# OPTIMIZATION OF THE STORAGE PROCESS OF STEEL COILS APPLIED TO THE STORAGE YARD OF HOT STRIP MILL*

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**Abstract**

This study, which was applied in the coil storage yard of the Hot Rolling Mill area, aimed at optimizing the process of making decisions of the operator during transport and storage of steel coils. The coil storage yard is a strategic area that, besides storage, has the function of sending the coils directly to the customer, and it also monitors the temperature, so that part of the coils is sent to the Temper Mill. These coils arrive in the patio with temperatures up to 600ºC. The ideal temperature for the rolling process in the Temper Mill is 80°C. This patio has the capacity to store 650 coils on two levels. According to the initial project, the crane operators inside the operating cabins should receive information only from where they should stock each coil. The decision to release the coil is from the floor controllers. Those are responsible for measuring the temperature of each coil, making the decision and communicating by radio to the crane operator. This measurement used to be done through a portable optical pyrometer. In order to optimize this process, a portable thermographic camera was acquired. Knowing the temperatures of coils stored in certain regions, the controller can quickly define the best place for cooling. The images of the thermographic camera will be transmitted to the tablet of the controllers, allowing its rapid analysis due to the possibility of checking a larger number of coils in each measurement. Through the new form of measurement, it is now possible to speed up this process, increase the level of precision during the activity, guarantee the process parameters and, more importantly, reduce the exposure of the floor controllers near the coils at high temperatures, which makes the activity safer.

**Keywords:** Hot Strip Mill, Rolls, Thermographic Camera.

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## 1 INTRODUCTION

Hot Strip Mill is a metal forming process where the steel plates are loaded in a reheating furnace where they are submitted to temperatures around 1,100 to 1,300 ° C and after being discharged in roll tables are directed to the mill where pass between two rolls which compress them, and have their thickness reduced and their length increased.

In this process, the material is subjected to high compressive stresses, resulting from the direct action of the rolls and surface shear stresses, resulting from the friction between the rolls and the material. These friction stresses are also responsible for traction of the material thus drawn out of the space between the rolling rolls, the first hot rolling operation being carried out in the thinning passes, which receives the solidified plate and turns it into a high plate thickness.

This type of Mill usually has a reversible duo configuration. Initially hot rolling starts at temperatures between 1,100 and 1,300 ° C and ends between temperatures in the range of 700 to 900 ° C. The produced coils follow the average dimensions from 1200mm to 2100mm in width and thickness from 2.0mm to 22.0mm. Once the coil is obtained, it is transferred to the intermediate storage yard.

The objective of this work is to present the application of thermography in the process of detecting the temperature of the coils stored in the intermediate storage yard.

The coil storage yard according to Figure 1 is a strategic area of the hot coil manufacturing process. In addition to storing the yard, the yard has the function of sending the coils directly to the customer and also monitoring the temperature that the coils must have be sent to the finishing mill. The entire finisher process requires that the coils are at temperatures below 100°C, so the coils are constantly monitored to prevent them being loaded with high temperature in the carriages and wagons, which can cause damages in them, and also to avoid being processed in the finishing Mill at temperature outside the specification.

Figure 1- Coil yard

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## 2 - MATERIALS AND METHODS

The implementation of the monitoring of the temperature of the coils in the storage yard with the use of the thermographic camera was a solution found to improve the evaluation of the point to store the hot coils coming from the mill, avoiding that the high temperature of these coils, suitable for dispatch to the customer, sample cutting or for processing in the finishing mill and also aims to eliminate the exposure of the patio operators to high temperatures.

### 2.1 - THERMOGRAPHIC CAMERA

The thermographic camera used is infrared, technology already widespread in other industrial areas, for monitoring of various temperatures such as electrical and mechanical systems. Infrared cameras, also known as thermal cameras, are optoelectronic devices intended to perceive images in the infrared range of the electromagnetic spectrum and convert them systematically to the visible spectrum, thus allowing humans to literally observe thermal imaging generated by bodies. The ease and agility with which the critical points are perceived is one of the advantages of thermography, as it presents a map of observed temperatures as well as their location, often difficult to reach. The camera performs the measurement with a large-scale accuracy and presents the data through reports of extreme reliability. Despite the apparent ease, the fidelity of the readings and interpretation of the images depends on knowledge and some experience to fix the parameters.

### 2.2 - CONSIDERATIONS ON THE HUMAN RESPONSE TO THE THERMAL CONDITION

Frota and Schiffer point out that: "the complex human organism can be roughly compared to a thermal machine which produces heat according to its activity and needs to release enough heat so that its internal temperature stays on the order of 37 ° C - homeothermia ". When ambient conditions are not favorable and the heat balance between the human body and the environment is not stable, it results in a feeling of discomfort from heat or cold, a sign that the human body is losing more heat or less heat than is necessary for maintenance of homeothermia. This is achieved with an additional effort that always represents an overload, with a fall in work efficiency, to the limit, under exceptional conditions of rigor: total loss of capacity to perform work and / or health problems [1].

The human body passes daily through a phase of fatigue - catabolism - and by rest phase - anabolism. Physiological catabolism involves three types of fatigue: physical (muscular, resulting from force work), thermo-hygrometric (relative to heat or cold) and nervous (visual and sound). Human thermal comfort and its physiological response to thermal stress depend on the metabolic heat production, the level of environmental factors, and the type of clothing the individual is using. The combined effect of these is that it will define the degree of comfort or thermal discomfort felt by the people.
Thus, the most important parameters of thermal comfort are subdivided into two classes: a) individual ones (metabolism and clothing); and b) the environmental ones (temperature, humidity, air velocity and average radiant temperature) [1].

The amount of heat released by the organism is then a function of the activity developed and will be dissipated from mechanisms of thermal exchange between the body and the environment. Resulting from the differences in temperature between the body and the environment, the heat exchanges can be dry exchanges (conduction, convection and radiation), which in this case is called sensible heat; or wet changes, called latent heat, which involves phase changes - the sweat (liquid) passes to the gaseous state through evaporation [2].

## 2.3 - FOUNDATIONS OF HEAT TRANSFER

Heat transfer is the transient thermal energy due to the difference in temperature in space. High temperature bodies lose some of their energy, while bodies with low temperatures assimilate this thermal energy and the two come into balance.
Heat exchanges involving temperature variations are often referred to as dry exchanges. These mechanisms happen by means of a basic condition: the existence of bodies at different temperatures. It is important to understand the physical mechanisms that underlie the modes of heat transfer, since they delimit the comfort zone for application in architecture, engineering and comfort design, in which basic aspects of thermal changes in a built environment , which occur in three ways: conduction, convection and thermal radiation [1].

### 2.3.1 – RADIATION

Thermal radiation is a form of heat transmission that does not require a material medium for its propagation, since surfaces with temperatures other than absolute zero emit energy in the form of electromagnetic waves. Unlike conduction and convection, in thermal radiation the energy transport is instantaneous and associated with a different mechanism. The energy is not transported point to point inside the medium, but from direct exchange between the distant surfaces and at different temperatures [4].

Radiation occurs through a double transformation of energy: a part of the heat of the body with high temperature becomes radiant energy, which reaches the body with low temperature, where it is absorbed in proportion that depends on the receiving surface, being again transformed into heat [3].

## 2.4 - INFRARED THERMOGRAPHY

Infrared thermography consists of capturing heat images, not visible to the human eye. The process is done by means of equipment that converts the energy emitted by the surface of the materials into thermal images. They basically consist of sensors or radiation detectors, signal amplifiers and a processor. The image is obtained by the infrared sensitive detectors, which capture the thermal radiation and convert it into electrical signals.
These signals are usually low and proportional to the radiation flux, so they are amplified, read and processed through software and are transformed into thermal images or thermograms [5].
The thermal imagers or camera make it possible to adapt the field of vision of the device to the specific needs of each observation. In this way, they capture, through interchangeable lenses, the infrared radiation that is emitted by the analyzed object and decodes (from algorithms) in tones that vary from the darkest to the lightest. In general, the recording of thermal images generated by infrared systems can be analog or digital, which allows the system to be connected to televisions or computers for later analysis and processing of information [5].

## 3 - RESULTS

The thermographic analysis provides an overview of the current situation of the stock, aiding in decision making.

The original process of monitoring and measuring the coil temperature was performed with an optical or contact pyrometer. With this development, we started using the thermographic camera in all measurements.

Figures 2 and 3 present the image obtained by the cameras in the coil yard in two situations: coils with high temperatures and coils with low temperatures.

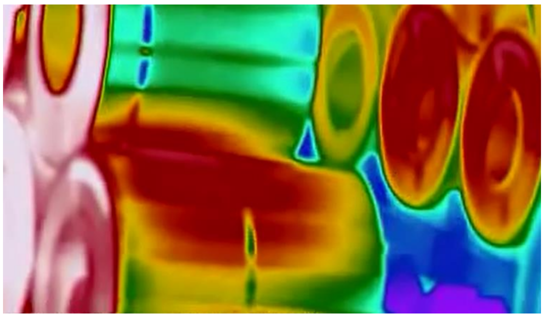

Figure 2- Image of coils with high temperature

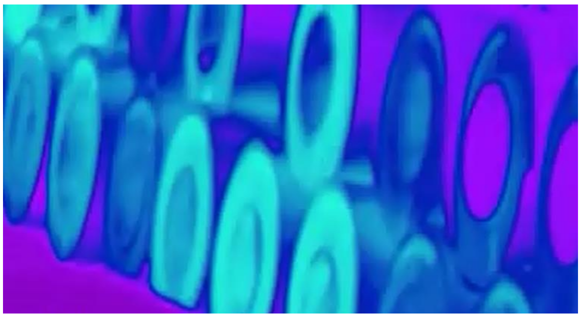

Figure 3 - Image of coils with low temperature

Thermographic cameras have another advantage, which is their great ability to monitor the performance of a system or object under study, making it possible to simultaneously monitor in real time several points in the same scenario.

In addition, aperture adjustment of the camera lens can be adjusted to vary the measurement scale, but also by applying various filters, thereby controlling the sensitivity of the system and its adjusted response to the captured thermal radiation.

The images of the thermographic camera allow us to make several analyzes, according to figure 4 it is possible to analyze the point temperature in a coil. In figure 5 it is possible to look for the temperature in very different points of the camera. We can also, according to figure 6, approximate the measurement of a specific point of a coil. Finally, as shown in figure 7, we can derive a temperature measurement from a set of coils.

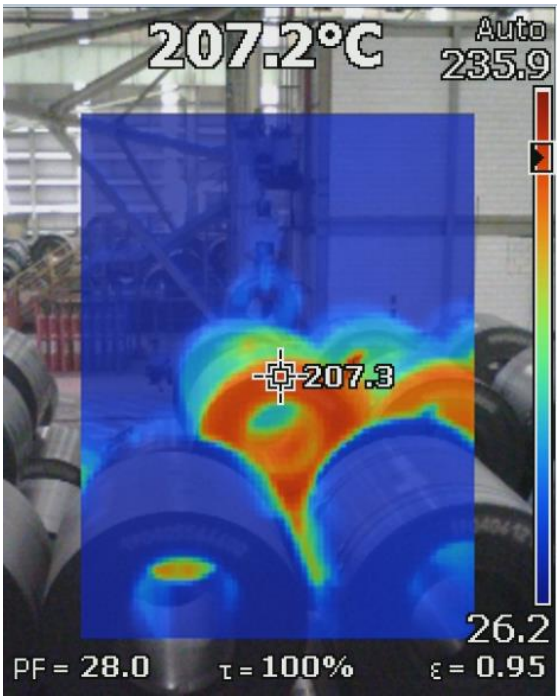


Figure 4 - Point image of the coil

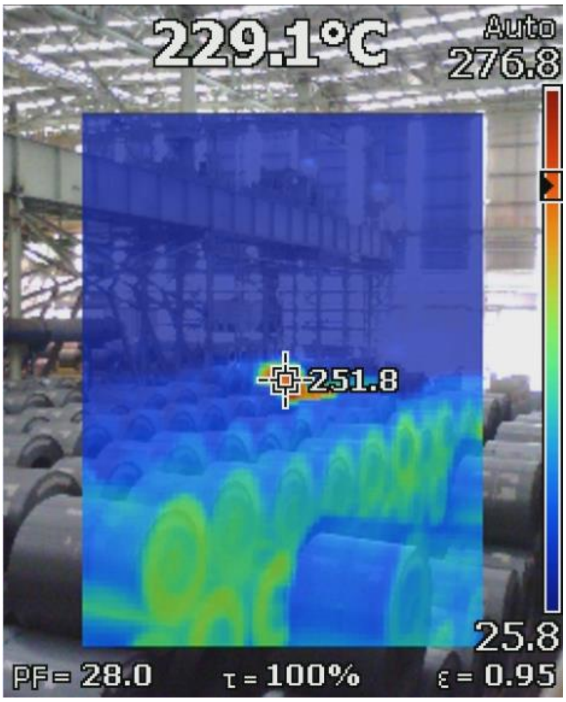


Figure 5 - Set image

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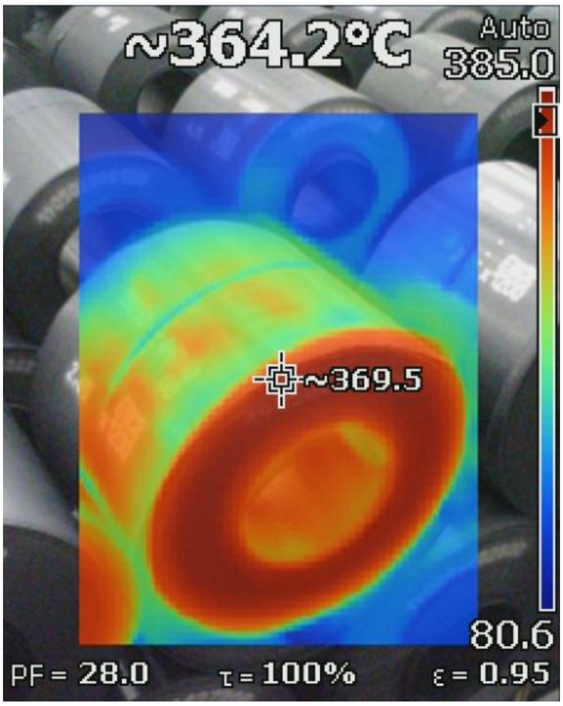


Figure 6 - Point image of the coil

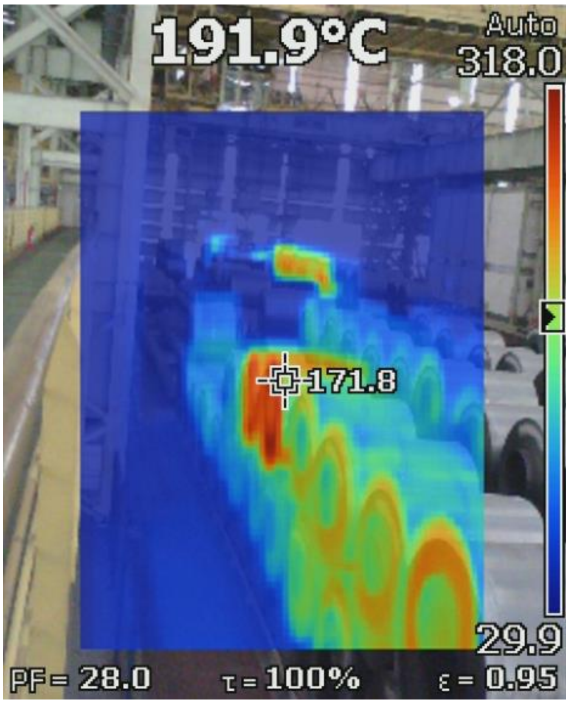


Figure 7 - Set image

## 4 – CONCLUSION

With evolution and new technologies, safety in industrial facilities becomes a constant target of monitoring. The thermography is being used as an innovative tool that seeks the removal of people exposed to the heat giving an end to the additional insalubrity, due to exposure of the coils coming from the mill to the patio with a temperature of approximately 600 ° C.

The generated images help in the more agile decision making in the storage of the coils through the analysis of the temperature distribution allowing a better packaging and programming of coils that can be sent quickly to the client or destined to the finishing process.

The main advantage of using this technology is that the operator of the crane and the controller has at his disposal the remote view of all the temperatures of the stored coils because the image is displayed in a monitor installed in the cockpit of the bridge operator and the controller of the patio has that same image on a tablet to assist in making decisions about the best storage point of the reels.

The evaluation of the coil that is at the ideal temperature for sending to the finishing mill is also indicated by the thermal image.

Finally, with this new measurement method, it is no longer necessary for the bridge operator to wait to measure the temperature of the coils and to communicate it via radio for decision making, as well as a greater precision in the value measured by the camera.

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