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ZMNIEJSZENIE WPŁYWU POJAZDÓW NA ŚRODOWISKO ORAZ KONSUMPCJĘ ENERGII

Streszczenie: Zmiany klimatu są jednym z istotnych zjawisk, z którymi spotykają się współczesne społeczeństwa. Eksperci klimatyczni wzywają ostatnio, aby kraje dokonywały istotnego zwiększenia wysiłków na rzecz ograniczenia ocieplenia do poziomu o 1.5°C (w stosunku do poziomu sprzed ery industrialnej). Sektor transportu jest istotnym 'dostarczycielem' tzw. gazów cieplarnianych, ocenia się że jest to poziom 23% tejże emisji w Unii Europejskiej. Z kolei, znaczna część energii dostarczanej do silników pojazdów poruszających się po obszarach zurbanizowanych jest tracona jako ciepło podczas hamowania. Te straty są większe niż wiele innych czynników – jak straty aerodynamiczne, opory ruchu obrotowego czy w systemie napędowym. Jednym w ujęć/rozwiązań, które mogą zredukować wpływ pojazdów na środowisko oraz zredukować pobór energii jest używanie tzw. Systemów Odzyskiwania Energii Kinetycznej (KERS). Taki system odzyskuje pewną porcję energii traconej w trakcie hamowania pojazdu.

Słowa kluczowe: transport, emisja, system odzyskiwania energii kinematycznej

REDUCING THE IMPACT OF VEHICLES ON THE ENVIRONMENT AND ENERGY CONSUMPTION

Summary: Climate change is one of the most pressing issues that today's society faces. Climate experts have recently called on countries to make significant progress in limiting global warming to 1.5°C compared to pre-industrial levels. The transportation sector is a significant contributor to greenhouse gas emissions, accounting for 23% of these emissions in the EU. A large portion of the energy supplied to vehicle engines operated in urban areas is lost as heat during braking. These losses are greater than many factors, including aerodynamic losses, rolling resistance, or drivetrain losses. One approach that can be used to reduce the environmental impact of vehicles and energy consumption is the use of a Kinetic Energy Recovery System (KERS), which recovers a portion of the energy that is typically lost during braking.

Keywords: transportation, emissions, kinetic energy recovery system

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1. Introduction

Due to the steadily increasing levels of emissions in the environment, the European Union has begun to address this issue in a significant way, along with potential solutions. The goal of this effort was the creation of the Fit for 55 climate package. The aim of this package is to reduce carbon dioxide (CO_2) emissions from new passenger and light-duty vehicles in the European Union. The Fit for 55 climate package, approved by the members of the European Parliament, introduces stricter emission standards and ambitious CO_2 reduction targets for the transportation sector. From 2035 onwards, new vehicles with internal combustion engines will no longer be allowed for sale. The primary goal of the Fit for 55 climate package is to achieve zero CO_2 emissions for new passenger and commercial vehicles by 2035. The objective for the entire Union's vehicle fleet is to reduce CO_2 emissions produced by new cars and vans by 100 percent compared to the year 2021. Before achieving the main objective in 2035, interim targets have been set. By 2030, the objective is to reduce CO_2 emissions by 55 percent for passenger cars and 50 percent for vans. These targets support the transition to zero emissions and incentivize manufacturers to develop cleaner technologies. The European Commission plans to establish a methodology for assessing and reporting CO_2 emissions data throughout a vehicle's lifecycle by 2025. By December 2026, it will monitor the disparities between emission limits and actual fuel and energy consumption data and propose appropriate follow-up measures. The Fit for 55 climate package introduces stringent targets and measures to reduce CO_2 emissions from new vehicles in the European Union. These targets are aimed at achieving zero CO_2 emissions by 2035 and present a challenge for the automotive industry and manufacturers of alternative propulsion systems. Monitoring, assessment, and incentives for manufacturers will be key tools in reaching these goals. The provisional agreement on a complete ban on the sale of vehicles with internal combustion engines using fossil fuels starting in 2035 was formally approved by the European Parliament in 2022.

In practice, this ban means that from 2035, only new passenger and light-duty vehicles with zero tailpipe emissions or vehicles with a neutral emission footprint will be allowed for sale. Currently, electric vehicles using batteries fall into this category because the use of hydrogen as a fuel and the use of synthetic fuels are still uncertain. The mentioned agreement proposal does not yet have all the details specified, and therefore, there is currently a discussion on the closer determination of the planned objectives. These targets aim for the transition to be gradual rather than abrupt, resulting in a gradual reduction of emissions from newly manufactured vehicles. This transition is applied from the year 2021 and consist of three stages, which are:

1) A 25% reduction in emissions from newly manufactured passenger vehicles and a 17% reduction in CO_2 emissions for commercial vehicles between 2025 and 2030.
2) Achieving a 55% reduction in emissions from newly manufactured passenger vehicles and a 50% reduction in CO_2 emissions for commercial vehicles between 2030 and 2035.
3) Zero CO_2 emissions production for both passenger and commercial vehicles.

This agreement naturally includes certain types of exemptions, for example, exemptions for vehicle manufacturers producing fewer than 1000 vehicles per year; this condition of zero emissions will not apply to them. In the case of electric vehicles, the majority of CO_2 emissions are generated during their production and recycling. Reduction of these emissions when using an electric vehicle is limited, especially if the charging power used is not sourced from renewable energy. For internal combustion engines, approximately 70% of CO_2 emissions in the entire vehicle lifecycle come from the operation of the vehicle. The remaining 30% is distributed across other stages, including vehicle production and recycling, and fuel production. In some cases, the share of emissions from electric vehicles is nearly equivalent to that of conventional vehicles. Therefore, the transition to electric propulsion will only be effective if the entire lifecycle is optimized. Key areas include battery production and the generation of electric energy for charging electric vehicles. Additionally, charging station infrastructure and the safety of high-capacity batteries are still insufficiently addressed. However, vehicles with internal combustion engines are still the most popular choice among consumers, which is why the development of new engine technologies will remain relevant. These technologies can include hybrid propulsion and energy regeneration systems [1-5].

2. Internal combustion engine and energy conversion

Internal combustion engines are machines that convert the chemical energy of fuel into mechanical work. The process of energy conversion occurs according to the scheme in Figure 1 [1].

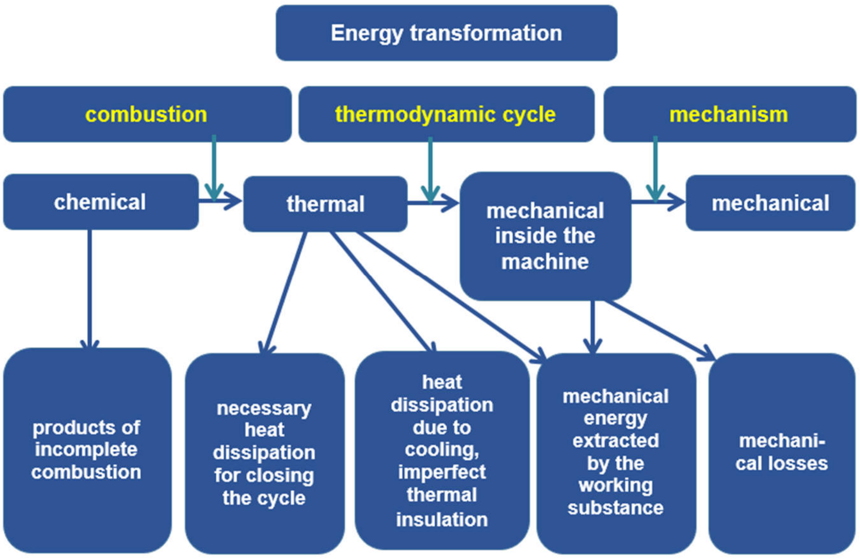

Figure 1. Scheme of energy transformation in internal combustion engines [1]

Internal combustion engines are heat engines in which the chemical energy of the fuel is converted in the combustion chamber into thermal energy, which the engine subsequently transforms into mechanical work. In the depicted energy transformation in Figure 1, the flows of lost energy are marked, which are determined by:

1. Imperfect chemical reaction processes during combustion (usually involving oxidation),

2. Necessary heat dissipation from the engine (typically occurring at ambient temperature),
3. Thermal losses due to unintentional or intentional heat dissipation from the engine (cooling),
4. Losses in the form of unused mechanical energy carried away by the working substance (e.g., kinetic energy of exhaust gases),
5. Mechanical losses (e.g., friction) during the conversion of mechanical energy inside the engine (e.g., piston work) into usable external mechanical work of the engine (e.g., work at the engine's output shaft).

3. Kinetic Energy Recovery System

The recuperation system, which is the utilization of braking or kinetic energy from the vehicle, has been under development in the automotive world since 2009. This system is known by the acronym KERS (Kinetic Energy Recovery System). Its goal is to capture a portion of the energy (through batteries or a flywheel) generated during braking and subsequently use this energy to enhance the vehicle's acceleration. The advantages of this system can also be applied to single-track means of transport.

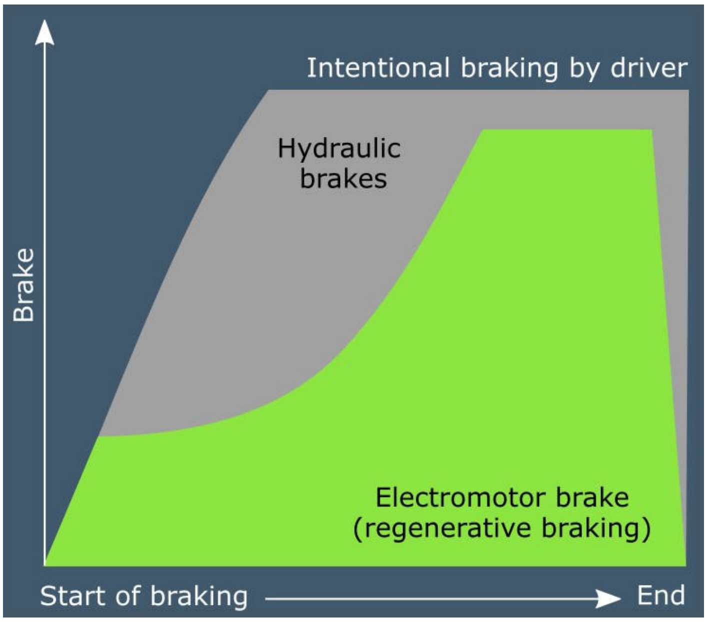

Figure 2. Conceptual diagram of the mechanism

The conceptual diagram of the mechanism illustrates the comparison between the characteristics of hydraulic and regenerative braking during intentional braking by the driver in a vehicle (Fig. 2). Regenerative braking harnesses kinetic energy, which is converted using an electric motor designed for electricity regeneration. Under normal circumstances, applying current to the electric motor causes its rotor to rotate. However, if an external force rotates the rotor, it functions as a generator and produces electricity. This allows for using the rotational force of the vehicle's drive axle to power electric motors and generate electrical energy stored in batteries while simultaneously slowing down the vehicle due to the influence of electric motors.

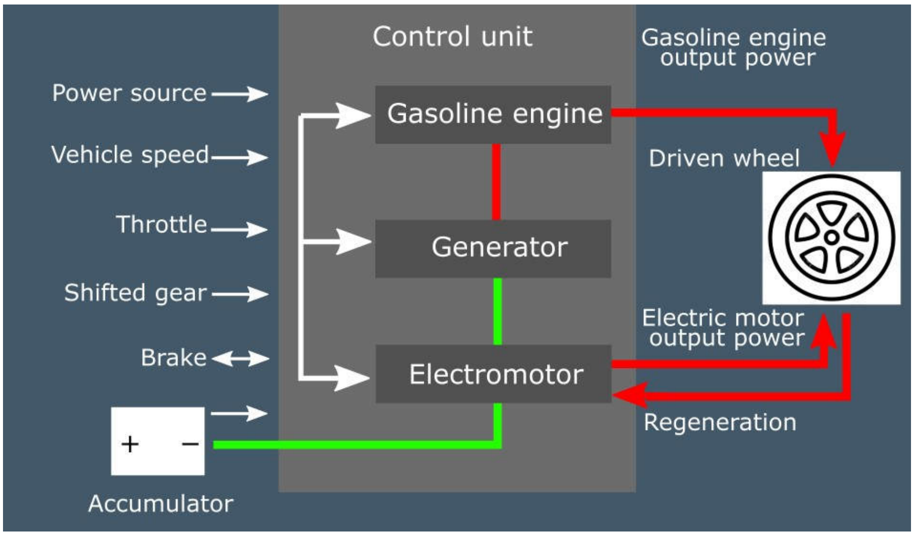

Figure 3. Control of the KERS system

The control system coordinates regenerative braking and the braking activity of the conventional hydraulic brake (Fig. 3) so that kinetic energy, which is typically dissipated as frictional heat during braking, can be collected for later use in normal driving mode. A typical example for the purposeful utilization of this system could be city driving, which consists of cycles of acceleration and subsequent deceleration. The energy utilization ratio in such driving conditions can be relatively high.

4. Conclusion

The vast majority of systems are based on accumulating energy in a battery with electrodynamic power transmission, despite the proven disadvantages of this system, such as higher weight and reduced battery lifespan when deeply discharged. In the realm of personal cars, the benefits of using regenerative systems (e.g., Toyota Prius) are evident when simulating urban driving conditions like the New European Driving Cycle (NEDC) with significantly lower fuel consumption compared to vehicles with a similar engine without regenerative capabilities. Furthermore, a KERS power unit, whether it's an electric motor or a flywheel gearbox, exhibits a significantly improved torque curve, allowing for smoother and faster vehicle acceleration without unnecessary clutch engagement and operation of the combustion engine at low RPMs, where it is less efficient. In combination with a START-STOP system, KERS can be highly effective in reducing fuel consumption in urban traffic. Other advantages of implementing KERS in personal vehicles include reducing brake wear, thereby extending their lifespan, and providing greater safety during overtaking maneuvers with a less powerful engine, where additional power can be supplied from the battery.

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REFERENCES

1. ABD ALLA, G., SOLIMAN, H., BADR, O. & ABD RABBO, M.,: Effect of injection timing on the performance of a dual fuel engine. Energy Conversion and Management, 2002, 43, 269-277.
2. SAHOO, B., SAHOO, N. & SAHA, U.,: Effect of engine parameters and type of gaseous fuel on the performance of dual-fuel gas diesel engines—A critical review. Renewable and Sustainable Energy Reviews, 2009, 13, 1151-1184.
3. AGARWAL, A., SINGH, A. & MAURYA, R.,: Evolution, challenges and path forward for low temperature combustion engines. Progress in Energy and Combustion Science, 2017, 61, 1-56.
4. PACHIANNAN, T., ZHONG, W., RAJKUMAR, S., HE, Z., LENG, X. & WANG, Q.,: A literature review of fuel effects on performance and emission characteristics of low-temperature combustion strategies. Applied Energy, 2019, 251, 113380.
5. MANIGANDAN, S., GUNASEKAR, P., DEVIPRIYA, J. & NITHYA, S., Emission and injection characteristics of corn biodiesel blends in diesel engine. Fuel, 235, 2019, 723-735.