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Manufacturing technology of a two-axial fiber-optic accelerometer

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Abstract. The paper presents the results of the development of constructive-technological parameters of a differential two-axial fiber-optic accelerometer with a cylindrical lens, which are basic elements of technical solutions in fiber-optic sensors of accelerations used in the industry in automated control systems.

Introduction. The widespread introduction of fiber optic technology in the aerospace and aviation industry requires the development of constructive and technological solutions of fiber-optic accelerometers (FOA) based on application of modern technologies, materials, which ensure their high metrological and operational characteristics, low cost, high manufacturability constructions, functionality in the most severe operating conditions, minimum weight and size. Because of this, the development of optimal manufacturing techniques for production of differential FOA is relevant.

Description of the constructive scheme of the differential fiber-optic accelerometer. In [1, 2], the authors developed a fiber optic accelerometer (FOA), designed to measure the acceleration in two coordinates (see Figure 1).

Figure 1. The constructive scheme of differential FOA

FOA consists of a housing – 1, two elastic elements – 2 in the form of an H-shaped leaf spring, the upper ends of which have four cylindrical lens – 3, and the lower ends are secured in the node adjustment – 4, an input optical fiber (IOF) – 5, four diverters of optical fibers (DOF) – 6, optical...
fibers. A node alignment is a cylinder, which is inserted into an opening in the housing. Adjustment is carried out by setting the thickness of the cylinder washers in the range of 0.01 ... 0.1 mm by 0.01 mm. To prevent accidental movement of the adjustment assembly in the housing and on the cylinder, there are grooves into which a key is inserted. After adjusting, the cylinder is rigidly secured to the casing of pulse welding. The optical fibers are arranged on the main part of a circle so as to avoid unnecessary bends. Moreover, IOF 5 is disposed at DOF 6 and is spaced apart by spacers 7. The main optical axis coincides with the IOF main optical axis of lens 3. The top view only shows DOF 6 and only one adjustment unit 4 of four.

The accelerometer works as follows. Under the influence of the acceleration deviation, elastic members 2 occurs from the static state under the influence of forces of inertia acting on the inertial mass and, as a consequence, moves in the directions of the X and Y axes of optical elements 3. Elastic elements fixed to base 2 via nodes alignment sensor 4. Since FOA are both measuring channels, they are connected differentially while moving optical element 3 with the increase of the optical signal intensity of the first and third measuring channels, while the second and the fourth ones are reduced. Light fluxes, having passed through optical elements 3 at DOF 6 of the first, second, third and fourth measurement channels, received photodetectors (P) of the first, second, third and fourth measurement channels, respectively. P converts optical signals into electrical signals, respectively.

The differential, converting optical signals, reduces the impact on the accuracy of the measurement of the non-informative bending fiber-optic cable, changing the radiation power of the light emitting diode and P sensitivity, as these factors cause proportional changes in the signal channels, which do not involve a change of attitude signals.

In the developed accelerometer purchased components are not applied, except for the cylindrical lenses, made of the quartz glass rod. Lenses obtained from the optical quartz glass, have a number of optical properties required for special, high-precision optical systems, as compared with lenses made of natural quartz glass [3]. Dimensions of the lenses are calculated and selected based upon the design parameters of an accelerometer [4]. In particular, the design uses a cylindrical lens blank diameter of 3 mm and a length of 2 mm.

After selecting the structural parameters of the optical element, parameters of the elastic element were calculated. For this, it is necessary to use steel 36NHTYU.

Production of structural parts of the sensor. The technological sequence of manufacturing FOA is the following.

Stage I Production of details

1) A plane-parallel spring of an H-shaped configuration of a given size (Figure 2) is produced by stamping.

After punching, a visual inspection of the spring for defects is performed. Ticks, jams and other mechanical damage caused to the spring are called defects.

2) The elastic element of the material is manufactured with the help of laths thickening the lower part of the resilient member. They simplify the assembly of the sensor and reduce manufacturing costs.

3) Elastic members are made of the material aligning the gasket size from 0.01 mm to 0.1 mm by 0.01 mm. Gaskets are stamped from sheet metal. They are brought to the desired thickness by grinding. Control of the thickness of the pads is carried out by a precision dial indicator. Sharp edges and burrs on metal pads are not allowed.

4) The base of the right diameter is made by turning from bar steel 12X18H10T.

There are:
- milled holes a) pins performed against rotation, b) sensors and optical fiber holders;
Figure 2. The elastic elements of an H-shaped configuration

Figure 3. A base

Figure 5. Element node alignment

Figure 6. A choke

Figure 4. A cover with a housing

- drilled holes for mounting a) alignment units, b) optical fibers;
- tapped micro screws holding the optical fibers (Figure 3).

5) By stamping and then grinding the gasket with thickness 0.09 mm in size, equal to the size of the base, was made, which serves to separate the IOF and DOF. It is necessary to keep the size of the settlement that will reduce uninformative bends of the optical fibers without losing the rigidity lining. An allowed increase in the size amounts to 0.1 mm, which exerts virtually no effect on the accuracy of the optical signal transmission.

6) The method allows turning the accelerometer body made of steel 12X18H10T (Figure 4) to the size required for installation in a base of the sensor. On the outer contour of the housing three screw fasteners are milled. A hole for the fitting installation of the fiber optic cable is drilled. Sharp edges are rounded.
7) The rod is cut from steel with necessary thickness of the circle, which serves the housing cover of the accelerometer (see. Figure 4). The plane of contact with the casing cover is polished for its close contact with the body.

8) Turning and milling the metal rod, the unit alignment was realized. The rod is a cylinder with two slots, one of which is designed to fit the pin from the rotating cylinder at the base of the sensor, and the other - for setting the lower parts of the sensor to thicken the pads (figure 5).

9) By turning the pin, a box is made with the needed sizes.

10) The fitting was machined for the fiber optic cable from bar steel 12X18H10T in which a through hole is drilled for the cable (figure 6).

After making all the structural parts of the sensor, we can move on to its assembly.

Stage II Assembling and mounting the sensor

1) Assembling the sensor should start with the connection of the optical elements with elastic elements (Figure 7a). Before assembling the sensor, make sure that the optical and the elastic member is free from defects.

The upper ends of the H-shaped spring is wrapped around a cylindrical lens and welded with dot pulse welding. Since the metal elastic element is sufficiently thin, it is necessary to choose the value of the welding current and pulse time in order to achieve a reliable connection and prevent burn-out of the metal.

In one elastic element, it is necessary to place two optical elements. During assembly, it is important to ensure alignment of the optical elements to prevent sensitivity reduction of the optical system. For these purposes and for the convenience of feeding contacts, the welding machine uses a special technology mandrel.

2) At the bottom of the sensor, there are two sides set and welded with the laying thickening (Figure 7b). This is done for ease of connection of the lower parts of the elastic member with the alignment unit. Simultaneously, this lowers the manufacturing cost of these units, since it becomes possible to make the groove in the larger adjustment assembly using less accurate equipment.

Suitable dot pulse welding electrodes are applied only to the bottom of spacers and the elastic member to prevent the metal spring vacation above the thickness of the gasket so that no damage may occur during the spring.

3) There is an adjustment of assemblies with the inserted elastic element having thick pads welded to it with argon arc welding (Figure 8).

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*a* - place point-pulse welding; 2 – elastic elements; 3 – cylindrical lens; 8 – thickening pad

**Figure 7.** The compound elastic member: *a* – with lenses and *b* - with thick linings

**Figure 8.** The compound lower portions of the elastic member with the alignment assemblies
2 – elastic elements; 3 – optical elements; 4 – assembly adjustment; 9 – pin from turning; 10 – base;

**Figure 9.** The connection scheme of sensing elements with the base of the sensor

It is important to connect the elastic member to the weld alignment nodes in the lower part of the elastic elements. Welding must be carried out in the technological mandrel by controlling the alignment of the alignment units. This prevents undesired deformation of the elastic element during assembly and handling, as well as manufacture of metal mandrels allows heat from nodes to align during welding, preventing the further deformation of the rental metal of the elastic element. Weld after cooling must be sanded to ensure that it does not prevent the placement of the nodes at the base of the sensor alignment.

4) Sensing elements with nodes installed in the base of the alignment of the accelerometer, set pins from turning (Figure 9). After adjustment (p. 5 of step 3), components are welded firmly to the base of the sensor.

**Stage III Assembling the sensor**

1) Assembling the sensor starts with the connection of fitting fiber optic cable to the housing of the sensor (Figure 10). Socket 11 is inserted into the hole in body 1 and is welded to the housing by argon-arc welding. When installing the fitting, it is necessary to make sure that it does not protrude into the interior of the housing. If a part of the nozzle body acts, it is necessary to grind off, otherwise it will interfere with the mounting base on the housing.

2) After cooling the metal body, we set the foundation with established sensing elements (see Figure 10 in the drawing are not shown) and welded them with argon arc welding.

3) The free ends of the IOF 5 and DOF 6 of fiber-optic cable (FOC) 12 are extended through the opening in fitting 11 into housing 1 (Figure 11). IOF 5 and DOF 6 are stacked on base 10 with the required bending radius and are fixed using microscrews 13.

4) Preliminary alignment of IOF 5 is made with respect to lens 3, which provides the required metrological characteristics of FOA.

**Figure 10.** Connection fitting and housing, the connection of base and housing

**Figure 11.** Installing the fiber-optic cable socket
After adjustment, IOF 5 is attached to base 10 (Figure 12) by means of adhesive sealant on gasket 7 (see, Figure 11).

5) Setting of DOF 6.
6) Making the final alignment and adjustment of the sensor.
7) Adjustment mechanisms are welded to the base pulse welding.
8) DOF adhesive sealant.
9) The head microscrews are further secured with adhesive, sealant to the base to prevent them from loosening during vibration.
10) The cover is installed and welded to the housing with argon-arc welding. This containment of the fiber optic cable is not attached to the connector for the possibility of release of gases from the cavity of the sensor.
11) After cooling the sensor body, the fitting dresses sheath 14 of cable 12 is further sealed with adhesive, sealant, and is attached to the socket by means of collar 15 (see Figure 11).

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