UDC 621.43.013:621.43.038

Natalya Yevsyeyeva — Candidate of Technical Science, Associate Professor, Department of Automobiles, Heat Engines and Hybrid Energy Plants, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: korskovanat@ukr.net*, ORCID: 0000-0002-3398-6537

Roman Sukhonos — Senior Lecturer, Department of Automobiles, Heat Engines and Hybrid Energy Plants, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: romevs@zp.edu.ua*, ORCID: 0000-0001-9683-3389

Natalya Ryaboshapka — Senior Lecturer, Department of Automobiles, Heat Engines and Hybrid Energy Plants, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: ryaboshapka.ne@gmail.com*, ORCID: 0000-0003-0334-8363

Vladyslav Timoshenko — Student of Department of Automobiles, Heat Engines and Hybrid Energy Plants, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: vladtimoha0@gmail.com*

RESEARCH OF THE EFFECT OF RAM AIR BOOSTING ON THE PERFORMANCE OF AN INTERNAL COMBUSTION ENGINE

Purpose. *To investigate the influence of gas exchange parameters, in particular ram air boosting, on the indicated and effective performance of a four-stroke spark-ignition internal combustion engine using the high-performance engine of the Kawasaki Ninja ZX-10R motorcycle as a case study.*

Research methods. *A combination of theoretical and analytical-calculation methods was employed. The magnitude of ram air boosting was analyzed by determining the dynamic air pressure as a function of vehicle speed within the range of 0–300 km/h. A thermodynamic cycle calculation of the spark-ignition engine operating at the rated condition was performed using the Engine Calculation software environment. The analysis was carried out for both naturally aspirated conditions and with ram air boosting, taking into account variations in intake pressure, charge density, cyclic air and fuel mass, as well as the thermodynamic state of the working charge at the beginning of the cycle.*

Results. *It has been established that with increasing vehicle speed, the dynamic air pressure rises according to a quadratic relationship and exceeds 4 kPa at speeds above 300 km/h. This results in an increase in intake pressure, a higher mass of air per cycle, and a corresponding increase in fuel supply. Consequently, the engine effective power increases by up to 4.2%, while average effective pressure shows a similar rise. At the same time, the indicated and effective thermal efficiencies, as well as the specific fuel consumption, remain practically unchanged. It has been found that the increase in engine power is primarily due to the increased mass of the working charge in the cylinder, whereas the main gas exchange coefficients exhibit only minor variations.*

Scientific novelty. *A methodology has been developed for evaluating the effect of ram air boosting on the indicated and effective performance of a spark-ignition internal combustion engine, taking into account variations in gas exchange parameters and intake conditions. The proposed approach enables a quantitative assessment of power gain as a function of vehicle speed.*

Practical value. *The proposed methodology and obtained results can be applied in the design and optimization of intake systems for high-speed vehicles, including motorcycles, sports cars, and aircraft, as well as in the modernization of existing engines to enhance their power output without significant structural complexity.*

Key words: *internal combustion engine, gas exchange, ram air boosting, intake system, dynamic pressure, effective power.*

Introduction

The use of internal combustion engines (ICE) as a power source for various types of machinery has both advantages and disadvantages. The advantages include compactness of the power unit, high specific power output, ease of refueling, and relatively long driving range. The primary disadvantages are associated with environmental impact, namely the harmful emissions resulting from fuel combustion and the pollution of the environment by combustion products. In addition, a vehicle is a source of vibroacoustic and electromagnetic emissions [1].

The main trends in the development and improvement of ICEs over recent decades have been focused on enhancing fuel and lubricant efficiency, increasing reliability, reducing exhaust emissions, improving the level of automation and diagnostic

DOI 10.15588/1607-6885-2026-2-8

capabilities, and decreasing mass and overall dimensions. These parameters determine the technological advancement and competitiveness of various applications (automobiles, motorcycles, marine vessels, locomotives, power generators, etc.), as well as the efficient utilization of key operating materials (lubricants, fuels, metals, etc.) and the associated maintenance and repair costs [2–4].

There are numerous approaches to improving the performance of internal combustion engines, which can be achieved by optimizing the operation of various subsystems. In the absence of boosting devices (such as superchargers or turbochargers), an internal combustion engine is referred to as naturally aspirated. One of the methods to increase the amount of air supplied to the intake system in such engines is the application of ram air boosting.

Analysis of research and publications

There are numerous methods for improving specific performance parameters of ICEs; however, each of them has certain drawbacks, such as complexity, cost, and reduced reliability. The possibilities for boosting ICEs installed on motorcycles are significantly limited. In addition to the conventional requirements of fuel efficiency, reliability, and environmental performance, rather strict constraints are also imposed on mass and dimensional characteristics.

Thus, one of the most obvious ways to increase ICE power – namely, the use of mechanical supercharging (supercharger) or gas-turbine boosting (turbocharger) – becomes complicated or even impractical. However, ram air boosting systems exhibit a certain level of effectiveness. Their efficiency is limited; however, their use in high-speed motorcycles does not lead to a significant increase in mass, and such systems are most effective at high vehicle speeds [5]. In contrast to “conventional” boosting systems (with superchargers or turbochargers), ram air systems have been less studied in the scientific literature; therefore, the research topic is relevant.

Ram air boosting systems have been widely used in aviation since the emergence of aircraft capable of reaching significant speeds (above 140–160 km/h), and later in high-speed automobiles (e.g., Ford Fairlane Thunderbolt, Porsche Panamera GTS) and motorcycles (Kawasaki ZX-11). The effectiveness of ram air boosting in passenger cars is limited due to the large length and significant curvature of intake ducts.

In motorcycles, the air intake is installed in the front part of the vehicle body, within the fairing. According to the study conducted by the authors [6], the increase in intake system pressure due to ram air boosting in a high-speed motorcycle is about 4 kPa. The best results (maximum pressure increase) are obtained with maximum smoothing of the intake duct, which has no sharp corners or abrupt bends.

According to data from [7, 8], the intake pressure of passenger car ICEs increases by 3–6 kPa at vehicle speeds of about 200 km/h.

Based on the analysis of sources [5, 9–12], it can be concluded that the implementation of ram air boosting requires:

- the presence of dynamic pressure (incoming airflow);
- a properly designed and optimally positioned air intake.

Purpose

The purpose of this work is to research the influence of gas exchange parameters on the indicated and effective performance of a four-stroke spark-ignition engine with ram air boosting, using the engine of the Kawasaki Ninja ZX-10R motorcycle as an example.

To achieve this objective, the following tasks were solved:

- determination of the main parameters characterizing intake gas exchange processes; consideration of the main structural elements of the intake system; analysis of aspects related to the application of the ram air effect to improve ICE performance; review of existing methods for studying the influence of ram air boosting on engine performance;
- development of a methodology for determining the effect of ram air boosting on the performance of a high-speed motorcycle spark-ignition engine;
- calculation of the magnitude of ram air boosting, i.e., the dynamic air pressure, at different vehicle speeds;
- performing a thermodynamic cycle calculation of the engine operating at rated conditions, both in the presence and absence of ram air boosting, and determining the indicated and effective performance parameters;
- conclusions based on the analysis of the obtained results.

Material and Methodology

The study employed theoretical (analysis, synthesis, induction, deduction) and practical (analytical-calculation) methods.

To investigate the effect of ram air boosting on the performance of a high-speed motorcycle spark-ignition engine, the engine of the Kawasaki Ninja ZX-10R motorcycle was choosen.

The engine is an inline four-cylinder, liquid-cooled unit with a displacement of 998 cm³, mounted transversely in the motorcycle frame (Fig. 1, 2). The valvetrain is of the DOHC type, with four valves per cylinder. The intake system is designed with reduced flow resistance and incorporates ram air boosting. The air filter element is of the viscous paper type.

DOI 10.15588/1607-6885-2026-2-8

Figure 1. Air intake of the Kawasaki Ninja ZX-10R motorcycle engine [13]

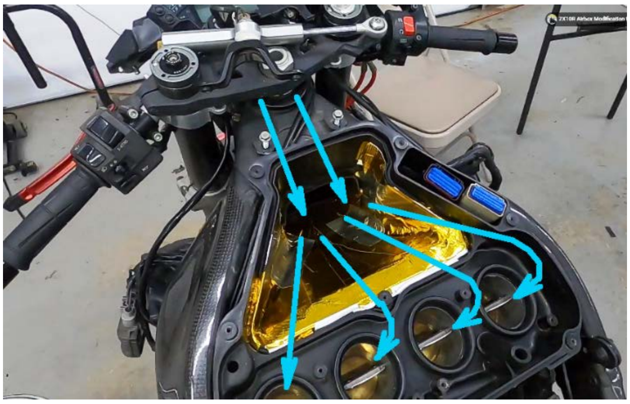

Figure 2. Schematic of the intake system and airflow path in the Kawasaki Ninja ZX-10R motorcycle (air filter not shown) [14]

Technical specifications of the Kawasaki Ninja ZX-10R engine [13, 14]:

- number of cylinders – 4;
- stroke – 76.0 mm;
- bore – 55.0 mm;
- compression ratio – 13;
- maximum effective power – 146 kW (197 hp) at 13,000 rpm;
- maximum torque – 113.5 N·m at 11,500 rpm.

Ambient air is drawn from outside through an intake duct (Figure 1), which is installed in the front part of the motorcycle fairing. The duct is protected by a mesh to prevent large debris from entering.

Then, the horizontal airflow is deflected upward, passes over the upper part of the engine, turns downward, and is directed toward the air filter and throttle valves (Figure 2).

Due to the large cross-sectional area of the air ducts and the orientation of the air intake in the direction of motorcycle motion, an increase in intake air pressure is achieved at high speeds as a result of ram air boosting. The maximum speed of the Kawasaki Ninja ZX-10R motorcycle, depending on the modification, can reach 304 km/h.

The methodology for determining the effect of ram air boosting on the performance of a high-speed motorcycle spark-ignition engine includes:

- calculation of the magnitude of ram air boosting by determining the dynamic air pressure at possible vehicle speeds;
- performing a thermodynamic cycle calculation of the engine operating at rated conditions using the physical and mathematical model of Prof. Yehorov, implemented in the Engine Calculation software [15–17], both without ram air boosting and with ram air boosting at vehicle speeds of 100, 200, and 300 km/h; calculation of indicated and effective performance parameters;
- analysis of the obtained results and formulation of conclusions and recommendations regarding the effectiveness and feasibility of using ram air boosting in engines of ground and aircraft vehicles.

Unlike existing studies, this research considers the influence of ram air boosting on the engine working cycle and indicated performance parameters, not only on effective performance.

Research results

In the course of the study, the nature of the dependence of the increase in dynamic (ram air) pressure on the vehicle speed was determined, i.e., $p_D = f(\upsilon)$ (Fig. 3). A quadratic equation was obtained that allows calculating the value of p_D for any value of υ within the range from 0 to 350 km/h:

$$p_D = 46{,}46\cdot10^{-6}\cdot \upsilon^2 - 0{,}8214\cdot10^{-6}\cdot \upsilon + 112{,}5\cdot10^{-6}. \quad (1)$$

A thermodynamic calculation of the working cycle of the four-stroke spark-ignition engine of the Kawasaki Ninja ZX-10R at rated operating conditions was performed. The calculation was carried out using the Engine Calculation software according to a methodology [16].

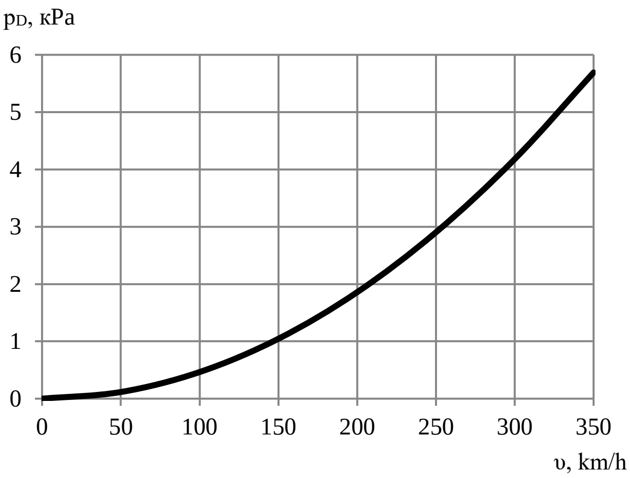

Figure 3. Variation of dynamic air pressure p_D as a function of vehicle speed υ under standard temperature and pressure conditions

DOI 10.15588/1607-6885-2026-2-8

The engine performance parameters, taking into account the magnitude of ram air boosting, were calculated with the following variable parameters:

- boost pressure p_k';
- charge density at the cylinder inlet ρ_k;
- intake pressure losses Δp_{int};
- volumetric efficiency η_v;
- cyclic air mass in the cylinder Δm_{air};
- cyclic fuel mass supply Δm_{fuel};
- pressure in the cylinder at the beginning of the cycle p_a;
- mass of the in-cylinder working medium at the beginning of the cycle m_a.

The intake air temperature T_o was assumed constant.

Table 1 shows the initial data for the thermal calculation of the Kawasaki Ninja ZX10R engine at rated conditions, taking into account ram air boosting.

Table 1 – Input data for the thermodynamic calculation of the Kawasaki Ninja ZX-10R engine at rated conditions taking into account ram air boosting

Parameter	Values			
υ, km/h	0	100	200	300
p_k, Pa	101325			
p_D, Pa	0	464,6	1858,5	4181,6
p_k', Pa	101325	101789,6	103183,5	105506,6
ρ_k, kg/m^3	1,204	1,210	1,226	1,254
Δp_{int}, Pa	4053,0	4071,6	4127,3	4220,3
p_a, Pa	97272	97718	99056	101286
$\Delta m_{air}\cdot 10^6$, kg/cycle	254	255	259	265
$\Delta m_{fuel}\cdot 10^6$, kg/cycle	19,31	19,40	19,67	20,11
$m_a\cdot 10^{-6}$, kg/cycle	272	273	277	283

The indicated performance parameters of the engine are presented in Table 2.

Table 2 – Indicated performance of the Kawasaki Ninja ZX-10R engine at rated conditions without (υ = 0 km/h) and with ram air boosting (υ = 300 km/h)

Parameter	Values			
υ, km/h	0	100	200	300
L_i, J/cycle	419,903	421,835	426,960	437,531
p_i, MPa	1,6853	1,6931	1,7137	1,7561

From Table 2, it follows that at a vehicle speed of Kawasaki Ninja ZX10R υ = 300 km/h under rated operating conditions, compared to υ = 0 km/h, the indicated performance parameters of the engine change as follows:

- indicated work L_i increases by 4.2%;
- indicated average effective pressure p_i increases by 4.2%;
- indicated specific fuel consumption g_i shows no significant change;
- indicated efficiency η_i shows no significant change.

The effective performance parameters of the engine are presented in Table 3.

From Table 3, it follows that at a vehicle speed of υ = 300 km/h under rated conditions, compared to υ = 0 km/h, the effective performance parameters change as follows:

- effective power N_e increases by 4.2% (Fig. 4);
- effective average effective pressure p_e increases by 4.2%;
- effective specific fuel consumption g_e shows no significant change;
- effective efficiency η_e shows no significant change.

Table 3 – Effective performance of the Kawasaki Ninja ZX-10R engine at rated conditions without (υ = 0 km/h) and with ram air boosting (υ = 300 km/h)

Parameter	Values			
υ, km/h	0	100	200	300
N_e, kW	145,57	146,24	148,01	151,68
p_e, MPa	1,348	1,354	1,371	1,405

As the speed of the Kawasaki Ninja ZX-10R motorcycle increases from 0 to 300 km/h, changes occur in the engine working cycle due to ram air boosting. In particular, this leads to an increase in the maximum in-cylinder pressure p_{max} by 0.597 MPa (4.2%) and an increase in the maximum temperature T_{max} by 3.3 K (0.1%).

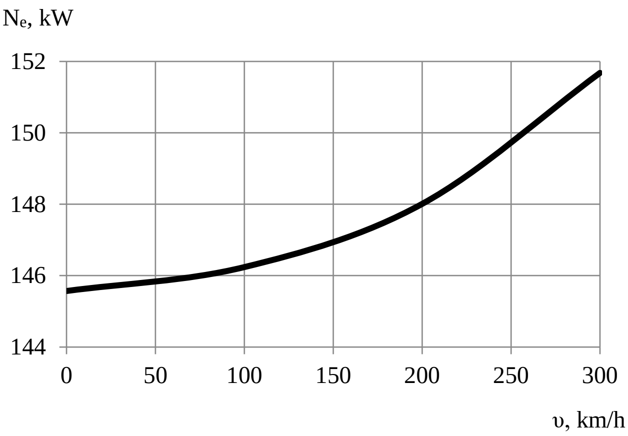

Figure 4. Dependence of the maximum effective power of the Kawasaki Ninja ZX-10R engine on vehicle speed due to ram air boosting

Conclusions

The study has established that motorcycle Kawasaki Ninja ZX10R at a vehicle speed of υ = 300 km/h under rated operating conditions, compared to υ = 0 km/h, the engine performance parameters change as follows:

- effective power Ne and average effective pressure pe increase by 4.2%;
- effective specific fuel consumption ge and effective efficiency ηe remain practically unchanged;

DOI 10.15588/1607-6885-2026-2-8

- maximum in-cylinder pressure p_{max} increases by 0.597 MPa (4.2%);

- maximum temperature T_{max} of the working charge remains practically unchanged.

It is shown that the main parameters characterizing gas exchange in the cylinder and the intake process – residual gas fraction γ, excess air ratio α, and volumetric efficiency η_v – remain practically unchanged when ram air boosting is applied. The increase in engine power is primarily due to the increase in the cyclic air mass Δm_{air} and the cyclic fuel mass Δm_{fuel}.

The results confirm that ram air boosting can provide a noticeable increase in effective power without additional complexity or increase in engine mass, which is critically important for motorcycles and related applications, including aircraft. The obtained results are recommended for experimental validation.

References

1. Chmyr, V. (2025). Analysis of methods for increasing the efficiency of piston internal combustion engines during their use in automotive technology for the organization of vehicle transportation. Collection of scientific works of the National Academy of the State Border Guard Service of Ukraine. Series: Military and Technical Sciences, 2(99), 142–151. https://doi.org/10.32453/3.v99i2.1858

2. Tsymbal, S. V., Zakorchevsky, A. V., Berezovsky, E. E. & Kozak, R. O. (2023). Perspektivni tendenciyi rozvitku porshnevih DVZ i agregativ na yihnij bazi [Promising trends in the development of piston internal combustion engines and units based on them]. VNTU, 8. https://atm.vntu.edu.ua/articles/15.pdf

3. Marchenko, A. P., Ryazancev, M. K. & Shehovcov, A. F. (2004). Dviguni vnutrishnogo zgorannya: Seriya pidruchnikiv u 6 tomah. T. 1. Rozrobka konstrukcij forsovanih dviguniv nazemnih transportnih mashin [Internal combustion engines: A series of textbooks in 6 volumes. Vol. 1. Development of designs of forced engines for ground transport vehicles]. Prapor, 384.

4. Slynko, G., Sukhonos, R., Slinko, V. & Lukyanenko, V. (2024). Research on the Influence of Resonant Charging of a Two-Stroke Gasoline Engine on its Power Curve. New materials and technologies in metallurgy and mechanical engineering, 4, 59–66 https://doi.org/10.15588/1607-6885-2024-4-6

5. Kee, R. J., Maynes, B. D. J., Kenny, R. G., Mackey, D. & Foley, L. (2002). Prediction of Formula 1 Engine and Airbox Performance using Coupled Virtual 4-Stroke and CFD Simulations. SAE Technical Papers. 2002-01-3318 https://doi.org/10.4271/2002-01-3318

6. Cabello, S. & Baz, P. (2013). Sistema aerodinámico Ram-Air: funcionamiento. Motociclismo. https://www.motociclismo.es/industria/el-ram-air_176725_102.html

7. Airboxes and Ram Effect (2008). Autosport. https://forums.autosport.com/topic/103265-airboxes-and-ram-effect

8. Does ram air work? (2012). Grassroots Motorsports. https://grassrootsmotorsports.com/forum/grm/article-topic-does-ram-air-work/48999/page1

9. Abramchuk, F. I., Gutarevich, Yu. F., Dolganov, K. E. & Timchenko, I. I. (2006). Avtomobilni dviguni [Automobile engines]. Aristei, 476.

10. Parry, L., Könözsy, L. & Temple, C. (2018). Airbox design, analysis and improvement for a highperformance road racing sidecar. Vehicle and Automotive Engineering. Lecture Notes in Mechanical Engineering, 2. 545–562. https://doi.org/10.1007/978-3-319-75677-6_48

11. Tan, J. & Abu Bakar, N. Z. (2021). Design improvement of an airbox for a passenger vehicle. Journal of Physics: Conference Series. https://doi.org/10.1088/1742-6596/2120/1/012010

12. Teck Yap, J., Abu Bakar, N. Z., Shaikh Dawood, N. F. & Rosli, M. A. (2021). Design Improvements of Acoustic Response of an Automotive Air Intake System. MATEC Web of Conferences, 335, 10. https://doi.org/10.1051/matecconf/202133503017

13. Kawasaki Ninja ZX-10R Motorcycle Service Manual (2008). Kawasaki Heavy Industries, Ltd., 694.

14. Kawasaki Ninja ZX-10R Racing Kit Manual (2006). Kawasaki Heavy Industries, Ltd., 82.

15. Slynko, G., Sukhonos, R. & Ivanov. P. (2019). Komp'yuterna programa dlya teplovogo rozrahunku robochogo ciklu dviguna vnutrishnogo zgorannya [Computer Program for Calculation of the Operating Cycle of Internal Combustion Engine]. Information technologies: theory and practice: II All-Ukrainian Internet Conference of Higher Education Applicants and Young Scientists, April 4, 2019. Zaporizhzhia. ZNTU, 96–97.

16. Slynko, G. I., Sukhonos, R. F. & Slynko, V. V. (2024). Thermal and dynamic calculation of internal combustion engines: a textbook for course design. National University "Zaporizhzhia Polytechnic", 130.

17. Slynko, G., Sukhonos, R. & Ivanov. P. (2019). Computer Program for Calculation of the Operating Cycle of Internal Combustion Engine. Science Week-2019. Faculty of Transport: annual scientific and practical conference, April 15-19, 2019: abstracts. Zaporizhzhia: ZNTU, 74–75.

18. Dziubak, T. & Karczewski, M. (2022). Experimental Study of the Effect of Air Filter Pressure Drop on Internal Combustion Engine Performance. Energies, 15(9). https://doi.org/10.3390/en15093285

Received 27.03.2026
Accepted 08.04.2026
Published 07.05.2026

DOI 10.15588/1607-6885-2026-2-8

p-ISSN 1607-6885 Нові матеріали і технології в металургії та машинобудуванні. 2026/2
e-ISSN 2786-7358 New materials and technologies in metallurgy and mechanical engineering. 2026/2

УДК 621.43.013:621.43.038

ДОСЛІДЖЕННЯ ВПЛИВУ ДИНАМІЧНОГО НАДДУВУ НА ПОКАЗНИКИ ДВИГУНА ВНУТРІШНЬОГО ЗГОРАННЯ

Наталія Євсєєва — канд. техн. наук, доцент, доцент кафедри автомобілів, теплових двигунів та гібридних енергетичних установок Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: korskovanat@ukr.net*, ORCID: 0000-0002-3398-6537

Роман Сухонос — старший викладач кафедри автомобілів, теплових двигунів та гібридних енергетичних установок Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: romevs@zp.edu.ua*, ORCID: 0000-0001-9683-3389

Наталя Рябошапка — старший викладач кафедри автомобілів, теплових двигунів та гібридних енергетичних установок Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: ryaboshapka.ne@gmail.com*, ORCID: 0000-0003-0334-8363

Владислав Тимошенко — студент кафедри автомобілів, теплових двигунів та гібридних енергетичних установок Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: vladtimoha0@gmail.com*

Мета роботи. *Дослідити вплив параметрів газообміну, зокрема динамічного (швидкісного) наддуву, на індикаторні та ефективні показники бензинового чотиритактного двигуна внутрішнього згоряння на прикладі високофорсованого двигуна мотоцикла Kawasaki Ninja ZX-10R.*

Методи дослідження. *Для досягнення поставленої мети використано комплекс теоретичних та аналітично-розрахункових методів. Проведено аналіз величини динамічного наддуву шляхом визначення динамічного тиску повітря залежно від швидкості руху транспортного засобу в діапазоні 0–300 км/год. Виконано термодинамічний розрахунок робочого циклу бензинового двигуна на номінальному режимі з використанням програмного середовища Engine Calculation. Розрахунок проведено для умов відсутності та наявності динамічного наддуву з урахуванням зміни тиску на впуску, густини заряду, маси повітря та палива в циклі, а також параметрів робочого тіла на початку циклу.*

Отримані результати. *Встановлено, що зі зростанням швидкості руху мотоцикла величина динамічного тиску повітря зростає за квадратичним законом і при швидкості понад 300 км/год досягає значення понад 4 кПа. Це призводить до підвищення тиску на впуску, збільшення циклового заряду повітря та відповідного зростання подачі палива. У результаті ефективна потужність двигуна збільшується до 4,2 %, а середній ефективний тиск – на аналогічну величину. При цьому індикаторний та ефективний коефіцієнти корисної дії, а також питома витрата палива залишаються практично незмінними. Виявлено, що підвищення потужності зумовлене переважно збільшенням маси робочого тіла в циліндрі, тоді як основні коефіцієнти, що характеризують процес газообміну, змінюються незначно.*

Наукова новизна. *Розроблено методику оцінювання впливу динамічного наддуву на індикаторні та ефективні показники бензинового двигуна внутрішнього згоряння з урахуванням зміни параметрів газообміну та умов впуску, що дозволяє кількісно визначати приріст потужності залежно від швидкості руху транспортного засобу.*

Практична цінність. *Запропонована методика та отримані результати можуть бути використані при проектуванні та оптимізації впускних систем швидкісних транспортних засобів, зокрема мотоциклів, спортивних автомобілів, літальних апаратів, а також при модернізації існуючих двигунів з метою підвищення їх потужнісних показників без суттєвого ускладнення конструкції.*

Ключові слова: *двигун внутрішнього згоряння, газообмін, динамічний наддув, впускна система, динамічний тиск, ефективна потужність.*

Список літератури

1. Чмир В. Аналіз способів підвищення ефективності поршневих двигунів внутрішнього згорання в ході їх застосування на автомобільній техніці під час організації автомобільних перевезень. Збірник наукових праць Національної Академії Державної прикордонної служби України. Серія :

DOI 10.15588/1607-6885-2026-2-8

військові та технічні науки. 2025. Том 99. № 2. С. 142–151. https://doi.org/10.32453/3.v99i2.1858

2. Цимбал С. В., Закорчевський А. В., Березовський Є. Е., Козак Р. О. Перспективні тенденції розвитку поршневих ДВЗ і агрегатів на їхній базі. Вінниця : ВНТУ, 2023. 8 с. https://atm.vntu.edu.ua/articles/15.pdf

3. Марченко А. П., Рязанцев М. К., Шеховцов А. Ф. Двигуни внутрішнього згорання: Серія підручників у 6 томах. Т. 1. Розробка конструкцій форсованих двигунів наземних транспортних машин. Харків : Прапор, 2004. 384 с.

4. Слинько Г. І., Сухонос Р. Ф., Слинько В. В., Лук'яненко В. П. Дослідження впливу резонансного наддуву бензинового двотактного двигуна на його швидкісну характеристику. *Нові матеріали і технології в металургії та машинобудуванні*. 2024. № 4. С. 59–66. https://doi.org/10.15588/1607-6885-2024-4-6

5. Kee R. J., Maynes B. D. J., Kenny R. G., Mackey D., Foley L. Prediction of Formula 1 Engine and Airbox Performance using Coupled Virtual 4-Stroke and CFD Simulations. SAE Technical Papers. 2002. 2002-01-3318 https://doi.org/10.4271/2002-01-3318

6. Cabello S., Baz P. Sistema aerodinámico Ram-Air: funcionamientoю Сайт «Motociclismo». 2013. URL: https://www.motociclismo.es/industria/el-ram-air_176725_102.html

7. Airboxes and Ram Effect. 2008. Сайт «Autosport». URL: https://forums.autosport.com/topic/103265-airboxes-and-ram-effect

8. Does ram air work? 2012. Сайт «Grassroots Motorsports». URL: https://grassrootsmotorsports.com/forum/grm/article-topic-does-ram-air-work/48999/page1

9. Абрамчук Ф. І., Гутаревич Ю. Ф., Долганов К. Є., Тимченко І. І. Автомобільні двигуні. Київ : Арістей. 2006. 476 с.

10. Parry L., Könözsy L., Temple C. Airbox design, analysis and improvement for a highperformance road racing sidecar. Vehicle and Automotive Engineering. Lecture Notes in Mechanical Engineering. 2018. № 2. P. 545–562. https://doi.org/10.1007/978-3-319-75677-6_48

11. Tan J., Abu Bakar N. Z. Design improvement of an airbox for a passenger vehicle. Journal of Physics: Conference Series. 2021. https://doi.org/10.1088/1742-6596/2120/1/012010

12. Teck Yap J., Abu Bakar N. Z., Shaikh Dawood N. F., Rosli M. A. Design Improvements of Acoustic Response of an Automotive Air Intake System. MATEC Web of Conferences. 2021. Vol. 335. https://doi.org/10.1051/matecconf/202133503017

13. Kawasaki Ninja ZX-10R Motorcycle Service Manual. Kawasaki Heavy Industries, Ltd. 2008. 694 p.

14. Kawasaki Ninja ZX-10R Racing Kit Manual. Kawasaki Heavy Industries, Ltd. 2006. 82 p.

15. Слинько Г. І., Сухонос Р. Ф., Іванов П. Є. Комп'ютерна програма для теплового розрахунку робочого циклу двигуна внутрішнього згорання. Інформаційні технології: теорія і практика : матеріали ІІ Всеукр. Інтернет-конф. здобувачів вищої освіти і молодих учених, 4 квітня 2019 р. Запоріжжя : ЗНТУ, 2019. С. 96–97.

16. Слинько Г. І., Сухонос Р. Ф., Слинько В. В. Тепловий і динамічний розрахунок ДВЗ : навчальний посібник з курсового проєктування. Запоріжжя : НУ «Запорізька політехніка», 2024. 130 с.

17. Slynko G., Sukhonos R., Ivanov P. Computer Program for Calculation of the Operating Cycle of Internal Combustion Engine. Тиждень науки-2019. Транспортний факультет : щоріч. наук.-практ. конф., 15-19 квітня 2019 р. : тези доп. Запоріжжя : ЗНТУ, 2019. С. 74–75.

18. Dziubak T., Karczewski M. Experimental Study of the Effect of Air Filter Pressure Drop on Internal Combustion Engine Performance. Energies. 2022. 15(9). 3285. https://doi.org/10.3390/en15093285

DOI 10.15588/1607-6885-2026-2-8