Influence of Selected Parameters of the Motor Controller on the Current Characteristics of the DC Brush Motor Used in the Silesian Greenpower’s Vehicle

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Abstract. The paper presents tests of the controller created by Silesian Greenpower team for a DC motor carried out on an motor test stand. The main scope of the work was to check how selected parameters of settings affect current characteristics and speed of the motor in order to optimize the efficiency of the chain transmission. Charts of current and revolutions of the Fracmo PM62 motor, a description of the applied testing methodology, photos of the testing process and results of measurements carried out on the test stand have been described in the article. The research has resulted in a comparison of obtained outcomes, summary and presentation of conclusions, which concern practical remarks related to the further development of the control system applied in the Silesian Greenpower’s car.

1. Introduction

The main scope of the research was to determine optimal current characteristics for Fracmo PM62 electric motor. This motor is powered by two 12 V batteries with a capacity of 36 Ah each and is used for driving the electric car created by Silesian Greenpower team. [1]

Regarding the fact that the car takes part in racing series, the priority was to optimize energy consumption at the start and during the race. [2]

Considering that motor controller used in research has never been tested on dyno station before, the original settings of its creator were tested at the very beginning. Next stages of the project were such adjustments that the energy consumption of the motor was optimized.

All tests have been carried out on the actual team’s car – “Bullet II” in which chain transmission, Shimano derailleur, Shimano cassette and DT hub have been applied. Due to car’s construction, only 3 out of 11 gears have been used in tests.

Interfaculty students’ project Silesian Greenpower created at the Silesian University of Technology has been founded in 2010. Since then, the main goal of annual editions is designing and constructing an ecologic electric vehicle, which will take part in the Greenpower racing series. Besides competition, the project’s aim is to promote ecological energy sources, especially in the automotive industry. [1]

Throughout the race, the goal is to pass as many laps as possible in a given time.

In the last season, the team has won such awards as Siemens Award for telemetry application, IET Award for innovations applied in the car and 4th place in F24+ league (Fig. 1).
Figure 1. Silesian Greenpower team and their trophies

One of the key tasks during designing an ecologic electric vehicle is minimizing the drag during a race and maximizing the efficiency of the drive system. Hence the need to ensure optimal motor operation through an efficient control system.

2. Test objective

2.1 Test stand
The inertial part of the motor test stand of the Silesian Greenpower team was used for the tests, along with the "Bullet II" car (Fig.2). In order to make current measurements, motor revolutions and further processing of obtained results, the "SG-Telemetry" measuring system by Adam Stalica was used.

Figure 2. Motor test stand along with the “Bullet II” car

2.2 Selected controller - “SG MotorController”
DC motor control is based on creating the appropriate voltage added to the commutator's brushes. The PWM (Pulse-Width Modulation) signal controls transistors – MOSFET in this particular case. Motor speed increases with increasing PWM signal. Examples of signal waveforms due to the PWM value are shown in Fig. 3. [3-6]

Figure 3. PWM duty cycle examples [7]
Selected controller, SG MotorController" is created by one of the Silesian Greenpower team members - Adam Stalica. In comparison to other available controllers on the market, it is possible to configure many parameters to optimize power consumption and ensure the best possible motor performance. Specification of “SG MotorController” has been presented in Table 1.

| Parameter                      | Unit | Range  |
|--------------------------------|------|--------|
| Normal voltage range           | [V]  | 0-48   |
| Minimum/maximum voltage        | [V]  | 0-60   |
| Motor current (max)            | [A]  | 300    |
| Motor current (1 minute)       | [A]  | 250    |
| Motor current (continuous)     | [A]  | 200    |
| Input signal                   | [V]  | 15-30  |
| Input power                    | [V]  | 5-36   |
| Reverse polarity protection    |      |        |
| Ramping                        | [min]| 0-4000 |
| Switching frequency            | [kHz]| 0.001-5 |
| Resistant (conduction)         | [mΩ] | 1.15   |

This controller enables integration with the aforementioned measuring system, which gives the possibility to control and change parameters in real time during the race. Parameters, which can be adjusted with its description have been presented in Table 2.

| Parameter          | Range     | Description                                                                 |
|--------------------|-----------|-----------------------------------------------------------------------------|
| PWM Start          | 0-4000    | Represents initial PWM                                                       |
| PWM UP-1           | 1-500     | Value added to previous one in each cycle of ramp no. 1                     |
| PWM Max            | 1-4000    | Maximum selected value of PWM                                               |
| PWM UP-2           | 1-500     | Value added to previous one in each cycle of ramp no. 2                     |
| PWM Fast Time-1    | 1-60 000  | Time in which controller does not increase PWM in ramp no. 1                |
| PWM Fast Time-2    | 1-60 000  | Time in which controller does not increase PWM in ramp no. 2                |

Selected controller – “SG MotorController” allows adjusting two increasing ramps which, depending on selected parameters, set the PWM signal in various ways.
2.3 Test stages
The test consisted of three stages. The first stage was to inspect default values of the controller. The second stage – inspecting the same values with the release of the throttle for five seconds. The third stage of the research was manipulating parameters set in stage 2.

2.3.1 Inspecting default values of the controller  Default values of the controller have been tested (Table 3.) and obtained results have been presented in Figure 4. In addition, during the tests, the difference in voltage was measured between this that was directly on the batteries and this that was delivered to the engine. The voltage summary, after the controller has reached the full PWM signal, is shown in Table 4.

Table 3. Default values of “SG MotorController”

| Parameter          | Value |
|--------------------|-------|
| PWM Start          | 800   |
| PWM UP-2           | 15    |
| PWM Max            | 4000  |
| PWM Up-1           | 500   |
| PWM Fast Time-2    | 1000  |
| PWM Fast Time-1    | 150   |

Figure 4. Motor characteristics with default values of the controller – derailleuer set to 4th gear

Table 4. Voltage measured on batteries and the motor

| Voltage  | Value  |
|----------|--------|
| Batteries| 23.87 [V] |
| Motor    | 24.77 [V] |
| Difference| 0.1 [V] |

Values shown above mean that voltage loss is slight, almost marginal. For comparison, the same measurement was carried out under the same conditions on a commercial Kelly Controls KDS24100E controller and the difference was 0.78 [V].
2.3.2 **Inspecting default values of the controller**  The test objective was to release the throttle by the driver which was supposed to simulate the braking of the car before entering the corner, and then re-engaging the gas, simulating the exit from the corner (Figure 5).

![Motor characteristics with release of the throttle](image)

**Figure 5.** Motor characteristics with release of the throttle - derailleur set to 4th gear

It is worth to mention that drivers of the car usually do not use a mechanical brake (it causes unnecessary energy loss), and it is only sufficient to release the throttle.

2.3.3 **Manipulating parameters of the controller**  The next step was modifying the parameters and observing the average current consumed by the engine. In the table below (Table 5) the results of the tests were collected.

|                      | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 | Test 6 |
|----------------------|--------|--------|--------|--------|--------|--------|
| Time to throttle release [s] | 105    | 124    | 115    | 126    | 151    | 151    |
| Average current [A]   | 27.32  | 24.85  | 25.44  | 25.81  | 23.88  | 24.14  |
| Ramp 1 time [s]       | 24.26  | 24.26  | 20.60  | 20.60  | 20.60  | 20.60  |
| Ramp 2 time [s]       | 2.5    | 9.3    | 9.3    | 13.8   | 27.4   | 20.6   |
| Velocity of the car after ramp 2 [km/h] | 56    | 52    | 54    | 52    | 48    | 50    |

As it can be seen above (Table 5), the ramp time has a significant influence on the average current consumed during the test. A short ramp results in a much higher current and a higher speed of the car. Obtained results should be used to set the controller for a specific track configuration.

3. **Conclusions**
1. Increasing "PWM UP_1" by 50 resulted in the sharpening of the starting ramp - the graph is linear with a greater inclination to the horizontal axis. As a result, the ramp has been shortened. Even though the current in the peak increased, the average current decreased significantly, which will have a positive impact on energy consumption during the race.
2. Fivefold reduction of "PWM Fast Time_2" caused in doubled time of the ramp. The speed of the car decreased and remained at a lower level for a longer time.
3. Setting the "PWM Fast Time_2" parameter to 200 resulted in ramp extension, but the average current of 24.14 [A] is higher than with parameter set to 100, and the time needed to stabilize the current has not changed.

4. Lowering the PWM UP_1 parameter below 150 caused malfunctions of the controller - the current was rising with a jumping manner creating steps on the graph.

The main purpose of the work was to test the new controller. Influence of individual parameters on characteristics of the Silesian Greenpower’s motor has been shown. The research and development of the SG MotorController are being continued. In the future, the data collected will be used to compare the controller to commercial products and with the computer simulation prepared in Siemens NX software.

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