RESEARCH AND DIAGNOSTICS FOR THE LABORATORY OF PRESSURE RESISTANT SENSORS

ROMAN ZELNIK, ADRIANA KAMENSZKA, PAVOL BOZEK

Slovak technical university in Bratislava, Faculty of Materials Science and Technology in Trnava, Slovakia

DOI: 10.17973/MMSJ.2021_10_2021041

roman.zelnik@stuba.sk

The use of the sensors shortens the service life, wears out and reduces their accuracy due to operation. For sensors with a susceptibility to inaccuracy, it is possible to create a sensor-device-software diagnostic set. Such a scheme of configuration should be able to provide autonomic diagnostic, calibration, evaluation and also recalibration of the sensor. The diagnostic equipment could also have a shock test function in order to intentionally and faster reduce the service life and thus test the correctly set parameters of the diagnostic algorithm in laboratory conditions. The diagnostic device is a specialized technical system that provides conditions for the future potential of the testing development, knowledge and experience. According to the design, it can be modularly enriched with new parts, fixtures and systems to provide a more diverse range of options. There would be space for exploring the possibilities of new types of sensors, their comparison, as well as full-fledged automation of the complex diagnostic process.

KEYWORDS

sensor, diagnostics, calibration, parameters, control algorithm

1 INTRODUCTION

At the beginning of the work, it is necessary to select the target type of sensor on which most of the testing, development and research will take place. For this purpose, I decided to determine the type of sensor with resistance pressure measurement. It is a technically simple and optimally designed sensor without any electronics, control, or intelligence. The sensor is commonly used for purposes other than direct pressure measurement in industry, but given its availability and price / performance ratio, it is a suitable choice.

2 THEORETICAL BACKGROUND

The primary goal is a multi-purpose laboratory providing new knowledge about sensors from the point of view of a progressive approach to control by computer program. The secondary goal is to gain knowledge about calibration using the autonomous control of the technical system. At the same time, opportunities for research and development of computer programs are offered. The developed application should be able to respond to new knowledge about sensors. It evaluates them and then sets the implementation of the calibration process within the diagnostics. The diagnostic laboratory as a technical system thus offers many possibilities for research, development, and testing for a wide range of specializations.

2.1 Sensor selection

As such, the sensor changes values by applying pressure to its measuring part, and with its simple connection, it is possible to measure its output resistance on a multimeter. As part of our research and development, we will use this sensor with a special encapsulation and connection directly via converters to a computer in real time and from recording also [Daus 2020].

In this case, a special type of industrial weight with the possibility of digital output directly to a computer is used as a standard of accuracy. This will make it possible to compare the results of the accuracy of the sensor and the standard in real time as well as from the measurement record. Another requirement for the standard, in addition to the accuracy and possibility of digital output, is also a specific force range, which will allow us sufficient testing possibilities and satisfactory reliability of the research and development process [Abramov 2015, Bajracharya 2020, Christiansen 2019].

2.2 Sensor diagnostics

Measurements in normal operation are performed by companies dealing with these sensors, however in my case, I will deal with the theory and practice of the sensor, which is to streamline the measurement process by increasing the service life and refining its output measured values, especially in laboratory conditions. In practice, the sensors may behave differently with a small deviation, but we take the laboratory state as required for the initial parameters of the sensor [Frankovsky 2017, Kadiyala 2017].

The biggest challenge is to gain knowledge, information, experience and practice from sensor analysis, as it is a simple device prone to inaccuracy, damage, error and common failures due to operation or damage from production. There are more such states, and constant sensor testing reveals enough failures for us to optimize these states with mathematical corrections at the record level [Bozek 2021]. At the same time, we will be able to clarify cases of fatal sensor failure and prevent irreversible damage, thereby increasing the operational life of the sensor and thus its real use.

The measured results will be evaluated from the stored outputs as well as the original sensor data (Raw data) as well as mathematically corrected values. The correction can be applied only after calibration. Calibration is therefore a necessary analysis, evaluation and correction mechanism of processes, without which measurement in the required quality of output cannot take place [Abramov 2014, Lopez Alcala 2019].

Sensor calibration is part of the diagnostic process, as the whole mechanism begins with a detailed analysis of the sensor, evaluation of the overall condition and a detailed result on the condition of the sensor, including any necessary new corrected values. In addition to the output inaccuracy of the sensor, the diagnostics can also detect errors and failures, which are recorded and the values corrected according to consideration. It may also be the case that, based on the diagnostics, the sensor is determined to be incorrectly correctable (by mathematical limit corrections) or uncorrectable (outside the range of recalculations).

3 METHODOLOGY

The correction takes place at several levels of recalculation according to the most frequently influencing parameters. In addition to accuracy, parameters include other variables such as low load stability, high load stability, maximum load accuracy, overload behavior, and others. In the process of searching for these properties an internal terminology of parameters and phenomena is proposed for the description, representation, and evaluation of the calibration with detailed output [Bishop 2020].

3.1 Correction of sensor parameters

Many names already exist, but for better internal orientation, each parameter is named according to the property so that the international designation of characteristics is respected as much as possible. As a non-standard term, I can mention as an example a variable that has its internal name “overload peak value”, which should be listed as “Po” from the English “Peak Overload”. This parameter Po considers the state when the sensor can no longer display a higher value. There can be several reasons, on the one hand the sensor damage itself, overload, but also the hypothetical limit of the transmitter device. Standardized parameters include commonly known terms such as sensor force range, sensor sensitivity, and so on [Li 2019, Maslakova 2012, Yan 2019].

Expected goals include maximizing accuracy to the desired extent and maximizing sensor life. The condition is the minimization of activities related to diagnostics so that it is performed automatically and efficiently [Nikitin 2020].

3.2 Principle of the diagnostic process

The diagnostic laboratory consists of seven parts (Figure 1.). By combining them into an assembly, an effective whole is created. Each part has its own demanding requirements. For example, the supporting frame (skeleton) has the rigidity to prevent losses of accuracy under force due to its oversizing. Likewise, the electronic and evaluation elements of the assembly have their prerequisites for accuracy, controllability, electronic efficiency and so on [Bucinskas 2018, Tlach 2017].

Legend for figure 1.: 1. Pressure tactile sensor, 2. Communication device, 3. Control computer, 4. Caliber (digital weight), 5. Pressure touch device, 6. Specific 3-axis CNC machine, 7. Supporting frame (skeleton).

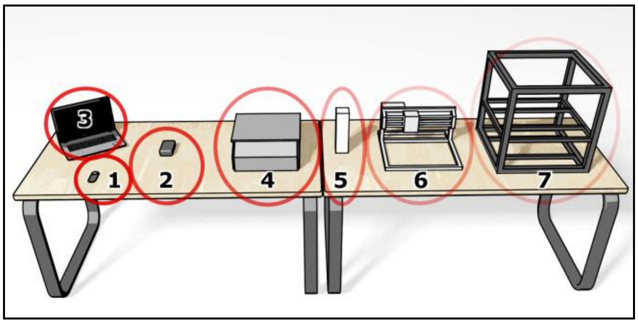

Figure 1. Diagnostic laboratory – assembly parts

3.3 Options of pressure tools diagnostic

For the purposes of dynamic diagnostics of sensors, a specialized pressure device is designed. Its primary function is to apply pressure to the sensor. The secondary function is a variable force decomposition system. The force is formed by the vertical movement of the CNC head and by the decomposition of the forces in the pressure device [Krivoulya 2016].

The jig anchored on the moving head of the CNC device is used for direct force contact with the sensor. It transforms force in a simple way with the perception of force being dual. The first stage of force development is the movement of the CNC head and the push of the tool jig onto the sensor. The second level of force is a secondary effect of the expanding the inner spring in jig. In the uncompressed rest state, the spring is incapable of reaction without contact and thus does not generate force.

The basic scheme of the effective pressure assembly is consisted by the system:

1. CNC head – 2. Jig – 3. sensor.

When touch with the sensor, a preload is created. When the CNC head moves vertically downwards, the compression of the spring is created. Compression will create a return force for the spring to return the spring to its original state. The force of the spring act logically also when CNC head already does not have any (especially vertical) movement. The spring continues to push constant pressure into the sensor. When the combination of these two types of creating power is possible to diagnose, test and monitor various processes [Dao 2015, Farhat 2019, Chudzikiewicz 2011].

Future benefits of the jig have other significant ambitions in the form of spring variability. By combining springs, it is possible to adjust the progressivity, characteristics, and development of force in the entire compression zone of the diagnostic process [Muller 2020].

4 RESULTS

Calibration as a complex process should in the future take place on a computer as an automated controlled algorithm encapsulated in a control application that analyzes, tests, records the current state as well as previous sensor states and evaluates the current situation. Based on values and comparisons history (state of progressivity/degressivity of sensor precision) detects the process of diagnosing changes and values will attempt to correct the maximum possible degree of accuracy.

For proper diagnosis of the sensors, we propose to implement the device (Figure 2.), which will be apply action force to the desired area of the sensor mechanically. It will be possible to control such a device with a computer. The basic requirement of the device is to perform a vertical gentle movement and the possibility of anchoring the force jig to the pressure head. By force jig we understand the jig that will directly mechanically exert force on the sensor.

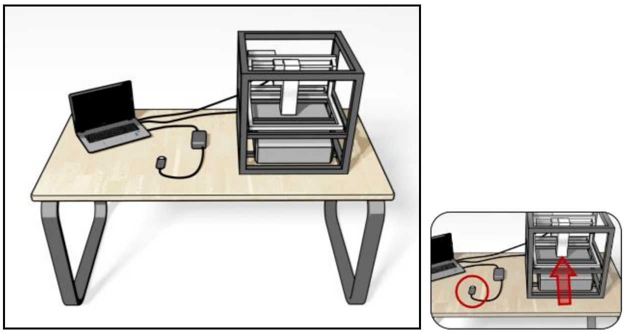

Figure 2. Assembly of diagnostic laboratory in practice

In addition to mechanical security of device operation is needed in the management of diagnostics to create an application (computer program), with the ability to fully control the hardware, collect data from sensor and caliber (etalons devices, e.g., Weight, and so on) (Figure 3.), to assess the status and perform subsequent calculations including output report.

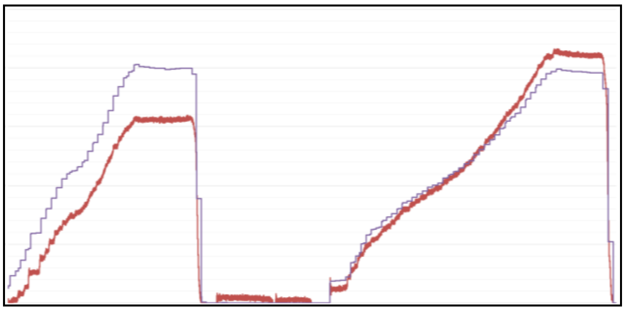

Figure 3. Display of an example of inaccurate sensor curves (red) to caliber (blue) (force range from 0N to 100N in duration 2 minutes)

Under ideal conditions, the computer program should have a dynamic graphical interface, thanks to which it would be possible to design an algorithm for diagnostics. Such interfaces tend to be difficult to design, implementation as well as the operation, therefore, be the subject leaves open according to future needs.

The algorithm for the management of diagnosis can be embedded directly into a single program or may be dynamic in the advanced version of the program (described above). A more complex solution in this case could lead to a better solution and more efficient analysis of parameters. Thus, it would be the algorithm dynamic and user (i.e. user applications) by changing procedures, variables and logic, would be faster and more comfortable create a process called debugging. In this case, debugging is the finishing process of the algorithm design so that we can clearly see the optimal path for maximum use of sensors according to the long-term results of measurements.

5 DISCUSSION

The basic principle of diagnostics is the analysis of the state of life and accuracy of sensors. Diagnostics as a process except analysis also includes calculation, optimization, and comparison. At the end of the process, it provides an overall assessment of the current operability of the sensor. The final report may contain the information about the possibilities of converting any inaccuracies, or on the contrary information about possible irreparable damage to the sensor.

The laboratory results provide a clear analysis of diagnostics, an overview of sensor parameters and an analysis of its behaviour. It is expected to be in the first place, improving the accuracy of test sensors. In the second-place laboratory offers potential for progressive algorithms of diagnostic management.

For the accuracy of the results, it is necessary to be sure that the sensors being measured are reliable from the point of view of the technical system. Otherwise, the entire machine or system diagnostics process is unreliable. Reliability is a key feature of the laboratory, since the draw durability, accuracy and reliability of the sensors can require reliable diagnostic technical system to even greater levels.

6 CONCLUSION

The laboratory for diagnosis has to provide a comprehensive range of processes to achieve the best possible results of the evaluation of the state of the sensors. The evaluation is performed by a combination of mechanical processes with digital computational control using a computer. The plan for successful sensor diagnostics is to analyze the sensor parametrically and determine the diagnostic methodology. In the second phase, construct an operational diagnostic device and create an advanced control program. Each of these topics is planned as valuable long-term work on the details, accuracy, and consistency of the entire output.

Under analysis of sensor parameters, we understand its specifications, as values in the unloaded condition, at nominal load, as well as limit load, at which begins to occur to unwanted damage. Other parameters are the type of characteristic (shape of the gradual load curve), pressure and thermal characteristics of operability and so on. Determining of the diagnostic methodology is designing a procedure for analysis, calibration, evaluation, and testing of sensors. Each of the named processes is specific and it is necessary to design an optimal methodology for reliability. We achieve this state by using a semi-autonomous algorithm for deciding on diagnostic steps. The designed diagnostic laboratory is controlled by a computer in each control zone. The first is the sensor itself connected to the transmitter. The second is a CNC three-axis positioning device with a pusher. The third is a calibrated weight measuring the back pressure. Comprehensive control should take place through a computer program capable of controlling every aspect of the assembly.

Options for future development will bring improvement of laboratory in the expansion of the other types of sensors. We can speak, for example, the temperature and other sensors, which is possible to electronically evaluate. Another development potential is the work on software, which offers unlimited possibilities in the world of machine - computer communication. At the same time, new possibilities are offered for testing future technologies, the potential of using artificial intelligence or exploring database or cloud recording options for complex online processes.

The expectation is not only dispose of equipment and software, but also acquire a number of valuable experience and skills, to push the man forward and create so the potential for additional future project ambitions.

ACKNOWLEDGMENTS

The contribution is sponsored by the project 013TUKE-4/2019: Modern educational tools and methods for forming creativity and increasing practical skills and habits for graduates of technical university study programmes.

Moreover, the contribution is sponsored by the project 006STU-4/2021 „Progresivna forma interdisciplinarneho vzdelavania a podpory rozvoja studia odbornych predmetov v univerzitnom prostredi" (Progressive form of interdisciplinary education and support for the development of the study of vocational subjects in the university environment).

REFERENCES

[Abramov 2014] Abramov, I., et al. Monitoring of technical condition of motors and beargis of woodworking equipment. Acta Facultatis Xylologiae Zvolen, 2014, Vol. 56, Issue 2, pp. 97-104.

[Abramov 2015] Abramov, I., et al. Diagnostics of electrical drives. In The 18th International Conference on Electrical Drives and Power Electronics. EDPE 2015, The High Tatras, Slovakia, 2015, pp. 364-367.

[Bajracharya 2020] Bajracharya, S., Sasaki, E. Investigation of effect of stress on eddy current response using phase diagram. Structure and Infrastructure Engineering, 2020, Vol. 16, No. 9, pp. 1276-1285.

[Bishop 2020] Bishop, P., Povyakalo, A. A conservative confidence bound for the probability of failure on demand of a software-based system based on failure-free tests of its components. Reliability Engineering and System Safety, 2020, Vol. 203.

[Bozek 2021] Bozek, P., et al. Diagnostics of Mechatronic Systems. Springer, Series: Studies in Systems, Decision and Control, 2021, Vol. 345.

[Bucinskas 2018] Bucinskas, V., et al. Research of the New Type of Compression Sensor. Automation, 2018, Vol. 743, pp. 561-573.

[Chudzikiewicz 2011] Chudzikiewicz, A., Sowinski, B. Simulation method of selection of diagnostic parameters in the process of monitoring the rail vehicle's conditions. Structural health monitoring, 2011, Vol. 1, pp. 1103-1110.

[Dao 2015] Dao, A.T. Wireless laptop-based phonocardiograph and diagnosis. PeerJ, 2015, Vol. 3. DOI: 10.7717/peerj.1178.

[Daus 2020] Daus, H., et al. Development of an Emotion-Sensitive mHealth Approach for Mood-State Recognition in Bipolar Disorder. JMIR Mental Health, 2020, Vol. 7, No. 7.

[Farhat 2019] Farhat, A., et al. Impacts of wireless sensor networks strategies and topologies on prognostics and health management. Journal of Intelligent Manufacturing, 2019, Vol. 30, No. 5, pp. 2129-2155.

[Frankovsky 2017] Frankovsky, P., et al. Experimental analysis of stress fields of rotating structural elements by means of reflection photoelasticity. Applied optics, 2017, Vol.56, Issue 11, pp 3064-3070.

[Christiansen 2019] Christiansen, J. M., Smith, G. E. Development and Calibration of a Low-Cost Radar Testbed Based on the Universal Software Radio Peripheral. IEEE Aerospace and Electronic Systems Magazine, December 2019, Vol. 34, No. 12., pp. 50-60.

[Kadiyala 2017] Kadiyala, E., et al. Global industrial process monitoring through IoT using Raspberry pi. International conference on nextgen electronic technologies, 2017, pp. 260-262.

[Krivoulya 2016] Krivoulya, G., et al. Expert diagnosis of computer systems using neuro-fuzzy knowledge base. Proceedings of 2016 IEEE East-West design & test symposium, 2016.

[Li 2019] Li, J., et al. A Remote Monitoring and Diagnosis Method Based on Four-Layer IoT Frame Perception. IEEE Access, 2019, Vol. 7, pp. 144324-144338.

[Lopez Alcala 2019] Lopez Alcala, J. M., et al. User-Printable Three-Rate Rain Gauge Calibration System. Frontiers in Earth Science, 2019, Vol.7.

[Maslakova 2012] Maslakova, K., et al. Applications of the strain gauge for determination of residual stresses using Ring-core method. Procedia Engineering, 2012, Vol. 48, pp. 396-400.

[Muller 2020] Muller, R., et al. Data or interpretations: Impacts of information presentation strategies on diagnostic processes. Human Factors and Ergonomics In Manufacturing, 2020, Vol. 4, No. 4., pp. 266-281.

[Nikitin 2020] Nikitin, Y., et al. Logical–Linguistic Model of Diagnostics of Electric Drives with Sensors Support. Sensors, 2020, Vol. 20, No. 16., pp. 1-19.

[Tlach 2017] Tlach, V., et al. Determination of the Industrial Robot Positioning Performance. 13th International Conference on Modern Technologies in Manufacturing (MTeM-AMaTUC), Cluj Napoca, Romania, MATEC, 2017, Vol. 137.

[Yan 2019] Yan, L., et al. Shock tube-based calibration installation for dynamic pressure transducers and performance testing. Journal of Engineering - JOE, 2019, Vol. 2019, Issue 23, pp. 8577-8582.

CONTACTS:

Ing. Roman Zelnik
Slovak technical university in Bratislava, Faculty of Materials Science and Technology in Trnava
Address: Jana Bottu 2781/25, 917 24 Trnava
E-mail: roman.zelnik@stuba.sk

Ing. Adriana Kamenszka
Slovak technical university in Bratislava, Faculty of Materials Science and Technology in Trnava
Address: Jana Bottu 2781/25, 917 24 Trnava
E-mail: adriana.kamenszka@stuba.sk

Dr.h.c. prof. Ing. Pavol Bozek, CSc.
Slovak technical university in Bratislava, Faculty of Materials Science and Technology in Trnava
Address: Jana Bottu 2781/25, 917 24 Trnava
E-mail: pavol.bozek@stuba.sk