Non-destructive weld inspection using laser thermography

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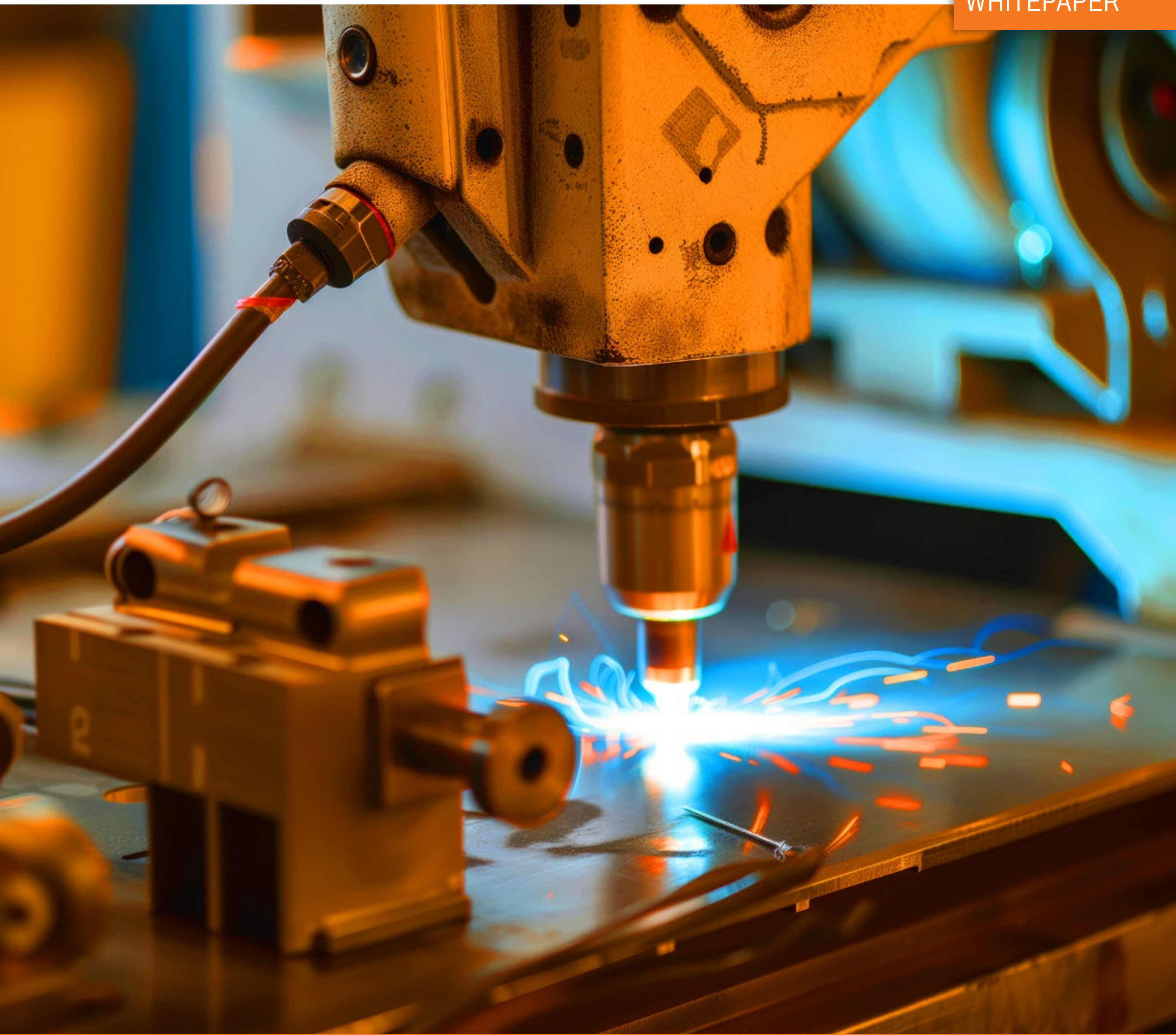
WHITEPAPER



Abstract

Nowadays there is an increasing demand for non-destructive inspection of welds, especially in the field of e-mobility. Defects in battery connections raise safety concerns, as well as have an impact on the efficiency and production costs of new electric cars. The laser thermography inspection technique developed and implemented by edevis provides a fast, precise, and reliable solution for non-contact and non-destructive quality control in an industrial environment.

Introduction

The automotive industry is currently experiencing a shift towards electric vehicles. Batteries are at the heart of these vehicles, and their efficiency and reliability are crucial to the success of electromobility. In this context, battery manufacturing processes and quality assurance are becoming increasingly important.

Cell connector welds are a particular focus as they are crucial to the electrical and mechanical integrity of the batteries. As numerous individual battery cells are connected in a traction battery (Figure 1), the quality assurance of the cell connectors is highly relevant.

- **Safety aspects:** Faulty welds can lead to field vehicle breakdowns as well as short circuits and overheating, which can result in fires or explosions. Thorough inspection minimizes this risk.
- **Performance optimization:** High quality weld seams contribute to optimal electrical conductivity and to overall battery performance. Accurate testing ensures that the battery reaches its maximum capacity and efficiency.
- **Battery longevity:** Ensuring the quality of the welds guarantees the lifespan of the battery, which is of great benefit to both the end user and the manufacturer.
- **Regulatory requirements:** Regulations and standards in the automotive industry require complete documentation and verification of production quality. A reliable inspection system helps to meet these requirements.
- **Economic relevance:** Inline automated quality control of the cell connectors enables early elimination of faulty components. It reduces the cost related to production waste and later warranty claims.

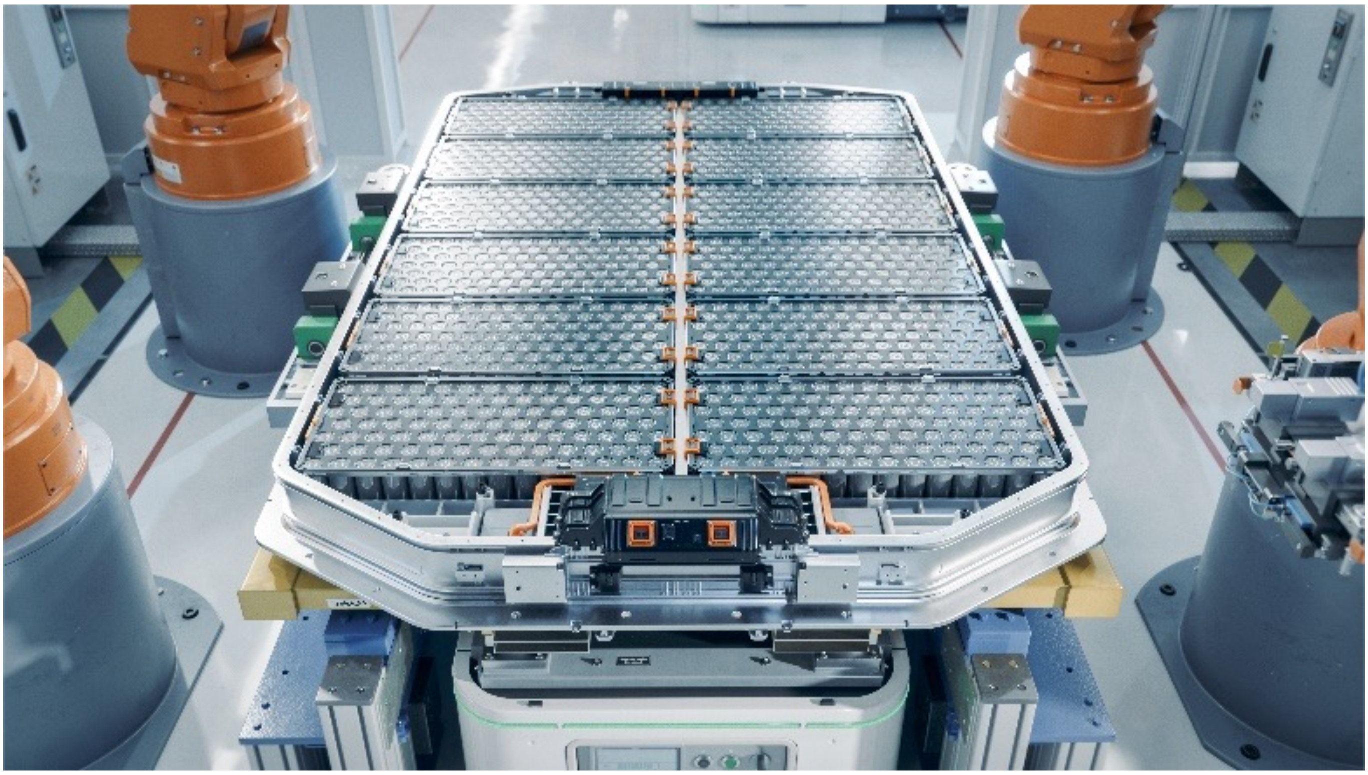
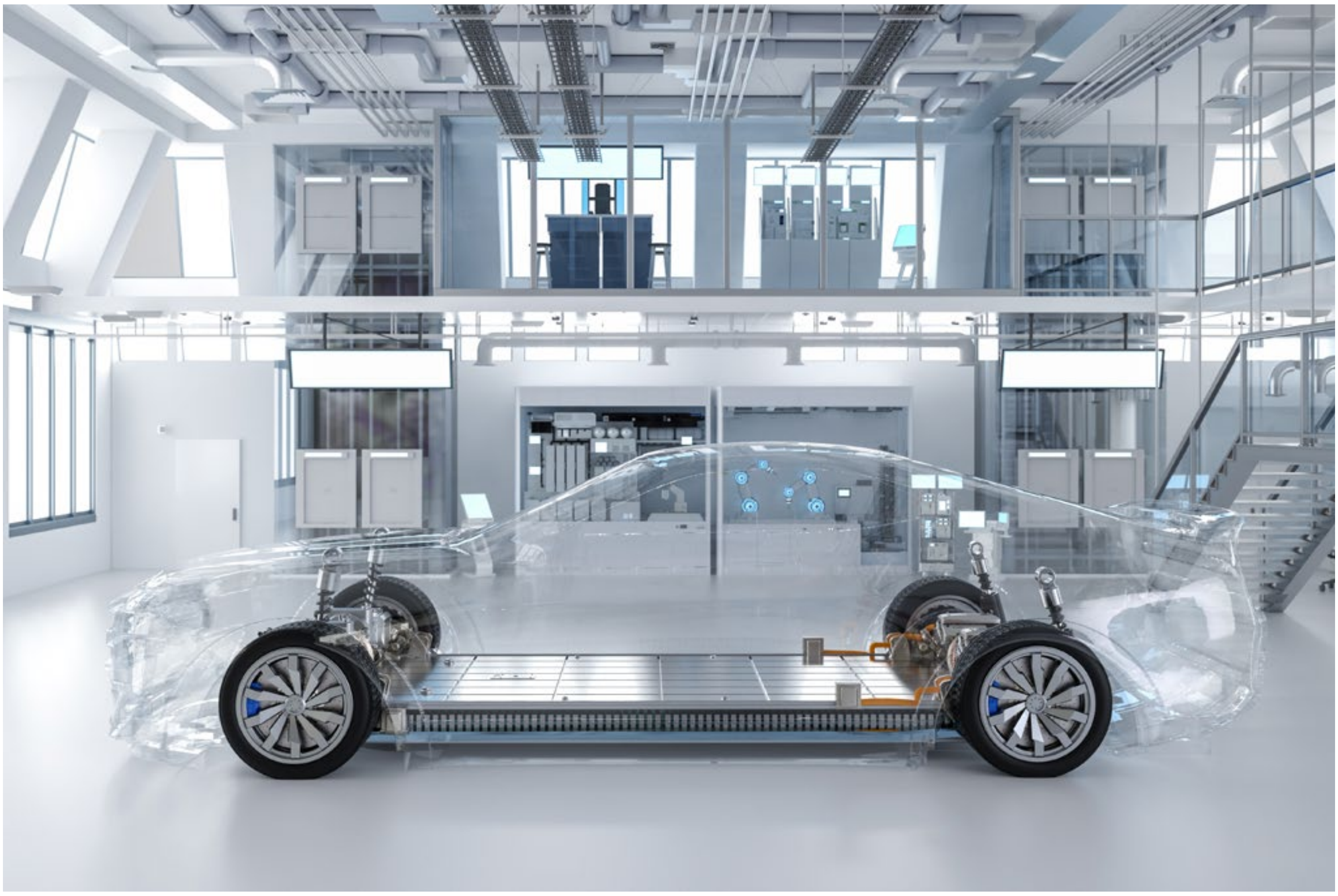


Figure 1: An EV traction battery pack



Background

Inline operation control of the welding process provides continuous monitoring and adjustment during production. Although it offers many advantages, especially in terms of real-time monitoring and process optimization, it also has some limitations that can lead to incomplete information about the quality of the welds. Only a limited number of parameters can be monitored, such as laser power, welding speed, and focus position. These parameters alone are often not sufficient to make a complete statement about the quality of the weld.

The mechanical strength of the joint and its electrical resistance are the most important criteria for the quality of the cell connector welds. They are influenced by factors such as the geometric properties of the seam, weld depth, and internal material defects that are not accessible via in-line process control.

Additional post-weld inspection can help by providing a detailed and comprehensive assessment of the weld quality. Visual inspection cannot evaluate the joint below the surface. Electrical conductivity measurements are unreliable due to the high contact resistance of a weld seam. Mechanical testing is complicated in operation, as well as destructive for a low quality weld, which eliminates the option of complete inline processing and re-welding in case of initial failure.

Laser thermography can overcome this and provide a very fast and extremely accurate way to evaluate the area of the connecting surface affecting the mechanical strength of a weld seam. The measured heat flow is highly correlated with the electrical conductivity, providing a clear and comprehensible quantitative characteristic of an individual seam.

The inspection process can be adapted to a wide range of materials and geometries. As a result, laser thermography offers unparalleled flexibility and efficiency for quality control in the production of high-value components.

Concept

Laser thermography combines infrared thermography with laser excitation, and belongs to the category of non-destructive testing using active thermography. This imaging technique uses heat flow analysis to enable efficient and contactless inspection of internal properties, potential material defects, and the quality of joints. The laser applies targeted heat to the weld seams, whereby the resulting heat flow is influenced by the different materials and joint qualities (Figure 2). A high-resolution infrared camera records the heat distribution in the weld seam in real time. The correlation between heating and cooling makes it possible to determine whether the cell junction is bonded, partially bonded, or not bonded. Inadequate welds and irregularities can be accurately identified.

Phase images from laser thermography measurements visualize the heat flow in the inspection area and provide information about structural variations hidden beneath the surface. In comparison to optical and thermal images, phase images are less sensitive to the surface effects and are suitable for evaluating of the actual joint area of welds (Figure 3).

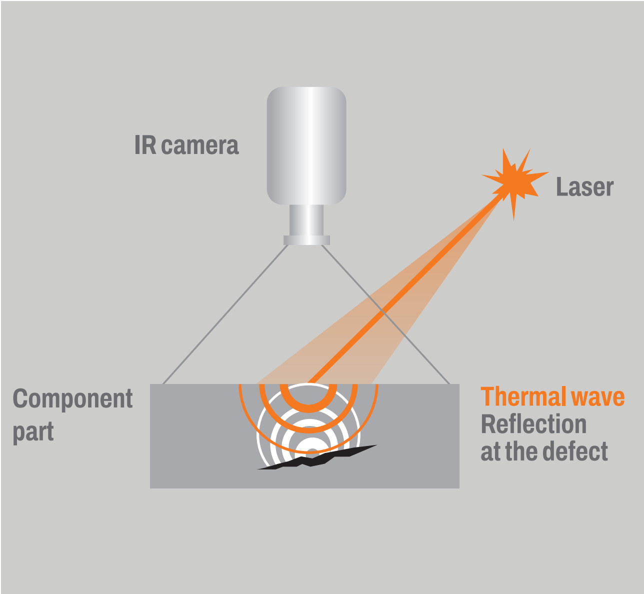


Figure 2: Principle of laser thermography

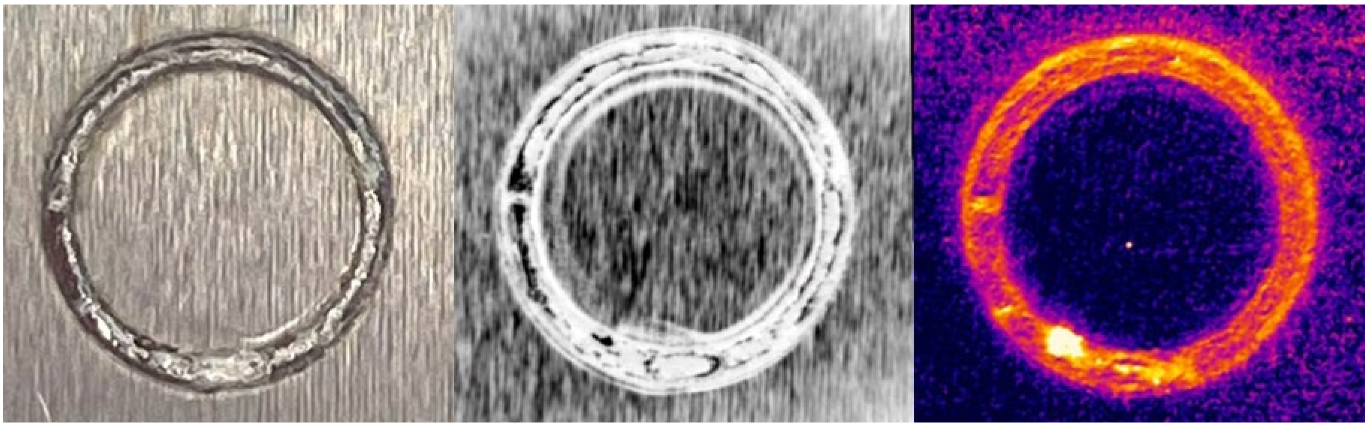


Figure 3: Images of an aluminum – steel weld seam
Left: an optical photo
Middle: IR emissivity image (surface information)
Right: phase image (subsurface information based on the heat flow)

Solution

The core of the edevis **INSIGHT-L** (**In**frared **S**ubsurface **I**nspection with **G**uided **H**eat **T**ransfer, **L**aser) technical solution is the precise optical and temporal coordination of laser and infrared camera, realized by specially developed electronics and software from edevis. Our encapsulated inspection head (Figure 4), which can be mounted on robots or gantries, enables this exact combination. The high-power laser is equipped with special focusing optics that allow variable illumination of the object to be inspected. A high-performance infrared camera uses a high-resolution, fast-reading sensor for accurate heat flow detection. The IR camera can detect thermal differences of less than 20 mK at frame rates up to 1000 Hz with a geometric resolution of approx. 50 µm. The inspection system is complemented by the in-house developed software package DisplayIMG, which uses various image processing algorithms and artificial intelligence for automated evaluation of the measurement results and online differentiation between OK and NOK samples. The inspection setup can be integrated into automated systems via PLC and standard industrial communication protocols, for example PROFINET, OPC UA, and others.

INSIGHT-L can be used to inspect connectors made of various materials (e.g. aluminium, steel, copper) and with faceplate thicknesses of up to ~1 mm.

Laser thermography systems developed by edevis have already been used for the automated inspection of weld seams at more than 100 installations in Europe, Asia, and the Americas.

Conclusion

INSIGHT-L is a thermography-based solution for non-contact and non-destructive testing and quality assurance of welds. It provides the necessary quantitative characteristic of welding joints. The competitive advantages over other methods make INSIGHT-L, developed by edevis, an excellent tool for automated quality control, helping to solve safety, reliability, cost and performance problems in the production of traction batteries and other relevant products.

Figure 4: INSIGHT-L inspection head with active pilot laser

Advantages of laser thermography

- **non-contact and non-destructive testing**
- **fast (≤1 s / measurement)**
- **accurate and reproducible**
- **flexible (adjustable inspection area and OK/NOK criteria)**
- **suitable for automation (PLC controlled), robot mountable**
- **applicable for inline inspection**
- **quantitative evaluation of the weld quality**
- **meaningful and comprehensible inspection results**

Technical specifications

Specification	Detail
Inspection head	
Weight	40 kg
Dimensions	50 cm × 50 cm × 20 cm
Typical working distance to a sample	~ 4 cm
Laser	
Laser type	diode laser
Wavelength	blue or NIR (900 – 1100 nm)
Cooling	water cooling
Illumination area	variable (min. 3 mm x 3 mm, max. 70 mm x 70 mm)
Power	up to 4 kW
Safety class	Class 4
Infrared camera	
Maximal frame rate	1000 fps
Camera opening angle	10°
Thermal resolution	20 mK
Sensor resolution	640 x 512 pixels
Spectral range	MWIR (2 – 5 µm)
Operation parameters	
Inspection in production cycle	< 1 s per weld seam
Possible inspection surface	glossy, matt
Cell connector materials	aluminium, copper, steel
Maximum cable feed length	30 meters between control cabinet and test head
Cables and laser light	compatible with robots
Communication standards	standard Cat 6 cable, Gigabit Ethernet
Automation interface	PROFINET, OPC UA, TCP/IP

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edevis GmbH, based in Leinfelden-Echterdingen, Germany, was founded in 2004 by Thomas Zweschper and Alexander Dillenz. The company specializes in testing equipment for non-destructive material testing using active thermography. The experts at edevis design and develop systems and equipment for the inspection of fiber composite structures, cracks in metallic components, welds and joints. In its own test laboratories, edevis conducts feasibility studies and series tests for customers using various active thermography testing methods. This enables rapid evaluation of testing technologies with limited initial investment by the customer. The company also offers product and technology training on all aspects of thermographic inspection systems and processes, either in its own laboratories or at the customer's site. Inspection systems and components from edevis are used in numerous industries: automotive, plant engineering, aerospace, e-mobility, electronics, research & development, food industry, medical technology, and many more. Porsche, BMW, and thyssenkrupp Automation Engineering are among the company's established customers.

www.edevis.com/en

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