Hybrid powertrain virtual driver of wheeled vehicle

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Abstract: The paper presents the concept of virtual driver of hybrid powertrain of wheeled vehicle. For this purpose was chosen NI LabVIEW software and dedicated controller – NI CompactRIO. The mathematical model of a wheeled vehicle and hybrid powertrain has been built in the LabVIEW software, where wheeled vehicle model has been optimized for metropolitan road conditions.

Keywords: LabVIEW, virtual driver, hybrid vehicle

1. Introduction

Wheeled vehicles with ICE-electric drive have better dynamics and higher efficiency than conventional solutions. In addition, the internal combustion engine running at higher load excreted much smaller amounts of toxic substances into the atmosphere. The electric motor does not require a clutch and maximum torque is available from minimum speed, so that it can serve as a machine scattering wheeled vehicles in the first phase of the movement [1, 2].

Hybrid driver can be broadly divided into 3 groups:
- a serial structure (fig. 1),
- a parallel structure (fig. 2),
- synergies of energy (fig. 3).

Serial structure is typically used in vehicles, in which the main driver of the vehicle is an electric motor. This engine is used to accelerate and drive the vehicle, while the internal combustion engine driver an electric generator which products the required electricity supply electric traction motor. The internal combustion engine in such a case is in the optima speed range, i.e. for which value the power and torque is optimized for the demand for electricity [1, 2].

Parallel structure is used mainly in vehicles where the main driver of the vehicle can be done through an electric motor or combustion engine. You can also assume that the electric motor propels the vehicle to the desired line speed, and then the transmission is switched to the internal combustion engine. The advantage of this approach is that the direct use of energy from the combustion engine to driver a wheeled vehicle, there is no intermediate conversion of energy by the generator drive.

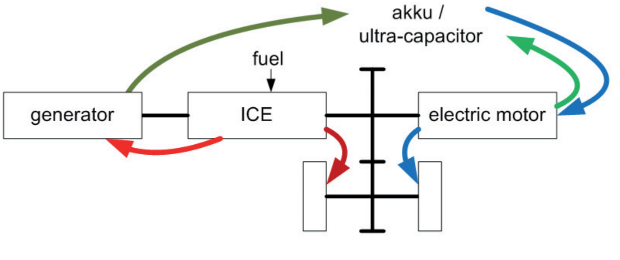

Fig. 1. Serial structure of hybrid powertrain [1]
Rys. 1. Struktura szeregowa napędu hybrydowego [1]

Synergy of energy is mainly used on wheeled vehicles, where it is possible to driver a vehicle using power from both engines [1, 2].

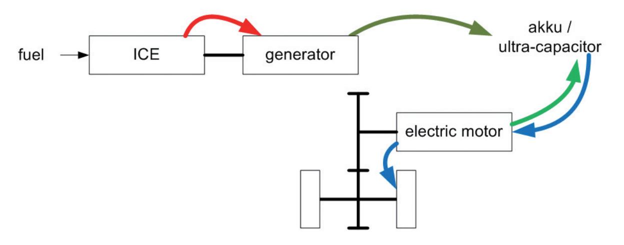

Fig. 2. Parallel structure of hybrid powertrain [1]
Rys. 2. Struktura równoległa napędu hybrydowego [1]

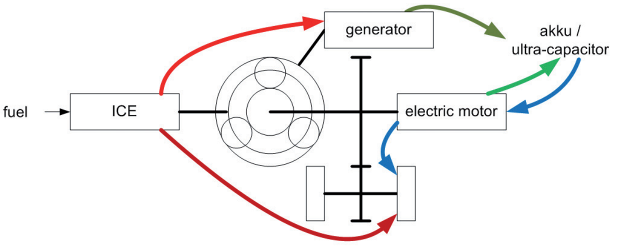

Fig. 3. Synergy of energy structure of hybrid powertrain [1]
Rys. 3. Struktura przepływu energii w napędzie hybrydowym [1]

2. Own work

A simulation on the hybrid system was carried out in National Instruments LabVIEW software. In the software, including a mathematical model of the direct current electric motor (DC Motor, fig. 4, fig. 5). In the simplest terms, a DC electric motor can be described by the following mathematical equation [1, 2]:
- torque of electric motor T is expressed as the flow of current in the armature winding and the armature constant of electric machine K_T:

$$T = K_T \cdot i \tag{1}$$

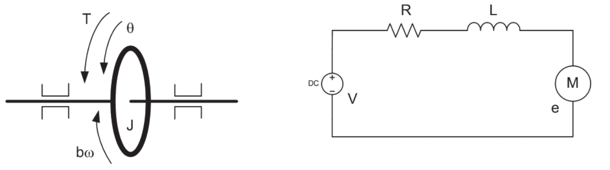

Fig. 4. Mathematical model of DC motor [1]
Rys. 4. Model matematyczny silnika prądu stałego [1]

– electromotive force (emf) that is expressed as a change in the position of the rotor angle $d\theta/dt$ (angular velocity) and a constant electric machine K_e:

$$e = K_e \cdot \frac{d\theta}{dt} \tag{2}$$

From fig. 4, can be written the following equations based on Newton's and Kirchhoff's laws:

$$J\frac{d^2\theta}{dt^2} + b\frac{d\theta}{dt} = K_T \cdot i \tag{3}$$

$$L\frac{di}{dt} + R \cdot i = V - K_e \cdot \frac{d\theta}{dt} \tag{4}$$

where: J – moment of inertia of rotor [kg·m²], b – damping of mechanical system [Nm·s], L – electric inductance [H], R – electric resistance [Ω], V – voltage [V].

From the equations can be written (1–4):

$$Js^2\theta(s) + bs\theta(s) = K_T I(s) \tag{5}$$

$$LsI(s) + RI(s) = V(s) - K_e s\theta(s) \tag{6}$$

$$I(s) = \frac{V(s) - K_e s\theta(s)}{Ls + R} \tag{7}$$

$$Js^2\theta(s) + bs\theta(s) = K \cdot \frac{V(s) - K_e s\theta(s)}{Ls + R} \tag{8}$$

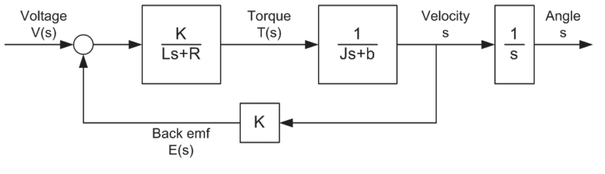

Fig. 5. A block diagram of DC motor [1]
Rys. 5. Schemat silnika prądu stałego [1]

2.1. LabVIEW model

Virtual Driver is a control system based on a mathematical model of a wheeled vehicle, including exact mathematical descriptions of electric and internal combustion engines stored in the LabVIEW software in conjunction with a National Instruments dedicated controller – cRIO. The combination of a mathematical model of the virtual real-wheeled vehicle with the control system allows a very accurate way to simulate the actual behavior of the drive system presented in every vehicle. The big advantage of this approach is to adopt a virtual drive system, which it is possible to optimize the operation of this system in the laboratory in LabVIEW, before constructing the real-hybrid system (fig. 6).

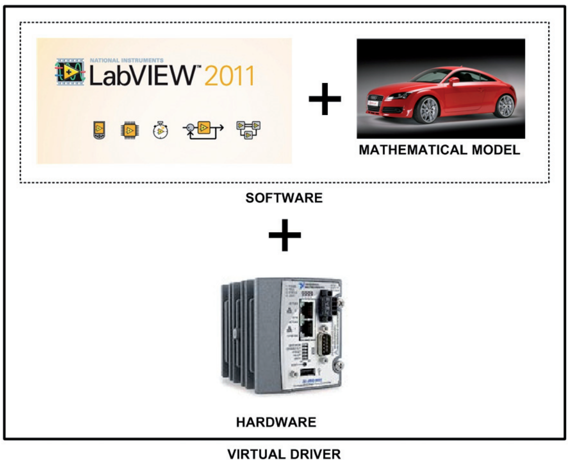

Fig. 6. Concept of Virtual Driver
Rys. 6. Koncepcja wirtualnego sterownika

Fig. 7. Logitech steering wheel
Rys. 7. Kierownica firmy Logitech

External signals, the control of a wheeled vehicle by the driver, are implemented through a Logitech steering wheel (fig. 7), which software and configured to work in LabVIEW as the diagram shown in fig. 8.

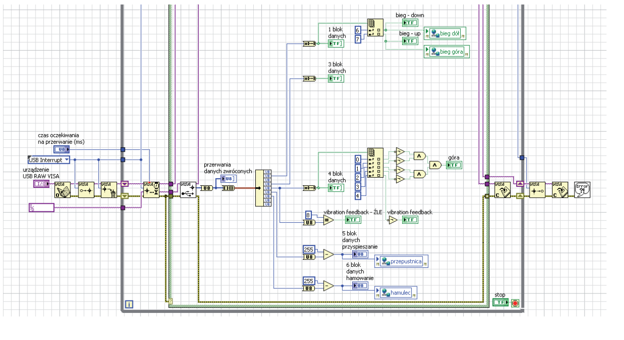

Fig. 8. Block diagram of steering wheel in LabVIEW
Rys. 8. Schemat blokowy sterowania kierownicą w LabVIEW

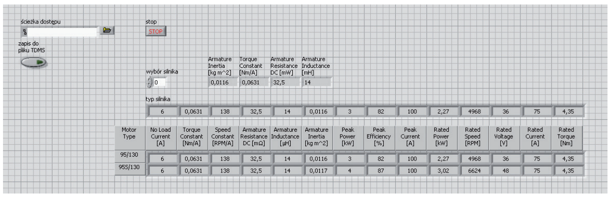

Fig. 9. Data of DC motors in front panel

Rys. 9. Dane silników DC

The fig. 9 shows the front panel of DC motors. Data from the engines come from the company L.M.C., which is now a leader in the manufacture of DC machinery used in electric vehicles. This particular engine can be chosen from a list of available engines or retrieve data from an external file.

2.2. LabVIEW simulation

The fig. 10 and fig. 11 show the block diagram and front panel of a wheeled vehicle with hybrid powertrain.

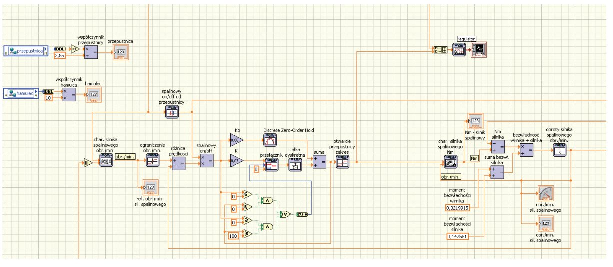

Fig. 10. Block diagram of wheeled vehicle in LabVIEW software

Rys. 10. Schemat blokowy pojazdu kołowego w oprogramowaniu LabVIEW

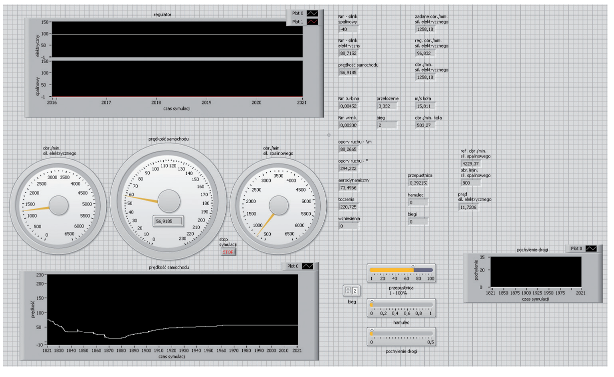

Fig. 11. Front panel of wheeled vehicle

Rys. 11. Panel przedni pojazdu kołowego

In fig. 11 individuals motor speed In RPM and linear velocity of the vehicle are specified. All the necessary parameters of the propulsion system devices are presented, such as motors torque, the current ratio in the gearbox, the throttle opening angle, current and voltage of the electric motor, and movement resistance of wheeled vehicle.

3. Conclusion

This paper presents the concepts of virtual driver of hybrid wheeled vehicle, which may well serve as a useful tool for research relating to hybrid powertrain in the first phase of design and construction of modern road vehicles. The enormous capabilities of LabVIEW with a dedicated controller allowed carrying out computer simulations of a wheeled vehicle moving in an urban area. Large selection and quick change of engines in the simulations carried out allowed the study of the selection of the appropriate class of machines for a wheeled vehicle and its destination.

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Wirtualny sterownik pojazdu kołowego o napędzie hybrydowym

Streszczenie: W artykule przedstawiono koncepcję wirtualnego sterownika napędu hybrydowego pojazdu kołowego. Dla tak przyjętego zadania wybrano oprogramowanie NI LabVIEW wraz z dedykowanym kontrolerem NI CompactRIO. Model matematyczny pojazdu kołowego oraz napędu hybrydowego zbudowano w środowisku LabVIEW, w którym przyjęto, że pojazd kołowy poruszać się będzie w aglomeracjach miejskich.

Keywords: LabVIEW, wirtualny sterownik, pojazd hybrydowy

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He was born in 1960. In 1984 graduated at the Silesian Technical University in Gliwice, in the Faculty of Mechanical Engineering, and he got a degree of mechanical engineer in speciality of machine technology and he began work at the Institute of the Machine Building in the Faculty of Mechanical Engineering of the Silesian Technical University. In 1991 he was given a doctor's degree of technical sciences, and in 2005 a doctor of science degree in the scope of the robotization of technological processes. He is interested in problems of the automation and the robotization of technological processes, off-line programming and motions planning of industrial robots.

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