Monitoring of the Fe_2O_3 Particle Size Distribution by Intensity in the Context of Digital Company

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Abstract – This research studies monitoring of Fe_2O_3 iron particle size produced in industrial companies on the premises of a hot rolling mill. The analysis used the distribution curve method - particle size distribution by intensity. This method determined which particles occur most often in the sample, what is the average particle size, smallest and largest particles. Digitization of individual procedures and monitoring of technological processes provides data that can be worked with at a given time.The obtained data represent a source of information for their further processing in the field of maintenance prediction.

***Keywords* – waste, monitoring, circular economy, digitalization.**

1. Introduction

Companies that create waste in their production activities should consider implementing reverse logistics [1]. It is reverse logistics that brings us closer to the sustainability of the production process, and to the sustainability of the state's economy [2]. Sustainability is fast becoming a global industry priority. [3].

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Currently, there are strict legislative goals of the European and world economy that emphasize production with zero carbon emissions, which are mandated in all industries to reduce their impact on the environment [1], [3].
Already today, composite materials support the pursuit of a carbon-neutral future through:

- lightening to reduce emissions
- production of more efficient products
- increasing the lifespan of products,
- support of the circular economy of individual states [3].

The circular economy (CE), is an economic model whose main goal is to reuse resources. We no longer consider them as waste, we consider them as possible inputs [4]. An important role is adopting sophisticated solutions that can bring new value to consumed goods and thus re-enter the economic process. The circular economy changes the concept of "take-throw-away", which is characteristic of the linear economy, to the concept of cyclicity in (circulation), from which the name "circular (circular) economy" also comes [5]. In the steel rolling process, the formation of scales is an inevitable accompanying phenomenon. Primary fittings are produced by heating in blast furnaces, secondarily by cooling the rolled material [6]. The aim of the contribution is to analyse the particle size of the formation of secondary scales in the form of Fe_2O_3 waste, in the conditions of a hot rolling mill, and their effect on selected types of components.
Secondary fittings in the forming process are removed from the surface of the roll with high-pressure water at a pressure of 20 MPa [6], [7].
After use, such ironwork water is pumped into sedimentation pits and reused in a closed circuit [5], [6]. Even though the water itself is filtered through multi-level filtration, there are Fe_2O_3 and Fe_3O_4 particles smaller than 4 microns in it. These then increase the wear of components in direct contact with water [1], [2]. According to the results presented in studies, which are updated annually by World Population Review, the European Union produced 159.4 Mt of crude steel in 2019, which is a decrease of 4.9% compared to 2018. [7],[8].

Crude steel production in North America fell 0.8% to 120.0 Mt in 2019. The Commonwealth of Independent States produced 100.4 Mt, down 0.5% from 2018. Crude steel production in South America was 41.2 Mt in 2019, which decreased by 8.4% [9]. Turkey produced 33.7 million tons of steel in 2019, down 9.6% from the previous year. Production in Africa fell by 2.3%, with 17.0 million tonsof steel produced in 2019. Oceania produced the smallest amount of steel, 6.1 million tons, in 2019. The Slovak Republic is in 28th place in 2019 with a production of 5.3 Mt of manufactured steel, where the leading producer is the company U. S. Steel Košice [7], [8].

2. Problem Definition

Currently, fittings, as a by-product of rolling, are further processed and find new uses in the industry [9]. The basis of the hot wide strip line is a continuous wide strip rolling line with a width of 1700 mm intended for rolling steel sheets in strips with thicknesses of 1.80 - 12.70 mm and widths of 765 - 1540 mm. The broadband line is fully mechanized and automated.

The main mechanical equipment of the company consists of four continuously connected sections [10]:
- preparatory sequence section
- section of the finished order
- belt cooling section
- winding section with offset paths

Sheets are produced by hot rolling technology, with rerolling, controlled cooling mode of winding the strips into coils, to ensure uniform material structure, geometric shape, dimensions of the strips and required surface quality, specifically in the premises of the hot rolling mill, the main problem is the effect of Fe_2O_3 on the individual components of the machinery, which subsequently causes their wear (Fig. 1).

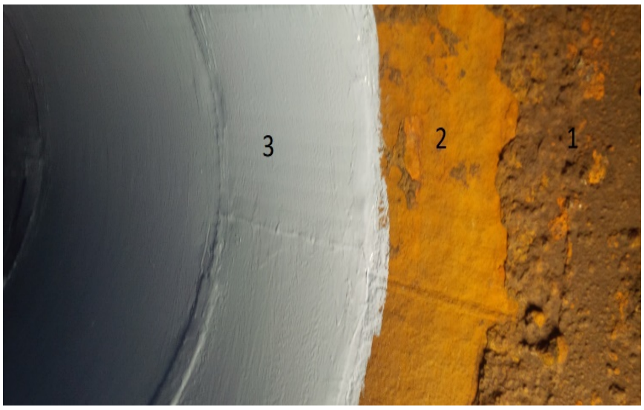

Figure 1. Pipeline DN 1200 [1].

The biggest problem of pipe distribution in connection with fittings is the chemical reaction of oxides with the inner wall of the pipe and the formation of deposits, in some cases up to 5 cm (Fig.2).

Figure 2. Detail on used pipeline [1].

Such deposits then cause turbulent flow, reduction of flow rates, or overheating of pipes and water. Turbulent flow and oxidations cause uneven wear of the pipeline, which leads to premature point damage of the pipeline and water leaks. The CND 5 feed pump is the pressure source for the descaling system. Reliability is key for this device [8], [10]. Without the removal of scale from the roll, production of the required quality is impossible. Therefore, the availability of this pump is essential for 24-hour operation. Fittings smaller than 200 micrometres on the expansion pipe caused a reduction in the cross-section of the pipe and, thus, a reduction in flow. The pump rotor [11] is axially balanced through the balancing pipe. This axial alignment was insufficient, which caused damage to the axial bearing. Thanks to the high temperature and timely inspection, it was possible to identify the fault quickly and prevent an accident that would have caused the pump to seize completely.
The financial damage to the price of the pump is more than 500.000 € and that is not even counting downtime in production.

3. Online Monitoring in the Context of Digital Company

The first step towards a company becoming digital is adopting a positive approach to digital solutions [3], [11]. Businesses should ensure that all employees use the potential of current digital solutions. The company can thus react faster and provide the personal experience that customers expect. Shifting to a digital solutions-focused attitude will put all employees at the forefront of digital innovation [12].

Although IT is an integral part of this process, it is precisely the other business units, such as maintenance, production, marketing, or sales that increasingly transform from a classic company to a digital one. For example, in the process of maintenance, production or logistics, RFID technology, QR codes, barcodes, smartphones, tablets, diagnostics, etc., are widely used. (Fig. 3). The more successfully a company builds a digital workplace, the more likely it will also attract the talent mentioned above that it needs [13]. In this way, the company will create a digital thinking culture that will support the transformation of the company. IoT is the basic part of Industry 4.0, which is intended for data collection, distribution and archiving. It is a basic pillar for the beginning of process digitization in the company. And data and analysis play an important role by our research. Figure shows a part of the blast furnace with possible pipe wear monitoring options.

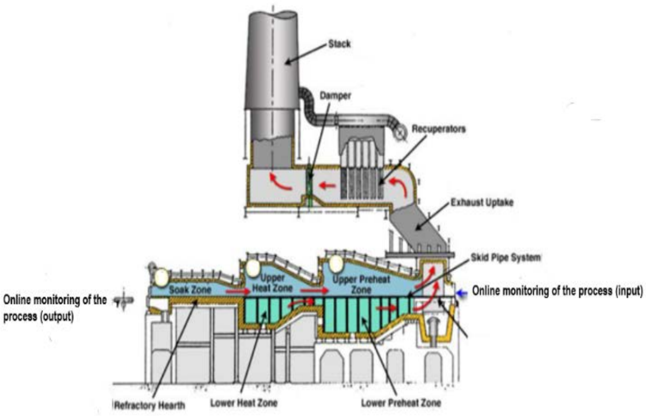

Figure 3. Basic parts of the furnace and the possibility of online monitoring of the process [3].

Hot rolling mills have one or more high-capacity heating furnaces (Fig.3) for uniform heating of gates supplied at intervals required for the rolling line.
The gates are inserted on the entrance side of the furnace, heated during passage through the furnace, and on the exit side, they are loaded onto the exit roller of the rolling line. The furnace has a steel casing and is insulated with several layers of refractory lining. The lining insulates the furnace and protects the steel structure from heat [3], [7].

4. Measurement of Fe_2O_3 Size Distribution by Intensity

Nanoparticle size is an important property related to the specific surface area, ability to pass through membranes and surface interactions, aggregation and stability of suspensions, functional capacity, and optical, mechanical and electrical properties.

The online monitoring of parts of the Fe_2O_3 material, which we obtained after removing the undesirable matter from the monitored pipe (Figure 1 and 2), is ready for the kinetic analysis of the size distribution of nanoparticles in a non-contact manner in the sample (in situ) in time-resolved experiment. Figure 4 shows a sample of scale that forms on pipelines and creates deposits.

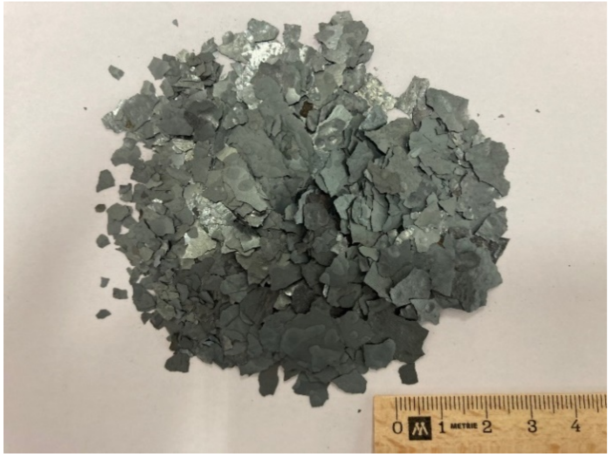

Figure 4. Particle of Fe_2O_3

It can be used for monitoring the synthesis of nanoparticles, assessing the stability of suspensions or as part of the physics-chemical characterization of nanoparticle suspensions. Refractive Index (RI) - simply put, the refractive index (RI) is a dimensionless number that represents the measurement of the bending of a light beam when passing through a material [12], [14].
It is calculated from the ratio of the speed of light in a vacuum, to the speed of the second medium (solid, liquid or gas) [13], [15]. Knowing and using the correct refractive index of the suspension and particle is critical to generating representative particle size distributions using light scattering techniques such as laser diffraction. The input characteristics of the measurement are in the following table No. 1.

Table 1. Input characteristics of the measurement

Sample Details	Fe_2O_3
Dispersant	Ethanol
Dispersant RI	1.364
Material RI	2.42
Material Absorption	1.000
Viscosity	1

During the entire monitoring of Fe_2O_3 particle size, Automatic measurement duration [15] was used. The basic parameters of the measuring device from Malvern Instruments are presented in the Table 2.

Table 2. Basic parameters of measurement

Temperature	20 °C
Cell Type	Disposable sizing cuvette
Cell Position (mm)	1.25
Scattering Angle (°)	173
Measurementduration (s)	140
Duration Used (s)	70

5. Results and Discussion

After the particle size distribution analysis, the results of the iron particle testing are known (Table 3.).

Table 3. Results after particle size distribution analysis

Mode 1 (d.nm)	300.8
Peak 1	295.4
Intensity (%)	49.5
Width (d.nm)	85.11
Mode 2 (d.nm)	8463
Peak 2	8024
Intensity (%)	42.5
Width (d.nm)	65.00
Mode 3 (d.nm)	93.54
Peak 3	100.5
Intensity (%)	8.00
Width (d.nm)	18.90

When analyzing Fe_2O_3 iron particles using particle size distribution analysis (Fig. 5), it was found that the size of individual particles ranged from 80-8000 d.nm, with a measurement intensity of 4-33%.

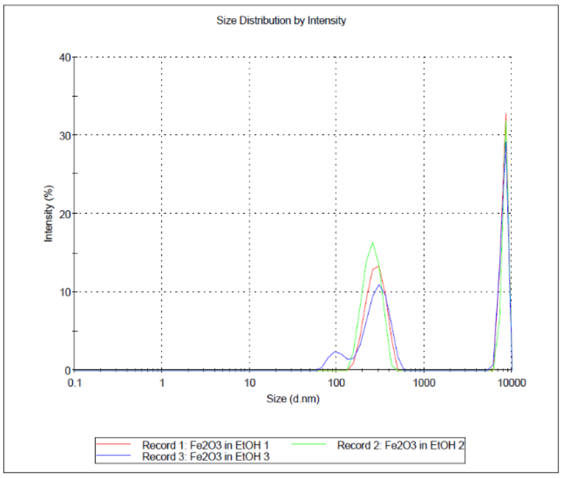

Figure 5. Particle Fe_2O_3 measurement results

A special problem in particle size distribution analysis is the determination of over and undersized particles [13], [16]. These are small partsof particles that are significantly larger or significantly smaller than the bulk of the sample. In the cumulative curve, is shown density distribution by a small second peak (second maximum) outside the real distribution. As a result of using the given method, Fe_2O_3 particle size distribution is an important parameter of analysis in quality control processes, because it is directly related to many other properties of the investigated material. Particle size distribution affects material properties such as flow behavior (for bulk/powder materials), reactivity, abrasiveness, solubility, extraction and reaction behaviour. In the context of a digital company, in order to achieve success, it is necessary to capture the data obtained through individual analyzes from the processes, transport them to cloud, process them and return part of them to the action members (drives, actuators...) for decision-making. In this way, we will influence production, operational and business processes.

6. Conclusion

Determining the particle size composition is a very important task, frequently encountered in many industries. For example, the cement industry, metallurgical industry, coal preparation, geotechnical testing and even food processing departments use particle size analysis, which is also an essential test in mineral processing tests. Crude ore products often require particle size analysis. A great advantage of Fe2O3 is its chemical stability, which is higher than fornanoparticles of pure metals. One of the important applications of Fe_2O_3 is its use as a red pigment. In further research, we will focus on applying Fe_2O_3 from hot rolling mills as a filler in the manufacturing process of composite materials, especially using additive manufacturing.

Reuse of "waste raw material" Fe_2O_3, in the manufacturing of a new product through BAT technologies. Implementation of newly created material into new products with the aim of:

- Savings on the company's input investments,
- Environmental suitability,
- Recyclability
- Support for the circular economy in the company

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