MECHATRONIC SYSTEM FOR THE EXPERIMENTAL STUDY OF FRONTAL BEAT OF THE VEHICLE BRAKE DISK

Alina Rodica Spanu[1] and Iolanda Constanta Panait[2]
[1] University Politehnica of Bucharest, Mechatronic and Precision Engineering Department, Splaiul Independentei, 313, Bucharest
[2] University Politehnica of Bucharest, Department of Industrial Process Equipment, Splaiul Independentei, 313, Bucharest
spanu_alina@yahoo.com, iolanda_pan@yahoo.com

Abstract: Taking into account the imposed safety conditions, the braking system of the vehicle should be designed and manufactured with great accuracy. The brake disc is one of the most important components and its frontal beat deviation may influence the braking process. The phenomenon is a very complex one and may produce wear and tear on the disk surface at the beginning. If the working causes are not carefully analysed and improved, the variation of the thickness may appear, so that some dangerous damages could be produced. The paper presents a method for analysing the frontal beat of the brake disc by using the mechatronic system comprising electrical actuation and ultrasound sensors. The variation of the rotational speed and torque are real time controlled with Arduino. The sensors are placed across the entire surface at minimum distance and the three dimensional analysis could be realised. A Visual Studio based software was implemented as a solution for analysing the relationship between the rotational speed and the frontal beat amplitude.

Keywords: Frontal beat, Brake disc, Real time control, Mechatronic system.

1. Introduction

The braking system of the vehicle is one of the most important assemblies taking into account the safety during the movement. The braking system should work only on the driver request and its functioning should be very silent. Consequently, all its components should be designed and should be manufactured with great accuracy and responsibility. According to the European Commission Road Safety 2015, the rate of road accidents should be decreased, so that one of the main goals are the improvements of braking system safety.

The phenomenon of frontal beat acting on the vehicle braking system conducts at first to the wear and tear of the disk surface and to an important variation of its thickness finally. The main causes are due to the manufacturing or assembling errors. The imposed limits of assembling accuracy are about 50 – 130 μm. The frontal beat is a very complex deviation including the perpendicularity as well as the shape of the tested surface.

For the system of vehicle braking, these errors imply a temperature variation too affecting the contact surface between the brake disk and brake plate. This is a reason why an important demand is the possibility of heat evacuation through some spatial designed channels. Meantime, on the contact surface should be avoided the chemical corrosion.

A consequence of braking disk frontal beat during the vehicle manoeuvring is the vibration of the braking system too, which could influence even the passenger comfort.

The vibrations and the shocks caused by the braking system should be real time controlled, so the designed solutions have to be based on the new technology brake by wire (BBW). The frequency of vibration is proportional to the vehicle speed and if the limits are exceeded, the clefts on the brake disk surface will appear. The friction between the brake disk and the plate causes the low level of the vibration, while the higher level of this vibration is due to the geometrical deviations of the spatial disk shape.

In order to compute the frontal beat of the brake disc, it has to be established the theoretical mark, which is considered along the normal direction on the rotational axis of the disc. The next step is the determination of the maximum and minimum distance of the points across the frontal surface and this theoretical direction.

The patent [1] proposed a solution for frontal beat determination by using contactless sensors with high accuracy level. The sensors are placed along two imaginary lines that are equidistant from the brake disk axis. In order to keep the imposed spatial position, it was used a frame where the sensors were mounted. All the measured values recorded by the electronic devices are compared with the standard values, so the errors are computed very accurate.

The paper [2] describes the method of experimental measurement of temperature nearby the contact surface between the brake disc and the plate by using electrical sounder. There are placed where the higher level of temperature could be real time recorded. During the measurement it is done the association between the angular position of the disk and of the frontal beat, by using contactless sensors.

The most important advantages of this method are: the control of the rotational speed; the theoretical and experimental processing of values; the analysis of the lateral and frontal disk surfaces, by using the three dimensional design.

The paper aims to points out a method for theoretical and experimental determination of the frontal beat characterizing the brake disk as part of the vehicle braking system.

The electrical actuation was used for the rotational movement of the brake disk. The ultrasonic sensors mounted along the frontal surfaces have to record the real time measured values for the frontal beat.

2. The Experimental Set-up

The frontal beat of the brake disk has been measured by using the mechatronic system with ultrasound sensors HC-SR04 with the length range of 2 – 500 cm with the accuracy of 0.3 cm. The sensor is supplied with the voltage of 5 V.c.c. and electrical current of 15 mA. The sensors were placed at the distance of 30.6 mm measured from the frontal side of the disk.

The Fig. 1 presents the main components three-dimensional representation and Fig. 2 presents a section view across the longitudinal axis.

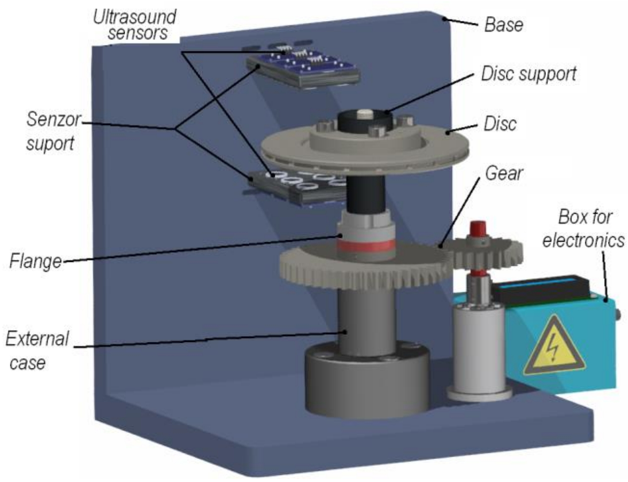

Figure 1. The experimental set-up as *for the frontal beat measurement*

The electrical motor Faulhaber Series 2619 012 SR 33:1 with the torque of 0.1 [Nm] has the main role of actuating the gear with the ratio 2.

The driven wheel is mounted on the second shaft with ball bearings in order to increase the accuracy of the rotational movement.

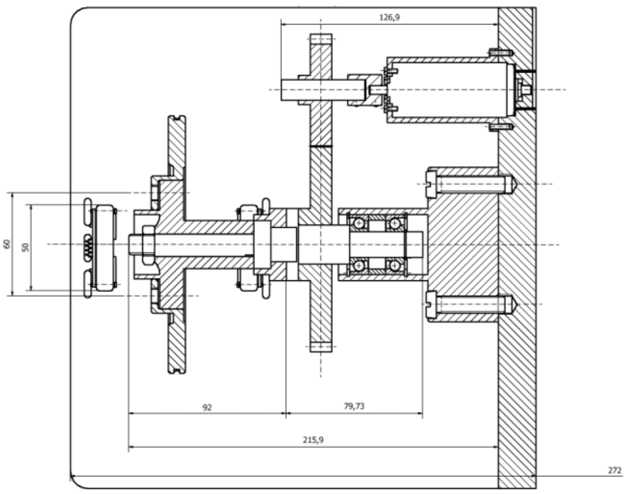

Figure 2. The section view across the longitudinal axis

The brake disc is receiving the rotational movement from the grooved shaft, which has the main advantage of minimizing the axial clearance between, so the accuracy is increasing.

We have proposed the designed solution presented in Fig. 3, where we may infer that the brake disk is mounted on the spherical surface in order to increase the accuracy.

Figure 3. The spherical surface used for assembling the brake disc with the shaft.

By using this designed solution, the experimental study was improved, so that all the deviations from the axial direction as well as all the errors of the frontal disc surface could be measured with the sensor system [3], [4].

The electronic components we have used for measurement is comprising the Arduino Uno microcontroller, the ultrasonic sensors and the LCD 1602 where the values are displayed in real time.

The Fig. 4 presents the ultrasonic sensor mounted upside the frontal surface of the brake disc and the values displayed on the LCD. The PWM variation and the vertical distance between the brake disc and the sensor are displayed.

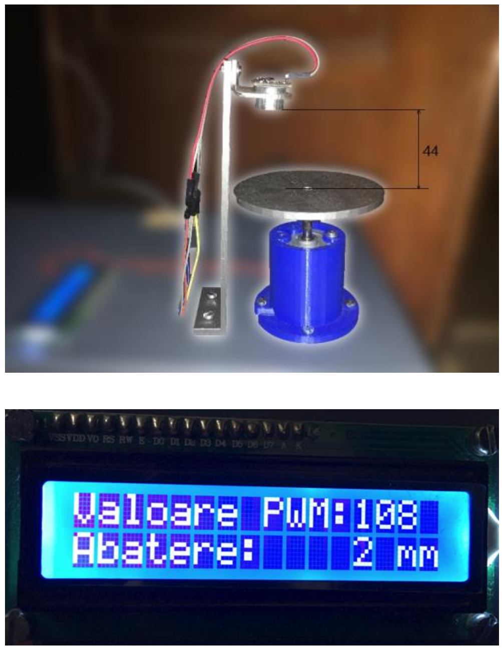

Figure 4. The ultrasonic sensor and the LCD where the values are displayed

Finally, a Visual Studio platform was designed, as it is presented in Fig. 5, so the rotational speed of the disc could be varied and the measured values could be displayed in the real time.

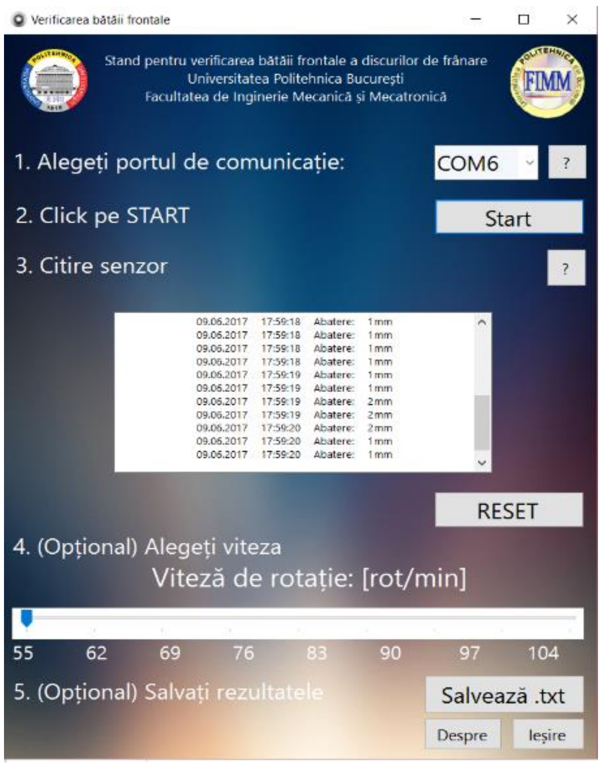

Figure 5. The Visual Studio Platform.

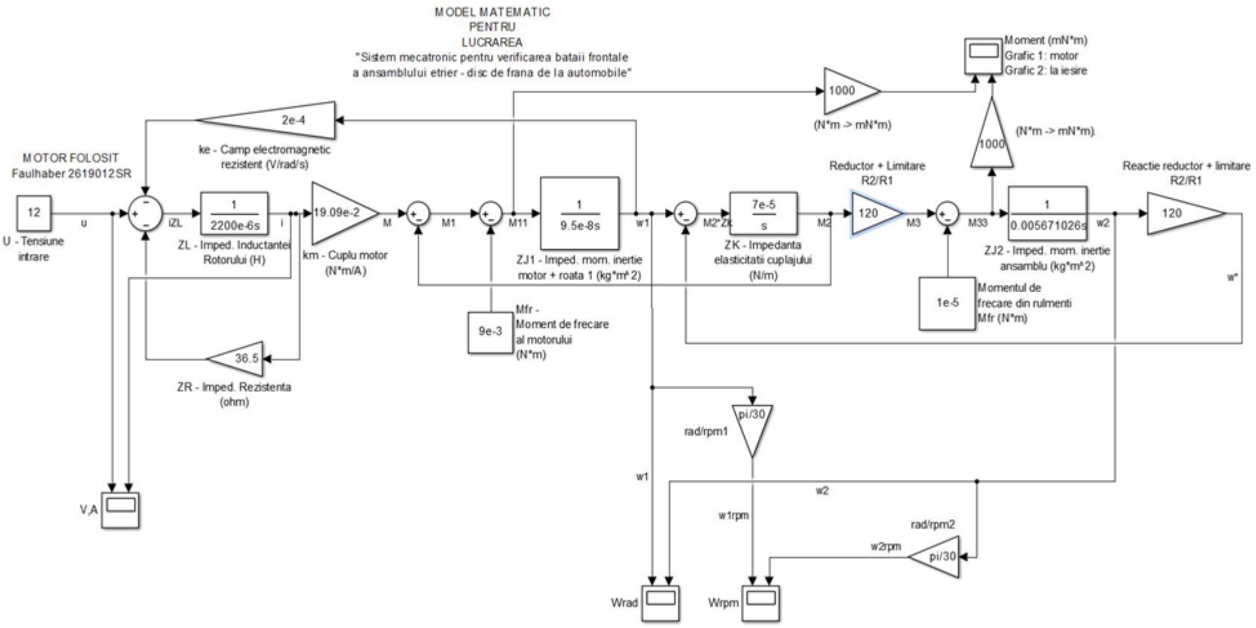

Figure 6. The mathematical model of the measuremet system.

3. The Mathematical Model

The mathematical model presented in Fig. 6 was written by using the Matlab-Simulink blocks, taking into account: the mathematical model of the electrical motor; the coupling elasticity; the mathematical model of the gear; the friction torque of the ball bearings as well as all the values for the inertial masses of all the elements that have rotational movement. By solving this model we have established the variations of the electrical current [A], torque [mN m] and rotational speed[rot/min] as time [s] functions.

These graphics are presented in Fig. 7, Fig. 8 and Fig. 9, so it may be observed that the time until the movement is stable is very short, about 0.8 s. The Fig. 8 presents the variation of the torque for the shaft where the brake disc is mounted.

The main goal of mathematical model computation was the analyse of rotational speed variation as time function, so we may analyse if the vibrations will occur.

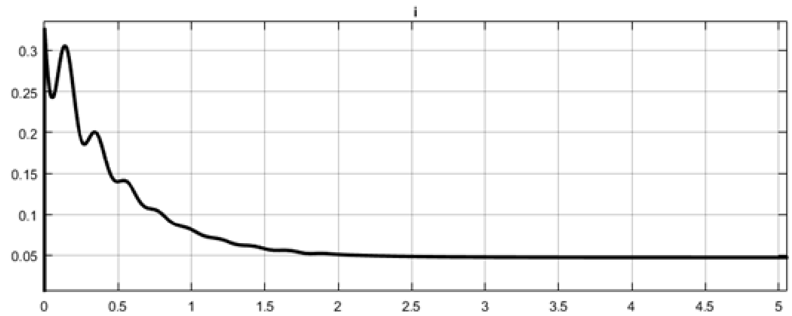

Figure 7. The variation of the electrical current

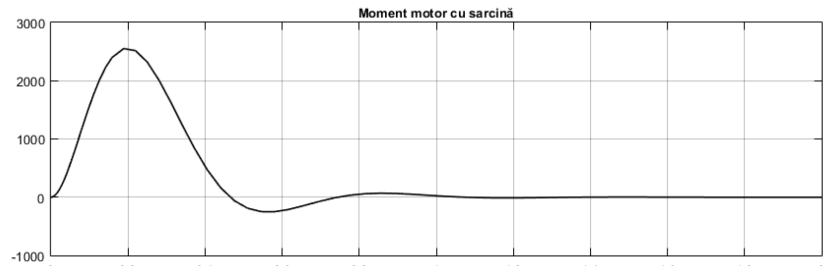

Figure 8. The variation of torque.

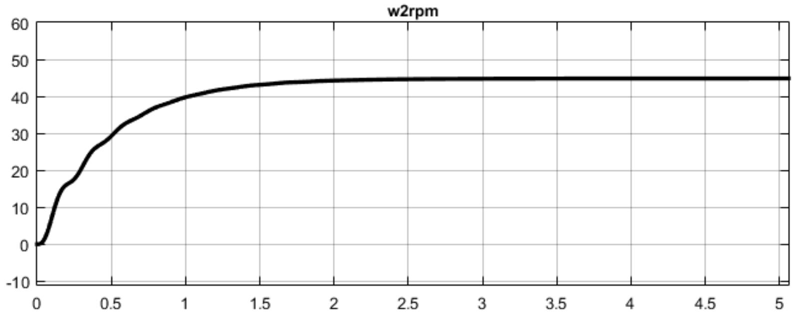

Fig. 9. The variation of rotational speed

4. Conclusions

The paper presents a method for measurement the frontal beat for the brake disk. There have been pointed out the designed solutions for the mechatronic system comprising ultrasound sensors, electrical actuation, LCD and Visual Studio platform for real time measuring.

The solution has great accuracy and it was improved by using the spherical external surface for mounting the brake disc. The mechatronic system was controlled by using the Arduino Uno microcontroller.

As future work we aim to study the influence of vibrations on the measured results, when a greater range of rotational speed of the electrical motor will be achieved.

References

[1] Cristopher, L., Greenwald, Concord, N.H., 19.10.1999, Disc Brake Testing Device and System Employing the Same, U.S.5970427.

[2] Robert J. McNaughton, Howell, MI (US); Mark Malburg, Columbus, IN (US), 21.10.2008, „Method of evaluating a disc brake rotor", US7437917.

[3] Cioboata, D., Dontu, O., Besnea, D., Ciobanu, R., Abalaru, A., Integrated mechatronic system for bearing rings control, The Romanian Review Precision Mechanics, Optics and Mechatronics, Issue 49, 2016, pp. 48 – 57. (ISSN 1584-5982)

[4] Cioboata, D., Dontu, O., Besnea, D., Ciobanu, R., Soare, A., Mechatronic equipment for bearing ring surface inspection, The Romanian Review Precision Mechanics, Optics and Mechatronics, Issue 48, 2015, pp. 262 – 266. (ISSN 1584-5982)