HARDWARE SOLUTION OF AN ABS SIMULATION STAND

Jan Knobloch

Doctoral Degree Programme (2), FEEC BUT

E-mail: xknobl00@stud.feec.vutbr.cz

Supervised by: Bohumil Klima

E-mail: klima@feec.vutbr.cz

Abstract: This paper describes a hardware design of a laboratory stand simulating ABS. It shows and describes the block diagram of the stand. An attention is paid mainly to mechanical calculations of rotating parts. A comparison of simulation capabilities with a real usage of ABS is performed.

Keywords: ABS, simulation stand, hardware conception

1. INTRODUCTION

ABS (Anti-lock Braking System) is now one of very basic equipments of modern cars. This is why the simulation stand of this system arose in order to familiarize students with its features. Furthermore we give a description of hardware and some calculations.

2. STAND CONCEPTION

Figure 1 shows the block diagram of the ABS simulator. It creates an imaginary vehicle that goes a certain speed and that has some weight. At some moment we depress the imaginary brake pedal with maximum force and the ABS ensures braking to a standstill.

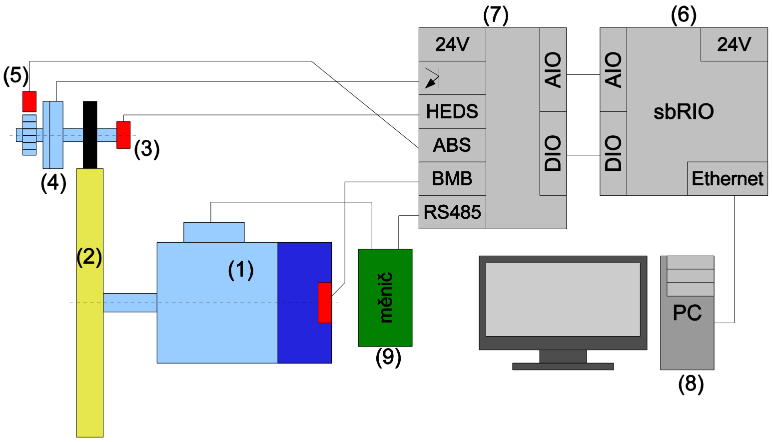

Figure 1: Block diagram of the laboratory stand

A description of diagram parts follows:

1. Motor with integrated encoder:

It serves to drive the flywheel with a desired speed. Braking is performed after the motor is unplugged – so braking only the flywheel. It simulates the situation where a car is slowing down while we are pushing the brake and clutch pedal fully. The encoder integrated in the bearing is an optical encoder with 48 pulses per revolution. It is used to determine the reference speed of an imaginary vehicle.

Motor type: EM Brno, AOM 90L06, 1.1kW, 2.9A, 935min-1, M_n=11.2Nm,

Encoder type: SKF, BMB-6205/048S2/EA002A

2. Flywheel and small wheel:

The flywheel accumulates the kinetic energy supplied by the motor. It simulates an imaginary weight of the braked vehicle with ABS. The car wheel is replaced by the small wheel.

3. Small wheel encoder:

It gives accurate information of the rotating speed of the imaginary car wheel. It is possible to compare and diagnose the ABS sensor signal.

Encoder type: Agilent, HEDS-5640 A13

4. Electromagnetic brake:

This is a replacement of hydraulic brakes of a car. There is a disc brake, where the disc is pulled by the electromagnet to the friction surface. The braking force is proportional to the current flowing through the electromagnet. We can simulate the behavior of electro-hydraulic brake system in a car, without using complex hydraulics. In addition, this system can be much faster and thus can simulate new types of brakes such as electronic wedge brake (EWB)[2].

Brake type: PSP Pohony Přerov, EKP 4, M_n = 40 Nm.

5. ABS sensor:

In the car with ABS all wheels have speed sensors. Schematic outline of these sensors is in Figure 2. The simulation stand is equipped with the original sensor from the Škoda Octavia. This sensor works on the induction principle. The magnetic flux is excited by the permanent magnet (1). Magnetic circuit with air gap and coil (2) is interrupted by code wheel blades (3). The rotation leads to periodic changes in magnetic resistance, thereby changing the magnetic flux and induced voltage in the coil. The voltage and frequency of the sensor output signal is proportional to the rotating speed.

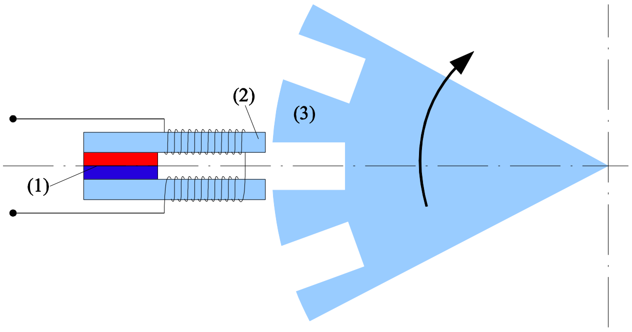

Figure 2: ABS sensor with code wheel

6. Control and measuring board:

Single Board RIO is a measuring and control board by National Instruments. A programmable logic FPGAs, a PowerPC microcontroller, AD converters and other interfaces for interacting with the environment and the PC are included. It also includes the simulator control algorithm. Furthermore the PC displays the measured data.

Control board type: sbRIO-9632, 400MHz procesor speed, 128MB DRAM, 256MB Flash, 2M gates FPGA, 110 DIO pins, 4 AO channels.

7. Converters board:

All the necessary circuitry which makes an interface between the control board sbRIO and its environment are implemented. For example, there is a power amplification of the PWM signal for the brake solenoid, power and logic level adjustment for the speed sensor and RS-485 port for communication with the inverter.

8. PC for data processing and control:

The LabVIEW is installed on a PC with a touchscreen. Here we provide programming and control the ABS algorithm in the sbRIO board.

9. Frequency inverter:

It supplies the induction motor, provides smooth start to the desired speed and may also influence the process of braking.

Inverter type: Emerson Control Techniques, Commander SKBD200110, 1,1kW, 230V, output 5,2A.

3. CALCULATIONS AND COMPARISON WITH REALITY

There are calculations of the torque and power, flywheel inertia, nominal brake torque, etc.

3.1. THE FLYWHEEL MOMENT OF INERTIA

The group of large rotating parts is outlined in Figure 3. It simulates the inertia of the imaginary vehicle. It consists of the flywheel, shafts, coupler and squirrel cage rotor.

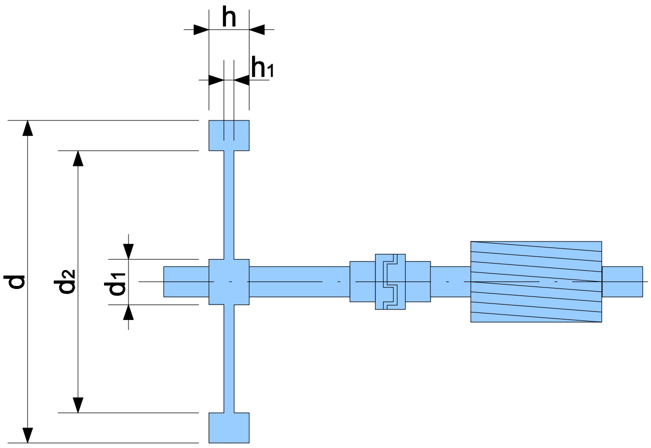

Figure 3: The set of rotating parts

Following equation can be written according to Figure 3:

$$J = \frac{1}{32}\pi\rho\left(hd^4 - h_O\left(d_2^4 - d_1^4\right)\right) \qquad (1)$$

Where ρ is steel density (7850kgm^{-3}), and $h_o = h - h_1$

The flywheel parameters are summarized in Table 1.

d	h	h_1	d_1	d_2	m	J
320 mm	40 mm	10 mm	45 mm	260 mm	13,1 kg	0,2177 kgm^{-2}

Table 1: Flywheel parameters

We need to add moment of inertia of the squirrel cage rotor, coupler and shaft to the flywheel.

Manufacturer gives motor moment of inertia $J_m = 0{,}0063kgm^{-2}$. Other moments are small, the order of $0{,}1gm^{-2}$, therefore they are negligible.

Total moment of inertia on the drive shaft is: $J_{celk} = 0{,}224kgm^{-2}$.

3.2. SMALL WHEEL MOMENT OF INERTIA

Following parts are on the small wheel shaft: rubber wheel: 1,08 gm^{-2} , both flanges: 0,2466 gm^{-2}, bake flange: 0,6187 gm^{-2}, brake disc: 1,062 gm^{-2}, ABS sensor rotor: 0,122 gm^{-2}.

Total moment of inertia on the small wheel shaft is: $J_{kol} = 0{,}00313 kgm^{-2}$.

3.3. FLYWHEEL ENERGY

Lets expect the tip speed $v_o = 50 kmh^{-1} = 13{,}9 ms^{-1}$.

Following is valid for the kinetic energy of the flywheel:

$$E = \frac{1}{2} J\omega^2 = \frac{1}{2} J \frac{4}{d^2} v_o^2 \qquad (2)$$

Energy of our imaginary vehicle is: $E = 843{,}9 J$.

3.4. IMAGINARY VEHICLE WEIGHT

From the equality of the imaginary vehicle and the real flywheel energies we can get the following formula:

$$m_{ekv} = J_{celk} \frac{4}{d^2} \qquad (3)$$

Imaginary vehicle has weight: $m_{ekv} = 8{,}75 kg$.

It is approximately 100x less than usual personal vehicle. The scale for our experiments is ca 1:100.

3.5. FLYWHEEL ACCELERATION TIME

Calculation of the starting time is important for the correct setting of the ramp in the inverter. The aim is to use maximum torque to minimize this time. But we must not exceed the maximum torque.

Rated torque is 11.2 Nm at 400V supply voltage 50Hz. The drive uses the U/f = const algorithm, which takes approximately a constant torque. Maximum inverter output voltage is 230V. Hence, the motor should reach maximum flux at a 28,8 Hz. Therefore the shaft torque is constant to this frequency (maximum) and then it decreases due to the motor field weakening. Torque at a constant frequency (50 Hz) is dependent to a square of voltage. Therefore the torque in our case is approximately $230^2/400^2$ times smaller than the nominal one. So we get 3,7 Nm insteade of 11,2. To obtain more torque reserve and simplify the calculation, let ´s assume a higher torque of 5,5 Nm (increasing the slip).

For angular speed is valid:

$$\omega = \frac{2v_O}{d} \qquad (4)$$

Angular speed will be $\omega = 86{,}8 rads^{-1}$.

Assuming a constant torque during acceleration we can use a simple relationship:

$$t = \frac{J_{celk}\omega}{M} \qquad (5)$$

The flywheel acceleration time will be $t = 3{,}54 s$.

3.6. BRAKING TORQUE AND BRAKING TIME

Torque which must act the brake is proportional to the friction force acting on the interface "tire – asphalt”. In our case this is replaced by a rubber wheel interface - the surface of the flywheel. The friction force F_t is proportional to the normal force F_n by the relation:

$$F_t = f \cdot F_n \tag{6}$$

Where f is friction coefficient (0,8 for dry asphalt, 0,6 for wet asphalt, 0,15 for snow and ice).

With load by $F_n = 50N$ a $f = 0{,}8$: $F_t = 40N$.

The breaking torque is:

$$M_b = r_{kol} F_t = \frac{d_{kol}}{2} F_t \tag{7}$$

Braking torque will be: $M_b = 2{,}5Nm$.

It is possible to calculate the braking time from the calculated imaginary weight. For simplicity, we assume that ABS will keep a constant maximum braking force. Braking time will be:

$$t_{br} = \frac{m_{ekv} v_O}{F_t} \tag{8}$$

After evaluation we get: $t_{br} = 3{,}04s$

4. CONCLUSION

The aim of this work was to design the concept of a laboratory stand, drive and brake. The drive and brake are dimensioned with a large reserve. The weight of the simulated imaginary vehicle was calculated. The approximate scale of actions that we can simulate was determined. This stand is mechanically designed to be the best possible to simulate real behavior of the ABS brake system.

ACKNOWLEDGEMENT

This work was solved in the frame of the faculty project FEKT-S-10-17 Efficiency Mapping of the electrical AC Drives and project 3093/G1 New excercise to the subject Car electronic from Ministry of Education, Youth and Sports.

REFERENCES

[1] Wikipedia [online]. 2011 [cit. 2011-03-04]. Moment of inertia. Avail. from WWW: <http://en.wikipedia.org/wiki/Moment_of_inertia>.

[2] Siemens [online]. 2011 [cit.2011-03-04]. Siemens AG-Braking Systems.Avail. from WWW: <http://www.siemens.com/innovation/en/publikationen/publications_pof/pof_fall_2005/auto_electronics/braking_systems.htm>