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ASSESSMENT OF FEASIBILITY THE USE OF INFRARED TECHNIQUES IN AVIATION – TESTING STRUCTURES AND AVIATION PARTS

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Abstract

This paper presents the use of infrared thermography in aviation. Each of the described applications has been proved experimentally and revealed the advantages and disadvantages of the thermography method. Thermography is a discipline of research that allows observation of many phenomena, e.g. simple temperature analysis, defectoscopic tests and actions of aerodynamic. Its use in aviation is multidirectional therefore; thermography is an attractive method for research. Thermal techniques seem simple; however require extensive knowledge of infrared radiation, the areas in which this technique is used, the influence of camera parameters on its capabilities and software knowledge applied depending on the purpose. This paper undertakes the verification of temperature analysis method, which is based on the tests of whole machine assembly and its parts during their operation - widely known as passive thermography. Another raised issue is defectoscopic study which aim is to detect structural defects by non-destructive testing (NDT) - active thermography. Several types of sandwich and composite materials were selected, and on the basis of the test results the limitations and possibilities of thermography in the field of active thermography were concluded. The last application considered in this study is the use of thermography for aerodynamic testing, i.e. verification transition point, laminar to turbulent layer on the aerodynamic profile.

Keywords: *NDT, composites, sandwich composites, active thermography, passive thermography*

1. Introduction

The paper present thermographic techniques use in aviation. Literature review and own researches allowed determining the extent in which thermal method can be used. Based on them selected structures and elements, which will provide test objects to verify the applicability of thermographic techniques. Each of the presented method has been proven experimentally allowing to find the advantages and weak points of this method thereby assessment its validity to use in aviation.

Thermography is a field of science dedicated to the detection, registration and visualization of infrared radiation, invisible to the human eye and emitted by any object with a temperature above 0 K (i.e. –273°C). The images created during testing – a thermogram – are projection of the temperature distribution on the surface of test object [5].

Real objects besides the emission radiation energy also reflect, absorb and in some cases permeable infrared radiation. When the temperature of the material is the same as the temperature of the environment that it is located in the amount of radiation energy absorbed by the object is equal to the amount of energy emitted by the object [2, 9]. The emissivity is a physical parameter that characterizes the radiant body and it is ability of a material to emit infrared radiation. The emissivity varies according to the test object material properties and in the case of some materials the temperature of measured object [4]. The emissivity of real bodies is less than one ($e < 1$) due to the reflection and transmission of radiation. The emissivity $e = 1$ is for an idealized perfect black body, never occurs in reality. Non-metallic materials (e.g. PVC, concrete) have a high emissivity in the range of long-wave infrared radiation, which does not depend on temperature ($0.8 < e < 0.95$). Materials with glossy surfaces (e.g., metals) have a low emissivity.

When considering the uses of thermography during the test is taken into account two main types, i.e. active and passive thermography [5]. More simple and does not require sophisticated measuring stand is passive thermography, for instance observation test object during work. Active thermography allows for non-destructive testing, requires a source of thermal excitation and modular test bench, and enables synchronization of the camera and the excitation source.

Thermography is used in so many fields that describing all existing applications would be very extensive. In each of the fields of industry, science, medicine, research and development, agriculture, military and security, there are many applications where the infrared radiation is the source of many essential information. Constantly increasing demand for the specified thermal cameras and improving the parameters of existing cameras forced the industry to focus on developing higher resolution cameras (spatial and temperature), multi-spectral thermal recording and better and more advanced programs to analyse thermal images.

This paper is focusing on describing and analysing the application of thermography in aviation considering tests carried out on aircraft, their structures, aerospace components and aerodynamic properties.

2. Active thermography – defectoscopic research

Active thermography is based on measuring the thermal response of the object. The method is intended for testing defects in the surface layers of materials. It allows verifying the existence of hidden defects occurring in homogeneous materials – this is one of the methods of NDT. Examples of such defects in a composite material are inclusions, air bubbles, and delamination. Active research requires the use of additional sources of heat stimulation. Most often it is heating or cooling the test object others: optical excitation, ultrasonic, eddy current and microwaves [10]. The main methods of active thermography classified as [6]:

- impulse thermography (Pulsed / Transient Thermography),
- Lock-In thermography,
- Long pulse termography method (Step Heating),
- Vibration thermography (Vibrothermography),
- Thermal stress analysis (TSA).

Each of the aforementioned method is adapted to research a specific materials group or detect specific defects (Tab. 1). They differ in excitation source, a way to provide heat for the object and mathematical analysis, on the basis of which formed the result of research. The measurement is based on the following principle: the direction of heat flow affects the temperature distribution on the surface of the test object. The lock-in method is to direct the heat waves to the surface of the object and analysing the penetration into the material. Upon encountering, a defect portion of the energy is reflected and stirred with a wave; entering what is shown in the temperature distribution on the surface and it gives the answer about structure of the test object. Pulse method is based on sending a pulse of heat to the surface of the object. As soon as heat encounters a defect it will be blocked, which is equivalent with increasing temperature. In this method, a proper software is able to determine the depth of the defect. Completely different method is TSA, which uses the effect of thermoplastic, generating changes in object temperature by changing the mechanical load. The result of this type of analysis is to determine the stress based on the temperature data [2].

The main application of active thermography is NDT for detecting defects in materials, evaluation of the features and quality without any change in their functional properties. Each type of flaw detection test consists of two phases. The detection defects phase and evaluation phase – mainly based on statistics. It allows showing the dimensions and the depth of defect (if we have the software with the appropriate mathematical apparatus or adequately prepared standard).

In order to demonstrate the feasibility test of composite structures based on NDT we performed several types of structures used in aviation. There are special samples with various types of defects,

Tab. 1. Possibility of using active thermography methods

	Lock-in	Pulse/Transient		TSA	The possibility of using
		short	long		
Halogen lamp	👍	–	👍	–	– composite materials – foamed materials – leather
Flash lamp	–	👍	–	–	– metal – composite materials
Ultrasounds	👍	–	👍	–	– detection of defects and delaminations
Laser	👍	👍	👍	–	– tests requiring precise directing heat
Eddy currents	👍	–	👍	–	– metal
Mechanical excitation	–	–	–	👍	– stress analysis

to verify the ability to detect them by termography. Each sample was mounted on a test bench then set the power and time of the excitation, power ranged from 1 kW to 2 kW, and the excitation time has been changed to verify how this parameter affects the possibility of testing samples.

After analysing the research based on active thermography, it is concluded that this method has great capabilities to test the structures and aerospace materials. As a method of qualitative, not quantitative gives us the answer about the existence of defects, not their type. By way of comparison or using standard depth or type of defect can be recognized. Research also revealed disadvantages of active thermography. In the case of the sandwich structures we can observe defects only at the first spacer layer. Fig. 1 shows the thermal image of test object before and after the test, based on it we can conclude that defects were detected in the sample. Brighter shapes correspond pasted paper elements, while the darker streak in the lower right corner is the result of move apart carbon workpieces – it can be one of the possible technological errors during lamination.

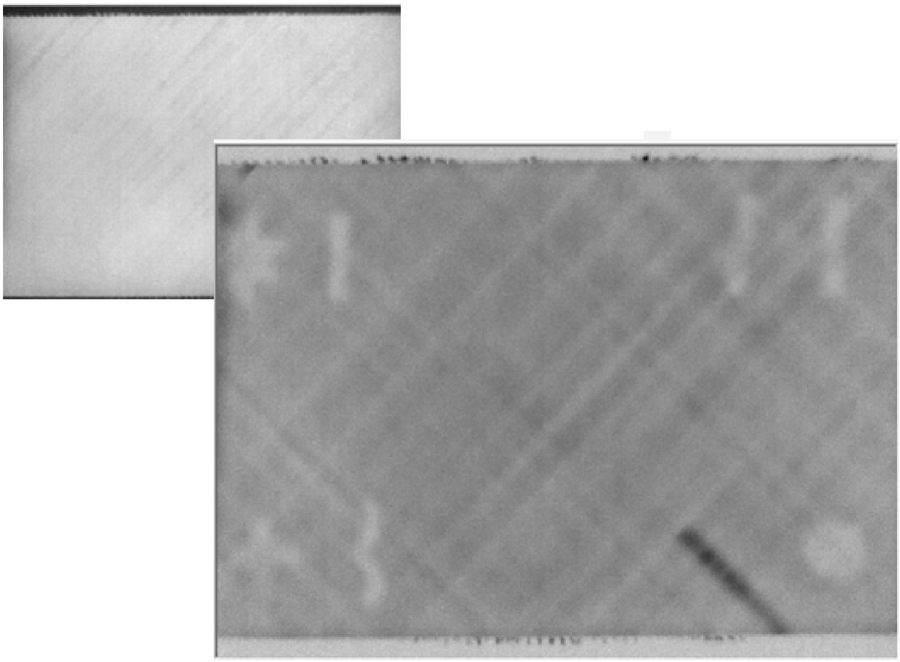

Fig. 1. Thermogram of special prepared test object (simulated defects and damages, in order to verify the possibility of detection) – image in stage of cooling the heated object (excitation source – 1 kW halogen lamp)

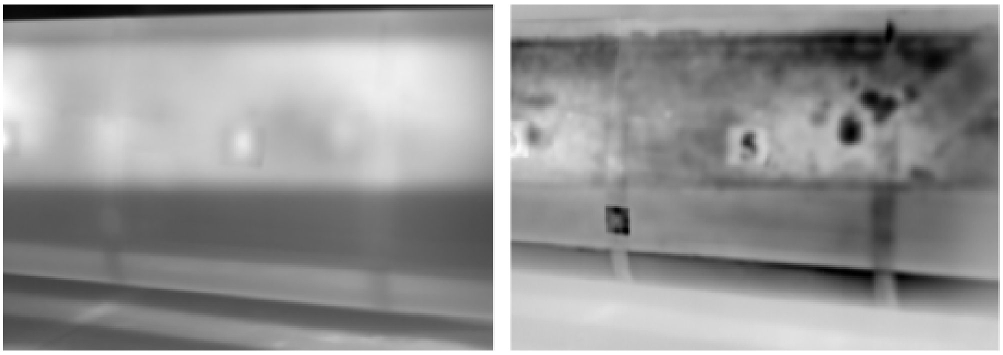

Fig. 2. View the blades in the infrared (left), view of the same fragment of the blades with the identified defects during active thermography tests

In the case of locating a defect in aviation structure first step is to refer to the “damage tolerance”, next is the defects observation at certain intervals in order to check the propagation of defects. Referring to defects in elements such as helicopter blades, fuselage, or rib etc., it is suggested to determine the lower service life and then observation.

Active thermography is a relatively simple method that immediately after the end of the study allows seeing the results. An additional advantage is the time required to perform the test, trained person is able to investigate the structure in a short time. In summary, due to the quick response, no interference in the material and unambiguous results regarding the existence of the defect, the method of active thermography is a method rightly used in aviation.

3. Passive thermography

In tests, using passive thermography temperature field created in the work process of the object is checked. Mainly used for testing devices and components at the time of their operation. Defects radiate or absorb thermal energy and in this way, passive methods allow for conducting the diagnosis [8].

The group of studies using passive thermography can be assigned to observe the objects temperature during work, e.g. drivers and other electronic components widely used in aviation, verification of heat sinks, the engine temperature analysis or entire objects, (helicopter during the bench tests). A major area of research are the studies concerning the emission of infrared radiation, heat dissipation of the waste by the drive systems of flying objects, checking exhaust behaviour during various manoeuvres.

Temperature observation is one of the simplest applications of infrared camera especially in terms of analysing the results. If determine correctly parameters such as emissivity, air temperature, humidity and the distance between the camera and the tested object actual temperature will be received in the form of a thermogram and a graph of the temperature distribution at the time. In such applications, the infrared camera can be compared to the pyrometer, however, a much higher capabilities, because the pyrometer measure temperature in one point. Temperature observation based on thermography can be a primary method of measuring the thermal power dissipated by the elements of the appliances during their work (Fig. 3, 5).

The most troublesome parameter to the settings is emissivity of tested element. Commercially available software are equipped with an extensive database of materials where we can find the appropriate parameters (Fig. 4). However, we do not always know the type of material that the test object is composed of or its parameters are not included in the database, then you must manually set the emissivity.

Thermal Research measurements are performed on properly prepared stands with particular attention paid to eliminate the light sources, which can cause reflections on the tested surfaces. On the basis of conducted tests, it is concluded that thermography is an optimal method for this type

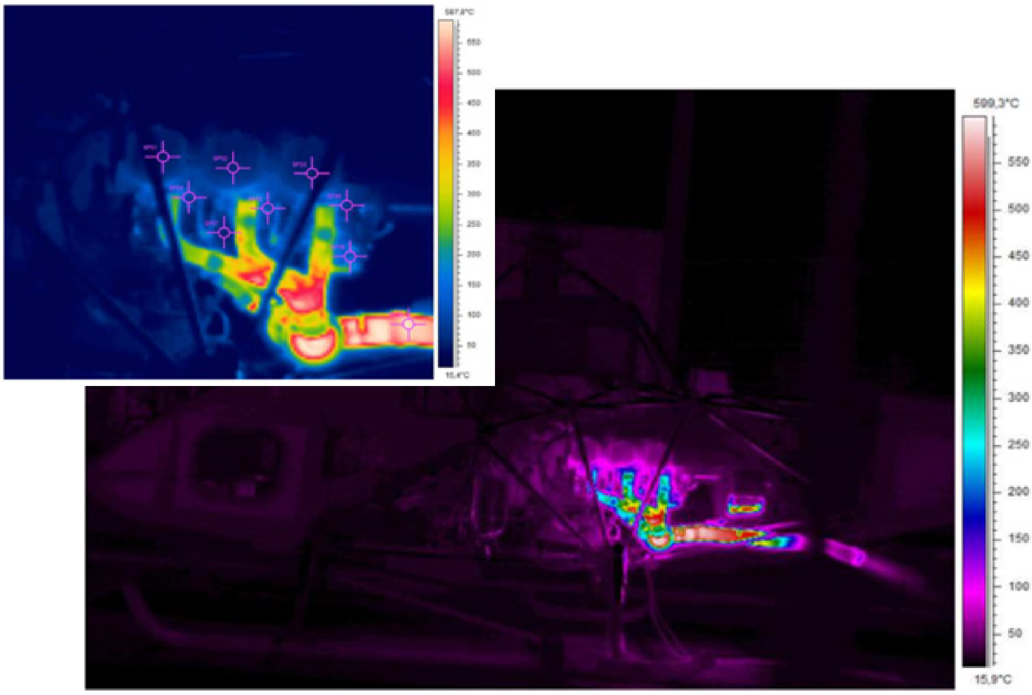

Fig. 3. The sample of use passive thermography – Thermogram of helicopter ILX-27 while working at 100% engine power. (in upper right corner) Measuring points on the surface of the engine

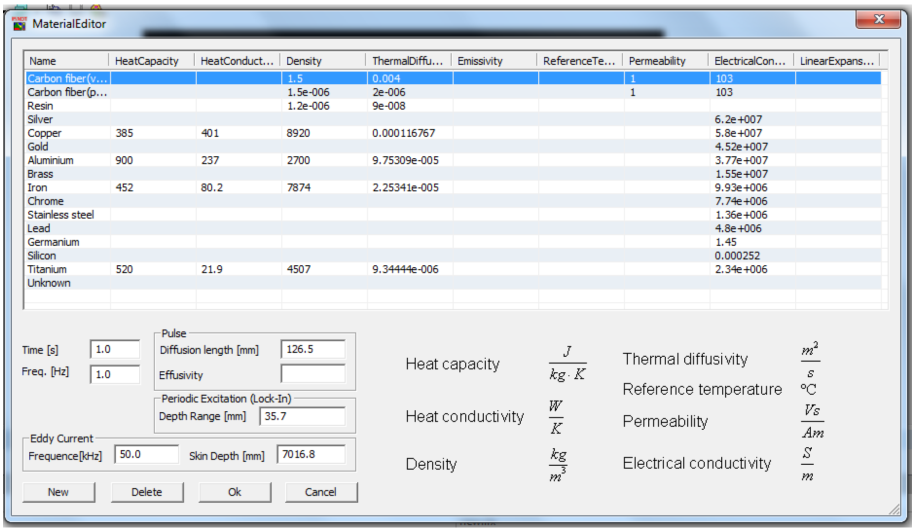

Fig. 4. IRNDT window – Material Editor

of tasks. High accuracy indications, especially during laboratory tests, surpasses the capabilities of the pyrometer measurements due to the possibility of recording time data at a very high frequency and visualization of results in the form of heat maps of infrared radiation.

4. Thermography in aerodynamics

Another application of thermography studies is aerodynamic research i.e. define boundary transition – laminar layer to turbulent on aerodynamic profile [1, 7, 10]. Thermal imaging techniques allow verifying one of the important issues arising in aviation in the field of aerodynamics. Using a set for detecting infrared radiation with an excitation source, i.e. halogen lamp, transition point can be verified. Ability to observe this phenomenon results from generated temperature differences on the profile within a flow time. To perform this type of studies proper

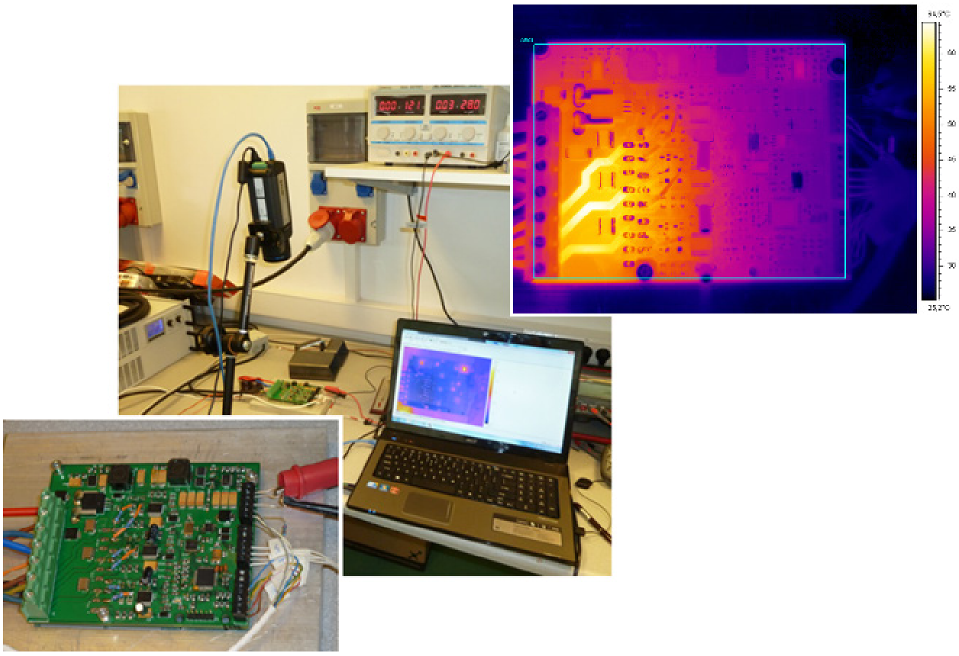

Fig. 5. The controller, test stand for his analysis of the temperature and the resulting image research

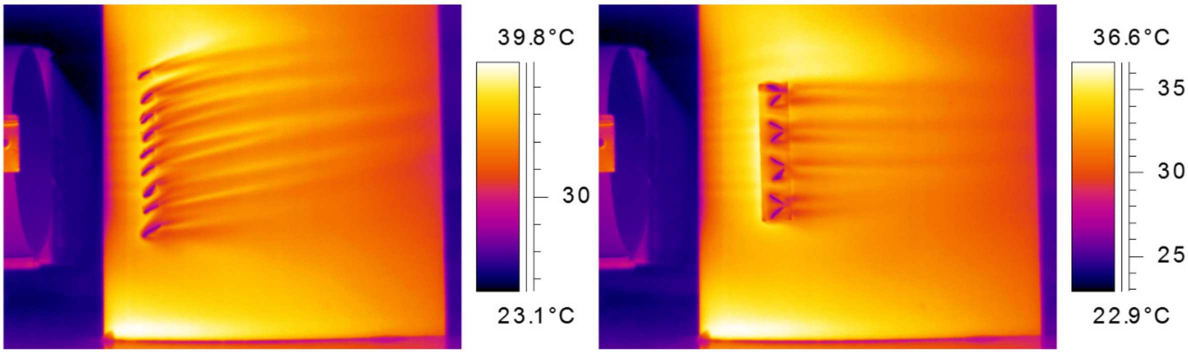

Fig. 6. Thermogram showing the distorted flow on the profile surface caused by turbulators

surface preparation is essential, minimum roughness and maximum homogeneity, because only this will provide meaningful results and not make noise. Thermal excitation of the test surface is necessary to observe that phenomena. Even with a simple laboratory stand (without using a wind tunnel), thanks to the additional turbulators can observe the behaviour of the boundary layer.

The method was tested experimentally in a wind tunnel, and the results were compared with calculations. On this basis, it is concluded that thermography can be used for aerodynamic testing, to observe transition point and flow behaviour disrupted by turbulators. The main problem during study is a flow disorder in the wind tunnel through the additional object such as camera and thermal excitation source. To avoid such problems, a cover made of glass germanium should be used.

5. Conclusion

In conclusion, thermography applied to the observation of temperature with the right parameters is much better method then other methods to measure temperature because allows for execution temperature maps of and graphic interpretation of results. Thermography enables the detection of structural defects only in homogeneous structures in the case of sandwich structures we can observe only the first layer. Despite this, it is method of great capabilities to obtain NDT results in a short time. Another application of thermography is aerodynamic study i.e. behaviour of flow and transition point. Based on a comparison of the experimental results and calculation, it is confirmed that it is method of high accuracy, enabling unambiguous determination of the transition points in a graphical way.

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