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WPŁYW MODYFIKACJI CHARAKTERYSTYKI ZAPŁONU NA SPRAWNOŚĆ SILNIKA

Streszczenie: Od początku powstania pierwszych samochodów sportowych jako główny napęd zastosowano silnik spalinowy. Stał się istotną częścią każdego samochodu wyścigowego, ale także motocykla. Silniki spalinowe definiuje się jako działające maszyny przetwarzające dostarczoną energię na pracę mechaniczną. Energia jest dostarczana w postaci paliwa. Wynikiem tej konwersji jest ruch obrotowy wału korbowego. Od samego początku inżynierowie kierowali rozwojem silnika spalinowego poprzez wyższą sprawność, później poprzez zmniejszenie zużycia paliwa i wpływ na środowisko. Po ukształtowaniu dyscyplin sportów motorowych rozwój został ukierunkowany poprzez maksymalną sprawność. Dziesięciolecia rozwoju doprowadziły do zaprojektowania silnika spalinowego o niemal maksymalnej sprawności, więc ostatnie dekady rozwoju skupiły się na modyfikacjach elektronicznych i rozwoju układów sterowania silnika.

Słowa kluczowe: moc i moment obrotowy, cylinder silnika, krzywa zapłonowa

FLUENCE OF IGNITION CURVE MODIFICATION ON ENGINE PERFORMANCE CHARACTERISTICS

Summary: Since the birth of the first sports cars, an internal combustion engine has been used as the main drive unit. He has become an essential part of every racing car but also a motorcycle. Combustion engines are defined as working machines converting the supplied energy into mechanical work. Energy is supplied in the form of chemical fuel, steam or electricity. The output of this conversion is the rotary movement of the crankshaft. From the beginning, the engineers directed the development of the combustion engine through higher efficiency, later by reducing consumption and environmental friendliness. After shaping the motor sports disciplines, the development was directed through maximum efficiency and optimal

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performance parameters. Decades of development have led to the design of the internal combustion engine at almost maximum efficiency, so the latest decades of development have focused on improving the engine's electronic control systems.

Keywords: power and torque, engine cylinder, spark curve

1. Introduction

Increasingly, motorcycle is becoming a popular means of transport. Motorcycle is especially popular in cities, where the roads are crowded every day, which is associated with congestion and long waiting. One-track motor vehicles are used not only in transport, but also as hobbies, sports and tourism. In tourism they are able to cover long distances with minimal consumption.

A major problem in increasing the output power of single-track motor vehicles is to maintain their reliability and durability.

The first part of the research was aimed at increasing the performance characteristics of the ROTAX 122 experimental engine by modifying its flushing system. Based on the experimental measurements we have concluded that the power and torque in a certain engine speed band is not smooth. This had a negative character when testing the engine under real conditions on the test circuit. The negative could be eliminated by adjusting the shape of the engine ignition curve.

2. Design of cylinder exhaust and intake channel system

Optimization of the irrigation system in a two-stroke internal combustion engine has a great effect on the resulting output power, torque, fuel consumption and also the production of pollutants present in the flue gas.

The two-stroke internal combustion engine exchanges gas, i.e. flue gas and fresh fuel / air mixture in one stroke, with the consequent problems of ideal flushing. Rinsing time is a short process of approximately 100-130° of total crankshaft speed.

For two-stroke internal combustion engines, one factor is important: the smallest volume in the crankcase, which implies that the smaller the volume in the crankcase, the more the mixture can be compressed and the better the release into the cylinder works. Because of this, the crankshaft flywheels have a cylindrical shape so that the crankcase can follow as much as possible. In some cases, the crankshaft flywheels are filled with heavier material to reduce the harmful space in the crankcase [2].

In order to define the rate of the compressed mixture under the piston, the term "primary compression ratio" is used, which gives us the ratio of the sum of the displacement and the free volume of the crankcase to the size of the crankcase volume.

The fuel-air mixture is then compressed by the piston in the crankcase. The pressure of this compressed fresh mixture is approximately 0.03 MPa. If the bypass channel is opened, this pressure is then increased to about 0.08 MPa. As soon as the piston reveals the passage channel with its upper edge, the compressed mixture flows into the cylinder and expels the flue gas out of the combustion chamber. The opening of the exhaust duct leads to a drop in overpressure as the exhaust duct opens rather than a discharge duct [3].

For two-stroke internal combustion engines, the method by which we expel unnecessary flue gas from the cylinder into the exhaust and consequently to avoid mixing the fresh mixture with the unusable flue gas is crucial. These unnecessary, unusable flue gases cause a reduction in engine efficiency. This problem is solved by increasing the number of passage channels to form a fresh mixture that expels flue gas into the exhaust.

An imperfect engine flush system in which the exhaust system consists of a straight pipe causes the mixture to leak into the exhaust. This results in increased fuel since the mixture that is formed by the carburation is not fully utilized.

For the flushing of the cylinder with the mixture to be effective, a back pressure in the exhaust pipe is required. This back pressure is intended to ensure that the mixture does not leak into the exhaust duct. Such backpressure in the exhaust manifold can be created by constructing an exhaust system that will include an expansion chamber. The constriction at the end of this chamber will result in pressure waves being reflected. These reflected pressure waves move towards the cylinder and push the fresh mixture back into the cylinder [4].

2.1 Adjusting the irrigation system to increase volumetric efficiency

From the knowledge of timing and flushing of the two-stroke internal combustion engine, it can be concluded that the indicated power will be the higher the volume of fresh mixture in the cylinder. This proves that the shape, dimensions and location of the exhaust and exhaust ducts affect the timing of the engine and the filling of the cylinder.

In view of this theoretical knowledge, we have tried to adjust the surface area of the passage and exhaust ducts. These modifications were carried out on the cylinder of the ROTAX 122. experimental engine. The main objective of this modification was to increase the conveyed amount of the mixture through the existing cylinder flushing system by constructively increasing the surface area of the passage and exhaust ducts.

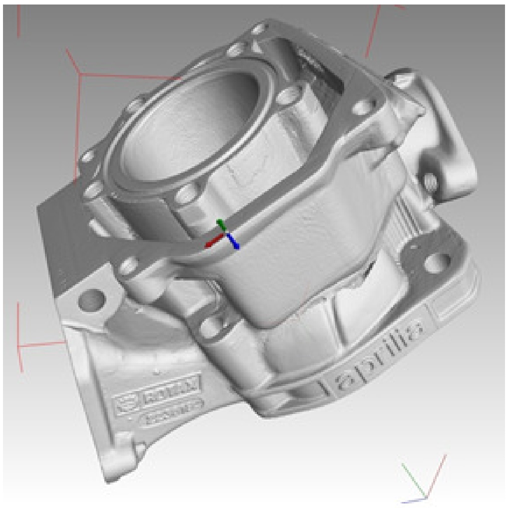

Figure 1. 3D model of ROTAX 122 experimental engine

The design change of the discharge and exhaust ducts was made while maintaining the original engine concept:

• Original Dell 'Orto PHBH 28BD carburetor
• retained 13.5: 1 compression ratio

The actual realization of the surface area of the cylinder discharge and exhaust ducts for the purpose of their enlargement was realized by gradual mechanical removal of material by milling and grinding.

It was necessary to use a specialized measuring device to determine precisely what increase in the area of the channels occurred after the cylinder was modified. After consultation with the staff from the Department of Biomedical Engineering and Measurement, we conclude that it is best to use the metering device for this type of measurement.

The measurement of the engine cylinder was carried out in two phases. In the first phase, an untreated, standard engine cylinder was taken. After a few days of adjusting the cylinder, a second phase of measurement was performed, at which the modified engine cylinder is taken. At the end of these measurements, a developed cylinder casing was generated and the necessary value was determined.

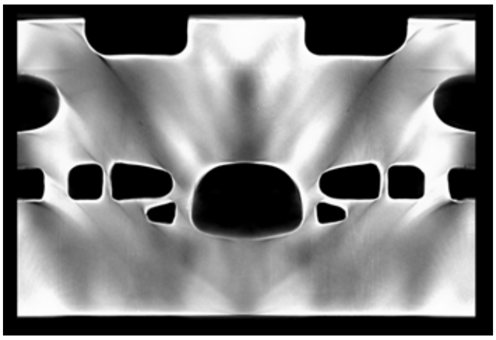

Figure 2. Unrolled roll uncoated

Fig. 3 shows a system of passage and exhaust ducts, where the blue color shows the sizes of the ducts of the untreated cylinder and the red cross-sections of the transfer and exhaust ducts of the treated cylinder. The area difference of these areas before and after the design is expressed as a percentage increase.

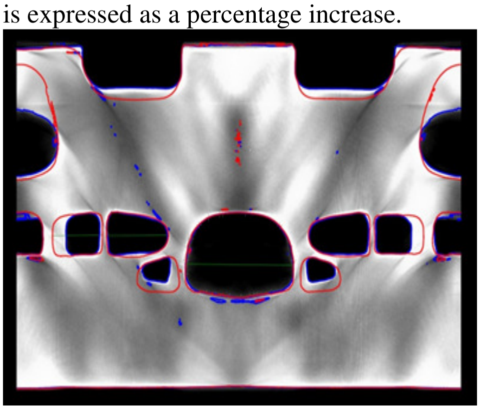

Figure 3. Area difference before and after construction of exp. engine

In order to be able to determine the surface area of the passage and exhaust ducts and then to express the area difference as a percentage, it was necessary to calculate the areas of indeterminate shapes. This calculation was carried out through the AUTOCAD 2006 program.

In the AUTOCAD program, the surface area of the channels of the untreated and subsequently treated cylinder was first determined. The quantification of the specific area size values was followed by the percentage determination of the area difference. In FIG. 7, the passage and exhaust ducts are numbered. The numbers 1, 2, 5, 7, 8 indicate the bypass and the numbers 3, 4, 6 indicate the exhaust ducts of the experimental cylinder.

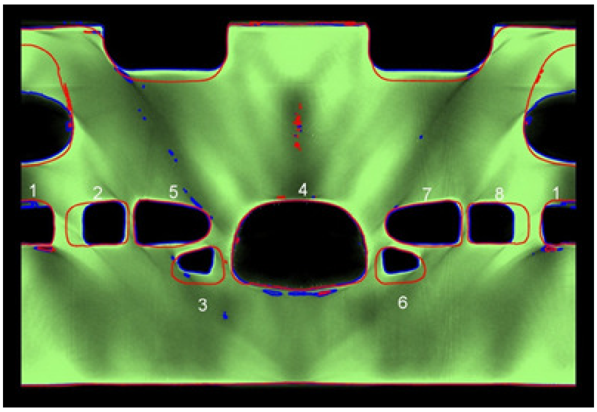

Figure 4. Numerical design of the cylinder passage and exhaust ports

The following table lists the specific values of the passage and exhaust duct surfaces before and after engine cylinder modification.

Table 1. The size of the cylinder passage and exhaust ports

Cylinder	Exhaust duct	Breather duct
Unmodified cylinder	1123,22 mm^2	1046,26 mm^2
Modified cylinder	1238,56 mm^2	1290,17 mm^2
Percentage differece	10,26% increase	23,31% increase

3. Experimental model and measuring devices

In major motorcycle companies, several modifications of the individual components for two-stroke internal combustion engines will be proposed in practice. Subsequently, they are verified and tested and, if necessary, improved in engine tests, especially on the power (engine) brake. For the measurement it was necessary to select the model on which the adjustment will be implemented and then evaluate the adjustment through measurement. The measurement was performed on the power brake.

3.1 Experimental model

The aim is to make such a modification of the engine, in particular its cylinder, while maintaining the standard settings in order to achieve the most efficient output power-torque characteristics of the engine. The Aprilia RS 125 motorcycle was used as an experimental model.
Italian motorcycle manufacturer Aprilia has always been a big leader in cubic capacity up to 125 cm3. This type of motorcycle is one of the best selling motorcycles mainly on the European market. The Aprilia RS 125 is designed for riders racing in the Sport Production class. This bike is especially suitable for beginners.

Figure 5. Experimental model on test stand

The Aprilia RS 125 is equipped with a powerful and reliable single cylinder engine ROTAX 122. This type of engine can be considered unbeatable in its class. This engine is constantly updated to meet stringent emission standards without sacrificing performance. The ROTAX 122 is the reference engine for the 125 cc class as a power unit.

Table 2. Technical parameters of Aprilia RS125 [5]

Type of engine	Radový , jednovalcový, dvojtaktný motor
Displacement	124,8 cm^3
Drilling x stroke	54 x 54,5 mm
Compression ratio	13,5:1
Torque	20,0 Nm
Power	22,0 kW

3.2 Device for measuring the power-torque characteristic

To determine the resulting effect of the adjustment, it is necessary to measure the values of the original and subsequently modified engine. These values are obtained by means of the power brake and the resulting values are finally compared. To make the measurement reliable, the measurement was carried out 3 times in succession under the same weather conditions (air temperature, air pressure, air humidity).

The starting brake is based on the principle of turning the flywheel of known mass m and the moment of inertia y, which is rotated through the chain transmission. When the flywheel starts, the exact speed is measured, recording the increase in kinetic energy (work of the measured motor) over a constant time unit (millisecond). Subsequently, the computer evaluates this work / time ratio and uses the software in the coordinate system to display at the points of the graph the dependence of the power, torque and speed of the measured motor. The time of one measurement depends on the size of the secondary transmission between the motorcycle and the brake. It takes a very short time.

The motorcycle is mounted on a power (motor) brake, where the rear wheel of the motorcycle is replaced by a flywheel. This flywheel is connected to the crankshaft by means of a chain transmission via a transmission, a clutch and a primary transmission. The signal from the flywheel electromagnetic pulse sensor is transformed into a converter.

In the converter, the signal changes to information that enters the parallel port of the PC. After evaluation in the PC, the monitor displays the dependence of the power, torque and speed of the measured motor.

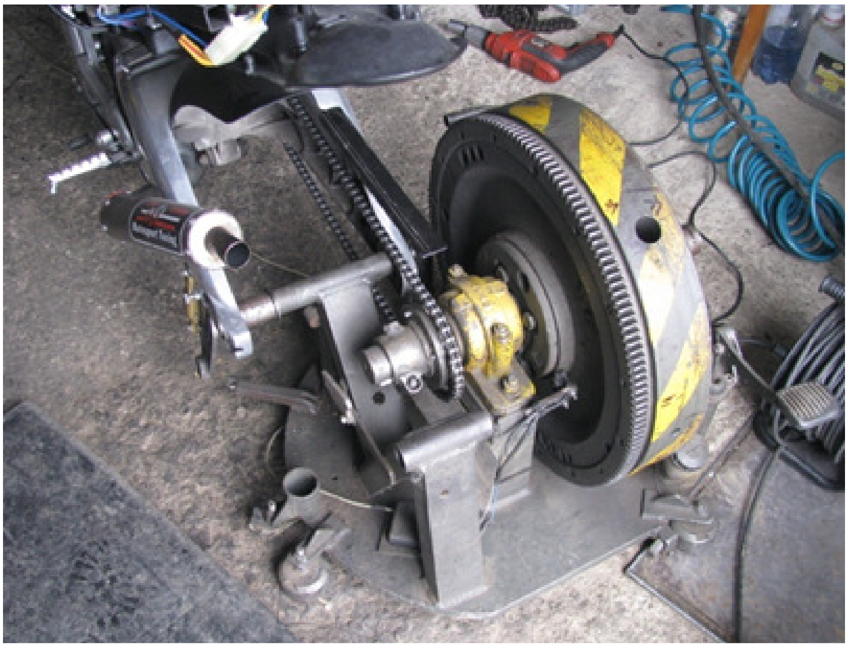

Figure 6. Measuring an experimental model on a power brake

3.3 Apparatus for measuring exhaust and passage ducts in a cylindrical meter

It was necessary to measure and then analyze how much the area of the inlet and exhaust ducts in the cylinder had changed. For this measurement it was necessary to use a special device which is able to measure and subsequently determine the area of the channels.

The Department of Biomedical Engineering and Measurement is equipped with a metrotome from Carl Zeiss. This modern measuring device enables non-destructive non-contact measurement of components using X-ray radiation.
With this device, information about the external geometry and volume of the part can be obtained by one measurement. After scanning a part using computed tomography (CT), we get an image of the whole part that can be viewed from any side and in any section. During measurement, the component rotates 3600 about a vertical axis.

The result of the measurement is a 3D image of the part with its inside. It makes it possible to measure components that are made of light alloys such as aluminum, magnesium or also plastic components.

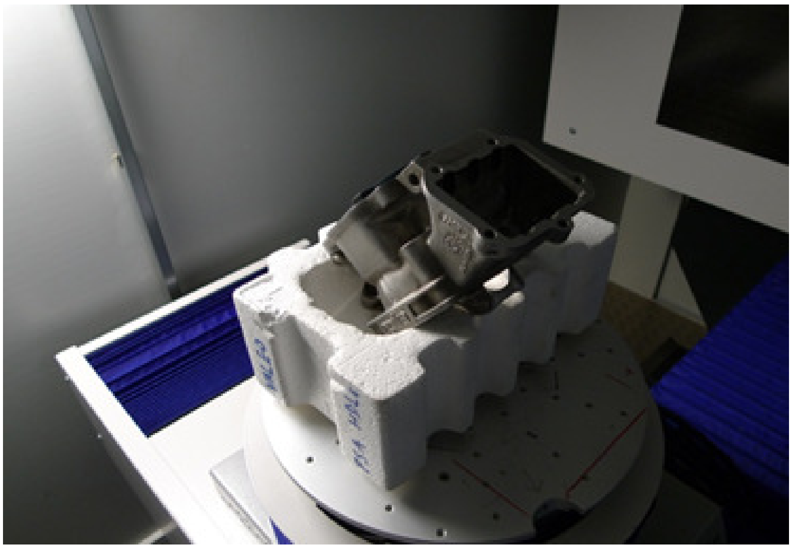

Figure 7. Measuring the engine cylinder using a metrotome

4. Experiment results

Determining power and torque parameters is a decisive step in modifying engines that are designed for motorsport. Retrospective verification of the impact of the adjustment is important in assessing its accuracy. Any major modification of the operation causes adequate changes, and therefore the best way to record the changes is to measure the characteristics of the internal combustion engine by means of the appropriate equipment. Original raw engine cylinder ROTAX 122 when fitted with original Dell 'Orto PHBH BD carburettor with main nozzle of # 132 without airbox intake system and MP Furt exhaust system used, measured to have a maximum Pmax of 31.0 hp at 11,210 rpm min-1 and maximum torque Mk 20.69 Nm at 9619 rpm. The values are shown in the area chart, where the green curve represents the power and the gray torque of the unmodified engine.

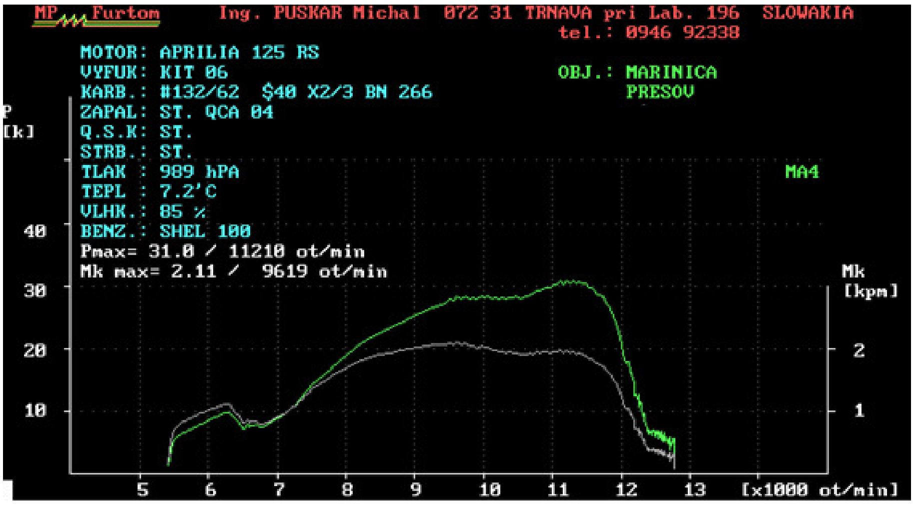

Figure 8. Performance and torque of untreated engine

While maintaining design limits in terms of strength and durability of the cylinder and piston, the cylinder was subsequently modified to increase bulk efficiency.

At the end of the treatment, the cylinder was mounted on an experimental engine while maintaining a 13.5: 1 compression ratio and timing of the passage and exhaust ducts.

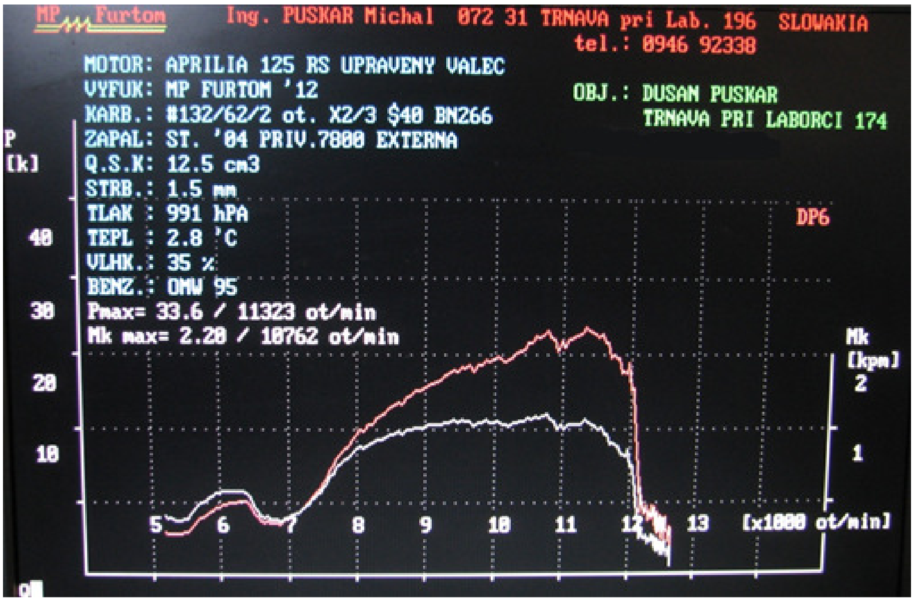

Figure 9. Performance and torque of modified engine

In fig. 9 shows the course of power and torque of a modified engine experimental engine. The above graph shows that in the engine speed spectrum 10500 - 11500 rpm. power and torque do not have a smooth increase. This problem can be solved by adjusting the shape of the ignition curve.

5. Control module ignition curve adjustment

The computer technology allows programming of the shape of the curve in virtually unlimited range of revolutions. It is possible to create countless variants of curves that significantly influence the output power - torque characteristic and also the emission production. The theoretical considerations and experience show that by increasing the ignition, the output power of the engine is increased, the fuel is used more efficiently and thus the combustion is improved. The limit for increasing the levels of pre-ignition is detonation combustion and hard engine operation. A constant amount of supplied fuel is assumed. Following these theoretical considerations, the entire standard ignition curve was shifted 2 degrees to the right (to plus values).

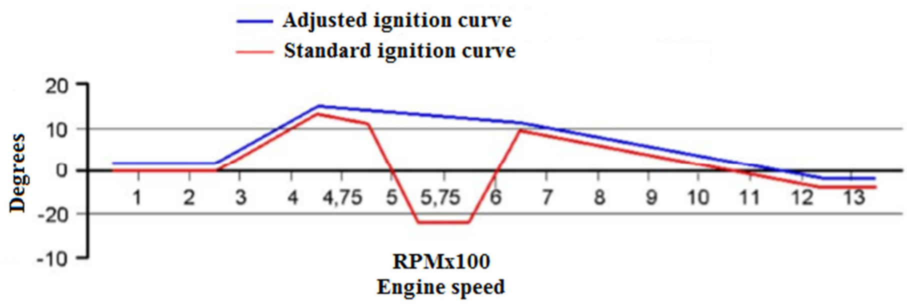

Figure10. Ignition curve shapes

Figure 11 is a graphical representation of power and torque versus engine speed using a modified ignition curve. This graph is the output of the power engine brake. The modified engine was then measured maximum power Pmax 33.6 hp at 10,913 rpm and maximum torque Mk 21.69Nm at 10,912 rpm.

The red curve in the graph represents maximum power and the gray torque curve of the modified engine with optimized pre-ignition map.

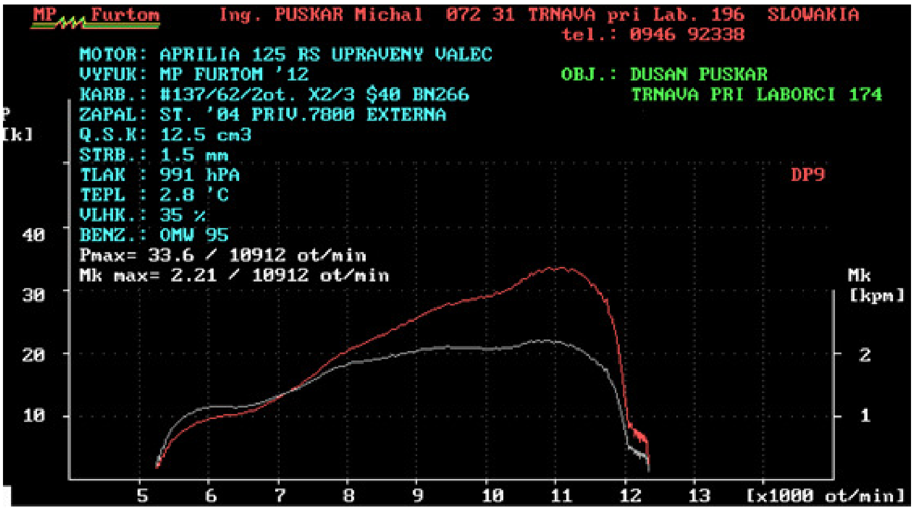

Figure11. Performance and torque of engine with modified ignition

Table 3. Performance characteristics of untreated and modified engine

Engine	**Max. power/ ot.min^{-1}**	**Max. torque/ ot.min^{-1}**
Standard cylinder	31,0k/ 11 210ot.min^{-1}	20,69 Nm / 9619ot.min^{-1}
Adjusted cylinder	33,6k/ 10 912ot.min^{-1}	21,67Nm/ 10 912ot.min^{-1}
Adj. cylinder+ curve	33,6k/ 10 913ot.min^{-1}	21,69Nm/10 912
difference	2,6k	1,0 Nm

6. Conclusions

The research was aimed at increasing the output power of a two-stroke internal combustion engine while maintaining the basic engine settings (13.5: 1 compression ratio as well as the diffuser diameter in the carburetor).

Said treatment of the roller has improved the way it is flushed. In the field of economy, this treatment has a particular impact on the efficiency of the fuel used, which is consequently related to the positive relation to the environment, when the operation of the internal combustion engine results in lower emissions of pollutants into the air, resulting in better combustion of the engine.

Almost all major motorcycle manufacturers rely on the theory that the maximum power of a given engine lies in the 11000-13000 rpm range when increasing the performance of a two-stroke internal combustion engine. It can be concluded from this that the two-stroke internal combustion engine is not able to fully utilize its low-speed performance potential below 11,000 rpm.

Through the performance brake measurements, we conclude that the engine modified in this way is able to utilize its power potential even at speeds below 11,000 rpm. The cylinder, which was modified and then mounted on an experimental engine, exhibited maximum power and torque at approximately 10,000 rpm. From this fact it can be stated that even at lower revs it is possible to achieve high engine power. An engine that is able to utilize its power potential at lower speeds is better in terms of durability, because reducing engine speed increases its life and hence its overall reliability.

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