PRODUCTIVITY INDICATORS IN THE MODERNIZED ZINC CONCENTRATE PRODUCTION PROCESS

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Abstract

In addition to meeting customer requirements and maintaining competitiveness, enterprises must now include social responsibility in their strategy, with particular emphasis on ecology. This trend is partly forced by changes in environmental protection regulations, including waste management. For many enterprises this may mean the need to introduce changes in the production systems. One of such companies is B. Recycling sp. z o. o., producing concentrate of zinc oxide. Adaptation to current standards required a thorough modernization of the technological lines used, so that the zinc-bearing waste, storing which brings a threat to water resources, could be used as batch material in the rolldown process. The rolldown process implemented in the company is technologically complex and any deviation from the discipline may result in a lesser quality product and a significant increase in the number of unscheduled stops, and thus a drop in productivity. Because of that, the modernization was also aimed at improving the efficiency of the production system. The article describes the conducted process analysis, the purpose of which was to determine whether the changes made have led to the desired effect and identifying the areas with the greatest improvement potential. The elements of the TPM method were chosen as the research method. After collecting the time and quality data, MTTR, MTBF and OEE indicators were determined for each of the modernized lines and selected subassemblies. One of the analysis results was the proposition of a solution which would shorten the duration of the failure once applied.

Keywords: Exploitation, zinc concentrate, TPM method, OEE

1. INTRODUCTION

The pyrometallurgical processes in roll down furnaces with zinc recovery is a commonly used method of zinc containing waste management. Unmanaged zinc-bearing waste are hazardous to the environment, in particular for aquatic resources in Poland Mining and Metallurgy Plant “Boleslaw” had the plant of this kind, however the strict requirements of environment protection, sulphur dioxide emission level in waste gases in particular, forced the company to discontinue the zinc recovery by means of this method [1,2]. A new company has been established - B. Recycling. The firm B. Recycling has taken the initiative of management of zinc-bearing waste from diffuse sources. To obtain the required level of carbon dioxide emission in waste gases, it was necessary to implement changes to the previously used technology and equip the plant with the system for absorption of sulphur dioxide from the emitted gases [3,4]. The firm B. Recycling has implemented the project of modernization and assembly of rotary furnaces and all other elements of lines. The change of suppliers of zinc-bearing waste was a key issue [5]. Activation of a mechanism stimulating system supply with wastes from different producers was a requirement necessary to keep supply continuity. This required the development of a capable technical station for zinc-bearing waste processing. It upgraded production processes to fully meet requirements of environment protection (among others, liquidation of several lines and sinter plant). It was assumed that modernization would cause the increase of process charge indices up to the European level. Upgraded technological lines are used to generate zinc oxide concentrate. **Figure 1** shows the diagram of the production system after the upgrade. There are three production lines in the company. Lines no. 1 and 6 are adjusted to process steel fly ashes and zinc-bearing sludges. While line no. 2 is intended to process sludges from zinc electrolysis only.

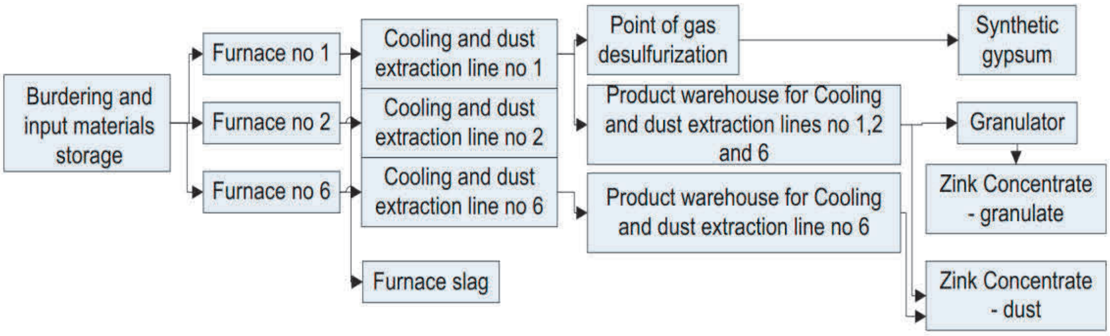

Figure 1 Diagram of the concentrated zinc oxide production system after the upgrade

Due to the complexity of technological process for generation of zinc concentrate from different zinc-bearing waste, during system operation, there are many unwanted downtimes (shutdown, failures, lack of supplies) that has a significant impact on production efficiency. That is why, this study purpose was chosen - analysis of results of implementation of new solutions after one year of monitoring of three technological lines: line no. 1, no. 2 and no. 6. TPM - Total Productive Maintenance was a chosen method, or actually, some part of it that relates to setting of defined indices [6].

2. ANALYSIS OF PLANNED DOWNTIMES AND FAILURES

The common assumption of Lean Manufacturing methods is to create, keep and improve the continuous flow of material in the production system [7,8]. One of the methods of achieving this is to ensure the continuity of the work of machines, which is the primary purpose of the TPM (Total Productive Maintenance) method [9]. The TPM method most commonly uses three indicators: MTTR, MTBF and, most distinctly, OEE [10]. The primary measure of the effects of introducing TPM is the OEE indicator (Overall Equipment Effectiveness). OEE means the overall efficiency of equipment (machinery, devices). The major focus of the analysis was on failures and planned downtimes of machinery and equipment in plant system for production of zinc oxide concentrate. Based on annual monitoring of work time and downtimes in the company, a results for three technological lines was obtained (lines no. 1, no. 2 and no. 6). Appropriate time histograms were made for those lines and the following indices were calculated [11]:

- OEE - Overall Equipment Effectiveness,
- MTTR - Mean Time to Repair,
- MTBF - Mean Time Between Failures.

The data related to the duration and the reasons of system downtime was collected over a period of one year, separately for each of the three technological lines. Due to the diversity of technological lines machinery and equipment failures, they have been divided into the following subgroups:

- slag reception system failures,
- rotary furnace failures,
- dust chamber failures,
- exchanger coolers failures,
- filter failures,
- failures of pneumatic transport system of the product,
- fan failures.

An exemplary monitoring histogram for line 1 is shown in **Figure 2**.

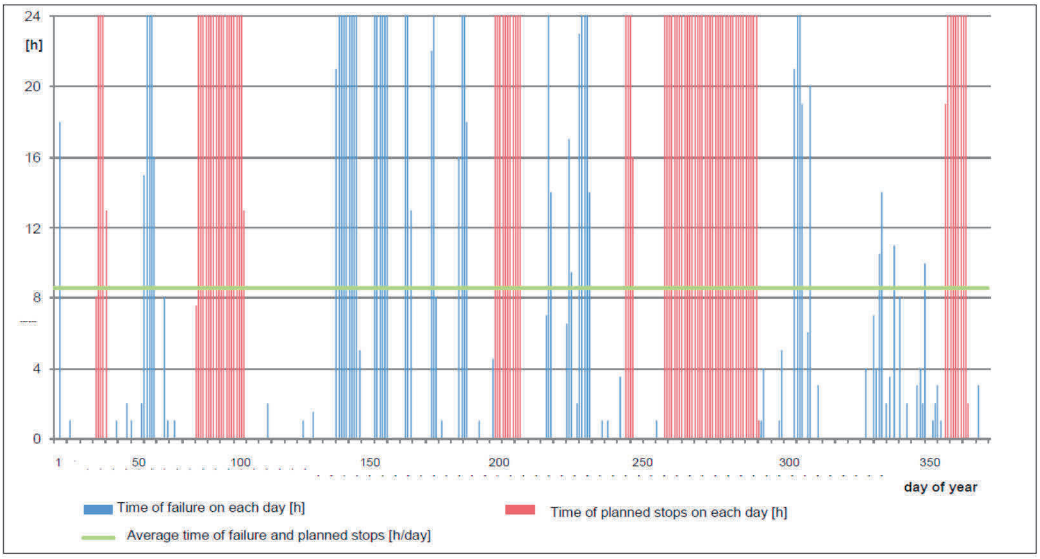

Figure 2 Histogram of monitoring within the year for technological line no. 1

Sample results for process line no. 1 are shown in **Table 1**.

Table 1 Selected duration of failures of technological line no. 1

Name of failure	Time (h)	Quantity
Rotary furnace		
Extinguishing	190	11
Removing	482	11
Warming up	159.5	11
Welding works at the end of the furnace	8	1
Technological failure - the appearance of build-up	2	1
Taring the feed weight	7.5	4
Total:	**849**	**39**
Exchanger coolers		
Failure of the screw feeder	22	2
Repair of the screw under hot radiator	67	3
Cleaning the space between the heat exchangers	51.5	9
Total:	**140.5**	**14**
Filter		
High filter resistance - cleaning	44	5
Filter inspection	2	1
Failure of the filter regeneration compressor	1	1
Total:	**47**	**7**
Pneumatic transport system of the product		
Failure of oxide pump	6	3
Failure of the line-plate feeder	41.5	10
Total:	**47.5**	**13**

Figure 3 presents percentage of individual failures with regard to all failures registered within a year on technological line no. 1.

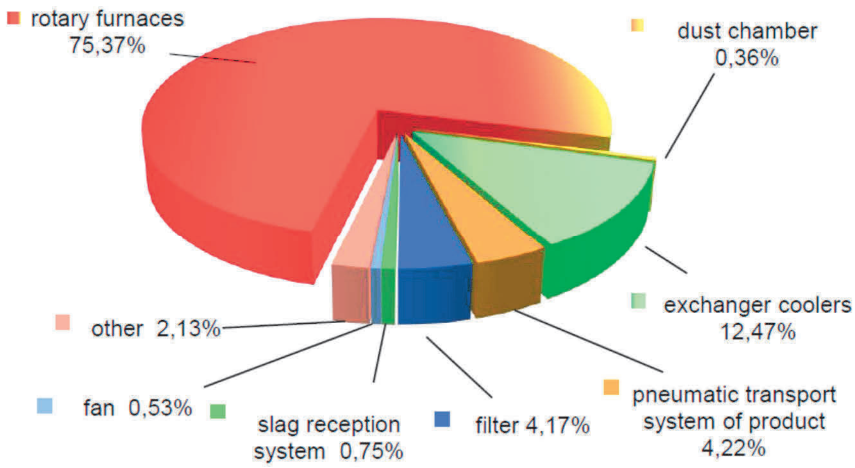

Figure 3 Percentages of different failures - technological line no. 1

The most failure-prone system component is the rotary furnace. Its failures are 75.37% of the time of all faults. Generally, failures are 5.28%, and planned downtime is 11.37% of total system operation time.

2.1. Designation of the OEE index for the selected technological line

The OEE indicator is usually calculated using this simple formula [12]:

OEE = Availability x Performance x Quality x 100 (%) (1)

Designation of the availability of A_i index for each i = 1, 2, 6 line

$$A_i = \frac{A_{i2}}{A_{i1}} \cdot 100[\%] \qquad (\%) \qquad (2)$$

where:

A_{i1} - net operating time (available time) (h)

A_{i2} - operating time (net operating time - planned downtime) (h)

Designation of the P_i performance of machinery and equipment at the no. i technological line:

When upgrading, all machinery and equipment included in the technological line was designed for the maximum design performance of the rolldown furnace no. i and therefore the performance index for the whole technological line no. i can be assumed as equal to P_i = 100 %.

Designation of the Q_i quality factor for the no. i - technological line:

The quality factor has been calculated according to the following formula:

$$Q_i = \frac{Q_{i2}}{Q_{i1}} \cdot 100[\%] \qquad (\%) \qquad (3)$$

where:

Q_{i1} - Zn content in feed (Mg)

Q_{i2} - Zn content in product (Mg)

The quality factor has been calculated on the basis of the quantity of feed material and the content of the pure zinc and on the basis of the produced concentrated zinc oxide and content of the pure zinc.

2.2. Designation of the MTBF and MTTR indexes for the selected technological lines

MTBF (Mean Time Between Failures) is a mean time diving occurrences of two failures or micro-downtimes. MTBF index was calculated based on the following formula (4):

$$MTBF_i = \frac{t_{ppri}}{n_{ppi}} \tag{4}$$

where:

t_{ppri} - sum of duration times of correct functioning for technological line no. *i*

n_{ppi} - number of events of correct functioning of technological line no. *i*

MTTR (Mean Time to Repair) is a mean time necessary to make repairs of equipment. Any “repair time” starts when a failure of equipment occurs, and ends when equipment works in its standard work cycle. MTTR index was calculated based on the following formula (5):

$$MTTR_i = \frac{t_{awi}}{n_{ni}} \tag{5}$$

where:

t_{awi} - sum of duration times of repairs of technological line no. *i*

n_{ni} - number of repairs of technological line no. *i*

The analysis was carried out for all technological lines. Collective results for all lines (including lines no. 1, no. 2 and lines no.6) have been presented in **Tables 2 and 3**.

Table 2 Collective table of results for individual technological lines

	Technological line no. 1	**Technological line no. 2**	**Technological line no. 6**
Time of failure (h/year)	1126.5	509.5	1331.5
Time of failure (%)	12.86	5.82	15.20
Time of planned stops (h/year)	1999.5	996	797
Time of planned stops (%)	22.83	11.37	9.10
Time to work properly (h/year)	5634	7254.5	6631.5
Time to work properly (%)	64.31	82.81	75.70
OEE (%)	**83.88**	**78.61**	**83.83**
MTBF (h/year)	**125.2**	**190.9**	**150.72**
MTTR (h/year)	**21.25**	**10.38**	**26.11**

After analysis of downtimes of technological lines no. 1, 2 and 6, it was noticed that equipment subject to major failures are rotary furnaces. Reduction of failure time of rotary furnaces (build ups inside a furnace are the major reason) will lead to increase in production of zinc oxide concentrate. Recondition of rotary furnace by means of removal of build ups is related to its extinguishing (cooling), removing (removal of build-up) and reheating. Appropriate data are shown in **Table 3**.

Table 3 Time of failures of individual rotary furnaces

		Technological line no. 1	Technological line no. 2	Technological line no. 6
Total time of failure (h/year)		1126.5	509.5	1331.5
Time associated with the removal of the furnace failure (h/year) and (%)	cooling	190	66	187
		22.38 %	18.91 %	18.80 %
	removing	482	224	629.5
		56.71 %	64.18 %	63.30 %
	reheating	159.5	32	156
		18.79 %	9.17 %	15.68 %
	other	17.5	27	22
		2.06 %	7.74 %	2.21%
	total	849	349	994.5
		75.37 %	68.50 %	74.69 %

To shorten the duration of the furnace failure it was proposed to use an industrial cannon from Winchester company in order to remove the build-up. To determine the usability of this equipment, experiments must be carried out. Therefore, decision on assembly of industrial cannon in all technological lines can be made after experiments being carried out for one device.

3. CONCLUSION

The above analysis enabled to determine the number and frequency of failures of individual components in technological lines no. 1, 2 and 6. The summary and assignment of failures to the individual technological lines allowed to identify the units that require attention in order to reduce the average failure time and thus to increase the production capacity of the zinc oxide concentrate. It was observed that failure time of machinery and equipment for technological lines no. 1 and 6 is much longer than in the case of technological line no. 2. It is caused by the type of charge material, as lines no. 1 and 6 are intended for steel fly ashes, while line no. 2 for zinc-bearing sludges. Diversity of charge material is related to the differences in technological process and its physical and chemical properties. Processing of steel fly ashes significantly impacts the increase of build-up. OEE indices calculated for each technological line allowed for the assessment of effectiveness of use of all machinery and equipment within the analyzed technological lines. The OEE index values for the technological lines no. 1 and 6 are similar to each other and are respectively: OEE_1 = 83.88 %, OEE_6 = 83.83 %. The overall performance index of the technological line no. 2 was OEE_2 = 78.61 %. On the basis of the results obtained and the data from the literature it can be concluded that indices obtained by means of modernization by B. Recycling are at very good level (OEE above 80 - 85 % as global class).

The analysis of index values for three factors distinguished when designating the OEE, allows to indicate the quality as the area of the largest potential for improvement.

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