POSSIBILITIES OF USE OF THE THERMOGRAPHIC MEASUREMENT AS A TOOL FOR DETECTING DEFECTS AND IMPROVING THE PRODUCTION PROCESS

Eva RYKALOVÁ, Zdeněk PEŘINA, Radek FABIAN, Petr JONŠTA

Abstract
Infrared radiometric long-waved systems are widely used in various industries as well as in research and development. This long-waved system is the perfect tool for quick diagnosis of the state of the equipment, easy defect detection, which is reflected by higher temperatures due to increased friction and wear. Infrared radiometric long-waved systems are used especially in civil engineering, electrical engineering, metallurgy and many other industries. They are also used to optimize and improve of the production processes. The series of measurements using the infrared radiometric long-waved system in steel plant were carried out due to prepared research project. Images of temperature fields of ladles with liquid steel, cooled exhaust knee of electric arc furnace and ingot mould were obtained during solidification of steel ingot. Information about the state of wear of the refractory lining of the ladle, exhaust knee can be gained from obtained images. The obtained results can be used for more accurate numerical simulations of the process of casting and solidification of steel ingots.

Keywords:
Infrared radiometric long-waved system, ladle, exhaust pipe, steel ingot

1. DESCRIPTION OF STEEL PRODUCTION AT EAF STEEL PLANT
The main technological aggregates at EAF steel plant VÍTKOVICE HEAVY MACHINERY a.s. are electric arc furnace (EAF), ladle furnace (LF) vacuum degassing station (VD/VOD). Final products of this steel plant are steel ingots weighing up to 200 tons and steel castings up to 370 tons of rough weight.

Electric arc furnace is melting unit. This EAF was renovated in 2007. The capacity of furnace is 80 tons of liquid steel. Transformer is 40/42 MVA. There are three oxygen-fuel burners. Only scrap is used for steel production. The bottom and the furnace heart are lined with refractory while walls are equipped by water-cooled panels. Exhaust pipe from EAF is also water cooled. Water cooled parts of unit which operates with liquid steel should be dangerous in cases of an accident. Therefore, these components must be carefully monitored and controlled. Although the furnace is equipped with a number of temperature sensors it is appropriate to carry out regular checks using other methods.

Secondary steelmaking is most commonly performed in ladles and often referred to as ladle (metallurgy). Some of the operations performed in ladles include de-oxidation, alloy addition, inclusion removal, inclusion chemistry modification, vacuum degassing, de-sulphurisation and homogenization. It is now common to perform ladle metallurgical operations in gas stirred ladles with electric arc heating in the lid of the furnace. Tight control of ladle metallurgy is associated with producing high grades of steel in which the tolerances in chemistry and consistency are narrow.
2. MEASUREMENT OF SURFACE TEMPERATURES ON MEASURED DEVICES

2.1 Ladle

Ladle is basic production unit in each steel plant. Secondary metallurgy, it means processing of liquid steel is carried out here. Ladle consists of steel shell and is lined by refractory material which must to resist very high temperature. The steel temperature in the ladle ranges from 1450 °C up to 1700 °C. This temperature depends on steel grades and the used kind of steel refining. Refractory must also resist to erosion which is caused by the movement of molten steel in the ladle. Intensive steel mixing is necessary due to dissolution of metallic and nonmetallic additives. Mixing is provided by blowing argon in the ladle bottom.

For these reasons, the life of refractory lining is limited. Ladle lining is divided into two main basic areas that have a different composition and properties. This is the lining to an area where the steel is and to the area where the slag is. Due to corrosive effects of the slag is the lifetime of this area shorter. Under conditions the steel plant VHM a.s. ladles lining of slag area is commonly replaced after 20 heats. Refractory lining of whole ladle is replaced usually after 40 heats.

The temperature field of the ladle can be mapped very well by using thermal camera. Some areas with defects should be identified very easily. These defects are mainly caused by worse state of ladle refractory. If there is a certain place with higher erosion of lining and refractory is so thinner than in other places, the place has a higher temperature. Decrease of ladle lining and also determination the appropriate term of replacement of ladle lining can be traced by long-term monitoring with the thermal camera. The risk of ladle shell melting can be thus avoided if the lining is already much worn. On the other hand, if the lining is really replaced up is really worn out and not according to normal practice after a certain amounts of heating it is possible to achieve certain savings.

Temperature field of ladle with capacity of 50 tones during ingot casting is shown in the figures No. 1, 2. Displayed temperature field is uniform.

Fig. 1 Ladle and its picture from thermal camera
The surface temperatures from the field in fig. 2 can be seen in fig. 3. The surface temperature of the ladle shell varies from 218.2 to 410.3°C, average temperature is 335.9°C. This indicates that the ladle lining is uniform without any defects. Number of heats cast into this ladle was 5, so ladle was at the beginning of its lifetime.

2.2 Exhaust pipe

Exhaust pipe from electric arc furnace (EAF) is composed of a set of water-cooled tubes that are hidden under the steel shell. The space between the tubes and the shell is filled with a heat-resisting concrete. The figures No. 4, 5 shows the picture from thermo camera showing the upper part of the exhaust pipe with the increased temperature of shell. The average temperature of the exhaust pipe shell is 65.3 °C, whereas there is also area with the increased temperature up to 93.5 °C. This increased temperature should be caused by erosion of the heat-resisting concrete in this place as well as it may indicate overheating of tubes at certain
place, which can be the first information concerning the future problems. In the case of the long-term local overheating of certain place and the cooling is not sufficient with the regard to the material properties of the used material and it may result in its damage and destruction.

Fig. 6 Exhaust pipe from EAF and its picture from thermal camera

Fig. 5 Exhaust pipe on the thermogram

Table 1 The surface temperatures in Fig. 5

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<th>Sp1 [°C]</th>
<th>Sp2 [°C]</th>
<th>Sp3 [°C]</th>
<th>Sp4 [°C]</th>
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<tr>
<td></td>
<td>90.8</td>
<td>85.3</td>
<td>63.4</td>
<td>58.1</td>
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The surface temperature in the line 1 in fig. 5 can be seen on fig. 6, where temperatures varies from 55.1 to 93.1 °C and average surface temperature on this line is 67.3 °C.
2.3 Steel ingots

Thermal camera can be effectively used in case of refinement of numerical simulations of steel ingots casting and their solidification [1]. Results of numerical simulation of temperature field of the ingot mold during solidification were compared with the results obtained during the measurement with thermal camera. Boundary conditions of numerical simulation were adjusted on the basis of this comparison, so the results of numerical simulations are more relevant to reality. The figures No. 7, 8 shows the temperature field of three ingot molds that are close together. Ingot weight is circa 32 tons and 45 tons. Steel temperature before casting is circa 1520 – 1570 °C and depends on its chemical composition. Solidification time of these ingot types is 10 – 12 hours. Ingot is fully solidified after this time and surface temperature is about 650 – 750 °C. Furthermore, there is seen that two sides of the mold, which are facing each other are warmer than the opposite sides. This phenomenon indicates that there is a partial interaction of two closely spaced ingots. Material of the ingot mold affects the rate of solidification of steel ingot and thus its final quality [2]. Heat capacity of used material for ingot mold has strong influence on the course of ingot solidification [3].

Fig. 6 Temperatures in the profile L1 from Fig. 5

Fig. 7 Steel ingots in mould and their picture from thermal camera
Table 2  The surface temperatures in Fig. 8

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<th>Sp1 [°C]</th>
<th>Sp2 [°C]</th>
<th>Sp3 [°C]</th>
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<tr>
<td></td>
<td>606.9</td>
<td>612.6</td>
<td>548.2</td>
<td>563.7</td>
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3. CONCLUSION

The maximum simplification of the measurement with an infrared thermocamera was used to determine the distribution of temperature fields on surfaces of measured devices. Determination of the real temperature on surfaces of measured devices was not primarily the purpose of the measurement, but identify and locate any anomalies manifested by increased surface temperature [4,5]. Therefore the input parameters of the surrounding environment, such as; emissivity of the material of measured devices, apparently reflected temperature [6], air humidity, ambient temperature, were not exactly surveyed. Nevertheless, the measured values are useful in practice because differences in temperature fields are always the same, regardless of input parameters of the surrounding environment which are used during the measurement. This conclusion is based on the used method of comparative qualitative thermography, which is based on comparing the temperature maps or temperature profiles of the same or similar element at the same or similar conditions. Determination of some input parameters mentioned above would be quite difficult in a very inhomogeneous environment of the hall of the steel plant VHM a.s. The approximate values of the input parameters of the surrounding environment were input into infrared thermocamera using Extech® MO297, which was used for measuring the temperature and the relative humidity. The obtained data were then recorded into thermograms. The thermographic long-wave system FLIR® ThermaCam SC640 (infrared camera), was used for scanning the range. All the acquired thermograms were elaborately analyzed with the help of the software equipment FLIR Reporter 9.0 PRO®.

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REFERENCES


