INNOVATION OF TECHNOLOGY FOR TESTING SELECTED PARAMETERS OF FINISHED PRODUCTS

Zdeněk MARTÍNEK, Petr BESTA, Nikola NĚMCOVÁ

VSB – Technical University of Ostrava, Ostrava, Czech Republic, EU,
zdenek.martinek.st@vsb.cz, petr.besta@vsb.cz, nikola.nemcova.st@vsb.cz

https://doi.org/10.37904/metal.2022.4443

Abstract

The aim of the manufacturing company is not only to innovate the production process in order to reduce production costs on the one hand and increase production on the other, but also to increase the resulting quality of products, which, with an increasing the level of quality of manufactured products, eliminates the costs associated with complaints (if any), increases the competitiveness of the manufacturing company in the markets and brings higher demand for products due to higher quality. This innovation of improving the quality of products has been neglected to a large extent in current trends, as great emphasis is placed on increasing productivity while reducing costs, and even brings with it the opposite effect, which is the above-mentioned costs of complaints and the associated outflow of customers. In order for innovations leading to reduced costs and increased productivity not to have an impact on quality, partial control mechanisms are implemented in the production process to detect scrap, or an output control is installed as the last step of the production process in order to find and discard the non-conforming product and avoid delivering it to the customer. The aim of the article is to analyse the innovative change of the selected production process.

Keywords: Innovation, technology, costs, quality

1. INTRODUCTION

Any purposeful, goal-oriented activity involving multiple people and aiming to achieve a pre-determined outcome requires management. This management takes the form of various decisions, measures, interventions, instructions, orders, dispositions and initiatives of specially authorised people – managers. Some management acts are directly influenced by managers in the course of the managed activities, others precede or follow the activities [1]. Management is a specific production factor that sets the production a target and brings order to it. Management has a short-term component (operational, tactical management) that ensures the mutual coordination of activities in the production system with regard to the intentions and objectives set by long-term (strategic) management. The management of the two components, short-term and long-term, differs considerably. Long-term management focuses on setting objectives, while short-term management focuses on implementation [2].

From the point of view of the complexity of managing production process, the most complex types of production are those that are continuous in nature. They typically include metallurgical production, which is based on the use of chemical, physical or thermal processes. Metallurgical production is also demanding in terms of the quantity and quality of input raw materials. The basic feedstocks include metal-bearing part, slag-forming additives and coke [3,4].

The metal-bearing burden portion of the batch is usually formed by iron or manganese ore, but also metal-bearing waste from industrial production. The metal-bearing constituents can be contained in the blast-furnace burden in the form of natural or sorted ore, but more often as blast furnace ore treatment products, i.e. agglomerates or pellets. From the chemical point of view, we distinguish four groups of iron ores [5]:

- Anhydrous oxides - ferric oxide Fe_2O_3 - hematite or bloodstone with the iron content of 70% in pure state, in nature up to 60%, ferrous-ferric oxide Fe_3O_4 - magnetite or lodestone with the iron content of 72.4%, pure, in nature 68%.
- Hydrated iron oxides $Fe_2O_3.n\ H_2O$ - limonites or brown hematites, hydro hematite $Fe_2O_3\ .n\ H_20$, where n < 1, contains in the pure state 62-69 % of Fe, götit $Fe_2O_3\ .\ H_2O$, where n = 1, i.e. FeO.OH contains in the pure state 62.9 % of Fe, hydrogötite or limonite $Fe_2O_3\ .\ n\ H_2O$, where 1 < n < 1.5, contains in the pure state 59.8 to 63 % of Fe.
- Carbonates, iron spar or siderite $FeCO_3$, contains up to 50 % of Fe in the pure state.

In many deposits, ore minerals occur in a combined composition. We can talk about belt deposits. In that case, the individual layers can contain different types of ores [6]. Besides the content of the metal itself, the content of pollutants and other negative substances is a key factor. All of these aspects can influence not only the iron oxide reduction process, but the production technology as a whole [7].

Due to the continuous nature of the production process and the necessity to modify the input raw materials before their use, metallurgical processes are also demanding in terms of in-house logistics [8,9]. Iron production is nowadays highly affected by environmental requirements. Those are not only oriented towards the reduction of negative externalities whether in the form of emissions or dust [10]. From a strategic point of view, the issues that are currently crucial for metallurgical companies are mainly related to the reduction of the carbon footprint.

The management of production processes is very challenging in the current highly competitive environment. In addition to high customer demands, there is also a significant increase in the prices of all raw materials and energy. Customers expect excellence not only in the product itself but also in the related services.

Manufacturing companies are now increasingly forced to look for possible sources of waste and to minimise their production costs. Within the framework of the conducted research, a possible change in the technology for oil filter tightness testing was analytically evaluated. The technology is used in the last inspection operation within the oil filter production line. The aim of the paper is to evaluate the possible options for changing this technology and the possible implications for the performance of the whole workplace.

2. PROBLEM FORMULATION

Quality assurance in the production process is achieved through a number of control mechanisms. Those are for example: quality control of input parts, poka-yoke systems, measuring systems, shape evaluation devices, presence control, control of specific properties of input parts and others. The main differences between continuous quality control in the production process and final inspection of a product are that any defect or non-conformity in continuous inspection is detected at a stage when the cost of repairing the part or reworking it is not as high as in the case of detecting a defect at the end of the production process. Unfortunately, some of the functional characteristics of the product can only be verified once the product is finally assembled. Such functional characteristics include, for example, the tightness of the product. It is this tightness control technology that is the subject of the innovation. Specifically, the tightness technology of the final product – the oil filter, which is shown in **Figure 1**. It is a complete oil filter assembly with cartridges, a cooler and an oil pump; the whole assembly is integrated into an aluminium block which is then mounted into a diesel engine that drives a truck.

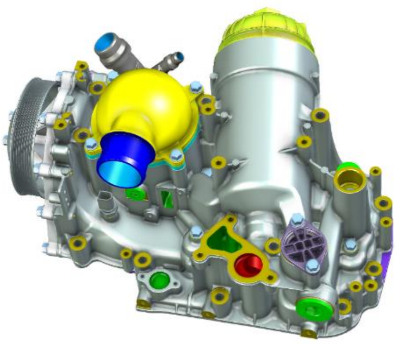

Figure 1 Oil filter

This oil filter is assembled on a semi-automatic assembly line operated by 3 assembly workers. The assembly line cycle time is 450 seconds, equivalent to a shift output of 60 units per shift. The annual production volume of oil filters is 41,400 oil filters. An outline of the assembly line is shown in **Figure 2**.

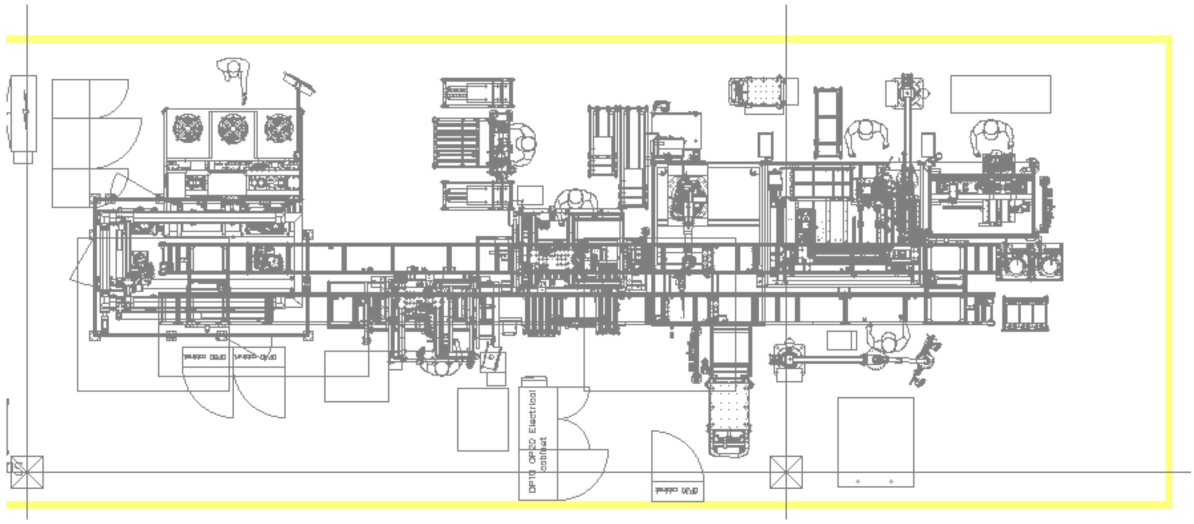

Figure 2 Assembly line outline

The air leakage detection method is a non-destructive method. The basic principle of the leakage testing method is to fill the parts under test with a pressure higher than atmospheric pressure and then to evaluate any leakage in three ways:

- by the pressure drop detection method – where only the pressure drop is evaluated and the possible leakage point detection is not localised,
- by the leakage point detection method – in this method the medium in the tested part is used to localise the leakage point,
- by the spectrometric method – in this method, the part under test is filled with helium (tracer gas), any leakage is detected by a spectrometer where its partial pressure is measured, the leakage is then evaluated by imaging. This test is therefore called the helium test.

The evaluation of part leakage using the pressure drop method is usually used in high-volume productions because the test time is shorter than that of the leakage point detection method. The disadvantage of this method is that the location of the leakage is not localised. This then has to be carried out subsequently using the leakage point detection method. The method has two uses. In the first one, the part is pressurised to the required pressure. The pressure is then stabilised and the pressure drop in the part is measured.

In the second method of leakage detection, the part is enclosed in a bell and pressurised to the required pressure. In the bell, in the vicinity of the part, a vacuum or a slight overpressure compared to atmospheric pressure is then created and then the pressure increase is evaluated. The first use is suitable for detecting larger leakages, while the second one is suitable for small leakages. An example of an air/air tightness test is shown in **Figure 3**.

Figure 3 Example of air/air tightness test

Locating a possible leakage by the leakage point detection method is, on the other hand, used for low-volume productions because it is time-consuming. This method can be performed in two ways. In the first way, the part under test is pressurised with compressed air, then it is immersed in a water bath under pressure. Air leakage is then visually detected by the presence of air bubbles. This method of evaluating leakage of a part is usually called the water test. This method is particularly time consuming, the part has to be dried, it is also not suitable for components and parts that can be damaged by water, and it can also lead to poor evaluation or missed leaks as this method is usually performed by a human. An example of the water test is shown in **Figure 4**.

Figure 4 Water test

The third detection option is through the spectrometric method. The principle is to pressurise the part under test with helium. Any leakage in the form of escaping helium molecules is evaluated using a magnetic sector mass spectrometer. The concentration of helium molecules is converted into an electric current which is amplified and its value is used to evaluate the test result [11]. The measured current is proportional to the helium concentration and therefore to the measured leakage (leakage). This method is very accurate and the test results are obtained in a short time. An example of a helium tightness test is shown in **Figure 5**.

Figure 5 Helium test

The use of all three detection methods for leakage testing must always be assessed according to the specific characteristics of the product.

3. EXPERIMENTAL WORK

In the first step of the research carried out, all three methods for leakage evaluation were experimentally compared. The evaluation was conducted in a team form through brainstorming. Each method was assessed in terms of three characteristics: test length, reliability in evaluation, cost of test equipment. The characteristics were rated on a 1–5 point scale (1 – worst, 5 – best). **Table 1** shows the results of the evaluation. For each method, an overall evaluation was also performed in terms of all characteristics.

Table 1 Comparison of methods for leakage evaluation

Method	Test Duration (1–5)	Reliability in Evaluation (1–5)	Cost of Testing Equipment (1–5)	Total
Air/air pressure drop method	2	4	4	10
Leakage detection method – water test	1	2	5	8
Spectrometric method – helium test	5	5	2	12

In terms of the comprehensive evaluation, the spectrometric method (helium test) was determined to be the most suitable, with a total score of 12 points. However, its major disadvantage is the high cost of the testing equipment. The results of the evaluation are then clearly displayed in the form of a graph in **Figure 6**. Therefore, when choosing a given technology, it is always necessary to take into account all the specificities of the technology and the production process.

The oil filter assembly line on which the research was carried out uses the air/air pressure drop detection method. The entire assembly process was evaluated by applying the bottleneck method. All individual operations were evaluated in terms of their duration and the performance of the workplace. Based on the analysis performed, it was found that the bottleneck of the entire assembly process is the output inspection which provides the tightness test. The total duration of this operation is 450 seconds. Even at ideal capacity utilisation, this output allows the production of 60 pieces per standard work shift. The second bottleneck in the assembly process was the final oil filter closing operation, which takes 220 seconds.

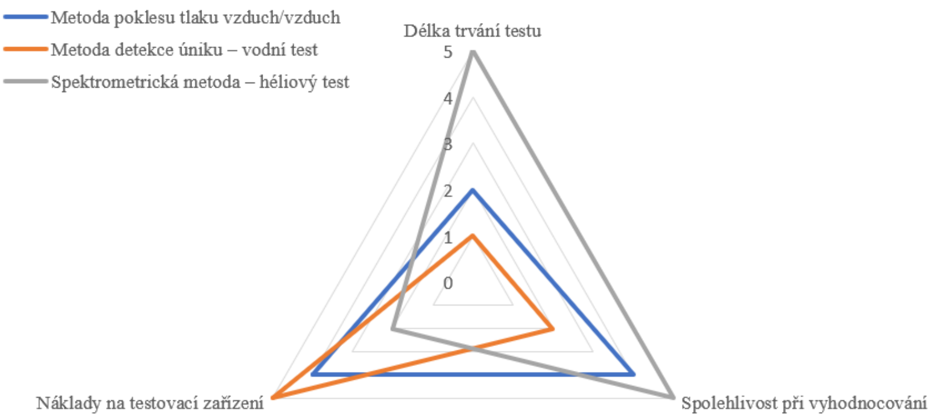

Figure 6 Network graph comparing tightness test methods

4. RESULTS AND DISCUSSION

An evaluation of the performance of the oil filter assembly line revealed a bottleneck in the output inspection that verifies the tightness of the product. Based on the evaluation of the individual options for tightness testing, a decision was subsequently made to upgrade the technology within the workplace. Helium-based test technology was selected as a suitable alternative. Based on the testing performed, it was found that this technology allows the test to be performed in 90 seconds. Its use therefore means a substantial reduction in the duration of the test operation, which is currently 450 seconds. Despite significantly higher acquisition costs, the acquisition of this technology is cost-effective. The total output of the assembly line will increase by 200 % after the introduction of the new technology. With the new technology, the required production quantity is produced in 339 standard working shifts instead of the original 690. A detailed analysis of the implications of the implemented innovation is presented in **Table 2**.

Table 2 Comparison of methods for leakage evaluation

Test type	Assembly line production capacity per shift (pcs)	Daily production capacity in three-shift operation (pcs)	Annual production capacity at 230 working days (pcs)	Number of shifts required to achieve a production volume of 41,400 pcs (days)	Difference
Air/air test	60	180	41,400	690	-
Helium test	122	366	84,180	339	351

The use of the new technology will have a major impact on the available capacity of the production line and its performance. The increase in the output of one operation will mean a real increase in the output of the entire workplace to twice the value.

5. CONCLUSIONS

On the basis of the research conducted, technology options for oil filter tightness testing were evaluated. The performance of the production line was limited by the performance of the output control workplace where the testing takes place. Based on the proposed changes and innovation of the testing technology, a 203% increase in performance was achieved. The substantial increase in the performance of the entire line allowed the cost of the new technology to be offset. At the same time, it will also be possible to optimise other workplaces and their performance. This is then fully within the principles of the bottleneck theory. Increasing performance and eliminating all kinds of waste will become increasingly relevant for manufacturing companies in all production areas. However, identifying and eliminating the selected source of waste is a never-ending process to increase production efficiency, reduce costs and develop added value for the customer.

ACKNOWLEDGEMENTS

The work was supported by the specific university research of the Ministry of Education, Youth and Sports of the Czech Republic No. SP2022/27.

The article was created thanks to the project No. CZ.02.1.01/0.0/0.0/17_049/0008399 from the EU and CZE financial funds provided by the Operational Programme Research, Development and Education, Call 02_17_049 Long-Term Intersectoral Cooperation for ITI, Managing Authority: Czech Republic – Ministry of Education, Youth and Sports.

REFERENCES

[1] PTÁČEK, S. *Řízení výrobních procesů [Production process management]*. Ostrava: VŠB – TUO, 2003.

[2] FOTR, J., ŠVECOVÁ, L. *Manažerské rozhodování [Managerial decision making]*. Praha: Ekopress, 2016.

[3] KRET, J. *Teorie procesů při výrobě železa* [*Theory of processes in iron production]*. Ostrava: VŠB- TUO, 2013.

[4] BESTA, P. Removal of zinc the blast-furnace process. *Przemysl chemiczny [Chemical industry]*. 2016, vol. 95, pp. 1752-1755.

[5] LU, L. Important iron ore characteristics and their impacts on sinter quality – a review. *Mining, Metallurgy & Exploration*. 2017, vol. 32, pp. 88-96.

[6] BESTA, P., WICHER, P. The optimization of the production of sinter as the feedstock of the blast furnace process. *Metalurgija*. 2017, vol. 56, pp. 131-134.

[7] FU, D., TANG, GW, ZHAO, YF, D´ALESSIO, J., ZHOU, CQ. Modeling of iron ore reactions in blast furnace. *International journal of heat and mass transfer*. 2016, vol. 103, pp. 77-86.

[8] SMALLMAN, Raymond E. *Modern Physical Metallurgy*. Tokyo: Butterworth-Heinemann, 2013.

[9] GEERDES, M., TOXOPEUS, H., COR, V. *Modern Blast Furnace Ironmaking*. Amsterdam: IOS Press, 2010.

[10] YIN, Ruiyu. *Metallurgical Process Engineering*. Berlin: Springer-Verlag Berlin Heidelberg, 2011.

[11] LABTECH s.r.o. *Mass spectrometry – helium method.* [online]. 2011. [viewed: 2022-05-18]. Available from: https://www.detekce-netesnosti.cz/hmotnostni-spektrometrie-heliova-metoda/