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# Identifying the Possibility of Using Unmanned Aerial Vehicles in the Process of Construction Projects Implementation

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**Abstract.** *Nowadays, dynamic progress in the field of modern technologies influences the development of unmanned aerial vehicles. The potential application area of this type of technology is constantly growing. The equipment is available to almost everyone and its use is becoming ever easier. The aim of the article is to present the possibility of using unmanned aerial vehicles in construction projects, for economic and time reasons, as well as to perform work in places that are inaccessible or too dangerous for humans. The article is the result of literature research, expert opinions and author's own analyses. The article draws attention to the fact that unmanned aerial vehicles may have a number of applications and unlimited possibilities. The use of modern technologies enables the flight at different heights and within a radius of many kilometers. Due to the fact that they are equipped with various types of cameras, they constitute a useful observation tool in various projects. The article presents thermal imaging tests in the area of construction and indicates that the value of energy consumption depends mainly on the effectiveness of insulation - increase in thermal insulation, while the effective way of their diagnosis is the use of thermal imaging camera. The authors of the article conduct research on a wide range of applications of unmanned aerial vehicles in construction projects.*

**Keywords:** *Unmanned Aerial Vehicles, Thermal Imaging, Modern Technology, Construction.*

## 1 Introduction

Unmanned aerial vehicles have been used in recent years in the civil market in a variety of economic sectors. They usually support aerial photography or filming. The equipment is available for almost everyone. In most cases, it is necessary to have ground-based staff to install or operate the platform itself and its systems. It should be noted that unmanned aerial vehicles combined with appropriate detectors and sensors are an excellent method of diagnosing and controlling the technical condition of objects. The combination of a thermal imaging camera and an unmanned aerial vehicle provides a useful tool for thermal imaging tests that can detect areas such as heat escapes from a building, thus preventing heat loss and significantly reducing building operating costs.

## 2 Unmanned Aerial Vehicles

Unmanned Aerial Vehicles (UAVs) is a generally accepted and used in engineering and science term. This term is also used by EUROCONTROL, the European Organisation for the Safety of Air Navigation, of which Poland has been a member since 2004 (Maj-Marjanska and Pietrzak, 2011). Unmanned aerial vehicles are defined by the U.S. Department of Defense as "powered, aerial vehicles that do not carry a human operator, use aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable. It can carry a lethal or nonlethal payload" (Maj-Marjanska and Pietrzak, 2011). Unmanned aerial vehicles fly thanks to the use of two basic principles: lifting force and reactive torque. In this type of devices, counter-rotating propellers are used, which stabilise the fuselage during spinning. An unmanned aerial vehicle may be remotely piloted beyond visual line of sight (by an operator), or fly autonomously (by itself using an autopilot or another on-board system). However, most of them are piloted within their operators' line of sight. In both cases, ground-based staff are needed to install and operate the systems and the platform. The most important interface between the machine and the user is the radio system, the range of which is measured in kilometres. Many types of materials are used to construct modern unmanned aerial vehicles. The most popular include glass fibre, carbon fibre, as well as various types of plastics or metals. The materials listed above are characterised by a very good weight to strength ratio, but they are also very expensive. Modern aerial vehicles (military, civil ones) are the objects (systems) of very complex technical construction. They are usually built of many on board devices and subsystems, some of which make flying possible, while others provide the performance of specific functions within the combat mission. Their multifunctionality makes it possible, among other things, to perform aerial reconnaissance (Becmer and Romanek, 2011). The UAVs adopt different configurations and sizes - usually quadrocopters and octocopters, which are equipped with four or eight propellers respectively. The main propulsion systems include propellers and engines, which play a significant role here. The size of the propellers (blades) determines the lifting force, as well as the flight stability. The UAVs fuselage is stabilised by the counter- rotating propeller movement (Audronis, 2015). The selection of the right engines, which have to cope with the aerodynamic resistance, is an extremely important task. Thanks to them, UAVs can hover in the air for up to several dozen hours, uninterrupted.

UAVs can be equipped with various types of detectors, e.g. hazardous substances, automatic data analysis and transmission devices, as well as thermal imaging cameras. These devices are mostly used for filming and photographing. Real-time video playback makes unmanned aerial vehicles an ideal tool for, among other things, monitoring of dangerous goods transport routes or supervision of mass events (Audronis, 2015). The combination of UAV with such devices as digital cameras, directional microphones, thermal imaging sensors and network transmitters creates a number of new possibilities. They can be used both in site protection and in investment control or logistics. They may be considered a tool that extends the range of offered services, but also significantly reduces operating costs. The potential for the use of aerial vehicles is being increased by the constantly developing structures of unmanned aerial vehicles and their resistance to atmospheric phenomena, greater range, as well as easier and more precise control. The dynamically developing market of telemetry and CCTV surveillance systems, with which unmanned aerial vehicles can be equipped, also contributes to the extended possibilities of using such devices (Bartkowiak, 2017).

## 3 Concept and Application of Thermal Imaging Testing

Thermal imaging, also called thermography, is a process of registering thermal radiation, emitted by physical bodies. The aim of the thermal imaging testing is, first of all, to present the image of heat emitted by physical objects in the Medium Wavelength Infrared (wavelength from about 900 to 1400 nm). This process makes it possible to record the thermal radiation emitted by all physical bodies in the temperature range typical of everyday conditions. It should be emphasised that objects do not need to be illuminated by an external light source. Such operation allows for a very accurate temperature measurement of objects in the places that interest us. Generally, thermal imaging testing is carried out in order to determine the level of emission and loss of thermal energy in, among others, industrial or residential buildings. This type of testing contributes to the determination of the object's thermal state. In addition, this method makes it possible to search for various inconsistencies and irregularities. Observation of heat emitted by objects in the field of vision is possible thanks to the use of a thermal imaging camera. It should be noted that all bodies whose temperature is higher than absolute zero are sources of radiation in the Medium Wavelength Infrared, i.e. infrared radiation with a wavelength of about 0.9 to 14 μm. Therefore, the functioning of a thermal imaging camera is based on a physical phenomenon concerning electromagnetic waves emitted by every body whose temperature is higher than absolute zero. Moreover, the intensity of infrared radiation is proportional to the body temperature.

The use of infrared has many advantages, especially when it is difficult to predict the temperature field distribution. Infrared has the advantage of producing accurate images of a thermal field in a non-contact manner. Even if it is difficult to determine where the problem is, it will appear in an easy to interpret thermal image.

## 4 Author's Own Research

Thermal imaging is more and more often used in various areas of life, including heat engineering, construction, power industry and medicine. A professional high-resolution thermal imaging camera should be used in order to obtain reliable results. Thermal imaging testing is common in the construction sector. The most frequently performed thermal imaging services during the year are, for example, detection of water leaks from the central heating system, leak detection and assessment of walls and ceilings dampness degree. Thermal imaging also makes it possible to search for leaks in underground pipe heating systems or to conduct testing. However, such projects require appropriate conditions and experience of the camera operator. Companies and individuals who own buildings control the water-tightness of facades and roofs to minimise heat loss. Improper construction may lead to significant financial losses over time, especially in winter. A tool that enables easy measurement in individual places is a thermal imaging camera. Using this type of camera, it is possible to determine the temperature in a place that may be leaky, *e.g.* between a window and a frame.

Thermal imaging may be considered one of the best ways to evaluate the quality of renovation work, such as thermal efficiency improvement of a building. Thanks to the combination of UAV and thermal imaging camera, this type of measurement can be performed even at considerable heights and in places not easily accessible to people. The advantage of this method is, first of all, accuracy, economy and a fast performance of measurements, thanks to which it is possible to rectify defects quickly (Kowalski and Bielecki, 2014). For this type of measurements it is also recommended to use radiometric cameras, thanks to which one may read the temperature in the given point of the registered infrared image.

The essential element during thermal imaging testing is the thermal transmittance, so the rate of transfer of heat through a structure, also known as U-value, calculated on the basis of thermographic measurements. Using the formula below we can calculate the heat transfer coefficient:

$$U_i = \frac{h_{si}(T_i - T_{si})}{T_i - T_e} \tag{1}$$

$$U_e = \frac{h_{se}(T_{se} - T_e)}{T_i - T_e} \tag{2}$$

$$U_{ie} = \frac{h_{si}\, h_{se}(T_i - T_{si})}{h_{se}(T_i - T_e) + h_{si}(T_i - T_{si})} \tag{3}$$

U- heat transfer coefficient
$h_{si}$ - internal surface heat transfer coefficient
$h_{se}$ - external surface heat transfer coefficient
$T_i$ - temperature inside the building
$T_e$ - temperature outside the building
$T_{si}$ - internal surface temperature for partitions
$T_{se}$ - external surface temperature for partitions (Kisilewicz and Wróbel, 2008).

Testing with the use of thermal imaging in open field may be subject to errors resulting from the so-called environmental factors. Direct sunlight strongly affects the readouts from the thermal imaging camera. Both sunlight and shade can affect the distribution of surface temperatures of the building for hours after the sun has stopped shining. Therefore, differences in thermal conductivity can lead to major temperature differences. Rain, which lowers the surface temperature of the material, is an equally dangerous factor. The evaporation of rainwater cools the material, which leads to a disturbed temperature distribution (Cwojdzinski, 2014)

When using a thermal imaging camera to detect insulation gaps or energy losses, it is best if the temperature difference between the inside of the building and the outside is at least +10 °C. With a high-resolution camera of high temperature sensitivity, the temperature difference can be smaller. Therefore, building inspections are often carried out in winter.

Currently, the authors are also conducting research on the application of UAV in the following areas:
- drawing up three-dimensional, detailed maps of the buildable lands, containing relevant data and information that may be of particular importance for the study phase and during conceptual preparation;

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- ongoing monitoring of the construction site and work in progress;
- controlling and supervising the works performed by the contractor, as well as supporting persons responsible for supervision;
- control over the supply of building materials and specialist equipment to the construction site;
- simulations that will provide the client with information on the topography and suggest what the best place for foundations excavation would be;
- monitoring the location of construction equipment that changes its position on the site, as well as supervising employees, properly performing their assigned duties and complying with occupational health and safety rules.

The authors' preliminary research shows that the application of UAV in the above mentioned projects will improve the effectiveness of their implementation.

## 5 Conclusions

Decreasing prices and increasing availability result in growing popularity of UAV. Thanks to the autopilot function, the device is easy to operate for almost every user. Determining parameters such as flight speed and altitude, flight course, monitoring of objects or phenomena in hard to reach locations is not a major problem. The possibility of using UAV with thermal imaging or HD cameras makes unmanned aerial vehicles a useful tool for conducting various types of tests. The conducted tests indicate that it is possible to identify areas of heat loss in the building and assess the temperature distribution. Moreover, the result is fast, accurate and non-invasive thanks to the use of an unmanned aerial vehicle combined with a thermal imaging camera. It allows, among other things, to identify defects in buildings, such as missing insulation, mortar flaking, dampness problems, and to assess the condition of heating, ventilation and air-conditioning systems. Such measurements are not only accurate, but also very cost-effective. Regular autonomous UAV flights may provide in a short period of time current and detailed data concerning the implemented construction projects.

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