



## Analysis of the Effect of Secondary Spring Stiffness on the Performance of Scoopy Motorcycles

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### ABSTRACT

*Continuously Variable Transmission (CVT) transmission system on automatic motorcycles has an important role in efficiently distributing engine power to the wheels. One of the main components in the CVT system is the secondary spring, which plays a role in regulating the back pressure of the secondary pulley to maintain belt tension in the power transfer process, the level of secondary spring stiffness can affect the characteristics of power transfer. This study aims to analyze the effect of the stiffness of the Dytona brand secondary spring with three variations of stiffness (1000 RPM, 1500 RPM, 2000 RPM) on the performance of the Honda Scoopy motorcycle. The method used is an experiment with a quantitative approach, where each variation of the secondary spring is tested using a BRT 50 LA dyno test machine to obtain data such as power, torque, acceleration and top speed. The test results show that the secondary spring with lower stiffness provides a faster initial response and is able to maintain the transmission ratio longer at high speeds. Meanwhile, the secondary spring with higher stiffness provides a greater power boost, but reduces top speed because the transmission ratio decreases faster. It can be concluded that the selection of secondary spring stiffness must be adjusted to the desired performance characteristics, whether to achieve maximum power or optimize acceleration efficiency and high speed. This finding can be used as a reference in modifying the CVT system to improve motorcycle performance, especially the Honda Scoopy.*

*Keywords: Secondary Spring, CVT, Performance, Dyno Test, Honda Scoopy.*

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### 1. Introduction

The development of automotive technology continues to advance, particularly in the two-wheeled vehicle sector. The Honda Scoopy utilizes an automatic transmission system known as Continuously Variable Transmission (CVT). According to Akhmadi et al. (2021), a CVT is a transmission system that simplifies the riding experience because it shifts automatically without the need for manual gear changes. Furthermore, Rifdarmon and Junaidi et al. (2023) define the CVT as a system that transfers power and force from the engine to the rear wheels using frictional principles, connecting the primary and secondary pulleys via a V-belt. The secondary spring is a critical component

of the CVT that significantly influences motorcycle acceleration (Rosid & Joko et al., 2023). This component functions to regulate the back pressure on the secondary pulley, ensuring the belt maintains adequate tension under various engine operating conditions.

Modifying the CVT system, specifically the secondary spring, is a common alternative chosen by motorcycle users to enhance vehicle performance. However, there is still limited academic reference specifically discussing the effect of secondary spring stiffness variations on motorcycle performance, particularly for the Scoopy model. This lack of data serves as the background for this study. An experimental study is required to determine the impact of varying secondary spring stiffness levels on

performance parameters such as power, torque, acceleration, and top speed.

The problem addressed in this study is: How do variations in secondary spring stiffness affect motorcycle performance, as characterized by the resulting power, torque, acceleration, and top speed? Based on this problem, the author limits the scope of the study as follows:

1. The research is conducted exclusively on the 2021 Honda Scoopy Prestige fuel-injection (FI) model.
2. The secondary spring variations are limited to three types from the Daytona brand: 1000 RPM, 1500 RPM, and 2000 RPM.
3. Performance parameters are measured using a dyno test, analyzing the power, torque, acceleration, and top speed for each secondary spring used.
4. Other CVT components, such as rollers, V-belts, and pulley housings, remain factory standard.

Accordingly, this study aims to analyze how the use of secondary spring variations with different stiffness levels affects the performance of the Honda Scoopy Prestige. Additionally, it aims to determine the most ideal secondary spring for daily use based on the dyno test results

### 1.1 Honda Scoopy Prestige

The Honda Scoopy is a scooter-type motorcycle manufactured by PT Astra Honda Motor



Figure 1. Honda Scoopy Prestige

#### 1.1.1 CVT (Continuously Variable Transmission) System

According to Akhmadi et al. (2021), the Continuously Variable Transmission (CVT) system is a type of automatic transmission in motor vehicles that utilizes a belt to produce smooth gear ratios. The operation of a CVT is based on the principle of centrifugal force, allowing vehicle acceleration to occur more stably and without shifting jolts. Furthermore, Made et al. (2008) state that the CVT automatic transmission system consists of a primary pulley and a secondary pulley connected by a V-belt.

### 1.2 Pulley Primer

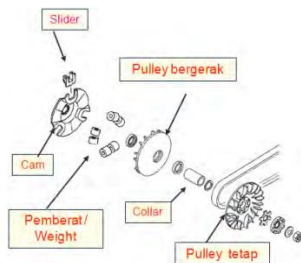


Figure 2. Primary Pulley Components

### 1.2.1 Primary Pulley Components

The primary pulley consists of the following components:

1. Fixed Sheave (Pulley Tetap): This component is permanently mounted to the primary pulley shaft and serves as the contact surface for the V-belt. It is equipped with cooling fins on its edge to help maintain a stable temperature within the CVT housing, preventing the belt from excessive wear and overheating.
2. Sliding Sheave (Pulley Bergerak): A primary pulley component that slides along the collar. It moves laterally (left and right) to adjust the primary pulley's operation. Its flexible mounting allows it to move closer to the fixed sheave, narrowing the gap between them to increase belt pressure and change the transmission ratio automatically. This component also serves as the roller housing.
3. Collar: Functions as a sleeve or track for the sliding sheave, allowing it to move smoothly during changes in the primary pulley's operation.
4. Weights / Rollers: These act as the actuators for the sliding sheave. When centrifugal force is generated by the engine's rotation, the rollers are thrown outward, pushing the sliding sheave.
5. Slider: Permanently mounted to the cam, the slider functions to dampen vibrations when the weights move within the sliding sheave.
6. Cam (Ramp Plate): Serves as the backplate or pivot to push the sliding sheave. Due to the tapered surface of the cam, the outward movement of the weights exerts pressure on the sliding sheave, forcing the belt toward the outer diameter of the pulley

### 1.3 V-Belt



Figure 3. V-Belt

V-Belt According to Sularso (1991:163), a V-belt is a type of power transmission component made of rubber with a trapezoidal cross-section. The V-belt is applied by wrapping it around pulleys that have grooves shaped like the letter "V." Furthermore, Nugraha and Ah Sulhan (2022) state that the V-belt is a critical engine component responsible for transmitting power and rotation from the driving motor to the driven device in systems where there is a specific distance between the two components.

### 1.4 Secondary Pulley

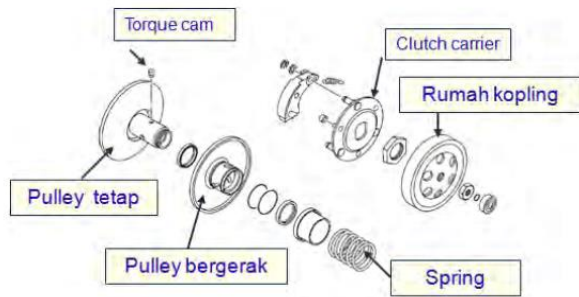


Figure 4. Secondary Pulley Components

#### 1.4.1 Secondary Pulley Components

The secondary pulley consists of several other components, as follows:

1. Sliding Sheave: The part of the secondary pulley that moves toward or away from the fixed sheave, following the pressure exerted by the belt and the secondary spring.
2. Fixed Sheave: This component does not change position; it serves as a balancer for the belt and provides a contact surface for one side of the belt.
3. Torque Cam: A component that regulates the movement of the sliding sheave based on changes in the engine ratio.
4. Clutch Carrier: The mounting base that holds the clutch shoes and is seated on the main shaft.
5. Clutch Housing (Clutch Bell): The part that encloses and provides a contact surface for the centrifugal clutch shoes. It is directly connected to the final gear and the rear wheel.
6. Secondary Spring: A helical spring located behind the sliding sheave. Its function is to provide back pressure to the sliding sheave as it opens or closes, maintaining belt stability and preventing slippage.

### 1.5 Secondary Spring

The secondary spring, also known as the driven spring (Akhmadi et al., 2021), is a vital component in the CVT system. Its functions include maintaining belt tension during the automatic transmission process to prevent slippage, regulating the opening speed of the secondary pulley so that the ratio shifting occurs smoothly and gradually, and balancing the centrifugal force from the rollers in the primary pulley to ensure the CVT system remains responsive to changes in engine rotation. The dimensions of this component are illustrated in Figure 5, which shows the dimensional parameters of the secondary spring.

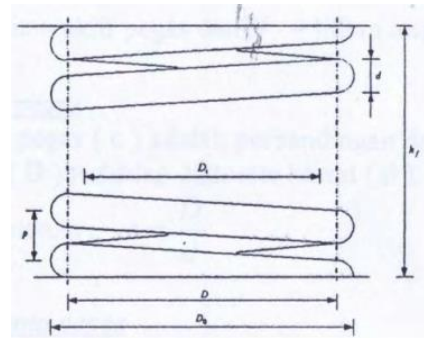


Figure 5. Secondary Spring Cross-Sectional Dimensions

Where:

$$D_o = D + d \text{ dan } D_i = D - d$$

$$k = \frac{G d^4}{8 D^3 N_a}$$

$$N_a = N - 2$$

Where :

- d : Wire diameter (mm)
- D<sub>o</sub> : Outer diameter of coil (mm)
- D : Mean diameter of coil (mm)
- D<sub>i</sub> : Inner diameter of coil (mm)
- k : Secondary spring constant (N/mm)
- G : Shear modulus of material (N/mm<sup>2</sup>)
- N<sub>a</sub> : Number of active coils
- N : Total number of coils
- P : Coil pitch (mm)

Table 1. Shear Modulus and Material Elasticity

Characteristics	Specifications
Material	SWOSC-V
Shear Modulus (G)	79.500 N/mm <sup>2</sup>
Modulus of Elasticity (E)	206.000 N/mm <sup>2</sup>

Main parameters such as the outer diameter (D<sub>o</sub>), inner diameter (D<sub>i</sub>), and free height (h<sub>f</sub>) of the secondary spring are used to determine the installation dimension constraints, which are based on the position or spatial clearance where the secondary spring is installed.

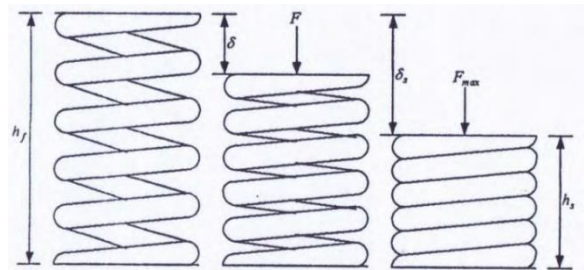


Figure 6. Secondary Spring Under Operating Load

As shown in Figure 6, the free height (h<sub>f</sub>) represents the height of the secondary spring in a no-load condition. When the secondary spring is subjected to pressure or a load (F), it undergoes compression or deflection (δ). If the operating pressure reaches its maximum value (F<sub>max</sub>) the height of the secondary spring will change to the solid height (h<sub>s</sub>). Based on these conditions, several relevant equations can be derived:

$$F = k \times \delta$$

$$h_f = h_s + \delta_s$$

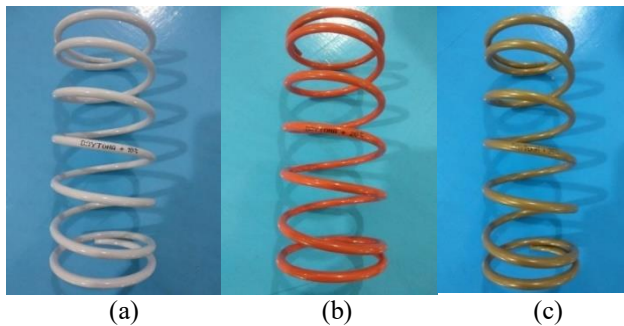
Where :

- F : Operating load (N)
- k : Spring constant (N/mm)
- $\delta$  : Operating deflection (mm)
- $h_f$  : Free height (mm)
- $h_s$  : Solid height (mm)
- $\delta_s$  : Deflection under maximum material load (mm)
- $F_{max}$  : Maximum operating load (N)

To determine the equation for the **spring constant (\$k\$)**, the following formula is used:

$$k = \frac{F}{\delta}$$

The spring constant is directly proportional to its operational limits, as illustrated in Figure 6. When the secondary spring reaches its solid height (\$h\_s\$), all the spring coils come into contact with one another, and the spring constant tends to approach the value of the material's modulus of elasticity. In this study, three types of secondary springs from the Daytona brand are utilized, specifically the 1000 RPM, 1500 RPM, and 2000 RPM variants (Table 2).

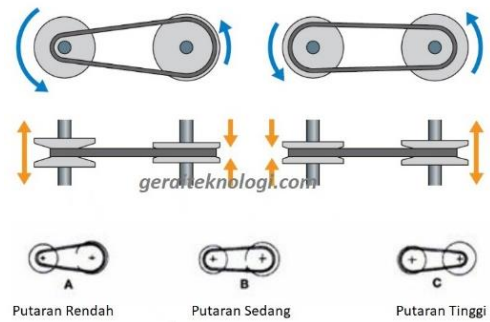


**Figure 7.** Secondary Spring: (a). 1000 RPM, (b). 1500 RPM, (c). 2000 RPM

**Table 2.** Specifications Secondary Spring 1000-1500-2000 RPM

Secondary Spring	1000 RPM	1500 RPM	2000 RPM
Color	Putih	Orange	Gold
Coil Wire Diameter (d)	4,40 mm	4,60 mm	4,80 mm
Material	SWOSC-V	SWOSC-V	SWOSC-V
Coil Outer Diameter (D <sub>o</sub> )	57,60 mm	57,50 mm	57,20 mm
Coil Inner Diameter (D <sub>i</sub> )	48,80 mm	48,50 mm	48 mm
Mean Coil Diameter (D)	53,2 mm	52,9 mm	52,4 mm
Free Height (h <sub>f</sub> )	125,30 mm	125 mm	124,50 mm
Number of Active Coils (N <sub>a</sub> )	5	5	5

### 1.5.1 Operating Principle



**Figure 8.** CVT Operating Principle

In a CVT system, the secondary spring works in conjunction with the secondary pulley to regulate the effective pulley diameter based on centrifugal force and spring tension. As engine speed increases, centrifugal force causes the primary pulley to close, forcing the V-belt to move to a larger diameter. In response, the secondary pulley opens to maintain V-belt tension, with variations in the secondary spring providing different levels of back pressure. A 1000 RPM secondary spring allows the secondary pulley to open more easily, resulting in a faster V-belt transition; this enables the motorcycle to accelerate more quickly from a standstill. A 1500 RPM secondary spring holds the secondary pulley with slightly more force, causing the ratio shift to occur at a higher RPM. This allows for an increased top speed without a significant loss of acceleration. A 2000 RPM secondary spring causes the secondary pulley to open more slowly, keeping the transmission in a lower ratio for a longer duration. This allows the engine to operate at high rotations within its maximum power band before the ratio shifts, thereby producing higher acceleration.

Several studies indicate that variations in the secondary spring can influence motorcycle performance, particularly in terms of power, torque, acceleration, and top speed. Research by Ulzan et al. (2025) states that variations in CVT rollers and springs can affect the torque, power, acceleration, and top speed of a motorcycle. Permana and Winarno (2020) demonstrated that variations in roller weight and sliding sheave spring constants significantly affect torque, power, and fuel consumption. Furthermore, research by Rosid and Joko et al. (2023) showed that using a standard drive face and clutch weight set produces more stable torque and power compared to the TDR brand.

### Honda Scoopy Motorcycle Specifications

**Table 3.** Honda Scoopy Prostage 2021 Specifications

Characteristics	Specifications
Engine Type	4-Stroke, SOHC, eSP, Air-Cooled
Fuel System	PGM-FI (Programmed Fuel Injection)
Displacement	109.5 cc
Bore x Stroke	47.0 x 63.1 mm

Transmission Type	Automatic, V-Matic
Compression Ratio	10.0 : 1
Maximum Power	6.6 kW (9.0 PS) / 7,500 rpm
Maximum Torque	9.3 Nm (0.95 kgf.m) / 5,500 rpm

- Motorcycle Type (Honda Scoopy Prestige 2021)
- Vehicle Condition (Standard/Stock)
- Fuel Type (Pertalite RON 90)
- Test Operator (the same individual for all tests)

## 2. Methodology of Research

### 2.1 Research Flowchart

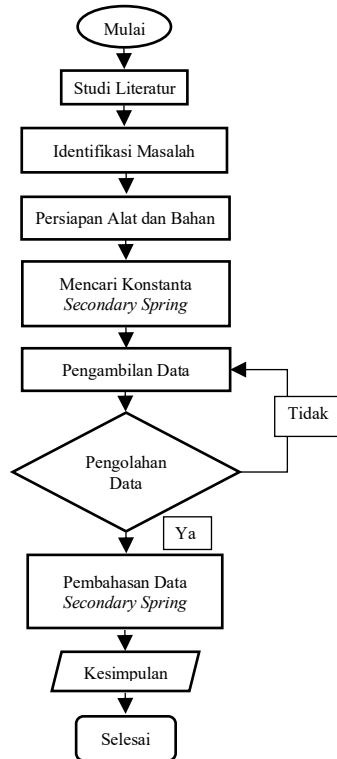


Figure 9. Research Flowchart

### 2.2 Research Design

In this study, the researcher conducted experiments using three variations of Daytona secondary spring stiffness: 1000 RPM, 1500 RPM, and 2000 RPM. The objective was to determine how the stiffness of the secondary spring influences the performance of a Honda Scoopy Prestige motorcycle. Each secondary spring variation was tested under uniform engine and environmental conditions to eliminate confounding factors. To measure vehicle performance quantitatively, the researcher utilized a BRT 50 LA dyno test machine

### 2.3 Research Variables

1. Independent Variable (X)
  - Secondary Spring Stiffness (1000 RPM, 1500 RPM, 2000 RPM)
2. Dependent Variable (Y)
  - Power
  - Torque
  - Acceleration
  - Top Speed
3. Control Variables

### 2.4 Research Location and Timeline

This study was conducted at the Mechanical Engineering Department of the University of Merdeka Malang. The data collection for Secondary Spring Stiffness was carried out at the Manufacturing Process Laboratory, Department of Mechanical Engineering, University of Merdeka Malang. The motorcycle performance data were obtained using a BRT 50 LA Dyno Test machine at the MD\_GARAGE workshop, North Gebuk, Wonorejo, Lawang. The entire experimental phase and testing activities took place from May to June 2025

### 2.5 Tools and Materials

#### 2.5.1 Tools

39 x 41 mm CVT Clutch Nut Spanner



Figure 10. 39 x 41 mm CVT Clutch Nut Spanner

Vernier Caliper



Figure 11. Vernier Caliper

8 mm T-Wrench



Figure 12. 8 mm T-Wrench

5 mm Hex Key



Figure 13. 5 mm Hex Key

Dyno Test BRT 50 LA



Figure 14. Dyno Test BRT 50 LA

Digital Scale



Figure 15. Digital Scale

Secondary Spring Test Load



Figure 16. Secondary Spring Test Load

Impact



Figure 17. Impact

19 mm Socket



Figure 18. 19 mm Socket

2.5.2 Materials

Honda Scoopy Prestige



Figure 19. Honda Scoopy Prestige

Secondary Spring

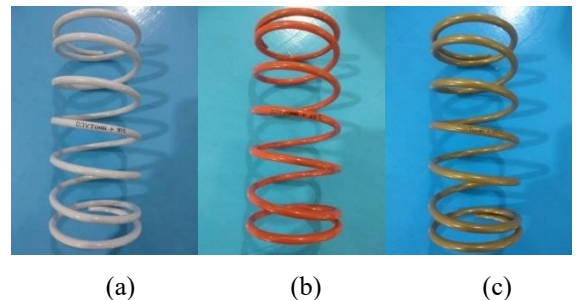


Figure 20. Secondary Spring: (a). 1000 RPM, (b). 1500 RPM, (c). 2000 RPM

2.6 Secondary Spring Testing

This test was conducted to determine the stiffness value of each Daytona Secondary Spring. Each test followed a consistent method to ensure the reliability of the results. The steps for testing the Secondary Spring are as follows:

1. Prepare all necessary tools and materials.
2. Measure the initial dimensions of the Secondary Spring, specifically the free length, using a vernier caliper.
3. Position the Secondary Spring vertically between two plates.
4. Apply a specific load to the Secondary Spring until it is compressed.
5. Measure the final dimensions of the Secondary Spring while under compression using a vernier caliper.
6. Calculate the Secondary Spring constant.
7. Finish.

2.7 Dyno Test Procedure

The dyno test machine is used to measure motorcycle performance quantitatively. Each Secondary Spring variation is tested three times to obtain an accurate average value. The steps for the dyno test procedure are as follows:

1. Prepare all necessary tools and materials.
2. Remove the CVT cover and the secondary components.

3. Replace the Secondary Spring according to the specific variation.
4. Ensure all components are installed according to the Standard Operating Procedure (SOP).
5. Position the motorcycle on the dyno test machine and secure it using ratchet track belts.
6. Conduct the dyno test in accordance with the workshop's SOP to collect performance data.
7. Finish.

### 3. Result and Discussion

#### 3.1 Theoretical Testing

The secondary spring is calculated theoretically using the data from Table 1 and Table 2 with the spring element formula as follows:

$$k = \frac{G d^4}{8 D^3 N_a}$$

Where:

- k : Spring constant (N/mm)
- d : Wire diameter (mm)
- D : Mean coil diameter (mm)
- N<sub>a</sub> : Active coils
- G : Shear modulus of material (N/mm<sup>2</sup>)

Calculation :

$$k = \frac{G d^4}{8 D^3 N_a} = \frac{79.500 \times 4,4^4}{8 \times 53,2^3 \times 5} = 4,94 \text{ N/mm}$$

**Table 4.** Theoretical Spring Constant Calculation Results

Variation	d (mm)	G (N/mm <sup>2</sup> )	D (mm)	N <sub>a</sub>	k (N/mm)
1000 RPM	4,4	79.500	53,2	5	4,94
1500 RPM	4,6	79.500	52,9	5	6,01
2000 RPM	4,8	79.500	52,5	5	7,33

#### 3.2 Manual Testing



**Figure 21.** (a) Manual secondary spring testing (b) Vernier caliper

The secondary spring was tested manually using a simple experimental method, which involved applying a load to the secondary spring. The length of the secondary spring was measured before loading, as shown in Table 2, and during loading, as shown in Table 5.

**Table 5.** Manual Testing Data

Variation	Manual Testing Data		
	1	2	3
1000 RPM	107,1	105,9	106
1500 RPM	107,24	107,9	107,68
2000 RPM	108,26	108,48	107,96

In calculating the spring constant (k) in the simple test, the following formula is used:

$$k = F/\delta$$

Where:

- k : Spring constant (N/mm)
- δ : Deflection due to load hf<sub>0</sub> (Table 2) - hf<sub>1</sub> (Table 5) (mm)

F : Working load 7,3kg (F = 7,3 x 9,81 = 71,61 N)

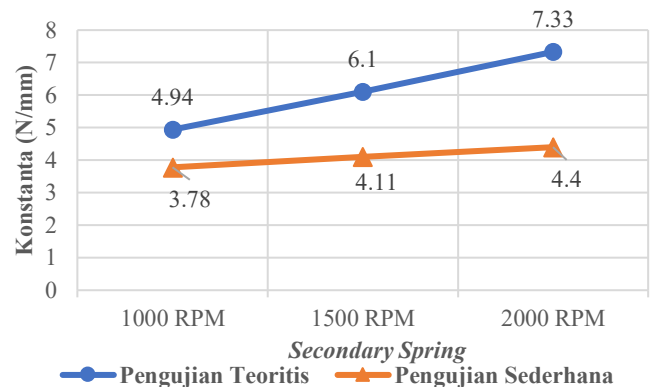
Calculation:

$$k = \frac{F}{\delta} = \frac{71,61}{18,2} = 3,93 \text{ N/mm}$$

**Table 6.** Results of Spring Constant Calculations Using Simple Experimentation

Variation	Spring Constant (N/mm)			Average
	1	2	3	
1000 RPM	3,93	3,69	3,71	3,78
1500 RPM	4,03	4,18	4,13	4,11
2000 RPM	4,40	4,47	4,32	4,40

#### 3.3 Discussion of Theoretical and Simple Experimental Results



**Graph 1.** Relationship Between Manual and Theoretical Testing

Based on Graph 1, a consistent trend in stiffness values was observed, where the secondary spring constant tends to increase as the RPM increases. This indicates that the secondary spring can withstand a greater compressive force at higher ratings (Ilmy, 2018). The constant values from the simple experimental testing were selected for further use due to technical factors encountered during the process.

From the test data, the spring constant values for each secondary spring were obtained as follows: 3.78 N/mm, 4.11 N/mm, and 4.4 N/mm. In the subsequent discussion,

these constant values are used for the naming/classification of the secondary springs.

### 3.4 Results and Discussion: Dyno Testing

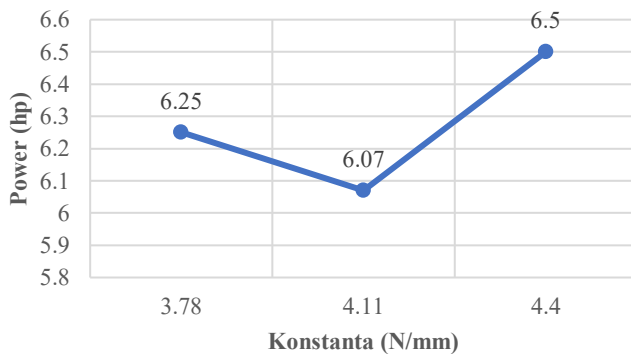


Figure 22. Dyno Testing

To determine the effect of secondary spring stiffness on the performance of the Honda Scoopy motorcycle, three tests were conducted for each secondary spring variation using a Dyno Test. The parameters evaluated include Power, Torque, Acceleration, and Top Speed. The following data was obtained from the dyno test result.

Table 7. Result Power pada Dyno Test

Spring Constant (N/mm)	Power (hp)			Average
	1	2	3	
3,78	5,88	6,38	6,50	6,25
4,11	5,81	6,27	6,13	6,07
4,40	5,85	6,75	6,85	6,5



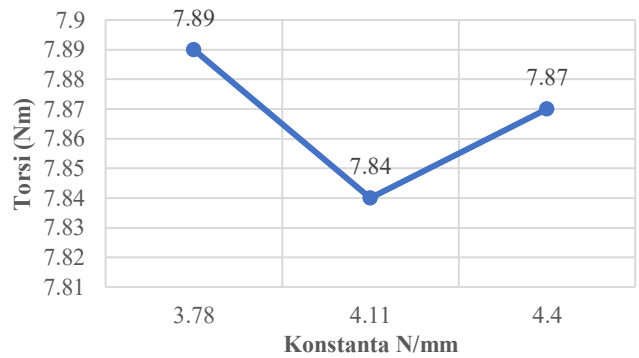
Graph 2. Relationship Between Power and Spring Constant

The test results in Graph 2 show that the secondary spring with a constant of 4.4 N/mm produces the highest power output, reaching 6.5 hp. Meanwhile, the lowest power was recorded from the secondary spring with a constant of 4.11 N/mm, which produced 6.07 hp.

Theoretically, increasing the stiffness of the secondary spring tends to increase the pressure on the secondary pulley, resulting in a more effective power transfer. However, the test results for the 4.11 N/mm spring show a dip. According to Ulzean, A., et al. (2025), performance improvements from stiffer springs are typically only optimal at high engine speeds (above 8,000 RPM). Furthermore, peak performance is not solely influenced by the spring, but also by the engine's torque characteristics. Consequently, the variation in power across different springs may occur non-linearly

Table 8. Torque Results from Dyno Testing

Spring Constant (N/mm)	Torque (Nm)			Average
	1	2	3	
3,78	7,50	8,04	8,14	7,89
4,11	7,45	8,09	7,98	7,84
4,4	7,32	8,10	8,18	7,87

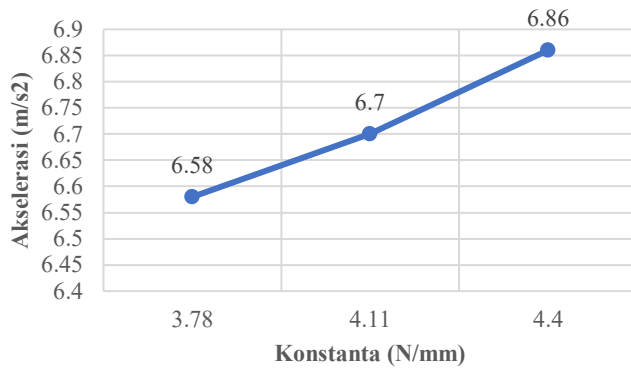


Graph 3. Relationship Between Torque and Constant"

The test results in Graph 3 show that the secondary spring with a constant of 3.78 N/mm produces the highest torque at 7.89 Nm. Meanwhile, the lowest torque is produced by the secondary spring with a constant of 4.11 N/mm, yielding 7.84 Nm. The test results in Graph 3 show a very small difference (< 0.05 Nm), indicating that the stiffness of the secondary spring does not have a significant effect on torque. This data is supported by the findings of (Shobirin, M, et al., 2025), which state that torque is more influenced by roller mass than secondary spring stiffness

Table 9. Acceleration Results on Dyno Test

Spring Constant (N/mm)	Acceleration (m/s <sup>2</sup> )			Average
	1	2	3	
3,78	6,35	6,65	6,74	6,58
4,11	6,16	6,02	6,91	6,7
4,4	6,56	6,56	7	6,86

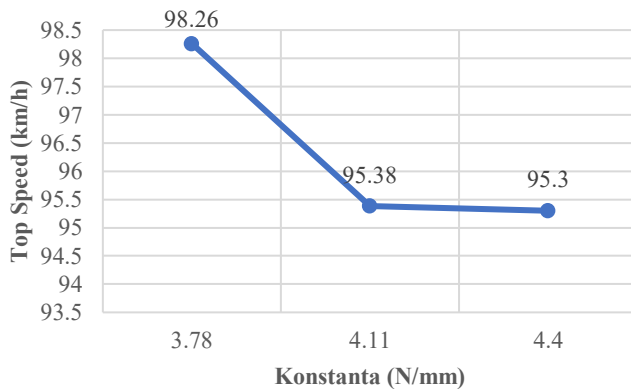


**Graph 4.** Relationship Between Acceleration and Constant

The test results in Graph 4 show that the secondary spring with a constant of 3.78 N/mm produces the highest acceleration at 6.58 m/s<sup>2</sup>. Meanwhile, the lowest acceleration is found in the secondary spring with a constant of 4.4 N/mm, which produces an acceleration of 6.86 m/s<sup>2</sup>. These test results are reinforced by (Fatahiah, et al., 2025), indicating that soft springs produce more responsive acceleration at low speeds because they maintain a low CVT ratio for a longer duration

**Table 10.** Top Speed Results on Dyno Test

Spring Constant (N/mm)	Top Speed (km/h)			Average
	1	2	3	
3,78	97,97	98,41	98,41	98,26
4,11	95,19	95,24	95,72	95,38
4,4	95,21	95,41	95,30	95,30



**Graph 5.** Relationship Between Top Speed and Constant

The test results in Graph 5 show that the secondary spring with a constant of 3.78 N/mm produces the highest top speed at 98.26 km/h. Meanwhile, the lowest top speed occurs with the secondary spring constant of 4.4 N/mm, which produces 95.3 km/h, slightly lower than the secondary spring with a constant of 4.11 N/mm that produces 95.38 km/h.

The test results in Graph 5 can be explained by the characteristics of a stiffer secondary spring, which tends to hold the secondary pulley earlier, causing the transmission ratio to change faster and the engine to rotate at higher RPM at initial speeds. However, at high speeds, a

secondary spring that is too stiff can limit the final CVT ratio, preventing the V-belt from reaching its maximum diameter on the primary pulley. Based on (Fatahiah, et al., 2025) and (Akbar et al., 2022), soft springs provide a longer CVT ratio at high speeds, allowing the V-belt to move fully to the maximum diameter on the primary pulley

**4. Conclusion**

Based on the test results and analysis using a dyno test machine on a Honda Scoopy Prestige motorcycle using variations of Daytona brand secondary springs with stiffness levels (3.78 N/mm, 4.11 N/mm, and 4.4 N/mm), it can be concluded that variations in secondary spring stiffness affect vehicle performance differently for each parameter. The 4.4 N/mm secondary spring achieved the highest power at 6.5 hp; however, the 3.78 N/mm secondary spring was superior in terms of acceleration at 6.58 m/s<sup>2</sup> and the highest top speed at 98.26 km/h. Meanwhile, the torque values for each secondary spring variation showed no significant difference, ranging from 7.84 Nm to 7.89 Nm

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