Measurement information security when using mechanoluminescent sensor elements with distributed sensitivity in aerospace engineering

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Abstract. Electromagnetic compatibility and protection of data transmission lines is currently one of the most important requirements for elements of modern technical devices. Especially should be considered the possibility of electromagnetic compatibility when introducing new sensors into operating technical systems. Fiber optic sensors, operating in generator mode and producing signals of an optical nature, are not susceptible to electromagnetic interference and do not emit interference into the surrounding space. Distributed mechanoluminescent pulse pressure transmitters belong to this type of sensors. One of the most important elements of this type of sensors is the transmission channel of the output optical signal. The analysis of the possibility of using fiber-optic harnesses for the transmission of measuring information is carried out.

1. Introduction
Ability to analyze a large amount of information very quickly allows you to constantly improve technical systems, including autonomous ones. To obtain information about the action of mechanical forces on working bodies, manipulators and bodies of mobile and stationary technical devices, sensor systems of contact interaction are used. In addition to receiving information about mechanical contact, tactile sensors are also used to determine the geometric characteristics of objects and to localize external influences. One of the most important requirements for modern tactile sensors is high sensitivity, high resolution, small dimensions, durability and reliability. There is a specific class of sensors designed to work in extreme conditions. For example, such as strong electromagnetic, thermal and radiation emissions, work in conditions of strong gas pollution and high explosion hazard. Besides electromagnetic noise immunity, an important characteristic of sensors is also electromagnetic noise emission. This parameter is becoming more and more important, since a sufficiently large number of electronic devices can be installed on one device and they can interfere with each other with their own electromagnetic radiation.

2. Mechanoluminescent sensors and composite materials
A mechanoluminescent sensor (figure 1) is a structurally isolated device or composite material, consisting of several materials rigidly connected to each other. In the sensitive element of the sensor, the impact energy is converted into mechanical stress acting on a certain area of the mechanoluminophor [1]. In this case, the glow of the phosphor will be observed. The mechanism of luminescence in mechanoluminophores is described in [2,3,4]. To ensure plastic deformation of the phosphor crystals
under the action of mechanical stress, impart rigidity to the sensor design, and to enable transmission and processing of the output optical signal of the sensor, the phosphor must be tightly pressed against the sensitive element using a transparent base. There is also the possibility of creating composite structures with the properties of detecting mechanical effects using mechanoluminophores [5,6,7].

**Figure 1.** Block diagram of a measuring device with a tactile mechanoluminescent pulse pressure sensor.

**Figure 2.** The implementation of mechanophosphor optical fiber with lengthwise light input into the optical waveguides in the composition of the composite material [5].

Such a sensor (or composite panel (figure 2) is functioning in a generator mode, can be removed from the registration and processing unit and generates an optical signal suitable for subsequent transmission, registration and processing. The transmission of the light information signal to the matrix photodetector is performed via the optical communication channel (open, closed optical channels, fiber-optic bundles). At the registration stage, the information signal is converted from optical to electrical and enters the information processing unit.

3. **Practical implementation**

Practical implementation of registration and measurement of external mechanical impulse influences with a distributed mechanoluminescent impulse pressure sensor can be carried out in different ways. The sensor can be a composite panel with SHM properties (figure 3) [8] or a device with a certain area of the sensitive element with a closed optical channel and a fiber-optic bundle for image transmission (figure 4).
Figure 3. Mechanoluminescent composite SHM panel with side input of radiation into the optical fibers: 1 - contacting object; 2 - protective coating; 3 - mechanoluminophore; 4 - transparent substrate; 5 - optical fibers with side light input (columns); 6 - optical fibers with side light input (lines); 8 - base; 9 - optical fibers with an end output of the glow; 10 - multi-element linear photodetector; 11 - signal processing unit.

Figure 4. Transmission of an optical measuring signal through a fiber-optic bundle with a uniform arrangement of fibers.
When determining the possibility of introducing a new type of sensors into existing technical systems and devices, it is necessary to work out the issue of its compatibility with other sensors and devices that ensure the operation of the system. In view of the fact that the overwhelming number of sensors and systems which powered by electricity and generate signals of electrical nature, there is a question about the electromagnetic compatibility of these devices in modern technics. Consider the security of measurement information with such an organization of data transmission from the sensor to the data processing unit.

4. Compatibility of devices and security of transmitted data

Interference emission - the emission of interference by the device during its operation. Theoretically, any technical device can act as a source of interference, the level of which depends on the principle of operation and the features of its design. A wanted signal from one device can interfere with another.

Typical sources of interference can be [9]:

- switching of an asynchronous motor, creating impulse voltages;
- computer technics generating interference in a wide frequency range;
- semiconductor converters leading to voltage sinusoidal distortion, low-frequency, pulse and high-frequency interference;
- DC motors generating interference in a wide frequency range;
- radio equipment and its antennas emitting a useful signal that affect other devices;
- external influences.

Installation of an electronic device in any technical system, it will act as a source of interference [9]:

- from the printed circuit board (power, synchronization and data circuits, video amplifiers, generators, etc.);
- from electrical cables (placing the photodetector in the sensor will require, in addition to transmitting an electrical measuring signal from it, also supplying power to it).

When deciding the placement of electronic devices, it is necessary to determine how a source of electromagnetic interference (a sensor with a power supply and an electrical output signal) will be associated with a receptor (in other words, a receiver of electromagnetic and radio interference). This can be common resistance communication (wired connection, magnetic induction, electrical induction), or distributed communication in the near field (low frequency, high frequency), or communication over the power supply network. In addition to preliminary calculations, it will be necessary to test the device for electromagnetic interference emission.

Distributed mechanoluminescent sensors operate in a generator mode and do not require power supply, and the information optical signal is transmitted through fiber-optic communication channels. In addition, the information processing unit can be installed remotely from the installation site of sensors and elements sensitive to electromagnetic interference. The sensor itself and the measurement information transmission channel will not act as a source of electromagnetic interference.

Another important property of a technical device is noise immunity. In this case, in the sources that consider the methods of information transmission, the lack of sensitivity to electromagnetic interference of fiber-optic communication channels is noted [9, 10]. Table 1 [10] shows the comparative characteristics of radio frequency and optical communication lines.

| Parameter | Twisted pair (UTP, FTP) | Coaxial cable | Optical fiber |
|-----------|------------------------|---------------|--------------|
| Information capacity | 100 MBit/s | 100 MBit/s | 0.8…3.2 TBit/s |
| Error rate | 10-10 | 10-10 | 10-12 |
5. Summary

Based on the considered data, it can be concluded that according to the requirements for electromagnetic compatibility, distributed mechanoluminescent pulse pressure sensors with transmission of an information signal via fiber-optic communication channels are the most preferable. Moreover, both in comparison with mechanoluminescent sensors that register an optical signal directly in the sensor and with pulse pressure sensors that generate information measuring signals of an electrical nature. Signal registration and processing units require power supply and work with signals of an electrical nature, which is why they have all the restrictions associated with this when working in extreme conditions and require mandatory protection from the influence of electromagnetic and radio emissions.

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