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POSITION SENSITIVE DETECTOR RESEARCH

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***Abstract**: The scope of this paper is investigating of PSD (position sensitive detector) diodes which enable non-contact measurements of relative displacements between machined workpiece and tool coordinate system in a lathe. In this work, the construction and principle of operation of such sensor is discussed. As a result of conducted research, static and dynamic characteristics of bespoken sensors were determined*
***Key words:** PSD sensor, static and dynamic chracteristic*

1. INTRODUCTION

The inspiration for conducting research over PSD diodes were attempts of their application in manufacturing systems known from the literature (Krzyżanowski,2005, Tonshoof & Inasaki, 2001, Beziuk & Marek 2008).

The objects of research were two models of displacement sensors built on Wroclaw University of Technology based on PSD diodes types 1880 and 2044 of Hamamatsu (fig. 1, 2).
The 1880 version has a larger light-sensitive matrix compared to the 2044 model.

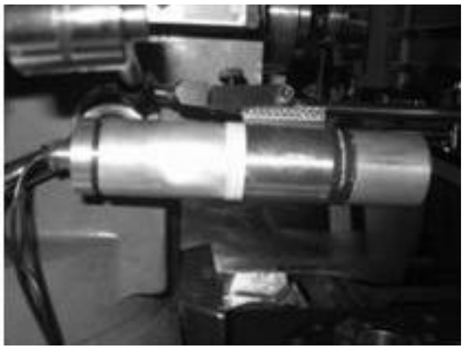

Fig. 1. Diode 2044 mounted on a milling machine

2. CONSTRUCTION AND PRINCIPLE OF OPERATION OF A PSD PHOTODIODE

PSD (Position Sensitive Detector) sensors for continuous operation (Skoczyński & Marek, 2008,) are constructed as diodes with PIN structure (fig. 3). PIN-type structure is built of an extensive, mildly doped internal layer of a semiconductor between heavily doped external type P and N layers. Ohmic contacts are usually placed on the outer layers. PSD diodes utilise a local photoelectric effect to detect the position of a spot illuminating the surface of a diode. Highly resistive type P layer together with a P-N junction form an active area of a PSD diode. When a P-N junction between layers 1 and 2 is illuminated by a light beam, a photocurrent starts flowing due to the photoelectric effect. The current obtained this way flows from the illuminated area in the direction of a, b, c and d anodes. A current signal from Ohmic contacts a, b, c and d of the diode allows determining the location of a mass centre for the light spot in relation to the point of symmetry of the active area.

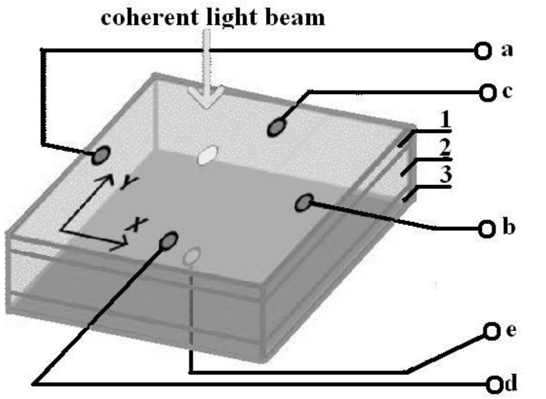

Fig. 3. construction of a four-sided PSD diode. 1 – heavily P-type doped layer (P), 2 – mildly N-type doped layer (Intinsic - I), 3 - heavily N-type doped layer (N), a,b,c,d – anodes, e – cathode

Utilising the following relationship:

$$\frac{I_b - I_a}{I_d - I_b} = \frac{2x}{Lx} \qquad (1)$$

$$\frac{I_d - I_c}{I_c - I_d} = \frac{2y}{Ly} \qquad (2)$$

where I_a, I_b, I_c, and I_d are currents from anodes, respectively: a, b, c and d, Lx and Ly are distances between anodes a-b c-d respectively, while x and y are unknown coordinates of the spot mass centre, it is possible to determine analytically the coordinates x and y. A special power supply and conditioning module has been built to be used with PSD diodes by Hamamatsu, types 2044 and 1880. Voltage signals from X and Y channels from the constructed circuit are proportional to the position of a spot on the diode surface according to x and y coordinates.

3. STATIC CHARACTERISTICS OF A PSD DIODE

A test stand was built when the photodiode circuit cooperated with a laser interferometer LSP 30 by LASERTEX. A PSD diode with a conditioning-power supply circuit and a laser illuminating the diode's matrix were powered by a stabilised power supply by NDN type DF1731SB5A. A milling machine was used as a control element – table's feed mechanism was used for controlling displacements. Voltage signal obtained from the PSD diode was visible in form of a spot on a screen of the oscilloscope. During the determination of static characteristics of a PSD diode, the milling table was moved in the direction of the laser interferometer in such way, as to ensure that a light spot illuminating the active matrix of the diode moves around the entire measurement range of the transducer.

Fig. 4. Test stand for measuring static characteristics of a PSD diode (1-PSD diode with conditioning-power supply circuits in a housing, 2-stabilised laser cooperating with the diode, 3-stabilised power supply NDN DF1731SB5A, 4-two-channel oscilloscope HP 54645A, 5-optical device cooperating with a measurement laser head, 6-laser head of the LSP 30 interferometer, 7-table of a FWD-32J milling machine; 8-magnetic base holding the PSD diode with its PCB, 9-vice for fixing the stabilised laser)

A displacement step was determined by a voltage change read from the screen of the oscilloscope. Each time when the displacement of the table was read, a real step was read from the screen of a computer controlling the LSP 30 laser interferometer and was logged with the read voltage value. The results of determining static characteristics of PSD diodes with the use of such method are presented below (fig. 5)

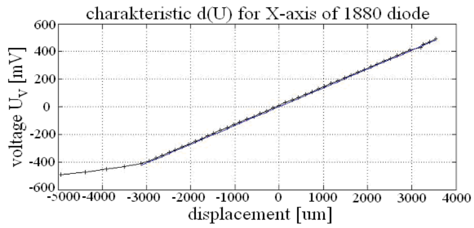

Fig. 5. Static characteristics of a measurement system with a type 1880 photodiode

4. DYNAMIC CHARACTERISTICS – PSD PHOTODIODES

A photo below (fig. 6) shows a test stand for determining dynamic characteristics of PSD diodes.

A PSD photodiode (1) was fixed on a stand (11). The diode cooperated with a stabilised laser (10) powered by a flat battery type R12 (12). The stabilised laser, together with a reference sensor-accelerometer 4384 (2), were fixed to a shaker (9). A stabilised power supply (3) was used to supply the diode. The photodiode was powered symmetrically by a voltage of +/-12 [V]. The accelerometer was powered by a charge amplifier (5). The shaker (9) was supplied by a power amplifier (8). The amplifier was controlled by a signal from a generator (6). Dynamic characteristics were measured for both axes of the investigated sensors. Before starting measurements, the light spot on the active matrix of the PSD diode was set and the diode's axis was adjusted so its axis matches the axis of operation of the shaker. After setting the axes of the sensor, laser spot was located in the middle of the PSD diode's active area. In course of research, the characteristics of PSD photodiodes were investigated in the frequency range of 0-620Hz. Constant amplitude of excitations was set and frequency was altered. The obtained dynamic characteristics of PSD photodiodes are shown below (fig. 7).

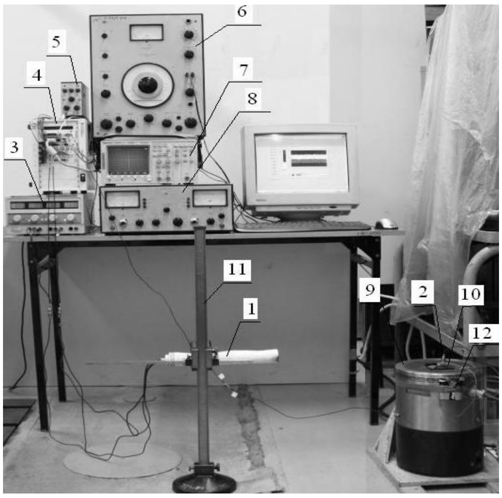

Fig. 6. Test stand for determining dynamic characteristics of PSD diodes (1-PSD diode with power supply and signal conditioning module, 2-accelerometer 4384, serial no. 1320379, 3-stabilised power supply NDN DF1731SB5A, 4-PC with a NI PXI-4472 measurement card, 5-amplifier type 2635 by Bruel & Kjaer, 6-generator Bruel & Kjaer type 1022, 7-two-channel oscilloscope HP 54645A, amplifier type 2707 Bruel & Kjaer, 9-shaker Bruel & Kjaer, serial no. 1412675, 10-stabilised laser cooperating with the PSD diode, 11-stand, 12-flat battery

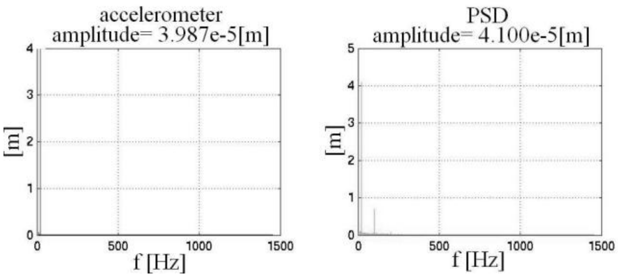

Fig. 7. Dynamic characteristics of a PSD photodiode 1880, OX axis for frequency of 20 Hz

5. CONCLUSION

As it results from comparing above data, the investigated PSD photodiodes have characteristics very similar to these from the reference sensor. Static characteristics are linear in the entire measurement range. This is of high importance from the point of view of applying them in diagnostics of machine tools, as well as in monitoring and diagnostics of manufacturing systems.

6. REFERENCES

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