JOURNAL OF MECHANICAL AND TRANSPORT ENGINEERING
Vol. 67 no. 4 2015
DOI 10.21008/j.2449-920X.2015.67.4.05

Maciej SIEDLECKI*
Jerzy MERKISZ*

USE OF HYDRAULIC HYBRID DRIVETRAIN IN PASSENGER CAR

The main factor influencing the structure of today's internal combustion engines and all vehicles are UE rules on emissions from exhaust systems. From 2020 year is expected to apply to limit average CO_2 emission for the entire fleet of LDV (*Light Duty Vehicle*) of the manufacturer at 95 g/km, which is directly proportional to fuel consumption. For this reason, manufacturers are looking for new solutions in the field of improving cars energy efficiency. An example of this type of action is using a hybrid powertrain which a combination of combustion engine and other source of energy. Example is series hydraulic drivetrain, used previously only in HDV (*Heavy Duty Vehicle*). The Battery are hydraulic oil which is pressed in a hydraulic system depending on driving conditions. The aim of the article is to present solution for a hybrid hydraulic drive system for possible use in passenger vehicles. This paper presents the basic structural problems of the hybrid system and a comparison with a conventional hydraulic drive. It may be futureproof solution to meet emission limits of CO_2 in the coming years.

Keywords: hybrid, powertrain, emission

1. BEGINING

The main factor determining trends in the development of powertrain vehicle emission standards compounds are exhaust emissions. Countries belonging to the European Union have signed in regulation which obliges vehicle manufacturers to reduce the average CO_2 emissions of the entire fleet to 95 g/km, equivalent to fuel consumption of approximately 3.9 dm^3/100 km [6]. It is connected with the need to significantly reduce it and improve the efficiency.

The most common solution for vehicle drivetrain is consistently over 100 years combustion engine. Despite the significant development of technology, the maximum efficiency of the present units oscillates between 40% and then only under specific conditions of load and the engine speed. This means that more than half of the chemical energy contained in the fuel is permanently lost [3]. Methods of search-

*Institute of Combustion Engines and Transport, Poznan University of Technology.

ing for a better utilization of the energy are recovery of kinetic energy during braking of the vehicle, avoiding operating conditions when combustion engine shows low efficiency etc.

For this purpose car manufacturers use hybrid cars, which mean they are fuel by two kinds of energy sources [5]. The most common solution is combining a combustion engine with an electric motor. This solution, however, requires the use of electrochemical batteries, in which electrical energy is stored. The batteries to provide range similar to that of fossil fuel must be big size and heavy. This implies that, especially in small vehicles (from segments A and B) it is not possible to use this solution. For this reason, there are contemplated other hybrid systems. One such solution is the combination of combustion engine and the hydraulic system in the English-speaking papers bearing the name of "hydrid", as an evolution of the word "hybrid".

2. DESIGN AND PRINCIPLE OF OPERATION

The basic types of hybrid drivetrains are serial, parallel, and their association called mixed hybrid. In the first internal combustion engine has no direct connection to the wheels, and serves only as a power generator. This parallel arrangement is such where both the engine and the other energy source are connected to the wheels and can drive them (separately or simultaneously) [5]. This mixed system combining both and the ability to work characteristic of the one or the other type of system. The authors of this paper will focus on the type of series, but nothing stands in the way of using the hydraulic systems in other types of hybrid systems.

The hydraulic serial hybrid drivetrain is smaller than the one which use to the electric motor with the same amount of torque and power (Fig. 1).

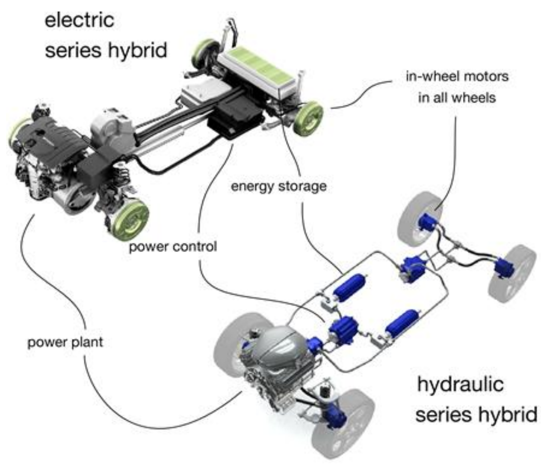

Fig. 1. Comparison of the eletric and hydraulic hybrid powetrains [2]

Parts indicated by serving the same role in the drive system. In both solutions, the source of energy is an internal combustion engine arranged in front of the vehicle. This facilitates the transfer of power to the generator (hydraulic pump).The batteries in electric solutions are much bigger, and their position reduces the space for luggage. In both embodiments there are no traditional gearbox, and the motors are located in the hubs of the drive wheels to minimize losses and improve efficiency. The main component is internal combustion engine connected to the pump, and to the hydraulic system (Fig. 2). It is used for pumping medium (hydraulic oil) form the low-pressure part of the system (shown on the Figure 2 above) to high pressure part (below on the Figure 2) [4].

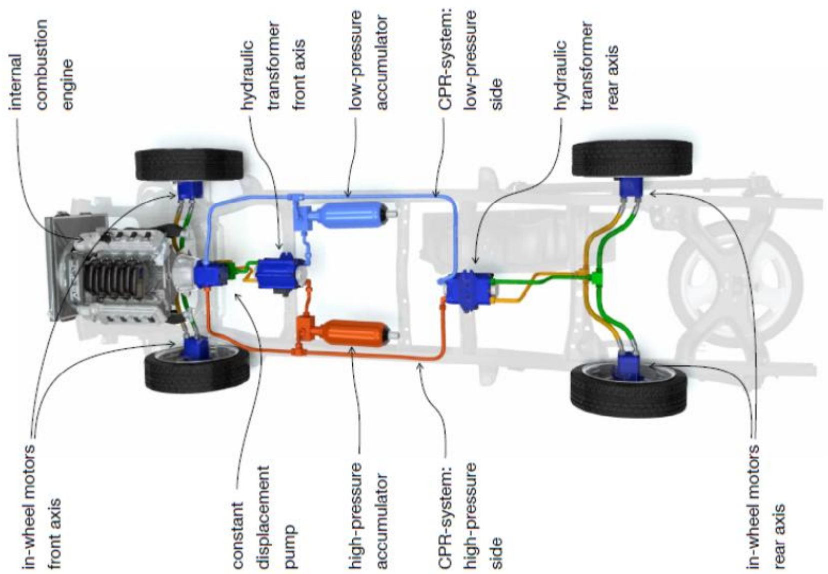

Fig. 2. Schematic diagram of the hydraulic hybrid system [4]

They are connected to the hydraulic transmissions that pressedfactor in the vicinity of the wheels, where the pressure is converted into mechanical energy, allowing movement of the vehicle. These transmissions are also used in inhibiting the recovery of energy, then they work as a turbine to compress factor. In comparison to electrical systems there is no problem receiving high-power energy that is dissipated during braking process. The pressure in the system reaches about 44 MPa. A major problem in hydraulic systems are pulsations due to changes in fluid pressure (like the injection systems in diesel engines) [4, 7]. To the needs of the hydraulic system for a passenger car developed a compressor, which is called Floating Cup, from the termination of pistons construction (Fig. 3).

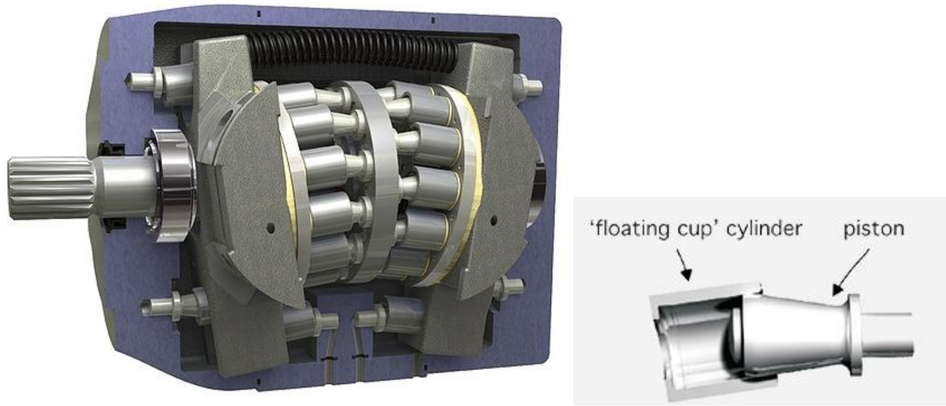

Fig. 3. The view of the pump and the single piston [1]

3. ANALYSIS OF THE EFFICENCY IN NEDC CYCLE

The benchmark conventional system with a hybrid will use the NEDC test (New European Driving Cycle) (Fig. 4), which is used in the measurement of fuel consumption as part of the type approval of LDV.

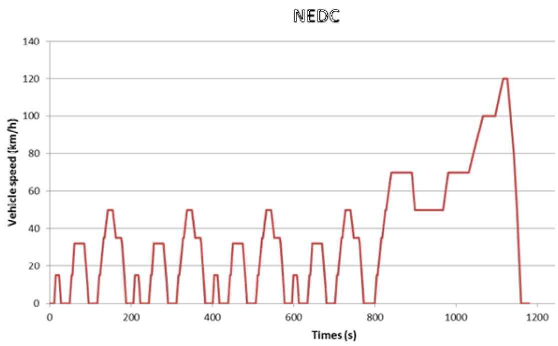

Fig. 4. Test run the NEDC as a function of $v = f(t)$

It is conducted on dyno chassis and consists in driving cycle, which simulates city driving, suburban and their combination – mixed mode. Test analysis showed that 80% of the length of the required power does not exceed 10 kW.

The analysis concerns two vehicles of the same weight, with 4-wheel drive and equipped with an internal combustion diesel engine and amount of power of 100 kW. Cars showed the same aerodynamicand rolling resistance. In the NEDC test, the area of engine work were different (Fig. 5).

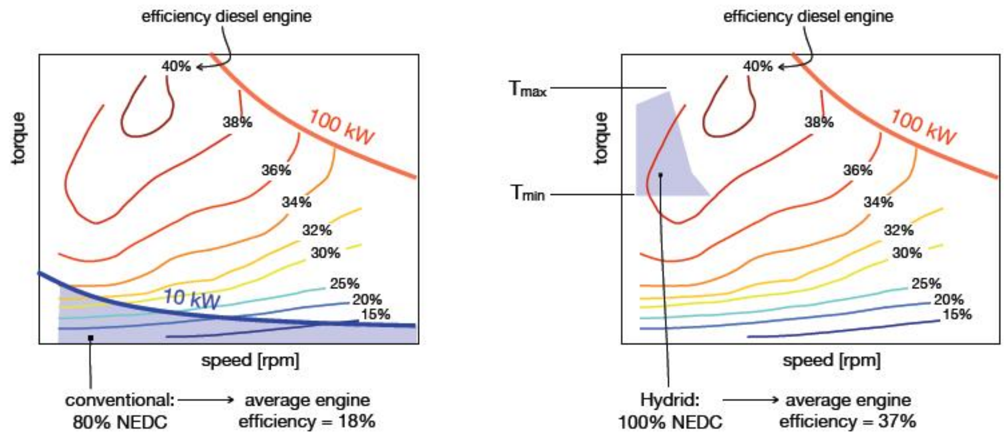

Fig. 5. Graphic illustration of the work area of combustion engine in: a) conventional drivetrain, b) hydraulic hybrid [2]

In whole test the average efficiency of combustion engine in vehicle without hybridyzation was about 18% and in hybrid solution over 2 times bigger, about 37%. The diferrence in energy consumption test was even bigger, because the hybrid could recuperate some of the energy while vehicle was breaking (Fig. 6).

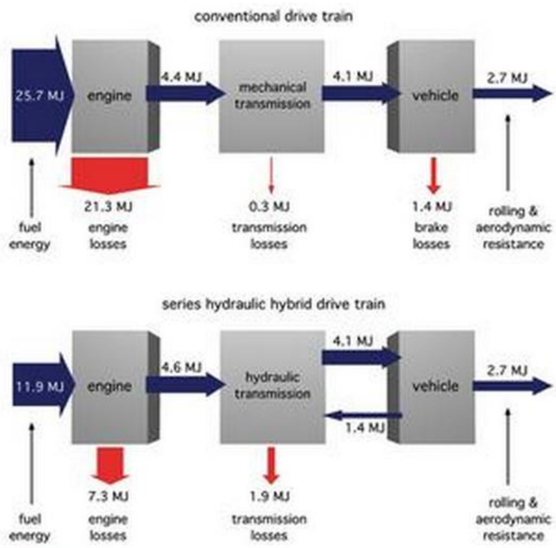

Fig. 6. Graphic illustration of the energy flow in conventional and hydraulic hybrid drivetrain [2]

The vehicles use only 2.7 MJ of energy to run whole NEDC test. The biggest loss were in combustion engine. Losses in mechanical gearbox in conventional drivetrain was lower than the hydraulic one, but almost all of the breaking energy was recovered and it cover the loss of the transmission. Overall, fuel consumption with the conventional drivetrain was 6.6 dm^3/100 km and in the hybrid solution 3,1 dm^3/100 km. The emission of CO_2 were respectively 177 and 88 g/km.

4. SUMMARY

The search for ways to reduce emissions of harmful compounds emitted by vehicles is a key trend currently prevailing in the automotive industry. Developing alternative propulsion systems to reduce them makes the emergence of modern solutions, often based for hybrid circuits. An example of such a solution is presented in the development of serial hydraulic hybrid system. It characterized by engine operation in terms of high performance, possibility of recuperation large amount of energy and its storage in the form of compression of the gas. These properties make when considering the NEDC test, especially in an urban cycle mileage consumption is significantly reduced. The motorway yields a smaller, but still pronounced gain. The solution can significantly contribute to reducing emissions from vehicles LDV, where the use of hybrid drivetrain with electric motors is uneconomical by a large mass of batteries.

REFERENCES

[1] Achten P., Vael G., Kohmäscher T., Ibrahim M., Design and fuel economy of a series hydraulic hybrid vehicle, in: Proc. of the 7th JFPS International Symposium on Fluid Power, Toyama, Japan, 16 September 2008.

[2] Achten P., Vael G., Murrenhoff H., Kohmascher T., Inderelst M., Low-emission Hydraulic Hybrid for Passenger Cars, ATZ 2009, 5, p. 44-50.

[3] Bajerlein M., Rymaniak Ł., The Reduction of Fuel Consumption on the Example of Ecological Hybrid Buses, Applied Mechanics and Materials, 2014, vol. 518 p. 96-101.

[4] Hessler J., Hydraulic transformer and hybrid drivetrain, SAE Off-Highway Engineering Online.

[5] Merkisz J., Pielecha I., Alternatywne napędy pojazdów, Wydawnictwo Politechniki Poznańskiej, Poznań 2006.

[6] Rozporządzenie Parlamentu Europejskiego i Rady (UE) nr 510/2011 z dnia 11 maja 2011 r. określające normy emisji dla nowych lekkich samochodów dostawczych w ramach zintegrowanego podejścia Unii na rzecz zmniejszenia emisji CO_2 z lekkich pojazdów dostawczych.

[7] Van de Ven J.D., Olson M.W., Li P.Y. Development of a hydro-mechanical hydraulic hybrid drive train with independent wheel torque control for an urban passenger vehicle, Proc. of the 51st Nat. Conf on Fluid Power, March 12-14, 2008, Las Vegas.

WYKORZYSTANIE HYDRUALICZNEGO UKŁADU HYBRYDOWEGO DO NAPĘDU POJAZDÓW OSOBOWYCH

Streszczenie

Celem artykułu jest prezentacja rozwiązania hybrydowego, hydraulicznego układu napędowego możliwego do zastosowania w pojazdach osobowych. Przedstawiono, podstawowe założenia konstrukcyjne układu hybrydowego oraz porównano go z układem hydraulicznym z konwencjonalnym napędem. Dodatkowo porównano punkty pracy z obydwu rozwiązań wraz z określeniem jednostkowego zużycia paliwa i wydatku energetycznego potrzebnego na przejechanie cyklu homologacyjnego dla pojazdów LDV (*Light Duty Vehicle*) w Europie – NEDC (*New European Drving Cycle*). Zdaniem autorów zastosowanie układu hybrydowego, opartego na instalacji hydraulicznej, w pojazdach osobowych może być się przyszłościowym rozwiązaniem, pozwalającym na spełnienie limitów emisji CO_2 w nadchodzących latach.