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Modern braking systems for high-efficient urban electric vehicles

Nowoczesne systemy hamowania wysokowydajnych miejskich samochodów elektrycznych

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Fast and dynamic development of automotive industry, especially in electric and hybrid drive field, forces on engineers elaboration of new solutions in a car design. An example of this process is a braking system. This paper is an attempt to show how modern braking systems help improve energy efficient by implementation of a regenerative braking and use of electromechanically braking systems.
KEYWORDS: braking system, high-efficient vehicles, regenerative braking

The continuous search for savings, dynamic development of ecological technologies and development of ways to effectively use resources have been reflected in the automotive industry. Solutions to reduce fuel consumption, reduce resistance, as well as the use of lost energy are being investigated. One of the components that allow the implementation of these postulates is the braking system, whose task is to enable speed reduction by converting the kinetic energy of the vehicle into thermal energy. In conventional brakes, the thermal energy generated as a result of the friction of the friction linings against the side surface of the haulette disc or the inner surface of the brake drum is lost by exchanging heat with the surroundings.

Fig. 1 presents executive elements of pop-up brake systems: disc brake and drum haulage. They still form the basis of vehicle braking systems, although drum brakes are less and less frequently encountered. These systems have great potential due to the significant amount of energy wasted in the form of heat emitted on the heating elements that warm up to a high temperature, especially when driving in the urban cycle. Therefore, the research focuses largely on developing ways to recover this energy.

Energy losses generated by braking process do not pose a significant problem in conventional drive systems based on drive units using the combustion process of a fuel-air mixture. However, in the case of electric drives, each energy loss is a problem. Electric vehicles have limited capacity of energy storage (accumulators, supercapacitors), and each time the recharge requires time and appropriate conditions. Therefore, in the structures focused on the most effective use of energy, special solutions have been started, the task of which is to:

- limit the loss of energy generated during braking,
- energy recovery and re-use.

For this purpose, KERS (Kinetic Energy Recovery System) systems are increasingly used within modern vehicle structures – both in the form of mechanical and electrical systems. In addition, specialized electronic systems are used, e.g. brake-by-wire, whose task is to choose the right braking strategy to make good use of the vehicle's energy.

a) *b*)

Fig. 1. Actuators of conventional braking systems: *a*) disc brake, *b*) drum brake

Brake energy recovery systems

The specificity of city traffic forces frequent stopping or slowing down of the vehicle, and the necessity of speed reduction causes that the accumulated kinetic energy is lost and turns into heat. The engineers, wanting to increase the range of cars, have developed braking energy recovery systems. Their task is to reduce the speed of the car by changing the kinetic energy of moving vehicle into a form of energy that can be collected to re-use it. The stored energy can be used to directly drive wheels or recharge batteries [1–2].

Depending on the method of energy storage, the regenerative braking systems can be divided into electric and mechanical ones.

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In the electric energy recovery system, the element responsible for changing the kinetic energy into the electric one is the vehicle engine, which during the braking assumes the role of the generator. The energy flow in the electric energy recovery system is shown in fig. 2.

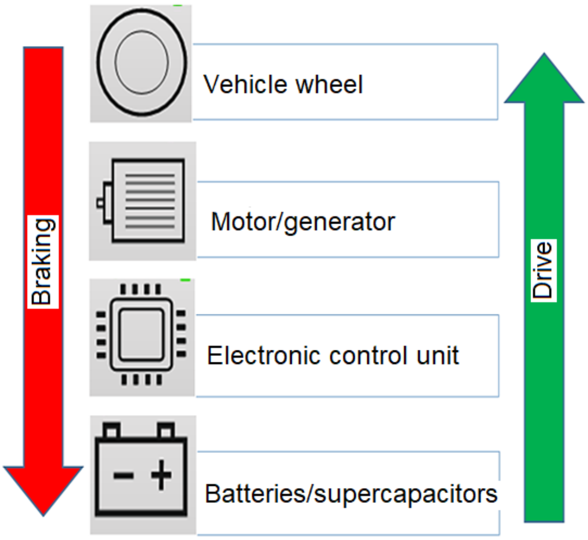

Fig. 2. Diagram of energy flow in the drive system in the configuration of the drive (green color) and regenerative braking (red color) [1]

During braking, energy is transferred from wheels to the generator. There, electricity is generated under the control of the control unit. The generated electricity band is stored in the vehicle batteries or in supercapacitors. Most elements of the energy recovery system are elements that are part of the propulsion system, which means that the implementation of regenerative braking does not require a significant increase in vehicle mass [1–2].

The application of braking energy recovery allows to reduce the size of elements of the classic system, which has a beneficial effect on the weight of the car, but does not eliminate the need to equip the car with friction brakes. They are used in emergency situations or as a parking brake. The disadvantage of the solution, in which the electric motor during braking acts as a generator, is the possibility of using regenerative braking only on the drive wheels. Another limitation is the insufficient recovery efficiency, which also means inadequate braking performance at low speeds [1–3].

In the mechanical recovery system, the kinetic energy of the moving vehicle is converted into the kinetic energy of the rotational motion of the flywheel. In the course of car deceleration, the flywheel is accelerated to a high rotational speed, becoming the energy store. The recovery system is connected to the propulsion system by a series of clutches allowing to control the amount of energy going to the wheels when using the accumulated energy to drive the vehicle. To reduce the resistance to movement, the swing wheel was placed in a vacuum. Elements that make up the mechanical energy recovery system are shown in fig. 3 [1–3].

Brake-by-wire system

An important element of modern braking systems are electronic systems. The use of energy recovery together with a conventional braking system made it necessary for constructors to create a new system in which both systems

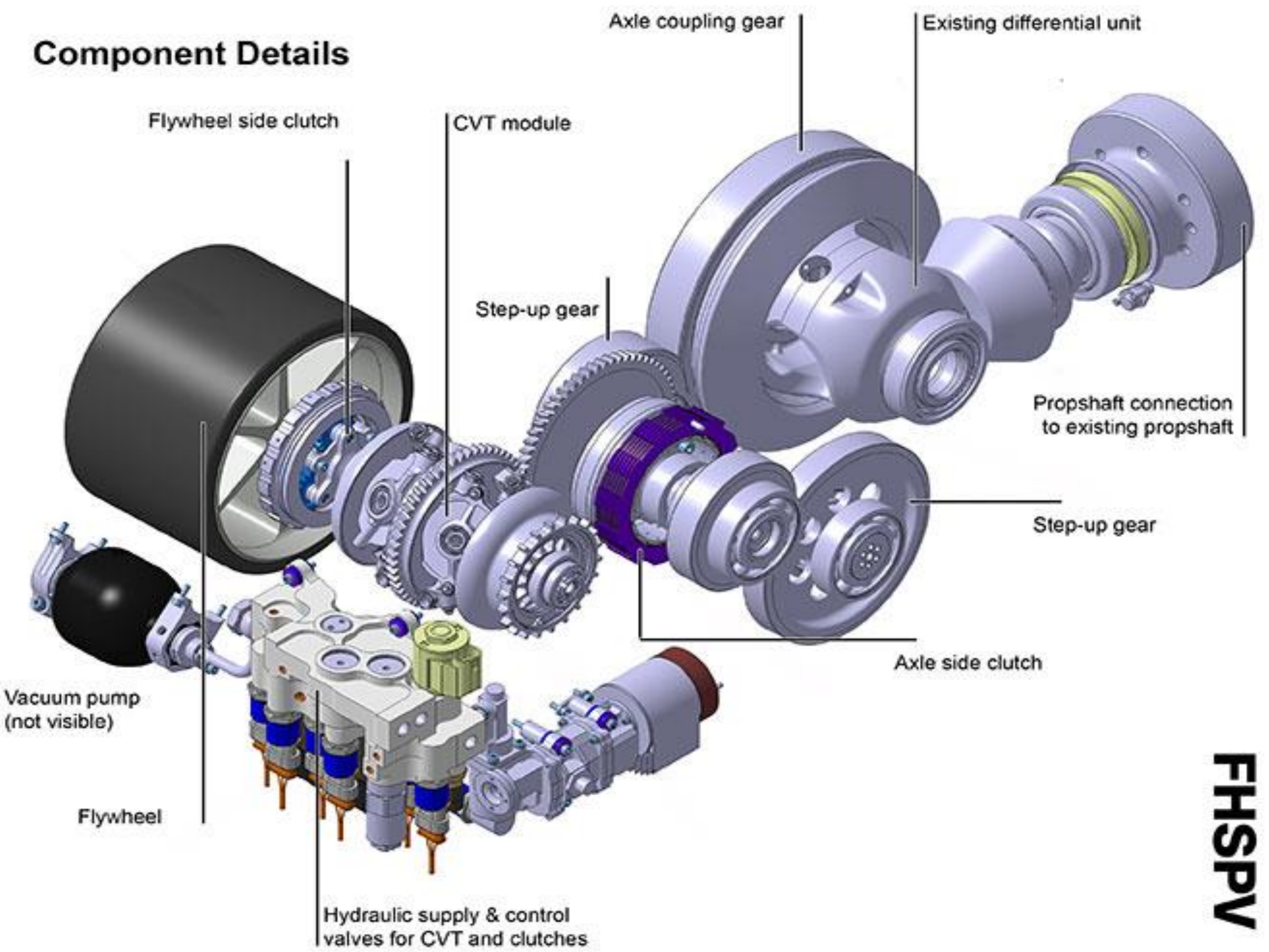

Fig. 3. Elements of the mechanical energy recovery system from noise [3]

will work seamlessly and reliably. An example of such a system is the so-called brake-by-wire [4]. It provides electronic control over the braking system, which is designed to control the distribution of braking forces, to provide a predictable response to the depression of the brake pedal, and to maintain the greatest possible efficiency of energy recovery. In contrast to the classic system, where the signal medium from the brake pedal to the brake calipers is hydraulic fluid filling the brake lines [4–5], in the brake-by-wire system the braking signal is an electric pulse generated when the brake pedal is depressed. The advantage of this solution is the reduction of vehicle weight by limiting the length of hydraulic hoses and the amount of brake fluid, which translates into lower energy consumption and increased range. Fig. 4 shows a diagram of a typical EBS system (Electromechanical Braking System) [5].

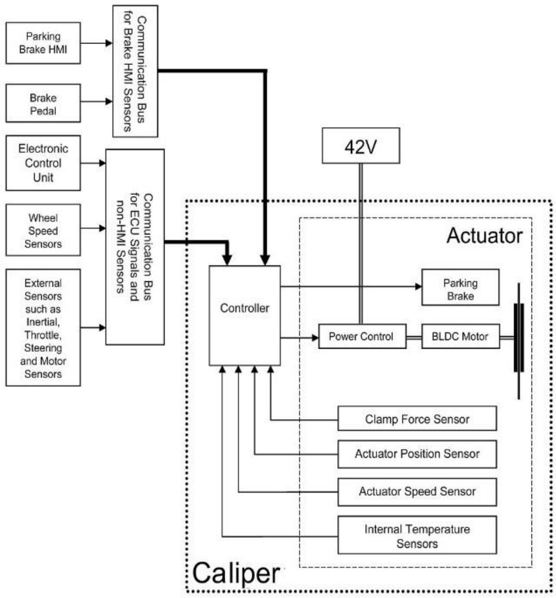

Fig. 4. Diagram of the electromechanical braking system [3]

In the EBS, the system measures the pressure when pressing the hauler pedal. This signal is transmitted to the control unit whose task is to generate a signal to the braking system. There – after taking into account additional information from the recovery system and driving parameters – a brake control signal is generated. If the demand for braking force is greater than the regenerative braking system is able to ensure, or if the vehicle moves at low speed and must be stopped, the system activates friction brakes [4–5]. The ABS system (Anti-lock Braking System) and ESC (electronic stability control) are also integrated with the brake-by-wire system. The data from the sensors of additional systems also goes to the computer controlling the system. The method of distribution of braking forces to brake systems may be modified depending on the driving mode. Appropriate treatment and selection of braking characteristics allow better adjustment of the braking method to the conditions and driving style of the driver [4–5].

Current research

At the Silesian University of Technology, the research is conducted on highly efficient solutions for the automotive industry. This is the subject of, for example, the Smart Power team, which brings together students who, under the supervision of scientists, carry out work focused on the construction of a highly-efficient electric vehicle. Currently, the foci are focused, among others, on the modification of the drive system enabling energy recovery from braking [6–7].

The propulsion system, being the starting point of the above-mentioned considerations, is presented in fig. 5. Research and simulations based on the vehicle's mathematical model allow to expect significant benefits from the implementation of the emerging system.

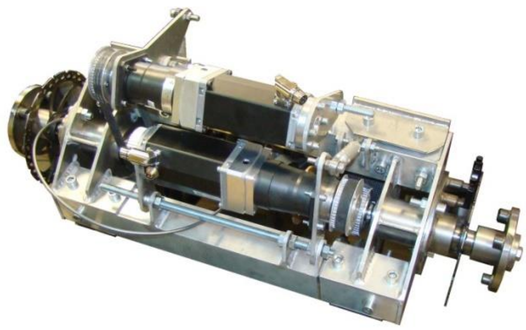
Fig. 5. Drive system of a high-efficiency electric vehicle with energy recovery [7]

Conclusions

Dynamic development of vehicles using alternative propulsion systems necessitates the adaptation of the remaining vehicle components. One of the most important components is the braking system, which is directly responsible for the driver's safety. The necessity of reconciling safety-related issues and the desire to increase the effectiveness of energy use forces development of new solutions, such as energy recovery systems or brake-by-wire systems. Recuperative braking systems allow you to recover some of the energy lost during braking and increase the range of the vehicle. However, without the support of electronic brake assist systems, they are useless. EBS systems, using brake-by-wire, allow you to recover even more energy while reducing vehicle weight. Directions of development indicate that electric and hybrid vehicles are the future of the automotive industry. In the light of pro-ecological efforts, developing methods of effective use of limited resources is a serious challenge for constructors both in the context of energy recovery and proper management.

REFERENCES

1. Cikanek S.R., Bailey K.E. "*Regenerative braking system for a hybrid electric vehicle*". American Control Conference. 2002.
2. Peng D., Zhang Y., Yin C.L., Zhang J.W. "Combined control of a regenerative braking and antilock braking system for hybrid electric vehicles". *International Journal of Automotive Technology*. 2008.
3. https://www.wired.com/2010/10/flywheel-hybrid-system-for-premium-vehicles/ (access: 26.11.2017).
4. Canuto F., Turco P., Colombo D. "Control development process of the brake-by-wire system". *Proceedings of 8th Biennial ASME Conference on Engineering Systems Design and Analysis*. 2006.
5. Hoseinnezhad R., Bab-Hadiashar A. "Automatic calibration of resolver sensors in electro-mechanical braking systems: A modified recursive weighted least squares approach". *IEEE Transactions on Industrial Electronics*. 2007.
6. Skoberla R., Skarka W. "Design of braking system in the leightweight electric vehicle". *Zeszyty Naukowe Instytutu Pojazdów Politechniki Warszawskiej*. 2 (2016): pp. 77–83.
7. Skoberla R., Skarka W. „Układ napędowy lekkiego pojazdu elektrycznego biorącego udział w zawodach Shell Eco-marathon". *Mechanik*. 4 (2016): pp. 324–325.

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