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# THE HUMAN ROLE IN A PROGRESSIVE TREND OF FOUNDRY AUTOMATION

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An increasing competition in the foundry market focuses on more efficient methods of production. High quality and efficiency requirements, but also rising labor costs, will make the foundry production largely automated. Currently, molding on automatic lines accounts for 40 % of the foundry production in Poland. The article discusses organizational, technical and ergonomic implications of automation in production processes and presents the results of research carried out in this field in Polish foundries.

*Key words:* foundry industry, production, human role, quality, ergonomics

## INTRODUCTION

According to data published by industry organizations, for the past few decades the global market for casting has demonstrated an upward trend [1]. This strong production growth is justified primarily by an increased demand for castings in China and India. It is accompanied by a decreasing trend in foundry production in Europe, which creates the continuous struggle of European producers to maintain market share in the global foundry market. In Poland, since entering the European Union there appears to be a gradual increase in the production of castings. Quantitatively, this sector is represented by small and medium-sized enterprises operating in the local market, though most of the production is carried out by a few very large foundries producing mainly for the automotive and construction industry.

Traditional casting has until recently been treated as an artistic crafts industry. This was due to the enormous workload of highly qualified and experienced workers in manual casting. The demand for castings, technical progress and at the same time the willingness to meet the demands of customers forced the automation and robotization of large and medium-sized foundries. From these changes they expect primarily the possibilities of an [2-4]:

– increase in production capacity, and also a reduction in employment,
– increase in the yield from the mold (e.g., by minimizing excess material during machining),
– reduction in the costs associated with poor quality (due to the appropriate density of molds, accurate representation of casting surface and the separation of molds from the models, as well as reducing the amount of surface defects such as: detachment, insufficient thickening, errors in shape, shifts, dusting, creases, excessive roughness, and internal defects of castings caused by insufficient rigidity of molds),
– reduction in the amount of labor necessary for finishing of castings,
– improvement of working conditions.

Changes in production technology involve a reconstruction and a re-division of responsibilities of employees. The introduction of automation eliminates a significant portion of previously manual tasks. However, it does not eliminate all activities, and even causes the addition of new tasks, where the role of a human is currently impossible to replace.

## HUMAN ROLE IN CASTING PROCESS

Like in other production systems, striving for greater efficiency of the casting processes is associated with automated systems [5-8]. This changes the role of the human from a direct performer of specific technical processes to an operator of complex machines.

The human in technical system can exist in four roles: controller, operator, service technician, and performer (Figure 1).

Different configurations of the human-technical object system are closely linked to the issue of the level and type of training of employees, the nature of their tasks and the type of workload they are under. The operators' tasks include: information processing, tracking the course of events and the states of controlled objects and performing control actions, as well as identifying flaws and making simple regulatory actions [10, 11]. In addition to knowledge about the operation of the production line, a serviceman should have qualified engineering expertise primarily in the areas of electrical engineering and automation, which is used during periodic inspections, maintenance and repair of specific devices and production line control systems. This leads to the conclusion that a special role in modern produc-

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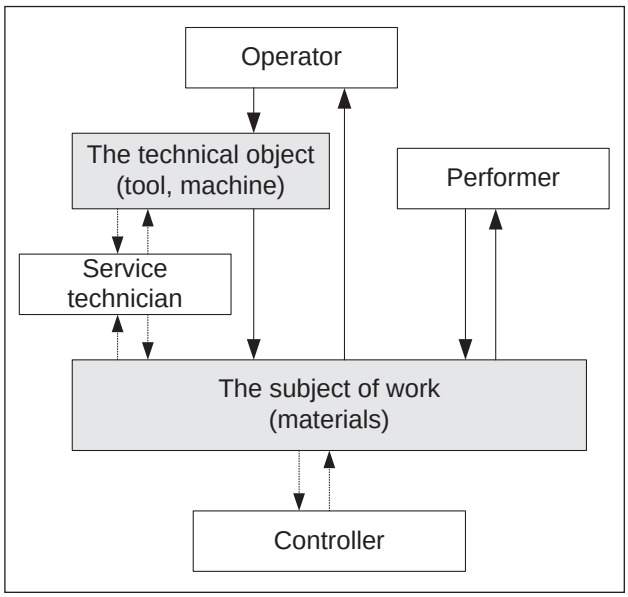


**Figure 1** The human role in the manufacturing system (own preparation based on [9])

tion processes is played by human intellect [3]. Analytical and rational thinking and decision-making is necessary when the workflow or detailed method of solving the situation is not known at first. It cannot therefore be programmed, because it requires an assessment of the situation, taking into account all of the evidence available, and only on this basis it is possible to determine the algorithm of operation. The basis for this decision is the multifaceted knowledge of the worker, but also experience from other similar situations in the past.

The advancing robotization and automation of production forces the search for solutions to replace the human decision-making process [12]. These expectations are met with artificial intelligence systems [13]. They try to meet the specific functions of human intellectual activity, but their widespread use is blocked most commonly by barriers such as:

– difficulty to express informal knowledge in a logical language, especially uncertain, incomplete and imprecise knowledge,
– limitlessness of human knowledge, so-
– called tacit knowledge,
– lack of the ability to create algorithms for all of the possible scenarios of a situation,
– lack of a multi-level analysis of the problem and flexibility of thinking that has the human mind.

These barriers mean that robotization and automation of production systems can replace the human in the performance of its tasks, however, it is not able to completely rule out human participation.

## RESULTS OF THE STUDY OF THE HUMAN ROLE IN FOUNDRY AUTOMATION

The study of the role of the human in automated foundry processes was based on pre-established levels of human function in the production system (Table 1).

Table 1 **Levels of human function in a production system (own preparation)**

| Function in the production process | Required level of intelligence | Ability to replace the function |
|---|---|---|
| controller | Conformity assessment of process and product, decision making during disruptions | partly |
| service technician | Servicing of technical objects according to instruction, state of the object and engineering knowledge | no |
| operator | Control of technical object according to instruction and based on data regarding the process | no |
| performer | Performance of actions based on strict instruction | to a large degree |

Such an arrangement of roles allowed to determine which production processes can be replaced by automated lines, which require support by artificial intelligence systems, and which need the knowledge and senses of a human.

The study was conducted in five Polish enterprises producing castings of gray cast iron and ductile iron. The tested foundries produce minor detailed products, that is, light products with a unit weight of less than 100 kg/pc. The castings of these alloys play a large role, as much as 62,5 % of cast materials in Poland (according to data for 2009, when production of castings was 807 thousand tons [14]). Percentage distribution of the technologies used in foundries for cast iron and ductile iron are shown in Figure 2. It can be assumed that the figures for 2013 do not differ significantly from those shown.

The study took place in 2013. The research tool was observation and research questionnaire. For analysis of the various stages of the manufacturing process, the casting process was divided into 6 stages [15,16]. Then were defined range of possible automation and human role (Table 2). A summary of human functions currently im-

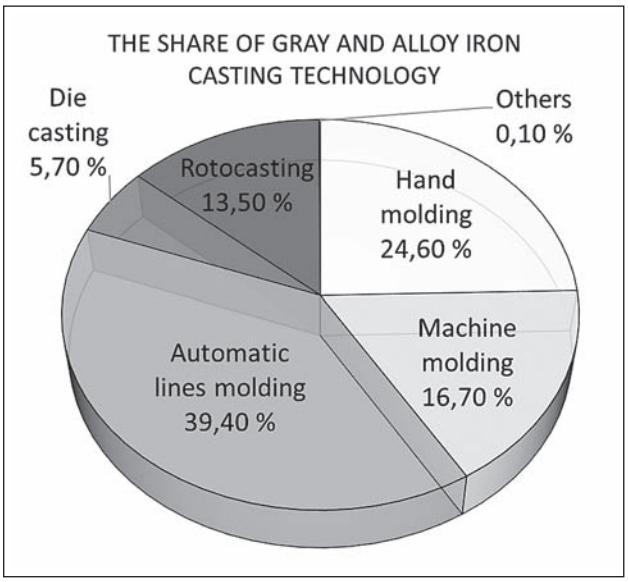


**Figure 2** The share of gray and ductile iron casting technology in Poland in 2009 (own preparation based on [13])

Table 2 **Human role in the background of foundry automation (own preparation)**

| Area | Range of automation | Human role |
|---|---|---|
| Homogenization of molding sand (homogenization of sand by breaking up lumps, mixing in order to aerate and average the temperature and cooling to a predetermined starting temperature) | - separation of metal parts from the molding mixture,<br>- separation from the molding mixture of parts of the core and excessively agglomerated mixture,<br>- cooling and homogenization of molding mixture | - setting the proper process parameters,<br>- monitoring of messages from signaling board,<br>- responding and decision making in the event of equipment failure or malfunction |
| Mixing of molding sand (giving it fixed and stable technological properties, which determine the quality of the mold and casting) | - preparation of molding sand, i.e. putting specified ingredients in the mixer and their precise mixing and aeration,<br>- transport systems of molding sand and additives (sand, bentonite, coal dust),<br>- electronic control system with programmable formulations of prepared molding sand | - selecting the formulation for the produced mold,<br>- setting the technological times,<br>- changing the setpoints,<br>- controlling the output signals,<br>- changing the type of work,<br>- responding to alarms, technological warnings, and hardware failures |
| Measurement of moisture level of the molding mixture (necessary for calculating the quantity of water to be dispensed to obtain a predetermined amount of moisture of fresh molding sand) and the dispensing of water in the processing of the molding mixture | - control-measurement apparatus for measuring and regulation of moisture of molding mixture,<br>- measurement of formability and compactibility of mixture,<br>- calculation and comparison of moisture value with the setpoint value,<br>- dispensing of the calculated amount of water | - monitoring the accuracy of input parameters and the results of dispensing,<br>- responding and decision making in the event of equipment failure or malfunction |
| Control and adjustment of technological properties of molding mixture – especially permeability and shear strength and compression strength (we also measure: temperature of molding mixture, deformation of the sample during strength testing, compactibility, abrasion resistance) | - gathering samples,<br>- measurement of technological properties of the mixture,<br>- recording results,<br>- changing setpoints of dispenser of binder or other ingredients | - supervising the course of inspection,<br>- performing laboratory tests (e.g., marking the binder content, sieve analysis, assessment of absorption, determination of sintering temperature),<br>- decision making about the suitability of molding mixture |
| Filling of tray with molding sand | - signaling of tray filling level (min. and max.),<br>- opening of scraper onto conveyor belt (filling),<br>- raising of scraper (stopping filling),<br>- distribution of molding sand into trays | - supervising the accuracy of filling the tray,<br>- responding to alarms, technological warnings, and hardware failures |
| Mixture formation and the associated operations | - shaking, pressing, moving, vibrating,<br>- pushing and punching of mold with cast,<br>- separation of mold from the pattern,<br>- administration of flasks,<br>- rotating, folding and adjustment of molds,<br>- separating and cleaning of flasks | - mold quality control,<br>- qualifying of mold inaccuracies,<br>- responding to alarms, technological warnings, and hardware failures |

possible to replace by automated production lines shows how much of a role the employee plays in foundries. This also confirms the thesis that an automated foundry line's main functions are performed by the operator and service technician. A controller's tasks can be partially performed by a production line's equipment system, although decision-making in situations that are unpredictable, unusual or require additional research belongs to the human.

## CONCLUSIONS

Automation of foundry processes is a technological innovation that improves the quality of molds and castings, reduces production costs and improves productivity and working conditions. It is also associated with relieving the human from performing heavy work under difficult conditions. This leads to a reduction in employment of workers directly in production. However, research conducted by the authors showed that certain functions of a human are impossible to replace, and some tasks will still need to be performed by him or her. The only part reduced in the whole production process is manual labor, while the degree of specialization of those working on the process increases.

## REFERENCES

[1] M. Butlewski, A. Misztal, M. Jasiulewicz-Kaczmarek, S. Janik, Metalurgija, 53 (2014) 4, 701-704.
[2] R. Wrona, Biuletyn konferencji, III Konfe-rencja Odlewnicza TECHNICAL 2000 Po-stęp techniczny w odlewniach, AGH Wy-dział odlewnictwa, Nowa Sól, 2000, pp. 9-17.
[3] P. Kuryło, S. Janik, Wybrane problemy projektowania procesu technologicznego w projektowaniu współbieżnym in Projek-towanie Procesów Technologicznych, Komisja Budowy Maszyn PAN Oddział w Poznaniu, Poznań, 2006, pp. 193-199.
[4] P. Kuryło, S. Janik, Proceedings, Pro-izvodstvo - Technologija - Ekologija - PROTEK 2005 Sbornik naucnych trudov, MGGU Stankin, Moskva, 2005, pp. 24-43.
[5] A. Jasiak, Kryterium czynnika ludzkiego w projektowaniu systemów wytwarzania, Rozprawy Nr 283, Wydawnictwo Poli-techniki Poznańskiej, Poznań 1993.
[6] A. Misztal, M. Butlewski, Life improve-ment at work, Wydawnictwo Politechniki Poznańskiej, Poznań 2012.
[7] A. Mazur, H. Gołaś, Management Systems in Production Engineering, 3 (2014) 15, 94-99.
[8] A. Mazurkiewicz, M. Uryniak, Nierówno-ści Społeczne a Wzrost Gospodarczy, 8 (2006), 219-234.
[9] E. Tytyk, Metodologia projektowania ergonomicznego w budowie maszyn, Rozprawy nr 252, Wydawnictwo Politechniki Poznańskiej, Poznań 1991.

[10] M. Sławińska, Reengineering ergonomicz-ny procesów eksploatacji zautomatyzo-wanych urządzeń technologicznych, Wy-dawnictwo Politechniki Poznańskiej, Poznań 2011.
[11] M. Jasiulewicz-Kaczmarek, Lecture Notes in Computer Science, 5624 (2009) Ergo-nomics and Health Aspects of Work with Computers, pp. 153-161.
[12] A. R. Pritchett, S. Y. Kim, K. M. Feigh, Journal of Cognitive Engineering and De-cision Making, 8 (2014) 1, 52-77.
[13] G. Maniarski, P. Kuryło, Komunikacja w systemach wieloagentowych stosowanych w sterowaniu robotami in Teoria maszyn i mechanizmów, J. Wojnarowski (ed.), Oficyna Wyd. UZ, Zielona Góra, 2006, pp. 375-380.
[14] J. Sobczak (ed.), Prognozy i trendy rozwo-jowe w odlewnictwie światowym i krajo-wym, Instytut odlewnictwa, Kraków 2011.
[15] Z. Samsonowicz, Automatyzacja procesów odlewniczych, Wydawnictwa Naukowo-Techniczne, Warszawa 1985.
[16] M. Szweycer, D. Nadolska, Metalurgia i odlewnictwo, Wydawnictwo Politechniki Poznańskiej, Poznań 2002.

**Note:** The responsible translator for English language is Paulina Butlewska, Poznan, Poland