
How to Maximize the Return on Investment.

Monitoring and Inspection of Mechanical Systems by Using Infrared Thermography

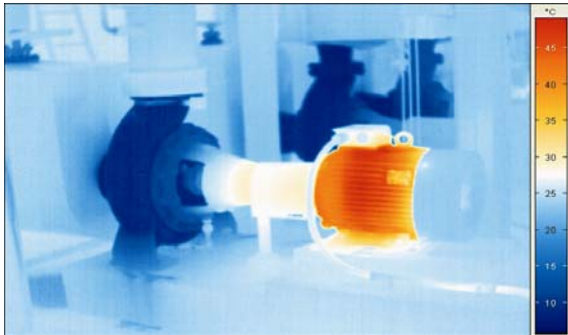
According to the recent developments in both theory and practice, the maintenance concept is no longer simply considered as a set of activities for preserving assets or preventing failures, but it has been developing towards the idea of a high technological system aimed at reducing risks and increasing plant's performances and life time. This evidence seems to be even more crucial if applied to the process industry, where well-run programs of predictive maintenance allows the early detection of potential problems, thus avoiding unexpected repairing costs due to damage which could occur. In the drafted framework, infrared thermography has been proven to be one of the most efficient and convenient available technologies to be integrated in high performance maintenance programs in terms of return on investment. According to the International Automation Society (ISA) - a non-profit organization based on the Research Triangle Park (USA) that helps automation professionals worldwide - starting an industrial predictive maintenance program results, on average, not only in a remarkable return of 10 times the initial investment, but also it cuts about 30 % of the maintenance costs. Moreover, it rises the production, estimated from 20 % to 25 %, by avoiding breakdowns and reducing downtime.

Mechanical systems represent a large proportion of equipment in the process industry. All rotating and reciprocating machines have the common characteristic that heat is generated as a result of friction caused by defective components including bearings, seals, pulleys, conveyors, pumps, couplings, shafts, gears, chain drivers, etc. This friction could be the result of excessive wear or misalignment and can lead to catastrophic failure; often it could simply be due to inadequate maintenance, lack of lubrication, overloading or even misuse. Having this in mind, infrared thermography gives you a precise and efficient solution for detection of overheating areas or hot spots of mechanical components in order to prevent failures and damage.

Infrared thermography is a measurement technology based on the physical phenomenon that all bodies with a temperature above the absolute zero (0.0 K or $-273.15\text{ }^{\circ}\text{C}$) emit electromagnetic radiations. Suitable infrared detectors, integrated in thermographic systems, are able to capture and convert into an electrical signal the energy of the radiations emitted at the object's surface, in the infrared spectrum range. In addition, being infrared, thermography is a non-contact measurement solution, it does not influence the object's temperature, and measurements can be taken without the need to interrupt the operation of the machine. High quality thermographic cameras, based on FPA microbolometers detectors, provide you with not only a high geometrical resolution (up to 1280 x 960 pixels), but also an excellent thermal sensitivity better than 80 mK (NETD).

The quality of the optical system is also fundamental to being able to obtain a high standard of image, by allowing as much energy (radiation) as possible through to the detector. You may also need the facility of being able to change the lens on the camera to meet the required field of view (FOV) and focus distance. Let's assume that a lens would have an IFOV equal to 0.8 mrad. At 1 m distance this would allow you to detect theoretically a hot spot of a side length of equal or bigger than 0.8 mm. As long as the measurement distance increases, both FOV and IFOV extend; therefore, you have to make sure that the hot spot to be detected would be bigger than the area represented by a pixel, which corresponds to the IFOV at a certain distance.

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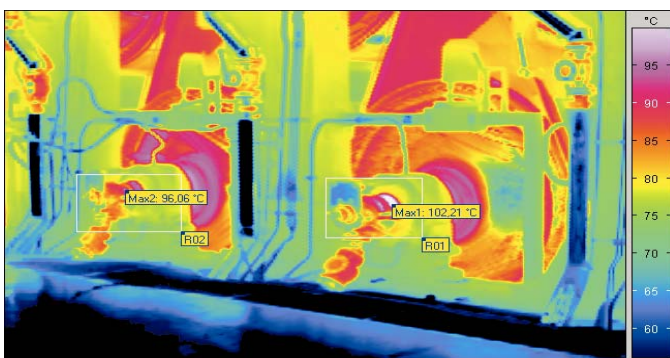
Img. 1 Thermogram of a running motor



Img. 2 Visual image of a running motor

When doing thermographic monitoring for maintenance tasks it is generally valuable not only to obtain the thermogram (image 1), which displays the temperature distribution of the measured mechanical system, but also the visual image of it (image 2). In this way, you are also provided with the kind of data the human eye is used to and that might be useful for distinguishing more clearly the problem, especially when detecting similar objects like a sequence of switches or bearings.

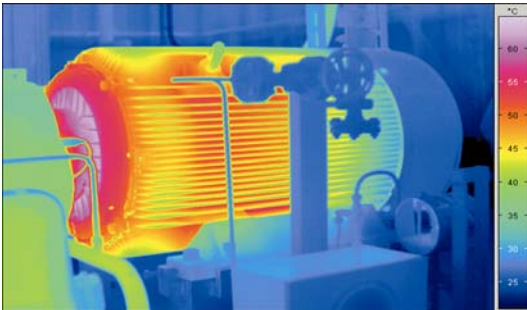
Bearings are necessary components in every motor system, since they are able to reduce friction between a rotating shaft and the fixture that holds the shaft in place. When attached to machinery, bearings have to support not only the weight of the rotor, but also an additional load is added. The motor power and the bearing strength limit the maximum mechanical load. Bearings do not fail instantaneously; it is a progressive failure where continual rotation increases the temperature and further damages the bearing. Overheating of a bearing is likely to occur if it is placed under excessive load or if there is a lack of or dirt in the lubrication, this overheating can easily be identified at an early stage using an infrared camera (image 3); in the image you can see the hot spots in the selected areas.



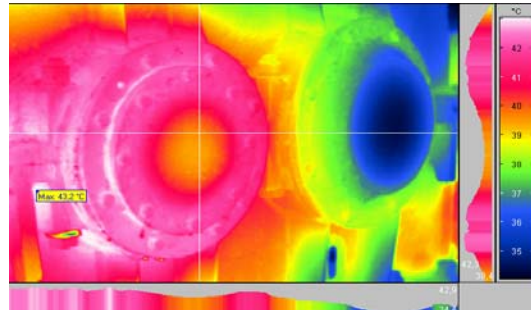
Img. 3 Overheated bearings of motors

Using high-quality thermographic cameras we can get not only an overview of the motor temperature distribution (image 4), but also a close up of the hot spot we want to detail by changing a lens of a standard range for a telephoto one (image 5).

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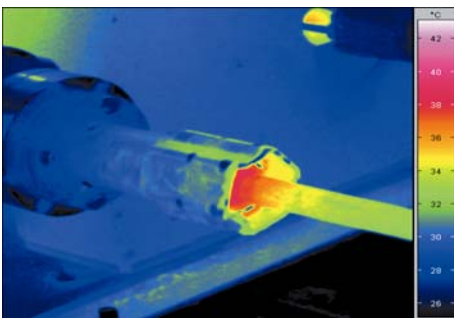


Img. 4 Motor diagnostics with standard lens

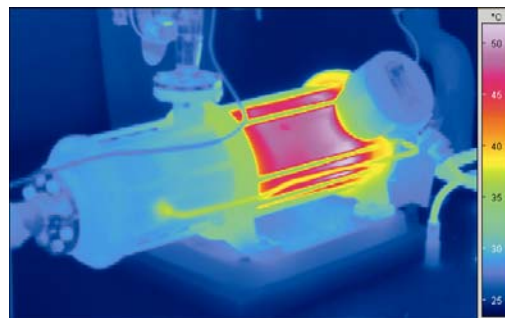


Img. 5 Hot spot with telephoto lens

Amongst the most common problems mechanical systems are subject to is misalignment which can cause expensive energy losses. This misalignment can also lead to problems such as looseness, bent shaft, imbalance, even catastrophic failure. It is clear that as the misalignment increases, the temperature increases. Consequently, a misalignment shaft will result in unequal loading causing heat generation at the point of highest mechanical resistance (image 6).



Img. 6 Overheated drive shaft due to misalignment

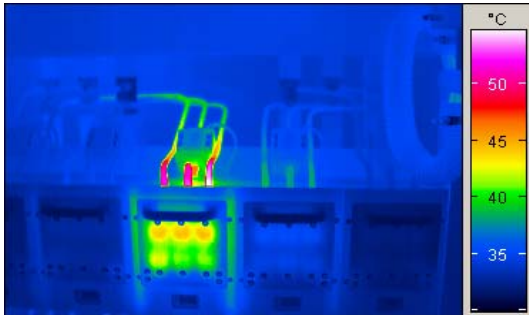


Img. 7 Surveillance of a pump

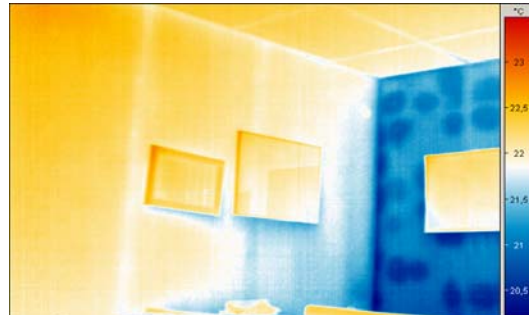
Other typical findings occur in pump motors (image 7), where the deterioration of lubricant is likely to heat up the motor itself; moreover, mechanical friction and stress points can cause the overheating of flexible couplings, like belts or gear trains, meant to overcome any misalignment in mechanical connections.

Besides mechanical equipment applications, thermographic solutions are commonly used for inspection of electrical installations in order to detect temperature raises, due to high resistance or excessive current flow, thus avoiding catastrophic failures of the components (image 9). Additionally, thermography could be used for checking the thermal efficiency of buildings both from inside and outside, as finding insulation defects (image 10) or weak points, causing relevant energy losses.

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Img. 8 Inspection of electrical installations



Img. 9 Poor insulation of an outside wall

Infrared thermographic systems locate problems well in advance of failure occurring, resulting in an immediate payback of investment and avoiding plant breakdowns. Payback can vary widely depending on the type of facility and use of the infrared equipment. However, according to the US Federal Energy Management Program (FEMP), on the average, a facility can expect a payback in 12 months or less. In addition, studies conducted by the FEMP estimate that a well-run predictive maintenance program can provide savings of 30 % over a reactive maintenance approach.

Among the critical factors to any effective infrared predictive maintenance solution, professional thermography training has to be taken into account. In order to maximise the return on investment on cameras, accessories and software, the professional maintenance personnel must be trained on how to use efficiently the infrared equipment. Therefore, it is strongly recommended to ask specialists for the solution that best fits your maintenance needs, including technical training and ongoing support. This will allow you to implement in-house infrared PM plans, thus eliminating existing expenses such as periodical thermographic inspections to be carried out by outside consultants. Moreover, since thermal imaging is a non-contact technology, safety will also be improved; in particular, while inspecting rotating machinery users can stay out of harms way.

Other benefits of investing in thermographic systems are the reduction of unexpected downtime and the increase of the life expectancy of the facilities. Among the several **unplanned downtime cost** variables that have to be taken into account, the lost revenue during downtime (in dollars per hour) and the replacement/repair costs are the most relevant. Once estimated the overall unexpected downtime cost, it is particularly worth comparing it to the initial investment on infrared thermography equipment. Calpine Corporation, which is a leading North America power company, based on a multiple-case survey, has figured the average unplanned downtime cost including replacement costs, due to a water pump failure, of approximately \$200,000. From a cost-avoiding perspective, the ISA estimated that an unexpected downtime costs about 12 times more than a scheduled one, which requires also suitable thermographic devices and certainly covers their purchase cost.

Ultimately, as the final goal of any predictive maintenance technology is to keep equipment up and running, it is clear that gaining the chance to schedule the necessary downtime during periods of production inactivity (off shifts, weekends, periods of slower demand, etc.) allows you to save a significant amount of money and justifies investment in infrared equipment.

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References and resources

1. US Federal Energy Management Program (FEMP), *O&M Best Practices Guide*, Release 26/04/2006, http://www1.eere.energy.gov/femp/pdfs/OM_6.pdf
2. International Automation Society (ISA), Research Triangle Park, USA, <http://www.isa.org/>
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