MODERNISATION OF MACHINERY STOCK IN METAL CASTING FOUNDRIES AS A DETERMINANT OF QUALITY IMPROVEMENT IN PRODUCTION PROCESSES

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Abstract

The increasingly returning subject of the financial crisis forces company owners to continuously monitor their results, not only in terms of safety at work, but also reliability of equipment. The purpose of the presented article is to identify actions necessary to maintain a reliable machinery stock, which would guarantee effectiveness of production processes and high quality of metal workpieces. The analysis referred to a project of modernization of deprecated machinery stock in an industrial establishment belonging to the foundry industry. Exchange of equipment involved in the production process and replacement and adjustment of supply and control devices was proposed.

Keywords: Foundry industry, reliability of machinery and equipment, modernization, indicators of the implementation of project objectives, production process

1. INTRODUCTION

For production companies, indicators are not only represented by the amounts of the manufactured product, but also by reliability and productivity. A production process consists of such activities as: repairs of machines and equipment, disposal of municipal and industrial waste, energy production, processing and transfer of information. [1] A production structure is influenced by a number of factors, such as the level of specialization at workplaces, associating workplaces with time and space, product range, product quantity, repeatability of products. Merging these factors allows to specify fundamental criteria affecting the type and form of production. [6] The complexity of products, differentiation of materials, repeatability of parts, level of unification (using the same elements in different machine parts), labor consumption and manufacturing technology affect reliability of the production process. [2, 4]

Among the causes of deterioration of economic situation in a company, as stated in subject literature, which results in lowering the standards of reliability - in addition to the low level of management, insufficient marketing activities and operations that exceed financial capacities of a company (i.e. overtrading) - indicates a conservative financial policy [7], which is not focused on the need of investing and reinvesting in equipment.[8] Entrepreneurs must have an effective system of productivity evaluation, based on relevant indicators. [3]

The purpose of the publication is to identify actions necessary to maintain a reliable machinery stock in metal casting foundries, which would guarantee effectiveness of production processes and high quality of metal workpieces.

To verify this purpose, theoretical research tools were used, such as: analysis, synthesis, generalization and comparison. In respect of the practical methods the following tools were used: logistics audit, interviews with employees; and the following methods: computation and analytical (analysis of measurements). The result of the carried-out tests was to develop the scope and method of modernization of a metal casting foundry.

2. FOUNDRY INDUSTRY IN POLAND

The Polish casting is on the sixth place in Europe in terms of the production volume. The number of metal casting foundries in Poland reaches approx. 390 foundries, including small-sized workshops with low production volumes and employment. Out of all plants, 61 % foundries are independent entities and the remaining 39 % are company's departments. Out of these, 58 % are joint stock companies and limited liability companies and 94 % foundries belong to the sector of small and medium-sized enterprises.

The average production capacity of Polish foundries is approximately 2.5 times smaller than the performance of e.g. German foundries. Polish foundries have suffered from underinvestment and cannot count on an evident increase of production without the introduction of modern technologies and relevant equipment that reduces labor and material consumption; and thus, reduces the costs of castings production. The level of production in the Polish foundry industry has been systematically increased for years and so has the performance. The total production of castings in Poland, in the years 2004 - 2014, was approximately 900 thousand tons per year, of which 49 % were intended for export (97 % to the European Union). The total value of export was 695 million EUR, while excluding the export castings, which constitutes a large part of production, Poland is also the importer. It imports around 350 thousand tons of castings per year. [10]

An important action intended to improve the situation of the Polish foundries should be focused on productivity growth, cost reduction and the implementation of BAT (Best Available Techniques). It is also necessary to draw attention to the protection of the environment - obtaining integrated licenses that from the point of view of the European Union are necessary for the functioning of each of the foundries.

Not less important factor is the development of alternative casting methods to the extent covering a much larger volume of cast than is currently the case. The task of research leading to the attainment of these objectives is to improve the quality of production, reduce its energy consumption and the consumption of traditional foundry molding materials. These actions imply, inter alia, the progress of economic indicators for the production of cast and less impact on the environment, associated with harmful effects of foundries.

The perspectives for the foundry industry are good, because iron casting has generally taken the path towards the production of high-quality products and the use of modern technologies. At the same time, it is also the time of the rapid development of non-ferrous metal foundries which process aluminium, copper and particularly magnesium.

The subject of the present case study was a metal casting foundry with its registered seat in Katowice, whose main activity profile includes the casting of light metals such as copper, zinc, aluminium and brass.

The basic business activity of the studied entity is production and commercial and service activity, in particular: manufacturing of copper semi-finished products; casting of copper and copper alloys; utilizing metal waste and scrap; casting of light metals; metals treatment and coating; mechanical treatment of metal components.

The main production profile of the analyzed foundry includes the production of shafts and bushings made from bronze and, when there is demand, also from brass. Moreover, the foundry produces zinc alloys, zinc-aluminium mortars, rolled zinc anodes, modified brass and offers treatment services on the delivered material.

The foundry has no separate logistics department and all processes associated with logistics are carried out in the sales department. The logistics costs amount to around 5 - 15 thousand EUR and the level of costs associated with such processes as: transport, storage, supply, distribution and customer service is maintained at a satisfactory level, while maintaining stock at an acceptable level.

3. ANALYSIS OF THE MACHINERY STOCK - LOGISTICS AUDIT

3.1. Logistics audit of the supply area

The main raw material used in the production is scrap of non-ferrous metals. Indispensable aspects in the production process and additional processes include auxiliary materials, refractory elements, packaging materials and deliveries of the media. Materials for production are delivered to foundries mainly via car transport provided by suppliers, tank-vehicles deliver components for making masses (resin coated sands, water glass and bentonite mixtures). [9]

Storage of basic materials used in the foundry is performed mainly with the use of storage areas located in indoor (covered) production halls. Charges consumed in large quantities (scrap, iron, coke, limestone, ore, fine coal) are stored in concrete bunkers located around the melting shop facilities. Other alloying elements, such as sensitive modifiers and mortars, are stored in commercial packagings (metal barrels or bags) in dry interior areas, while liquid mass additives and protective coatings for molds and cores are stored in originally sealed transport packagings (containers of metal and plastic or reusable containers), in designated areas of production halls. Furthermore, refractory materials and other materials delivered on pallets are stored on hand-held dry stockpiles. Fuels, oils and coolants are stored mostly in warehouses with solid concrete ground, in original packages located in original packagings placed on specially designed sump trays protecting the materials against leakages.

The internal distribution of materials in the foundry is carried out with the use of different transport techniques. Basic equipment used for the internal transport includes transporting cranes with thrust-system-controlled engines (cabin cranes). In addition to suspended cranes, the following are used: belt conveyors, roller tables and loading ramps for cupolas. A separate group are means of internal wheeled transport, which include mostly combustion-engine forklift trucks and hand pallet trucks. [9]

The selection of a given supplier is made on the basis of the list of qualified suppliers, which is regularly updated. The foundry draws supplies from suppliers being company's partners. Market research is carried out by a staff member, who analyses stock exchange listings of metals.

Depending on their price purchasing decisions are made. When selecting suppliers, the company follows primarily such criteria as: quality, price, obtained certificates and form of payment. The lead time is always stated in the contract and depends on the type, quantity and demand for the given raw material. The level of own stock, which translates into freezing of the capital, never exceeds 35 %, as the supply process is realized according to the Just In Time method.

3.2. Logistics audit of the production area

In the foundry, there are 3 separate technology lines, which take the form of a casting socket. The above-mentioned sockets are used for the production of bronze and brass bushings. The process of melting and production of alloys is carried out only in electrical induction furnaces, hence each socket at the base must be fitted with a transformer and capacitor banks, which are an integral part of each technology line and decide upon the parameters of production. Each socket consists of: a transformer with the corresponding control system, 1 melting furnace with a capacitor bank, assigned with 2 foundry furnaces, each with an own capacitor bank. This is a system formed by a single casting socket. The diagram of the production process in a foundry is shown in **Figure 1**.

There is also an induction crucible furnace with a capacitor bank, intended to melt alloy additives in the production process, zinc alloys and zinc anodes, equipped with an automatic temperature control system and coupled with furnace's supply system, which prevents exceeding the temperature setpoint.

Production is realized in a continuous manner, i.e. furnaces are not quenched (apart from quenching due to technical maintenance works, repairs or excluding a given line from production), which means that the products are produced 24 hours per day.

The main equipment used for foundry's internal transport is a crane. In addition to the crane, the following transport equipment is used: Hand trucks - used for transporting individual pieces of finished products to shelves, forklift trucks - used for transporting larger quantities of finished products across the hall, and transporting by cars and loading trolleys - special vehicles used for charging melting furnaces in order to avoid burns with liquid metal.

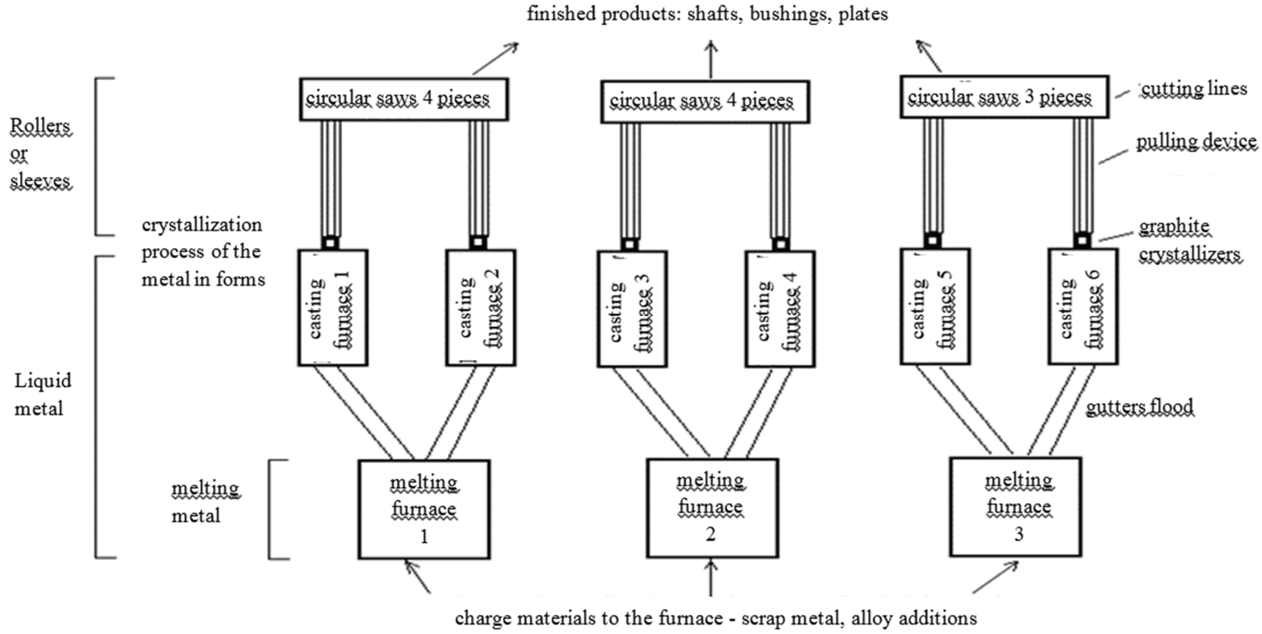

Figure 1 Diagram of the production process in a foundry. Source: [9]

Moreover, the company uses the following transport automation techniques for transporting production materials and finished products:

- Systems of roller conveyors, conveyor belts.
- Automatic overhead conveyors (crane).
- Forklift trucks, both traditional and AGV.

3.3. Logistics audit of the distribution area

Products manufactured at the foundry are sold via three main distribution channels:

- Directly to the recipient - produced and sold are finished products, manufactured in most cases on request, on the basis of a signed contract with the recipient.
- Indirectly (to another manufacturer) - semi-finished products or finished products, which are further processed by this manufacturer.
- Through a network of trading partners, through networks of small wholesalers.

Because of the nature of this process, products are manufactured usually for business customers, as semi-finished products for further processing.

Finished goods, produced in the foundry, are delivered to the recipient by recipient's own transport or by shipping companies, such as DHL or PEKAES. Due to the separation of external processes associated with the transport of finished products, the company has made substantial savings. Taking into account the fact that the finished products leaving the foundry are of high value, they are always insured in transport. Apart from the shipping services, the carrier does not provide any additional services to the foundry. Freight rates are determined in PLN per km and the costs of transport are calculated every 3 months. Cooperation with carriers is carried out on the basis of short-term contracts.

The foundry products are manufactured only on request, due to the high value of products (high prices of light metals). The customer chooses the category of a product and decides whether it is to be consistent with the industrial standard or the Polish standard. Furthermore, the customer has the right to specify product dimensions (in case of shafts and bushings). [9]

Customer expectations survey, regarding the offered standards of service, is carried out every 6 months.

In the foundry, the following customer service standards have been defined: lead time and flexibility of deliveries. Moreover, the following qualities have been evaluated as satisfactory, i.e. level of cooperation in distribution channels, service quality and errors in deliveries. The level of finished product stocks and the dates of payment are acceptable, however, customer access to foundry's products requires modification.

4. RESEARCH RESULTS

The logistics audit at the examined foundry has shown that the main problems of the company concern deprecated machinery, equipment and power supply system. Furthermore, the present activity of the foundry is inappropriate from the ecological and economic point of view.

In view of the production capacity of the installation fitted in the foundry, considerably exceeding 20 tons of products per day, the plant is subject to the obligation of obtaining an integrated license. In addition to the arguments of the deprecated power supply and the age of machinery which needs to be replaced, the general problem consists in the lack of possibilities to comply with the BAT requirements in terms of the equipment being part of the IPPC installation. The current condition of the induction furnaces, due to the outdated technology concerning their main element (the driving force), is contrary to the principle of implementing new and "cleaner" technology.

The presence of transformers and capacitors, as constituent elements of the IPPC installation, leads to the situation where the requirements set for these installations cannot be met, which generates problems on the following planes:

- No prevention of industrial accidents, including uncontrolled emissions of PCB (PCB is a substance that creates particular risk for the environment) to the environment (devices do not have protection against oil leakages, and the visual inspection indicates a high level of corrosion).
- Hazard of fire, due to lack of flame-resistant structures of transformers and capacitor tanks.
- Insufficient power of transformers in relation to the power of furnaces contributes to greater emissions (release) of dust during the process of melting, as these furnaces are currently not able to operate in high ranges, but only in ranges allowed by the transformer. This, in turn, causes increased time of melting the metal and higher emissions of dust.
- Age of equipment (dated down to 1974) proves poor technical condition and indicates non-application of modern solutions.
- Illegible identification plates and labels on the capacitors make it impossible to determine the type of the PCB medium in capacitors, resulting in inaccurate records and lack of possibility to determine the scope of risk.
- Lack of implementation of one of the main BAT objectives, which is "lowering environmental impact through the use of environment-friendly raw materials".
- Lack of adjustment to legal requirements, including the regulation of the Minister of Economy on the requirements concerning the migration of substances presenting particular risk for the environment and the use and treatment of installations and equipment in which substances causing a particular risk for the environment were or are used (OJ of 2002, No. 96, item 860).
- Deprecated transformers and power cables, apart from the PCB content, constitute another type of risk in the form of electromagnetic fields. So, large condensation of old devices, devoid of shielding elements (emitting electromagnetic fields), may lead to exceeding acceptable levels of emission.

The above conditions are built up with 3 main aspects, which indicate to the replacement of the above-mentioned equipment in order to adapt it to the BAT requirements:

- Legal aspects - dictating the replacement of equipment containing PCB, as a factor creating specific risks for the environment.
- Technological aspects - in view of the specific nature of the induction-based installation, the devices of transformers and capacitors are an important part of the installation, responsible for the process parameters (output power value and field strength around the heater change during a single technological process and too low power of the transformer allows operation only in lower ranges, which prolongs the time of melting and lowers the quality of the process). According to the reference documents concerning the casting industry, induction furnaces must work in ranges which allow to obtain the correct temperature of melting point; and it depends on the power of the transformer. In addition, current devices show very high load losses.
- Aspects of pollution emissions - due to the nature of production based on the use of induction of eddy currents in a conductor placed in a variable magnetic field used to heat the semi-finished products, the dominant source of electromagnetic field is the inductor winding (induction coil), supply cables and the generator. The current number of transformers and voltage cables, representing outdated technology and without the shielding elements, is the source of electromagnetic fields emission. The second type of emission, which depends on the power of the transformer, is the dust arising during melting the metal. The too low melting temperature (due to too low power of the transformer) extends the time of the process and thus causes an increase in emissions (release).

The collected data, concerning the installed devices of transformers and capacitors, produced in 1974, indicate poor condition, outdated technology and massive loss of load, while the overall dimensions of transformers eliminate any possibility of modernizing the remaining casting sockets of the installation. Taking into account the small number of suppliers of industrial transformers and the need to individually produce capacitor tanks (produced on individual request), it is necessary to prioritise modernization of the power supply system (including devices of capacitors and transformers), which in turn will be accompanied by modernized casting sockets. Such modernization schedule would considerably facilitate the course of work regarding the adaptation of furnaces to the possibilities of power supply devices and their size. [9]

The need to modernize many elements of the installation is mainly due to their long time of operation. Most devices have not been replaced since their first commissioning, which dates back to the beginning of the seventies. The age of these devices translates not only into the poor technical condition, but also into the lack of compliance with environmental requirements. These are devices containing substances causing a particular risk for the environment, devices which are not energy-efficient and poorly dimensioned. As the technology used in the foundry is based on electrical energy supply (with only induction furnaces installed), it must first be decided to replace power supply components consisting of capacitors and transformers containing PCB. These devices are an integral part of the installation expected to be modernized.

5. MODERNISATION PROPOSAL AIMED AT INCREASING RELIABILITY

On the basis of the carried-out analysis it was decided to modernize the entire plant. In view of the production capacity of the installation fitted in the foundry, considerably exceeding 20 tons of products per day, the plant is subject to the obligation of obtaining an integrated license. After the examination of the technical condition of particular devices included in the installation and comparing them with the BAT guidelines, a specific order of modernization works was decided.

The need to modernize many elements of the installation is mainly due to their long time of operation and increased pollution emission. The technology used in the foundry is based on electrical energy supply (with only induction furnaces installed), thus it was first decided to replace power supply components consisting of capacitors and transformers containing PCB. The above-mentioned devices are an integral part of the installation expected to be modernized and adapted to solutions which meet the BAT requirements, which will enable obtaining an integrated license.

The work schedule expected the implementation of all activities within 9 months. Total expenditure on the selected solution amounted to 405 875 EUR and has been incurred in 50 % from foundry's own resources and in 50 % from the European Regional Development Fund. The highest costs have been incurred for the equipment - 349 000 EUR, due to the fact that they are produced exclusively on request and must be closely integrated with the existing infrastructure of the plant. Transport and disposal of waste, including the utilization of the harmful PCB, cost 33 750 EUR, while costs of documentation, i.e. the cost of the feasibility study and the technical documentation, amounted to 23 875 EUR.

The issue shall be considered resolved when the objectives are realized on two levels:

- Product - solving the problem helped the enterprise expand its machinery stock by 11 new fixed assets, which include: transformers, transformer control systems, melting furnace capacitor banks, an induction crucible furnace and a foundry furnace. An estimate of the total value of new fixed assets was 304 000 EUR. The foundry is equipped with equipment and electrical wiring necessary for the correct installation and start-up of the fixed assets. The cost of equipment and its wiring amounts to 45 000 EUR.
- Result - indicators at the level of the result have been planned in the scope of the following categories: number of new jobs and the number of installations, which as a result of this support will obtain an integrated license, increased efficiency of the installation for waste recycling and energy savings per production unit (this indicator will be measured in 2 measurement units: MW and MW/Mg). [9]

In pursuance of the objective the company has planned to raise employment by 10 new jobs. The estimated level of human resources is minimal and depends on the pace of further development of the business. Thanks to the implementation of this undertaking the foundry has obtained integrated certification. In pursuance of the objective the company has also planned to increase the capacity of the installation for the recovery of the recycled waste to the level of 1 200 Mg per year. The implementation of this undertaking has also allowed energy savings per production unit in the scale of 0.01 MW.

6. CONCLUSION

On the basis of limitations concerning the internal capacity and preconditions for development lead modern companies to verification of the validity of their resources in the context of building a relevant position on the market. The purpose of the present article was to identify actions necessary to maintain a reliable machinery stock, which would guarantee effectiveness of production processes and high quality of metal workpieces. The research included the exchange of equipment involved in the production process and the replacement and adjustment of supply and control devices.

On the basis of the performed analysis of the machinery stock in the studied company, it should be noted that the implementation of the solution will lead to:

- Increased production - following the replacement of the problematic devices and power supply components, the foundry can increase production to the level of the maximum performance of furnaces, which previously was not possible, because of the limited scope of work of capacitors and transformers. In addition, due to furnaces working in their full range, there are no harmful emissions of dust, which previously constituted an additional problem.
- Modernization of machinery stock - 11 modern fixed assets were purchased (capacitors and transformers), new wiring was installed and the whole power supply system was modernized.
- Obtaining integrated certification - thanks to replacing outdated capacitors and transformers containing PCB (polychlorinated biphenyls - substances that are particularly dangerous for the environment), the

foundry has obtained integrated certification, necessary for companies producing above 20 tons per day.

- Savings in energy consumption - modernization of power supply systems, purchasing and installation of new wiring and using modern capacitors and transformers, has led to savings in energy consumption per production unit in the scale of 0.01 MW, which means significant yearly savings in energy.
- Greater safety of employees - old devices emitted electromagnetic fields with values exceeding the acceptable standards several times. Moreover, there was a hazard of fire associated with the absence of flame resistant transformers and capacitors, replacement of the devices to new ones has led to a significant increase in the safety of employees.
- Elimination of the industrial accident hazard - old devices of capacitors and transformers contained PCB and did not include protective components that would prevent PCB leakage. A failure and emission of PCB would lead to long-term contamination of the environment and therefore the company has installed new devices equipped with another, more secure coolant, which is approved for use by legal provisions.

Elaboration of the modernization principles aimed at improving the functioning of the entire logistical system was very important during the implementation of the proposed solution. High costs of implementation were observed. However, it is important that the researched company has undertaken to implement such a solution. The end results shall not wait long to be seen - based on the positive experience of companies operating in this industry in the world, the undertaking is expected to give positive effects. The carried-out research is a continuation of research on the restructuring project and most applications concern both processes.

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