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Analysis of CVT (Continuously variable transmission) and the influence of roller weight variations on the motorcycle

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Abstract*:* This study was aimed to determine the working principle, troubleshooting, and the influence of CVT roller weight variations on Suzuki Nex-FI 2014 motorcycles. This research was conducted by analyzing and comparing the measurement results for each CVT component. This study used an experimental research by holding the throttle at 3,250 rpm. Once steady state is reached, the throttle is rotated up to 10,000 rpm. The results of the troubleshooting analysis and measurement of drive belt wear were from the standard size of 19.50 mm to 18.00 mm. The usage tolerance limit is 18.60 mm. As for the results of the roller variation test using a lighter weight namely 8 and 9 grams. The results show that the maximum results are achieved at low and medium rotational speeds, compared to the use of 11 gr (standard) roller. The weakness of the lighter roller (8 & 9 grams) is that they only get good acceleration and torque at low revs while at high rotation speed is less than the maximum. The use of standard (11 gram) roller has less maximum acceleration and torque but produces maximum power.

Keywords: *CVT, troubleshooting, roller*

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INTRODUCTION

The development of the automotive world with the increasing popularity of motorcycles with increasing market demand and changes in output efficiency (Dai, 2021). Differences in efficiency are one of the changes in the transmission system. The transmission system is designed to achieve increased fuel efficiency, power output, and safety of automotive vehicles (Kaushik, 2015). Furthermore, the transmission system is carried out from a manual to an automatic transmission, commonly called a Continuously Variable Transmission (CVT), to make driving easier and increase driving comfort (Supriyo, Ariyono, Tjahjono, & Sumiyarso, 2019).

CVT is a widely used technology by motorcycles because it is more cost-effective, lighter, and smaller in size (La Battaglia, Giorgetti, Marini, Arcidiacono, & Citteti, 2022). On the other hand, this transmission has limited variables, so the vehicle engine will work at the highest and most efficient phase (Bhirud, Bodke, & Rane, 2016). This transmission system also requires special tools and additional power to regulate the speed (Milazzo *et al*., 2020)

The vehicle's speed and performance improvements use a CVT with a drive shaft that maintains the output speed (Ariyono *et al*., 2021). The CVT changing the vehicle speed allows engine speed to remain at the level of efficiency at its peak (Aher & Shelke, 2018). Vehicles widely used for motorcycles with CVT transmission systems or on automatic motorcycles

provide performance in driving with more effortless transmission shifts (Supriyo, Ariyono, & Sihono, 2021). In addition, the transfer of the transmission makes it easy for automatic motorbike riders, so many people rarely use manual motorbikes (Anugrah, 2019).

Modify CVT components to increase engine transmission performance on the CVT (Widodo, Mulyadi, Iswanto, Tjahjanti, & Anggara, 2019). The transmission ratio to the operating points is followed by the drive unit's efficiency (Grzegożek, Szczepka, & Adam, 2017). The drive of the transmission system consists of the primary pulley (driver pulley) and a secondary pulley (pulley driven) connected to a V-belt with the main pulley that changes the diameter of the primary pulley (Arta, Arifin, & Yudantoko, 2020). The V-belt must have a significant degree of stiffness so that in the axial direction, the pulley only makes short radial movements as it slides in and out of the pulley (Vignesh, Calcuttawala, Quazi, & Thomas, 2016).

The pulley that plays an essential role in the CVT system is a pulley drive with a pulley dimeter that can change automatically, which is influenced by engine speed based on the centrifugal force with the encouragement of the roller (Jatira, Rajab, Anwar, & Lukman, 2022). This roller determines the performance of the variator or pulley; this is because the roller is very influential on changes in the variables of the variator or pulley (Li, Li, Li, Zhang, & Yaos, 2019). Therefore, the roller certainly influences the performance of the vehicle, especially the metric motor. The weight of the roller on an automatic motorcycle has various variants. It can be experimented with to replace the importance of the roller on an automatic bike related to torque, rotational speed, and acceleration (Bertini, Carmignani, & Frendo, 2014).

In the previous study, the CVT system was tested to determine the RPM that affected the replacement of the roller weight (Akhmadi & Usman, 2021; Salam, 2016). Several previous studies have also tested the CVT system by changing the importance of the roller to find out how much power and torque it produces (Abidin & Pamungkas, 2020; Akbar, Albanjari, & Setiawan, 2022; Nofendri & Christian, 2020; Permana & Raharjo, 2020). However, in an experiment by changing the diameter of the roller or the weight of the roller to produce maximum power on an automatic motorcycle, this research relates to testing and analysis to determine the working principle, troubleshooting, and the effect of variations in CVT roller weight on a Suzuki Nex-FI 2014 motorcycle.

This study aims to provide an effort to improve the automotive world, specifically automatic motors. This can be seen in the Suzuki Nex-FI motorcycle, which has several systems, including the CVT automated transmission system, electrical system, ignition system, and FI (Fuel Injection) system. Moreover, currently, automatic motorcycles are favored by consumers or have become a trend, not only in one region but throughout Indonesia.

METHOD

Process description and research objects. In this study, the experimental method with the object of the Suzuki Nex-FI motorcycle was disassembled, and the transmission was by holding the throttle at 3250 rpm. After stabilizing, the throttle is rotated spontaneously up to 10000 rpm. In the process of disassembling and assembling the transmission on a Suzuki Nex-FI motorcycle using tools and materials, including a clutch spring compressor, a set of shock locks, a clutch center compressor, a T8 key, a flywheel holder, a 39 x 41 mm socket wrench, a knock screwdriver, a micrometer in 5-30 x 0.01 mm, screwdriver (-) and (+), micrometer in 25-50 x 0.01 mm, caliper, micrometer ex 0-25 x 0.01 mm, iron hammer, micrometer ex 25- 50 x 0.01 mm, dynamometer/Dyno test, stopwatch, speed tracker application, 2014 Suzuki Nex-

FI motorcycle, roller weighing 8 grams (17 mm x 12 mm), roller weighing 9 grams (17 mm x 12 .30 mm), 11-gram standard roller (17 mm x 12.30 mm). The system in the Suzuki Nex motorcycle manual is shown in Figure 1 and Table 1.

Figure 1
Suzuki Nex CVT system

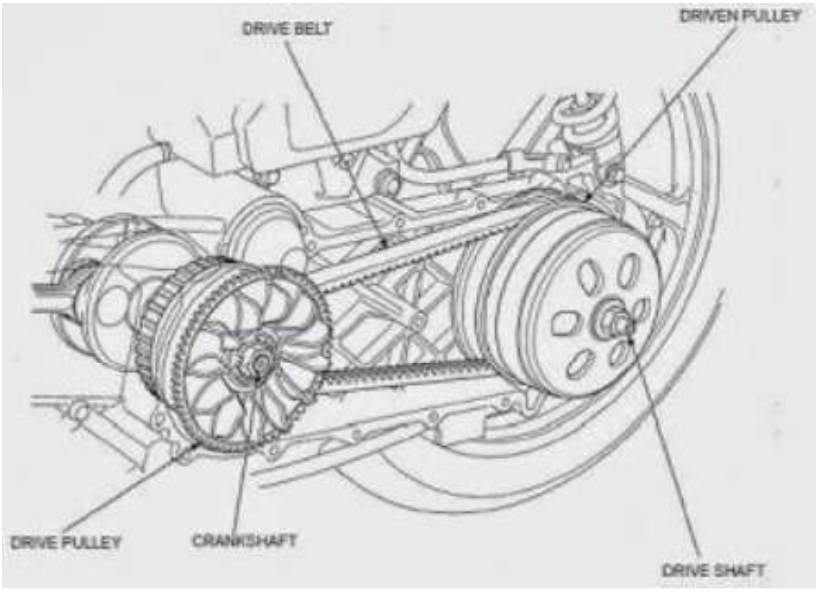


Table 1
Suzuki Nex-FI engine specifications

Specification	Information
Machine Type	4 Step, Air Conditioning, SOHC
Diameter x Step	51 x 55.2 mm
Capacity	113 cc
Compression Comparison	9.4: 1
Spark plug (Spark plug)	NGK CPR7EA-9 or DENSO U22EPR9
Lubrication System	Wet sump
Drive System	V-belt drive
Clutch	Dry shoe, automatic, centrifugal type
Reduction comparison	Variable (2.665 – 0.806)
Final reduction ratio	9,519 (44/16 x 45/13)
Maximum power	9.4 HP/8,800 rpm
Maximum torque	8.7 Nm/6,500 rpm

Troubleshooting CVT Suzuki Nex-FI Motorcycles is a problem that affects engine performance. Vehicle drivers feel problems that often occur; noises from the CVT cover and excessive vibration when driving. Table 2 shows CVT troubleshooting and the causes that usually occur in the motor.

Table 2
Troubleshooting CVT

Troubleshooting	Reason
The engine is running, but the motor won't move	a. Drive belt has worn b. The ramp plate is broken c. Clutch shoes worn/damaged d. Broken face-driven spring
The engine stops suddenly, or the motor crawls	a. Broken clutch shoe spring
At high rpm, less powerful pulling	a. Drive belt has worn b. Worn roller housing c. Centrifugal canvas wear
The engine runs, but power is lacking	a. Drive belt eroded b. eroded weight roller c. Weak-driven face spring

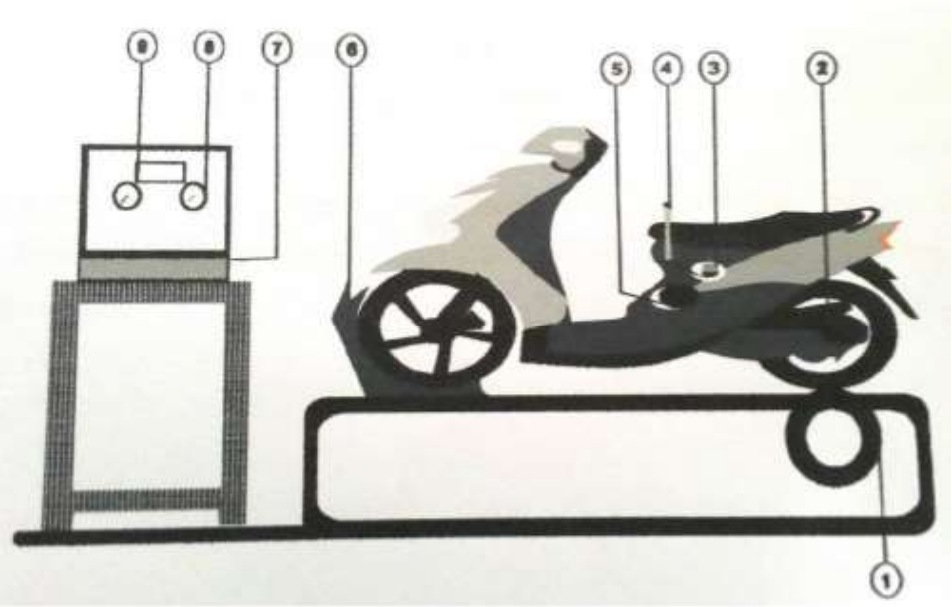
Measurements and analysis. This study used a 0.05 mm caliper to measure several components, including the drive belt/v-belt, spacer/boss, clutch housing, movable driven face spring, and clutch shoe/. Not only taking measurements using a caliper but a micrometer in 5-30 x 0.01 mm to measure the movable drive face components. Micrometer ex 0-25 x 0.01 mm specifically for measuring roller weight. Micrometer ex 25-50 x 0.01 mm to measure the driven face and movable driven face. Next, check the movable-driven face pin and roller for cracks and wear.

Before the analysis, it is necessary to test the object to determine the effect of roller weight variations on acceleration and top speed. The process of testing and retrieval of power and torque data with the steps of preparing the material to be tested, placing the motorcycle on the dynamometer unit, carrying out the power and torque testing process according to predetermined procedures, recording all test results based on engine power parameters (Hp). And engine torque (N.m) measured in the experimental results. The test equipment on the research object can be seen in the schematic in Figure 2.

The information in Figure 2 is the number 1 Dynamometer, number 2 Exhaust, number 3 Injector, number 4 Burret, number 5 engine, number 6 Motor holder, number 7 Computer, number 8 Tachometer, and number 9 Torsiometer. The dynamometer consists of a rotor driven by a motor to be measured and rotated in a magnetic field. The strength of the magnetic field is controlled by changing the current along the arrangement of coils placed on either side of the rotor. This rotor serves as a conductor that cuts the magnetic field. Due to the magnetic field cutting, a current is induced in the rotor so that the rotor becomes hot.

The analysis of this test was carried out to obtain one way to increase the rotary power produced by the engine by changing the weight of the roller on the CVT. The test was carried

Figure 2
Schematic of motor power and torque test equipment



out by experimenting with three variations of rollers with different weights. In the first process, we tested with a standard 11-gram roller; in the second process, we tried with an 8-gram roller; in the third process, we experimented with a 9-gram roller. The test results compare so that the maximum acceleration and top speed can be known.

FINDING AND DISCUSSION

The first results ring and check the parts con parts. These components include: drive belt, spacer/boss, movable drive face, ramp plate, weight roller, clutch housing, movable driven face spring, clutch shoe, driven face, portable driven face, movable driven face pin, and roller shown in Tabel 3. In addition, the author also discusses the effect of CVT roller weight variations on Suzuki Nex motorcycles; the rollers used in the test include standard rollers of 11, 8, and 9 grams.

Troubleshooting checks are carried out by opening and removing components, checking and measuring, and reassembling the CVT system components. The steps to find out troubleshooting are a reference in carrying out maintenance and repairs on the automatic motorcycle CVT system. The trouble that often occurs in the CVT system will significantly affect an engine's performance. Therefore, checking or maintaining a sound CVT system must prevent and overcome these disorders. Some of the diseases that often occur in the CVT system are shown in Table 4, which explains the causes.

One way to increase the rotary power produced by the engine is by changing the weight of the roller on the CVT. This test uses three variations of rollers with different weights. The test results compare so that the maximum acceleration and top speed can be known. Roller test

Table 3
Results of checking CVT components

Component Name	Usage Limit	Checking result	Description
Drive belt	drive belt/V-belt : 18,60 mm	18 mm	The condition of the drive belt/V-belt has shrunk and is worn and must be replaced immediately
Spacer/boss	outside diameter : 22,48 mm	22,50 mm	The measurement results are still within the standard of use and are still suitable for use
Movable drive face	inner diameter : 22,60 mm	22,55 mm	The measurement results are still within the tolerance of use and are still suitable for use
Ramp plate		No cracks and wear	The ramp plate is still suitable for use because there are no cracks and wear
Weight roller	roller : 16,30 mm	16,70 mm x 12 mm	The weight roller is still worth using because it hasn't crossed the usage limit yet
Clutch housing	112,50 mm	112,00 mm	Clutch housing is still suitable for use because it is still in standard use
Clutch shoes	clutch canvas: 2,0 mm	2,2 mm	It's still worth using because it hasn't crossed the usage limit
spring	spring : 81,50 mm	85,00 mm	Spring is still worth using because it hasn't crossed the usage limit
Driven face	outside diameter : 33,93 mm	34,96 mm	Drive face is still in standard use and is still suitable for use
Movable driven face	inside diameter : 34,06 mm	34,00 mm	The movable drive face is still in standard use and is suitable for use
Pin dan roller		In no-wear condition	Pins and rollers are still in good working condition

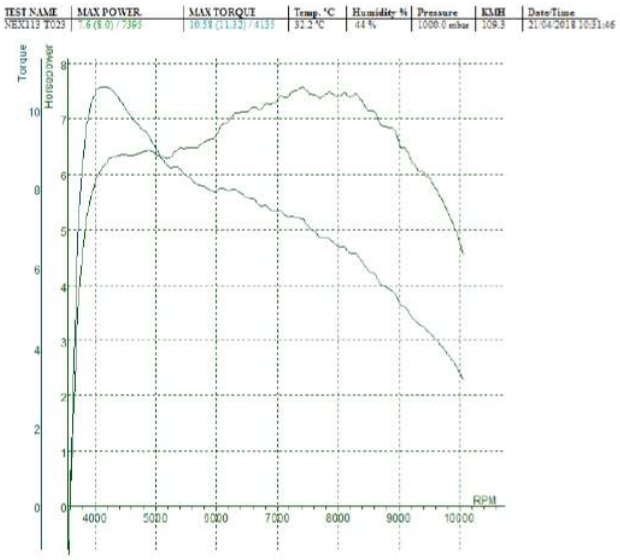
results using a dynamometer test equipment with roller variations. Figure 3 shows the results of the 11-gram roller dynamometer test (standard). Figure 4 shows the results of the 9-gram roller dynamometer test. Finally, Figure 5 shows the 8-gram roller dynamometer test results.

According to the manufacturer, the power test results used a standard 11 grams roller and an 8 and 9 grams variation roller. This differs from previous studies that used a roller variation more significant than the typical 11 grams (Abidin & Pamungkas, 2020; Akbar *et al*., 2022; Permana & Raharjo, 2020). The Suzuki Nex object is 113 cc (standard) with a roller weight variation of 8, 9, and 11 grams (average) at a certain rpm compared to the power per rpm. The test results can be seen in Table 5 that the emphasis on the Suzuki Nex 113 cc using an 8-gram

Table 4
Troubleshooting on CVT

Symptoms that often occur	Reason	How to overcome
Sounds/squeaks	The drive belt shrinks/wears and cracks appear in the drive belt	Replacing the drive belt with a new one because it has passed the usage limit
The engine is less powerful when going uphill	The movable driven face is broken, pin guide is worn	Replace portable driven face, replace pin guide
The engine starts but won't move	The drive belt is worn or broken; the ramp plate is broken; clutch shoes are worn/ damaged	Replacing the drive belt with a new one, replacing the ramp plate with a new one, replacing clutch shoes with new ones
There is a noise from inside the CVT cover	The drive belt is worn; the rollers are very pale, and there is excessive oil/grease in the clutch	Replace the drive belt, replace the roller with a new one, and clean the clutch with oil or alcohol
Excessive vibration on CVT	Incorrect installation of the clutch, the lock is not tight enough, the clutch housing has oil	Correct the clutch mounting position, re-tighten the lock, clean the clutch housing
The engine is not stable when the motorcycle is running slowly	Spring-driven face clutch lining is broken	Replacing the spring-driven face

Figure 3
(a) Graph of 11-gram roller dynamometer test results (standard); (b) Explanation of the graph



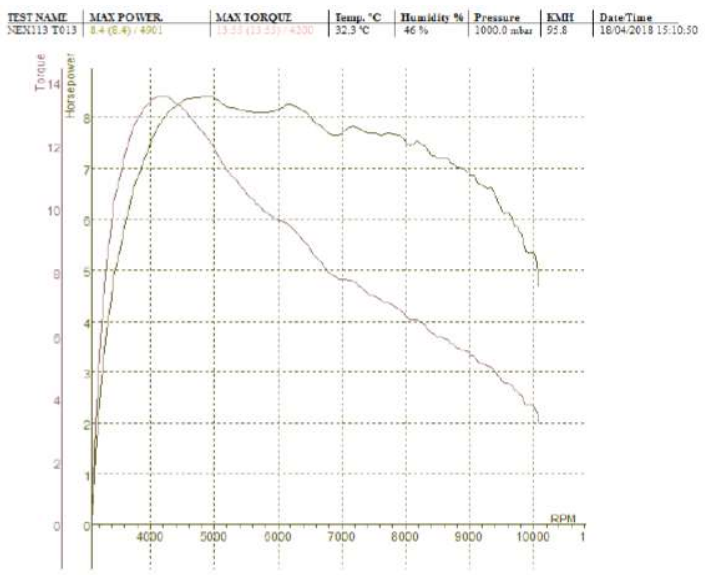
a

DATA FOR TEST: NEX113 T023

RPM	HP (HP)	Q (N*M(*M)	T
3750	4.2	7.95	0,70
4000	5.9	10.41	0,92
4135	6.1	10.58	1,04
4250	6.3	10.59	1,16
4500	6.4	10.05	1,40
4750	6.4	9.54	1,66
5000	6.4	8.99	1,94
5250	6.5	8.54	2,20
5500	6.5	8.35	2,50
5750	6.6	8.06	2,82
6000	6.7	7.93	3,10
6250	7.0	7.98	3,40
6500	7.1	7.79	3,72
6750	7.2	7.56	4,04
7000	7.4	7.44	4,38
7250	7.5	7.31	4,70
7395	7.6	7.25	4,90
7500	7.4	7.01	5,06
7750	7.4	6.76	5,40
8000	7.4	6.53	5,78
8250	7.4	6.36	6,16
8500	7.2	5.95	6,58
8750	6.9	5.55	7,02
9000	6.5	5.11	7,52
9250	6.2	4.71	8,04
9500	5.9	4.39	8,60
9750	5.4	3.91	9,22
10000	4.8	3.36	9,94
LOSSES:	-0.4 HP	-0.73*M(*M	
TOTAL ENGINE:	8.0HP	11.32N*M*M(	

b

Figure 4
(a) Graph of 9-gram roller dynamometer test results; (b) Explanation of the graph



a

DATA FOR TEST: NEX113 T013

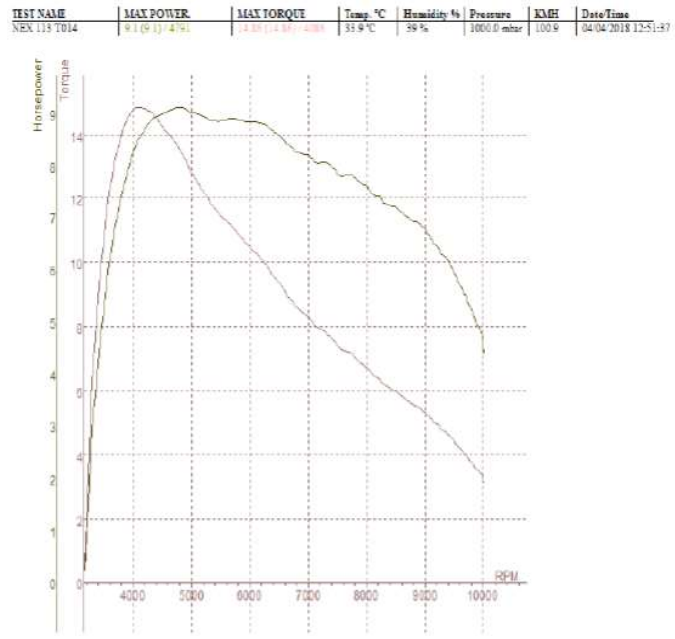
Comments
ROLLER 9 GRAM

RPM	HP (HP@Q	(N*M*M)	T
3250	3.3	7.17	0,62
3500	5.3	10.92	0,76
3750	6.6	12.69	0,90
4000	7.5	13.43	1,04
4200	7.9	13.56	1,14
4250	8.1	13.53	1,18
4500	8.3	13.18	1,32
4750	8.4	12.53	1,48
4901	8.4	12.23	1,56
5000	8.4	11.89	1,64
5250	8.2	11.10	1,80
5500	8.1	10.43	2,00
5750	8.1	9.98	2,18
6000	8.2	9.63	2,38
6250	8.2	9.29	2,58
6500	8.0	8.69	2,80
6750	7.7	8.06	3,04
7000	7.7	7.78	3,26
7250	7.8	7.60	3,50
7500	7.7	7.23	3,78
7750	7.7	7.02	4,02
8000	7.5	6.60	4,32
8250	7.4	6.36	4,62
8500	7.2	5.98	4,94
8750	7.1	5.71	5,26
9000	6.9	5.38	5,62
9250	6.6	5.03	6,02
9500	6.2	4.57	6,44
9750	5.8	4.20	6,94
10000	5.3	3.75	7,48

LOSSES: 0.0 HP 0.0N*M*M
TOTAL ENGINE: 8.4HP 13.55N*M*M

b

Figure 5
(a) Graph of 8-gram roller dynamometer test results; (b) Explanation of the graph



a

DATA FOR TEST: NEX 113 T014

Comments
ROLLER

RPM	HP (HP@Q	(N*M*M)	T
3250	2.1	4.59	0,56
3500	5.5	11.16	0,72
3750	7.3	13.85	0,86
4000	8.3	14.81	1,00
4086	8.5	14.86	1,04
4250	8.8	14.76	1,14
4500	9.0	14.26	1,28
4750	9.1	13.66	1,44
4791	9.1	13.57	1,46
5000	9.0	12.77	1,62
5250	8.9	11.99	1,80
5500	8.8	11.41	1,98
5750	8.9	10.98	2,16
6000	8.8	10.43	2,38
6250	8.8	9.97	2,58
6500	8.7	9.30	2,82
6750	8.3	8.68	3,06
7000	8.2	8.30	3,30
7250	8.1	7.86	3,58
7500	7.8	7.38	3,86
7750	7.8	7.14	4,14
8000	7.6	6.72	4,46
8250	7.3	6.28	4,80
8500	7.2	5.96	5,16
8750	6.9	5.58	5,54
9000	6.7	5.27	5,96
9250	6.4	4.86	6,38
9500	5.9	4.39	6,88
9750	5.3	3.84	7,42
10000	4.4	3.09	8,14

LOSSES: 0.0 HP 0.0N*M*M
TOTAL ENGINE: 9.1HP 14.86N*M*M

b

Table 5
Comparison of rotational speed (rpm) with power (HP)

Power/Rpm		
Roller 8 grams	Roller 9 grams	Roller 11 grams (standard)
7.3/3750	6.6/3750	4.2/3750
9.1/4086	8.4/4000	6.4/4000
9.0/4500	8.4/4200	6.4/4135
7.8/4500	7.7/4250	7.6/4250
7.3/8250	7.4/8250	7.4/8250

roller has decreased ability to 7.3 HP at a rotating speed of 8250 rpm; on a 9-gram roller, it has reduced power to 7.4 HP at a rotating speed of 8250 rpm, while the 11-gram roller (standard) with the same rotational speed experienced a decrease in the ability to 7.4 HP. In contrast to previous studies that tested the weight of the roller against rpm on the object of the automatic motor itself (Akhmadi & Usman, 2021; Salam, 2016).

From the results of the roller test on the Suzuki Nex 113 cc with a roller weight variation of 8, 9, and 11 grams (standard), the highest power was obtained by a roller of 8 grams. This is because a study once focused only on the result of the object's rpm rotation by replacing the roller variation (Akhmadi & Usman, 2021). In addition, this is because the 8-gram roller has the lightest weight, so the roller can be thrown and pressed on the movable drive face quickly, and there is no slip between the portable drive face and the drive belt/V-belt. At the same time, the 11-gram roller (standard) is heavier, so the roller will tend to be thrown more slowly but is faster in pressing the movable drive face. Therefore, the more serious the roller, the slower the roller will be thrown on the portable drive face.

Comparing the rotational speed (rpm) with the torque (N.m) on the Suzuki Nex 113 cc motorcycle with a roller weight variation of 8, 9, and 11 grams (standard) related to an increase in the rotational speed (rpm) until it reaches the maximum torque, the torque will return down even though the engine speed continues to increase. This is because the higher the engine speed, the greater the centrifugal force received by the CVT roller so that the roller will be thrown out, pressing the movable drive face at the top or outermost position, and the drive belt on the portable drive face will shift to the pulley diameter the most many primers. The results of the comparison of rotational speed with torque can be seen in Table 6.

Table 6
Comparison of rotational speed (rpm) with torque (N.m)

Torque/Rpm		
Roller 8 grams	Roller 9 grams	Roller 11 grams (standard)
13.85/3750	12.69/3750	7.95/3750
14.86/4086	13.43/4000	10.41/4000
14.76/4500	13.55/4200	10.58/4135
14.26/4500	13.53/4250	10.53/4250
6.28/8250	6.36/8250	6.36/8250

From the results of the roller test on the Suzuki Nex 113 cc with a roller weight variation of 8, 9, and 11 grams (standard), the highest power was obtained by a roller of 8 grams. This is because the 8-gram roller has the lightest weight, so the roller can be thrown and pressed on the movable drive face quickly, and there is no slip between the portable drive face and the drive belt/V-belt. At the same time, the 11-gram roller (standard) is heavier, so the roller will tend to be thrown more slowly but is faster in pressing the movable drive face. Therefore, the more serious the roller, the slower the roller will be thrown on the portable drive face.

From the results of testing the roller on the Suzuki Nex 113 cc with a roller weight variation of 8, 9, and 11 grams (standard), the highest torque was obtained by a roller of 8 grams. This is because the 8-gram roller has the lightest weight, so the roller can be thrown and pressed on the movable drive face quickly, and there is no slip between the portable drive face and the drive belt/V-belt. At the same time, the 11-gram roller (standard) is heavier, so the roller will tend to be thrown more slowly but is faster in pressing the movable drive face. Therefore, the more serious the roller, the slower the roller will be thrown on the portable drive face.

Comparison of the acceleration and top speed testing results on a Suzuki Nex 113 cc motorcycle using a roller weight variation of 8, 9, and 11 grams (standard). The results of the comparison of acceleration and top speed can be seen in Table 7.

Table 7
Acceleration and top-speed test results

Roller Weight Variation	Acceleration and Top Speed		
	Distance (m)	Speed (km/h)	Time (s)
8 grams	201 meters	75 km/h	13,31 second
9 grams	201 meters	73 km/h	13,81 second
11 grams (standard)	201 meters	75 km/h	14,73 second

The last results of roller testing on the Suzuki Nex 113 cc with variations in roller weight of 8, 9, and 11 grams (standard) show a roller of 8 grams obtains the highest acceleration. This is because the 8-gram roller has the lightest weight, so the roller can be thrown and pressed on the movable drive face quickly, and there is no slip between the portable drive face and the drive belt/V-belt. But the top speed decreases at a high rate because the centrifugal force received by the roller is getting bigger, so the roller will be thrown out, pressing the movable drive face at the top position or the outer side. The drive belt on the portable drive face will shift to the most significant primary pulley diameter. Big. While the 11-gram roller (standard) is heavier, so the roller will tend to be thrown more slowly but is faster in pressing the movable drive face. The heavier the roller, the slower the roller will be thrown on the portable drive face.

CONCLUSION

Research with the object of the Suzuki Nex 113 cc motorbike on the working principle of the automatic transmission system (CVT) is related to the rotation results received by the ballast roller on the primary pulley. Furthermore, power and torque testing has been carried out using a roller weight variation of 8, 9, and 11 grams (standard). The highest power is by an 8-gram roller with a capacity of 9.1 HP at 4791 rpm and the most increased torque of 14.80 N.m at 4086 rpm.

On the 9-gram roller, the highest power is 8.4 HP at 4901 rpm, and the highest torque is 13.55 N.m at 4200 rpm. At the same time, the 11-gram roller (standard) has the highest power of 7.6 at 7395 rpm and the most increased torque of 10.58 N.m at 4135 rpm. The lighter the CVT roller, the greater the torque produced at low rotations, but the power and torque begin to decrease for high revolutions. On the other hand, the heavier the CVT roller is, the less maximum torque is produced at low rotations, but the power generated is quite full for high reels.

Due to the frequent disturbances in the CVT system that affect the acceleration of the motor, the acceleration, and top speed tests were carried out. The results of the fastest acceleration by an 8-gram roller with the quickest time of 13.31 seconds, a distance of 201 meters, and a top speed of 75 km/hour. The fastest time on the 9-gram roller is 13.81 seconds, with a distance of 201 meters and a top speed of 73 km/hour. At the same time, the 11-gram roller (standard) has the fastest time of 14.73 seconds with the same distance and a top speed of 75 km/hour. Disturbances in this CVT system are noise in the CVT chamber, excessive vibration, and a squealing sound when acceleration begins to increase. How to overcome these disturbances with regular maintenance, for example, cleaning the components and CVT space, replacing the drive belt/V-belt every 20,000 km, and don't forget to change the gear oil every 10,000 km.

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