Cooling and Heating Times of Apparatus in the Steel Industries: Effects on Production Planning, Control, and Maintenance Performance

Rubens Alberto dos Reis[1], Rui Francisco Martins Marçal[2], Kazuo Hatakeyama[3]
[1]Control and Industry Processes, Federal Institute of Parana, Paranagua, Parana, Brazil
[2]Industrial and Systems Engineering, Pontifical Catholic University of Parana, Curitiba, Pr., Brazil
[3]UNISOCIESC, Production Engineering Dept., Joinville, SC., Brazil

Abstract--**This paper states and alerts over the overall and attribution of cooling and heating times of apparatus or furnaces as the indicators utilized for the assessment of the maintenance performance and production planning. It states that, where the variable temperature is present in any hot processing apparatus of the steel industries, the maintenance group should act integrated with production in order to adequate the planning practices sharing the responsibilities. The time of apparatus stoppage or operational unavailability for production does not follow the standard and attribution as an indicator for the "time taken to repair" or the "time without production", which depends on the cause of the needs to stop. In the case of maintenance process such times are recorded as the total time of intervention. Through the survey was possible to assert that the cooling and heating times are not considered separately. Ratios between the total time of stoppage with cooling time, repair maintenance time, and heating time ready for production were investigated. The conclusion of the study shows that integrated planning is an important factor for optimized planning and control for the efficacy of production output of the company.**

I. INTRODUCTION

Due to the constant upgrading of technology, and as a result of the adaptation to the customer´s needs, the maintenance and production sectors must adapt to the new market demands. They must apply the principles of "benchmarking", i.e., the process of improving performance by continuously, identifying, understanding and adapting the outstanding practices and processes that can be found inside and outside of organizations.

Important changes in the goals and processes of production caused some subjects to emerge. The most prominent of these is the degree of performance achieved. To Lucero [4] points out that "performance is the main tool to support scientific management, based on facts that can lead the manufacturing system, business and society to reach new and higher levels of efficiency and effectiveness, contributing to the sustainable development of our society through better living conditions for their workers, better customer service and respect for the environment".

To Slack [7], given to improving the reliability of the production operations, maintenance is the term used by organizations to address the activities and functions that prevent failures, taking care of the physical facilities. To the author, maintenance is an important part of the production, and the reliability of the facilities depends on it. The various approaches of maintenance are related to concern of the production management in taking care of their facilities in a systematic way, having in mind the availability, enhanced security, higher quality in process and product, lower operating costs and increased equipment life.

According to the demand created by the management processes in the new industrial organization, new indicators, in addition to those used in the production base for services, need to be included and considered in making-decision for maintenance and production.

To Nelly (apud [4]), changes in the nature of factory work shifted the focus from direct to indirect costs. The need for a system of priorities in the improvement processes became a must. The completion between companies has generated a strong demand to provide information on all the organizational and production criteria for managers. Companies seek to differentiate as for new criteria, such as service quality, innovation, flexibility, delivery deadline, not only mere costs. This information is used as performance measures so to encourage the implementation of the company strategy. The author points out that the tendency of companies to decrease the hierarchic conventional model has shown the importance of the performance measures, acting as internal communication mechanism to facilitate business operation.

Regarded in the production process as one of its factors, the job of maintenance must be part of the processes of performance management of this area and the company as a whole. It must reach the status of political decision since a system of performance measurement is part of a support system responsible for quantifying the past and current state of a production process, providing information as to predict possible future states and the needed improvements to achieve them [4].

In everyday reality, aspects concerning the deadlines for production, market factors and strategic goals of organization, are all considered by managers as a whole, although not mentioned in the decision support systems. Empirical observation of how this process occurs highlights that the decision about production and maintenance takes into account strategic aspects of the planning of the company and its production, as well as emerging factors in the relations with marketing, suppliers, customers and logistics.

In the setting of steel and metallurgical industries, the manufacturing process is developed by equipment incorporating technologies and as a result of the characteristics of such equipment, they require a certain period of time for cooling before repair or preventive revision, as well as another period of time for heating and then reinitiate production, after the maintenance takes place. These times are not being specifically computed in the current CCMS (Computer Maintenance Management System) and also, are not referred to in the given literature the standardized way, which is, maintenance or production times.

Braglia et al. [3] complement that the CCMS are already present in most organizations and now play a role of paramount importance though their efficient and effective management of maintenance activities.

The ways to generate temperatures in equipment at appropriate levels require proper techniques. Procedures and specialized techniques for monitoring, risk assessment and failure analysis are also needed.

Because of this risk, the maintenance function becomes a system of information as part of the planning and production control process, for it contains information about the characteristics of the equipment, its life, safe working load, history of defects and flaws, etc. so as to allow the production management and the control of risk issues (critical points).

Reis [5], investigated the impact of cooling and heating time on equipment used in the steel industry. He hypothesized that such cooling and heating timing do not follow a standard calculation equal to downtime for corrective or preventive maintenance and thus is not added to the indicator for maintenance or production, hindering performance evaluation related to the activities performed and any comparisons with world class indicators. He analyzed the impact of these times on the evaluation of the production performance and of maintenance services performance as well, seeking to answer the following questions: in practice, is there an indicator for these times? If so, what is the degree of importance in the making decision as to when to stop production? Then is it portraying, with reliability, the actual situations of the production, and thus providing safer grounds as to the making decision process on maintenance shutdowns? When it comes to the steel industry, how should this indicator be set for performance evaluation: to the time of production or to the time of maintenance? What is the weight of this factor in each of these situations?

II. THEORETICAL FRAMEWORK

A. Maintenance

To Alves [1] maintenance not only restores the operation of machinery and equipment, but becomes a strategic function within the organization, as a factor able to offer competitive differential to organizations. The author describes its role in the management of production quality and offers a decisive role in preventing failures and reliability, so to achieve improvements in the production process. In steel industries, which have equipment that require extended time for cooling and heating, there is a huge commitment on the part of maintenance, to increase its reliability, in prevent crashes and hangs that will bring in themselves, other consequences for the equipment. In a production environment, the expectation is that all production and maintenance behavior help avoid arrest.

The main purpose of the equipment is its availability, as it becomes increasingly sophisticated, high tech and productive in the production lines. The cost of inactivity or under-activity requires the operation to be rational and productive. Based on these ideas, the techniques of organization, planning and control within organizations evolved along with the production processes.

As for steel industry, given the relevance and importance of the impact of cooling and heating timing in production activities, these by themselves, establish that the purposes of maintenance are not limited to mere rehabilitation of the equipment, but to integrated work and efforts of the production and maintenance sectors, which bear in mind the good performance of the equipment, and try hard to minimize in every way its downtime, which would result in lack of production.

B. Indicators of Maintenance

Today the maintenance operations are responsible for a large portion of the operating budget of the organizations, because of investments in facilities, machinery and equipment. Monitoring the performance of maintenance must be one of the key issues in the management of organizations [8].

The indicators show the solution for the possible problems and, beyond that, are guides that allow the appreciation of the effectiveness of the actions that have been taken, as well as the deviations between the planned and what has actually been realized. With them it is possible to compare, over time, when it comes to internal and external data, the performance of an organization, and identify their weaknesses [6].

Viana [10] reports that the maintenance indicators should portray important aspects in the process of the organization. He also points out that the most used in maintenance are those called world class indicators. This is due to the fact they are the most used in western countries. Four of them are related to equipment management, and two to cost management.

C. Roles of production systems

According to [9], in order to achieve their goals, the production systems must carry a number of operational functions performed by people, ranging from product design to inventory control, recruitment and training of staff, use of financial resources, product distribution, etc.. In general, these functions can be grouped into three basic functions: finance, production and marketing.

The basic functions, in turn, as the production systems grow, are broken down into its activities, generating support functions performed by specialists, such as, maintenance, controlling, engineering, distribution, etc.

In the record of the development of the production sector, it appears that the maintenance sector exerted a support function, representing an activity. Given the complexity of

TABLE 1 - TIMES UNAVAILABILITY CAUSED BY HEATING AND COOLING TIMES IN EQUIPMENT AND PRODUCTION LOSSES ARISING.

Enterprises and production sectors	Equipment	Temperature	Cooling time	Heating time	Corrective Maintenance	Production lost
CSN (steel industry	Induction furnace (used for melting aluminum and zinc)	1202 °F (650 °C)	12 hours	12 hours	500 hours	21 thousand tons of plates, coated galvalume (aluminum + zinc)
INCEPA (ceramic industry)	Oven (used for firing ceramic plate)	2192 °F (1200 °C)	96 hours	72 hours	192 hours	48 thousand square meters of ceramic floor
MADEK (plywood industry)	Boiler (used to generate steam for drying the slides plywood)	2192 °F (1200 °C)	5 hours	24 hours	24 hours	200 thousand square meters of plywood
RENAULT (carmaker)	Oven (used for drying paint of the bodywork of the vehicle	338 °F (170 °C)	1 hour and 30 minutes	1 hour and 30 minutes	5 hours	150 bodies of vehicles cease to be painted
SADIA (food industry)	Boiler (used to generate steam for heating the fat and oil)	410 °F (210 °C)	4 hours	36 hours	52 hours	780 tons of finished product (margarine)

operating systems and of the information on which the planning and the productive action depend, the maintenance has become engineering added up engineering.

Planning and Production Control when developed takes into account the production capacity of its manufacturing process. All actions inherent or not, that interrupt the production process must be planned, designed, programmed and taken into consideration the fact that they could compromise the planning, either as regards the deadlines, production capacity and costs.

When it comes to equipment that denote specific care, such as equipment work or produce heat, which add time beyond those expenses with the repair, resulting in longer downtime, the result can be seen as no longer produced and on their values.

Table 1 lists some production sectors that use equipment that need these times of cooling and heating to come back to be available and producing and what could be producing if it did not occur.

III. PRODUCTION PROCESS IN STEEL INDUSTRIES

A. Production Flow

The flow of production in the steel industry is as follows:

Process 1 – Picking (where you do the surface of the plate);
Process 2 – Cold rolling (thickness reduction);
Process 3 – Plating (where the coating is made with aluminum and zinc);
Process 4 – Painting (where the coating is made with plastic film);
Process 5 – Service center (cutting, shaping and packaging).

Fig. 1 shows a large furnace used in steel industries. They are large equipments and high working temperature.

Figure 1 - Hot processing apparatus of the steel industries

At high temperatures the heat is used in the following processes: pickling, plating and painting. In the process of plating internal temperatures are around 1112 ºF (600 ºC), more specifically in the continuous annealing oven (used to repair the mechanical properties of the sheet after the lamination process), and in the induction furnace (used for melting aluminum and zinc).

These devices considered critical because if stopped for corrective maintenance, the continuous annealing furnace needs 72 hours to repair and likewise the induction furnace requires 500 hours, taking into consideration the time of cooling and heating.

B. The Process in Practice

Regarding induction furnaces, where aluminum and zinc fusion takes place, failure occurs when the liquid material passes though the working wall of the furnace and gets to the coils which generate heat, causing a short circuit.

The very of the oven is one of the factors causing cracks in the walls, through which the liquid material leaks, and there is no way to know the extension of the cracks. The only possible way to monitor it is via thermography and monitoring of leakage current, which is measured constantly through CLP (Programmable Logical Controller). Problem is that going from failure to the actual glitch occurs instantaneously.

There is a huge unpredictability as to the reasons why the cracks occur, and thus, the indicators do not reflect the problem. There are many unknown variables.

The induction furnace is the "heart" of the organization, and it should never be turned off. If this occurs and the liquid material solidifies, the furnace will no longer have power to perform the melting of the material, and that will cause the total loss of the oven.

On the record about the halt, the operator defines whether the reason for it was an operational or maintenance failure. As it is determined that the failure came from maintenance, the downtime directly affects the availability of the line.

The timings of cooling and heating are not considered apart from each other. When a corrective maintenance takes place the total time of the intervention is recorded. Depending on the reason for the glitch, the responsibility for the halt will go to maintenance or operation. The analysis of the failures is subjective and depends on competence, knowledge and urgency of decision.

C. Maintenance Timing

A more specific study [5] on the issues related to cooling and heating has showed that the responsibility for the heating and cooling of the furnaces is upon the operations team, because the maintenance team does not operate the equipment.

The operation team receives information and procedures from the maintenance sector to run the heating and cooling of the furnaces. This sector watches carefully if it is being carried out correctly, for it is the one sector that has information on how to operate the equipment properly.

This proves that the traditional maintenance activities, due to the technology and modus of operation of the automated line, changed hands and responsibility, evidencing that, in some cases, maintenance works as a technical assistant or consultant.

In analyzing the impact of cooling and heating timing of equipment, on the indicators used to assess the performance of maintenance and production, it was found that organizations use the heat as an input to the transformation of raw materials and does not highlight this factor, although they study all the variables related to their performance in production, due to it being inherent in the process.

The timing of cooling and heating, which are controlled by curves that must be taken into account is order to ensure reliability in equipment operation, are technical references, which are more observed than an indicator measuring the shutdown for preventive or corrective maintenance. A graph illustrating the heating and cooling steps can be seen in Fig 2. Each process has its characteristics and times for the two phases. In some cases these operations are carried out in stages to preserve the oven, because a rapid heating or cooling can cause damage to the oven.

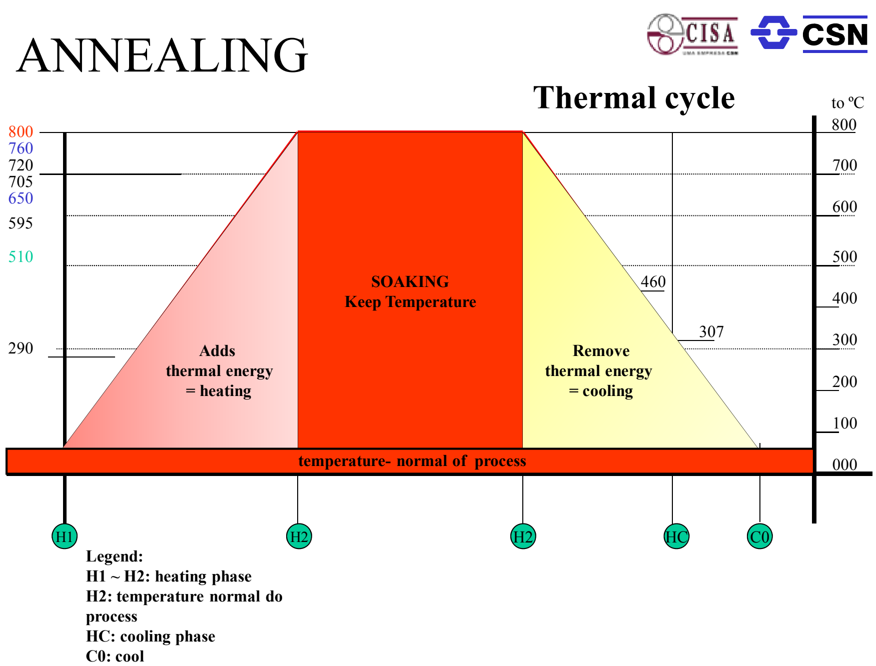

Figure 2 – Steps of heating and cooling in the furnace annealing process

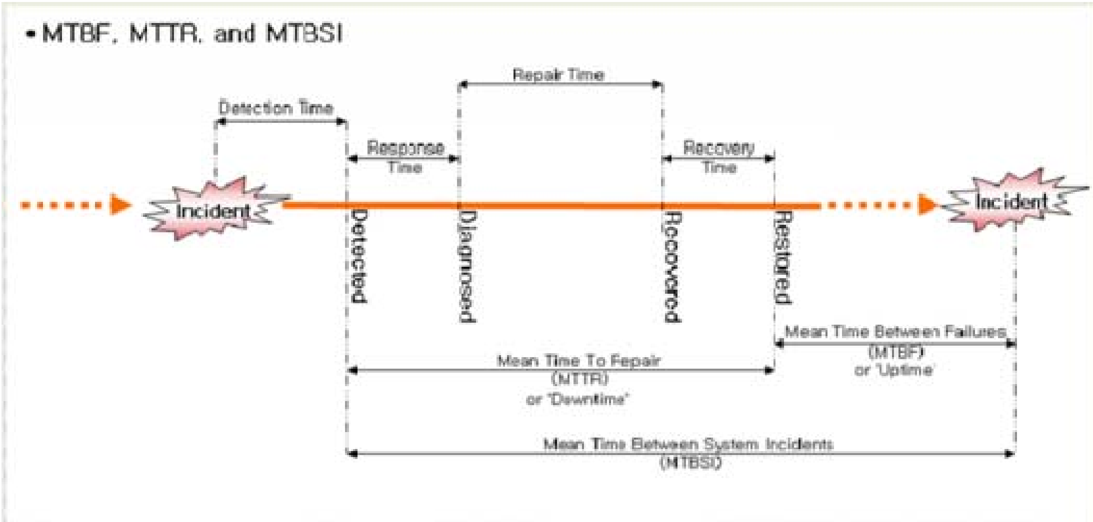

Figure 3 - Timeline and indicators of maintenance time and dowtime.

Organizations understand that this input is not to be detached from the operation of the equipment, using the time of use for production and availability (DISP) for maintenance as an indicator to evaluate its performance, relating to Overall Equipment Efficiency (OEE).

So the world class indicators, referring to the Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR) and Overall Equipment Efficiency (OEE), are the indicators used to assess the performance of maintenance, even if the production process has the specifics for the use of heat, the great amount of time for cooling, heating and maintenance in the setup.

The shutdowns are planned, production and maintenance seek to avoid cooling having in mind the danger of cracks and falling refractory-lined bricks. Full shutdowns only take place in the event of failure or when scheduled, seeking to integrate the interests of production and legal requirements.

It has been observed that the characteristics of the process and procedures are facilitated by a technology that meets the need to avoid total shutdown of the furnaces in most cases when a defect occurs.

Given the specificity of this process, the evaluation of the performance and production is measured based on the indicators of world class, aiming adjustment to international standards of overall performance. Operationally, they perform adjustments and improvements in the process and procedures to control the impact of this factor on the reliability of the process and on the availability of the items. So, turn the question into operation problem, seeking to prevent harm productivity.

Maintenance timing in the downtime are shown in Fig. 3, where the indicators relating to the maintenance are related to the time line, representing its distribution.

According to [2], “downtime” is defined as part of the time during which a machine, equipment or system is unable to perform its operational functions. More specifically in the case of ovens, this time comprises: cooling time, plus repair time and plus heating time.

IV. FINAL REMARKS

The objective of this study was to address and discuss the impact of the cooling and heating time of the equipment on the indicators used to assess the performance of maintenance and production. Explorative research, aiming to examine the maintenance indicators already used for evaluation of the management of the maintenance process, sought to verify the need for more descriptive ability and unfolding of the indicators related to the cooling and heating timing on the equipment. The study investigated the possibility of using / enabling those variables in order to construct a valid indicator for the performance evaluation of the production and maintenance jobs in manufacturing processes with these characteristics.

The process described and researched brings up a common misconception when assessing the performance of the maintenance crew is done by taking as a basis the indicator MTTR (Mean Time To Repair), which is often directly associated with the indicator A (Availability), which reflected in stopped production time. In this case study we cannot make the evaluation computing the unavailability of the oven, as this is increased by times previously seen. Such times can be viewed as the setup time. These setups cannot be modified, that is minimized because they are related to each process and each type of furnace.

The purpose throughout the production process and one of the goals of maintenance is increasing machine availability, which directly contributes to the maximization of production and the performance of production planning. Any actions that contribute to this purpose is welcome , whether reducing the mean time to repair (MTTR), prevention is adopting a higher frequency of preventive interventions, is planning actions to prevent the oven without a break and even weather caring for the operation of the furnace .

In short, due to the fact these times (setups) cannot be excluded or reduced, being the innate, that the maintenance staff does their best, hourly equipment which fits as a solution and contribution is the suggestion that occur joint actions between the operation and maintenance to avoid breaking or stop scheduled.

The complexity of the process, involving a great amount of variables, causes the need to redistribute and share responsibilities and procedures between the leaders of the processes and the operators, turning the maintenance function into an activity of technical support, which, if eventually a failure occurs, causing an unforeseen stop, will behave as reparative and restorative of the original status of that item.

In practice, a model of production management / maintenance functions through an integrated engineering design, suggests a joint planning considering actions and criteria involved. These include maintenance policies that allow the monitoring of the operating condition of the furnace, plans scheduled preventive intervention, proper furnace operation, planning and control of production consistent with the conditions of furnaces and spread these joint actions and the relevance of decisions. Certainly these considerations being taken in production planning / maintenance will result in an increase in availability over the life of the furnaces in a better OEE. These new ideas, promote new forms of interactions, based on the integration of data, plans and procedures, as well as the interaction of decisions, based on data collected by expert systems for monitoring and diagnosis, applied to the process and methodologies of monitoring predictive and control assembly.

ACKNOWLEDGMENTS

We are grateful to CSN Company for the opportunity of research.

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