Testing Platform for Analysing 3 Axles Small Platforms Skid Steering Behavior

Daniela VOICU, Laszlo BAROTHI, and Ramona-Monica STOICA

***Abstract*—The present paper aims to present the development of an application written in C# programming language, intended to command a measuring system that records parameters specific to skid steering wheeled vehicles, such as: wheel speed, wheel torque. The application commands all six electrical motors that are attached to the platform wheels. The application can command the wheels individually, simultaneously, at both constant and variable engine speeds. Furthermore, the application is able to gather information from all the sensors that can be attached to the 6×6 platform.**

***Index Terms*—measuring system, skid steering wheeled, sensors, programming code.**

I. Introduction

A major part in analyzing the steering system which allows skid steering of a 6×6 wheeled platform is represented by the experimental validation through specific formulas. Main goal of experimental research consists of establishing existing correlations between wheels' angular speed and platform's trajectory (Fig. 1).

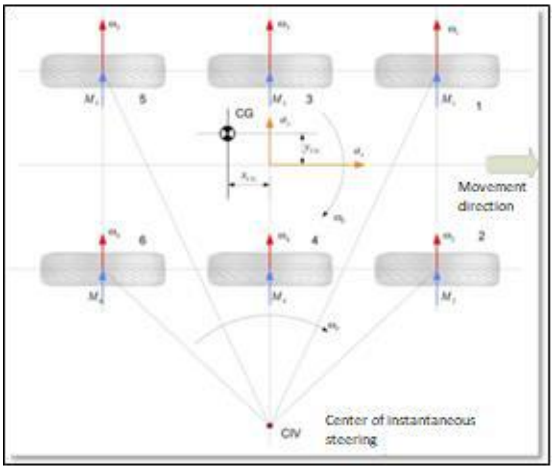

Figure 1. Parameters to be measured

By establishing these correlations, the issue regarding optimized control of trajectory can be solved by asserting appropriate wheel speeds.

By calculating relative skidding of wheels on tread as well as optimal wheel speeds it is aimed to unify the center of steering for all three axles.

In addition, there are presented several kinematic parameters in order to determine the behavior of the 6×6 wheeled platform in case of skid steering.

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The setup of the measuring system was difficult as regards building-up the entire configuration and assembling the programming code for the 2560 Arduino Mega board, which is needed to record information from sensors.

Therefore the C# programming language consists of codes able to receive information from:

- The Encoder attached to the engine;
- Power sensor;

but also able to command the platform to move back - forth, left - right.

This paper represents a testing phase for the system, limited to working with only two channels, in addition to the broadening to all six channels.

II. Experimental Set-up

A. *The measuring system*

This phase is meant for the development of a system for data acquisition, which would consist mainly of the following: a 2560 Arduino Mega microcontroller, 3 L298N engine drivers, 6 L298N power sensors, an ADXL335 accelerometer, an Ublox NEO-6M GPS module, laptop, charging battery.

The entire measuring system is presented in Fig. 2.

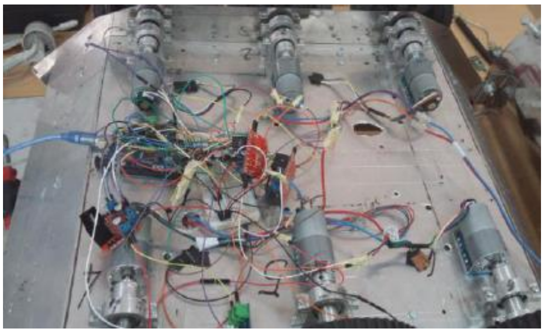

Figure 2. The measuring system layout platform

The assembly used to determine engine torque includes a ACS712 current sensor. The output is an analogue signal of voltage which has a linear variation with the input current.

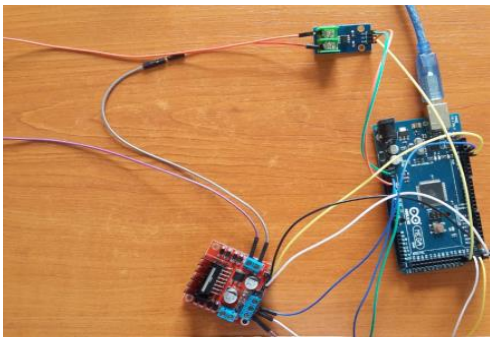

Figure 3. Current sensor attached to measuring system

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Due to the fact that the engine driver is amplifying the signal from source so that it provides power for two engines, the driver from Fig. 3 will have another engine connected, along with a current sensor.

B. Measuring engine speeds and wheel torque

The parameters that need to be measured are the following:

- Wheel torques;
- Wheel's angular speeds.

It is mentioned the fact that the platform is carried along by 6 electrical engines which can be actuated individually. The electrical engine has a metallic reduction gear with a reduction ratio of 13:1, produced by Pololu. Also, it has a two channel encoder with Hall sensor which assures 64 imp/rev acceptable 5.626° resolution.

Engine characteristics lack the current and voltage constants which allow establishing torque and engine speed based on the current absorbed and power-supply voltage, respectively.

For the engine power-supply voltage for obtaining angular [2] speed is given by formula:

$$E = K_E \cdot \omega + I \cdot R_i, \tag{1}$$

where: ω – angular speed of electrical engine axle; K_E – constant of voltage; I – the current absorbed by electrical engine; R_i – internal resistance of electrical engine.

In case the engine is being charged and the axle is blocked, angular speed is null and the internal voltage leads to a value of current given by Ohm law:

$$I_{\max} = \frac{E}{R_i} \tag{2}$$

Hence:

$$R_i = \frac{U}{I_{\max}} \tag{3}$$

Engine speed constant is obtained in case the engine is powered with voltage E and the axle has a free revolution [3], in which case engine torque is null.

Formula (1) becomes:

$$E = K_E \cdot \omega_0 + I_0 \cdot R_i, \tag{4}$$

where: ω_0 – angular speed of electrical engine axle in case of no-load running; K_M – constant of voltage; I_0 – the current absorbed by electrical engine.

It results that the engine's axle speed is:

$$\omega_0 = \frac{E - I_0 \cdot R_i}{K_M} \tag{5}$$

Considering the existence of reduction gear with the i_R transmission ratio and a global efficiency (engine and reduction gear) noted with η, the torque at engine axle is generally:

$$M = \frac{M_R}{i_R \cdot \eta} \tag{6}$$

and engine speed of axle is:

$$\omega = \omega_R \cdot i_R \tag{7}$$

Using established formulas, engine efficiency has been determined [4] in such a way that could obtain the engine speed in case of no-load, indicated by producer; therefore, from the definition of torque constant it results:

$$M_{R\max} = M_{\max} \cdot \eta = K_M \cdot I_{\max} \cdot \eta \tag{8}$$

Hence:

$$K_M = \frac{M_{R\max}}{I_{\max} \cdot \eta} \tag{9}$$

From the above formulas, it is obtained:

$$\omega_{R0} \cdot i_R = \frac{\left(E - I_0 \cdot R_i\right) \cdot \eta \cdot I_{\max}}{M_{R\max}} \tag{10}$$

Wherefrom results the formula of global efficiency for engine-reduction gear assembly:

$$\eta = \frac{\omega_{R0} \cdot i_R \cdot M_{R\max}}{\left(E - I_0 \cdot R_i\right) \cdot I_{\max}} \tag{11}$$

Knowing the values of angular speed in case of 6 Vcc and 12 Vcc charging, and performing specific calculations, there was obtained the electrical engine speed characteristic and engine-reduction gear revolution characteristic [5]; these are presented in Fig. 4 and Fig. 5, respectively.

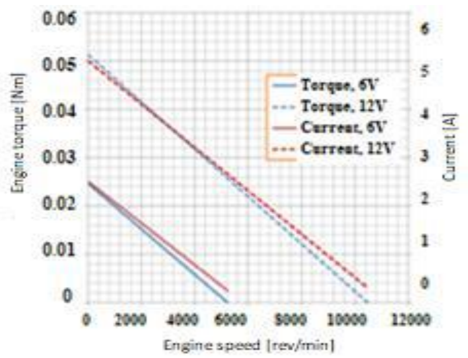

Figure 4. Revolution characteristics of electrical engine axle

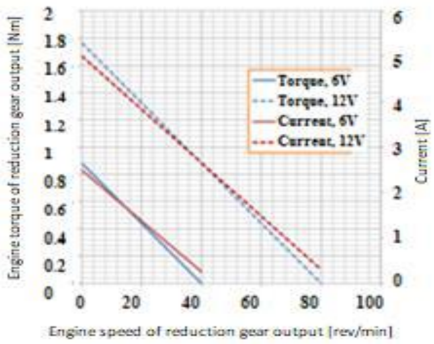

Figure 5. Revolution characteristics of reduction gear axle

Determining engine speed characteristics allows establishing wheel revolution for different power-supply voltage of electrical engines based on measuring the voltage, but it also determines the torque by measuring currents absorbed by electrical engines.

III. CONTROL OF ENGINE THROUGH A COMPUTER PROGRAMME

In order to control engine functioning through an Arduino Mega board, but also to record data from the encoder attached to the engine, there was developed a computer programme in sharpduino, which was subsequently uploaded. The programme allows the platform's wheels to run in both directions. The programme's interface is presented in Fig. 6.

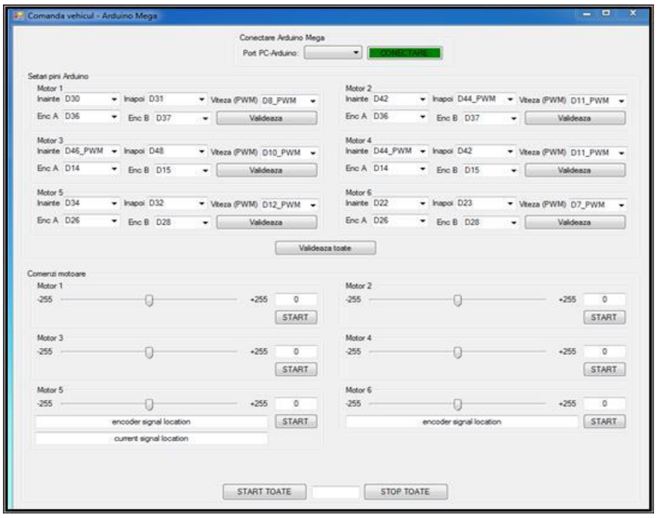

Figure 6. Programme's interface

IV. EXPERIMENTAL RESULTS

All six engines were connected to Arduino board in order to argue whether the programming code is feasible to control the entire platform. However, data were recorded only from the encoder and current sensor of a front wheel and a rear one. The results obtained from the encoder through the programming code written in C# were saved as .txt and subsequently processed in Matlab. In Fig. 7 there is presented the evolution of a signal originating from a single channel of the encoder corresponding to the right wheel of rear axle.

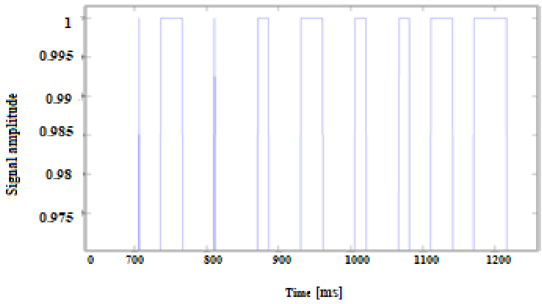

Figure 7. The signal originating from the encoder corresponding to the right wheel of rear axle

As can be seen in Fig. 4, the recording lasted 18.475 s, during which time there have been stored 24.16 revolutions. This implies that in case of no-load, for a maximum energy absorption of the engine, wheel speed is 78.6 [rev/min].

Hereinafter the same strategy is applied in order to determine the speed of front axle right wheel so that the same outcome is ensured in case of no-load. Therefore, Fig. 8 presents the results obtained during tests.

Fig. 8 shows that in case of right wheel of front axle the recording lasted 15.3 seconds, during which there have been stored 20.58 revolutions. This result allows determining wheel speed, which is 81 [rev/min]. The values of both speeds are approximately the same; the small differences could be caused by lower or higher friction of each engine axle within the bearing.

Also, in order to verify the accuracy regarding recorded data and signal shape, at one channel end of the encoder was attached an oscilloscope which showed that the signal has a rectangular shape, with small differences compared to the signal presented in Fig. 4 and Fig. 5. This aspect is on the one hand due to the oscilloscope's capacity to moderate and adjust the signal and on the other hand due to the existence of background noise which led to some errors during the recording with the measuring system.

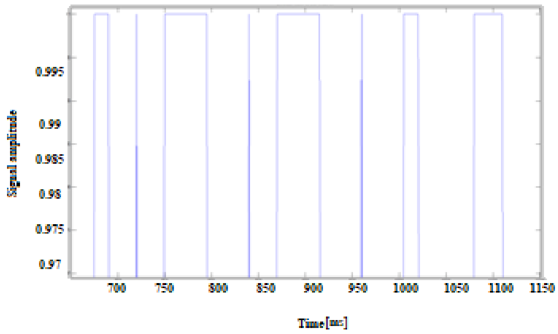

Figure 8. The signal originated from the encoder corresponding to the right wheel of front axle

The following phase consisted in writing the programming code in order to obtain information from current sensor. The results recorded from current sensor were saved as .txt and subsequently processed in Matlab. The signal captured was analogue and it has been observed that its variation is linear with current intensity and it allows one to determine engine torque value. This latter value and its variation, for right wheel of rear axle, are depicted in Fig. 9.

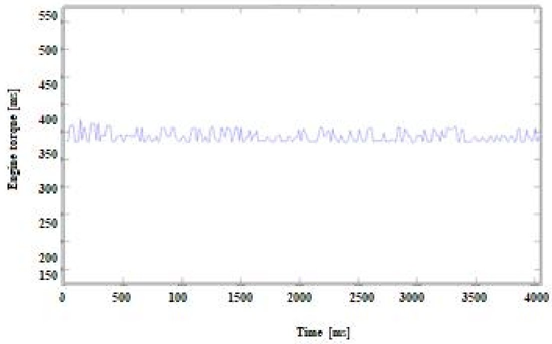

Figure 9. Time variation for engine torque corresponding to right wheel of rear axle

Fig. 9 shows that voltage value is constant for the entire interval which was expected considering that the input speed was also invariable.

The main drawback of this method recommended for determining engine speed is the restriction regarding minimum interval of recorded data, namely 15 ms. It is impossible to select a lower time frame due to the timer's inability to read parameters in such conditions.

As in the case of engine speed, there was also recorded engine torque value for left wheel of front axle. The results are presented in Fig. 10.

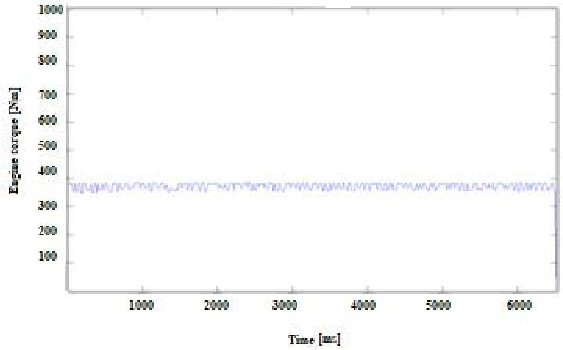

Figure 10. Time variation of engine torque for left wheel of front axle

A comparative analysis of the two engine torques indicates similar values. The value 400 recorded by the data acquisition board is within the interval 0 (corresponding to power supply voltage of 0 V) - 1023 (corresponding to maximum power supply voltage of 5 V). Practically, the value 400 is given by the current sensor. In order to transform this value in Amper, the following formula is used:

$$A = \frac{0.0049 \cdot 400 - 2.5}{0.185} = 0.026 \cdot 400 - 13.51 = \left|-2.981\right| [\mathrm{A}] \quad (12)$$

The above formula was obtained considering sensor's sensitivity which is 185 mV/A. Current sensor is able to measure both positive and negative values (between –5 A and 5 A), so for an input value of 0, the output value would be 2.5 V. The sensor returns a value between 0 (0 V) and 1023 (5V) which means 0, 0049 V for each reading.

Therefore it was expected a constant result, but the value 400, which is within the interval –5 V÷0 V indicates an error in the algorithm or the way the current sensor works. The same observation results from analyzing engine specifications, where it is specified that the maximum absorbed current is 2.2 A, for a braked engine. In this case, no resistance was introduced.

V. Simulink Validation

To validate the experimental results, in order to expand the system to all six channels, the measuring system was created in Simulink and the outcome is presented in Fig. 11.

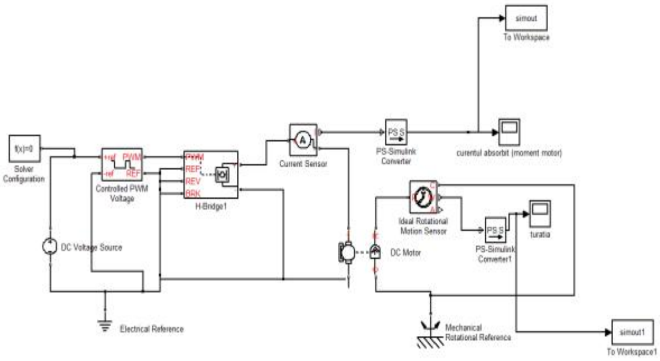

Figure 11. The measuring system in Simulink

In the above blocks there have been introduced the same parameters as in the experimental study and the intended result was a variation graph of engine speed and engine absorption of power. Therefore Fig. 12 depicts engine speed variation.

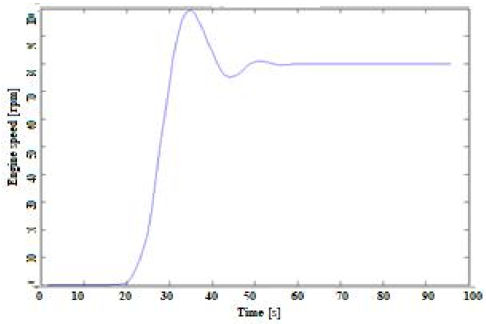

Figure 12. Time variation of engine speed

Due to differences in processing the results, engine speeds from experimental tests and simulation could not be displayed on the same graph. However, the comparison pointed out similar engine speed values.

Regarding the amperage absorbed by the engine, the Matlab simulation showed that the value obtained was according to the one specified by the producer in case of no-load running, 75 mA.

Therefore the values of parameters in question are appropriate due to the precision of the model created in Simulink. This model will subsequently be used to validate results obtained during experimental tests.

VI. Conclusions

This paper presents the testing of electrical engines in order to validate specifications given by the producer. Differences may appear due to the fact that these engines are produced using a low-cost technology which may determine technological differences; testing procedures proved to be relevant and efficient.

Testing of the measuring system was conducted considering two channels.

The programming code written in C# was able to command all six engines individually, simultaneously, at both constant and variable engine speeds. Likewise, the programme is able to store real time information from the sensors attached to the 6×6 platform. The code can be improved and adapted at any type of sensor likely to be used on the platform.

Lower speeds, the lack of tyres [6] and the scaling effect of terrain determined a very specific interaction between wheels and tread. This is why it is important to continuously monitor the dynamical behaviour of engine parameters.

VII. Future Work

Present paper represents only a testing phase of the system and might be seen as a starting point for future prospects in approaching the study of skid steering of small platforms:

- The usage of measuring system for all six channels;
- An improved programming code able to pick-up information from both channels of the encoder;
- The addition of a measuring system by GPS aided by an inertial system, which has the advantage of high accuracy in estimating movement speed but also movement trajectory;
- The addition of a measuring system by an accelerometer able to determine accelerations of the 6×6 platform, both on longitudinal and transversal direction;

VIII. References

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