

Analysis of Competitive Factors in Casting Processes

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Abstract. The goal was to develop a model for identifying and analyzing internal factors with the greatest impact on the competitiveness of the production processes of foundry companies. The model is closely related to the evaluation of companies in terms of the first principle of Toyota management (focusing on factors determining the concept of development) and uses a modified BOST method. The analysis of the results of the study allowed to gather valuable knowledge for the company's management. The results pointed out the direction of the company's development, which should be aimed at ensuring high quality products, increasing the level of automation and caring for customer relations (ensuring customer welfare and a high level of service). Future directions of research will concern expansion of the model to include more areas to identify factors of competitiveness and market success of foundry companies.

Introduction

Increasing competition and dynamic market conditions are urging foundry companies to take improvement measures. The foundry industry is part of the metallurgical industry, which produces metal products [1,2]. A variety of plastics are used in production, distinguished by their physical properties and chemical composition, which ultimately determines their applicability [3,4]. Foundry customers include many manufacturing industries, which can be divided into: automotive industry, mechanical engineering and industrial valve manufacturers [5,6]. The diversity of purchasers makes casting, on the one hand, dependent on the demand for final products, and on the other hand, none of the listed industries can produce final products without acquiring castings. This dependence between entities gives the foundry industry a great importance for the economy [7,8]. Suppliers of coke, scrap, foundry pig iron, as well as other materials and technical solutions are suppliers to foundry companies [9]. The diversity of technologies used, materials used, products manufactured and target markets, contribute to the considerable heterogeneity and specificity of the foundry industry [10]. These features define the reality of the market economy of entities operating in the foundry industry [11,12]. Indicated, the conditions are complementarily reinforced by the fact that this industry, despite significant modernization, is still identified with a "dirty" industry, which has a negative impact on the environment, uses outdated technologies, and creates harsh working conditions, which adversely affects its attractiveness [13-15]. At the same time, foundry industry is still characterized by lower (in relation to the achievements of other industries) economic indicators, such as capital intensity of production and labor productivity [16]. For this reason, foundry companies imply patterns of decision-making activities that bring them closer to achieving the desired level of competitiveness [17].

The peculiarities of the foundry industry force managers to implement ever newer development concepts of production processes to ensure competitive superiority [18,19]. Competitive superiority can be closely linked to a well-thought-out and realistic technical development strategy, adequate to the concept of *Industry 4.0* [20,21]. A variety of methods are available in the literature

for identifying factors of competitiveness and analyzing its level. Companies are most often compared with each other within the same industry and in a specific context, such as energy efficiency [22]. With regard to the identification of success factors, multi-criteria indicator analyses [23-25], rough set methods (used to assess the benefits of resources) [26] or the integration of several methods (formalization method, content analysis, system analysis) [27]. Market (marketing) research is carried out [28,29] sometimes marketing research is combined with comparative analysis [30]. Sometimes single characteristics of foundry companies (e.g., costs) understood as a success factor are studied [31]. However, there is a lack of methods that directly address more internal competitive factors that are closely related to the foundry processes implemented. Therefore, the goal was to develop a model for identifying and analyzing the internal factors with the greatest impact on the competitiveness of foundry companies' production processes.

Environment and Social Impact

The competitiveness of enterprises strongly influences social relations [32], and thus has a reciprocal effect on management schemes [33,34], especially in the case of lean production [35,36] characterized by very tight schedules and negligible buffers. In order to maintain sustainable development in such conditions, it is necessary to use appropriate optimization tools [37-39] that allow both the reduction of the complexity of issues [40] and the consideration of the elusive "human factor" [41,42], which is usually the main cause of process variability [43]. The above "soft" tools must be supplemented with "hard" technological solutions. First of all, appropriate design solutions [44,45] are at stake, but also machining [46,47] and welding [48,49]. Surface modifications with special layers that increase wear resistance are also important e.g. ESD [50,51] or DLC [52,53], especially after additional laser processing [54-56]. Paint coatings [57] that increase corrosion resistance [58,59] and composite modifications [60] are also helpful. All these activities improving quality [61,62] require appropriate training of highly qualified staff [63], who are then able to implement appropriate research [64,65], diagnostic [66,67] and preventive [68,69] activities.

Method of Research

In order to identify the internal competitive factors of a foundry enterprise, a model was developed to analyze the production processes of a cast product (Fig.1).

Step 1. Preparation of studies

In view of the purpose of the research, one of the main production processes carried out in a foundry company was considered the subject of the study. Selecting a group of experts means selecting employees from among the management. These people should have knowledge of the selected research subject, the competitiveness of the enterprise and the situation in the industry. The formulation of the research objective should be done using the SMARTER technique. The name of the technique refers to the key characteristics that the objective should meet (S - "specific", M - "measurable", A - "attractive", R - "realistic" and T - "time - based", E - "exciting", and R - "recorded"). This technique was used in the model and considered the best because it supports the formulation of the goal in a way that: will allow it to be realized, allow progress to be monitored, and allow development plans to be adjusted in response to changing conditions.

Step. 2. Diagnostic test

Specifying the group of respondents involves selecting employees who have knowledge of the final product, the selected production process, manufacturing technology, market position, industry and competition. The method takes into account the applications of the BOST (an acronym for the author's name – Borkowski Stanisław) survey in a variant oriented to employees. This variant identifies a set of factors related to the elements of the Toyota house roof and the

following principles: 1, 2, 3, 4, 6, 7 and 14. The model refers to Toyota's first management principle, which states that management decisions should be based on a long-term philosophy, even at the expense of short-term financial goals. The BOST method takes into account intangible enterprise resources such as customer well-being, product innovation, cooperation with cooperators, employee self-reliance and responsibility, technology development and nurturing enterprise culture. Additional factors were included to expand the scope of the analysis. As a supplement to the information obtained, the model includes face-to-face interviews with employees regarding technological advancement and trust and brand recognition, i.e. competitive potential.

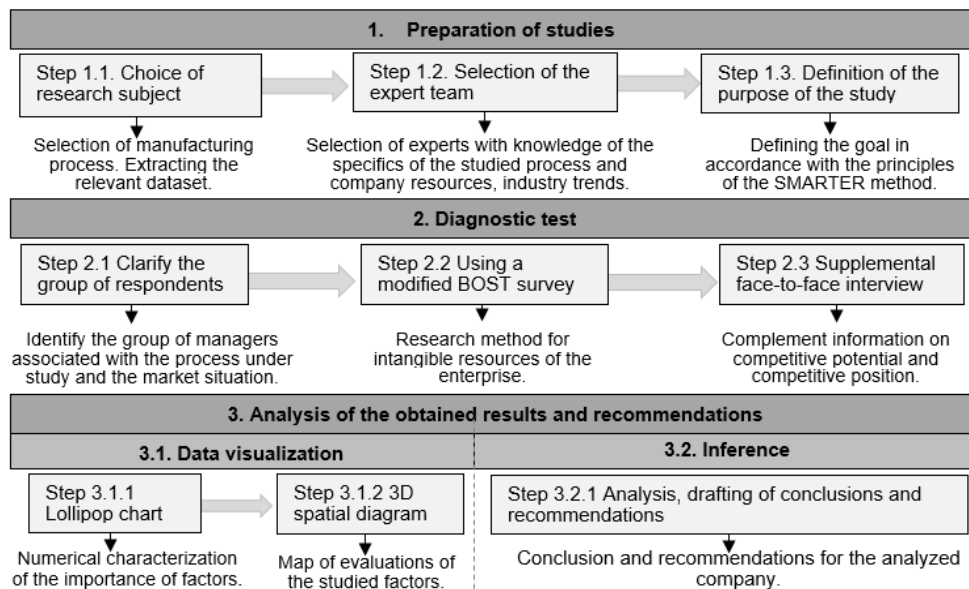


Figure 1. Concept of a model for the analysis of competitiveness factors of casting processes

Step 3. Analysis of the obtained results and recommendations

As part of the graphical representation of the collected information, the data should be numerically characterized – assessing the importance of factors from two levels: technological advancement and trust and brand recognition. In order to have a good understanding of the obtained factor evaluations, the result should be illustrated using a lollipop chart and then a 3D spatial chart as a summary of the results. On the basis of the data thus presented and analyzed, conclusions should be drawn and recommendations made, taking into account the specifics of the foundry company.

Method Verification and Results

The foundry industry, which is popular in Poland, especially in the southeastern part of the country, belongs to the heavy industry, with a significant negative impact on the environment. For this reason, the verification of the developed model for analyzing the competitiveness of foundry processes was carried out at an enterprise located in this part of the country.

Step 1. Preparation of studies

As part of the model verification, the subject of the study was the manufacturing process of a gearbox cover used in light vehicles. The cover, weighing 26.4 kg, is cast from AlSi7Mg0.3 alloy and has dimensions of 750 x 410 x 100. The casting is one of the company's key products (in terms of volume and economy).

The task force included a technology manager, a quality control manager, a marketing and product manager and a product auditor. The selection of experts took into account their

predisposition to meet the requirements of the method related to the acquisition and analysis of data on factors indicative of technological advancement and trust and brand recognition. The implementation of the developed model was aimed at gathering adequate data and information (regarding the current state of the production process of one of the main products) and performing their analysis in the context of identifying key success factors in terms of technological advancement and brand trust and recognition. Implementation of the method also makes it possible to identify sensitive factors that interfere with the implementation of the process and its development and improvement.

Step. 2. Diagnostic test

The respondents were the management staff of the department: technology, production, quality control and product marketing cell. A total of 52 employees participated in the survey. The choice of the number of people participating in the survey was determined by the fact that the research was a pilot study. In addition, the research relates to a selected manufacturing process which also narrows the group of respondents. The research was performed in the third quarter of 2023. The selected employees were to answer the following question: what factors determine the development concept of your company? thinking about the company using the example of a selected production process. It was necessary to evaluate the listed factors for implementing improvements on a scale of 1-9 (1 - the least important factor, 9 - the most important factor). The factors evaluated in technological advancement were (1) self-reliance and responsibility of employees, (2) product innovation, (3) cooperation with cooperators, (4) technology development, (5) modernity of products, (6) quality of the product, (7) price of the product, (8) automation. On the other hand, the factors relating to trust and brand recognition were (9) customer welfare, (10) nurturing company culture, (11) company reputation, (12) customer service, (13) implemented strategy, (14) loyal customers, (15) recognition of market needs, (16) product customization. The factors considered in the study make up the company's competitive potential. After completing the survey, the expert team conducted face-to-face interviews with management employees. The interviews focused on: the competitiveness of the company's key product (gearbox covers), internal sources, management practices and the company's market position.

Step. 3. Analysis of the obtained results and recommendations

A numerical specification of ratings of the degree of significance of the analyzed factors indicating the potential for competitiveness in the areas of technological advancement and trust and brand recognition was made (Fig.2).

The lollipop chart shows the structure of the importance of the competitive factors assigned to the areas studied. Within technological advancement (TA), product quality (TA6) and automation (TA8) were considered the most important success factors, while within trust and brand recognition (TBA) were customer service (TB12) and customer welfare (TB9). Respondents identified technological advancement as a more important area of development. In order to realize a detailed analysis of the distribution of indications by respondents, 3D spatial charts were made (Fig.3).

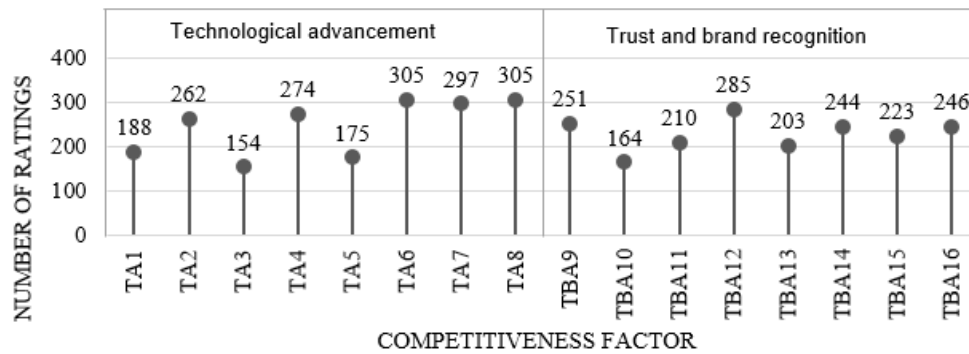


Figure 2. Describing the level of significance of assessments of the studied competitiveness factors

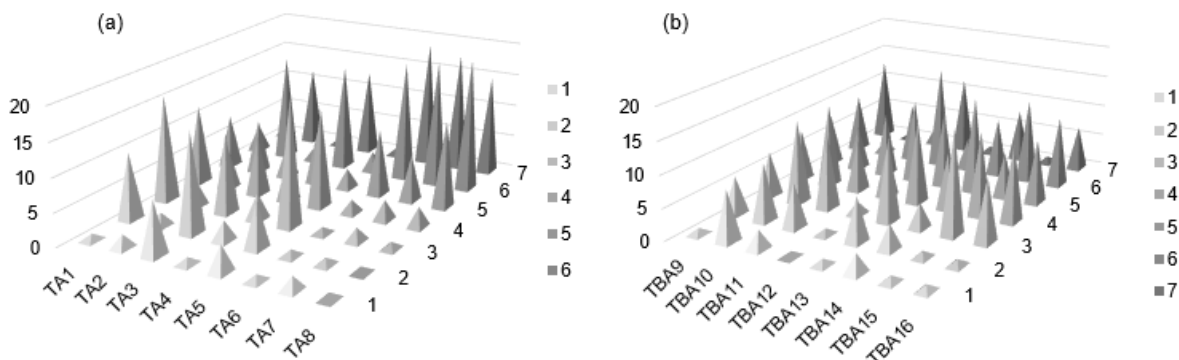


Figure 3. The structure of the importance ratings given to the analyzed competitiveness factors

Analyzing the data (Fig.3) first, there is considerable variation in the votes cast within the areas studied and on individual factors. In the area of technological advancement, the highest level of concentration and unanimity in summoning the highest ratings (5-7 points) is characterized by: product quality (TA6) and automation (TA8). The second area studied is characterized by a higher level of flattening of the degree of ratings awarded.

The results of the survey indicated that the respondents are aware that in order to achieve success in the market, the company should focus its activities on (mission and development strategy) on ensuring high quality products and increase the level of automation. Executives should pay special attention to customer care, especially in terms of customer service and broadly defined well-being.

Conclusions

The purpose of the study was to create a model for identifying and analyzing the internal factors with the greatest impact on the competitiveness of the production processes of foundry companies. The model refers to the evaluation of foundry companies in terms of the first principle of Toyota management, which focuses on the factors that determine the concept of development.

A test of the model confirmed its usefulness. Respondents evaluated the relevance of competitive factors. The analysis of the results of the survey helped gather valuable knowledge and rationale for the company's management. The results of the research indicated that in order to achieve success in the market, the company should focus its activities on ensuring high quality products, increasing the level of automation, and taking care of customer relations (ensuring customer welfare and a high level of service). Future research directions will concern expanding the model to include more areas for identifying factors of competitiveness and market success of foundry companies.

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