Linear Heat Detection in Special Applications

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Abstract

A major advantage of the linear heat detection (LHD) technology is the immunity to electromagnetic interference, dust, chemicals, moisture, vibration and other environmental factors. Since no electrical energy is used in the sensor cable and the optical energy can be safely limited, such systems can also be applied for fire detection in explosive areas. We present some new special applications where LHD is advantageous compared to other fire detection technologies.

Keywords: linear heat detection, fire detection, special application, fibre-optic sensing

Introduction

LHD using fibre-optic sensing systems was introduced to the marked about 15 years ago and is meanwhile a well-established technology for fire detection in tunnels. The LHD technology is suited for the surveillance of thousands of locations in a distance up to 2x 10 km using a single interrogator. The sensing element is a fibre optic cable with no electricity or individual sensing elements.

LHD is based on Raman scattering of laser radiation in optical fibres. Raman scattering is an intrinsic property of the glass material of the optical fibres. It generates two wavelength-shifted signals (anti-Stokes and Stokes) that differently depend on temperature. Modulation of the exciting laser enables the assignment of signals to locations along the fibre. The ratio of both Raman-signals is then used for calculating the temperature at hundreds to thousands of positions along the fibre. A zone-based alarm processing using maximum temperature, rate-of-rise and zone-differential criteria is used for fast and reliable fire detection and for a precise determination of the position, size and propagation direction of the fire.

Robust sensor cable designs protect the optical fibre reliably and enable the use of the LHD technology in rough industrial environments. We show examples for requirements, solutions and applications in cable trays, nuclear power plants and chemical plants.

Reactor Skin Monitoring

Possible challenges for LHD in chemical plants are high temperatures, presence of hydrogen, corrosive chemical environment and danger of explosion. For such environments, we design hydrogen resistant optical fibres with chemical resistant high temperature coating as well as sensor cables made of high-alloyed steel or superalloy tubes and optional fluoropolymer sheath. The optical power in the sensor cable can be safely limited to enable operation of the sensor cable in explosive areas. Encapsulation of the LHD interrogator in a flame and pressure proof cabinet allows installation of the whole system in the explosive area.

Huge, complex reactors with several reaction, mixing and separation zones are used in the chemical industry. Temperatures inside the reactors can vary considerably depending on location, composition of reactants and other process parameters. Our LHD systems are ideally suited for customized solution of the reactor skin temperature monitoring of chemical plants, reactors and vessels using high-temperature fast-response fibre-optic sensing cables. A meander-like laying of the sensor cables enables temperature monitoring and hotspot detection on the whole reactor skin with high spatial, temporal and temperature resolution.

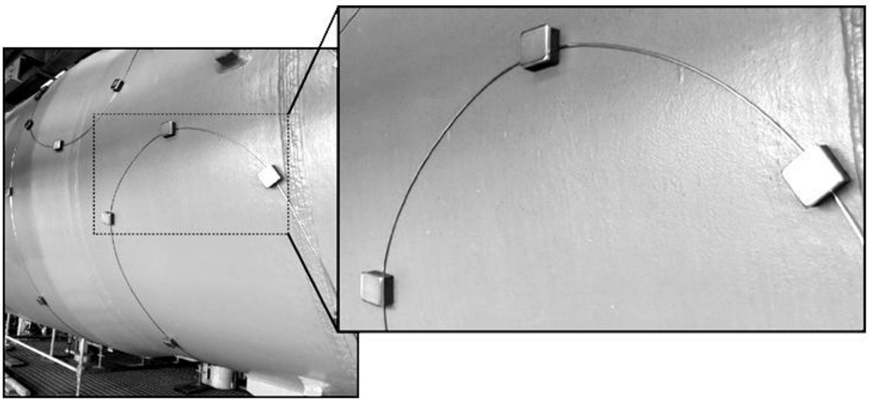

Fig. 1. Stainless-steel sensor cable mounted on a reactor skin using high-temperature magnetic fixtures.

A loop configuration of the sensor cable and a double-ended measuring mode using 2 interrogators serve for full redundancy and enable automatic self-calibration in case of fibre ageing at high temperatures up to 300°C. The cable is mounted on the reactor skin by using proprietary high-temperature magnetic fixtures in order to avoid any welding on the pressure vessel. The knowledge on the temperature pattern on the skin allows a safe operation of high-pressure and high-temperature reactors and enables an optimization of process parameters for enhanced efficiency of the overall process.

Galvanization

Galvanization is widely used for protecting electrically conductive materials against environmental impacts by deposition of ultra-thin corrosion-resistive layers. The electrochemical process requires the maximum care and accuracy of the operators to avoid any risk for environment, equipment and health. PVDF-sheathed stainless steel sensor cables are used for monitoring the skin of electroplating bathes to ensure high reliability, low maintenance and long lifetime of the LHD system. Besides fire detection, the LHD system also detects in real-time deviations from regular operation conditions with high spatial and temperature resolution. Thus, the LHD system enables to trigger corrective actions even before the process is out-of-control and a fire is ignited.

Pickling Lines

Impurities from ferrous metals, copper and aluminum surfaces are efficiently removed by pickling in dilute or concentrated acids. Heating the acid solutions to temperatures around 70°C improves the cleaning performance considerably. However, the hot acid causes considerable hazards and monitoring the surface temperatures of the pickling lines is highly desired to avoid them. LHD systems with chemically inert sensor cables similar to that used in galvanization allow to detect deviations from normal operation quickly and to take countermeasures immediately. Again, cable loops and double-ended measuring mode are used for full redundancy. The zone-differential (hot spot) criterion has proven to be most efficient in detecting local fatigue of the skin material. Our LHD systems proved to be a powerful tool to ensure safety and to eliminate the risk of damages in this application.

Combined Room and Local Protection

The LHD systems of the LHD3-series are approved as line type heat detector systems according to the European standard prEN54-22. The systems are not only approved for room protection using response classes A1N or A2N, but also for local protection in close proximity to a potential fire risk using response classes BN or CN. Whereas the maximum application temperature on room protection is 50°C, the application temperature in local protection in the approved classes can be as high as 65 or 80°C, respectively. Examples for local protection applications are paint-spray lines, ovens in industrial bakeries, compost works and other industrial production facilities.

The same types of LHD3 system and sensor cable can be used for both, room and local protection. The alarm parameters of each zone of the LHD3 system can be easily configured in a way that they are either compliant with room protection or local protection in one of the approved classes. Accordingly, a single LHD3 system can be used for combined room and local protection.

Floating Roof Tanks

Floating roof tanks are used for the storage of liquid educts and products containing hydrocarbons originating from petroleum refining and/or petroleum distillation. The special feature of this type of storage tank is the pontoon roofs floating on the stored product. Hence, low gas volume is present even at the lower filling level.

The tanks have a typical height of 25 to 30 m and a diameter of 30 to 100m. The edge of the roof cannot be connected to the wall, but must be as gas-tight as possible to prevent excessive evaporation of the product.

Since the rim is not hermetically sealed, there is a permanent build-up of flammable gas atmosphere in the annular gap and also on the roof. These conditions correspond to explosion protection zone 0.

To avoid an emergency situation in case of lightning or other ignition, the entire pontoon roof of the tank can be flooded with extinguishing foam. The extinguishing pipes are usually symmetrically arranged radial at the top of the tank.

The LHD3 system triggers the activation of the extinguishing pipes in case of a fire alarm. For the early detection of a fire it is best practice to mount the fibre optical sensor cable at the pontoon roof above the rim seal, as shown in figure 2.

The LHD3 systems are approved for use of the sensor cable in zone 0 according the European ATEX directive and the IECEx scheme. It is classified as intrinsically safe protection equipment using optical radiation according to IEC / EN 60079-Part 28.

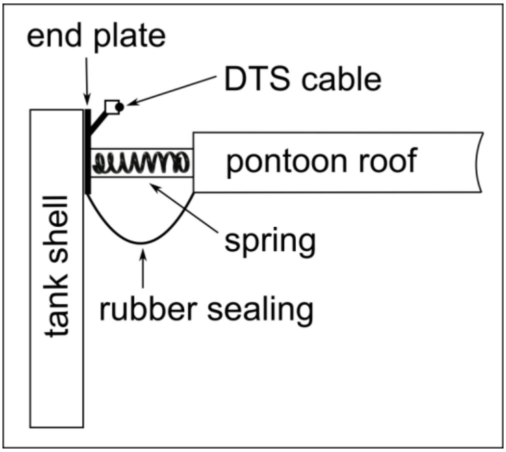

Fig. 2. Schematic of the rim seal and the mounting of the sensor cable

Conveyor Belts in Power Plants

In coal-fired power plants a system of conveyor belts is installed to connect the coal dumps with the power plants units. Caused by friction of the bearings and abrasion the rollers in the roller seats of a conveyor belt can significantly heat themselves up to the annealing. This event can be a source of an ignition for e.g. coal dust or slack coal in the surrounding of the roller seat.

The LHD3 linear heat detection systems can be used to permanently monitor the ambient temperature of the roller seats. An abnormal increase of the temperature can be identified and a roller seat can be located precisely before a source of an ignition arises.

The fibre optical sensor cable is a purely passive sensor, immune against EMC and robust and almost maintenance free even in harsh operating environments. The fibre optical sensor cable is sensitive to radiated as well as conventional heat. Therefore an early fire alarm is achieved by a positioning near potential fire loads along the conveyor and at the roller seats. The figures 3 and 4 show an example of a conveyor belt in a coal-fired power plant.

Fig. 3. Conveyor belt in a coal-fired power plant

Fig. 4. View on the roller seats of a conveyor belt

The fibre optic sensing cable is easy to install with clamps, tension wires or cable tray clips. The interrogator can be operated with multiple sensor cables in single- or double-ended operating mode. The last offers redundancy in case of a single break of the sensor cable, which can have a length of up to 10km.

The temperature data and derived zone alarm information can be transmitted to the operator's management system via number of standard protocols, like e.g. MODBUS TCP/IP.

Concert Halls

Concert halls are buildings with an extreme ceiling height. Inside the hall the broad seating and the floor decking represent a substantial fire load.

In case of fire an automatic local fire suppression can avoid a fire spread, while the damage caused by water for fire-fighting is limited.

The automatic local fire suppression system requires a fast triggering and the exact localisation of a fire only activating relevant areas of the suppression system. It was evaluated that the linear heat detection system LHD3 is well-suited for this tasks.

For a real fire test a part of a tribune of a concert hall with its seating was setup. The fibre optical sensor cable was integrated into the floor decking positioned in the ground and on the backside of each line of seats in the step of a staircase.

The LHD3 system was configured to measure with a sampling interval of 0.25 m and 4 s measuring cycle time. Its alarm parameterization comprised a set of rate-of-rise criterions and a maximum temperature value. The alarm zone definition covered a line of stairs aiming the triggering of a locally limited part of the fire suppression system.

In the fire test a single chair with a defined fire load was ignited using a pillow made of paper.

Fig. 5. Fire testing of the LHD3 response time and localisation ability

It could be verified that the LHD3 system suitably responded within less than 3 minutes. The fire alarm was signalled at the correct meter position, activating the corresponding alarm zone.

Cable Trays

The maximum current load of electrical cables is specified for a standard environment. In cable trays, the ambient temperature of a cable can be considerably increased by the heat generated by other cables and heat transfer from the cable can also be reduced by the. Consequently, the cable reaches the maximum permitted temperature at clearly lower load than specified. Continuous monitoring of temperatures along the cable tray can be used to signal any overheating. It thus enables a safe operation of all the cables without melting or degradation of the insulation and the resulting electrical firing. The same LHD system can be used for fire detection.

Optical fibres for monitoring cable temperatures can be integrated into the electrical cables. However, the sometimes quite thick electrical cables have comparably long thermal response times. For fire detection, separate fibre-optic sensor cables have to be laid inside the cable trays to ensure the short response times required for fire detection.

Radioactive Areas

LHD is also used for fire detection and for avoiding overheating of cable trays in nuclear power plants or research facilities. The radioactive radiation can cause darkening of standard optical fibres. Radiation-hardened optical fibres show considerably lower radiation-induced darkening. The remaining darkening is compensated by automatic self-calibration of LHD systems with looped sensor cable. Finally, blow-in technologies using microducts enable a periodic exchange of fibres where the radiation level is extremely high. All that measures enable a long-term, reliable fire-detection in those environments.

Summary

The linear heat detection system LHD3 is suitable in a wide range of applications with special demands. The various types of sensor cables offer immunity against EMC, harsh environment and the suitability in a wide temperature range. The light wave guide as distributed fibre optical sensor is mechanically protected by the sensor cable design. The LHD3 interrogator is capable of parameterisation. Short measuring cycle times and high spatial resolution are available for up to 10km per measuring channel. The parameterisation of alarm zones along the sensor cable enables the alarm and event processing on the basis of the measured temperature profile of the entire sensor cable. Alarms, events and the temperature data can be communicated via a number of standard protocols.

The current applications include fire detection in chemical plants, galvanization, pickling lines, floating roof tanks, conveyor belts, park garages, cable systems to concert halls. Further applications can be easily accessed due to the adaptability of the technology.