Measurement system for special surface mapping using miniature displacement sensors

Martyna Zowade[1], *Maciej* Bodnicki[1,*]

[1]Warsaw University of Technology, Faculty of Mechatronics, Institute of Micromechanics and Photonics, ul. Boboli 8, 02-525 Warszawa, Poland

Abstract. The aim of the work was to design a special system for measurements of elements with repetitive geometry or assemblies with repeating components, set in a linear patterns. The main focus was based on developing a computer program for signal analysis from variable number of miniature displacement sensors. It was set that the response for displacement of measuring tip from each sensor was a 0-5 V voltage signal with possibility of using different type of sensors. Requirements were determined based on projected measurement method. A special design of sensor was made for testing the computer program. If the characteristics of the sensor is known, it is possible to compute the type A evaluation of uncertainty. The results are presented in XY chart on computer screen. The program allows the user to choose any number of the sensors and determine the distance between them. Also, the possibility of calibration of sensors' set was provided. The test were conducted on a prototype handle for sensors, made on a 3D printer.

Keywords: linear displacement sensor, matrix of sensors, surface measurement,

1 Introduction

Geometric dimensioning is a crucial stage of a production process and obtaining shape and position deviation is no less important than taking the measurements of dimensions. Measurement of shape and position deviation requires some advanced equipment. This, in turn, needs a test method and auxiliary elements, e.g. custom made sensors. An accurate measurement system is needed in the case of precision machines, or when engineering tolerance is low. However, a single one-off method of production in small companies poses an obstacle as maintaining low unit cost of production is fundamental and their access to costly measurement equipment is limited.

Using standard, general purpose sensors might solve the problem. It could be done either by mounting them to a dedicated handle or, taking an entirely different approach, by designing a low- cost custom-made measurement equipment.

In the Institute of Micromechanics and Photonics (IM&P), Warsaw University of Technology a research process led to the design of Hall effect based linear displacement/position sensors, useful for analysed devices [1].

The structure of the system is shown symbolically in Figure 1.

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* Corresponding author: m.bodnicki@mchtr.pw.edu.pl

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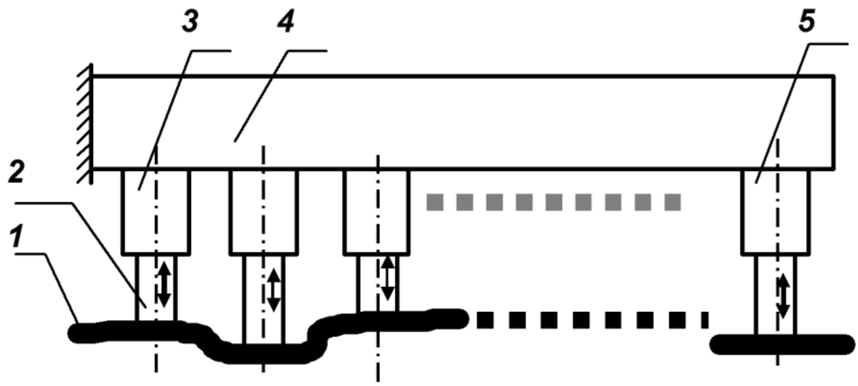

Fig. 1. Symbolic presentation of the idea of the measurement system with set of linear position/displacemnt transducers used for analysis of shape of surface,
1 – analysed object, 2 – measurement tip of the transducer no 1, 3 – body of the transducer no 1, 4 – handle, 5 – body of the transducer no N.

Potential applications include measuring the heights of repetitive elements e.g. such as guitar neck.

2 Mechanical design

Figure 2 shows the designed handle for mounting the transducer assembly. Method of communication between a computer workstation and sensors was necessary when the software was tested. The configuration was tried using a prototype of a linear displacement Hall effect sensor (see [1]) and results were satisfactory. However, the sensor design needs readjustments, e.g. creating an electronic circuit that is mechanically integrated with the sensor.

Fig. 2. Visualisation and real view of the handle with sensors

This solution concerns the manner of positioning the handle in relation to the surface. The device is manually brought close to the measured element on two flat supports. In this design, the handle is made of austenitic steel and the tips have a proper tolerance of flatness.

In order to prevent errors during the research, it was checked/controlled for a possible motion of material due to applied load – see Fig. 3.

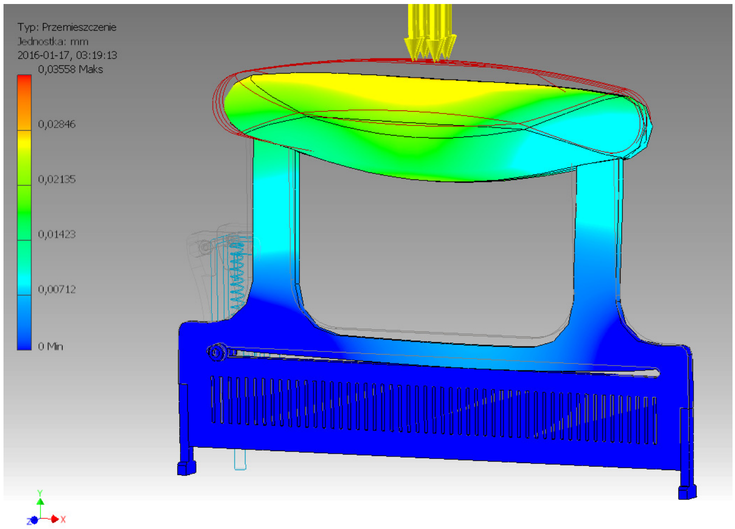

Fig. 3. MES analysis of the handle

3 Calibration of the sensor system

Since reliable measurements/diagnostics require information on the position of sensor's measuring tips, maintaining calibration of sensor position is a necessary condition for properly operating stand. This can be done twofold – mechanically or with a use of dedicated software.

The first method is to design a technique of mounting sensors to a handle so that their position is fixed. This, however, requires reduced/limited engineering tolerance in the production of parts and is not possible to achieve in FDM 3D printing which is a technology employed to create displacement sensor for a matrix.

The alternative involves hardware calibration and taking prefabricated specimens of flatness as a reference. Here, calibration would be done in an early stage of measurement/dimensioning or when the position of sensors is adjusted. Although this method does not require highly precise mounting of sensors, it is nevertheless essential that the shape of a handle does not impede placing it in proximity/close to the specimen of flatness.

4 Software and control system

Figure 4 depicts main elements of the hardware-software system. It comprises mentioned handle with a set of sensors mounted to it. Signals generated by sensors are captured by data acquisition system through controller area network and it is later processed by software. Data transmission is executed by a software-controlled microcontroller. Measurements results are displayed on a user operating panel.

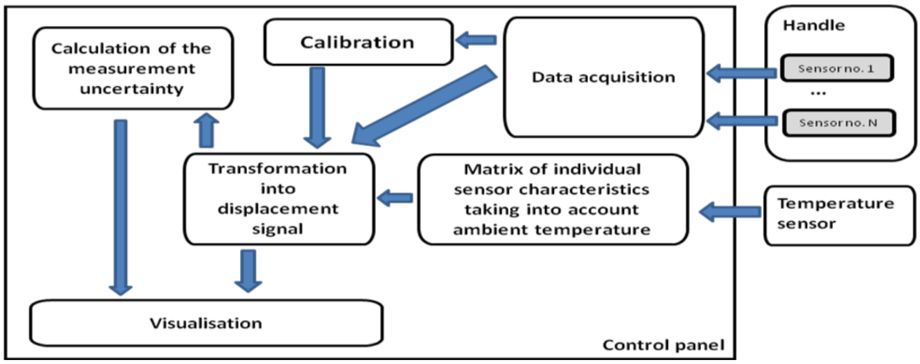

Fig. 4. Structure of the hardware-software system

The software that reads results from sensors through analogue ports was written and installed on a microcontroller. Arduino Platform was chosen for the task as it is user friendly and offers good communication with software.

In the first stage, types of variables are defined and their values are initially set equal to 0. Then, at launching the program, setup loop is run and serial communication (with a selected speed of transmission) begins. When the program is looped, it reads data from analogue ports of Arduino Leonardo board and starts transmitting it with a 10 ms time lag so that LabVIEW program can be run and the synchronisation is not disrupted. Function keys are placed on the left-hand side of operating panel.

User can configure the equipment by choosing a number, characteristics and spacing of sensors along the handle. These settings are saved in the program and can be easily read and applied again if needed. Operating panel and visualisation of the uncertainty are depicted in Figure 5.

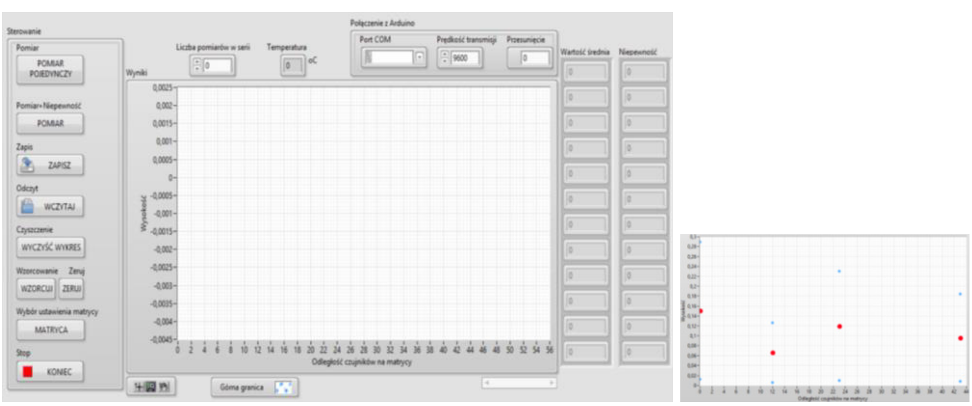

Fig. 5. The control panel and example of the uncertainty analysis for set of sensors

User can choose from available actions:

- one-off measurement,
- full measurement, including Type-A estimate of standard uncertainty (in this case the number of samples must be indicated),
- saving the output data (results of measurement) into a file,
- loading previous measurements,
- clearing a graph before new measurement,
- calibration of the handle,
- sensor settings: selecting number, type and their spacing,

- turning the program off.

The output from sensors depends on the voltage signal on analog input pin of Arduino controller chip and its value ranges from 0 to 1023, in conformity with resolution of the device. In order to obtain a value of the motion of measurement tip these two values need to be properly correlated.

A special test stand was prepared with that purpose, where sensors were tested, as presented in the paper [2]. Settings are saved (with names corresponding to particular sensors) and stored on a computer hard drive.

The handle should be recalibrated if any adjustment of sensor position on the handle was done and before every new measurement. User chooses a number, spacing and characteristics of sensors and every change of their position is stored in the program. It is also important to set proper values in control panel of Arduino controller. Once a calibration is requested by the user, a single measurement is taken and processed in a subprogram. The outcome expresses the length of a strip where sensor tips are in zero point. This is later subtracted from every measurement taken after calibration.

A display where processed data from sensors is plotted as a graph is a central point of operator panel. The graph changes depending on spacing of sensors (as chosen by user) and results of measurement. It is also embedded on a panel at the bottom of the program. There is calibration data, results of single measurement and results of a series of measurements displayed, together with three graphs that accompany it: of results of measurement, upper and lower bounds of uncertainty for particular sensors. Since sensor characteristics are sensitive to ambient temperature, a specific code was implemented which enables user to choose particular values in the course of data processing. This means that individual characteristics of sensor can be updated accordingly to ambient conditions. Sensor is mounted to the handle in two places: by a push-fit into positioning slots and by driving a screw into the handle. If spacing of slots is done properly, this manner of mounting allows using casing of various dimensions and shapes.

Conclusions

Detailed properties of a test system were formulated. A review of solutions for particular functions was done, concerning both the handle for sensors and the computer program. A specific design was chosen and, subsequently, an equipment was built and a program was written and launched. A documented and built system based on a set of sensors of motion is of the aim. All the assumptions concerning the design and functionality of the finally version were met.

A prototype of a handle carrying a set of linear displacement transducers was created. The measurement system was tested for correct operation of the computer program. A demonstration model of the handle was completed and a user manual with measuring algorithm prepared.

Some additional assumptions are met by the computer program, eg. any number of sensors connected to the computer can be supported. This makes the program useful for further research and development of the system. There is a built-in algorithm in the program that sets characteristics of sensor accordingly to ambient temperature. It is done automatically in the course of processing the measurement signal into corresponding displacement. A function that prevents the program from looping in erroneous signal - one that does not match the characteristics of a particular sensor - was also implemented. Thanks to the selected system of storage of measurement data in memory of the computer, it is possible to save information regarding date of measurement, user's id, etc., while using small amount of memory.

It was observed that in case of using prefabricated mounting elements a shrinkage of the material results in sensors protruding from mounting surface. This can be overcome and prevented by either a specific technology of 3D printing that does not cause material shrinkage or a material with better characteristics/properties, eg. PETG. This material has low contractility and, like ABS (used in the research), it is also magnetically neutral.

System was analysed/studied not only for its potential application in a research on guitar necks but also for testing performance of production of parts, with certain tolerance applied.

Moreover, system could be useful in research on wear of material in elements with regular structure, e.g. toothed bars that are used in sliding gates to transform circular to linear motion.

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