

RISK ANALYSIS OF INFRARED THERMOGRAPHIC EQUIPMENT

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ABSTRACT

This paper presents a risk analysis of the use of a thermal imaging camera in a production environment. Infrared thermography is a method used for condition monitoring of machines, quality control, and non-destructive testing. Thermal imaging enables non-contact temperature measurement and visualization of thermal phenomena in real time, making it highly suitable for industrial diagnostics. The risk analysis was conducted by determination of the limits of the machine, hazards identification and risks estimation, in accordance with the ISO 14121-1 standard. Mechanical, electrical, thermal, laser, ergonomic, and other hazards that may arise during operation in the cutting zone and while handling the thermal imaging camera were identified. Hazard identification using standardized forms was applied as the risk assessment method.

Key words: Risk analysis, Hazard identification, Thermographic.

INTRODUCTION

Modern industrial systems require reliable monitoring and diagnostic methods in order to ensure the safe, efficient, and continuous operation of machines and equipment. One of the key parameters for monitoring machine condition is temperature, since its variations often directly indicate operational irregularities, component wear, or the occurrence of failures. Infrared thermography, also known as thermal imaging, represents a modern, non-invasive method for measuring and visualizing temperature distributions on object surfaces, thereby enabling the early detection of potential problems and the improvement of maintenance systems.

In addition to the technical advantages that thermography offers in diagnostics and quality control, it is also necessary to consider the safety aspects of its application. The operation of a thermal imaging camera in an industrial environment, particularly near machine tools and cutting zones, exposes operators to various types of hazards. Therefore, conducting risk analysis and assessment in accordance with relevant international standards is of great importance.

The aim of this paper is to present the application of infrared thermography in monitoring machine conditions during the manufacturing process, as well as to perform a systematic risk analysis related to the use of a thermal imaging camera in accordance with ISO 12100 and ISO 14121-1 standards.

Standard ISO 12100 is the overarching international standard for machinery safety, defining the principles of design, risk assessment, and risk reduction throughout the entire life cycle of a machine. It provides a systematic framework for hazard identification, risk analysis and evaluation, as well as methods for reducing risks to an acceptable level.

Standard ISO 14121 is the predecessor of ISO 12100 and is specifically dedicated to risk assessment. Standard EN 292 was the first standard to clearly define that safety must be integrated into the design process rather than addressed afterward through protective measures, forming the foundation of the modern principle of inherent safety.

In the available scientific and professional literature, infrared thermography is widely used as a method for machine condition monitoring, predictive maintenance, quality control, and non-destructive testing. Numerous authors emphasize its advantages in terms of non-contact measurements, rapid response, and the possibility of early detection of irregularities in the operation of electrical and mechanical systems. However, an analysis of the available studies shows that most research focuses on the technical aspects of thermography applications, while the assessment of safety risks associated with the use of thermal imaging cameras in industrial environments is considerably less represented.

Certain studies examine risk assessment in combination with thermography, mainly in the field of occupational health and safety, where thermographic data are used to identify ergonomic and physiological workloads of workers [Soares et al., 2020].

Furthermore, the literature includes studies pointing to limitations and potential sources of error in thermographic measurements, such as the influence of emissivity, reflections, and thermogram interpretation, which may indirectly be considered risk factors in the application of this method [Livada et al., 2023].

Nevertheless, systematic analysis and risk assessment of thermal imaging cameras as technical equipment, conducted in accordance with ISO 14121-1 and ISO 12100 standards, are rarely the subject of dedicated scientific studies, thereby confirming the justification and significance of the research presented in this paper.

THERMOGRAPHY

Infrared thermography (IRT), also known as thermal imaging, can be used for the identification and documentation of irregularities for the purposes of machine condition monitoring, quality control, and non-destructive testing, as well as for monitoring temperatures during various manufacturing processes, such as temperature in the cutting zone, extrusion temperature in forming processes, casting and cooling temperatures of castings, and thermal phenomena occurring during welding.

In machine condition monitoring, irregularities are caused by mechanisms such as the operating process, lubrication issues, misalignment, component wear, or mechanical loading. Thermography is based on the detection and measurement of the distribution of thermal radiation emitted from the observed surface and its conversion into a representation of radiation intensity differences, i.e., a surface temperature map known as a thermogram. Therefore, the proper application of infrared thermography requires the operator–thermographer to possess fundamental knowledge of heat and temperature concepts, as well as heat transfer mechanisms.

Thermal energy is generated during the operation of all machines and may arise due to friction, energy losses, fluid characteristics, the technological process itself, or a combination of these factors. For this reason, temperature represents one of the key parameters for machine operation monitoring, condition assessment, and the identification of potential failures.

IRT has proven to be a highly suitable method for temperature monitoring because it enables comprehensive thermal imaging of machines or their components through non-contact (non-invasive) measurements, with minimal setup requirements and very rapid acquisition of results. A significant advantage of infrared thermometers compared to contact temperature measurement methods lies in their extremely fast response time, since the radiated energy is transferred from the object to the sensor at the speed of light, enabling an almost instantaneous response. An additional advantage of these instruments is their high sensitivity, as they are capable of detecting and displaying thermal images composed of very small temperature differences. Nevertheless, despite its numerous advantages, infrared thermography has certain limitations, since radiometric measurements may be affected by significant errors when applied to surfaces with low emissivity.

RISK ANALYSIS

Risk analysis of the thermal imaging camera, as shown in the decomposition diagram in Figure 1, consists of the following phases: determination of machine limits, hazard identification, and risk estimation. After the completion of the risk analysis and the implementation of risk evaluation, the overall risk assessment process was carried out.

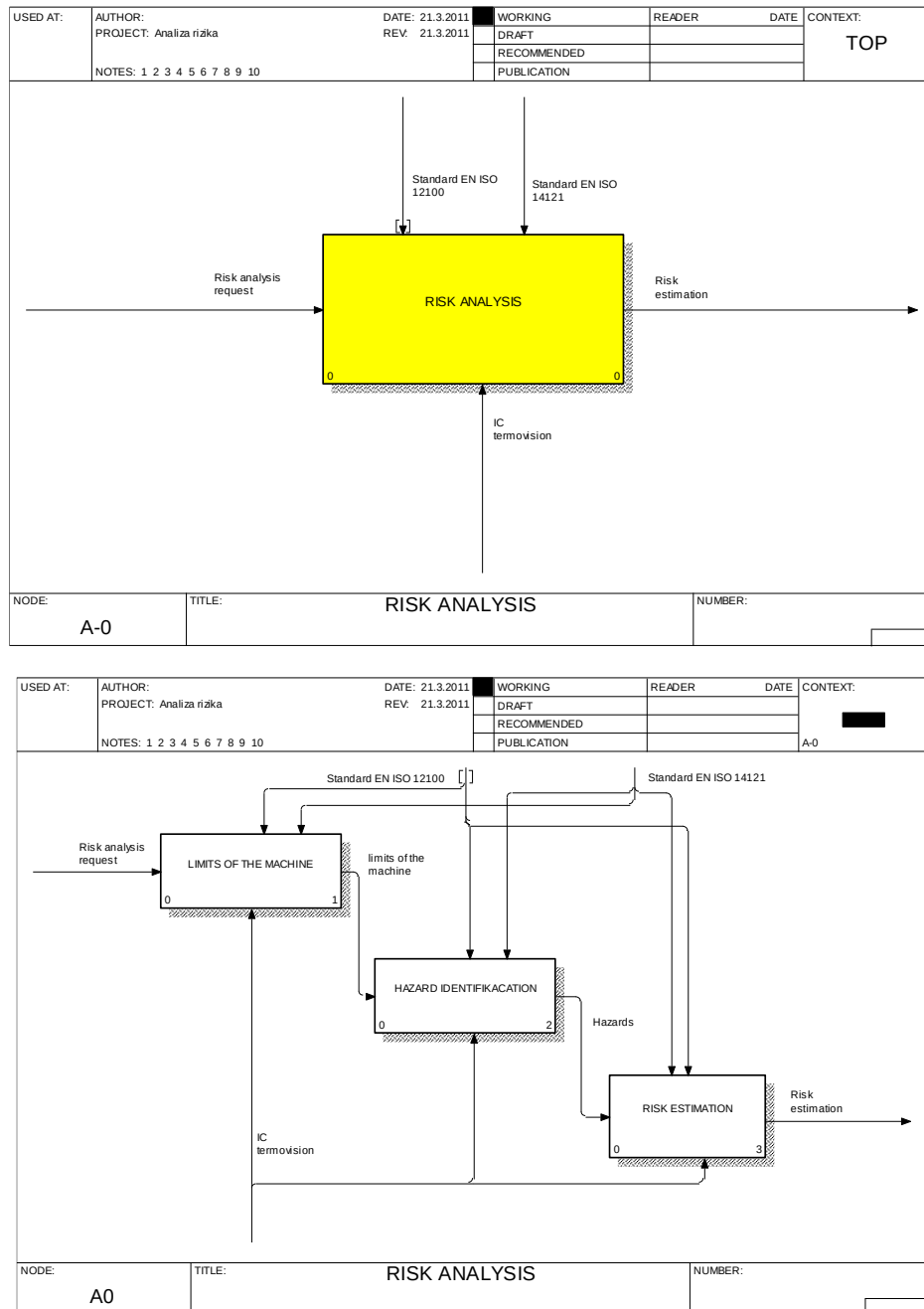


Figure 1: Decomposition diagram of activity risk analysis

The activity tree of the risk analysis is shown in Figure 2.

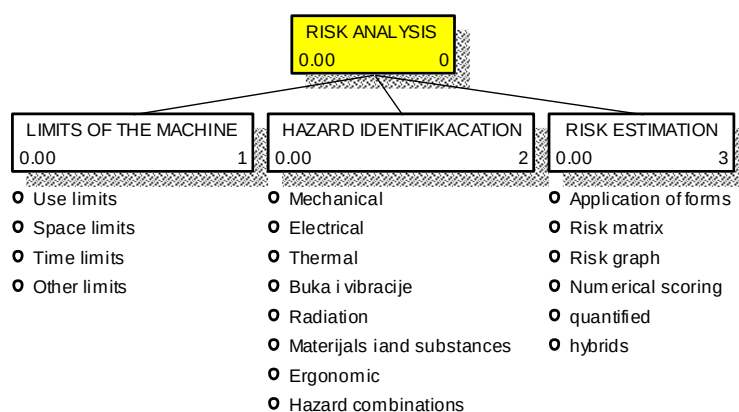


Figure 2: The activity tree of the risk analysis

Determining the machine limits

Risk analysis begins with determining the machine limits, taking into account all phases of the machine life cycle, and consists of: use limits, space limits, time limits, and other limits. Use limits define the different operating modes of the thermal imaging camera and the various intervention procedures for users. The thermal imaging camera has no restrictions regarding use based on gender, age, dominant hand usage, or physical abilities. The required training level for operator–thermographers is defined by EN ISO 9712 and ISO 18436-7. Space limits related to the use of the thermal imaging camera are defined by restricted access to the equipment whose temperature is being measured during operation, as well as by the spatial requirements for the operator.

Time limits define the service life of the thermal imaging camera and some of its components, as well as the maintenance intervals recommended by the manufacturer. Other limits define the measurement range, as well as the properties of the measured material, including emissivity, reflection, transmissivity, calibration, camera location, distance, range, focus, as well as machine condition and ambient conditions.

Hazard identification

Hazard, hazardous situations, and events are identified for all phases of the machine life cycle: design, transport, assembly and installation, commissioning, operation, and decommissioning, after which measures must be taken to eliminate or reduce the associated risks and shown in Table 1. For the purpose of hazard identification for the thermal imaging camera, it is necessary to define the operations it performs, the tasks of the operator, and the environment in which it operates. The thermal imaging camera is primarily intended for the diagnostics and temperature measurement of electrical and mechanical machine components, as well as for quality control through non-destructive testing (NDT) and the creation of thermograms.

The tasks performed by operator–thermographers include setting the measurement range, material emissivity, reflectivity, transmissivity, and focus, laser marking, monitoring and diagnostics (thermogram generation and analysis), as well as charging and maintenance.

Regarding the environment in which the thermal imaging camera operates, given that its primary purpose is the monitoring and diagnostics of electrical and mechanical equipment and NDT, the associated hazards are mainly electrical and thermal, as well as other hazards and harmful effects resulting from the operation of the machines and components being inspected.

During temperature monitoring in the cutting zone using a thermal imaging camera, the following hazards were identified, in accordance with the Regulation on the manner and procedure of risk assessment at the workplace and in the working environment: mechanical hazards arising from the use

of work equipment, hazards related to workplace characteristics, hazards arising from the use of electrical energy, harmful effects arising or appearing in the work process, and harmful effects resulting from psychological and psychophysiological strain associated with the workplace and job tasks performed by the employee.

Table 1: Hazard identification using application of forms

Machine		IC Thermal Camera FRIK	Method / Standard	Application of forms/ ISO 14121	
Phase		Work Process – Production	Analyst	Dr D. Jovanić	
Hazard Zone		Cutting Zone	Date	20.12.2025.	
no	Task	Hazard	Origin	Consequences	Hazardous Situation / Event
1	Monitoring – temperature measurement	Mechanical hazards related to the machine, machine parts or surfaces, tools, workpieces, loads, or projected solid or liquid materials	Approach of a moving element (tool) to a fixed part (workpiece); Rotating elements (tool); Moving elements (tool, machine parts); Sharp edges (tool, workpiece, chips)	- crushing - severing - cutting - entanglement - trapping - impact - puncture	Working near moving parts; Exposure to ejected parts; Unexpected machine movement
2		Mechanical hazards caused by the machine, machine parts (including material holding mechanisms), workpiece, or loads			
3		Electrical hazards – direct contact	Machine tool electrical installations; Live parts due to malfunction; Short circuit; Camera power supply	Electric shock; Shock	Contact with power cable; Poor insulation of the power cable; Restoration of power supply
4		Electrical hazards – indirect contact			
5		Thermal hazards – burns from contact with objects or materials at extreme temperatures, flame or explosion, and radiation from heat sources	High-temperature materials (tool, workpiece, and chips); Radiation from heat sources (machine tools)	Burns; Injuries caused by heat radiation; Fire	Contact with the workpiece, chips, or drill; Working near high-temperature objects
6		Radiation	Laser radiation	Eye and skin damage	Laser pointer directed toward the eyes
7		Noise	Production process (cutting)	Discomfort; Tinnitus	Tool wear; Lack of lubricant (MWF)
8		Material / Substance	Dust; Liquid (coolant/lubricant); Smoke	Breathing difficulties	Splashing of MWF, smoke, and dust from the cutting zone
9		Ergonomics	Strain; Posture; Visibility	Fatigue; Stress; Any other	Holding the camera in an awkward position; Physical strain

Risk estimation

Risk estimation together with the determination of machine limits and hazard identification the risk analysis, which, when combined with risk evaluation (i.e. determining whether the risk has been adequately reduced), represents the overall risk assessment process. Risk assessment methods, according to ISO/TR 14121-2:2012– Part 2: Practical guidance and examples, include: application of forms, risk matrices, risk graphs, numerical scoring, quantified risk evaluation, and hybrid methods.

Hazard identification using application of forms, as a risk estimation method, is an approach for identifying hazards that primarily uses checklists defined in ISO 14121-1:2007. These checklists cannot be considered exhaustive; therefore, other risk assessment methods should be used as a supplement. This method can be applied for risk assessment at any stage of the machine life cycle. Risk

estimation using application of forms is presented in a table and performed in accordance with ISO 14121-1.

CONCLUSION

Temperature measurement using an infrared thermal imaging camera is a safe and non-contact method, but it requires careful planning, training, and compliance with prescribed safety measures, particularly due to the presence of mechanical and thermal hazards associated with the machines being monitored and diagnosed.

Infrared thermography represents a powerful tool for machine condition monitoring and optimization of industrial processes, thanks to its speed, high sensitivity, and ability to perform non-contact temperature measurements. Its application enables the timely identification of irregularities in machine operation, thereby reducing downtime, increasing system reliability, and improving work safety.

However, the use of thermal imaging cameras in industrial environments involves certain risks, especially in proximity to machines and high-temperature zones. The conducted risk analysis has shown that it is necessary to systematically identify all potential hazards throughout the entire life cycle of the equipment and to implement appropriate technical and organizational protective measures. During temperature monitoring in the cutting zone using a thermal imaging camera, mechanical hazards were identified related to machines, machine parts or surfaces, tools, workpieces, loads, or projected solid or liquid materials, as well as mechanical hazards caused by machine components (including workpiece holding mechanisms), the workpiece, or loads. Electrical hazards arising from direct and indirect contact were also identified, as well as thermal hazards causing burns due to contact with objects or materials at extreme temperatures, flames, explosions, and radiation from heat sources. Among harmful effects, the most significant were laser radiation during marking of the measurement target, ergonomics, noise, and material/substance-related hazards.

Based on the conducted risk assessment, it can be concluded that the proper application of standards, adequate operator training, and adherence to safety procedures enable the safe and efficient use of thermal imaging cameras in industrial practice. This ensures full utilization of infrared thermography while minimizing risks to human health and workplace safety.

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