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EXPERIMENTAL MODEL FOR A BRAKE TEST STAND

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Abstract

A brake test stand is a mechanical system that simulates a driveway in order to test the efficiency of the braking system of an auto vehicle. It hosts a range of sensors and transmitters which measure the braking forces applied to the wheels of the vehicle under test. In order to develop the computer software that controls the entire system, we first build an experimental model that can emulate the real brake test stand.

Key words: brake test, stand, sensors, data acquisition, analog converter, experimental model, prototype

1. Introduction

The purpose of a brake test stand is to measure and report the status of the braking system for the vehicle under test. The information is gathered, processed and displayed by a computer in real time. The end result is a report which shows whether the parameters of the vehicle are within the recommended range.

Our goal is to build a system that controls the stand and facilitates the communication with a computer. As a first step of the development process, we simulate the real data acquisition system, which enables us to build the master control application in isolation.

2. Brake Test Stand

The driveway is simulated using two-cylinder rollers (2) -- left and right -- connected through a transmission chain (6). They are set in rotational motion by a motor-reducer group (4). An electro-resistive force transducer (9) measures the brake torque reaction (fig. 1). The geometry of the system can then help to measure the braking force applied on the wheel.

The drive rollers simulate [3] a speed of minimum 5.2 km/h. The diameter of the rollers (200 mm) is sufficiently large in order to reduce the effects of mechanical relaxation or tire deformation. The special coating of the rollers ensures high resistance to wear and is characterized by a high coefficient of friction under both dry and wet conditions [1].

The intermediary roller (3), placed between the drive rollers, detects the presence of the vehicle on the test stand, measures the peripheral speed and keeps the sliding of the tire within predefined bounds.

The frame of the test stand (1) rests on four weight transducers, which connect its corners to a frame attached to the concrete (9). Together, these components make up the integrated weighing system [1].

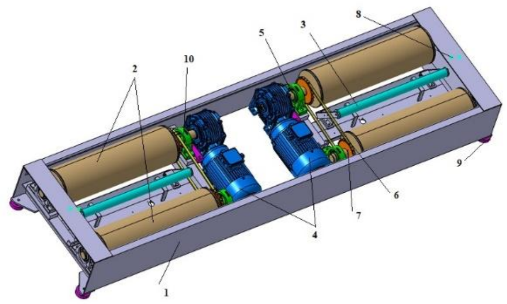

Fig. 1: Brake test stand

The brake test stand [1] is an electromechanical system that exercises the braking system of an auto vehicle, including the foot and hand brakes. It measures various quality aspects of the braking system, such as: a) the braking forces between the wheels and the driveway (simulated by the rollers), b) the resistance force on rolling, c) the press force on the brake pedal, and d) the weight on the wheel during braking. Additionally, the test stand can provide information about the imbalance of the braking forces on the two wheels, the braking coefficients of the axles, and the overall efficiency of the braking system. The measured values are then compared against the legal bounds set by the Romanian Auto Registry, in order to determine whether the vehicle is allowed to operate on public roads.

The vehicle is placed on the simulated driveway, and its braking system is exercised. The system measures the resulting force (i.e., the reaction force) determined by the motor-reducer group, transmitted from the rollers to the electro-sensitive transmitters. The data received by the transmitters is monitored by the electronic control system, and sent to the central unit processor (dedicated software). The latter stores the highest value only.

Taking into account the difference between the testing speed and the speed of the intermediary roller, using an inductive proximity sensor, the sliding of the tire is controlled and kept under 24%, to prevent its wear.

Determining the weight of the vehicle on each wheel is done by an automated system made out of four load cells, placed in the 4 points that hold the stand frame.

The wheel measurements provide the rolling resistance (N), the friction force (kN), and the brake disk / ovality. The system displays the highest weight applied on the wheel (kg), the imbalance of the braking forces on the axles (%) and the overall performance of the brake (efficiency %). These measurements are registered for both the foot and hand brakes [2].

In order to facilitate the communication between the test stand and the computer [4], we need a data acquisition and processing system able to handle digital inputs and outputs, signal events, and receiving values from the transmitters. The digital inputs are produced by the proximity inductive sensors (left and right), inputs for presence detection (left and right), inputs from the control panel (MAIN, STOP, etc). The digital outputs are the outputs for the electrical engine controls.

3. Data Acquisition Experimental Model

The next step is building an experimental model for the data acquisition system, which can simulate the data coming in from the test stand. We also need to establish a communication protocol between the data acquisition system and the computer. The experimental model is required in order to build the master application that controls the stand.

We chose a multi-IO acquisition system, with 6 analog inputs, 8 digital inputs, and 8 digital outputs, and implement it using an ARDUINO MEGA 2560 board. The 6 digital inputs are connected to potentiometers, which can simulate analog inputs between 0 and 5 V. We simulate the signals that come from the electro-resistive force sensors. The digital inputs are also connected to switches that simulate command buttons. The digital outputs are connected to LEDs, which simulate the completion of the instructions. Additionally, they are connected to a rectangular variable frequency generator, which simulates the speedometer. The speedometer measures the effective rotational speed of the wheel. This speed is continuously compared against the rotational speed of the rollers. When the braking force drives the speed under 24% of the speed of the rollers, the value of the braking force is reported. This is the effective braking force of the auto vehicle [1].

In order to compute the frequency of the generator, we used a tire with the following specification: 195 / 65 / R15. The height of the tire profile is given by the formula:

$$H = 195 * 0.65 = 126.76 \text{ mm} \quad (1)$$

The diameter of the tire is given by the sum between the diameter of the ring (1 inch = 25.4 mm) and the double of the height of the tire profile:

$$D = 2 * 127.75 + 15 * 25.4 = 634.5 \text{ mm} \quad (2)$$

The perimeter of the wheel is given by:

$$P = 3.14 * 6324.5 \text{ mm} = 1.9908 \text{ m} \quad (3)$$

Given a speed of 24 km/h (equivalent to ~6.7 m/s), the wheel performs 6.73 / 1.9908 = 3.35 rotations per second. Given a disk with 100 slits, we get 335 impulses per second. So, the generator that simulates the speedometer is calibrated on a frequency spectrum between 0 and 700 Hz.

The digital outputs are necessary in order to simulate the instructions sent to the roller brake system, such as: left wheel spin, right wheel spin, left wheel spin, right wheel spin, stop spin engine, etc.

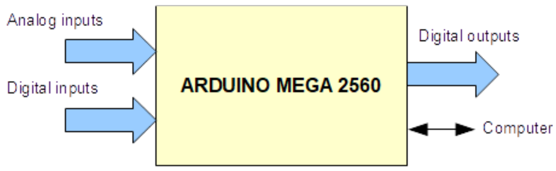

Fig. 2: Experimental model

The computer is connected to the experimental (fig. 2) model via a USB cable, using a virtual serial port. This connection requires programming the development board accordingly.

4. Data Acquisition Prototype

Once the data acquisition system is developed, the next step is to replace the experimental model with a data acquisition prototype. The latter involves replacing the potentiometers (which simulate analog inputs) with electro-resistive force sensors, replacing switches (which simulate digital inputs) with inductive sensors, and replacing LEDs (which simulate digital instructions) with contactors that are capable of sending instructions to the engines in the test stand.

The analog converter of the development board (ARDUINO MEGA 2560) operates on 10 bits; therefore, it can store numerical values between 0 and 1023. The input signal is in the 0 - 5 V range. We use SC8320 electro-resistive force sensors, with a sensitivity of 1.9995mV/V. In order to connect to the analog inputs, we need an intermediary amplifier. The precision of the amplifier is not enough, so we chose a different converter.

The analog-digital converter that we used is placed on a separate electronic board, with its own power supply. The communication between the converter and the data acquisition system is done via the serial protocol SPI -- the measured values are sent from the transmitters in digital form. We need 5 analog inputs for the following parameters:

- Instantaneous weight on left wheel (kg);
- Instantaneous weight on right wheel (kg);
- Instantaneous left braking force (daN);
- Instantaneous right braking force (daN);
- Exertion on brake pedal (daN).

The type of the analog-digital converter is sigma-delta, with 6 channels, operating on 24 bits. Each channel has its own converter, so there are 6 converters in total. This brings a significant advantage, since no time has lost by commution between conversion channels, or waiting for the input to stabilize.

The converter over-samples by a factor of 256. We did not use the internal amplification available in the converter, in order to prevent the deterioration of the signal. Under this configuration, we obtained 489 conversions per second for each channel.

The converter sends out the data in 24-bit format. For 16-bit outputs, the converter rounds the lower bits in order to preserve words on 16 bits and to minimize truncation error.

The command buttons and inductive sensors are connected to 24V. In order to ensure compatibility with the data acquisition system (which takes inputs between 0 and 5V) and galvanic separation, we intercalated a optocoupler board.

The contactors are also connected to 24V, so any digital signals between 0 and 5V must be converter by transistors to the interval 0 - 24V, as shown in fig. 3.

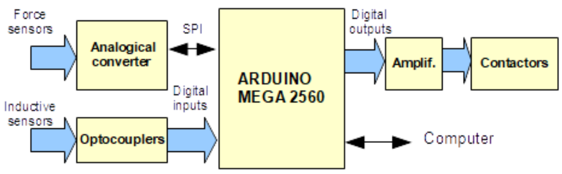

Fig. 3: Data acquisition prototype

5. Results

We determined that the experimental model is essential for building both the master and slave applications. The frequency generator is a very good speedometer simulator, and allows us to develop the data acquisition system in isolation, without having to connect it to an actual test stand. This prevents any potential design or implementation errors at this stage to negatively impact the physical stand.

The data acquisition prototype was easy to integrate with the real test stand. The applications built in the first stage were easy to adapt to the prototype. No significant errors were surfaced, and the physical stand was not damaged.

6. Conclusions

We built an essential experimental system, that enabled the first development phase of the master and slave applications for data acquisition. To simulate the speedometer, we used a rectangular wave generator with variable frequency (0 - 1000 Hz). We determined that the precision of the analog converter was not sufficient, so we needed a different solution for building the prototype. The experimental model proved to be indispensable for testing the applications, in order to avoid damaging the expensive physical stand. The master and slave applications were finalized using a prototype of the data acquisition system, with no additional risks to the equipment.

Acknowledgement

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