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Effect of Changing The Spring Constant of *Continuously Variable Transmission* On The Performance of Honda Vario 150 cc Motorcycle

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ABSTRACT

This study analyzes one of the components in the Continuously Variable Transmission (CVT) system, namely the CVT spring. The aim of this research is to determine the power, torque, acceleration, and fuel consumption produced by each different CVT spring. The study utilizes an experimental approach by testing four CVT springs with varying spring constants. Each spring was installed on the vehicle and tested using a dynotest to measure the resulting power, torque, acceleration, and engine speed. Fuel consumption tests were conducted through road testing over short and long distances (10 km to 90 km) with a maximum speed of 75 km/h. The test results indicate that each spring generates a different transmission ratio, which affects the resulting power, torque, acceleration, and fuel consumption. The highest maximum power was achieved when using a CVT spring with 20% stiffness, reaching 11.3 hp at 6493 RPM. The maximum torque was obtained with a 10% stiffer CVT spring, reaching 13.1 Nm at 6042 RPM. The highest acceleration was recorded with a 30% stiffer CVT spring, achieving 8.8 m/s² at a speed of 22 km/h in 0.51 seconds. The most efficient fuel consumption was found with the standard CVT spring, both for short and long distances, achieving 47.6 km/L over a short distance of 10 km and 54.7 km/L over a long distance of 90 km.

Keywords: Continuously variable transmission, CVT spring, dynotest, performance, fuel consumption

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1. Introduction

Today, the rapid development of technology has a big impact on the world of technology, especially the automotive world. The large number of consumer demands in the use of motorbikes has made motorcycle manufacturers compete and innovate to make motorbikes with automatic transmission or what is often referred to as automatic motorbikes. At this time, matic motorbikes are very suitable for use because the price is relatively cheaper and this matic motorbike also provides comfort in driving. The advantages of this comfort are mainly seen in the automatic setting without the need to switch gears, this makes the variety of automatic motorbikes in Indonesia currently available more and more.

Today's vehicles, especially two-wheelers (motorcycles), are equipped with an automatic transmission system, namely the CVT (*Continously Variable Transmission*) transmission system. The use of this automatic transmission allows the motorcycle to drive stably and the rider no longer needs to change the transmission speed of the vehicle manually, but can automatically change according to the engine speed [1]. A motorcycle equipped with an automatic transmission is the right choice, especially for use in urban areas that often experience traffic jams because there is no need to shift gears. In general, a higher transmission ratio (larger drive pulley diameter) is more efficient in terms of fuel consumption, because the engine operates at lower revs. Conversely, a low transmission ratio will increase fuel consumption, because the engine has to work harder at high revs to produce the required power.

Continously Variable Transmission (CVT) consists of a*primary pulley (primary* pulley or *driver* pulley) and a secondary pulley (*secondary pulley* or *driven pulley*) connected by a *v-belt*. On the primary pulley there is a *speed governor* whose role is to change the size of the diameter of the primary pulley. In the *speed governor* there are 6 centrifugal *rollers* that receive centrifugal force due to *crankshaft* rotation [2]. Therefore, the centrifugal *roller* will be thrown out pressing part of one side of the pulley that can be shifted (*sliding sheave*) towards the side of the*fixed* pulley (*fixed sheave*) thus causing changes in the diameter of the primary pulley, which is enlarged and reduced. This change affects the transmission ratio.

The difference in power and torque produced by each automatic motorcycle with the same engine capacity causes the performance of the standard engine to be felt less than optimal. Many users consider that matic motorcycles have weaknesses in the aspects of power and torque. Therefore, most people turn to aftermarket products to improve engine performance. According to Fani et al [3], there are various ways used to increase power, improve acceleration, and save fuel on automatic motorcycles. One method that can be done is to modify some CVT components to improve engine performance.

In this final project discussion, the CVT component to be analyzed is the spring located on the secondary pulley of the Honda Vario 150 cc motorcycle. There are various levels of spring stiffness that can be selected to achieve optimal performance on the Honda Vario 150 cc. On the *driven pulley*, the size of the *sliding shave* compressive force against the spring has a direct relationship with the spring constant. The greater the spring constant, the higher the compressive force of the *sliding shave* against the spring in the *driven pulley*, which causes the movement of the *pulley* to be more limited [4]. A stiffer spring will keep the pulley position more stable at a higher transmission ratio, which means the engine will work at lower revs at high speeds. Under these conditions, the vehicle can reach higher speeds with better fuel efficiency, because the engine is running at lower RPM, which reduces fuel consumption. Therefore, it is necessary to analyze the CVT spring to determine the constant value that can provide optimal performance on the Honda Vario 150 cc.

2. Methodology of Research

The experimental method was chosen to directly observe the effect of certain variables on the measured results, so it is expected to be able to provide accurate data and support the research objectives. This research was conducted from August 2024 to October 2024. The research was conducted in several places, namely the Engineering Materials Laboratory, Department of Mechanical and Industrial Engineering, Gadjah Mada University to conduct compressive test tests on CVT springs. 43 Motors BRT workshop to conduct *dynotest* testing on the Vario 150 cc. Pantura road and Cibitung area road to conduct long and short distance road tests to see the results of fuel consumption.

2.1. Tools and Material

The following are the tools and materials used in this research.

1. Honda All New Vario 150 cc matik-type motorcycle
2. Automotivenet *dynotest* tool
3. *Universal testing machine* tool
4. Vernier calipers are used in measuring the dimensions of the springs and the magnitude of the deflection
5. Standard CVT spring, 10% hardness, 20% hardness, and 30% hardness.

Table 1. Honda All New Vario 150 cc motorcycle specifications

Dimensions (P x L x T)	1919 x 679 x 1062 mm
Wheelbase	1,280 mm
Lowest distance to the ground	132 mm
Empty weight	112 kg
Frame	Underbone
Front Suspension	Telescopic
Rear Suspension	Swing Arm with Single suspension
Front tire size	90/80 – 14M/C 43P Tubeless
Rear tire size	100/80 – 14M/C 48P Tubeless
Front Brakes	Hydraulic Disc, Single Piston
Rear Brakes	Drum
Braking System	Combi Brake System (CBS)
Engine Type	4 stroke, SOHC with liquid cooling
Fuel supply system	PGM-FI (Programmed Fuel Injection)
Diameter x stroke	57,3 x 57,9 mm
Transmission Type	Automatic, V-matic
Compression Ratio	10,6 : 1
Maximum Power	9.7 kW (13.1 PS) / 8500 rpm
Maximum torque	13.4 Nm (1.37 kgf.m) / 5000 rpm
Starter Type	Electric
Clutch Type	Automatic *Centrifugal* Clutch Dry Type
Fuel tank capacity	5,5 liters of fuel
Lubricating Oil Capacity	0,8 liter pada penggantian periodik
Battery Type	MF 12V-5 Ah
Ignition System	Full transisterized
Spark Plug Type	NGK CPR9EA-9 / Denso U27EPR9
Headlights	LED 2.6 W x 2 (low), 5,2 W x 2 (high)

Table 2. CVT spring specifications

Specifications	Spring			
	Standart	Daytona 10%	Daytona 20%	Daytona 30%
Length (mm)	14,3	13,9	14	13,9
Coil Outer Diameter (mm)	5,8	5,8	5,8	5,8
Coil Inner Diameter (mm)	4,9	4,9	4,8	4,8
Wire Diameter (mm)	0,4	0,4	0,4	0,4

2.2. Research Flow Chart

This flowchart aims to provide a comprehensive overview of the stages carried out during the research.

The initial stage of this research is a literature study, which formulates the problems that occur and examines these problems. The study was carried out by looking for books, journals, and previous studies on the effect of changes in CVT components on the performance of motorcycle vehicles. Then determining the type of vehicle that will be used as the object of research. In this study, the vehicle to be tested and analyzed is the Honda All New Vario 150 cc. Then planning the tests that will be carried out such as spring press test, vehicle dynotest test, and fuel consumption test. After that, test the CVT spring compressive test using a universal testing machine. Then conduct a motorcycle performance test using a dynotest to get data results on power, torque, and acceleration. Then conduct a road test to get data on fuel consumption results. After obtaining all vehicle data through testing, the influence of the four types of continuously variable transmission (CVT) springs on vehicle performance will be analyzed. Fuel testing was carried out with a distance of 10 km to 90 km with a maximum speed of 75 km/h

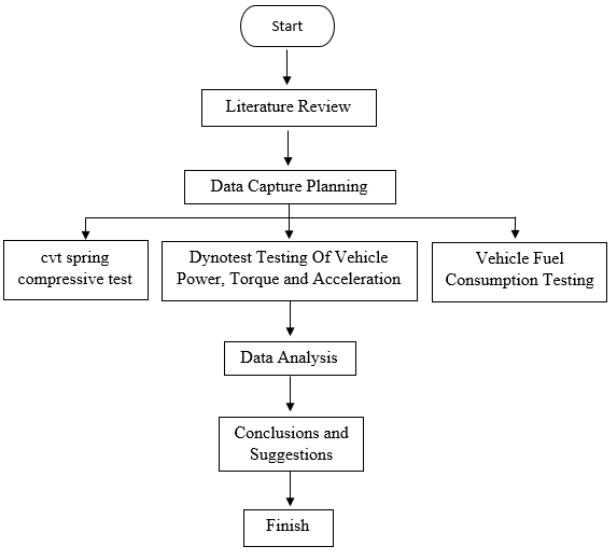


Figure 1. Research Flow Chart

3. Result and Discussion

3.1 Spring Press Test Result Data

The test results can be seen in the table 3.

Table 3. CVT spring test result data

Force(N)	Standard CVT Spring Deflection (mm)	CVT Spring Deflection 10% (mm)	CVT Spring Deflection 20% (mm)	CVT Spring Deflection 30% (mm)
0	0	0	0	0
20	4,18	3,45	3,35	3,1
40	10,12	9,04	7,95	7,47
60	16,33	14,31	12,99	12,1
80	22,26	19,46	17,37	16,59
100	28,37	24,8	22,03	20,57
120	34,54	29,83	26,4	24,87
140	39,94	34,89	31,12	29,36
160	45,48	40,31	35,46	33,54
180	51,09	44,88	40,01	37,48
200	56,65	49,45	44,89	41,89
220	61,91	54,72	48,89	45,89
240	66,79	58,77	53,41	49,65
260	71,93	63,36	57,8	53,59
280	77	68,07	61,23	57,02
300	81,93	73,05	65,41	61,41
320	86,58	77,4	69,26	65,07
340	91,64	81,92	73,47	68,82
360	96,76	86,43	76,91	72,18
380	100,78	90,33	80,53	75,96
400	104,8	94,34	84,2	79,85

Table 4. CVT spring constant calculation data

Standard CVT Spring Constant (N/mm)	CVT Spring Constant 10% (N/mm)	CVT Spring Constant 20% (N/mm)	CVT Spring Constant 30% (N/mm)
3,817	4,240	4,751	5,009

Based on table 3, it can be seen that the deflection or change in length of the standard CVT spring is reduced by 28.37 mm at a load of 100 N, 56.65 mm at a load of 200 N, 81.93 mm at a load of 300 N, and 104.8 mm at a load of 400 N. For the deflection or change in length of the 10% CVT spring, it is reduced by 24.8 mm at a load of 100 N, 49.45 mm at a load of 200 N, 73.05 mm at a load of 300 N, and 94.34 mm at 400 N load. Then the deflection or change in length at 20% CVT spring decreases along 22.03 mm at 100 N load, 44.89 mm at 200 N load, 65.41 mm at 300 N load, and 84.2 mm at 400 N load. Then the deflection or change in length at 30% CVT spring decreases along 20.57 mm at 100 N load, 41.89 mm at 200 N load, 61.41 mm at 300 N load, and 79.85 mm at 400 N load.

The change in length on the spring will decrease along with the increase in the amount of force applied to the spring during the testing process. This can occur becuse the greater the force applied to the spring, it will make the spring depressed and change from the initial length without load.

Based on table 4, it can be seen that the constant in the standard CVT spring is 3.817 N/mm, 10% CVT spring is 4.240 N/mm, 20% CVT spring is 4.751 N/mm, 30% CVT spring is 5.009 N/mm.

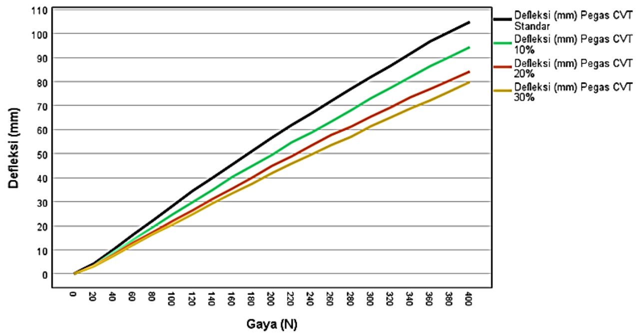


Figure 2. Comparison graph of CVT spring test results

Based on Figure 2, it can be seen in the graph that the deflection or change in spring length when given a load produces a different graph. The standard CVT spring is the CVT spring that experiences the largest deflection and the 30% CVT spring is the CVT spring that experiences the smallest deflection. This happens because each CVT spring has different constants. The standard CVT spring constant is the smallest spring constant while the 30% CVT spring constant is the largest spring constant.

3.2 Power Dynotest Vehicle Test Results

3.2.1 Power Dynotest Test Results of Vehicles with Standard CVT Springs

Vehicle power test data was obtained from tests conducted using a *dynotest* tool at the 43 Motors BRT workshop. The test results can be seen in table 5. Based on Table 5, it can be seen that vehicles with standard CVT springs experience an increase in power from 0 to 1.3 hp at engine speed of 4521 RPM. The power continues to increase as the engine speed increases until it reaches a maximum power of 10.4 hp at engine speed of 6752 RPM. After reaching maximum power, the vehicle began to experience a decrease in power until it reached 6 hp at the maximum engine speed of 9552 RPM and 3.9 hp at the maximum speed of the vehicle.

Table 5. Vehicle power test result data with standard CVT springs

Engine Speed (RPM)	Power (Hp)
4521	1,3
4756	2,4
5013	4,6
5243	6
5505	7,3
5756	8,2
6000	9,1
5904	9,7
5831	9,4
5901	9,8
6001	9,9
6250	9,9
6504	10,2
6752	10,4
7002	10
7251	10,2
7503	10,3
7752	9,7
8001	9,7
8249	9,6
8502	9,7
8751	10
9003	9,4
9251	9,1
9502	8,4
9552	6
9412	3,9

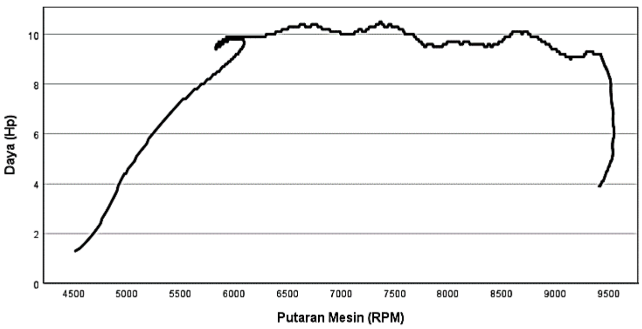


Figure 3 Power graph based on engine speed with standard CVT springs

Based on Figure 3, it can be seen that the vehicle with the standard CVT spring starts to experience an increase in power at 4521 RPM and there is a slight decrease in engine speed from 6000 RPM to 5831 RPM so that the power decreases slightly. This occurs due to slippage when ratio adjustment occurs which sometimes makes the engine speed decrease slightly before increasing again. According to Lee et al [5], slip on the *v-belt* occurs because it is not strong enough to press the *pulley* and *v-belt* together properly. It happens because the standard CVT spring pressure is not strong enough to hold the *sliding sheave of* the secondary *pulley* to remain in the large diameter position, resulting in a change in the diameter of the secondary *pulley* from a large diameter to a small diameter changing rapidly which results in a slight decrease in engine speed. A strong force is needed between the *pulley* and the belt or between the balls and *rollers* for it to function properly, but this causes quite a lot of power loss as the belt has to bend constantly. The springs on both pulleys regulate the tension on the belt connecting them. When the engine load increases (for example, during acceleration), the springs will adjust the position of the pulleys to ensure that the belt remains sufficiently tensioned to prevent slippage. If the springs are too weak or not strong enough, the belt will not have enough grip between the pulleys, causing slippage. Vehicles with the standard CVT spring only need an engine speed of 4521 RPM lower than the other three springs to start moving from a standstill.

A harder spring also keeps the secondary *pulley* at a larger diameter for a longer time, which helps increase power at low revs. A spring with a higher constant will produce stronger power changes compared to a constant spring, as stated by Rahman et al [6]. This is useful during acceleration from a standstill, as it produces more power to the rear wheels. This causes the power graph of the standard CVT spring to increase longer because it is not hard enough to hold the secondary *pulley* fixed at the initial diameter.

The power then decreased after reaching an engine speed of 8500 RPM until the maximum engine speed. This occurs because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so that the power also decreases.

3.2.2. Power Dynotest Test Results of Vehicles with 10% CVT Spring

Table 6. Vehicle power test result data with 10% CVT spring

Engine Speed (RPM)	Power (Hp)
5181	3,8
5258	4,1
5505	5,5
5756	7,6
6001	10,4
6039	11,1
6250	10,7
6502	10,6
6749	10,6
6998	10,6
7247	10,7
7504	10,6
7750	10,2
7999	10
8253	10,1
8449	10,1
8752	10,2
9001	10,2
9252	9,6
9500	7,8
9537	6,6
9415	4,1

Based on table 6, it can be seen that vehicles with 10% CVT springs experience an increase in power from 0 to 3.8 hp at 5181 RPM engine speed. The power continues to increase as the engine speed increases until it reaches a maximum power of 11.1 hp at engine speed of 6039 RPM. After reaching maximum power, the vehicle began to experience a decrease in power until it reached 6.6 hp at the maximum engine speed of 9537 RPM and 4.1 hp at the maximum speed of the vehicle.

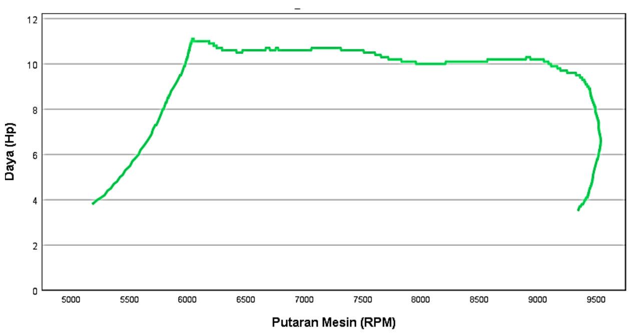


Figure 4. Power graph based on engine speed with 10% CVT springs

Based on Figure 4, it can be seen that the vehicle with 10% CVT spring requires a high engine speed of 5181 RPM to overcome this pressure and start the ratio change. The higher engine speed makes the primary *pulley* press the v-belt to increase the ratio of the primary *pulley* diameter and shrink the secondary *pulley* diameter, so that the centrifugal clutch can start to contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary *pulley* to keep the secondary *pulley* at a larger diameter for a longer time, which helps to increase power at low revs and reduce slip on the v-belt that can affect power. Slip on the *v-belt* occurs because the compressive force is not strong enough to press the *pulley* and *v-belt* together properly. This is useful when accelerating from a standstill, as it produces more power to the rear wheels. This is what causes the CVT spring power graph to increase 10% faster. Rahman et al. stated that springs with higher constants will produce stronger power changes than low-constant springs.

The power then decreases after reaching an engine speed of 8500 RPM until the maximum engine speed. This happens because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on the reduction of combustion pressure, so the power also decreases [7].

3.2.3 Power Dynotest Test Results of Vehicles with 20% CVT Spring

Based on Table 6, it can be seen that the vehicle with 20% CVT spring has increased power from 0 to 2.7 hp at 5748 RPM engine speed. The power continues to increase as the engine speed increases until it reaches a maximum power of 11.3 hp at engine speed of 6493 RPM. After reaching maximum power, the vehicle began to experience a decrease in power until it reached 6.9 hp at the maximum engine speed of 9528 RPM and 4.8 hp at the maximum speed of the vehicle

Based on Figure 5, it can be seen that the vehicle with 20% CVT spring requires a high engine speed of 5748 RPM to overcome this pressure and start the ratio change. The higher engine speed makes the primary pulley press the v-belt to increase the ratio of the primary pulley diameter and shrink the secondary pulley diameter, so that the centrifugal clutch can start to contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps increase power at low revs and reduces slip on the v-belt that can affect power. This is what causes the CVT spring power graph to increase 20% faster. Rahman et al. state that springs with higher constants will produce stronger power changes than low-constant springs.

Table 6. Vehicle power test result data with 20% CVT spring

Engine Speed (RPM)	Power (Hp)
5748	2,7
6001	4,7
6252	7,3
6496	11,3
6428	11,1
6448	10,8
6501	10,8
6607	11
6751	10,7
6998	10,1
7247	10
7501	9,9
7747	9,6
8003	9,4
8247	9,6
8498	9,5
8748	9,5
9002	9,4
9249	8,8
9499	7,6
9528	6,9
9415	4,8

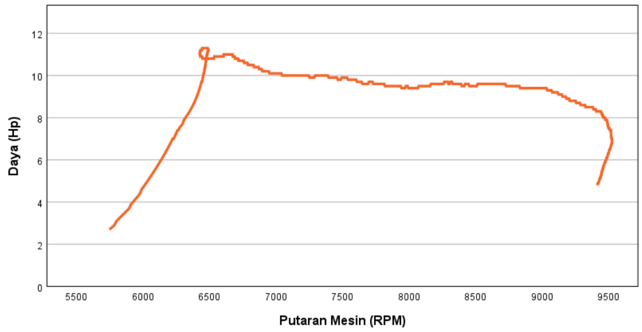


Figure 5. Power graph based on engine speed with 20% CVT springs

In the graph, it can be seen that the vehicle with 20% CVT spring starts to experience an increase in power at 5748 RPM and there is a slight decrease in engine speed from 6496 RPM to 6428 RPM so that the power decreases slightly. This occurs due to slippage when ratio adjustments occur which sometimes makes the engine speed decrease slightly before increasing again. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly [8]. It occurs because the change in the diameter of the secondary pulley from a large diameter to a small diameter changes quickly, resulting in a slight decrease in engine speed. A strong force is needed between the pulley and the belt or between the ball and the roller for it to function properly, but this causes quite a lot of power loss as the belt has to bend constantly.

The power then decreases after reaching the engine speed of 8500 RPM until the maximum engine speed. This happens because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so that the power also decreases, in accordance with the statement put forward by Dharma and Wulandari.

3.2.4 Power Dynotest Test Results of Vehicles with 30% CVT Spring

Vehicle power test data was obtained from tests conducted using a dynotest tool at the 43 Motors BRT workshop. The test results can be seen in table 7.

Table 7 Vehicle power test result data with 30% CVT spring

Engine Speed (RPM)	Power (Hp)
5707	3,2
5752	3,6
6001	10,8
6044	10,9
6102	10,8
6250	10,7
6501	10,7
6751	10,8
7002	10,6
7251	10,3
7498	10,1
7752	9,9
7998	9,4
8055	9,3
8252	9,5
8503	9,8
8749	10,1
8999	9,7
9251	9,1
9500	8,1
9523	7,7
9360	4,6

Based on Table 7, it can be seen that the vehicle with 30% CVT spring has an increase in power from 0 to 3.2 hp at engine speed of 5707 RPM. The power continues to increase as the engine speed increases until it reaches a maximum power of 10.9 hp at engine speed of 6044 RPM. After reaching maximum power, the vehicle began to experience a decrease in power until it reached 7.7 hp at the maximum engine speed of 9523 RPM and 4.6 hp at the maximum speed of the vehicle.

Based on Figure 6, it can be seen that the vehicle with 30% CVT spring requires a high engine speed of 5707 RPM to overcome this pressure and start the ratio change. The higher engine speed makes the primary pulley press the v-belt to increase the ratio of the primary pulley diameter and shrink the secondary pulley diameter, so that the centrifugal clutch can start to contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps to increase power at low revs increases and reduces slip on the v-belt that can affect power. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly, in accordance with the statement put forward by Lee et al. This is useful when accelerating from a standstill, as it produces more power to the rear wheels. This causes the CVT spring power graph to increase 30% faster. A spring with a higher constant will produce a stronger power change than a low constant spring.

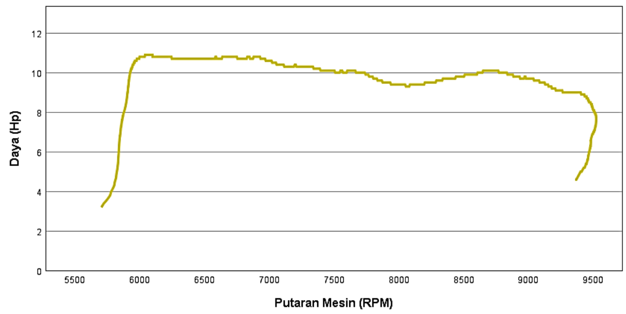


Figure 6. Power graph based on engine speed with 30% CVT springs

3.3 Torque of Vehicle Dynotest Test Results

3.3.1 Torque Dynotest Test Results of Vehicles with Standard CVT Springs

Vehicle torque test data was obtained from tests conducted using a dynotest tool at the 43 Motors BRT workshop. The test results can be seen in table 8. Based on table 8, it can be seen that vehicles with standard CVT springs experience an increase in torque from 0 to 2 Nm at 4521 RPM engine speed. The torque continues to increase as the engine speed increases until it reaches a maximum torque of 11.8 Nm at 5901 RPM. The maximum torque that can be transmitted is limited by slippage on the belt or roller. After reaching the maximum torque, the vehicle starts to experience a decrease in torque until it reaches 4.5 Nm at the maximum engine speed of 9552 RPM and 2.9 Nm at the maximum speed of the vehicle

Table 8 Vehicle torque test results data with standard CVT springs

Engine Speed (RPM)	Power (Hp)
4521	2
4756	3,5
5013	6,3
5243	8
5505	9,3
5756	10
6000	10,7
5904	11,6
5831	11,5
5901	11,8
6100	11,2
5831	9,4
6250	11,2
6504	11,2
6752	10,9
7002	10,2
7251	10
7503	9,8
7752	8,9
8001	8,6
8249	8,2
8502	8,1
8751	8,1
9003	7,4
9251	7
9502	6,3
9552	4,5
9412	2,9

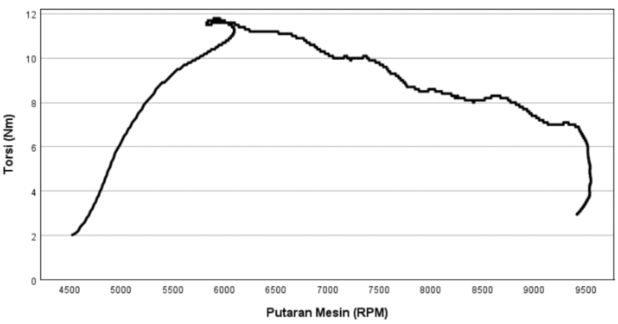


Figure 7. Torque graph based on engine speed with standard CVT springs

Based on Figure 7, it can be seen that vehicles with standard CVT springs begin to experience an increase in torque at 4521 RPM and there is a slight decrease in engine speed from 6000 RPM to 5831 RPM so that the torque decreases slightly. This occurs due to slippage when ratio adjustments occur which sometimes makes engine speed decrease slightly before increasing again. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly. It occurs because the pressure of the standard CVT spring is not strong enough to hold the sliding sheave of the secondary pulley to remain in the large diameter position, resulting in a change in the diameter of the secondary pulley from a large diameter to a small diameter change quickly which results in a slight decrease in engine speed. The vehicle with the standard CVT spring only requires an engine speed of 4521 RPM lower than the other three springs when starting to move from a standstill.

Harder springs also keep the secondary pulley at a larger diameter for a longer time, which helps increase torque at low revs. According to Rahman et al, a spring with a higher constant will produce a stronger change in torque compared to a low constant spring. This is useful when accelerating from a standstill, as it produces more torque on the rear wheels. This causes the torque graph of the standard CVT spring to increase longer because it is not hard enough to hold the secondary pulley fixed at the initial diameter [9].

The torque then decreases after reaching 6000 RPM engine speed until the maximum engine speed. This occurs because the higher the engine speed, the faster the process of opening and closing the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so the torque also decreases.

3.3.2 Torque Dynotest Test Results of Vehicles with 10% CVT Spring

Based on Table 9, it can be seen that the vehicle with 10% CVT spring increases torque from 0 to 4.9 Nm at engine speed of 5181 RPM. The torque continues to increase as the engine speed increases until it reaches a maximum torque of 13.1 Nm at engine speed of 6042 RPM. The maximum torque that can be transmitted is limited by slippage on the belt or roller[10]. After reaching the maximum torque, the vehicle starts to experience a decrease in torque until it reaches 4.9 Nm at the maximum engine speed of 9537 RPM and 3 Nm at the maximum speed of the vehicle.

Table 9. Vehicle torque test result data with 10% CVT springs

Engine Speed (RPM)	Power (Hp)
5181	4,9
5258	5,2
5505	6,9
5756	9,2
6001	12,3
6042	13,1
6250	12,2
6502	11,5
6749	11,2
6998	10,8
7247	10,5
7504	10
7750	9,4
7999	8,9
8253	8,7
8449	8,5
8752	8,3
9001	8,1
9252	7,4
9500	5,8
9537	4,9
9415	3

Based on Figure 8, it can be seen that the vehicle with 10% CVT spring requires a high engine speed of 5181 RPM to overcome this pressure and start the ratio change. The higher engine speed makes the primary pulley press the v-belt to increase the ratio of the primary pulley diameter and shrink the secondary pulley diameter, so that the centrifugal clutch can start to contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps to increase torque at low revs and reduce slip on the v-belt that can affect torque. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly. This is useful when accelerating from a standstill, as it produces more torque on the rear wheels. This causes the CVT spring torque graph to increase 10% faster. Springs with higher constants will produce stronger torque changes than low-constant springs[11].

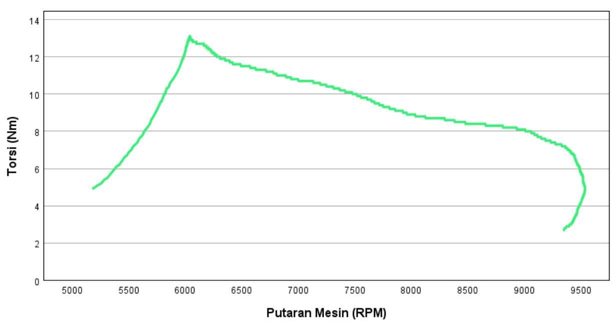


Figure 8. Torque graph based on engine speed with 10% CVT springs

The torque then decreases after reaching the engine speed of 6000 RPM until the maximum engine speed. This happens because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so the torque also decreases.

3.3.3 *Torque Dynotest Test Results of Vehicles with 20% CVT Spring*

Table 10. Vehicle torque test result data with 20% CVT springs

Engine Speed (RPM)	Power (Hp)
5748	3,2
6001	5,4
6252	8,1
6496	12,4
6428	12,3
6501	11,8
6751	11,2
6998	10,3
7247	9,8
7501	9,4
7747	8,8
8003	8,4
8247	8,3
8498	8
8748	7,7
9002	7,4
9249	6,7
9499	5,7
9528	5,2
9415	3,6

Based on table 10, it can be seen that the vehicle with 20% CVT spring increases torque from 0 to 3.2 Nm at 5748 RPM engine speed. The torque continues to increase as the engine speed increases until it reaches a maximum torque of 12.4 Nm at 6496 RPM. The maximum torque that can be transmitted is limited by slippage on the belt or roller. After reaching the maximum torque, the vehicle starts to experience a decrease in torque until it reaches 5.2 Nm at the maximum engine speed of 9528 RPM and 3.6 Nm at the maximum speed of the vehicle.

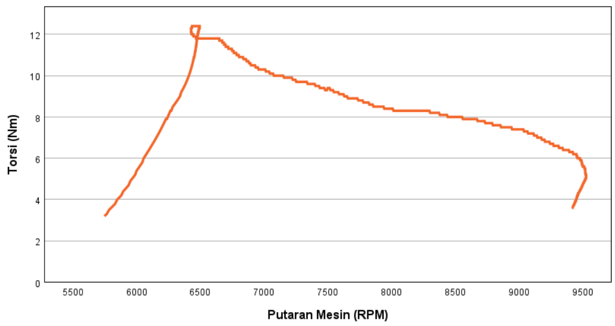


Figure 9. Torque graph based on engine speed with 20% CVT springs

Based on Figure 9, it can be seen that the vehicle with 20% CVT spring requires a high engine speed of 5748 RPM to overcome this pressure and start the ratio change. The higher engine speed makes the primary pulley press the v-belt to increase the ratio of the primary pulley diameter and shrink the secondary pulley diameter, so that the centrifugal clutch can start to contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps to increase torque at low revs and reduce slip on the v-belt that can affect power. This causes the CVT spring torque graph to increase 20% faster. A spring with a higher constant will produce stronger torque changes compared to a low constant spring.

In the graph, it can be seen that the vehicle with 20% CVT spring starts to experience an increase in torque at 5748 RPM and there is a slight decrease in engine speed from 6496 RPM to 6428 RPM so that the torque decreases slightly. This occurs due to slippage when ratio adjustments occur which sometimes makes engine speed decrease slightly before increasing again. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly. It occurs because the change in the diameter of the secondary pulley from a large diameter to a small diameter changes rapidly which results in a slight decrease in engine speed.

The torque then decreased after reaching 6000 RPM engine speed until the maximum engine speed. This happens because the higher the engine speed, the faster the process of opening and closing the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so the torque also decreases.

3.3.4 *Torque Dynotest Test Results of Vehicles with 30% CVT Spring*

Table 11. Vehicle torque test result data with 30% CVT springs

Engine Speed (RPM)	Power (Hp)
5707	4
5752	4,4
6001	12,7
6015	12,8
6250	12,2
6501	11,7
6751	11,3
7002	10,7
7251	10,1
7498	9,5
7752	9,1
7998	8,3
8252	8,1
8503	8,2
8749	8,2
8999	7,7
9251	7
9500	6,1
9523	5,8
9360	3,4

Based on table 11, it can be seen that the vehicle with 30% CVT spring increases torque from 0 to 4 Nm at engine speed of 5707 RPM. The torque continues to increase as the engine speed increases until it reaches a maximum torque of 12.8 Nm at engine speed of 6015 RPM. The maximum torque that can be transmitted is limited by slippage on the belt or roller. After reaching the maximum torque, the vehicle starts to experience a decrease in torque until it reaches 5.8 Nm at the maximum engine speed of 9523 RPM and 3.4 Nm at the maximum speed of the vehicle.

Based on Figure 10, it can be seen that the vehicle with 30% CVT spring requires a high engine speed of 5707 RPM to overcome this pressure and start the ratio change. The higher engine speed makes the primary pulley press the v-belt to increase the ratio of the primary pulley diameter and shrink the secondary pulley diameter, so that the centrifugal clutch can start to contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps to increase torque at low revs increases and reduces slip on the v-belt that can affect torque [12]. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly. This is useful when accelerating from a standstill, as it produces more torque on the rear wheels. This causes the CVT spring torque graph to increase 30% faster. Springs with higher constants will produce stronger torque changes than low-constant springs

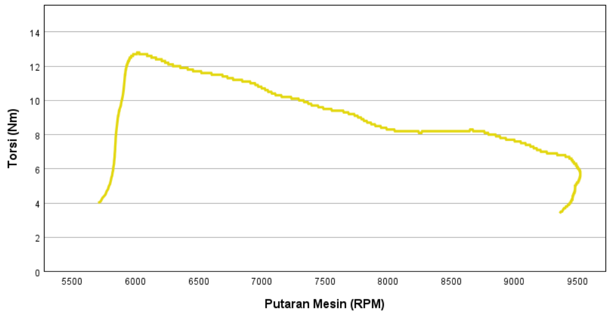


Figure 10. Torque graph based on engine speed with 30% CVT springs

Based on Figure 10, it can be seen that the vehicle with 30% CVT spring requires a high engine speed of 5707 RPM to overcome this pressure and start the ratio change. The higher engine speed makes the primary pulley press the v-belt to increase the ratio of the primary pulley diameter and shrink the secondary pulley diameter, so that the centrifugal clutch can start to contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps to increase torque at low revs increases and reduces slip on the v-belt that can affect torque [12]. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly. This is useful when accelerating from a standstill, as it produces more torque on the rear wheels. This causes the CVT spring torque graph to increase 30% faster. Springs with higher constants will produce stronger torque changes than low-constant springs.

The torque then decreases after reaching the engine speed of 6000 RPM until the maximum engine speed. This happens because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so the torque also decreases.

3.4 Acceleration of Vehicle Dynotest Results

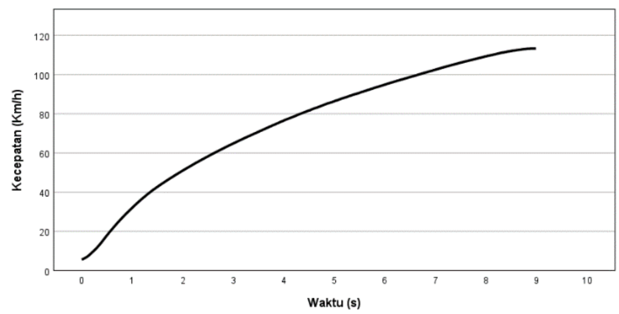
3.4.1 Acceleration of Vehicle Dynotest Test Results with Standard CVT Spring

Based on table 12, it can be seen that a vehicle with a standard CVT spring experiences an increase in speed from 0 to 10 Km/h takes 0.24 seconds and experiences an increase in acceleration of up to 6.9 m/s2. The maximum acceleration of 8.4 m/s2 occurs when the motorcycle speed is 20km/h. The speed continues to increase until it reaches a maximum speed of 113.3 km / h takes 8.88 seconds and acceleration of 0.4 m / s2 at maximum speed.

Table 12. Vehicle acceleration test result data with standard CVT spring

Time (s)	Speed (Km/h)	Acceleration (m/s^2)
0,01	5,7	4,2
0,24	10,1	6,9
0,56	20	8,4
0,92	30	7,2
1,35	39,9	5,7
1,93	49,9	4,4
2,62	59,9	3,8
3,42	69,9	3,3
4,33	80	2,8
5,41	90	2,4
6,67	100	2,1
8,12	110	1,6
8,88	113,3	0,4

Based on Figure 12, it can be seen that the vehicle with the standard CVT spring produces an initial acceleration of 4 m/s2. This happens because the standard CVT spring pressure is not strong enough to hold the sliding sheave of the secondary pulley to remain in the large diameter position, resulting in a change in the diameter of the secondary pulley from large diameter to small diameter changing rapidly which results in lower initial acceleration. The vehicle with the standard CVT spring produces lower acceleration than the other three springs when starting to



move from a standstill.

Figure 11. Speed graph by time with standard CVT springs

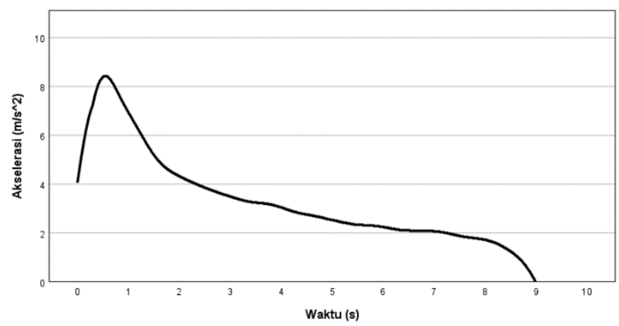


Figure 12. Acceleration graph by time with CVT spring

The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps increase torque at low revs resulting in increased acceleration and reduces slip on the v-belt that can affect power [13]. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly. According to Rahman et al, springs with higher constants will produce stronger torque changes compared to low-constant springs. This is useful when accelerating from a standstill, because it produces greater torque on the rear wheels so as to accelerate the speed increase from a standstill to 20 km / h. Acceleration then decreases after acceleration.

Acceleration then decreased after reaching maximum acceleration at 20 km/h and continued to decrease to maximum speed. This occurs because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so that the torque also decreases, as stated by Dharma and Wulandari.

3.4.2 Acceleration Dynotest Test Results of Vehicles with 10% CVT Spring

Vehicle acceleration test data is obtained from tests conducted using a dynotest tool at the 43 Motors BRT workshop. The test results can be seen in table 13.

Table 13. Vehicle acceleration test result data with 10% CVT spring

Time (s)	Speed (Km/h)	Acceleration (m/s^2)
0,16	10	6,2
0,33	20,0	8,4
0,49	24	8,5
0,67	29,9	8,3
1,05	40,0	6,6
1,54	49,9	5,1
2,16	60,0	4,1
2,9	69,9	3,4
3,77	80,0	3,0
4,8	90,0	2,5
5,98	100,0	2,2
7,36	110,0	1,7
8,21	113,4	0,2

Based on table 13, it can be seen that the vehicle with 10% CVT spring increases speed from 0 to 10 Km/h takes 0.16 seconds and experiences an increase in acceleration of up to 6.2 m/s2. Maximum acceleration of 8.5 m/s2 occurs when the motorcycle speed is 24 km/h. The speed continues to increase until it reaches a maximum speed of 113.3 km / h takes 8.88 seconds and acceleration of 0.4 m / s2 at maximum speed.

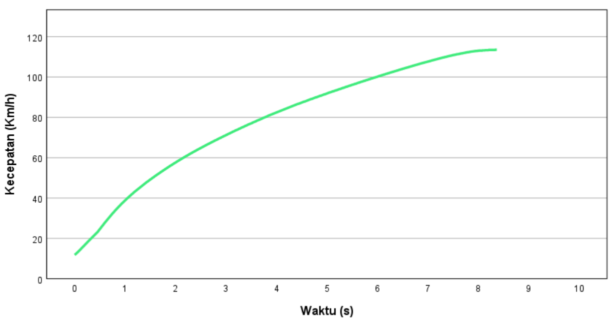


Figure 13. Speed graph by time with 10% CVT spring

Based on Figure 14, it can be seen that the vehicle with 10% CVT spring produces an initial acceleration of 6.1 m/s2. This acceleration is higher than the standard CVT spring because it requires a high engine speed to overcome this pressure and initiate the ratio change. The higher engine speed makes the primary pulley compress the v-belt to enlarge the ratio of the primary pulley diameter and shrink the secondary pulley diameter, so that the centrifugal clutch can start to make contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps increase torque at low revs so that acceleration increases and reduces slip on the v-belt that can affect torque and acceleration. Lee et al stated that slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly. This is useful when accelerating from a standstill, as it produces greater torque on the rear wheels. This is why the CVT spring acceleration and speed graph is 10% faster to reach maximum speed and acceleration. Springs with higher constants will produce stronger torque changes than low-constant springs.

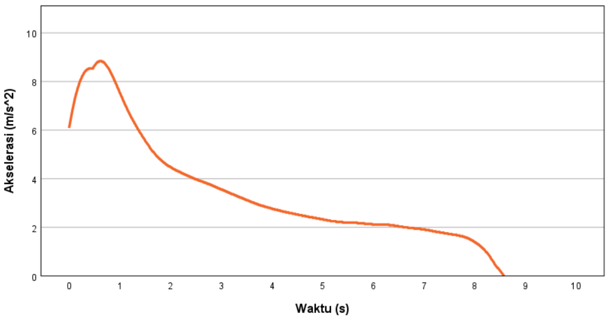


Figure 14. Acceleration graph by time with 10% CVT spring

Acceleration then decreased after reaching maximum acceleration at 20 km/h and continued to decrease to maximum speed. This occurs because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so the torque also decreases [3].

3.4.3 Acceleration Dynotest Test Results of Vehicles with 20% CVT Spring

Based on table 14, it can be seen that vehicles with 20% CVT springs experience an increase in speed from 0 to 10 Km / h takes 0.12 seconds and experiences an increase in acceleration of up to 7.3 m / s2. The maximum acceleration of 8.8 m/s2 occurs when the motorcycle speed is 22 km/h . The speed continues to increase until it reaches a maximum speed of 113.3 km / h takes 8.57 seconds and acceleration of 0.1 m / s2 at maximum speed.

Based on Figure 16, it can be seen that the vehicle with 20% CVT spring produces an initial acceleration of 6.1 m/s2. This acceleration is higher than the standard CVT spring because it requires a high engine speed to overcome this pressure and initiate the ratio change. The higher engine speed makes the primary pulley compress the v-belt to enlarge the ratio of the primary pulley diameter and shrink the secondary pulley diameter, so that the centrifugal clutch can start to make contact with the clutch housing, and the motor starts to move from a standstill [14]. The harder CVT spring exerts stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, which helps to increase torque at low revolutions so that acceleration is improved and reduces slip on the v-belt that can affect torque and acceleration. Slip on the v-belt occurs because the compressive force is not strong enough to press the pulley and v-belt together properly. This is useful when accelerating from a standstill, as it produces more torque on the rear wheels. This is why the acceleration and speed graphs of CVT springs are 20% faster to reach maximum speed and acceleration. Springs with higher constants will produce stronger torque changes than low-constant springs.

Table 14. Vehicle acceleration test result data with 20% CVT spring

Time (s)	Speed (Km/h)	Acceleration (m/s^2)
0	7,5	6,1
0,12	10	7,3
0,5	20	8,6
0,56	22	8,8
0,81	30	8,4
1,18	40	6,7
1,67	50	5,1
2,29	60	4,2
3,01	70	3,6
3,9	80	2,8
4,99	90	2,3
6,26	100	2,1
7,73	110	1,6
8,57	113,3	0,1

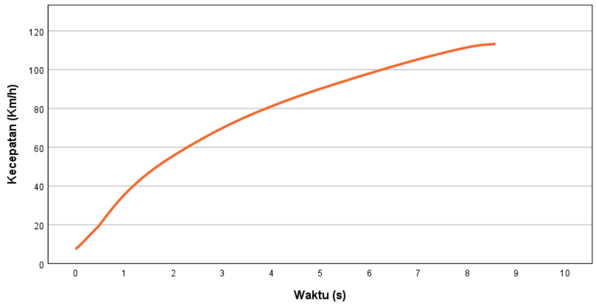


Figure 15. Speed graph by time with 20% CVT spring

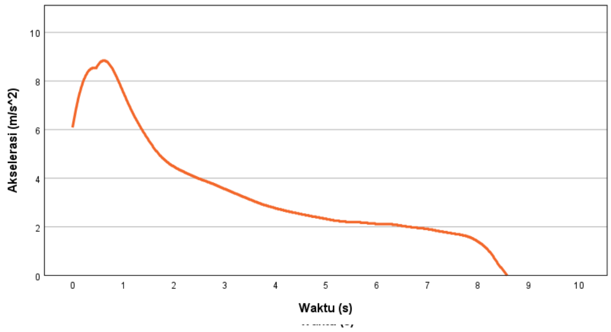


Figure 16. Acceleration graph by time with 20% CVT spring

Acceleration then decreased after reaching maximum acceleration at 22 km/h and continued to decrease to maximum speed. This happens because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. This decrease has an impact on reducing the combustion pressure, so the torque also decreases.

3.4.4 *Acceleration Dynotest Test Results of Vehicles with 30% CVT Spring*

Based on table 15, it can be seen that the vehicle with 30% CVT spring has an increase in speed from 0 to 10 Km/h takes 0.07 seconds and has an increase in acceleration of up to 7.3 m/s2. The maximum acceleration of 8.8 m/s2 occurs when the motorcycle speed is 22 km/h. The speed continues to increase until it reaches a maximum speed of 112.9 km/h, which takes 8.38 seconds and acceleration of 0.3 m/s2 at maximum speed.

Based on Figure 18, it can be seen that the vehicle with 30% CVT spring produces an initial acceleration of 6.5 m/s2. This acceleration is higher than the standard CVT spring because it requires a high engine speed to overcome this pressure and initiate the ratio change. The higher engine speed makes the primary *pulley* compress the v-belt to enlarge the ratio of the primary *pulley* diameter and shrink the secondary *pulley* diameter, so that the centrifugal clutch can start to make contact with the clutch housing, and the motor starts to move from a standstill. The harder CVT spring exerts stronger back pressure on the secondary *pulley* to keep the secondary *pulley* at a larger diameter for a longer time, which helps to increase torque at low revolutions so that acceleration is improved and reduces slip on the v-belt that can affect torque and acceleration. Slip on the *v-belt* occurs because the compressive force is not strong enough to press the *pulley* and *v-belt* together properly. This is useful when accelerating from a standstill, as it produces more torque on the rear wheels. This is why the CVT spring acceleration and speed graph is 30% faster to reach maximum speed and acceleration. Springs with higher constants will produce stronger torque changes than low-constant springs.

Acceleration then decreased after reaching maximum acceleration at 22 km/h and continued to decrease to maximum speed. This happens because the higher the engine speed, the faster the opening and closing process of the suction valve and exhaust valve. As a result, the intake time of the fuel and air mixture into the cylinder becomes shorter, which causes a decrease in volumetric efficiency. According to Dharma and Wulandari, this decrease has an impact on reducing the combustion pressure, so the torque also decreases.

Table 15. Vehicle acceleration test result data with 30% CVT spring

Distance Traveled (km)	Fuel Consumption (km/L)			
	Standard CVT Spring	CVT spring 10%	CVT spring 20%	CVT spring 30%
10	58,7	56,3	53,2	53
20	57,7	53,4	51,6	52,3
30	56,4	51,7	51	52,1
40	54,7	51,8	51	51,9
50	54,3	53,2	50,7	52
60	54,5	53,8	51,5	51,7
70	54,3	54,2	52,1	52,1
80	54,6	54,9	52,8	52
90	54,7	53,5	52,2	52,4

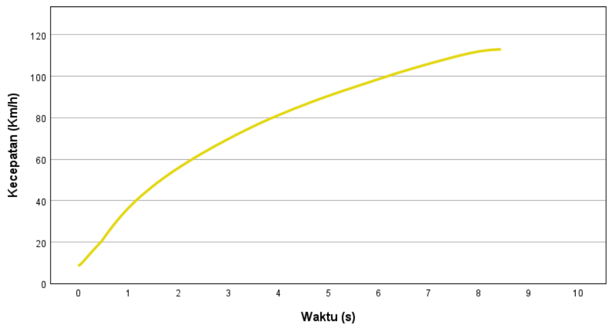


Figure 17. Speed graph by time with 30% CVT spring

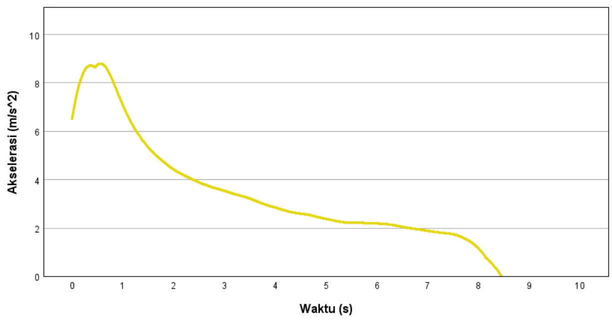


Figure 18. Acceleration graph by time with 30% CVT spring

3.5 Vehicle Fuel Consumption Result Data

Based on table 16, it can be seen that the results of the vehicle fuel consumption test for daily use on short distance travel with a maximum speed of 45 km/hour. Vehicles using standard CVT springs produce fuel consumption of 47.6 km/L, vehicles using 10% CVT springs produce fuel consumption of 46.3 km/L, vehicles using 20% CVT springs produce fuel consumption of 45.1 km/L, and vehicles using 30% CVT springs produce fuel consumption of 45.1 km/L.

Table 16. Vehicle fuel consumption test data with short distances

Distance Traveled (km)	Fuel Consumption (km/L)			
	Standard CVT Spring	CVT spring 10%	CVT spring 20%	CVT spring 30%
10	47,6	46,3	45,1	45,1

Table 17. Vehicle fuel consumption test data with long distance

Time (s)	Speed (Km/h)	Acceleration (m/s^2)
0	8,5	6,5
0,07	9,9	7,3
0,45	20	8,6
0,51	22	8,8
0,76	29,8	8,3
1,15	39,9	6,4
1,66	50	5,0
2,28	59,9	4,1
3,02	69,9	3,5
3,89	80	2,9
4,95	90	2,4
6,19	100	2,2
7,64	110	1,6
8,38	112,9	0,3

Based on table 17, it can be seen that the results of vehicle fuel consumption testing for daily use on long-distance trips with a maximum speed of 75 km/h. Vehicles using standard CVT springs produce fuel consumption of 54.7 km/L, vehicles using 10% CVT springs produce fuel consumption of 53.5 km/L, vehicles using 20% CVT springs produce fuel consumption of 52.2 km/L, and vehicles using 30% CVT springs produce fuel consumption of 52.4 km/L. Based on table 16 and table 17, the most economical fuel consumption results from both short and long distance tests are vehicles using standard CVT springs. While the most wasteful fuel consumption results from both short and long distance tests are vehicles using 20% and 30% CVT springs. This is because the harder CVT springs exert stronger back pressure on the secondary pulley to keep the secondary pulley at a larger diameter for a longer time, requiring high engine speeds to overcome this pressure and initiate ratio changes. The higher engine speed can lead to more wasteful fuel consumption. This happens because higher engine speed is directly proportional to the number of combustion cycles that occur to be more. The frequency of combustion cycles is proportional to the frequency of fuel injection into the combustion chamber. If the frequency of fuel injection is high, the fuel consumption in unit time will also be high, so that fuel consumption becomes more wasteful, in accordance with the statement put forward by Pessireron et al [15].

Based on table 16 and table 17, the long distance test results in a more efficient average vehicle fuel consumption for the four CVT springs compared to the average results of the short distance vehicle fuel consumption test for the four CVT springs. This is because the use of short distances is more wasteful because the mileage for one drive is closer. Meanwhile, long distance testing is more efficient because the mileage for one drive is further away. Then in short distance use also tends to use low speed, often braking and stopping a lot. So that the engine works harder to produce enough power for the vehicle to accelerate. In the acceleration process to speed up the vehicle, the engine requires a lot of fuel. The higher the acceleration rate, the more fuel is required. As for long-distance use, it tends to use a constant speed because it does not often brake and does not stop much. According to Tong et al, in cruising mode or constant speed driving, the engine uses fuel to maintain the vehicle at a certain speed so that fuel consumption is generally lower.

4. Conclusion

Based on the results of research, analysis, and discussion that has been carried out on the effect of changing the CVT spring constant on the performance of a Honda Vario 150 cc motorcycle, it can be concluded as follows.

The highest maximum power generated by a Honda Vario 150 cc motorcycle is achieved when using a CVT spring with a 20% increase, which is 11.3 hp at 6493 RPM engine speed.

The highest maximum torque obtained by a Honda Vario 150 cc motorcycle occurred when testing with a 10% CVT spring, which amounted to 13.1 Nm at 6042 RPM.

The highest maximum acceleration achieved by a Honda Vario 150 cc motorcycle is 8.8 m/s^2 when using a 30% CVT spring, with a motorcycle speed of 22 km/h achieved in 0.51 seconds.

The most efficient fuel consumption was achieved using standard CVT springs, both for short and long distance travel. The short distance test of 10 km resulted in a consumption of 47.6 km/L, while the long distance of 90 km achieved a consumption of 54.7 km/L.

5. Acknowledgments

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