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X-RAY METHODS

The Detection of Flaws in Optoelectronic Systems

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Abstract—Potentially dangerous spots (PDSs), for example, leaks in product pipelines (oil and gas pipelines), are revealed using optoelectronic systems (OESs) that are usually mounted on airborne vehicles (e.g., helicopters). Earlier, a relevant problem consisted of revealing the onset of leaks in PDSs; however, today it is necessary to detect the PDSs of leaks in order to prevent their development. The complexity of the problem is related to the fact that product pipelines are most often located near densely populated areas and near reservoirs with drinking water. The appearance of PDSs is usually characterized by deviations in the temperature and other physical parameters from standard values in small areas. The detection of such spots necessitates decreasing the flying height of an OES carrier. As a rule, this yields a deterioration of imaging quality and OES overheating, which decreases the efficiency of this PDS detection method. Conservative OES developers believe that a low imaging quality and OES overheating result from random flaws in the OES assembly. Contrary to this, it is shown that failures occur due to a deterministic flaw at the stage of designing drives for an OES platform.

Keywords: optoelectronic system, released power, body overheating, aerodynamic heating, thermal model

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1. RELEVANCE OF THE DEVELOPMENT OF AN OES THERMAL MODEL

For almost 10 years, the specialists of the physical-engineering faculty of Ural Federal University have been working on the problem of using OES optical-data transfer channels, including their interconnection with the channels of other systems. Figure 1 shows a complex that is intended for radiation monitoring of the atmosphere, which includes an OES [1]. Thermal conditions during low-altitude flights are known to be very complex, thus forcing researchers to perform a detailed OES analysis from the standpoint of a traditional concept of designing of such systems.

The concept of OES design took shape in the 1960s–1980s and is primarily based on heuristic solutions [2, 3]. Some provisions of this concept can be formulated as follows.

First, the revolving platform (RP) of an OES should provide a smooth rotation of the pointing direction (PD) to allow for the analysis of the video images that are recorded with OES without image "smearing."

Second, OESs are used at high altitudes $h \geq 2$ km at temperatures inside the OES body $T_{\text{in.min}}$ and $T_{\text{in.max}}$ that are admissible for normal operation of the electronic equipment with the minimal $T_{\text{eq.min}}$ and the maximal $T_{\text{eq.max}}$ temperatures

$$\begin{cases} T_{\text{in.min}} > T_{\text{eq.min}}; \\ T_{\text{eq.max}} > T_{\text{in.max}}. \end{cases} \tag{1}$$

Moreover, the fulfillment of the second condition in (1) is considered to be a simpler problem and it is usually expressed as the inequality

$$\Delta T_{\text{in.max}} > 10^{1.5}\ \text{K}, \tag{2}$$

where $\Delta T_{\text{in.max}} = T_{\text{eq.max}} - T_{\text{in.max}}$.

Third, the reduction units of the OES RPs should be simple in their design and should not allow for jamming; therefore, free plays are allowed. In this case, the above-mentioned smoothness in the PD motion in conditions of a free play can be achieved by using spring-loaded power transmissions of the RP reduction units [4].

Fig. 1. An OES-based helicopter complex of radiation monitoring.

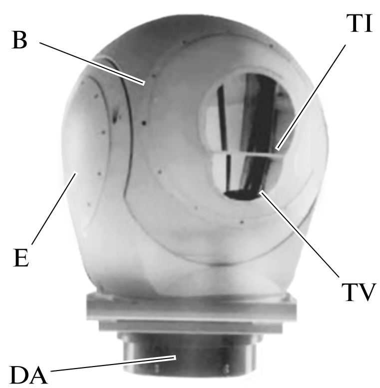

Fig. 2. A typical OES design.

Fourth, the power scattered inside the OES by the data blocks (DBs) and the RP

$$P_{sc} \approx P_{DB} + P_{RPav}, \tag{3}$$

can be very high [2]:

$$P_{sc} \approx 10^{2.5} \text{ W. (4)} \tag{4}$$

Such high power scattered inside the OES body (4) is due to the necessity of the secure fulfillment of the first condition in (1).

Today, the conditions of OES operation have become more complicated. For example, an admissible temperature increase inside the OES during flights at altitudes of hundreds of meters can be

$$\Delta T_{\text{in.max}} \approx 10^1 \text{ K} \tag{5}$$

instead of (2) at an altitude above $h > 2$ km, since the temperature increases by 7 degrees/km with a decrease in the altitude [3]. The admissible scattered power inside the OES body that depends on the admissible consumed power can be [5]

$$P_{sc} \approx (10^{1.5}—10^2) \text{ W.} \tag{6}$$

In connection with the operating conditions (5) and (6), which become more complicated as compared to (2) and (3), the question arises as to whether the application of traditional OESs in new operating conditions is justified. Therefore, the temperature increase inside the OES is determined below in Section 2 as a function of the OES parameters; the analysis of the efficiency of an RP with free play is presented in Section 3, and Section 4 considers the maximum scattered power and gives an analysis of the results.