INCREASING EFFICIENCY OF FOUNDRY PRODUCTION BY DIGITIZING PRODUCTION DATA

[1]Jiří MACHUTA, [2]Josef BRADÁČ, [3]Vojtěch DYNYBYL, [4]Michal BENEŠ

[1]Škoda Auto a.s., Mladá Boleslav, Czech Republic, EU, jiri.machuta@skoda-auto.cz
[2]Škoda Auto University, Mladá Boleslav, Czech Republic, EU, josef.bradac@savs.cz
[3]Škoda Auto University, Mladá Boleslav, Czech Republic, EU, vojtech.dynybyl@savs.cz
[4]Škoda Auto a.s., Mladá Boleslav, Czech Republic, EU, michal.benes2@skoda-auto.cz

https://doi.org/10.37904/metal.2025.5100

Abstract

Die casting continues to play an important role in producing key automobile components such as engine blocks, transmission housings and new parts related to electromobility. Die casting is the main production technology for aluminium alloys. Due to the nature of the foundry process, the operation of the foundry consumes a lot of energy. To achieve a high degree of production efficiency, it is therefore increasingly important to monitor energy consumption and possible leakages of operating fluids, which can cause high losses. Thanks to the development of digitalization and trends such as Industry 4.0, it is now possible to effectively monitor individual production machines. The data collected from production machines can then be used to analyse operational data and monitor production trends and production stability. It is also necessary to compare the results with the expected consumption values according to the actual production and possibly also with changes in climatic conditions, thus the usage of effective consumption management. The paper presents the foundry operation and the production process of castings at Škoda Auto. The main benefits of using digitalization into the foundry operation are presented. Furthermore, the possibilities of using data to increase the efficiency of foundry production are mentioned. Production data can also be used to accurately identify individual products and thus for retrospective analysis of products concerning the level of quality achieved. Thanks to the precise monitoring of the foundry's operation in a real-time digital environment, potential problems can be detected early and solved very quickly and efficiently.

Keywords: Foundry, casting machines, digitization, data monitoring, production efficiency

1. INTRODUCTION

The trend towards digitalization of processes is being applied in all various sectors of industrial production. The use of digitalization brings various benefits in the form of in-depth monitoring of the production process and production machines and equipment [1]. It is thus possible to monitor, for example, energy consumption or operating fluids, which brings economic benefits, increases production efficiency and builds energy resilience. In addition to the economic benefits, there are also environmental aspects and the reduction of the emission footprint [2]. These steps are moving towards carbon neutrality [3]. The digitization of production processes and intelligent digital manufacturing are also important steps towards efficient and sustainable production [4]. The trend towards digitalization is closely related to the modern concept of manufacturing, referred to as Industry 4.0, where the data collected is processed, analysed, and evaluated, enabling the wider implementation of predictive systems [11]. Systems used for data processing are characterized by increasing performance variability and flexibility. The use of artificial intelligence and machine learning systems is increasing in the field [10]. The situation is similar in energy-intensive plants where molten metal is handled. Here, saving energy and reducing emissions is a key prerequisite for efficient and sustainable production [13]. To achieve this, it is necessary to apply Industry 4.0 principles to foundry operations as well, referred to as

Foundry 4.0 [9]. Artificial intelligence systems, smart systems and machine learning can be used here, for example, to increase production efficiency [8] or to detect defects in castings associated with the automatic readjustment of production parameters [12]. A comprehensive focus on, resource availability, energy efficiency and production efficiency is needed in the production of aluminium alloy castings for the automotive industry [5]. Another trend is the wider use of recycling in the foundry sector, enabling the reuse of resources in foundry production [1, 6].

The paper's main objective is to present the possibilities of using digitalization in the operation of an aluminium foundry, including concrete examples and benefits. The basic prerequisite is the correct setup of the data acquisition, processing and evaluation process for efficient production.

2. FOUNDRY PRODUCTION DATA

In 2018, the Škoda Auto foundry introduced datamatrix code minting into the production of engine blocks. This is a unique number or birth number for each engine block produced.

Datamatrix contains information about the group foundry code, casting date, fixed field, part sequence number on the machine per day (every midnight the machine is zeroed), production line number, product type, product index, mould number and mould acquisition number, see Figure 1.

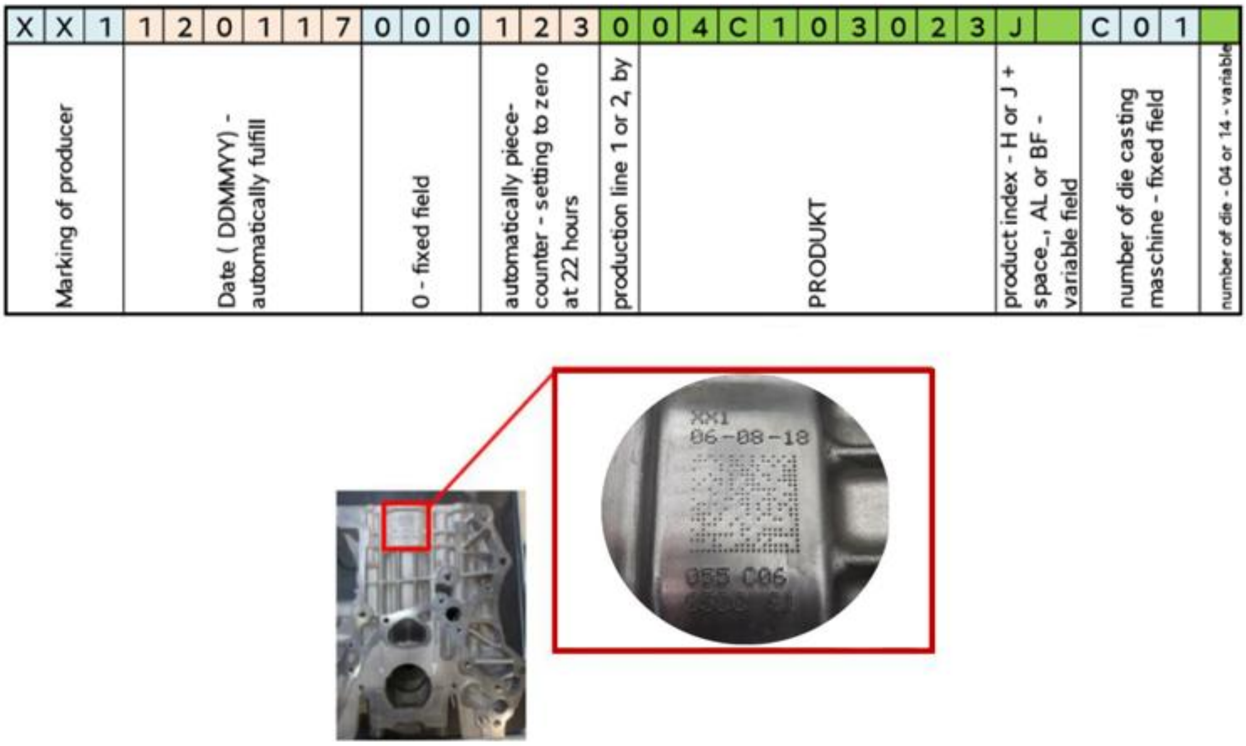

Figure 1 Example of using datamatrix code and its explanation

The knowledge of the code and its reading by cameras in different parts of the production allows for mapping the entire production flow of a specific part and assigning all production data to it, e.g., during the manufactured part's operation. For example, suppose the engine is to be serviced for a fault. In that case, we can trace casting curves (pressure, speed, piston movement), vacuum values, temperature in the holding furnace, separator consumption or even flow and temperature through the cooling and tempering channels.

2.1 PLC data evaluation

Each machine or periphery from which the data is read is equipped with a PLC device for reading data see Figure 2. For casting machines, the system exports all data to the Postgre SQL database from the PLC machine directly. We also store the read data from the PLC using the Kepware ŠA standard into the DASOP platform (Kepware ŠA - industrial communication platform) see Figure 3. The DASOP platform is then the standard analytical platform for fast data reporting at Škoda Auto. Fast data, such as machine operating statuses, is therefore processed via DASOP. All other data is exported to the Cloudera data lake (Microsoft). To the data lake, the information from other production systems, such as downtime and repair data, or parts produced and production quality information are added. The data is then displayed in special Power Bi reports, which are customized for each user group, according to their needs, using updated data from the Cloudera data lake at regular intervals.

In addition, data from the KOVNAR foundry's production software and maintenance data from the AMU system are fed into the Cloudera platform. The AMU system contains complete data on all downtime and the duration of downtime until successful repair. All data is then displayed in Power BI according to the requirements of the specific worker in the corresponding online report.

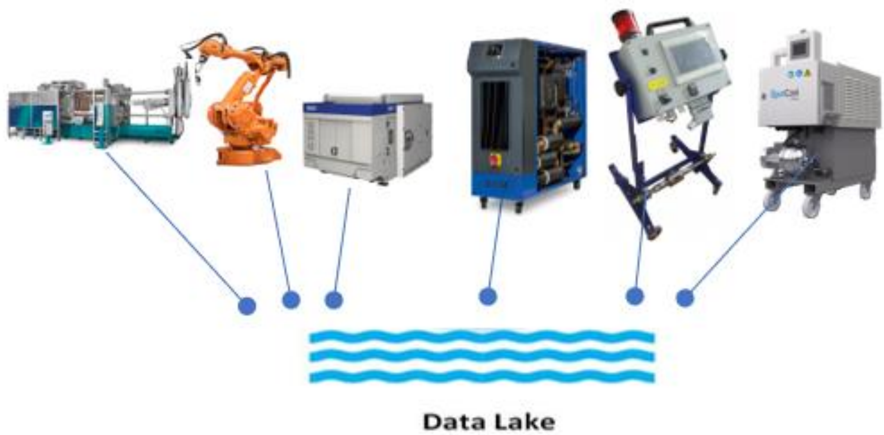

Figure 2 Data collection from PLC located on the individual machines and machine peripherals

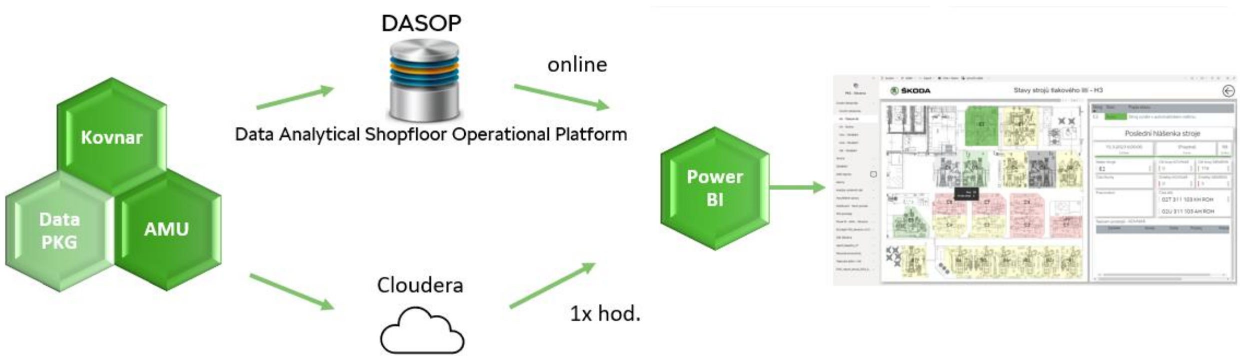

Figure 3 Data flow structure in the foundry operation

3. DIGITIZATION AND ENERGY MANAGEMENT

The principle of MONITORING & TARGETING is used to evaluate and monitor energy consumption in metallurgical operations. Unlike traditional consumption reporting, Monitoring & Targeting defines how much energy should be used under given climate conditions and production volumes and can reveal whether this is being achieved. It is a tool for sustainable smart energy management.

Important points for the correct function of the energy consumption evaluation are:

- Energy data collection of individual machines, technologies, but also the influence of weather and outside temperature.
- Creating the right structure, dividing operations into groups and meaningful units (machining, forging, casting, melting, air management, etc.).
- Identification of consumption drivers, i.e. all influences that affect energy consumption - weather, parts produced, machine occupancy, number of personnel, etc.
- Consumption modelling, where the model settings determine how much energy the operation should consume under given conditions.
- Visualization of consumption savings and losses, comparison of expected consumption with actual consumption and visualization of savings and losses in Power BI reports, see Figure 1 and Figure 2.

It is possible to immediately see how well the foundry is doing in a clear online application. Energy savings by implementing M&T enable to saving 4-5% energy. It quickly reveals moments of waste and helps to identify their causes. Many energy management tools only offer monitoring and reporting with the basic logic of setting consumption limits. M&T compares actual consumption with expected consumption, not year-on-year, because different conditions require different consumption.

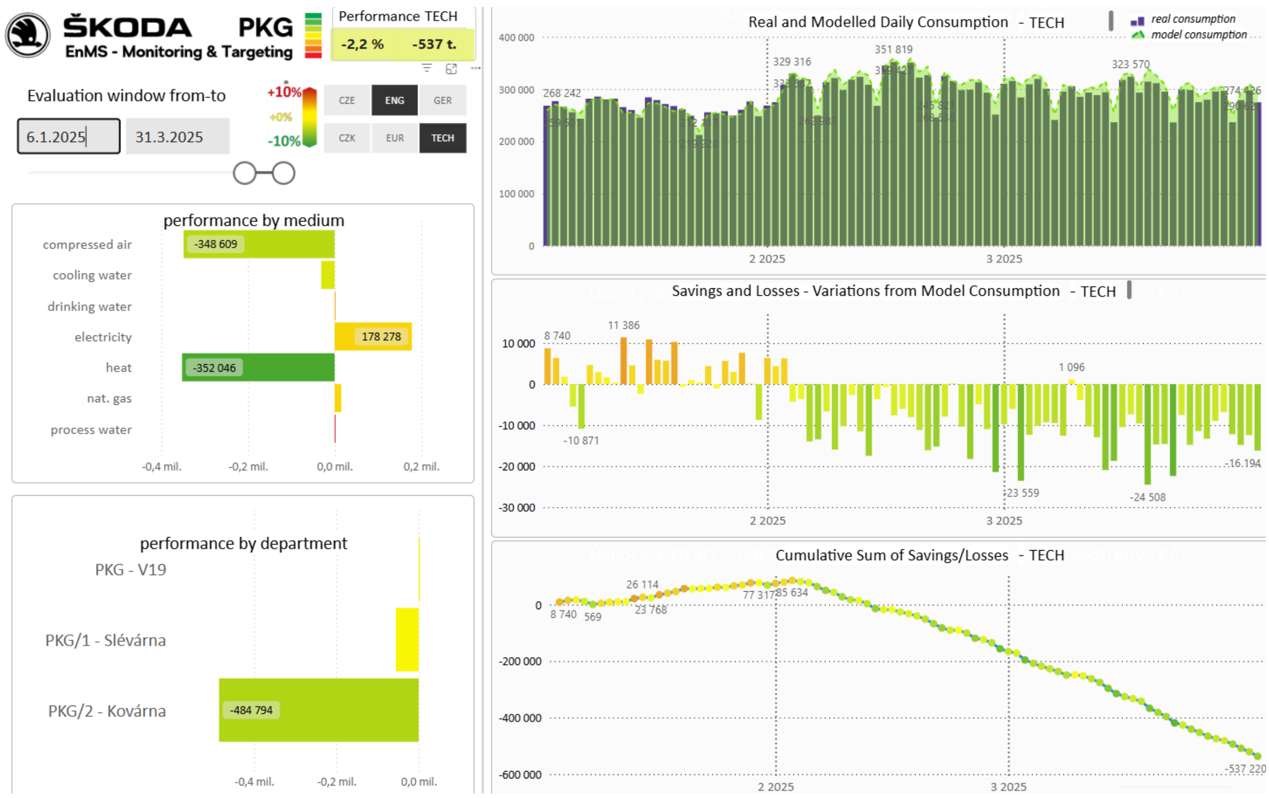

Figure 4 Monitoring & Targeting for the complete foundry plant

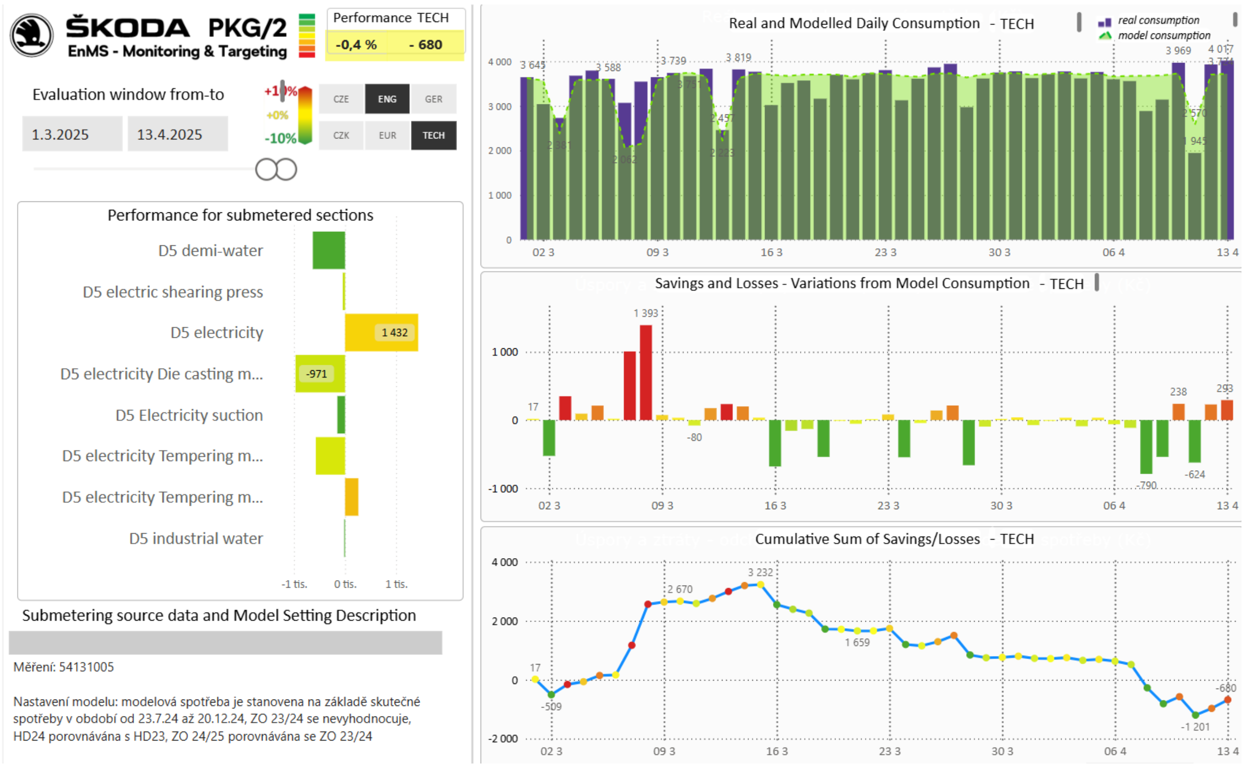

Figure 5 Monitoring & Targeting for the die casting machine IDRA D5

Another important tool for monitoring energy consumption is the IS ENERGIS application. IS ENERGIS is a comprehensive SW tool for business process management (balancing, planning, invoicing, cost accounting, production controlling, operational production management, business process modelling). It is particularly useful in the energy sector, distribution companies and industrial enterprises whose management is interested in maximally efficient management of production, distribution and sales.

The Energis system ensures global data collection, operation of a company dispatching center, efficient management of energy production and distribution, objective allocation of energy costs to cost centers, optimized electricity consumption, minimization of energy losses in distribution, optimization of energy consumption to production volume, and optimization of resource planning.

4. CONCLUSION

Digitization of operational data, consumption monitoring and unified Power Bi reports allow to have the operational overview of the current consumption status of all process substances and energies. Up-to-date PowerBi reports allow to detect an anomaly very quickly, trace the cause of the problem and arrange a solution. Furthermore, individual production lines or entire departments can be compared in terms of energy consumption. These are the benefits of the visualization in the Energis software. After deploying the systems and monitoring described above, we have reduced industrial water consumption per produced ton by 10% compared to 2022. Furthermore, in the sum of all other monitored energies such as electricity, compressed air, heat and natural gas, we achieved savings of around 9% per produced ton. One of the next steps based on an ecological approach is to use the waste heat from two annealing furnaces to temper the moulds on the casting machines or to heat the production hall in the winter months.

ACKNOWLEDGEMENTS

This paper was made with partial support from the internal grant agency project IGA/2024/01 Application of innovative trends in the automotive sector.

REFERENCES

[1] DROWATZKY, L., MÄLZER, M., WEJLUPEK, K.A, WIEMER, H., IHLENFELDT, S. Digitization Workflow for Data Mining in Production Technology applied to a Feed Axis of a CNC Milling Machine. Procedia Computer Science. 2024, vol. 232, pp. 169-182.

[2] WANG, H., WANG, J., LYU, Y., LI, X. The impact of supply chain digitisation on sustainable development in global panel data. Does the energy efficiency matter? Energy Economics. 2025, vol. 141, pp. 1-13.

[3] GU, Z., MOUSA, S., MENG, D., ELKADY, A.M, LEONG, L.W. Digitizing energy supply chains for enhanced resilience: Exploring the nexus between supply chain digitization, carbon neutrality, and natural resource extraction. Energy Economics. 2025, vol. 142, pp. 1-12.

[4] FUSKO, M., BUCKOVA, M., KRAJCOVIC, M., SVITEK, R. The strategy for implementation of the digitization in factories. Transportation Research Procedia. 2019, vol. 40, pp. 1045-1052.

[5] VAGAS, M., MAJERCAK, O. Usage of IoT Devices as Progressive Technology in the Era of Digitization: Case Study. IFAC-PapersOnLine. 2024, vol. 58, pp. 79-84.

[6] KATSIGIANNIS, M., MIKONIATIS, K. Enhancing industrial IoT with edge computing and computer vision: An analog gauge visual digitization approach. Manufacturing Letters. 2024, vol. 41, pp. 1264-1273.

[7] BRADÁČ, J., FOLTA, M., MACHUTA, J., SLABÝ, J., BENEŠ, M. Green Innovations in Foundry Production Processes of Automobile Castings. Rocznik Ochrona Środowiska. 2024, vol. 26, pp. 558-567.

[8] SCHARF, S., SANDER, B., KUJATH, M., RICHTER, H., RIEDEL, E., STEIN, N., FELDE, J.T. Foundry 4.0: An innovative technology for sustainable and flexible process design in foundries. Procedia CIRP. 2021, vol. 98, pp. 73-78.

[9] LI, Z., TAN, H., E.W JARFORS, A., JANSSON, P., LATTANZI, L. Smart-Cast: An AI-Based System for Semisolid Casting Process Control. Procedia Computer Science. 2024, vol. 232, pp. 2440-2447.

[10] DETTORI, S., ZACCARA, A., LAID, L., MATINO, I., VANNUCCI, M., COLLA, V., BONTEMPI, G., FORLANI, L. Machine Learning models to forecast defects occurrence on foundry products IFAC-PapersOnLine. 2024, vol. 58, pp. 113-118.

[11] LIU, W., PENG, T., KISHITA, Y., UMEDA, Y., TANG, R., TANG, W., HU, L. Critical life cycle inventory for aluminum die casting: A lightweight-vehicle manufacturing enabling technology. Applied Energy. 2021, vol. 304, pp. 1-10

[12] GONG, X., XIAO, X., LI, Q., ZHAO, J., FAN, Z. Rapid recycling of waste salt core materials in foundry industry using fractional crystallization. Journal of Industrial and Engineering Chemistry. 2023, vol. 211, pp. 1322-1327.

[13] XIANG, R., LI, Y., LI, S., XUE, Z. HE, Z., OUYANG, S., XU, N.. The potential usage of waste foundry sand from investment casting in refractory industry. Journal of Cleaner Production. 2019, vol. 98, pp. 73-78