Comparison of Comfort Level using Air Suspension with Electric Control 2.5 Bar and Factory Standard Hydraulic Suspension on a 2011 Vario 110 cc Motorbike Unit

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Abstract: The comfort in driving either by motorbike or car is the most important factor for drivers and passengers. Motorbikes or cars always experience vibrations or shocks due to the engine or the passed road. To reduce the vibrations and shocks, motorbikes or cars are equipped with suspensions. This initiated the authors in conducting the study about the Comparison of Comfort Level Using Air Suspension with Electric Control 2.5 bar and Factory Standard Hydraulic Suspension on a 2011 Vario 110 cc Motorbike Unit. This study used experimental method by testing the both types of suspensions on a rocky road. The aim was to find out how big the ratio of the vibration speed using the two types of suspensions. The result indicated that the ratio of the average acceleration of the vibrations produced by the Air Suspension System using the Electric Control 2.5 bar and the Factory Standard Hydraulic Suspension at each rotation was 1:1.6 at 3500 rpm; 1:2.5 at 4500 rpm and 1:2.1 at 5500 rpm, which meant that the air suspension using electric control 2.5 bar had a higher level of comfortability and stability compared to the factory standard hydraulic suspension.

1 INTRODUCTION

Suspension is one of the parts on vehicle system that plays an important role in vehicle stability in addition to the engine system, steering, drive line, brake system, chassis and vehicle body. The study in increasing the comfort and safety by improving the quality of comfort in the vehicle suspension system that encourages researchers to continue carrying out various research and experiments in order to create various suspension system innovations which have more effective performance with a higher level of comfort compared to existing suspension.

Air suspension or Pneumatic is one of the innovations in a vehicle suspension that offers higher performance and comfort compared to previous types of suspension. According to (Ka'ka et al., 2018), using a pneumatic actuator instead of the real dynamic load of the vehicle provided the characteristics overview of the connection between working pressure and dynamic load. If the working pressure P2 (bar) given

is greater, then the vertical dynamic load Ft (N) which burdens the road structure will also increase (Ka'ka et al., 2018). This was added by (Handriyanto, 2014) who stated that mass response and energy generation from the spring constant from their test results indicated that the higher the load, the greater the damping value produced (Handriyanto, 2014).

In addition, (Fernandes et al., 2020) claimed that geometric nonlinearity induces changes in the springs and damping forces due to the different slopes of the spring-damper assembly during expansion and compression, resulting in changes in the acceleration amplitude and resonant frequency. This effect lies in the effect of the asymmetric damping coefficient only, which ultimately affects the acceleration of the suspension mass. Therefore, these two effects must be carefully considered when designing a suspension system with comfort criteria (Fernandes et al., 2020).

Vibration is a factor which affects comfort due to engine performance and road ruggedness. Based on the above analysis there are two factors, namely

internal effects related to vibration intensity and external effects related to frequency, amplitude, direction and duration of vibration. ISO, which evaluates the effects of vibrations used on humans, provides a limit value for vibration transmitted to humans in a frequency 1:8 Hz for longitudinal vibrations. The comfort limit in the ISO 2631 standard is expressed in terms of vibration

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acceleration whose value is influenced by the frequency and time of vibration.

Comfort is basically a subjective thing. However, some research has been conducted to solve this problem. One of them was a study that introduced an understanding of the discomfort experienced by the drivers or motorists toward vibrations. For this study, the standard of comfort was used to analyze the comfort and stability of the air suspension with electrical control and the factory standard hydraulic suspension, using ISO 2631.

ISO 2631 standardization is a convenience criterion that is given by the International Standard Organization. Thus, there is a standard for whole body vibration. This standard is recommended for evaluating the effect of vibration on a vehicle or industry. This criterion describes three different limits for whole body vibrations in the 1 to 80 Hz frequency ranges. The limits are: (1) reduce comfort boundary. It is related to the comfort. While in transportation vehicles, this is related to activities being done in the vehicle during the trip, such as reading, writing, and eating. (2) fatigue or decreased proficiency boundary which is related to preservation of work efficiency, such as driving a vehicle. (3) exposure boundary is related to the preservation of safety or health which should not be exceeded without special provisions.

(Shen et al., 2016) stated that ISD suspension has superior damping performance than passive suspension. Besides, it can solve the contradiction between comfort and handling effectively Shen et al., 2016). Then, (Nugroho et al., 2018) said that the effect of the type of two-wheeled vehicle suspension system on the vibration of the vehicle was very significant according to the level of the road bumps it passed and the type of suspension system (Nugroho et al., 2018).

(Prastiyo et al., 2021) conducted a research in two types of suspension. They stated that the type of linear double wishbone suspension and the type of progressive suspension did not show superiority in terms of vehicle suspension system stability and driving comfort. However, conventionally, a linear suspension system will be the best choice to be applied to the rally class (Prastiyo et al., 2021).

(Yatak et al., 2021) on their research entitled "*Ride Comfort-Road Holding Trade-off Improvement of Full Vehicle Active Suspension System by Interval Type-2 Fuzzy Control*" said that it is possible to simultaneously increase the ride index and vehicle stability with a hybrid fuzzy controller (Yatak et al., 2021).

2 METHOD

This study carried out experimental method by testing the both types of suspensions on a rocky road. The tools used were vibration meter, tachometer, and measure tape. Vibration meter was used to measure the vibration of both types of shock absorber when the testing was conducted. The tachometer was used to measure the engine rotation speed which calculates the rotation speed of the 2011 Vario 110 cc motorbike engine. Measure tape was used to measure the length of the field that would be passed by the 2011 Vario 110 cc motorbike unit to conduct experiments in the process of analysis and data collection.

This study used a 2011 Vario 110 cc motorbike unit, factory standard hydraulic shock absorber, and pneumatic suspension with electric control 2.5 bar.

2.1 Procedures

The preparation and testing steps were conducted in this study. They are explained as follow:

2.1.1 Preparation Steps

- Prepare 1 unit of 2011 Vario 110 cc motorbike unit and the driver. The empty mass of the 2011 Vario 110 cc motorbike unit is 99.3 kg and the mass of the driver was 50 kg so the total load received by the suspension was 149.3 kg.
- Assemble and prepare a pneumatic suspension system with electric control and factory standard hydraulic suspension on a 2011 Vario 110 cc motorbike unit.
- Ensure the tools used for the testing worked and functioned properly.

2.1.2 Testing Steps

- Attach the vibration meter to the pneumatic suspension type with electrical control.
- Turn the ignition key to the engine starter position.
- Turn on the compressor.
- Wait for the air tube to be fully filled as needed.
- Start the air filling process on the pneumatic shock, on low position (2 bar) and high position (2.5 bar).
- Adjust the engine speed using a tachometer with variations of 3500, 4500, and 5500 rpm on rocky terrain. The reason for taking the maximum rpm

was 5500, because the vehicle could only run with a maximum rpm of 5500 on a rocky road.

- Run the motor in a predetermined field while pressing the vibration meter button. After the vehicle ran stable at a distance of 30 km and at a predetermined rpm, stop pressing the vibration meter button and the maximum value of vibration acceleration would be obtained.
- Record the vibration acceleration of the pneumatic shock absorber with electrical control using a vibration meter. Each test for each rpm was repeated for seven (7) times.
- Replace the vibration meter stick on the factory standard hydraulic suspension material.
- Repeat steps.

3 RESULT AND DISCUSSION

Based on the measurement results of vibration speed using air suspension with electric control 2.5 bar and factory standard hydraulic suspension on a 2011 Vario 110 cc motorbike unit on a rocky road, the result was shown on Table 1 below.

Table 1: Vibration Speed using Air Suspension with Electric Control 2.5 bar and Factory Standard Hydraulic Suspension on A 2011 Vario 110 cc Motorbike Unit.

No	Rotation (rpm)	Vibration Speed (m/s²)	
		Air Suspension with Electric Control 2.5 bar	**Factory Standard Hydraulic Suspension**
1	3500 (25km/h)	7.8	13.1
		7.9	12.7
		8.3	12.7
		7.8	11.5
		8.4	13.4
		8.9	12.8
		8.1	13.2
	Average	**8.2**	**12.8**
2	4500 (35 km/h)	7.8	19.4
		7.6	19.5
		7.1	18.6
		7.2	18.3
		8.1	18.9
		7.3	19.3
		7.7	18.9
	Average	**7.5**	**19.0**
3	5500 (45 km/h)	10.0	20.4
		9.7	21.0
		10.1	19.9
		9.2	20.8
		9.5	20.2
		10.4	19.8
		10.5	21.1
	Average	**9.9**	**20.5**

From the Table 1 Vibration Speed using Air Suspension with Electric Control 2.5 bar and Factory Standard Hydraulic Suspension on A 2011 Vario 110 cc Motorbike Unit above, it was obtained averages of vibration speed which then explained in the following graphic.

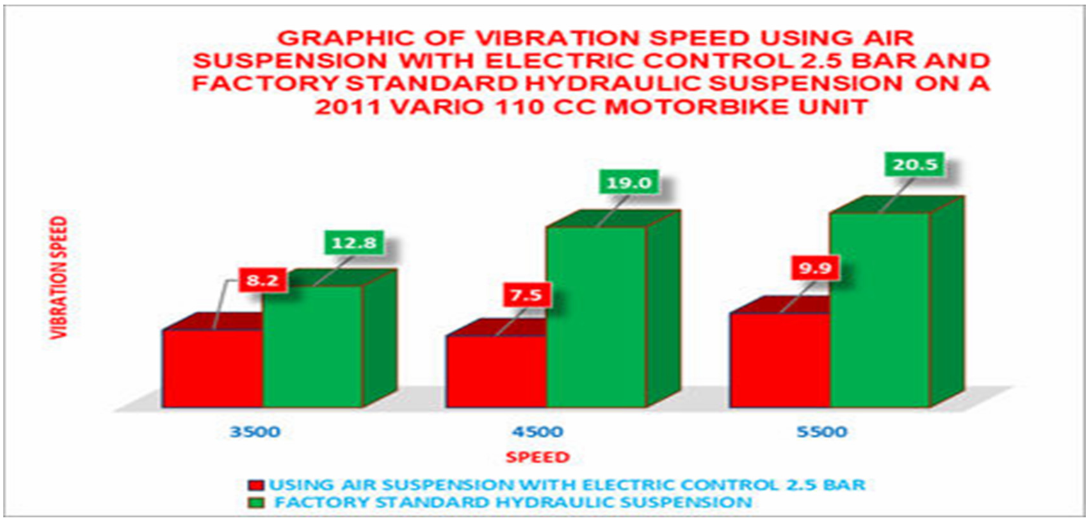

Figure 1: The Graphic of the Vibration Speed Averages Using Air Suspension with Electric Control 2.5 bar and Factory Standard Hydraulic Suspension on a 2011 Vario 110 cc Motorbike Unit.

From the Figure 1 The Graphic of the Vibration Speed Averages Using Air Suspension with Electric Control 2.5 bar and Factory Standard Hydraulic Suspension on a 2011 Vario 110 cc Motorbike Unit above showed that the averages of vibration speed using air suspension with electric control 2.5 bar on Vario 110 cc 2011 motorbike unit on a rocky road to all rpm testing variations were lower than factory standard hydraulic suspension. The comparison of the vibration speed averages using air suspension system with electric control 2.5 bar and the factory standard hydraulic suspension at each rotation was 1:1.6 at 3500 rpm; 1:2.5 at 4500 rpm and 1:2.1 at 5500 rpm.

4 CONCLUSIONS

Based on the results, it can be concluded that: (1) The comparison of the vibration speed averages using air suspension system with electric control 2.5 bar and the factory standard hydraulic suspension at each rotation was 1:1.6 at 3500 rpm, 1:2.5 at 4500 rpm, and 1:2.1 at 5500 rpm, (2) Pneumatic suspension system with electric control 2.5 bar has better comfort level than the factory standard hydraulic suspension system.

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