Research Article

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Testing the relationship between the technical condition of motorcycle shock absorbers determined on the diagnostic line and their characteristics

https://doi.org/10.1515/eng-2022-0435
received December 01, 2022; accepted March 30, 2023

Abstract: The article presents the results of research on the relationship between the technical condition of motorcycle shock absorbers determined on the diagnostic line and their damping characteristics. The basic division of shock absorber tests was characterized, which includes tests of shock absorbers installed in the motorcycle and disassembled, carried out on a test stand made of MTS components. The results of two sets of shock absorbers tested using the EUSAMA and THETA methods, as well as tested on a stand for testing shock absorbers removed from a motorcycle, are discussed. Based on the obtained results, the best method of diagnosing shock absorbers was indicated.

Keywords: shock absorbers, shock absorber test methods, diagnostics and operation of the motorcycle suspension, characteristics of damping, safety of motorcyclists

1 Introduction

The suspension of a motorcycle is a complex mechanism consisting of numerous cooperating and interrelated elements, which include control, guiding, springing, and damping elements. These elements are responsible for the proper contact of the tire with the road surface and the damping of vibrations of the sprung and unsprung masses [1–4]. The main source of vibrations is the uneven road surface, and the most important vibration-absorbing element is the shock absorbers. These are mechanisms with high damping properties and usually with asymmetrical work characteristics. The efficiency of shock absorbers has a large impact on ride comfort (vibration comfort), motorcycle handling, and active safety, which is determined by the correct contact of the tire with the road surface [5–8].

Taking care of the proper contact of the tire with the road surface, shock absorbers affect the proper operation of systems such as ABS. Among the symptoms of the deteriorating technical condition of shock absorbers, one can notice accelerated tire wear, longer braking distances, steering wheel vibrations, and unstable cornering [9–12].

The choice of shock absorbers is a difficult issue due to the conflicting issues of comfort and safety. The conflict lies in the different resonant frequencies of the sprung and unsprung masses of the motorcycle. The first range determines the comfort of riding, and the second determines the safety of riding a motorcycle [13–15]. Although vibration comfort is regulated by standards, the issue itself is still debatable due to its very subjective nature. Drivers have different perceptions of what they find comfortable. And the selection of shock absorbers in terms of safety is also difficult due to the variable excitation of the road surface affecting the motorcycle [16–19].

The operational wear of shock absorbers is a slow and gradual process. Like any other part of a motorcycle, shock absorbers also wear out and well performed technical inspections allow for early detection of damage [20–23]. Damping efficiency can be tested in two ways: testing the shock absorbers installed on the motorcycle and testing the shock absorbers removed from the motorcycle. In the first type, there is a method of free vibrations

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and forced vibrations. The test results are primarily influenced by the air pressure in the tires, the sprung mass, and the friction force in the suspension [24–27].

2 Test bench

A universal testing module is used to test shock absorbers removed from motorcycles, which includes:

- electrohydraulic pulsator model 244.12,
- servo valve model 244.12,
- hydraulic power system model Silent Flow 505.20,
- Controller Model 407 control system,
- mounting system of the tested shock absorbers.

The task of the electrohydraulic pulsator model 244.12 (Figure 1) is to apply a mechanical load to the tested shock absorber. The pulsator enables the measurement of displacement and force [1,7].

A universal structure, anchored to the technological plate (1) with an electrohydraulic actuator, was used to fasten the tested elements. During the tests, the cross beam (2) is locked in the upper position. A handle with adjustable length (3) is installed on the beam, to which a force sensor (4) is attached. The test stand allows you to recreate the actual working parameters of shock absorbers in motorcycles. The basic technical parameters of the operation of the pulsator assembly are presented in Table 1 [2,7,28].

Figure 1: Test stand for shock absorbers.

Table 1: Basic technical parameters of the pulsator assembly

Technical parameters	Values
Piston rod load	−25 kN ÷ 25 kN
Piston rod stroke	−75 mm ÷ 75 mm
The frequency of movements	100 Hz
Output signal voltage range	−10 V ÷ 10 V

Figure 2: Beissbarth diagnostic line: (a) THETA SAT690 device and (b) EUSAMA SA640 device.

Table 2: Basic parameters of THETA SAT 690 stand

Technical parameters	Values
Maximum axle load	2,200 kg
Station dimensions	800 × 2,350 × 286 mm
Station weight	500 kg
Vibration amplitude	3.5 mm
Vibration frequency	10 Hz
Indication range	0 & ÷0.35
Indication accuracy	±2%
Engine power	2 × 1.1 kW

Table 3: Basic parameters of the EUSAMA SA 640 stand

Measurement range	Values
Adhesion	0 ÷ 24 Hz
przyczepność	0 ÷ 100%
Maximum axle loads	2,500 kg
Engine power	2 × 2.5 kW
Power	5 × 2.5 mm^2
Power protection	3 × 20 A

The shock absorbers installed in the motorcycle were tested on the Bosch Beissbarth diagnostic line (Figure 2). The line is designed to measure the damping efficiency using two methods: EUSAMA SA640 and THETA SAT690 [1,15,27].

On the diagnostic line, shock absorbers are assessed using the EUSAMA and THETA methods. The technical data of the stands are presented in Table 2 (THETA SAT 690) and Table 3 (EUSAMA SA 640) [1,27].

The EUSAMA method consists in excitation of a tire wheel to vertical vibrations with an amplitude of 3 mm and a frequency of 25 Hz to zero. The evaluation of the shock absorber damping effectiveness using this method is made based on the index (WE) [4,29].

The adopted evaluation criterion is as follows:

(a) WE = 0 ÷ 19% – poor technical condition of shock absorbers (insufficient damping value),
(b) WE = 20 ÷ 39% – permissible damping value - the shock absorber needs to be checked,
(c) WE = 40 ÷ 59% – good damping value,
(d) WE = 60 ÷ 100% – very good damping value.

Table 4: Group I – vehicles weighing more than 1,400 kg

Indicator value WE	Shock absorber condition assessment
0 ÷ 29%	Insufficient
30 ÷ 49%	Sufficient
50 ÷ 69%	Good
70 ÷ 100%	Very good

Table 5: Group II – vehicles weighing from 900 to 1,399 kg

Indicator value WE	Shock absorber condition assessment
0 ÷ 19%	Insufficient
20 ÷ 39%	Sufficient
40 ÷ 59%	Good
60 ÷ 100%	Very good

Table 6: Group III – vehicles weighing less than 899 kg

Indicator value WE	Shock absorber condition assessment
0 ÷ 19%	Insufficient
20 ÷ 29%	Sufficient
30 ÷ 59%	Good
60 ÷ 100%	Very good

Tests of the effectiveness of damping suspension vibrations for light vehicles raise doubts. The Hoffman company proposes a solution to this problem by dividing the vehicles into three groups depending on the weight [30].

Group I – higher class vehicles weighing more than 1,400 kg receive the following assessment criteria presented in Table 4.

Group II – medium class vehicles weighing from 900 to 1,399 kg receive the following assessment criteria presented in Table 5.

Group III – light class vehicles weighing less than 899 kg receive the following assessment criteria presented in Table 6.

In the case of testing motorcycles using the EUSAMA method, the shock absorber assessment criterion for group III was adopted.

THETA method uses forced vibrations to assess the damping properties of shock absorbers. The engine in the test stand, accelerated to a rotational speed, causes vertical vibrations of the overrun plate with a frequency of 10 Hz, and then the drive is turned off, which contributes to the free coasting of vibrations of the stand. The assessment of the damping effectiveness of shock absorbers with this method is made based on the dimensionless vibration coefficient (D) [1,31].

3 Course of research

The subject of the tests were two sets of motorcycle shock absorbers for the Yamaha Virago XV 125 motorcycle:

a) b)

Figure 3: View of the tested elements: (a) shock absorber and spring assembly factory-installed in the vehicle and (b) YSS suspension shock absorber and spring assembly.

- oil plugs factory-installed in a Yamaha motorcycle with a mileage of 35,000 kilometers (Figure 3(a)),
- oil – by YSS Suspension (Figure 3(b)).

Selected new shock absorbers are dedicated as replacements for the factory shock absorbers found in the Yamaha Virago 125 motorcycle, in accordance with the guidelines provided on the manufacturer's website [20,32].

The shock absorbers were first tested on the Bosch Beissbarth diagnostic line, and then they were removed from the motorcycle to check their damping effectiveness on a test stand built based on MTS components. The diagnostic line was equipped with stands for testing the suspension control of the axle operating based on the EUSAMA and THETA methods.

Considering the disadvantages of the EUSAMA method, which includes, among others, the impact of tire pressure and the sprung mass of the tested motorcycle on the shock absorber effectiveness evaluation results, before each measurement, the tire weight and pressure were controlled. The weight of the motorcycle taking part in the tests with the driver was 220 kg (150 kg curb weight of the motorcycle plus the driver's weight of 70 kg), while the air pressure in the front and rear tires was 0.17 and 0.2 MPa, respectively.

At the stand for the identification of the damping coefficient (built based on MTS components), shock absorbers dismounted from the motorcycle and previously tested on the diagnostic line were tested. Their purpose was to determine the work diagrams, based on which the damping characteristics were prepared, and then the damping coefficients of the shock absorbers were determined, which are the direction coefficients of the regression line of the linear characteristic. The shock absorbers were tested with a constant stroke of 20 mm and a variable excitation velocity of 0.2 to 0.8 m/s.

4 Analysis of test results

The article presents exemplary results of testing shock absorbers installed in a motorcycle and exemplary results for bench tests of shock absorbers removed from a motorcycle.

Figure 4 presents a research motorcycle prepared for the suspension test on the Bosch Beissbarth diagnostic line.

The results of the shock absorber damping effectiveness tests using the EUSAMA and THETA methods are shown in Figures 5 and 6. Graphs of the vibration waveforms obtained on the diagnostic line using the EUSAMA and THETA methods are shown in Figures 7 and 8. Figure 9 shows the graphs of the adhesion test of the suspension

Figure 4: The motorcycle before the suspension test on the Bosch Beissbarth diagnostic line.

Adhesion	36%
Mass	130 kg
Vibration frequency	15 Hz

a)

Absorption Theta	0.30
Mass	116 kg

b)

Figure 5: Test result of oil shock absorbers factory-installed in a motorcycle using the method: (a) EUSAMA and (b) THETA.

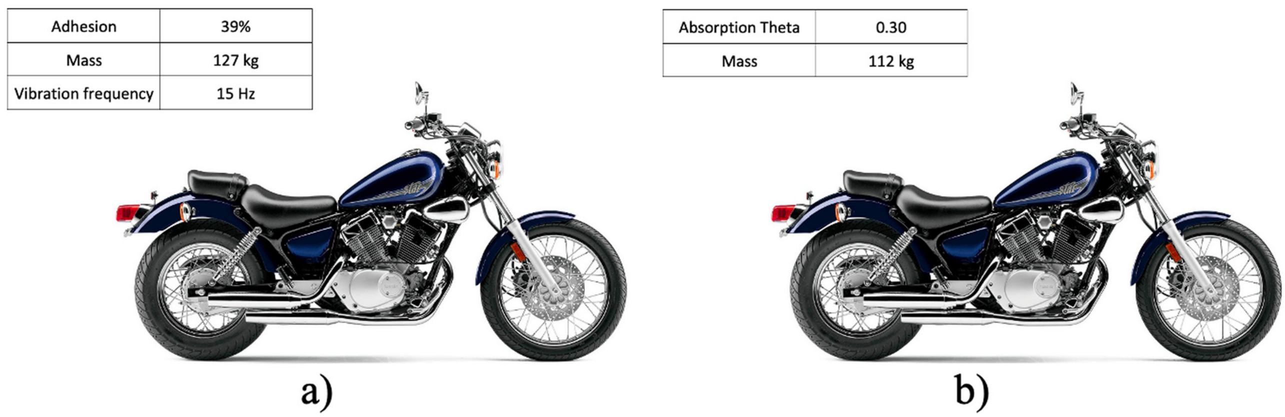

Figure 6: Test result of new oil shock absorbers installed in a motorcycle using the method: (a) EUSAMA and (b) THETA.

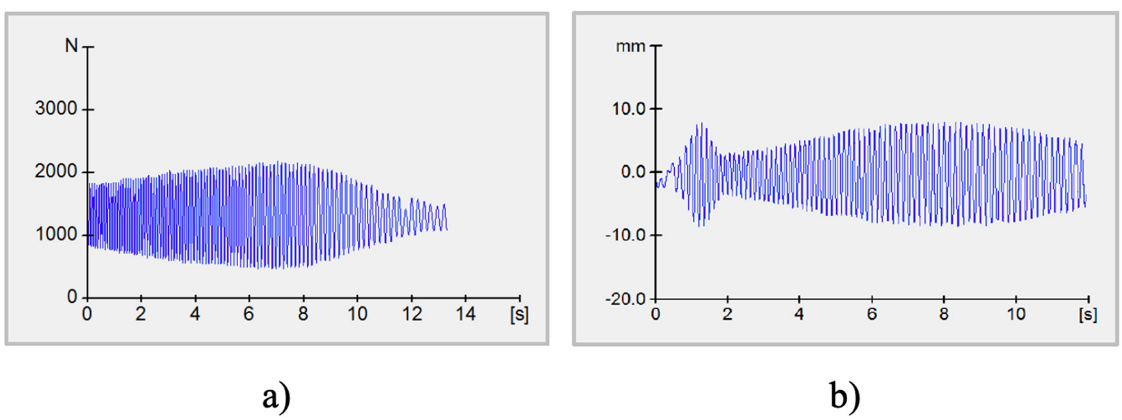

Figure 7: Suspension vibration diagram for a motorcycle with factory-installed oil shock absorbers, tested using the method: (a) EUSAMA and (b) THETA.

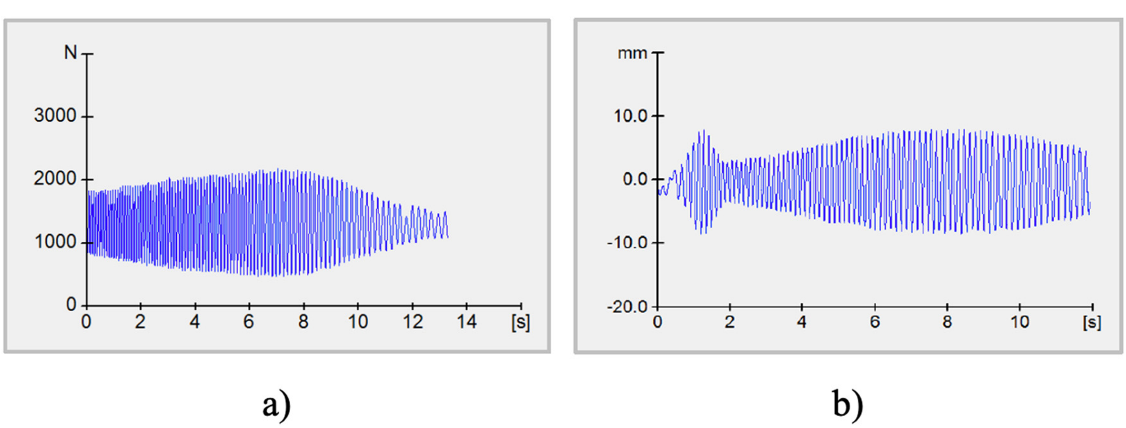

Figure 8: Suspension vibration diagram for a motorcycle with new oil shock absorbers, tested using the method: (a) EUSAMA and (b) THETA.

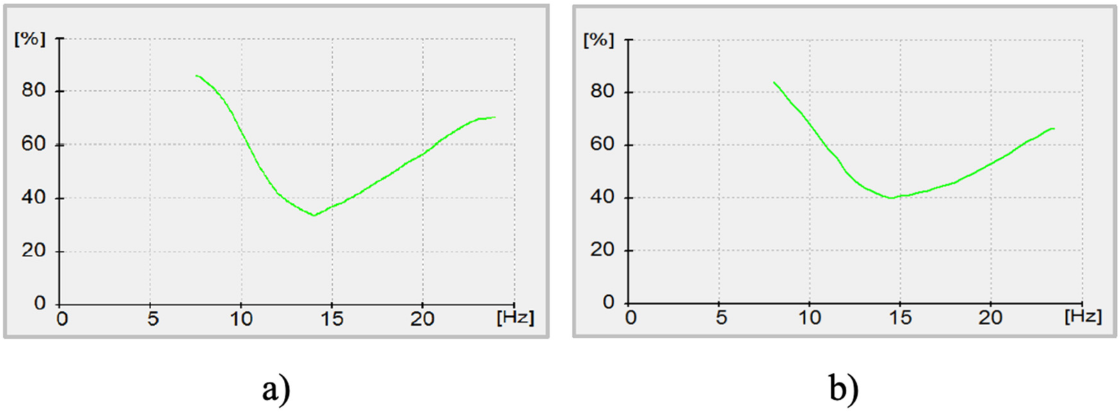

Figure 9: Graph of the course of adhesion during the suspension test: (a) factory YAMAHA shock absorbers and (b) new YSS Suspension shock absorbers.

test using the EUSAMA method for two types of shock absorbers.

Figure 10 shows the operating characteristics of oil shock absorbers. Based on which the damping characteristics presented in Figures 11 and 12 were prepared. They show the dependence of the maximum damping forces as a function of the maximum velocities.

5 Evaluation of test results

The methods of testing shock absorbers installed in the vehicle do not eliminate the impact of the condition of the wheel suspension and tire stiffness on the result of the technical condition of the shock absorber. The tests of shock absorbers removed from the motorcycle were

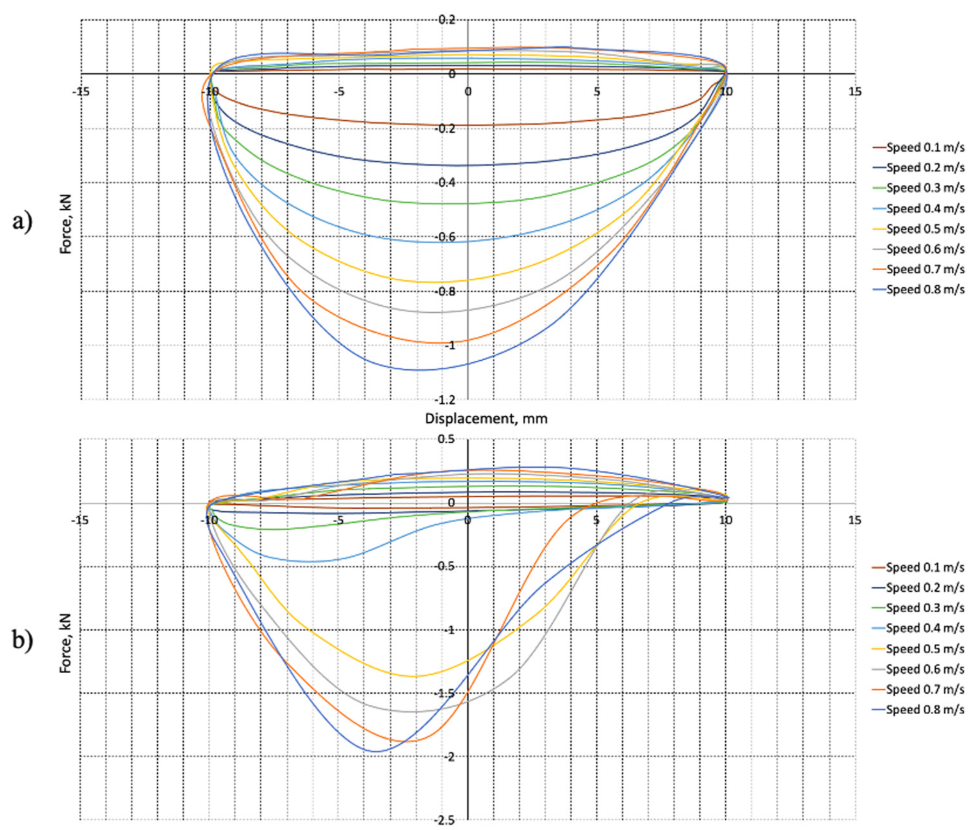

Figure 10: Diagrams of operation of oil shock absorbers: (a) factory YAMAHA shock absorbers, (b) new YSS Suspension shock absorbers.

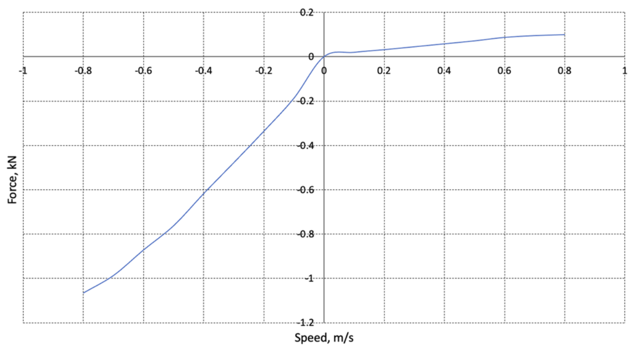

Figure 11: Characteristics of oil shock absorbers factory-installed in the motorcycle.

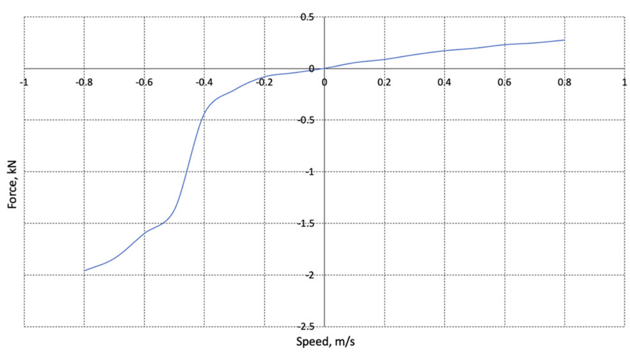

Figure 12: Characteristics of the new shock absorbers installed in the motorcycle.

carried out on a test bench made of MTS components. Each of the tested shock absorbers has a degressive damping characteristic. Based on the damping characteristics, it is possible to assess whether the shock absorber has leaks and whether there are oil shortages.

The results of tests using the EUSAMA and THETA methods showed positive results in all cases. Adhesion for all shock absorbers tested is in the range of 36–39%. According to the EUSAMA index, the tested shock absorbers have good damping characteristics for vehicles weighing less than 899 kg. The dimensionless THETA coefficient for all performed tests is equal to 0.30.

The resistance coefficient of the shock absorbers during the compression movement should be lower than the resistance coefficient during the decompression movement. Among the tested shock absorbers, all shock absorbers have such a relationship.

Table 7 presents the results of the maximum values of prestressing and relieving forces obtained during the testing of individual shock absorbers.

It is important to note the results of the shock absorbers installed as standard on the production line. Even

Table 7: Summary of maximum compression and relaxation forces

Section	Maximum (kN)	Maximum (kN)
Types of shock absorbers	Unwinding force	Prestressing force
YAMAHA	1.06	0.09
YSS suspension	1.96	0.27

though the motorcycle has covered 35,000 km during their lifetime, the results obtained using the EUSAMA and THETA methods are not significantly different from new shock absorbers.

Shock absorbers installed as standard on the production line obtained lower maximum values of the unwinding and compressing forces in relation to the new shock absorbers. This may be because the shock absorbers have been operated for a long time (they were significantly worn out). Even though during the movement of compression and decompression they pose less resistance, they are still suitable for further operation. Based on the results presented in Table 7, the stress-relieving force obtains higher values than the prestressing force. For oil shock absorbers normally installed on the production line, this value is 11 times higher. In the case of new shock absorbers, this value is over 7 times higher.

6 Summary

The condition of the shock absorbers has a decisive impact on the behavior of the motorcycle while driving, and affects the durability of the suspension components, motorcycle structure, and tires. Shock absorber failures are noticeable while riding a motorcycle, in the form of:
- too slow damping of vibrations after driving over uneven roads,
- insufficient grip of the wheels with the road surface,
- extended braking distance,
- increasing vibrations of the motorcycle structure while driving on uneven roads.

Shock absorbers are subject to wear and tear over time. Manufacturers recommend replacing them, e.g., after driving a certain mileage.

During the periodic examination of motorcycles at diagnostic stations, most often no method of testing shock absorbers is used. Bench tests are performed mainly by companies producing shock absorbers to introduce new shock absorbers to the market and during the complaint of a damaged shock absorber. Testing the shock absorbers removed from the motorcycle involves an extended test time as opposed to nondisassembly tests, which could take several minutes as in the case of tests for motor vehicles.

The assessment of the technical condition of the shock absorbers installed in the motorcycle using the EUSAMA and THETA methods should be treated as illustrative. The tests of shock absorbers removed from the motorcycle are more accurate, because they eliminate the influence of the wheel suspension and tire stiffness on the assessment result. Such tests are much more expensive than tests on the diagnostic line, and more laborious.

By examining the shock absorbers on the diagnostic line and on the test stand equipped with MTS subsystems, it was found that the new YSS Suspension shock absorbers received the best results. However, the results of oil shock absorbers, which are standard equipment of the motorcycle, are surprising. Even though during their operation the motorcycle covered 35,000 km, the obtained results indicate good damping efficiency. Bench tests confirmed no damage to the shock absorbers. The shock absorbers have the same degree of wear, characterized by a low value of the maximum compression and release force obtained. Even though the oil shock absorbers normally installed on the production line are corroded and work for such a long period, they are still suitable for further use, as evidenced by the positive result of the assessment made using the THETA and EUSAMA methods.

Conflict of interest: Authors state no conflict of interest.

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