EXPERTISE OF A SPECIALISED FIXTURE WITH A VARIABLE VERTICAL PUSHING EFFECT FOR DIAGNOSTICS OF MEASURING DEVICES

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Sensor diagnostics is an increasingly hot topic nowadays. It helps to improve their operational accuracy, analyze and evaluate their lifetime and monitor wear rates. A diagnostic laboratory has been constructed for force-measuring sensors with the ambition of future experiments. A current topic is the monitoring of the influence of deformation of progressive materials in the measurement and diagnostic process. The deformation and elasticity of these materials is evaluated by measuring the forces in the diagnostics laboratory. To perform the experiment, a specialized jig was made in which measurement segments of different materials were implemented. The main objective of the experiment is the expertise of the influence of elastic material in diagnostics. The expected logical negative factor of using flexible segments is the reduction of the measurable range due to the deformation of the flexible element. An expected important conclusion of the experiment is the increase of the sensitivity and especially the stability of the measurement. The aim of the expertise is to quantify the percentage values of the measurement deviations.

KEYWORDS

sensor, measurement, diagnostics, additive manufacturing

1 INTRODUCTION

Progressive technical systems are part of modern advanced production. They have diverse sensor implementations that can analyze, measure, calibrate and diagnose the system. Currently, force measurement sensors are also being used in the sensor field, and they come in a variety of designs, qualities, and materials [Duhancik 2024]. Our focus in the sensor field is concentrated for standard less precise resistive sensors, which are still frequently used mainly because of their simplicity of design and favorable price. Compared to modern and expensive sensors, these simple ones are equivalently reliable.

Modern times offer us a variety of progressive materials that are used in the industry for prototype development and production as well as in the field of experimentation. Flexible materials are a suitable material for contemporary experimentation [Bozek 2021].

2 THEORETICAL BACKGROUND

The theoretical preparation for conducting the experiment consists of two main parts. The first contains information on the diagnosis and calibration of pressure and force sensors. The second area of the theoretical background defines the main information in the field of additive manufacturing [Daus 2020].

2.1 Diagnostics and calibration of pressure sensors

Current research and development is focused on the diagnosis of these standard pressure sensors, mainly in laboratory conditions. Based on current requirements, a preparation has been developed in the testing and diagnostic laboratory to allow unique testing of different material capabilities and related hypotheses [Frankovsky 2017, Li 2019, Yan 2019].

To enable the experiment to be carried out, a specialized custom preparation was made for use in the actual diagnostic laboratory. Several types and designs of jigs with different construction were proposed within the engineering. The jig has a strict application condition, which is the possibility to change the measuring segments as required. The final version of the jig meets this condition, but also offers other benefits in the measurement application, such as fast and stable anchoring in the jig stabilization head, etc. Other equally important conditions are the rigidity of the design, the stability during measurement and the overall reliability to comply with the specified conditions of each gauge [Dao 2015, Farhat 2019].

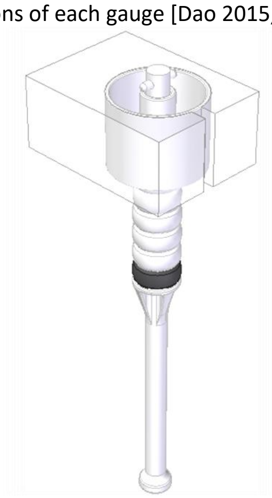

Figure 1. Design of a specialized fixture (with variable vertical pushing effect) anchored in a diagnostic laboratory

2.2 Additive manufacturing in technical systems

Additive manufacturing is the technology of producing solid three-dimensional objects on additive manufacturing equipment of different types but based on the same principle. The spatial object is created on the printer by successive layering and joining of individual 2D layers [Polacek 2017, Vasko 2020].

In additive manufacturing it is also possible to come across the term Rapid Prototyping, which is also a very common term for this method of production. It is already clear from this name what additive manufacturing equipment is designed to do. In most cases, additive manufacturing is not economically suitable for series production, but when it comes to the production of one or a few shape-complex spatial objects, additive manufacturing is unrivalled [Krivoulya 2016, Polacek 2017].

An independent study found that additive manufacturing can accelerate the digitization of existing production processes, and moreover 96% of respondents said that it contributes to faster time to market [Barnik 2019, Bucinskas 2018, Polacek 2017].

3 METHODOLOGY

3.1 Research question and hypothesis

- Research question: "How does the implementation of elastic material affect the force measurement process of pressure sensors?"

- Hypothesis: "An elastic material in the pressure sensor measurement process will allow smaller measurement deviations and a more stable process but will reduce the achievable force."

3.2 Production of prototype parts by additive manufacturing

The test segments are the most important part of the experiment and were therefore manufactured with high quality modern material. Different materials as well as segment shapes were chosen during the testing phase and the preparation of the experiment, where their elasticity as well as their suitability for further measurements were subsequently assessed. These segments are shown in Figure 2.

Figure 2. Types of flexible segment prototypes

The target material chosen was a progressive material of the TPE (thermoplastic elastomer) group of elastic materials, namely Filaflex (Filaflex 82A Skin 1.75mm). In general, we can say that it is a very elastic material with suitable properties for our experiment [Lopez Alcala 2019, Maslakova 2012, Kelentev 2017].

For the rigid segments of the Hard type, PETG material (PETG White 1.75mm) was designed and used. In this case, a material with high stiffness was designed to avoid possible deformations and to create an optimal environment for testing the measurements with flexible segments without the side strain of the other materials. This material was also used for the manufacture of the other parts of the specialized fixture [Christiansen 2019, Nikitin 2020, Tlach 2019].

The equipment used to produce all components is a Prusa i3 MK2.5 3D printer. It allowed us to produce suitable experimental parts according to the needs of the measurement in a high quality and fast way [Muller 2020].

Figure 3. Types of flexible segments

Table 1. Table of flexible segments and their parameters

Segment type	Wall thickness	Infill	Model orientation	Hotend temperature	Material Flow
Type A	0.8mm	10%	horizontally	230°C	110%
Type B	0.8mm	50%	vertically	230°C	110%
Type C	0.8mm	50%	horizontally	230°C	110%
Type D	1.2mm	50%	horizontally	225°C	110%
Type E	1.2mm	50%	horizontally	230°C	115%

3.3 Measurement process and subsequent modification of the acquired data

The measurements in the diagnostic laboratory took the form of an experiment using a specialized preparation designed exclusively for the purpose of material expertise [Dodok 2017, Kuric 2016, Stepanov 2014].

The specialized jig contains the main parts such as the pusher tip, the shank, the function part and the anchoring head. The functional part consists of a simple structure including a cylindrical section on which the measuring segments are integrated. These segments form the practical material part of the experiment, since the experiment has two types of material measuring segments. The segments are interchanged separately and individually within the experiment to produce a sequence of measurements in a logical sequence.

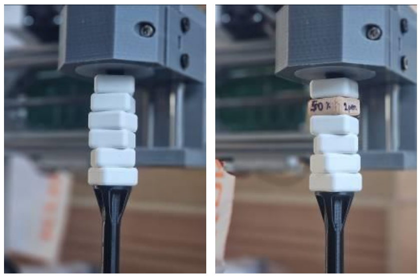

Figure 4. Measurement in the diagnostic laboratory (6 rigid segments on the right, flexible segment between the rigid segments on the left)

3.4 The evaluation procedure of individual measurements

An appropriate visual interpretation is to illustrate the procedure using graphs (Figure 5) in a sequence that describes the data processing steps.

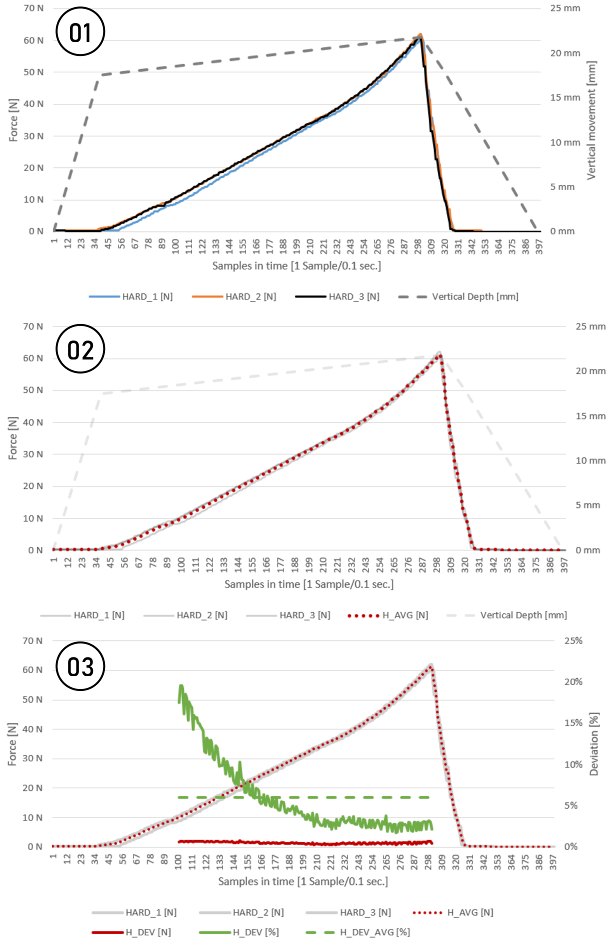

Figure 5. Graphs showing the sequential evaluation steps

The first step is to collect the data of each segment separately in three separate measurements under the same conditions, such as the value of the vertical movement, or compliance with the ambient temperature, etc. In the graph, the effect of vertical motion on the measurement can be seen in all three measurements of each segment.

The second step of data processing is to create an average force from the three measurements, which can be seen in the graph below. The calculated average force matches the nature of the curves and can therefore be legitimately calculated as the final result of the measurement Since even with visual inspection, the average force agrees with all curves with small deviations.

The last mathematical step is to calculate several parameters derived from the average force. These parameters are the average deviation value in newtons, in percent as well as the overall average of the whole measurement. These last parameters can determine the nature of the measurement as a combination of the selected material against the vertical force. To calculate the necessary values, the arithmetic mean calculation (formula 1) is mainly used for a large amount of data (in this case the measurement samples).

$$\mu = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (1)$$

Subsequent data collected continue to be processed sequentially, for each data separately. All results obtained must conform to a common standard and rules so that they reflect the logic and intent of the statistical evaluation.

4 RESULTS

The resulting processed values of the measurements underwent a so-called alignment to a common point, which in this case is determined as the maximum force to which all measurements were concentrated. Subsequently, all variables were evaluated. From the large number of results, target values such as the average and maximum force of the measurement, the average force deviation as well as the overall average deviation are selected. The graphs in the result (Figure 6) show the behavior of the material.

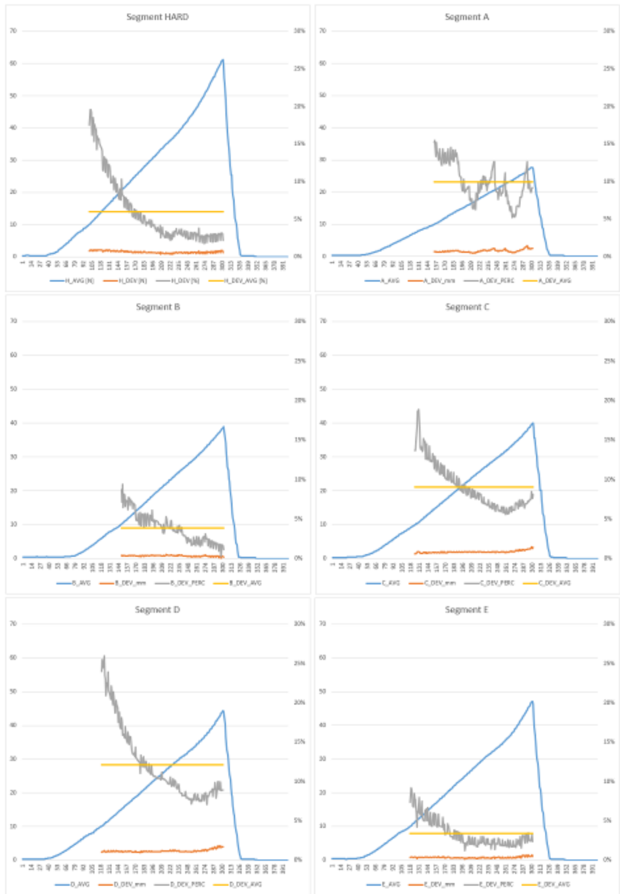

Figure 6. Fully processed charts of individual segments

5 DISCUSSION

The evaluation of the experiment is shown in Table 2. Based on all the values, it is appropriate to focus on the total measurement bias (last row of the table), where two variants with low bias values are appropriate. From these, the appropriate segment with the larger achievable force is then selected (Maximum force row). Thus, for our experiment, the most suitable type of elastic segment comes out as type E, since it has a sufficient maximum achievable force in the measurement and the smallest measurement deviation. It is even more suitable than the Hard segment (Type H), since it was more stable in the measurement with smaller measurement deviation, which has a positive effect on the overall diagnosis process.

Table 2. Table of overall measurement results by segment type

Target variables	Type H	Type A	Type B	Type C	Type D	Type E
Average Force	18.9 N	9.1 N	11.3 N	13.0 N	14.2 N	14.7 N
Maximum Force	61.2 N	27.8 N	38.9 N	40.0 N	44.4 N	**47.1 N**
Average Force Dev.	1.4 N	1.8 N	0.8 N	2.0 N	2.8 N	0.8 N
Average Deviation	6.0%	9.9%	3.9%	9.1%	12.2%	3.4%

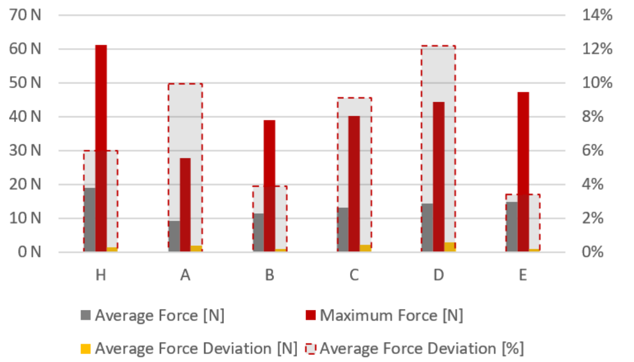

Figure 7. Final experiment evaluation graph

Research Question - Determining the Result

- The implementation of the elastic material proved to be effective in the measurement process. The elastic material was capable of the required deformation, which eliminated inaccuracies and side effects. It is the appropriate combination of the chosen material and suitable manufacturing that is crucial for the optimum properties required.

Methodological test - hypothesis testing

Based on the measurements, the accuracy and repeatability of the measurements were shown to be increased by selecting a suitable flexible material. The measurement deviation was reduced in a more significant way, the achievable force is reduced.

- "The hypothesis has been confirmed".

6 CONCLUSION

The experiments and their evaluation took place in a specialized laboratory designed for the diagnosis of pressure sensors in technical systems. The course of the experiment was enriched by the implementation of research and development of preparations and their construction. The final design of the jig enabled the decomposition of forces in the vertical position, while allowing the refinement and stabilization of the measurement process. The most important element of the experiment is the elastic segment, which has the effect of mitigating the impact force when touching the sensor and refining the measurement process. The disadvantage of the elastic segment is the possible half-mass of force due to material deformation, as well as the issue of accuracy, stability, etc., it is the advantages and disadvantages that the experiment focuses on. Its realization was carried out in each of the five produced elastic segments in three measurements, also measurements with the Hard type rigid segment were realized. The result of the experiment clearly shows two suitable and applicable variants of flexible segments, these are type B and type E. In a detailed analysis of the manufacturing technology, it is not possible to clearly identify one particular initial parameter of additive manufacturing affecting the desired result of the experiment. Thus, it is a combination of parameters that together have a positive effect on production, quality and meeting the expected values.

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