Series Wound DC Motor Simulation Applying MATLAB SIMULINK and LabVIEW Control Design and Simulation Module

Gusztáv Áron Szíki[1*], Kornél Sarvajcz[2], Attila Szántó[3], Tamás Mankovits[3]

[1] Department of Basic of Basic Technical Studies, Faculty of Engineering, University of Debrecen,
  H-4024 Debrecen, Ótemető u. 2-4, Hungary
[2] Department of Mechatronics, Faculty of Engineering, University of Debrecen,
  H-4024 Debrecen, Ótemető u. 2-4, Hungary
[3] Department of Mechanical Engineering, Faculty of Engineering, University of Debrecen,
  H-4024 Debrecen, Ótemető u. 2-4, Hungary
* Corresponding author, e-mail: szikig@eng.unideb.hu

Abstract

In our previous publication a model for series wound direct current (SWDC) motors was described and a simulation program was presented which is based on the above model and was developed in MATLAB environment. In the publication mentioned above, the measurement process of the parameters (bearing resistance torque, electric resistances, dynamic inductances) of the SWDC motor was also described. From the parameters the program calculates the current intensity, rpm and torque of the motor as a function of time. The recent publication is about the realization of the above program applying the Control Design and Simulation Module of NI LabVIEW. This module enables the adjustment of input parameters (e.g. supply voltage) during the running of the program, thus the realization of real time driving simulation. In addition, among others, it can be applied with data acquisition, GPIB, CAN, and FPGA (field-programmable gate array) hardware platforms of National Instruments.

Keywords

series wound DC motor, simulation, LabVIEW, Control Design and Simulation Module

1 Introduction

At the University of Debrecen, Faculty of Engineering we have made significant efforts regarding talent care in the last decade (Gábora et al., 2017; Juhász, 2013; Nagy-Kondor, 2005; 2011). As a part of this activity student teams regularly participate in competitions for alternative driven vehicles (MVM Energy Race, Széchenyi Race, Shell Eco-marathon). For efficient racing continuous development is required, applying highly developed computer science and mathematics. One of these developments was the creation of a simulation program by the authors in MATLAB environment previously, which calculates the dynamic functions (e.g. the velocity-, acceleration-, and covered distance-time functions) of an electric vehicle, driven by SWDC motor, from its technical parameters (Szántó et al., 2016; 2017; Sziki et al., 2015). The mentioned simulation program can calculate the optimal technical parameters, at which the most advantageous dynamic characteristics can be achieved. Constructing a vehicle with the above parameters successful racing is more possible.

A key part of vehicle dynamic simulation is the modeling of the SWDC motor (Szíki et al., 2017) and the development of a simulation program, which is based on the model, and capable of computing the torque, angular speed of the SWDC motor, and also the intensity of current flowing through it versus time, from its basic electromagnetic and dynamics parameters.

Table 1 shows the nominal values of the SWDC motor, that was previously analyzed experimentally by our research group and – applying the obtained experimental data – was simulated in MATLAB environment (Szíki et al., 2017).

Fig. 1 shows the applied model for SWDC motors. The bases of the model (Szíki et al., 2017) are the following differential equations (Hadziselimovic et al., 2011; Salem, 2013):

$$U_{batt} - U_{brush} - \left(R_s + R_r + R_{batt} + R_{wire}\right) \cdot I$$

$$-\left(L_s(I) + L_r(I)\right) \cdot \frac{dI}{dt} - L_{sr}(I) \cdot \omega \cdot I = 0 \tag{1}$$

$$L_{sr}(I) \cdot I^2 - M_{res}(\omega) - M_{load}(\omega) = J_r \frac{d\omega}{dt}. \tag{2}$$

In Eq. (1) and (2) U_{batt} is the electromotive force of the battery, R_r, R_s are the electric resistances of the rotor and the stator windings of the SWDC motor, while R_{wire}, R_{batt} are the resultant resistance of the wires connecting the battery to the motor and the internal resistance of the battery. Characteristics $L_s(I)$, $L_r(I)$ and $L_{sr}(I)$ are the self dynamic inductances of the stator and rotor windings, and the

mutual dynamic inductance respectively (Hadziselimovic et al., 2011). The above characteristics are functions of the intensity of current flowing through the SWDC motor. Characteristics $M_{load(\omega)}$ and $M_{res(\omega)}$ are the loading torque on the rotor of the SWDC motor and its bearing resistance, and Jm is its moment of inertia. Characteristics $L_s(I)$, $L_r(I)$, $L_{sr}(I)$ and $M_{res(\omega)}$ have to determined experimentally, while the value of J_r is sometimes contained by the catalog of the motor. Fig. 2 shows our simulation program's block diagram, that was developed considering differential equations (Eqs. (1) and (2)).

Voltage U_{batt} and electric resistances R_r, R_s, R_{batt} and R_{wire} are constants in the above block diagram, while dynamic inductances $L_s(I)$, $L_r(I)$, $L_{sr}(I)$ and torque $M_{res(\omega)}$ are in the form of "Lookup Tables".

In the recent publication the realization of the simulation program, that was described above, is presented for the same series wound DC motor (Szíki et al., 2017) applying the Control Design and Simulation Module of NI LabVIEW (National Instruments, n.d.). Several input data of the electric motor – like its supply voltage (when we push or release the gas pedal of the vehicle) or the load on its shaft – are changing continuously during the race. Thus to realize a real time race simulation we had to achieve the continuous control of these input parameters. The LabVIEW simulation environment provides an

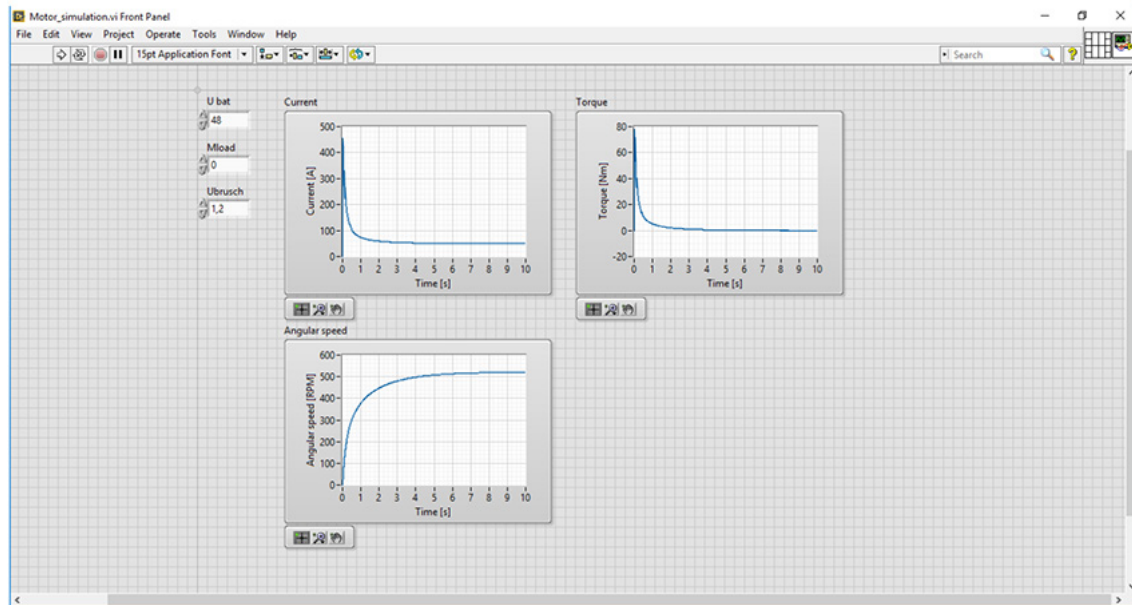**Table 1** Nominal values of the tested SWDC motor

Type:	Voltage:	Power:	Current:	RPM:	Torque:
DC/T4-48	48 [V]	4 [kW]	104 [A]	2800 [1/min]	14.7 [Nm]
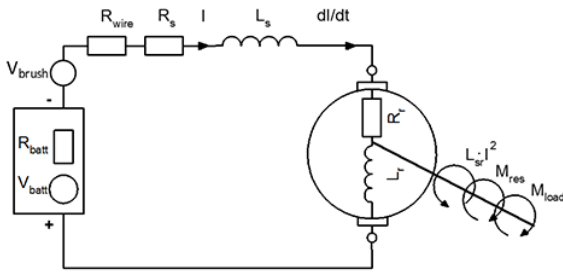
Fig. 1 Our model for series wound DC motor simulation
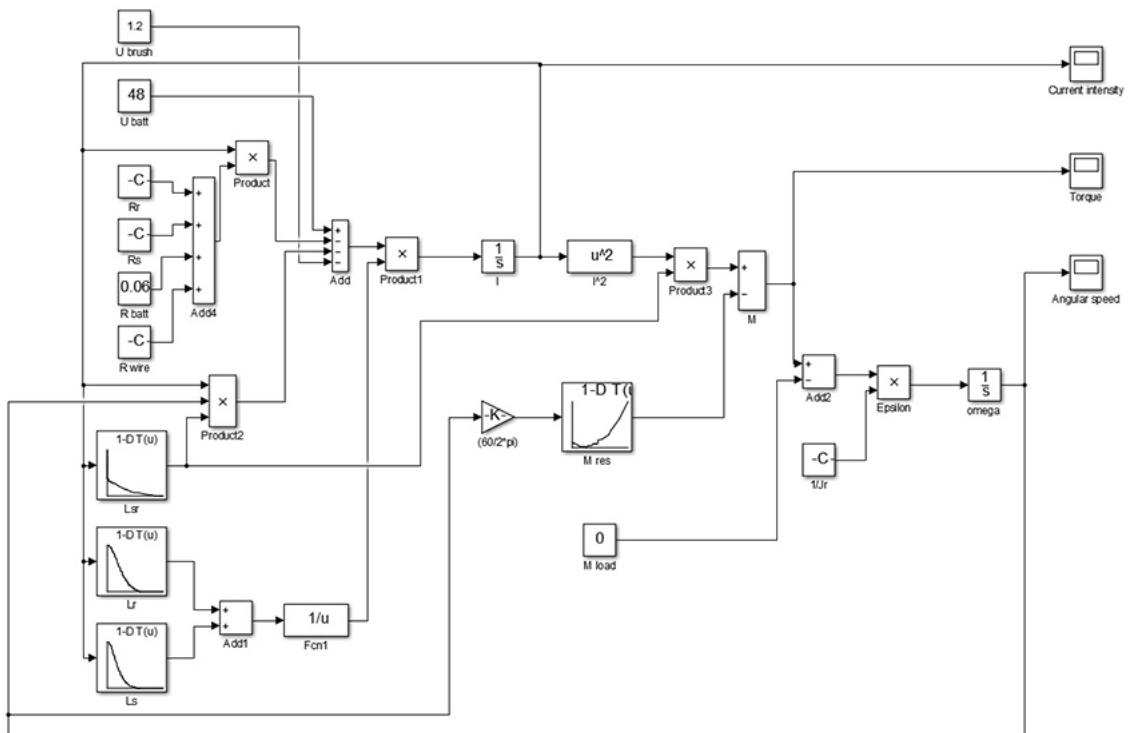
Fig. 2. Our simulation program's block diagram developed in MATLAB (MATLAB, n.d.)

easy solution for this problem, making the values of these parameters dynamically adjustable during the simulation.

In addition, the Control Design and Simulation Module of LabVIEW can be used with the data acquisition, GPIB, CAN, and FPGA (field-programmable gate array) hardware platforms of National Instruments.

On the other hand, Control Design and Simulation Module of LabVIEW is included in the graphical development environment of LabVIEW, so other toolkits and LabVIEW modules can be integrated into the given application. Along with the LabVIEW FPGA and Real-Time modules, advantages of the LabVIEW DataFinder Toolkit, Database Connectivity Toolset, and more can be taken (National Instruments, n.d.). In addition, other tools, which are characteristic for control applications, such as the LabVIEW System Identification Toolkit, the Fuzzy Logic Toolkit and LabVIEW PID, or the NI VeriStand software can be used.

2 Simulation results and discussion
In this section the simulation of the analyzed SWDC motor (Szíki et al., 2017) is presented applying the Control Design and Simulation Module of NI LabVIEW. Fig. 3 shows the developed motor simulation front panel and block diagram.

The input parameters can be adjusted on the front panel, and the output functions are also displayed there. The block diagram window visualizes the program code. The supply voltage of the motor (U_{batt}), the load on its shaft (M_{load}) and its brush voltage drop (U_{brush}) are dynamically adjustable during the simulation. The output functions of the simulation (angular speed-, current intensity-, and torque-time function) are calculated in real time mode from the actual data.

The simulation results (angular speed-, current intensity, and torque-time functions) were compared with the ones that were calculated by our MATLAB-SIMULINK program (Szíki et al., 2017). The calculated functions are exactly the same apying the two different programs as it is shown in Fig. 4.

3 Conclusions
The simulation of a SWDC motor was realized applying the Control Design and Simulation Module of NI LabVIEW. The simulated functions were compared with the ones obtained by the MATLAB-Simulink program previously. The calculated functions were exactly the same applying the two different programs. Nevertheless, by the application of the Control Design and Simulation Module of NI LabVIEW the input parameters of the program can be adjusted even while the program is running, thus a real-time race simulation can be realized. In addition the LabVIEW Control Design and Simulation Module can be applied with all NI hardware platforms, including CAN, GPIB, data acquisition and FPGA (field-programmable gate array).
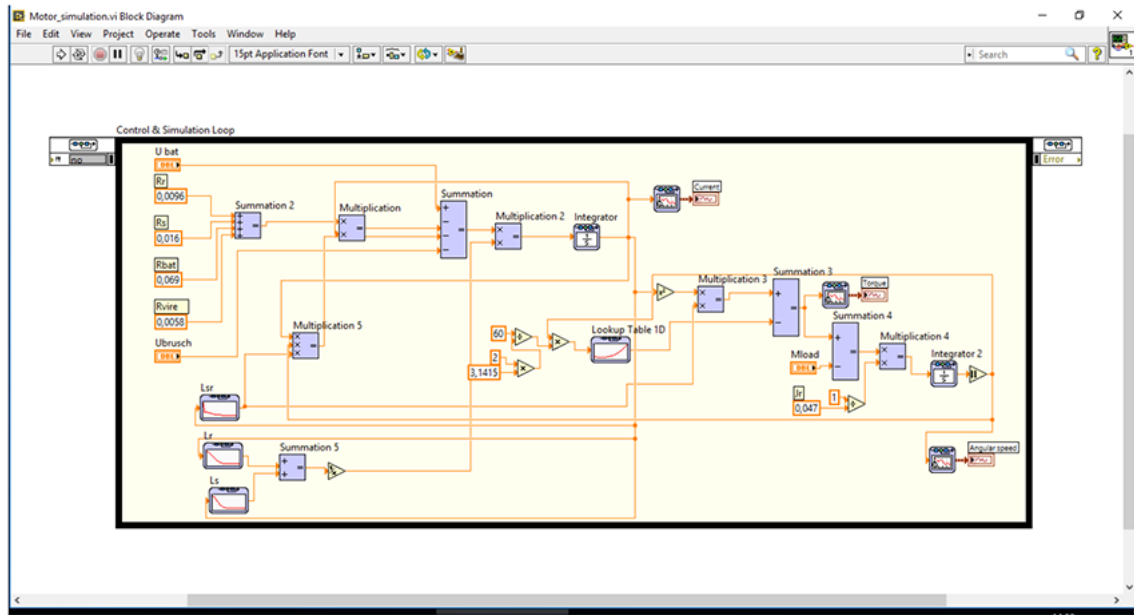
Fig. 3 The front panel and block diagram of the motor simulation program in NI LabVIEW Control Design and Simulation Module
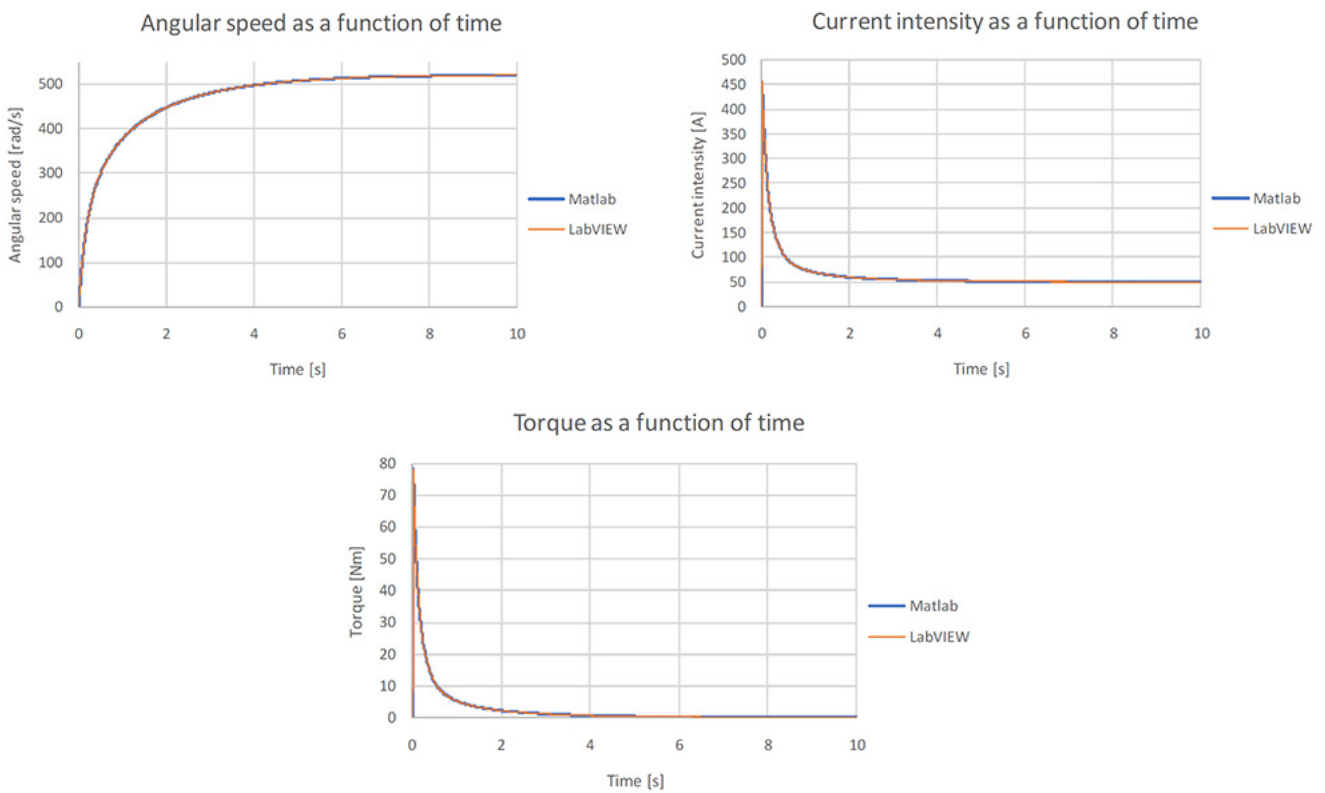

Fig. 4 Comparison of the angular speed-, current intensity-, and torque-time functions of the analysed SWM simulated by the NI LabVIEW Control Design and Simulation Module and the MATLAB-Simulink program

References

Gábora, A., Szíki, G. Á., Szántó, A., Varga, T. A., Magyari, A., Balázs, D. (2017) "Prototípus elektromos tanulmányautó fejlesztése a Shell Eco-Marathon versenyre" (Prototype battery electric car development for Shell Eco-Marathon competition), In: XXII. Fiatal Műszakiak Tudományos Ülésszaka (XXII International Scientific Conference of Young Engineers), Cluj-Napoca, Romania, pp. 167–170. (in Hungarian)

Hadziselimovic, M., Blaznik, M., Štumberger, B., Zagradišnik, I. (2011) "Magnetically Nonlinear Dynamic Model of a Series Wound DC Motor", Przeglad Elektrotechniczny, 87(12), pp. 60–64.

Juhász, G. (2013) "Szakmai versenyek az oktatás szolgálatában" (Technical competitions for the education), In: Proceedings of the 1st International Scientific Conference on Advances in Mechanical Engineering (ISCAME 2013), Debrecen, Hungary, pp. 74–78. (in Hungarian)

MathWorks (n.d.) "Matlab", [online] Available at: https://www.mathworks.com/products/matlab.html [Accessed: 27 June 2018]

Nagy-Kondor, R. (2005) "Special characteristics of engineering students' knowledge of functions", International Journal for Mathematics Teaching and Learning, 10, pp. 1–9.

Nagy-Kondor, R. (2011) "Technical mathematics in the University of Debrecen", Annales Mathematicae et Informaticae, 38, pp. 157–167.

National Instruments (n.d.) " White Papers", [online] Available at: http://www.ni.com/white-paper/11281/en/ [Accessed: 27 June 2018]

Salem, F. (2013) "Dynamic Modeling, Simulation and Control of Electric Machines for Mechatronics Applications", International Journal of Control, Automation and Systems, 1(2), pp. 30–42.

Szántó, A., Szíki, G. Á., Hajdu, S., Gábora, A. (2017) "Soros gerjesztésű egyenáramú motor szimulációja MATLAB környezetben" (Simulation of a series wound DC motor in MATLAB environment)", In: XXII. Fiatal Műszakiak Tudományos Ülésszaka (XXII International Conference of Young Engineers), Cluj-Napoca, Romania, pp. 367–370. (in Hungarian)

Szántó A., Szíki, G. Á., Hajdu, S. (2016) " Elektromos hajtású versenyautó járműdinamikai modellezése" (Dynamic modelling of a race car driven by series wound DC motor), In: Műszaki Tudomány az Észak-Kelet Magyarországi Régióban Konferencia, Miskolc, Hungary, pp. 587–591. (in Hungarian)

Sziki, G. Á., Hajdu, S., Szántó, A. (2015) "Vehicle Dynamics Modelling of an Electric Driven Race Car", In: Proceedings of the 3rd International Scientific Conference on Advances in Mechanical Engineering (ISCAME 2015), Debrecen, Hungary, pp. 208–217.

Sziki, G. A., Sarvajcz, K., Kiss, J., Gál, T., Szántó, A., Gábora, A., Husi, G. (2017) "Experimental investigation of a series wound DC motor for modeling purpose in electric vehicles and mechatronics systems", Measurement, 109, pp. 111–118.
https://doi.org/10.1016/j.measurement.2017.05.055