per Minute, RPM) are automatically recorded and displayed on the Dynotest monitor screen. In addition, supplementary parameters such as fuel consumption (liters per kilometer, l/km) are also carefully collected and recorded [13].

The final stage of the research is comprehensive data analysis (Data Analysis). The collected quantitative data are processed and analyzed using statistical software and comparative methods to identify trends, relationships, and the statistical significance of each finding. This analysis process is designed to provide an objective interpretation of the data, allowing readers to understand the basis of the conclusions drawn. Based on the results of this analysis, valid and measurable conclusions are formulated to answer the research questions [14]. Furthermore, relevant suggestions are developed to guide future research or practical applications. Finally, all research results and analysis are presented in a systematic, detailed, and organized written thesis report, making it easy to understand, verify, and evaluate by the scientific community [15].

Result and Discussion

This research examines the impact of changes in the stiffness level of the CVT spring on the torque and power of a Beat Deluxe motorcycle. The testing was conducted using 15-gram rollers and a rider load of 68 kg. The results show performance differences between the standard spring (1000 RPM) and springs with stiffness levels of 1500 RPM and 2000 RPM. The data obtained from this series of tests is then visualized in the form of a graph as in Figure 2 below:

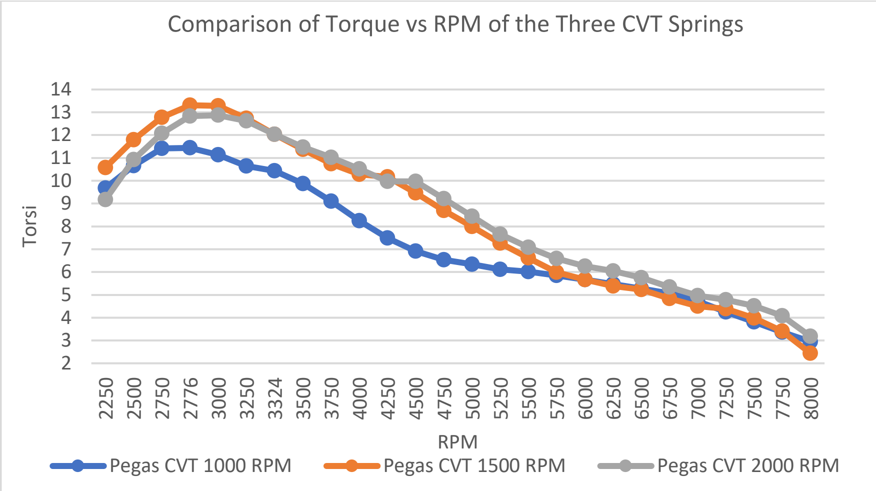

Figure 2. Torque to RPM Comparison Chart With Rider Weight 68 KG

Based on the test results, there was an increase in torque as the engine speed increased from 2250 RPM to 3000 RPM. This is likely because within that RPM range, the engine is able to achieve optimal fuel combustion, resulting in higher compression. This condition allows the air-fuel mixture to fill the cylinder effectively for combustion. However, when the engine speed exceeds 3000 RPM and reaches 8000 RPM, a decrease in torque occurs. This is indicated by the throttle body's inability to supply the required air to the cylinders, leading to a reduction in combustion efficiency.

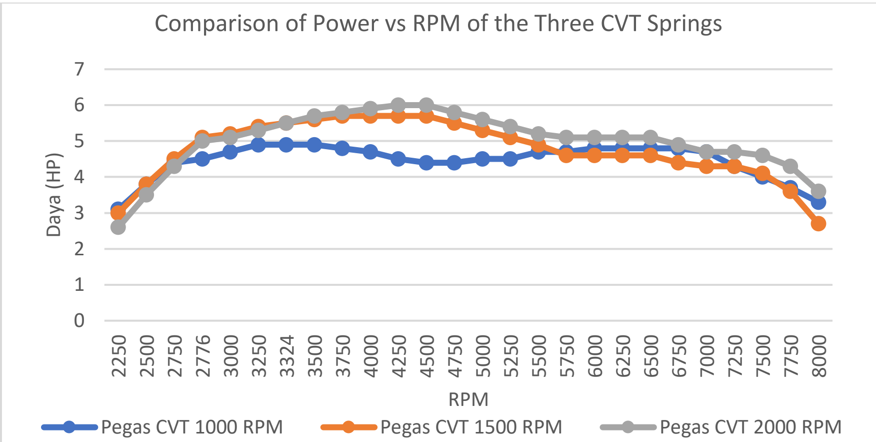

Figure 3. Power to RPM Comparison Chart With Rider Weight 68 KG

The relationship between power and engine speed indicates that the faster the engine speed and the higher the torque produced, the greater the power will be, up to its peak. Power will decrease after reaching its peak, even if the engine speed continues to increase. This occurs because power is the result of torque and engine speed.

The next test was conducted with a 134 kg rider load using 15-gram rollers. The results, summarized in [missing information - likely a table or figure reference], show the performance differences between the standard spring spring (1000 RPM) and springs with stiffness levels of 1500 RPM and 2000 RPM.

The data obtained from this series of tests was then visualized in graphical form as follows:

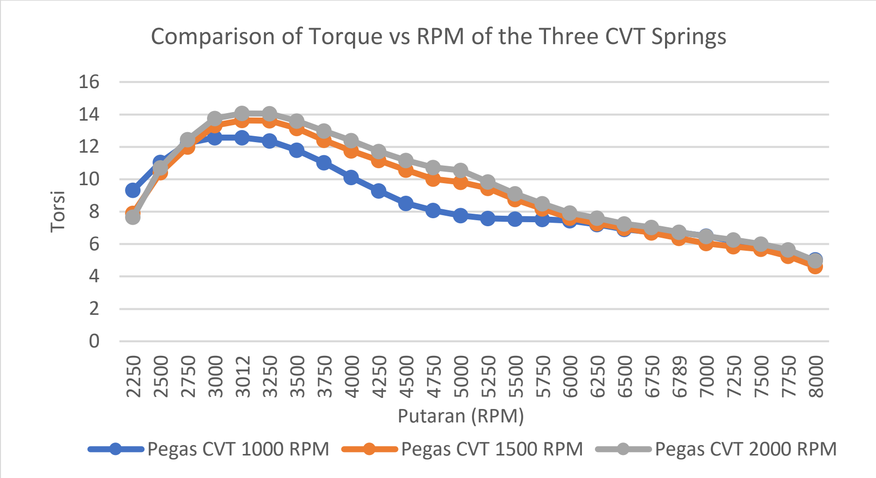

Figure 4. Comparison of Torque vs RPM of the Three CVT Springs

Based on the test results, there was an increase in torque as the engine speed increased from 2250 RPM to 3000 RPM. This is suspected to be because within that RPM range, the engine is able to achieve optimal fuel combustion, resulting in higher compression. This condition allows the air-fuel mixture to fill the cylinder well for combustion. However, when the engine speed exceeded 3000 RPM and reached 8000 RPM, there was a decrease in torque. This is indicated by the throttle body's inability to supply the required air to the cylinder, which results in a decrease in combustion efficiency.

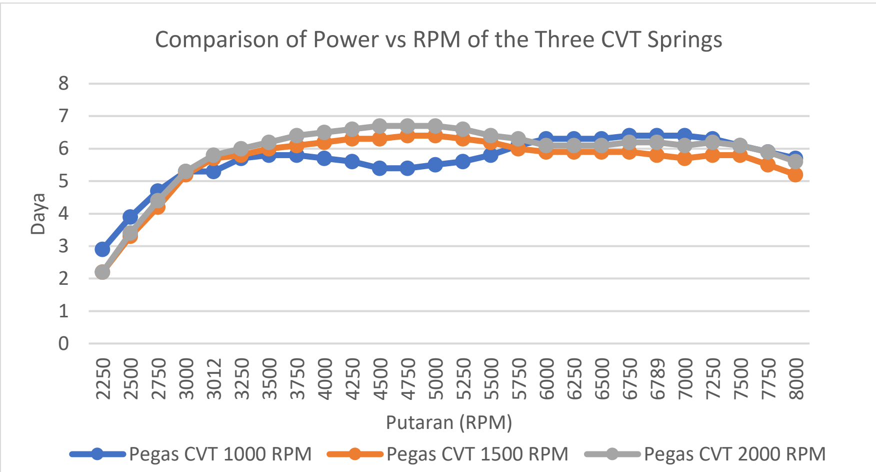

Figure 5. Comparison of Power vs RPM of The Three CVT Spirngs

The relationship between power and engine speed shows that the faster the engine speed and the higher the torque produced, the greater the power will be, up to the peak power point. Power will decrease after reaching its peak, even if the engine speed continues to increase. This occurs because power is the result of torque and engine speed.

The performance test results, when compared to theoretical calculations, show a difference in values. This difference, assuming a driver weight of 68 kg, resulted in a graph displaying the power difference between CVT springs. Below is a graphical representation of the theoretical power comparison for each CVT spring.

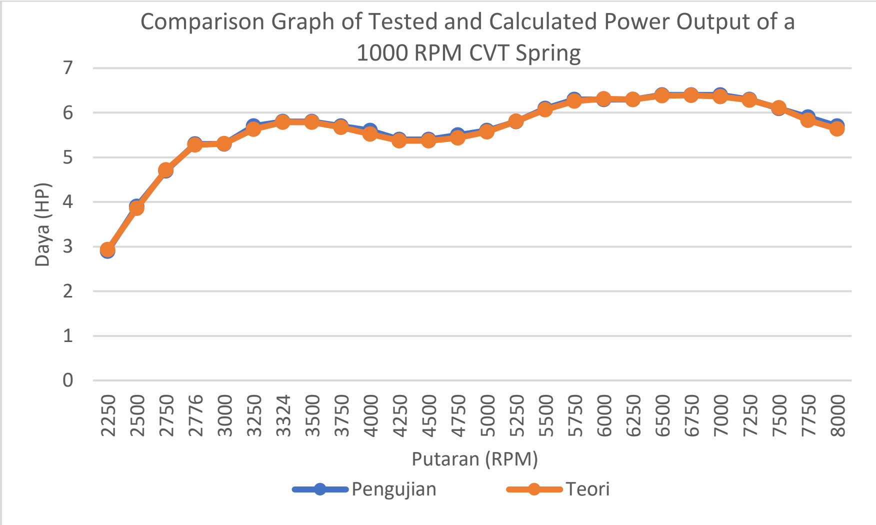

Figure 6. Comparison Graph of Tested and Calculated Power Output of a 1000 RPM CVT Spring

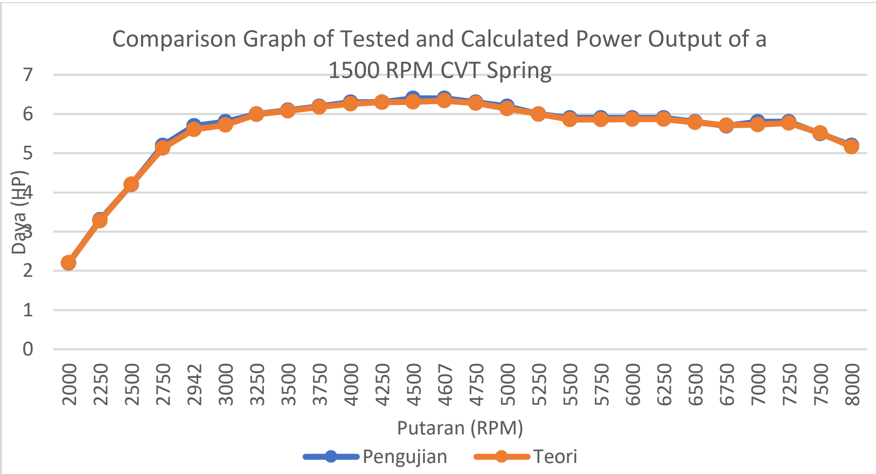

Figure 7. Comparison Graph of Tested and Calculated Power Output of a 1500 RPM CVT Spring

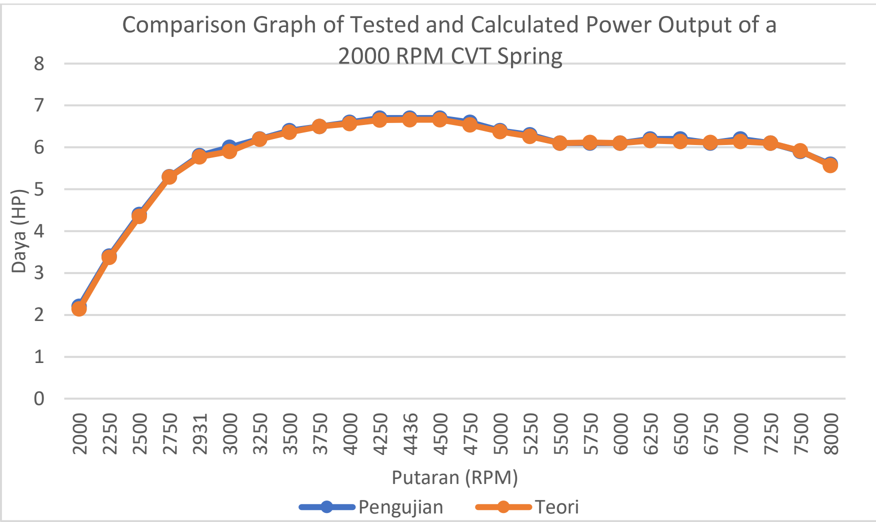

Figure 8. Comparison Graph of Tested and Calculated Power Output of a 2000 RPM CVT Spring

The power comparison between experimental results and calculations is shown in the displayed graph. It can be concluded that there is a difference, but the value is very small. The accuracy of the Dynotest machine, based on ISO 1585 standards, has a tolerance limit of ± 1%.

The test results of a 134 kg driver's weight on performance, compared to theoretical calculations, show a difference in values. This difference, below is a graphical representation of the theoretical power comparison of each CVT spring.

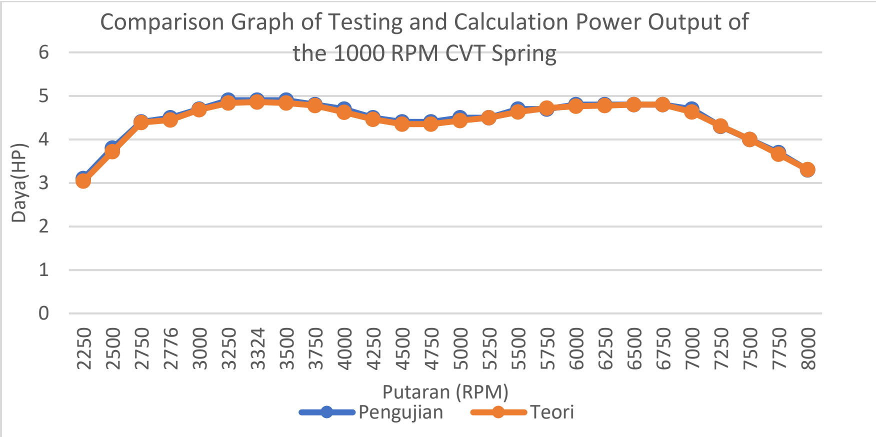

Figure 9. Comparison Graph of Testing and Calculation Power Output of the 1000 RPM CVT Spring

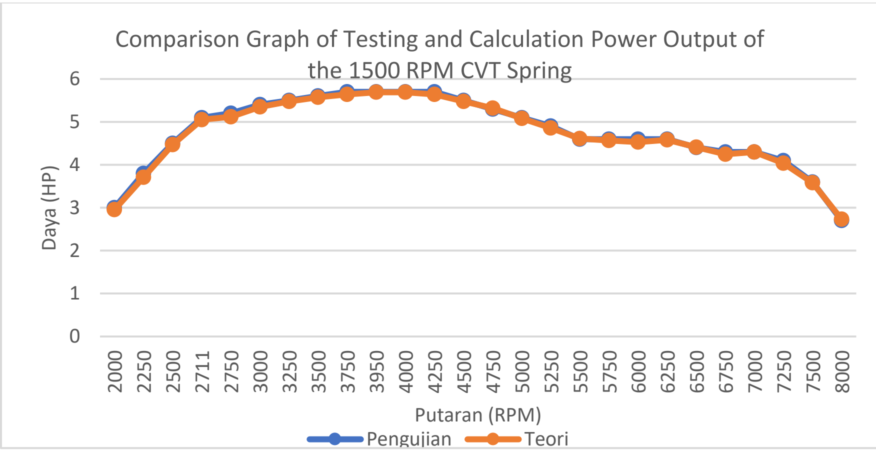

Figure 20. Comparison Graph of Testing and Calculation Power Output of the 1500 RPM CVT Spring

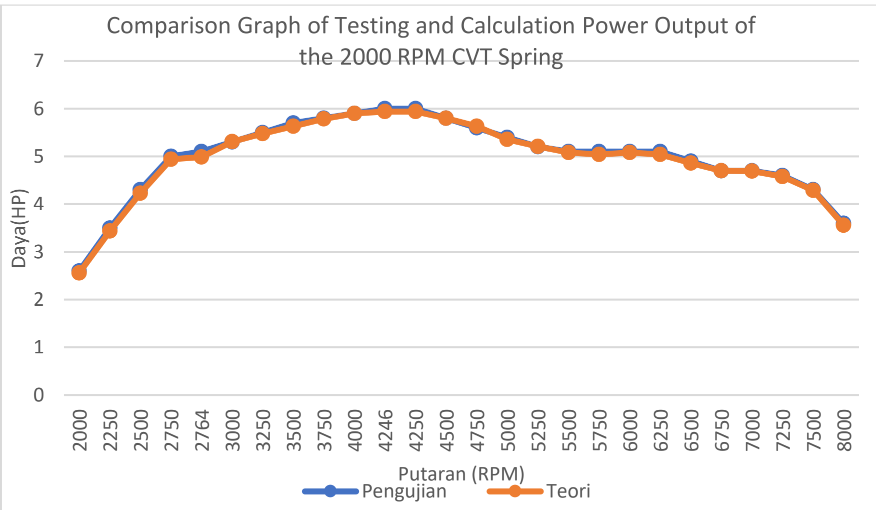

Figure 31. Comparison Graph of Testing and Calculation Power Output of the 2000 RPM CVT Spring

The power comparison between the experimental results and the calculation results is shown in the displayed graph. It can be concluded that there is a difference, but the value is very small. The accuracy of the Dynotest machine, based on ISO 1585 standards, has a tolerance limit of ± 1%.

Fuel Consumption Test Results

The fuel consumption test, conducted through a simulation of highway conditions on a dyno test machine with a rider weight of 68 kg, is followed by a graph comparing the fuel consumption of the three CVT springs.

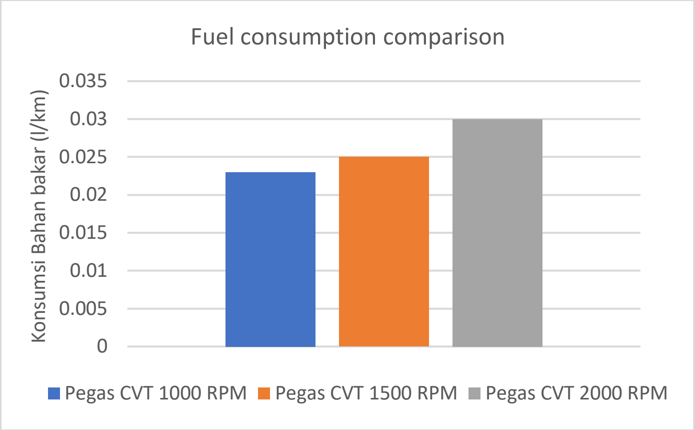

Figure 42. Fuel consumption comparison

The results of three experiments show that the stiffness of the CVT spring significantly affects fuel efficiency, as seen in the consumption differences across each spring variation. The accompanying bar chart indicates that the 1000 RPM (standard) spring resulted in the lowest fuel consumption (0.018 l/km) and the longest travel distance (13.5 km). Meanwhile, the 1500 RPM spring recorded a consumption of 0.019 l/km with a travel distance of 12.7 km. The 2000 RPM spring, the stiffest, showed the highest consumption (0.021 l/km) and the shortest travel distance (11.5 km).

All experiments used the same fuel volume, which was 250 ml. The consumption difference between each spring is relatively small, but the 2000 RPM spring consistently used more fuel due to the faster piston action.

In the testing, the 2000 RPM CVT spring exhibited stiff characteristics, causing the motorcycle to experience a momentary delay during initial acceleration. This stiffness triggered increased fuel consumption due to faster piston action and a greater fuel supply to the combustion chamber. Additionally, this spring forced the CVT clutch lining to work harder to drive the wheels.

Of the three springs tested, the 1000 RPM (standard) CVT spring resulted in the lowest fuel consumption, consistent with the performance it produced. The test results indicate that the 1500 RPM CVT spring provides an optimal balance between increased performance and fuel consumption, although its fuel consumption is higher than the 1000 RPM CVT spring.

The fuel consumption testing, conducted through simulations of highway conditions on a dyno test machine with a rider weight of 134 kg, is followed by a graph comparing the fuel consumption of the three CVT springs.

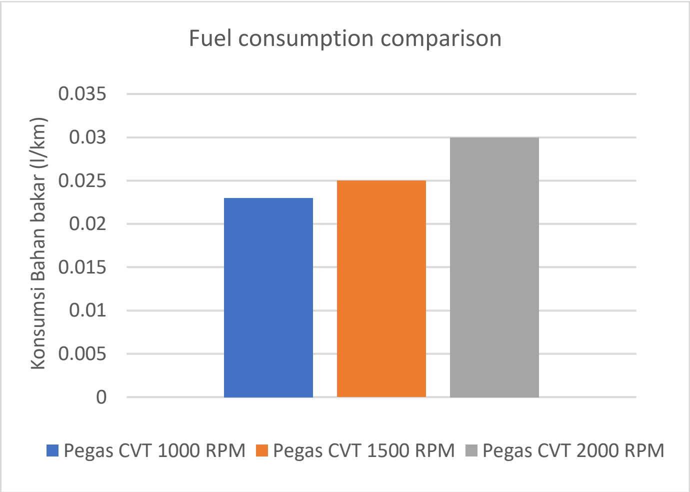

Figure 53. Fuel consumption comparison

Results from three trials indicated that the stiffness of the CVT spring significantly affects fuel efficiency, as evident from the consumption differences across each spring variation. The accompanying bar chart shows that the 1000 RPM (standard) spring resulted in the lowest fuel consumption (0.023 l/km) and the longest travel distance (10.6 km). Meanwhile, the 1500 RPM spring recorded a consumption of 0.025 l/km with a travel distance of 9.8 km. The 2000 RPM spring, the stiffest, showed the highest consumption (0.030 l/km) and the shortest travel distance (8.2 km). All trials used the same fuel volume of 250 ml. The consumption difference between each spring was relatively small, but the 2000 RPM spring consistently used more fuel due to faster piston action.

During testing, the 2000 RPM CVT spring exhibited stiff characteristics, causing the motorcycle to experience a momentary delay during initial acceleration. This stiffness triggered increased fuel consumption due to faster piston action and a greater fuel supply to the combustion chamber. Additionally, this spring forced the CVT clutch lining to work harder to drive the wheels.

Of the three springs tested, the 1000 RPM (standard) CVT spring yielded the lowest fuel consumption, consistent with its performance. The test results indicated that the 1500 RPM CVT spring provided an optimal balance between increased performance and fuel consumption, although its fuel consumption was higher than the 1000 RPM CVT spring.

Comparison of Wear on V-Belt, Roller, and Slider Piece

1. **V-Belt** Results from three trials indicated that the stiffness of the CVT spring significantly affects wear on the V-Belt, as evident from the wear differences across each spring variation. The 1000 RPM (standard) spring, after 1500 km of use, showed approximately 0.1 mm of wear on both the outer and inner parts of the V-Belt. Meanwhile, the 1500 RPM spring, after 1500 km of use, showed approximately 0.2 mm of wear on both the outer and inner parts of the V-Belt. The 2000 RPM spring, the stiffest, showed 0.2 mm of wear on the outer part of the V-Belt and 0.4 mm on the inner part.

During testing, the 2000 RPM CVT spring showed the most wear compared to the 1000 and 1500 springs because the stiffest spring caused a higher friction force on the V-Belt. The 1000 RPM (standard) CVT spring resulted in the lowest wear, consistent with its performance. The test results indicated that the 1500 RPM CVT spring provided an optimal balance between increased performance and V-Belt wear, although the V-Belt wear was higher than that of the 1000 RPM CVT spring.

2. **Roller** Results from three trials indicated that the stiffness of the CVT spring slightly affected wear on the rollers, as evident from the wear differences across each spring variation. The image shows that the 1000 RPM (standard) and 1500 RPM springs, after 1500 km of use, showed no wear on their surfaces. Meanwhile, the 2000 RPM spring, after 1500 km of use, showed 0.1 mm of wear.
3. **Slider Piece** Results from three trials indicated that the stiffness of the CVT spring significantly affects wear on the slider piece, as evident from the wear differences across each spring variation. The image shows that the 1000 RPM (standard) spring, after 1500 km of use, showed 0.3 mm of wear. Meanwhile, the 1500 RPM spring, after 1500 km of use, showed approximately 0.4 mm of wear. The 2000 RPM spring, the stiffest, showed 0.6 mm of wear on the slider piece.

During testing, the 2000 RPM CVT spring showed the most wear compared to the 1000 and 1500 springs because the stiffest spring caused a higher friction force on the slider piece. The 1000 RPM (standard) CVT spring resulted in the lowest wear, consistent with its performance. The test results indicated that the 1500 RPM CVT spring provided an optimal balance between increased performance and slider piece wear, although the slider piece wear was higher than that of the 1000 RPM CVT spring.

Comparison of Engine Temperature Results from three trials indicated that the stiffness of the CVT spring significantly affects the engine temperature, as evident from the temperature differences across each spring variation. The image shows that the 1000 RPM (standard) spring, after 25 km of use, had a temperature of 76.5 °C. Meanwhile, the 1500 RPM spring, after 25 km of use, had a temperature of 79.7 °C. The 2000 RPM spring, the stiffest, showed a temperature of 84.1 °C.

During testing, the 2000 RPM CVT spring showed the highest temperature compared to the 1000 and 1500 springs because the stiffer CVT spring makes the opening of the secondary pulley slower. This forces the engine to work harder to achieve the desired RPM. The 1000 RPM (standard) CVT spring resulted in the lowest temperature, consistent with its performance. The test results indicated that the 1500 RPM CVT spring provided an optimal balance between increased performance and engine temperature increase, although the engine temperature was higher than that of the 1000 RPM CVT spring.

Overall Test Result Analysis In terms of torque, the lowest engine speed was produced by the 1000 RPM spring, followed by the 1500 RPM, and the highest by the 2000 RPM. However, this was directly proportional to the torque value produced, where the 2000 RPM spring produced the highest torque, which was 14.06 Nm. The same was also seen in terms of power, where the 2000 RPM spring produced the highest power, which was 6.7 HP.

However, this performance increase also comes with consequences. Fuel consumption was seen to increase with the increase in spring RPM. In addition, wear on the V-belt, roller, and slider piece was also seen to be higher on springs with higher RPM. Engine temperature also experienced a significant increase with the 2000 RPM spring.

There is a visible trend of increasing performance with the increase in CVT spring specifications. In terms of torque, although the engine speed (RPM) at torque did not show a consistent pattern, the highest torque value (Nm) was achieved by the 1500 RPM spring, which was 13.31 Nm. However, in terms of power, there was a clear increase in engine speed (RPM) at power, where the 2000 RPM spring produced the highest engine speed, which was 4250 RPM, as well as the highest power (HP), which was 6 HP. This indicates that springs with higher specifications tend to produce greater power at higher engine speeds.

However, this performance increase also comes with consequences. Fuel consumption was seen to increase with the increase in CVT spring specifications, where the 2000 RPM spring had the highest fuel consumption, which was 0.03 l/km. In addition, wear on the V-belt and slider piece was also seen to increase significantly on springs with higher specifications. V-belt wear reached 0.4 mm and slider piece wear reached 0.6 mm on the 2000 RPM spring. Engine temperature also experienced a significant increase, reaching 84.1 degrees Celsius on the 2000 RPM spring. Overall, this table shows that using CVT springs with higher specifications can improve motorcycle performance, but with the consequence of more wasteful fuel consumption, faster component wear, and higher engine temperatures. The selection of the appropriate CVT spring needs to be adjusted to the rider's needs and preferences, as well as considering the balance between performance and component durability.

CONCLUSION

Based on a series of comprehensive tests regarding the influence of CVT spring variations on the performance of the Beat Deluxe motorcycle, several significant findings were identified. In terms of torque, tests conducted with a 68 kg rider showed that at an engine speed of 3000 RPM, there was a progressive increase in torque values corresponding to the increase in CVT spring specifications, namely 12.57 Nm for the 1000 RPM spring, 13.61 Nm for the 1500 RPM spring, and peaking at 14.04 Nm for the 2000 RPM spring. A similar trend was also observed in tests with a heavier rider load of 134 kg, where the torque values produced at the same engine speed were 11.42 Nm (1000 RPM), 13.28 Nm (1500 RPM), and 12.84 Nm (2000 RPM), although there was a slight decrease for the 2000 RPM spring compared to the lighter load.

The increase in CVT spring specifications also positively correlated with power output. In tests with a 68 kg rider at 4000 RPM, the power produced sequentially was 5.7 HP (1000 RPM), 6.3 HP (1500 RPM), and 6.6 HP (2000 RPM). A similar pattern was also seen in tests with a 134 kg rider at the same engine speed, with power values of 4.7 HP, 5.7 HP, and 5.9 HP, respectively. However, this performance increase comes with consequences for fuel consumption. Road test simulations showed that fuel consumption tended to increase with the use of higher specification CVT springs, both for the 68 kg rider (0.018 l/km, 0.019 l/km, and 0.021 l/km for 1000, 1500, and 2000 RPM) and for the 134 kg rider (0.023 l/km, 0.025 l/km, and 0.030 l/km). Furthermore, the analysis of CVT component wear (V-Belt, roller, and slider piece) indicated that the use of the 1500 RPM spring potentially accelerates wear slightly more than the standard 1000 RPM spring, but the wear rate is still lower than that of the 2000 RPM spring. Finally, engine temperature measurements after traveling 25 km showed that the 1000 RPM spring produced the lowest operating temperature (76.5 °C), followed by the 1500 RPM spring (79.7 °C), and the 2000 RPM spring recorded the highest temperature (84.1 °C), indicating a correlation between spring stiffness and increased engine temperature due to the heavier work required to achieve the desired RPM. Overall, the 1500 RPM CVT spring offers an attractive compromise between a significant increase in performance and a relatively moderate impact on fuel consumption, component wear, and engine temperature increase.

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