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COMPARATIVE ANALYSIS OF THE INSTRUMENTATION OF A TEST BENCH

Cynthia Beatriz Scheffer Dutra
Marcelo Vandresen
Instituto Federal de Ciência, Educação e Tecnologia de Santa Catarina, Av. Mauro Ramos - nº950 – Centro – Florianópolis – Santa Catarina – CEP 88020-300
cynthia@ifsc.edu.br
vandresen@ifsc.edu.br

Michel Fabre Almeida
Instituto Federal de Ciência, Educação e Tecnologia de Santa Catarina, Av. Mauro Ramos - nº950 – Centro – Florianópolis – Santa Catarina – CEP 88020-300
michelfabrealmeida@gmail.com

Vinicius Ghellere Sbardelotto
Instituto Federal de Ciência, Educação e Tecnologia de Santa Catarina, Av. Mauro Ramos - nº950 – Centro – Florianópolis – Santa Catarina – CEP 88020-300
viniciusghellere@gmail.com

Abstract. *In an automotive shock absorber test bench is necessary to measure the linear displacement, linear velocity and linear acceleration to lift the damper characteristics, so the accuracy and repeatability in the acquisition of data is essential to ensure the reliability of the tests performed on the bumper. The paper presents a comparison of the following sensors used in data acquisition: potentiometric linear transducer, velocity transducer, accelerometer and the combination of hall sensor and gear tooth, in order to evaluate which sensor or group of sensors has better accuracy and repeatability in relation to its price to be used in a bench for testing shock absorbers. For evaluation of the sensors it was used an automotive dampers test bench developed by the same research group. Test methodology: controlled test, comparing tests at the same speed, electronic boards developed for condition the signals from the sensors, sensor calibration and measurement, the measurement process reliability and collection of measurement errors. Through mathematical tools and mathematical modeling of system, it was studied the use of the hall sensor with the phonic wheel to measure the displacement, velocity and acceleration system. This study aims to determine if the hall sensor is sufficient precise and economically viable, and it can replace other sensors.*

Keywords: *optimization, shock absorber, testing bench, instrumentation.*

1. INTRODUCTION

Automotive shock absorbers are the key element to stabilizing the vehicle. Some vehicles use more than one shock absorber at each wheel and which has adjustment to its compression and traction. However there isn’t an accurate indicator of its performance for every setting adjustment, making it difficult to select a set of shock absorbers to use. Therefore, it is of paramount importance to gather the characteristics of the shock absorbers in order to know its situation in order to select the right set.

On a test bench of automotive shock absorbers, it dynamically measures the following physical quantities: force, position and linear speed to generate graphs and numerical data of the shock absorbers characteristics.

Some workbenches use potentiometric ruler to measure the position (displacement) during the test, the linear speed is obtained by linear velocity transducers or sensors of angular velocity and the force is measured by a load cell. The system repeatability is satisfactory when you can identify at least one variation on the shock absorber adjustment setting.

2. SHOCK ABSORBER TEST BENCH

The test bench is a prototype developed by the same research group that wrote this article, it has sensors to measure the position (displacement), linear speed and the shock absorber force. Graphics can be drawn by measuring these physics quantities that facilitate the interpretation of the characteristics of the shock absorbers (Dixon, 2007). Figure 1 shows generic graphics for these quantities.

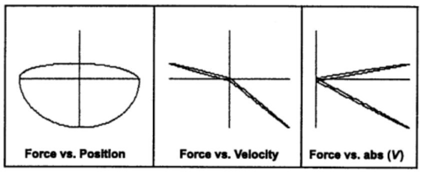

Figure 1. Generic graphs for a shock absorber test (Dixon, 2007).

The main use of graphics, apart from viewing maximum and minimum values, is the comparison between the different shock absorbers. It is also possible to obtain the damping coefficient by the graph of force vs. velocity.

The bench allows to perform tests with the course of 12.5mm, 25 mm, 50 mm and 100 mm. It currently uses an electric motor of 3 HP 4-pole with a reduction of 1:5 from the motor shaft to the shock absorber excitation mechanism. The mechanism used is known as Scotch Yoke, which converts the angular velocity to linear velocity in a cosine shape. This mechanism is illustrated in figure 2.

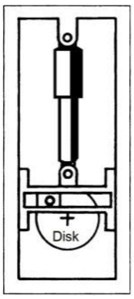

Figure 2. Scotch Yoke mechanism (Dixon, 2007).

Figure 2 shows the drive mechanism together with a shock absorber, as the disc spin, is the relative movement of the rectangular profile attached to the shock absorber.

The mathematical model is presented in equations 1, 2 and 3.

$$Displacement(t) = r * sin(\omega * \mathrm{t}) + r \tag{1}$$

$$Velocity(t) = \omega * r * \cos(\omega * t) \tag{2}$$

$$Aceleration(t) = -(\omega)^2 * r * \sin(\omega * t) \tag{3}$$

Based on the equations presented with only the angular velocity (which is a constant) and time, or the angular velocity and the angle of the mechanism in the system, it is possible to obtain two quantities required for testing shock absorbers, lacking only the force which is directly obtained by the load cell.

A photo of bench test can be seen on Figure 3.

Figure 3. The test bench developed.

Figure 3 shows the test bench with an installed shock absorber. The motor is positioned below the base of the bench, its power is transmitted through a double belt pulley that transmits to the axis of the mechanism. A gear tooth with 180 teeth is fixed to the pulley, with the purpose of using a hall sensor for measuring the angular velocity of the mechanism.

2.1 Sensors

To measure the force on the shock absorber (resistive load) during the test, it was used a load cell Reacción CZCB-1000 to support a maximum of 1000 kgf (Reaccion, 2015). For conditioning the signal, an instrumentation amplifier was used INA125 (Burr-Brown, 2015) for signal amplification and an operational amplifier for the offset in the signal. The processed signal is sent to an analog to digital converter 12-bit MCP3208 (Microchip, 2015), which transmits the converted data to the microcontroller Raspberry pi. In this system the resolution of the load cell is 0.244 kg.

The position measurement is accomplished using a potentiometric ruler Gefran LT-0100-MP, according to its datasheet this device has a repeatability of 0.01 mm (Gefran, 2015). However its response signal is analog, it is also used an analog to digital converter MCP3208 12-bit, with the signal conditioner the resolution is 0.02 mm.

The linear speed transducer has sensitivity of 45 mV/in/s, an operational amplifier is used for the offset, in order to read the speed in both directions. As the signal is analog is also used analog to digital converter MCP3208 12-bit. The linear speed reading resolution is 0.69 mm/s.

The aim of this work is to check the efficiency of the use of a Hall Effect sensor in conjunction with a gear tooth with 180 teeth in order to replace the linear speed and position sensors. For this, it was used a commercial automotive hall sensor model Volkswagen "032 906 433 B". With this measuring system it was achieved a resolution of 2 degrees on the angular system position.

3. METHODOLOGY

The bench actuator used is the CFW-08 frequency inverter, which has a vector control optimizing the torque which ensures a 0.5% variation of the rated angular speed when properly configured (WEG, 2015). In this case ensures a maximum variation of 8.55 rpm.

3.1 TESTS

All tests were made at the same angular speed, a shock absorber was not used during the test to not influence the variation of the system speed, the only movement was the bench's structure. The objective is to acquire experimental values with possible errors due to mechanical positioning of sensors, mechanical slack in the system, ambient temperature, geometric and dimensional imperfections of the system.

To raise the uncertainty of measurement of load cell a experimental method was used by multiplying the standard deviation with the student coefficient. In this experiment, it was used a display device Flexar Model LR-22 with accuracy class III (INMETRO, 2006) with a load cell Reacción CZCB-500. This display device has a resolution of 0.05 kg. It was applied a constant load of 317.80 kgf, the values read are shown in Figure 4.

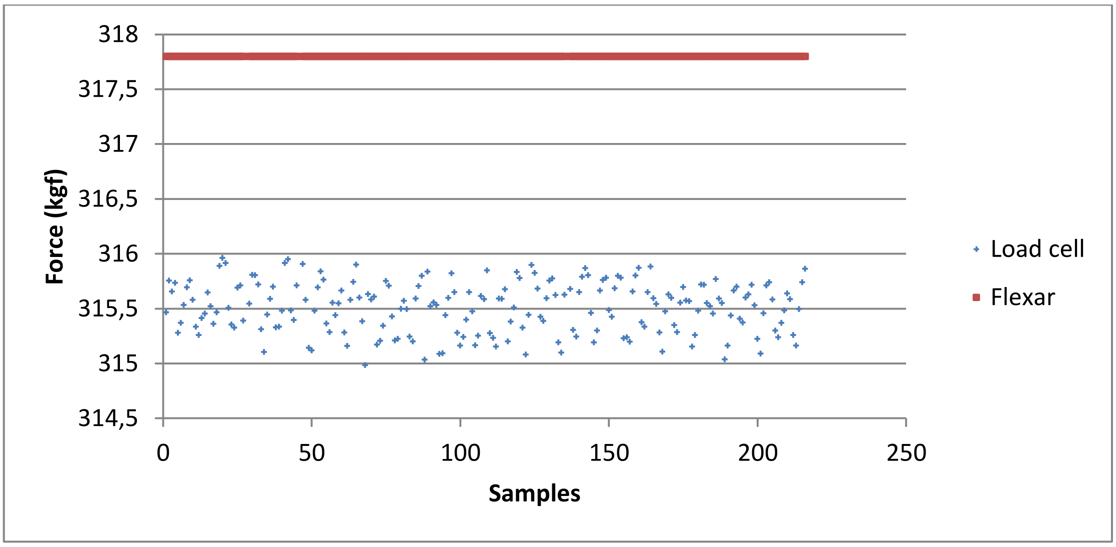

Figure 4. Force measurements of the load cell and Flexar.

The Flexar display device uses average for displaying the values, and there is also a stabilized load indicator. When the load was stabilized a reading was made from the bench load cell with 216 samples, results are shown in Figure 4, a repeatability of ± 0.46 kilograms is achieved. The average of the load cell sample values is 315.5 kg, in this case the correction factor is 2.3 kg which will be done by the bench software.

For comparison of position and velocity sensors (linear and angular), it was used the data acquisition module ShockAnalyser made by SportDevices (SportDevices, 2015), this module comprises a hall sensor GVS-02 Yuanben (Yuanben, 2015), a tooth gear with 120 teeth and a cell load Senel SX-3 with a capacity of 2000 kg. The tooth gear of this module was installed on the same axis as the 180 teeth tooth gear. Figure 5 shows a picture with the two tooth gear installed on the shaft.

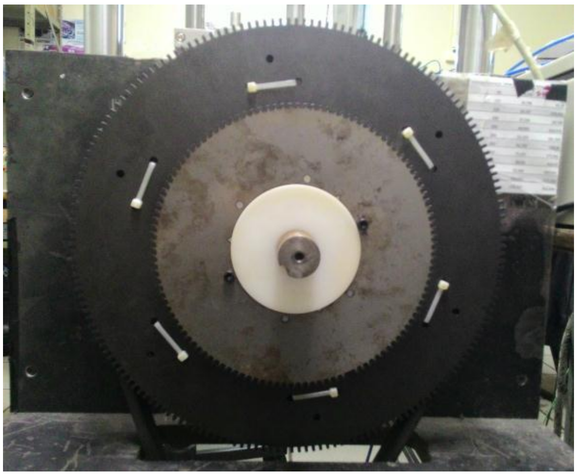

Figure 5. The 120 and 180 teeth tooth gear installed on the shaft.

To check the speed measurement made by the SportDevices data acquisition module (hall sensor with tooth gear of 120 teeth) it was compared to a tachometer Minipa model MDT-2245 with accuracy of ± 0.5% (Minipa , 2015).

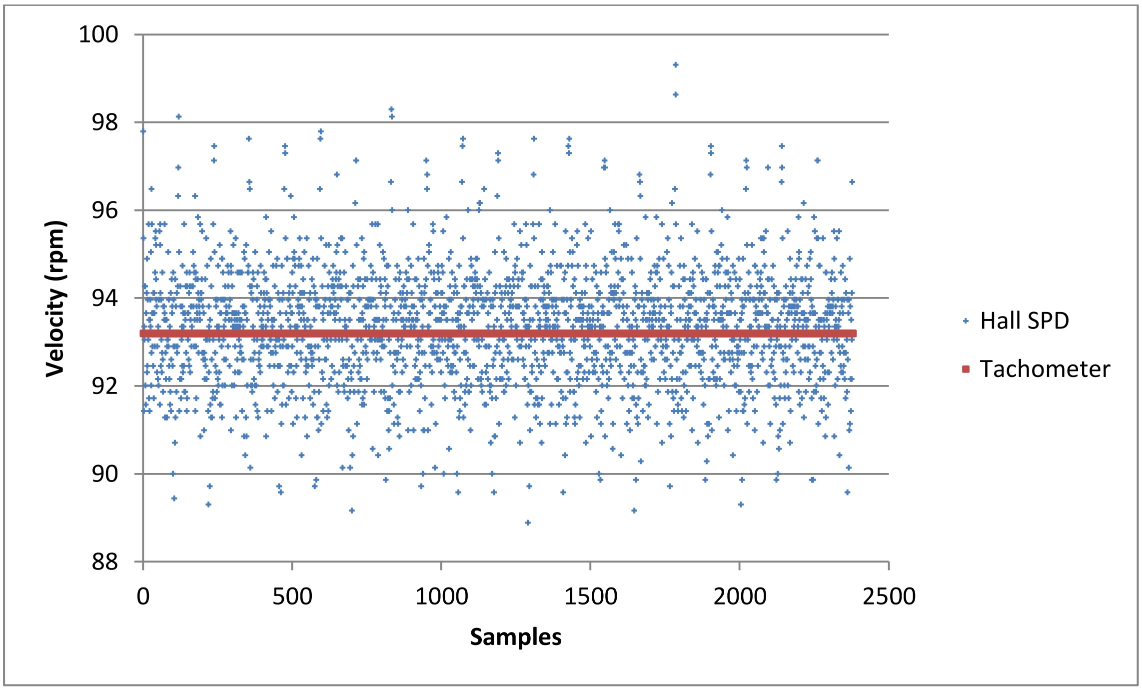

Figure 6. Readings from the SportDevices hall sensor and the tachometer.

As can be seen in Figure 6, there is a dispersion value around the tendency of the Hall sensor reading taken by the SportDevices module "SPD". Through the standard deviation of the method, it was obtained a repeatability of ± 2.8 rpm. The Minipa MDT-2245 tachometer performs many average calculations during its reading, its value stabilized at 93.2 rpm during the test.

To obtain the position of the shock absorber the SportDevices data acquisition module uses the hall sensor and tooth, it was compared potentiometric ruler Gefran readings with the SportDevice position data for the same test. The result is shown in Figure 7.

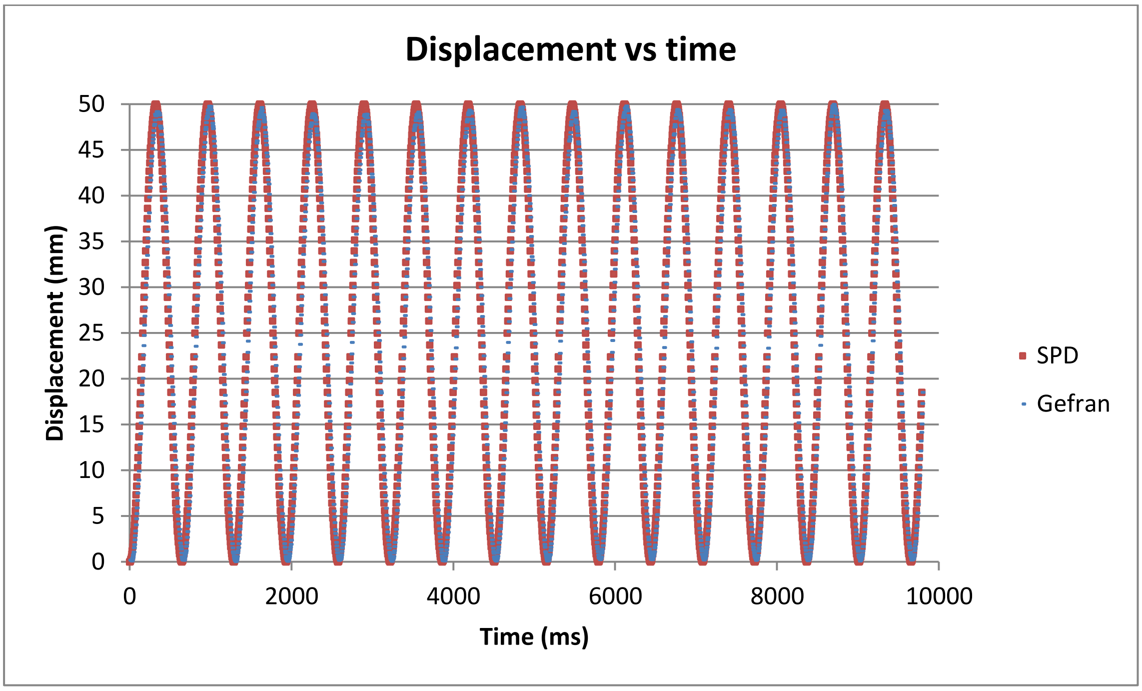

Figure 7. Displacement readings from the SportDevices and the Gefran potentiometric ruler.

As can be seen in Figure 7, it is shown the displacement of the test bench with the simultaneous measurement of the potentiometric ruler and the SportDevices module "SPD". During the time interval displayed, the test bench took 2113 samples with the ruler potentiometric Gefran while SportDevice module obtained 1812 samples.

It was compared the measurement of linear velocity transducer data with the SportDevices data. The result is shown in Figure 8.

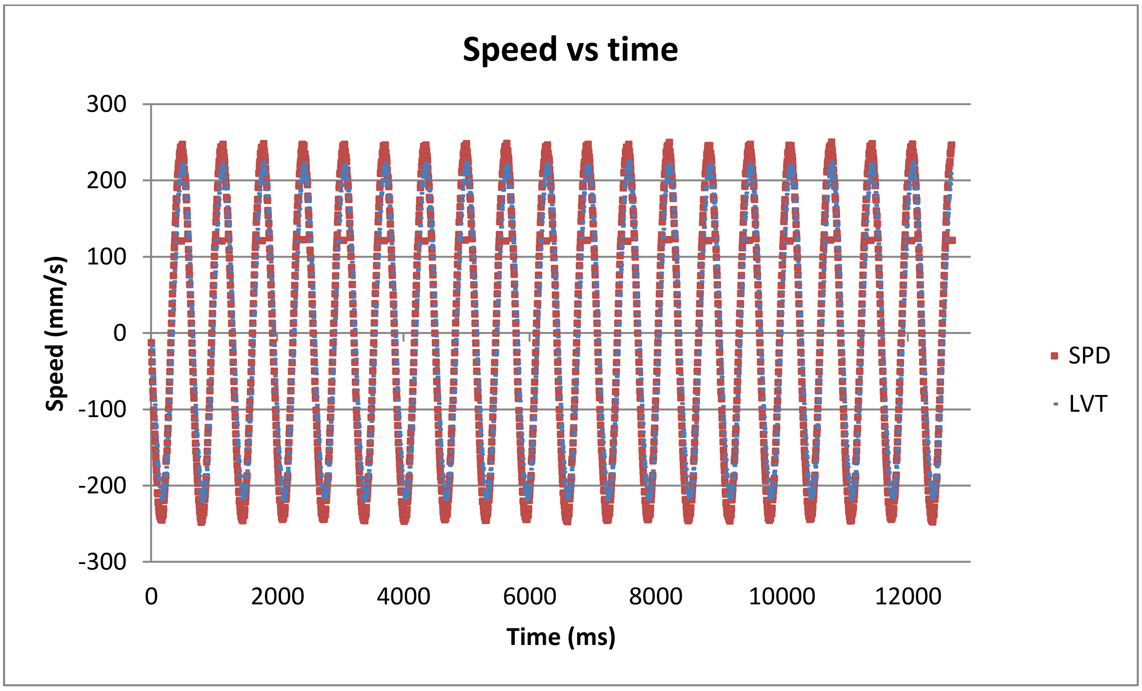

Figure 8. Linear speed readings from the SportDevices and the LVT.

As can be seen in Figure 8, both the linear speed transducer "LVT" and the SportDevices "SPD" measurements have good repeatability. However it is needed to apply a correction in measuring the "LVT" to approach the result of SportDevice.

With the proposal to only use the hall sensor in order to calculate the position and linear velocity, the hall sensor from the SportDevices module was installed on the test bench electronic acquisition system and its angular velocity readings were compared to the tachometer (Minipa MDT-2245). The result is shown in Figure 9.

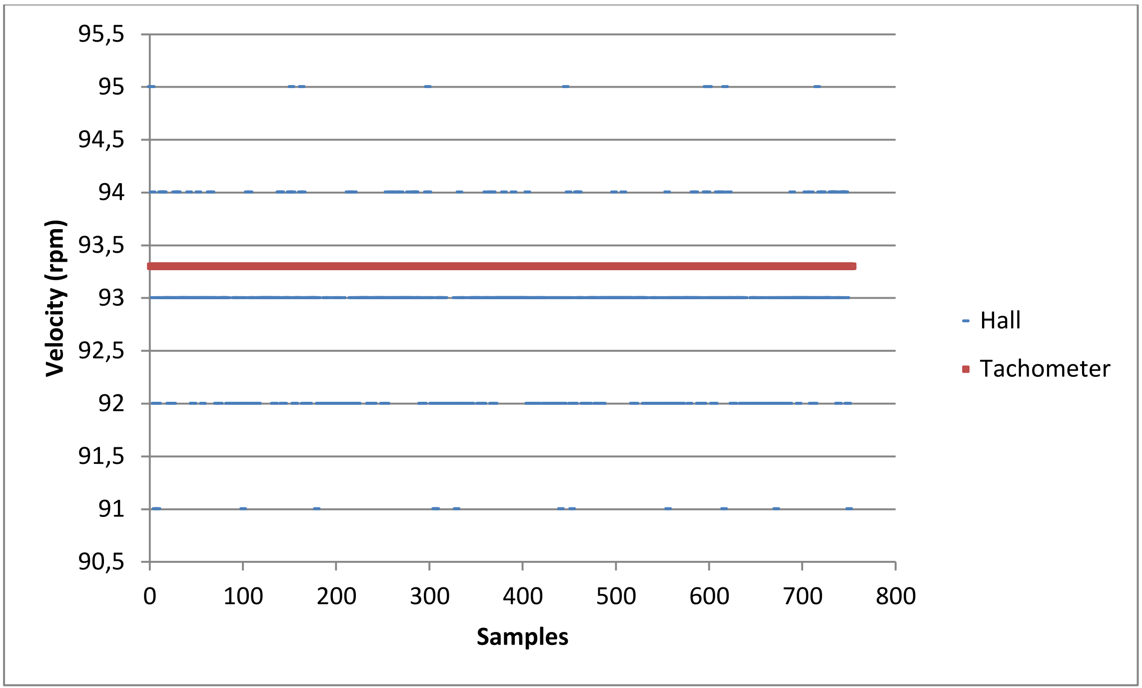

Figure 9. Readings from the hall sensor and the tachometer.

As can be seen in the data presented in Figure 9, the resolution of the reading of the Hall sensor for test bench is 1 rpm, the repeatability is approximately ± 1 rpm (numerically ± 1.4 rpm). The tachometer reading for this test was 93.3 rpm.

Both hall sensors were used at the same time on the test bench and the results are compared in Figure 10.

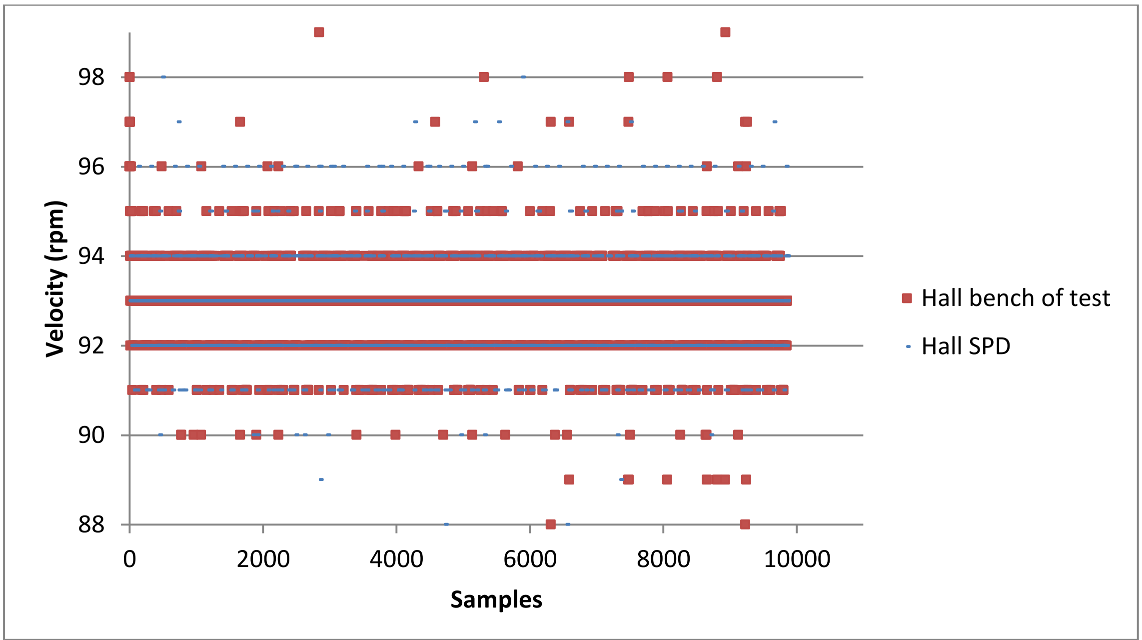

Figure 10. Angular velocity readings from the bench test hall sensor and the SportDevices sensor.

As can be seen in Figure 10 the two sensors are very similar, with measurement trend of 93 rpm.

The hall sensor from the test bench was tested with both 120 and 180 teeth tooth gear. The result is shown below in Figure 11.

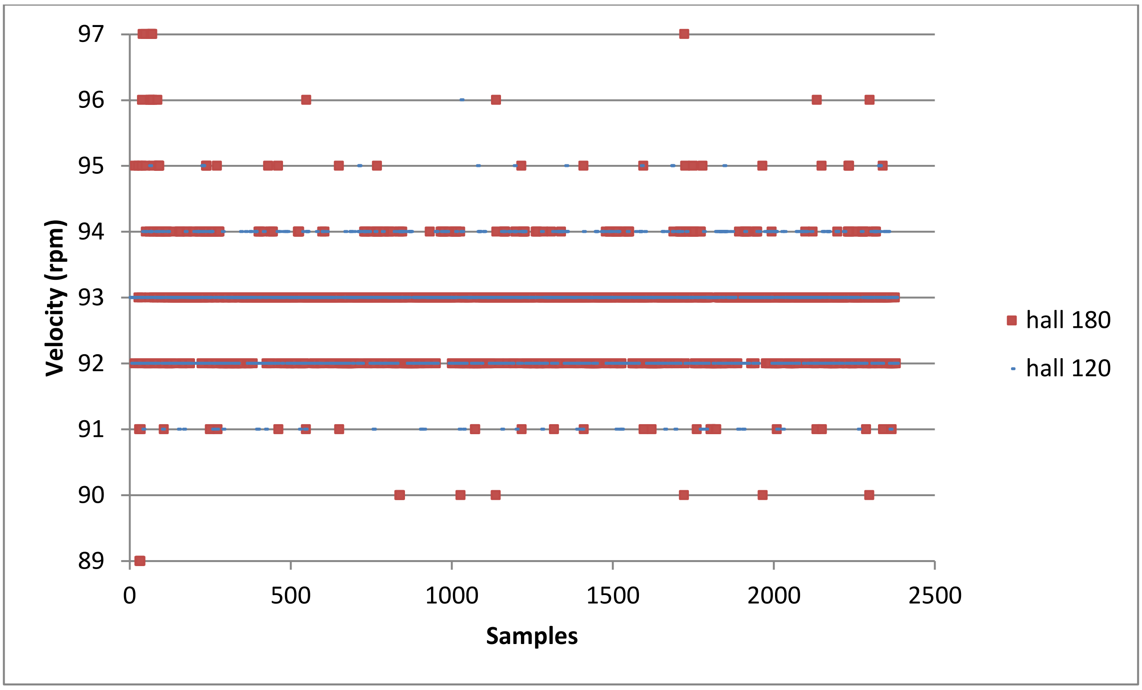

Figure 11. Angular velocity readings from the hall sensor for both 120 and 180 teeth tooth gear.

By analyzing Figure 11, it is clear that the hall sensor got a little better performance in the 120 teeth tooth gear than in the 180 teeth tooth gear. This difference may be related to the positioning of the sensor in relation to tooth gear, the finishing of the teeth and settling of the tooth gear in the system mechanism shaft.

4. CONCLUSIONS

The objective of this work was accomplished, it was verified that the hall sensor can replace the position and linear velocity sensors, as its done in the SportDevices data acquisition module.

For the test bench system, the hall sensor and tooth gear with 120 teeth have proved sufficiently precise in comparison with the other sensors used in the test bench. It was noticed that the tooth gear with 180 teeth needs to be better positioned or have its teeth finishing improved.

An improvement to the hall sensor readings would be to raise its measurements resolution, it could be done by software.

In the future it is intended to use another excitation mechanism to excite the other end of the shock, so that it is in compliance with the Brazilian norm NBR 13308, which deals with "Motor Road vehicles - suspension shock absorbers - Check performance and durability - Test method".

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