

Thermographic inspection of industrial gas turbine components

Insightful hot spots

Lock-in thermography is a versatile inspection method capable of identifying defects in gas turbine parts. Sulzer Turbo Services Venlo uses this advanced method not only to examine turbine components, but also as an R&D instrument to improve turbine design and repair to the benefit of the customers.

Finding defects in turbine blades is one important task of the lock-in thermography setup at Sulzer Turbo Services ¹. An ultrasound transducer introduces elastic waves (propagating elastic deformations) into the turbine component. In homogeneous material, the reflected waves are evenly distributed. However, at locations where the alloy is

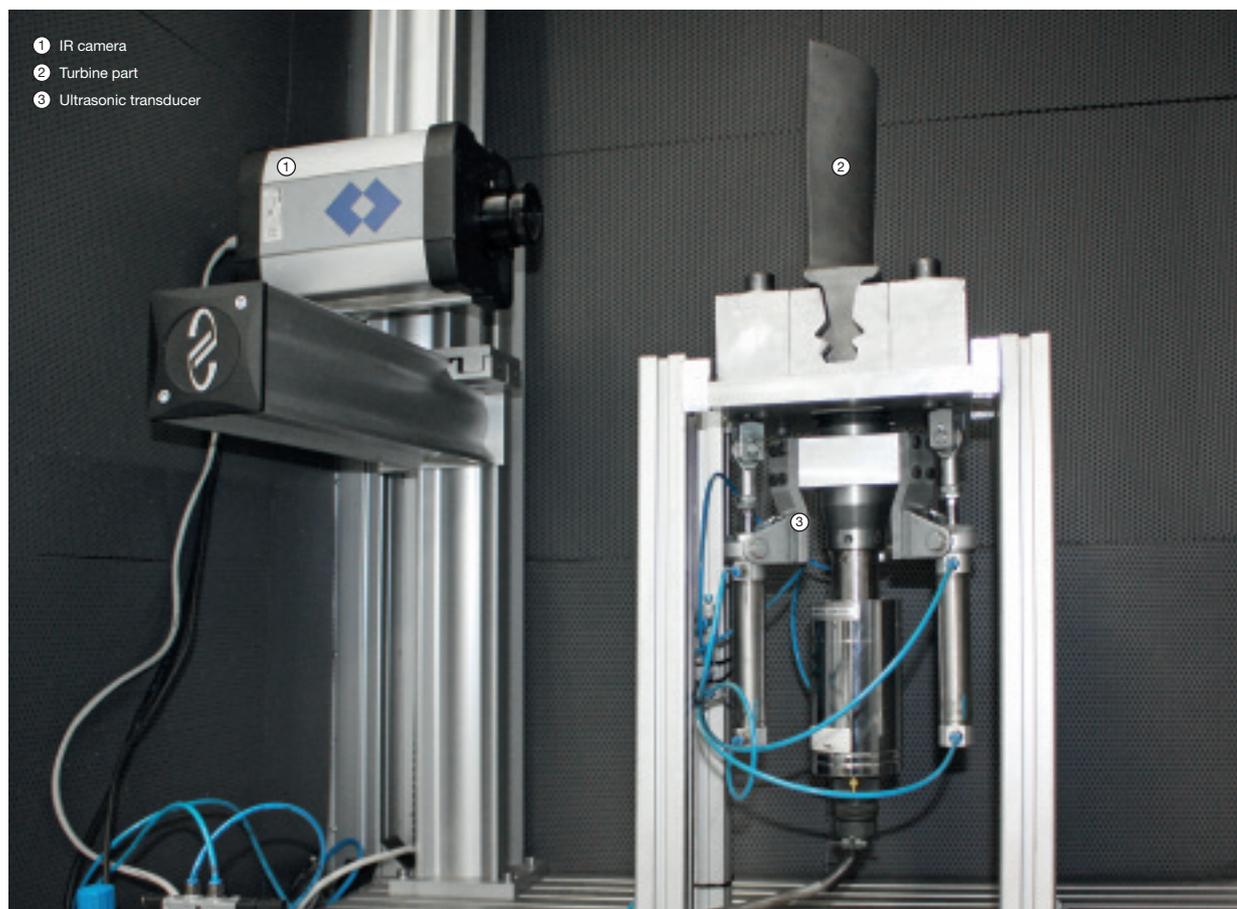
damaged, some of the wave energy is absorbed, and heat is generated. This heat has a different infrared (IR) radiation than its surrounding area and is detected by the IR camera ² (see infobox).

Infrared images reveal defects

Modulation of the ultrasonic wave improves the heat contrast and provides

an amplitude image and a phase image of the turbine component. The amplitude image is a measure for the temperature and is related to the thermal diffusivity. The phase image reveals the size and depth of the defect. The phase is a result of a shift in the output signal with respect to the input signal and is related to the propagation time or depth.

¹ Sulzer Turbo Services Venlo uses ultrasonic thermography for turbine inspection and research.

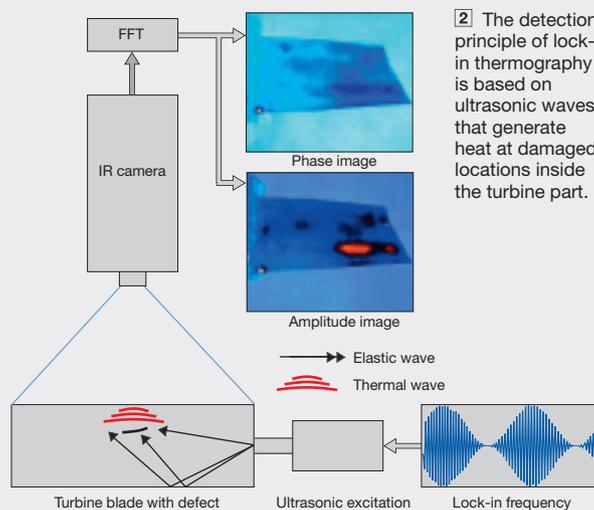


Thermographic inspection

In thermographic inspection, an infrared (IR) camera measures and visualizes the heat distribution within an object.

There are two approaches:

- In **passive thermography**, the existing thermal radiation of an object is measured. Common applications are the detection of insulation faults in housing, detection of overheating in power supply stations, and level detection in storage tanks.
- **Active thermography** introduces energy into the object and measures the object's response. One method is lock-in thermography, which uses a transducer to introduce ultrasonic waves into the object.



The bright spots in the phase image need to be inspected in more detail in order to determine whether the hot spot is a real defect. For this reason, the sequence profile—which is the amount of radiation measured on one spot in time—is analyzed. The sequence profile of a defect is different from the profile of other surrounding heat sources, for example, the reflection of a lamp. A defect shows a response curve similar to the modulation frequency of the excitation.

approaches. For instance, fluorescent penetrant inspection cannot detect internal defects and borescopic inspection is time consuming.

Evaluating coatings with thermography

Ultrasonic lock-in thermography can also detect a lack of proper bonding between the parts and their metallic coating. The elastic waves cause vibration in

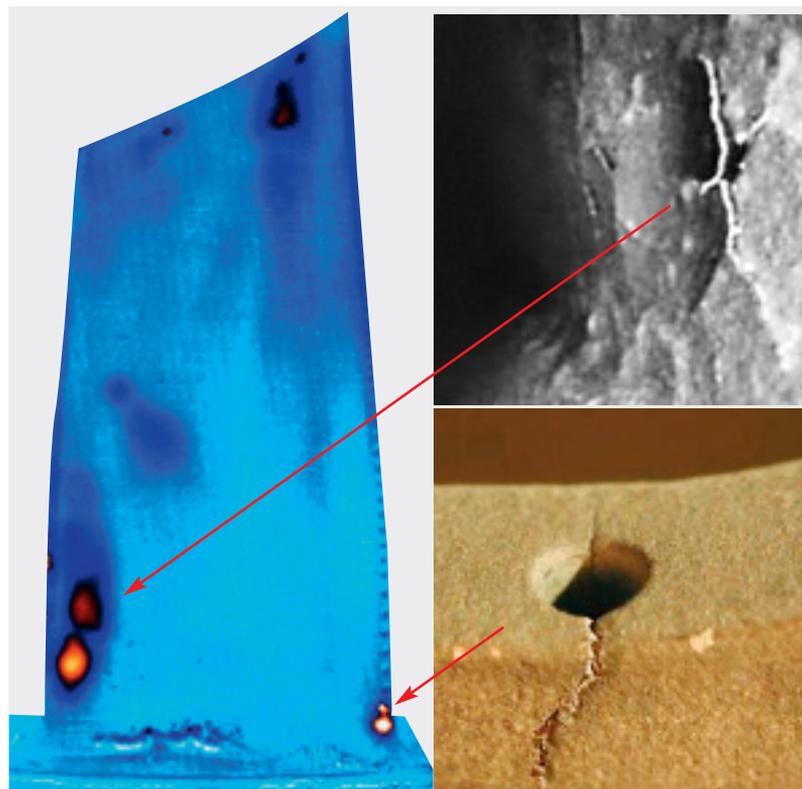
the part. If the coating is bonded properly to the base material, no friction heat is observable. Friction between the part and the poorly bonded coating creates a bright thermal signature. Recently, thermographic inspection has been compared with conventional manual ultrasonic inspection with a probe, and a 100% match of observed indications has been achieved.

Distinguishing between internal and external defects

Sulzer Turbo Services Venlo applies lock-in thermography to identify structural defects in turbine parts. Such defects include cracks along the grain boundary that have been caused by corrosion, oxidation, mechanical stresses, or casting defects.

Because turbine parts are made of metal alloys, the heat signature generated is not just limited to the defect itself. The heat is conducted and creates a slightly weaker “hot spot” that is larger than the defect itself. The advantage of this thermal conduction is that the heat signature of internal defects is detectable as a diffuse heat source at the surface. Thus, ultrasonic lock-in thermography can detect both external as well as internal defects. Figure 3 shows the detection of cracks on the surface and inside of a blade. This method has significant advantages over other

3 The results of a thermography inspection show damage to a turbine blade. The magnified image on the top shows an internal crack; the magnified image on the bottom shows a crack on the surface.





4 Cooling channels protect turbine blades from high temperatures.



5 The thermographic measurement of a blade shows open and blocked cooling channels.

Detection of blocked cooling channels

For turbine components, cooling is very important to extend and protect component life 4. During the repair of vanes or blades with cooling channels, it must be ensured that all cooling holes are open.

An IR camera can show at a glance whether cooling holes are blocked or open. This is achieved by blowing

warm air through the component. A thermal image of the part is recorded in order to visualize the heating of the component. Figure 5 shows an example of such a recording. Open cooling holes appear in bright yellow because of the heating by the warm air. Blocked cooling channels are not heated; they appear as a blue-black color.

Research on the efficiency of cooling holes

Sulzer has started a research project in order to develop a method of evaluating the efficiency of cooling channels of turbine blades and vanes. The results of this project will provide more information about how the cooling-hole geometry affects the cooling efficiency.

The research is based on a heat transfer model that has been developed by the

National Aerospace Laboratory of the Netherlands. This model describes the heat transfer between combustion gas, cooling air, and surface temperature of the part. In order to validate the model, Sulzer built a test rig that represents the turbine situation, just with inverse

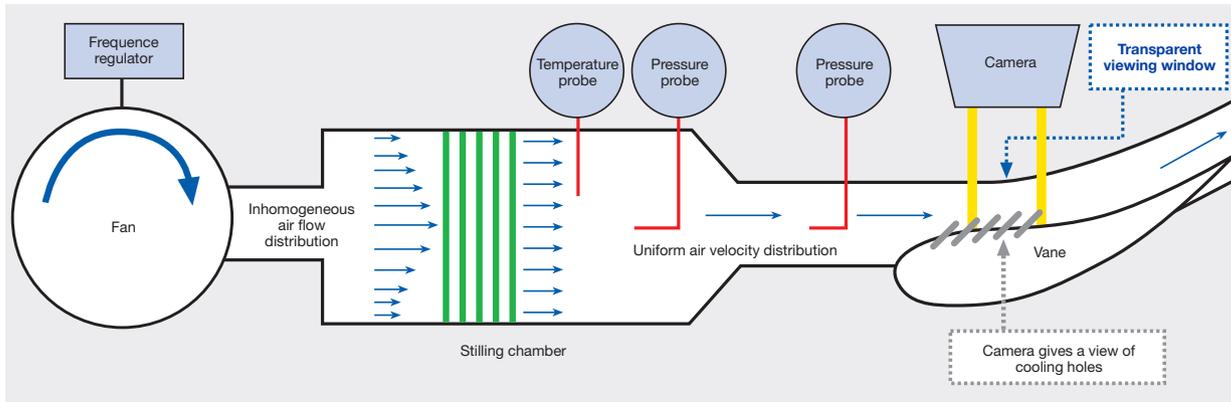
The research results will allow the optimization of the cooling efficiency.

thermal conditions. Warm air is guided through the cooling channels and cold air flows along the outer surface of the part. The parameters have been scaled down to ensure proper flow regimes and flow ratios.

Validation of heat transfer model

The test rig 6 is designed to achieve a controlled flow of air along the airfoil. For the hot air that flows through the vane, a temperature and flow control is used. The actual setup consists of a vane surrounded by a heating element, cold airflow section, and IR camera. It allows the measurement of the wall temperature of the component.

An example of a measurement is shown in Figure 7. The homogeneity of the cooling-hole pattern of four rows of ten holes is easily recognizable by the



6 The test rig is designed to achieve a controlled flow of air along the airfoil.

peak temperatures. These results will be used as input for the model verification in the ongoing research project.

Versatile use of thermography

The projects of Sulzer show that the lock-in thermography technique is able to detect:

- Cracks in turbine blades, both external and internal
- Grain boundary attack in turbine blades

- Corrosion in turbine blades
- Spallation in the coating
- Blocked cooling holes

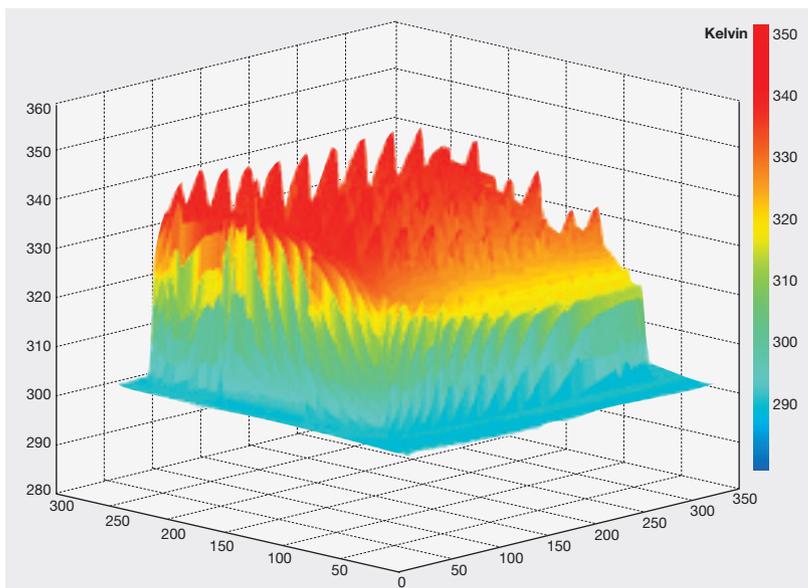
Due to the high sensitivity of the IR camera, even minor hot spots can be detected. A careful analysis by experienced technicians is important in order to decide whether small defects are within allowable limits or whether the defects need to be repaired.

Apart from fault detection, ultrasonic lock-in thermography is very successful as an R&D instrument that enables engineers to increase their knowledge of turbine parts, improve repairs, and

With ultrasonic lock-in thermography, engineers increase their knowledge of turbine parts.

develop new designs to the benefit of the customers.

7 The thermographic analysis of the cooling holes delivers data to help verify the heat transfer model.



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