DOI 10.52209/2706-977X_2023_3_15 IRSTI 55.42.27 UDC 621.403

The Impact of the Modernization of the Ignition and Injection System in the Dniepr MT 11 Motorcycle on the Frequency of Service Operations

Warguła Ł.[1*], Waluś K.J.[1], Wieczorek B.[1], Zakaria R.[2]
[1]Poznan University of Technology, Poznan, Poland
[2]Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia
*corresponding author

Abstract. Circular economy principles works with nature built environment with water, air, carbon cycles with no waste. Industrial revolution enable society led to development of engine and became more powerful machines. This include motorcycle which is has a life span based on the revolution of engine technologies. Modern ignition and injection systems significantly reduce servicing. In the Dniepr MT 11 motorcycle from 1989, in accordance with the manufacturer's guidelines, the following should be checked every 5,000 km: cleanliness and fastening of the interrupter contacts, oiling the felt and friction elements of the ignition advance mechanism, and adjusting the spark plug gap. As regards the fuel supply system, the carburetor should be washed and blown out and the tap strainer should be cleaned every 500 km. Additionally, due to climatic conditions, the position of the carburetor needle should be adjusted. In addition, before working on the fuel system, check the gap between: spark plug electrodes, breaker contacts, valve stems and levers. After modernization and the use of an electronically controlled injection and ignition system, service activities were limited to adjusting the gaps on the spark plugs (every 5,000 km) and replacing the fuel filter and cleaning the filter element in the pre-filter every 30,000 km. The developed solutions confirm the possibility of improving the operation of older structures in the field of injection and ignition systems at the level of modern structures.

Key words: motorcycle operation, modernization, improvement of operational properties, new technologies in old structures, motorcycle use, circular economy

Introduction

Historically, in 1963, motorcycles have played a crucial part in the motor vehicle fleets of some currently developed countries such as Poland (70%), Sweden (70%), Portugal (64%), Japan (60%), Netherlands (58%), Italy (55%), Austria (44%), and France (41%). By the year 2010, these percentages have dropped to below 14% [1]. End-of-life vehicles (ELVs) include motorcycles are fast-growing waste streams in the EU. In industrialised countries with saturated markets the new technologies faster with new trend which the number of new goods coming to market is comparable to the number of similar goods going to waste [2]. Thus, the disposal require specific collection and treatment activities to avoid environmental pollution and resource depletion fed by the linear economy model [3]. It is important to understand this issue of discontinuity. Circular Economy is a conscious choice to cope with abundance and to reduce waste and shift a consumer society based on fashion [2]; example restoration of engine of antique motorcycles.

Modernizing the design of the fuel supply and ignition systems in motorcycles can bring many benefits. The first is greater fuel savings. Modern systems utilize advanced fuel injection technology, which allows for precise control over the fuel-air mixture [4,5]. This results in better combustion and improved fuel efficiency, leading to reduced fuel consumption and longer riding range. The second is enhanced performance. Upgrading the fuel supply and ignition system can significantly enhance the overall performance of motorcycles. Modern systems provide better throttle response, smoother acceleration, and increased power output [6]. This can greatly improve the riding experience and make the motorcycle more enjoyable to ride. Thirdly, easier starting. Traditional carbureted systems often require manual choke adjustments and multiple attempts to start the engine, especially in cold weather. Modern fuel injection systems eliminate these issues by automatically adjusting the air-fuel mixture based on various parameters, ensuring easier and more reliable starting [7]. Fourthly, reduced emissions. Modern fuel injection systems are designed to meet stringent emission standards. By precisely controlling the fuel delivery, these systems can optimize combustion and minimize harmful exhaust emissions, contributing to a cleaner environment [8]. Fifth, diagnostic capabilities. Modern systems often come equipped with onboard diagnostics, allowing for easier troubleshooting and maintenance. These diagnostics can provide valuable information about the performance of the fuel supply and ignition system, making it easier to identify and address any issues [9]. Overall, modernizing the design of the fuel supply and ignition system in motorcycles offers improved fuel efficiency, enhanced performance, easier starting, reduced emissions, and advanced diagnostic capabilities. These advantages make it a worthwhile investment for motorcycle owners seeking a more efficient and enjoyable riding experience.

The aim of the article is to determine the impact of modernization of the injection and ignition system in the Dniepr MT 11 motorcycle (Fig. 1) on service operations during everyday operation.

Fig. 1. – Dniepr MT 11 motorcycle

1. Materials and method

In the Dniepr MT11 motorcycle, the ignition and injection systems work with a counter-rotating boxer engine. The cylinders lie in one plane opposite each other [10]. Arranging the cylinders in this way makes it difficult to use a single source of power for the fuel-air mixture. The use of two carburetors in the system, one for each cylinder, increases its power and facilitates starting the engine. Figure 2 shows the engine with the installed systems. The valve timing mechanism is responsible for closing and opening the intake and exhaust valves at a time that corresponds to a specific angle and rotation of the crankshaft. Therefore, the timing shaft makes one revolution and the crankshaft makes two revolutions. This information is important when the ignition system's impulse wheel is mounted on the camshaft. Then it must have twice as many teeth as if it were mounted on the crankshaft. Maintenance of the ignition system mainly concerns the ignition advance breaker, which should be kept clean. At the same time, check the fastening of the interrupter, oil the felt and the friction surfaces of the ignition advance mechanism. Contacts and any adjustments should be made every 5,000 km during normal operation, and every 500 km at the beginning of use. After removing the current ignition system, a contactless ignition system can be installed. In place of the interrupter, a toothed disc will be placed on the camshaft, and dismantling the ignition coil will enable the installation of inductive sensors. The coil will be changed to a bipolar coil, mounted externally to the crankcase housing. The power supply system consists of: a fuel tank, a three-position tap with a fuel filter and a separator, two carburetors, an air filter, fuel lines and air lines. The petrol tap is directly screwed into the fuel tank. Gasoline flows by gravity to the fuel tap, which has two fuel lines in the tank at different heights. Additionally, it has a mesh settler, which is the only fuel filter. It is then connected to carburetors with rubber hoses. Two K63T carburetors are interchangeable, power the engine, are mounted on the cylinder heads. This is where the intake manifolds will be attached after dismantling the carburetors. When the motorcycle is operated in specific conditions, e.g. hot climate, temperature 35-40C° or higher or at an altitude of 2000m or higher above sea level, it is recommended to lower the dosing needle. When operating the engine in cold climate conditions, air temperature – 15C° and lower, it is recommended to raise the dosing needle. Two exhaust system solutions were used in the Dniepr MT 11 motorcycle. The modernized vehicle has a solution with two separate exhaust systems, one for each cylinder. Modernization requires connecting these systems in order to correctly read the exhaust gas composition using a lambda probe.

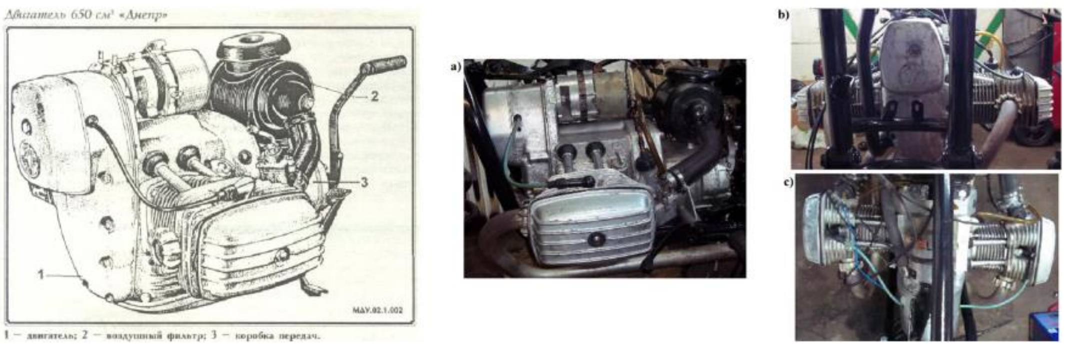
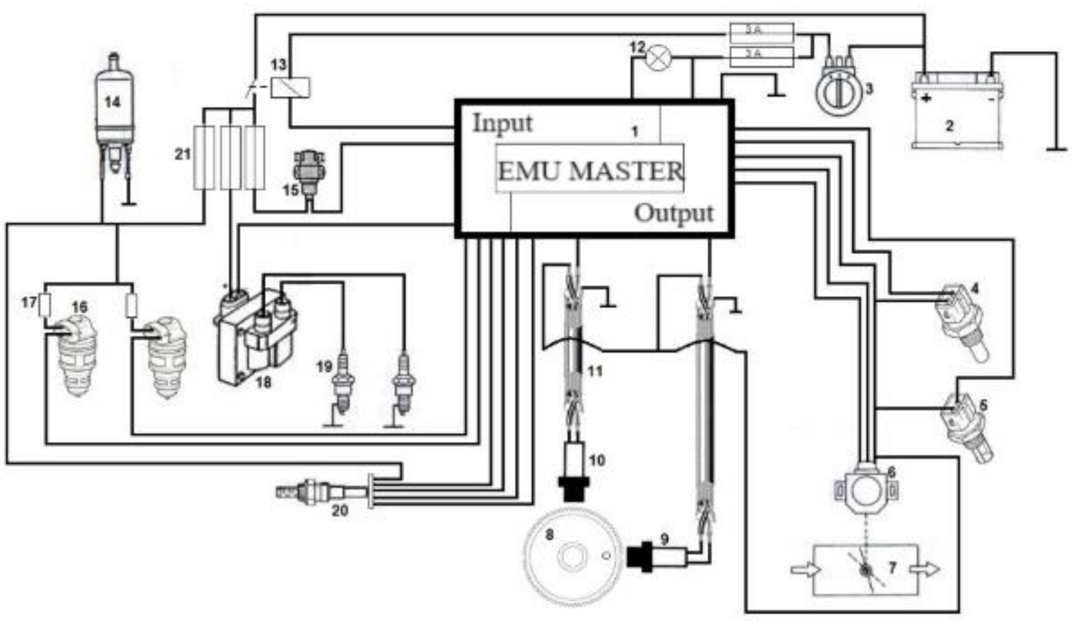


Fig. 2. – Internal combustion engine with a displacement of 650 cm^3 Dnepr where: 1 – engine, 2 – air filter, 3 – gearbox, engine photos 650 cm^3 Dniepr engine, where a) view from the right side, b) main view, c) view from above

After the modernization, the motorcycle has an integrated ignition and injection system, presented in the electrical diagram (Fig. 3). The heart of the system is the ECUMASTER EMU controller. It is a universal controller that allows you to manage the operation of an engine with an integrated ignition and injection system. It allows you to monitor and control all components responsible for the operation of the engine and can operate in an emergency mode resulting from incorrect operation of sensors or damage. The modernized ignition system used is an electronic system where the spark is released turns on electrically and the ignition timing adjustment is electrical. The system uses the induction phenomenon to generate high voltage. The modernization of the fuel supply system is based on the 32 MM4 injector assembly from Weber, used, among others, in the Opel Astra F 1.4i car. The purpose of the injector assembly is to supply fuel to all four cylinders through one injector. The modernized motorcycle uses two such injector assemblies, one for each cylinder.

The SPI (Single Point Injection) injection system has one electronically controlled injector, mounted centrally in relation to the cylinders, directly over the throttle in a common housing. It dispenses fuel in portions to the intake manifold. In the original applications of the 32 MM4 injector assembly from Weber, the intake manifold assumes the role of a distributor of the combustible mixture to individual cylinders. The Weber 32MM4 injection unit consists of two basic parts: upper and lower. The upper part consists of the injector, fuel pressure regulator, air temperature sensor, fuel supply and return connections to the tank. The lower part consists of the throttle, throttle position sensor, idle speed control stepper motor and fuel vapor inlet connector.

In the modernization used, the injector assembly of the first cylinder is powered by an electric fuel pump. The fuel pressure regulator of the first cylinder is always open, so fuel flows freely to the injection unit of the second cylinder. The constant opening of the fuel pressure regulator allows the pressure spring to be removed from it. The second cylinder fuel pressure regulator regulates the fuel pressure in both injector assemblies. Two filters are used in the system. The first one is necessary due to the possibility of contamination in the system. The second BOSCH fuel filter, 0 450 905 280, stops impurities in the gasoline, protecting the precise elements of the fuel system against wear.



1 – EMU MASTER controller, 2 – 12V battery, 3 – ignition switch, 4 – engine temperature sensor, 5 – air temperature sensor in the intake manifold, 6 – throttle position sensor, 7 – throttle, 8 – impulse dial, 9 – inductive sensor (determines the compression point of the first cylinder), 10 – inductive sensor (informs about the rotational speed and determines the position of the shaft), 11 – two-wire shielded cable, 12 – check engine light, 13 – system relay, 14 – fuel pump, 15 – idle speed control valve, 16 – injector, 17 – resistor, 18 – high voltage coil, 19 – spark plug, 20 – oxygen sensor in exhaust gases; 21 – fuse

Fig. 3. – System diagram after modification

The electric fuel pump is connected through a relay connected to the ignition switch. The pump selection depends on the injectors used, which require a supply pressure of 0.08 MPa. The capacity of the installed pump is 120 L/H.

The CLT engine temperature sensor is an NTC thermistor characterized by non-linear resistance, strongly dependent on temperature. The resistance of this sensor decreases as the temperature increases. The sensor is located in the head cover of the first cylinder. Supports engine operation control. Due to the engine temperature, the composition of the fuel-air mixture and the ignition advance angle change.

The inlet air temperature sensor, often called IAT (Inlet Air Temperature), as an NTC thermistor, is characterized by non-linear resistance strongly dependent on temperature. It is mounted in the injector assembly in front of the throttle (Fig. 4). It is used to plot the mass of sucked air. This sensor is installed in both injector assemblies, but the controller can only read the signal from one sensor. The characteristics of the CLT engine temperature sensor and the IAT intake air temperature sensor are similar, but they are created for different temperature ranges. The intake air temperature sensor is more sensitive to temperature changes. In case of sensor damage, the controller adopts the programmed constant temperature value.

The socalled absolute pressure sensor the MAP sensor is built into the controller and connected to the two intake manifolds through wires built into each manifold. The sensor measures pressure in the intake manifold and atmospheric pressure. The following function of the sensor is to determine the engine load. It is a basic parameter when calculating the fuel dose and ignition advance angle. The connection of the manifolds and the location of the measurement holes as close to the throttle as possible allows for obtaining a result that most accurately reflects the average pressure value in the intake manifold. The connecting hoses are made of material with durable walls, which prevents the cable from getting stuck and making the measurement impossible. The measurement range of the intake manifold pressure sensor installed in the controller is 400 kPa.

The TPS throttle position sensor, together with the absolute pressure sensor, allows you to define the engine load. Supports the calculation of the mixture enrichment factor when accelerating. This is one of the key signals needed to control the operation of the idle speed valve. The sensor is located in the injector assembly and responds to the movement of the accelerator lever by moving the cable. The controller allows reading the throttle position only from one sensor.

The Bosch LSU 4.2 lambda probe used in the modernized system is a broadband probe. It allows you to determine the composition of the fuel-air mixture based on the composition of exhaust gases. The lambda probe is installed in the exhaust system in front of the muffler and behind the connection point of the exhaust pipes of both cylinders. As already mentioned, due to the fact that the controller can only support one lambda probe, the exhaust system had to be modified in such a way as to connect the exhaust systems of both cylinders. This allows for measurement of the average exhaust gas composition of all cylinders. The installation conditions of the lambda sensor require that the exhaust gas temperature does not exceed 750°C, the installation position should be as close to the vertical as possible.

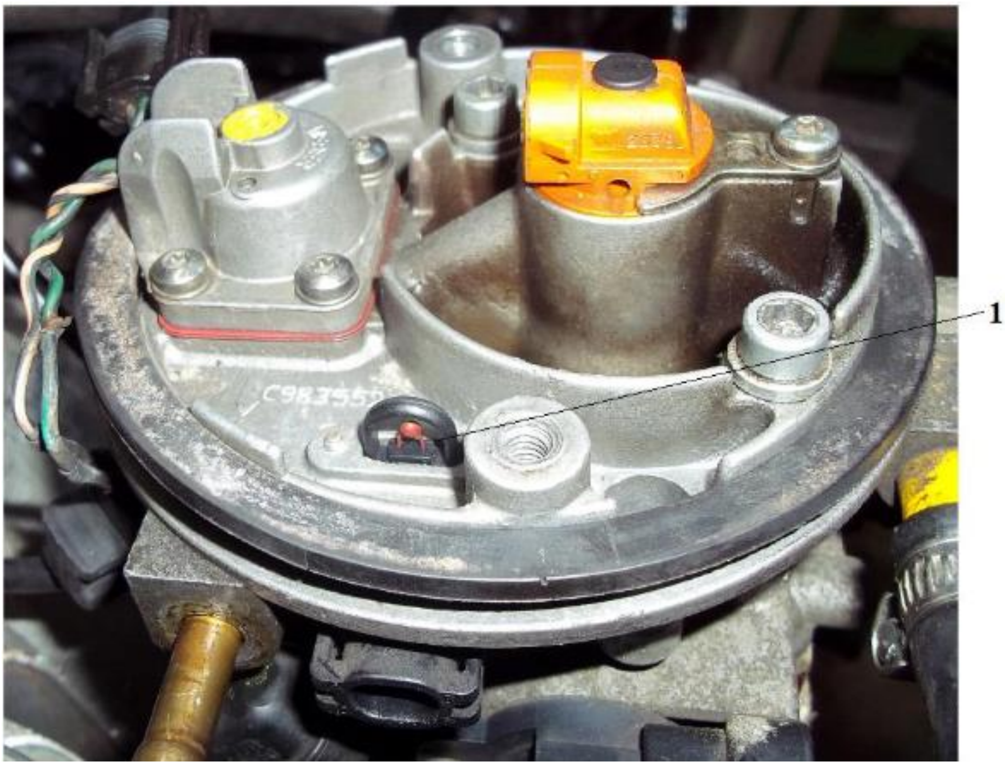


Fig. 4. – Installation location of the intake air temperature sensor, where: 1 – IAT

2. Results and discussion

Contact-controlled ignition systems had reached the limit in the development of maximum ignition energy, which was crucial in engine design. Wearing contacts did not allow for constant maintenance of the ignition timing, which resulted in misfires, which led to higher fuel consumption and, consequently, the exhaust gas composition was more harmful. Contactless electronic systems are a solution to precisely setting the ignition moment. These solutions are based on the operation of inductive or hall effect sensors. Advantages of the contactless ignition system: greater maintenance-free and durability, ability to operate at higher rotational speed, higher ignition voltage, maintaining the set ignition moment, short-circuit angle control and primary current limitation, elimination of quiescent current. The division of ignition systems is presented in table 1. The area in table 1 marked in pink is the current solution, the blue area is the ignition system after modification. This system may be the best available because it eliminates mechanical control elements, which prevents any disruptions due to wear or contamination of the elements .

Table 1. Division of battery ignition systems

Battery system:	with ignition coil	transistor	electronic
Spark release:	mechanical	electronic	electronic
Ignition timing adjustment:	mechanical	mechanical	electronic
A phenomenon used to produce high voltage:	induction	induction	induction
High voltage distribution to cylinders:	mechanical	mechanical	electronic

Injection systems can be divided according to: fuel and air dose regulation strategy, injector placement, and dose regulation implementing mechanism. The first one, due to the fuel and air dose regulation strategies, can be divided into systems controlled by: throttle position, cargo pressure behind the throttle, and air flow rate. The second division can be made in terms of the location of the injector and can be divided into: central injection with one injector in the intake manifold, direct injection into the combustion chamber with an injector in the cylinder and injection with individual injectors placed in the intake ports. System with individual injection into the intake channel is divided into two solutions: direct injection into the intake stub and direct injection into the intake stub with the stream directed towards the intake valve. The third division, taking into account the implementation mechanism of dose regulation, is divided into electronic and mechanical. Injection systems: allow you to increase the average effective pressure by uniformly feeding the cylinders. Lower flow resistance through the intake system allows for a higher filling factor. A more precise composition of the fuel-air mixture reduces harmful components in exhaust emissions. A faster response of the system to new operating conditions results in an improved ability to accelerate. Vehicle tilts do not affect the operation of the system. It allows for self-diagnosis of the system and can operate in emergency mode. Reducing system maintenance to a minimum, consisting of replacing filters. Power system components are more durable and reliable. They increase engine power and dynamics and reduce fuel consumption. A comparison of ignition and injection systems is presented in table 2. The comparison of selected systems shows that the Motronic system is the closest to the designed solution.

Table 2. Comparison of ignition and injection systems

Bosch system:	Control:	Injection system:	Type of injection:	Integration with the ignition system:	Feedback signal:
Mono-Jetronic	electronic	central	periodic	no	Yes
K-Jetronic	mechanical-hydraulic	individual	continuous	no	no
KE-Jetronic	electronic, mechanical, hydraulic	individual	continuous	no	yes
L-Jetronic	electronic	individual	periodic	no	yes
LH-Jetronic	electronic	individual	periodic	no	yes
Mono-Motronic	electronic	central	periodic	yes	yes
KE-Motronic	electronic	individual	continuous	yes	yes
Motronic	electronic	individual	periodic	yes	yes
After Modernization	electronic	individual	periodic	yes	yes

For proper operation of the ignition and plug-in systems, it is necessary to determine the engine operating conditions. Both systems can use the same sensors, and the systems also influence each other. To solve this problem and simplify the system, a common controller is used, responsible for the operation of both sensors, so that the same values are not measured twice. These systems are known as "Motronic", "Digital engine control system", "Electronic engine control system". The systems discussed have a common feature - they are based on the principle of operation of electronic ignition and injection systems, creating their combinations. These systems can be enriched with a number of additional functions that support even more precise control and regulation. Depending on their advancement, ignition and injection systems use signals from sensors: engine speed, crankshaft position, camshaft position, throttle angle, engine temperature, intake air temperature, knock sensor, code connector, battery voltage, automatic transmission activation signal, signal from the flow meter, signal from the lambda probe, signal from the brake pedal position sensor and vehicle speed.

The serviceability of the systems has been limited to current operating standards. The ignition system only requires adjustment of the spark plug gap. However, the fuel supply system requires periodic replacement of the fuel filter and cleaning of the filter element in the oblique filter. A comparison of the serviceability of the ignition and fuel supply systems before and after modernization is presented in Table 3.

Table 3. Comparison of the serviceability of the ignition and fuel supply systems, before and after modernization

Before modernization		After modernization	
Action	Repetition frequency	Action	Repetition frequency
Ignition system			
Maintaining cleanliness	5,000 km	Adjusting the gaps on the spark plug	5,000 km
Checking the fastening	5,000 km		
Oiling the felt	5,000 km		
Oils for the friction surfaces of the ignition advance mechanism	5,000 km		
Adjusting the gaps on the spark plug	5,000 km		
Fuel supply system			
Flushing and blowing carburetors	500 km	Replacing the fuel filter	30,000 km
Cleaning the faucet strainer	500 km	Cleaning the fuel pre-filter element	30,000 km
Needle adjustment depending on climatic conditions	Not specified		
Additionally, before working on the fuel system, you should: • Check the gap between the spark plug electrodes. • Check the gap between the breaker contacts. • Check the gap between the lever valve stems.			

The view from the left side of the motorcycle (Fig. 5) and the view from the top of the motorcycle (Fig. 6) show that the modernization did not reduce the driver's space. Presentation of the stages of changes made under the front cover of the crankcase (Fig. 7). The spaces occupied by the modernized systems meet the conditions for safe operation.

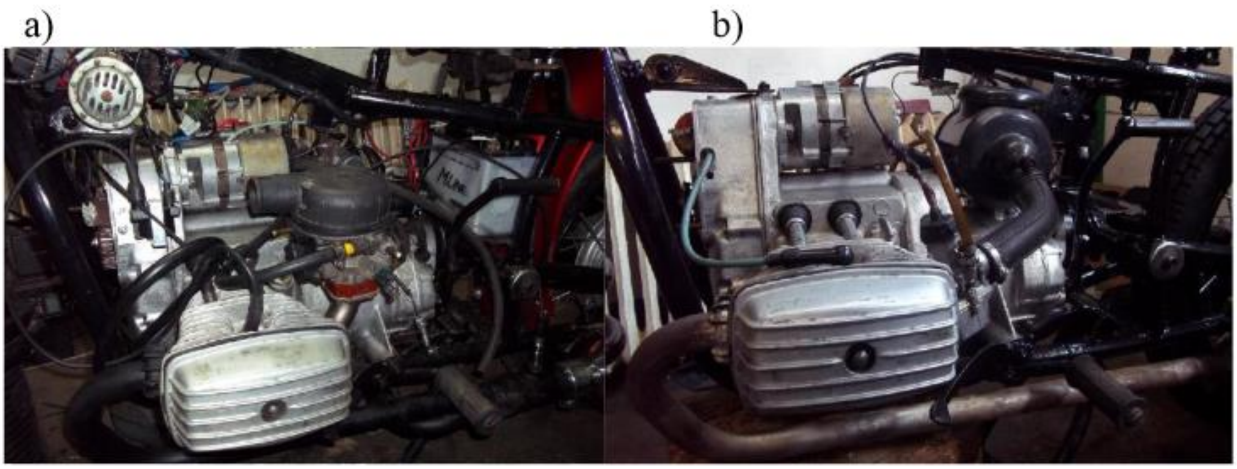


Fig. 5. – View of the model from the left side of the motorcycle, where: a) after modification; b) before modification

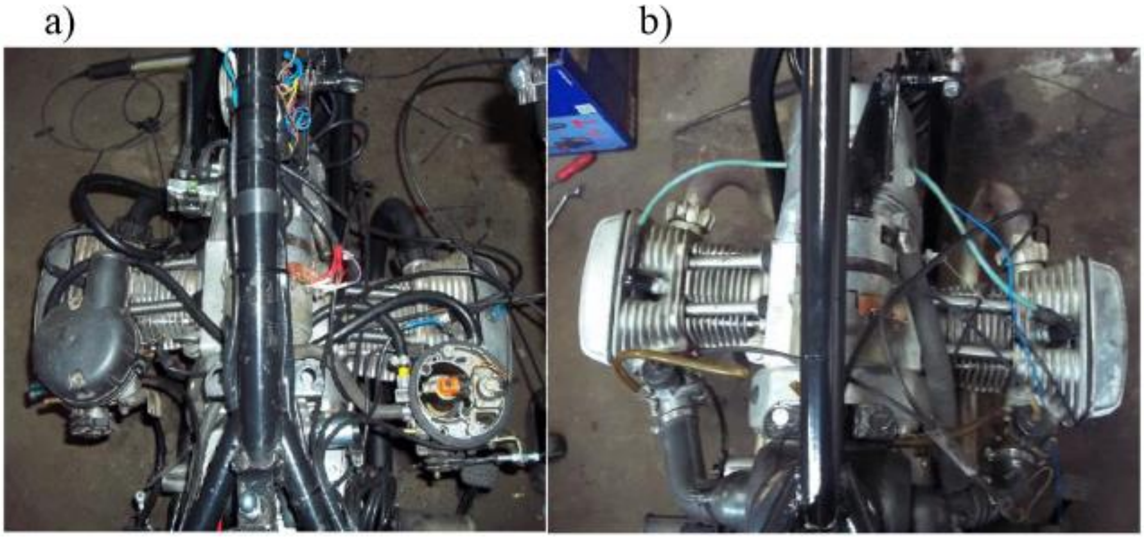
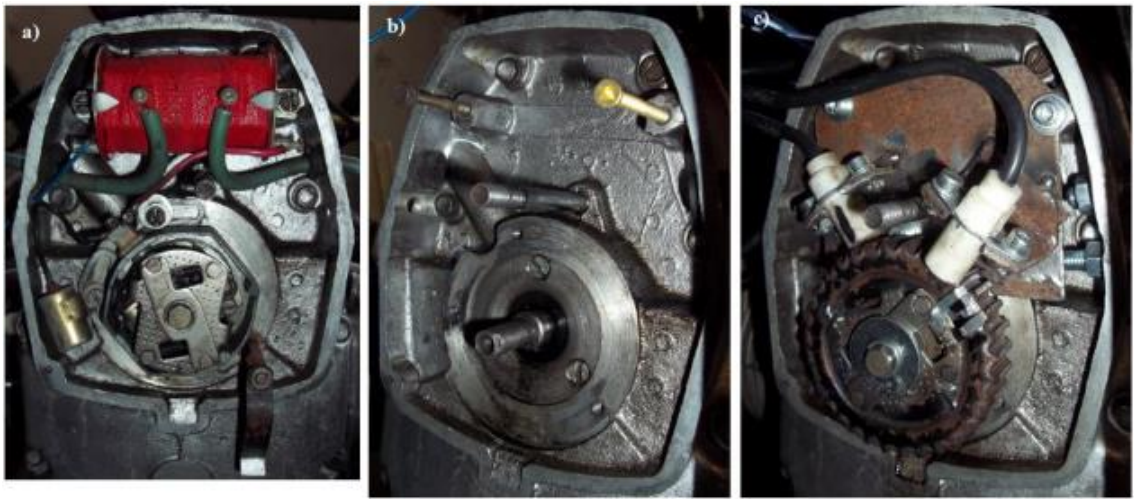


Fig. 6. – Top view of the motorcycle, where: a) after modernization, b) before modernization



a) before modernization, b) after dismantling the ignition system, c) after modernization

Fig. 7. – View of the space under the front cover of the crankcase

Conclusion

Modernization of the ignition and fuel supply system in the Dniepr MT 11 motorcycle made it possible to reduce the emission of harmful exhaust gases, fuel consumption, and improved the dynamics of drying, which was confirmed by previous tests. The article also shows improvement in the aspect of service work. The number of activities has been significantly reduced and the period of their performance extended. The advantage of the revised modernization is that in most cases the existing installation holes were used to carry out the modernization. For this reason, the motorcycle can be restored to its pre-modernization condition without any major difficulties. The spaces occupied by the modernized systems meet the conditions for safe operation and do not pose a threat to life or health. Additionally, they do not limit the driver's space and do not extend beyond the outline of the vehicle. After connecting to a PC, you can also preview parameters and activate or deactivate selected functions. Additionally, the injection system makes it easier to start the engine by performing pre-injection. The research carried out is described in the contemporary European trend, which aims to extend the life of products. From the point of view of environmental protection, it is equally important to reduce fuel consumption and exhaust emissions as well as maintain the functionality and attractiveness of the product in the long term. This study also have direct significant contribution to the sustainability 3R (Recycle, Reduce and Reuse) which is providing continuity of the product (motorcycles) lifespan. At the hand, it is concluded to the perspective circular economy, old product is possible to reform into more fashionable way of use in the form of antique restoration and preservation.

References

[1] S. Nishitateno i P. J. Burke, „The motorcycle Kuznets curve", *J. Transp. Geogr.*, t. 36, s. 116–123, kwi. 2014, doi: 10.1016/j.jtrangeo.2014.03.008.

[2] W. R. Stahel, „History of the Circular Economy. The Historic Development of Circularity and the Circular Economy", w *The Circular Economy in the European Union: An Interim Review*, S. Eisenriegler, Red., Cham: Springer International Publishing, 2020, s. 7–19. doi: 10.1007/978-3-030-50239-3_2.

[3] O.-C. Modoi i F.-C. Mihai, „E-Waste and End-of-Life Vehicles Management and Circular Economy Initiatives in Romania", *Energies*, t. 15, nr 3, 2022.

[4] N. V. Iyer, F. Posada, i A. Bandivadekar, „Technical Assessment of Emission and Fuel Consumption Reduction Potential from Two and Three Wheelers in India", SAE International, Warrendale, PA, SAE Technical Paper 2013-26–0050, sty. 2013. doi: 10.4271/2013-26-0050.

[5] M. T. Muslim, H. Selamat, A. J. Alimin, N. Mohd Rohi, i M. F. Hushim, „A review on retrofit fuel injection technology for small carburetted motorcycle engines towards lower fuel consumption and cleaner exhaust emission", *Renew. Sustain. Energy Rev.*, t. 35, s. 279–284, lip. 2014, doi: 10.1016/j.rser.2014.04.037.

[6] G. Cathcart, R. Houston, i S. Ahern, „The Potential of Gasoline Direct Injection for Small Displacement 4-Stroke Motorcycle Applications", SAE International, Warrendale, PA, SAE Technical Paper 2004-32–0098, wrz. 2004. doi: 10.4271/2004-32-0098.

[7] K. J. Waluś, Ł. Warguła, P. Krawiec, i J. M. Adamiec, „The Impact of the Modernization of the Injection-ignition System on the Parameters of Motion of the Motorcycle", *Procedia Eng.*, t. 177, s. 393–398, sty. 2017, doi: 10.1016/j.proeng.2017.02.221.

[8] P. Lijewski, N. Szymlet, P. Fuć, A. Domowicz, i Ł. Rymaniak, „The effect of start-stop systems on scooter exhaust emissions", *Transp. Res. Part Transp. Environ.*, t. 91, s. 102684, luty 2021, doi: 10.1016/j.trd.2020.102684.

[9] J. Wengert, „On-Board Diagnostics in Engine Management Systems for Motorcycles", SAE International, Warrendale, PA, SAE Technical Paper 2005-32–0103, paź. 2005.

[10] J. A. Wajand i J. T. Wajand, „Medium and high speed piston combustion engines (original text in Polish: Tłokowe silniki spalinowe średnio i szybkoobrotowe)", *Wydaw.-Tech. Warszawa*, 2000.

Information of the authors

Warguła Łukasz, PhD Eng., associate professor, Poznan University of Technology
e-mail: lukasz.wargula@put.poznan.pl

Waluś Konrad Jan, PhD Eng., associate professor, Poznan University of Technology
e-mail: konrad.walus@put.poznan.pl

Wieczorek Bartosz, PhD Eng., associate professor, Poznan University of Technology
e-mail: bartosz.wieczorek@put.poznan.pl

Zakaria Rozana, PhD, associate professor, Universiti Teknologi Malaysia
e-mail: rozana@utm.my