Development of the Specialized Contact Highly Productive Scanning Sensor

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Abstract. The article is devoted to the development of specialized high-contact scanning probe, intended to equip the technology of measuring and processing equipment. Conducted a literature review allowed to identify the main types of design solutions for contact measurement sensors on the basis of which was formed by generalizing the decision tree by type layouts. The first part of the selection of parameters is performed using a sensor structure in a simulation environment ANSYS. After selecting the design performed sensor fabrication including the use of additive technology for the production of the main structural elements of the sensor. Experimental studies to identify the calibration curves and the homogeneity of the developed sensitivity of the sensor fields.

Introduction

The conditions and Industry 4.0 IoT are important sensors and sensors of high accuracy, enabling to perform dimensional control parts, workpieces, assembly units, as well as to collect the processes of data errors and accidents occurring in production. Sensors are needed for the creation of high accuracy measurement systems, the demand for which is increasing in various industries and spheres of human activity. Particularly relevant in this matter production GTE blades having complex surfaces of double curvature. Control surfaces of double curvature in the production process is carried out using high-precision measuring systems, which include the coordinate measuring machine (CMM). The accuracy and reliability of the coordinate measuring machine depends on the design used sensor. An important condition for extensive use of measuring sensors in the production cost is relatively low. Proceeding from aggressive media and hard operating conditions, the sensors must meet high standards moisture-dustproof protection, have a relatively high accuracy, and also have optimum weight and size characteristics for easy operation and maintenance. One of the most difficult tasks is difficult to process control profile details. The relevance of the development of specialized high-contact scanning probes is high in the aviation industry and general engineering. Appearances developed measuring sensors are shown in Fig. 1, as: uniaxial not symmetrical measuring sensor used: uniaxial symmetric measuring sensor.

Literature review

A review of the articles in the direction of the development of contact scanning probes. Encoders have a significant influence on measurement errors of coordinate measuring machines [1]. Level measurement sensors perfection offers substantial opportunity to improve the accuracy and performance measurement of geometrical parameters on a coordinate measuring machine [2]. Increasing technological processing characteristics of critical parts, including aircraft engines can be achieved through the use of inline measuring sensors including optical laser machines [3, 4]. The sensitivity and reliability of the contact sensors depends upon their design and materials used in them.
Figure 1. The external kinds of measurement sensors, a) uniaxial not symmetrical, b) uniaxial symmetric

The use of structures with a large number of sensors ray memory location in all directions of deformation, providing enough information on the vector and the unit of force applied to the measuring probe, but such designs have a significant disadvantage of a large limb of the probe during the measurement. The use of smaller amounts of the axes and the sensors reduces the limb at a force probe, but introduces complexity in analyzing data from the sensor. Three axial sensors located in one plane sensing elements are of non-linearity associated with the vector of applied forces. This requires the development of sophisticated mathematical models to compensate for sensor measurement errors with similar designs.

Analysis known designs allowed to form generalizes decision tree represented in Figure 2. The solutions Generalizing tree predictive positive and negative characteristics or properties of this design the contact sensor. With this tree may make certain changes in the already pre-selected design, to reduce measurement errors and approaching the measuring sensor characteristics to the required values. An integral part of measuring sensors are sensors which, depending on the physical principle implemented steps geometrical parameter measured is converted into an electrical value. The design of sensors may be provided as own sensors (SCHE) directly sensing a force or other effects in the measurement of the geometrical parameter or additional sensing elements (DCHE) which indirectly perceive phenomena arising in the measurement of the geometrical parameters and converts them into an electrical magnitude. Application DCHE involves the use of extra transmission elements or mechanisms provided in the sensor design. To implement scan cycle involving continuous contact tip of the measuring sensor with the measured control surface must perform its spatial position. The control problem is maintaining the predetermined mode parameters arising in the contact measurement probe tip and measured surface, to which the nominal pressure force, limits this pressure change, the nominal slip velocity, the allowable slip speed.
limits harmful phenomena arising during probing, such as vibration. The control can be performed based on data from DCHE or SCHE.

Depending on the form of the integral sensitivity zone sensors can be isolate having symmetrical and balanced characteristics. For the purpose of hanging the measurement accuracy, elimination of nonlinearities occurring during the conversion of the measured geometrical parameter, it is desirable to use sensors with symmetrical integral sensitivity zone. It should be noted that the various tasks and areas of application can tolerate sensors not symmetrical integral sensitivity zone, which often reduces the cost of the sensor.

The work will be considered the task of developing single-axis sensor for process control difficult profile details. Selecting new sensor arrangement execute based on the results of experiments conducted with the use of uniaxial not symmetric sensor developed previously [6]. According to the results of experimental studies, it was decided to apply the principle of symmetry in the design of the new sensor. The issue is not fully resolved and requires further research.

**Theoretical part**

Finite-element model, which can be used for sensor selection and design of rational geometrical dimensions and for the specified requirements developed in MATLAB and ANSYS systems. Scheme designed finite element model of the sensor shown in Figure 3.

![Figure 3. Scheme of a finite element model of the sensor](image)

During the measurement process, the point of contact of the ball 1 and the measured surface 12 acts reaction force F, through which the leg of the probe 2 is transmitted to the tool holder 3 and the clamp 4. This creates an effort in the elastic element 5, such as a carbon plate, resulting in its deformation. On its surface pasted sensitive elements 6 in the form of strain gauges, the contacts of which are defined in the finite element model (FEM) type - Bonded, or converting a force or other effects occurring during the measurement into an electrical magnitude. The elastic member 7 is pressed against the hold-downs to the vertical supports 8 provided on the base of the measuring sensor 9. The contact surface 10 between the supports, the elastic member and the clamps are set in the finite element model type - Bonded. measuring sensor in the base of the FEM is assigned to limit displacement in space.

The finite element model can account of different materials: D16 aluminum, steel, carbon fiber. Mathematical model of the elastic element of the material, which acts as carbon fiber, has been verified by means of tests of prototypes made from the same material.

Performing research to develop sensor under the specified requirements conducted in accordance with the flowchart shown.
Studies two measuring sensor arrangement were examined with a different arrangement of the plate and carbon fiber probe shown respectively in Figures 5.a and 5.b.

Arrangements for data in the system ANSYS simulation was conducted impact forces measured on the surface of the measuring tip. Particular attention was paid to the task model material carbon fiber plate. We considered various ways of specifying the parameters and the force vector applied to the tip of the probe.

The developed finite element model makes it possible to perform the calculation for a single experiment with the given parameters. must perform a series of experiments at different input parameters for constructing stray fields developed sensor sensitivity. This calculation has been automated with the use of MATLAB system, the system loads the appropriate settings for the current experiment, launched a calculation, and then performs the export of the results to a file.

Research
The developed sensor is designed to solve the problems associated with partial automation of industrial processes such as the dimensional control parts, workpieces, assembly units. The basis of measurement is the principle surface contact method. Control of the geometry of the measuring object is performed by determining the coordinates of the touch surface to be measured and the probe. The tip of the probe is made of synthetic ruby, having high hardness and wear resistance, thus ensuring high stability of operation and durability of the probe.

Analysis turbomachine blade geometry limits of variation shown applying a force to the measuring tip angle: \( \alpha \in [0; 360], \beta \in [60; 120] \). The simulation was calculated change in the strain gauge length arising from a carbon fiber stiffener plates and the change in coordinates of the probe center. Field sensitivity dispersion for sensors, with the first version and new designs are shown in Figures 6a and 6b, respectively.
Picture 6. Field sensitivity dispersion: a) uniaxial sensor is not symmetrical; b) uniaxial symmetric sensor

According to the calculation results of the analysis of the data revealed a strong change in sensor sensitivity. It was found that the introduction of symmetry in the sensor design has resulted in a dramatic increase of hardness sensitive element and consequently reduce the sensitivity of the sensor. But desensitization compensated by the presence of large amounts of data collected from the sensor, which allows to estimate and compensate for errors with increased accuracy.

Experimental studies on the measurement of the geometric pattern with known geometry, sensor calibration and measurement repeated patterns was performed to determine the accuracy of the developed sensors. We designed the sensor there is a high repeatability of measurement results.

Conclusions
During the study, it was designed with the basic measurement sensor sensors strain gauges. To improve the accuracy and reliability of the measuring sensor calculated mathematical model, two principal variants flowmeter sensor arrangements have been developed and analyzed. According to the results in the ANSYS simulation system layout has been selected for the developed sensor, allowing us to obtain a greater amount of data needed to analyze errors and improve measurement accuracy. After the analysis of the fields were obtained simulation dispersions integral sensitivity of the sensor. According to the results of practical experiments were constructed a graph of change of the strain gage resistance from vector applied to the measuring bulb strength. It can be concluded, developed that perform the tasks sensor, characterized by a relatively low cost, small weight and size characteristics, the accuracy of measurement reference element is 3-4 m. Measuring sensor will be used for process control high geometry gas turbine engine blades.

Further studies are planned in the direction of the development of high-contact scanning probe. Will be developed issues of increasing measurement accuracy and improving the integrated area sensor sensitivity due to the use of data obtained during calibration of the mathematical function for generating the sensor measurement error compensation. Using the functions of compensation errors will significantly speed up the operation of the sensor and to increase its accuracy.

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