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Original Research

Analysis of the Technological Position in Relation to Aluminium Casting Production

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Abstract

The dynamically developing production market, and in particular the metallurgic industry, enforces constant improvement of the level of production efficiency and product quality, which influences company position on the market and the level of its competitiveness. Therefore, the aim of the study was to determine the current position of the foundry enterprise, taking into account the aluminium gearbox casting, in the context of technological capabilities and market position, as well as to identify critical factors and, finally, to indicate the conditions for its strengthening. The study used a 3x3 matrix. The company under study, in the context of manufacturing the analysed product, is classified in the area of "marketing improvement". This area demonstrates the need to take measures to establish a marketing and development department and the need to make better use of the company's identified technological potential. The method presented in the study can be useful for analysing the position of manufacturing and service companies in various industries, in order to select an appropriate development strategy.

Keywords: metal industry, mechanical engineering, quality management, 3x3 matrix, aluminium casting

1. Introduction

Productivity growth in the modern world is perceived as one of the key sources of social improvement, social progress and economic growth. This approach has contributed to the fact that productivity growth in many countries has become a goal pursued in almost all enterprises, regardless of the type of products manufactured or services provided (Pacana et al., 2019; Piętowska–Laska, 2015). In industry, a manufacturing system that enables production of high-quality products with minimum inputs is important. This can be achieved with an increase in the productivity of enterprises (Hys, 2014; Ligarski, 2018; Wolniak & Skotnicka–Zasadzień, 2010). Productivity is a category depicting the efficiency of the inputs incurred. As such, it has a significant impact on the competitiveness of economic units. It is crucial that the development of productivity reflects all types of inputs incurred. Productivity is an important issue in the context of analysing the performance of manufacturing enterprises, as it allows assessing their development, paying particular attention to the resources involved in the production process (Klimecka–Tatar, 2018; Ulewicz & Novy, 2019; Wolniak, 2020). In an era of increased market volatility, technology development and significant competition, the manufacturing process requires continuous improvement. Seemingly small improvements can affect the success of a company, which indicates that the production process should be subjected to constant monitoring, analysis and improvement, in order to eliminate imperfections and to increase technological efficiency, competitiveness, and, thus, improve market position (Pacana & Czerwińska, 2020).

Technology can be understood as the science relating to the processes of processing raw materials and producing semi-products and products from input materials. In such an approach, technology refers to the fixed assets of the sub-entity and including the equipment of production lines. Technology can refer to the results of research and development and production-engineering functions of an enterprise (Chiu et al., 2010). The effective use of technology is significantly influenced by a variety of

measures. A significant number of factors determining its level depend directly on the enterprise, but also on its suppliers and environment. A failure to ensure an adequate level of these resources and factors not infrequently results in a loss of competitiveness (Ligonenko, 2016).

Competitiveness is the process by which one entity strives to outperform another. For manufacturing firms, competitiveness indicates the ability to produce products in a timely and cost-effective manner that meets buyers' demands and market needs (Zhamoida, 2009; Zhou & Zhu, 2005). The activities undertaken by enterprises are carried out with the aim of gaining and expanding market share, which determines their profits, i.e. achieving the main objective of any manufacturing enterprise (Pacana & Czerwińska, 2017).

The aim of the study is to clarify the current position of the foundry company, taking into account aluminium gearbox casting, in terms of technological capabilities and market position, as well as to identify critical factors and, ultimately, to identify conditions for its strengthening. It is important to take appropriate action in relation to the identified position in the 3x3 matrix.

2. Analysis

2.1. Aim and subject of the study

The main objective of the study was to analyse the technological strategies followed by the selected foundry company. The study will make it possible to assess the existing technology and compare it with similar technologies on the market. Achieving the objective will enable to make changes within critical areas of the strategy.

The gearboxes are manufactured in series at one of the companies located in the south-eastern Poland. The gearboxes in question, measuring 600 x 500 x 150 mm, are used in light-duty vehicles. The gearboxes are responsible for changing the gear ratios, thus effectively utilising the power generated by the engine within the combustion of the fuel-air mixture. Figure 1 shows an illustrative model of the test object.

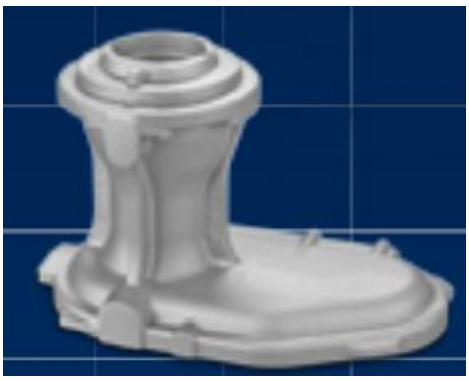

Fig. 1. Model of the subject of research – gearbox

The gearboxes are cast from the AlSi7Mg0.3 alloy, by using gravity sand moulds. The chemical composition and mechanical properties of the alloy used are shown in Table 1.

Table 1. The chemical composition and mechanical properties of the alloy

Chemical composition									
Element	Fe	Si	Mn	Ti	Cu	Mg	Zn	Others	Al
Min., %	-	6.50	-	-	-	0.45	-	each:0.03; total: 0.01	remainder
Max, %	0.19	7.50	0.10	0.25	0.05	0.70	0.07		

Mechanical properties									
Property Name	Tensile strength R_m		Yield strength $R_{0.2}$			Elongation at break A		Brinell hardness	
Min, %	300		320	240	240	4	6	100	151
Max, %	350			280		6		151	
Unit of measure	N/mm^2		N/mm^2	N/mm^2	MPa	%	%	HB	HB

Source: Own elaboration based on (PN-EN 1706:2011. Aluminium and aluminium alloys Castings. Chemical composition and mechanical properties, 2011, Warszawa: PKN)

The AlSi7Mg0.3 alloy (EN AC-42200) used by the company is used to manufacture castings of moderately loaded engine parts with complex shapes. Thanks to the presence of such elements as silicon and magnesium, the alloy exhibits relatively good mechanical properties (Briol, 2010; Mueller et al. 2016). The alloy has exceptional corrosion resistance and very good machining and welding properties (Julis et al., 2011; Pereira et al., 2020; Salomon et al., 2017). For this reason, the alloy is used in automotive, architectural, aerospace (Brungs, 1997; Cavaliera et al., 2004), food and chemical industries, mechanical engineering and in shipbuilding and moulds and models (Chokkalingam et al., 2017; Pysz et al., 2014).

2.2. Research methodology

The volume-driven orientation of the economy has resulted in a concomitant high material, labour and energy intensity, resulting in increased technology development. This mainly concerns highly processed aluminium alloy products. The level of technological capabilities influences the company's position on the market. When building a stable competitive position, it is important to identify the relationship between the characteristics of the technology used and the company's market position.

The study uses a 3x3 matrix, which presents the correlation that occurs between technological capabilities (X axis) and the company's market position (Y axis). A 9-point Parker scale was used, with indications of 1-3 weak, 4-6 medium, 7-9 strong impact on technological capabilities and market position (Konstanciak, 2021). The matrix is divided into 9 areas, which indicate the technological position of the analysed company. This makes it easier to indicate future technology development activities and define a development strategy. Enterprises should strive to achieve the field numbered 1 - "Focus on the revealed Chance", i.e. the field whose component values achieve high parameters. A field marked with this number indicates a very good market position and significant technological opportunities (Borkowski et al., 2014; Borkowski et al., 2021).

The first stage of the study consisted in identifying two groups of factors: those reflecting technological capabilities and factors influencing market position, i.e. factors that represent the functioning of the company. Factors that do not fit into either of the identified groups were not included in the study. The factors were assessed on a 9-point scale. In the next step, the average value for both categories of factors was calculated. The values obtained were placed in a 3x3 matrix in order to determine the technological position of the company and identify the factors that influenced it.

3. Analysis

The listed factors determining the technological capabilities and market position of the foundry company, as well as their evaluations, are presented in Table 2. 13 characteristics of the company influencing the evaluation of the technological level and 13 characteristics determining the market position were distinguished.

Table 2. List of highlighted factors

No	Factors indicative of technological capabilities	Evaluation	Factors indicative of market position	Evaluation
1.	Availability of information on good foundry practices	6	Location	6
2.	Motivation system	4	Regular customers	7
3.	Modern means of transport	7	Competition	2
4.	Ability to transport large parts	7	New markets	4
5.	Extensive network of distribution channels	6	Exports	5
6.	Flexibility in production	8	Unemployment	6
7.	Technical equipment	6	Company image	7
8.	Machinery park	6	Demand for products	7
9.	Production technology	6	Product prices	8
10.	Accessibility of services on the Internet	8	Labour costs	5
11.	High quality of manufactured products	5	Charges	7
12.	Qualified personnel	7	Marketing and advertising	4
13.	Implemented management systems	7	Customer service	8
Average value		6.38	Average value	5.85

Based on the data in Table 1, a 3x3 matrix was developed (Fig. 2). The average values of the assessed factors indicate that the studied foundry company is located in the field number 2 - "improvement of marketing".

Fig. 2. A general treatment of the 3x3 matrix for the foundry company under study

The factors determining the technological level of the enterprise reached an average value of 6.38, while its position on the market reached 5.85 (Fig. 2). The achieved position indicates that the examined enterprise should pay more attention to improving the factors related to its position on the market.

In order to better understand the distribution of the analysed enterprise characteristics, a map of the number of assessments was drawn up against a 3x3 matrix (Fig. 3a). It can be seen that the distribution of assessments is not even. The pairs of assessments are concentrated at the junction of areas 8 and 9.

From a substantive point of view, it is advisable to draw up a graphical representation of the data in the form of an axis-radar diagram to complement the interpretation of the data (Fig. 3b). Based on the characteristics of the 3x3 matrix (Fig. 1), the analysis of Figure 3b clearly shows that five pairs of factors are located in area 8, while areas: 4, 5, 6 and 7 do not contain pair ratings.

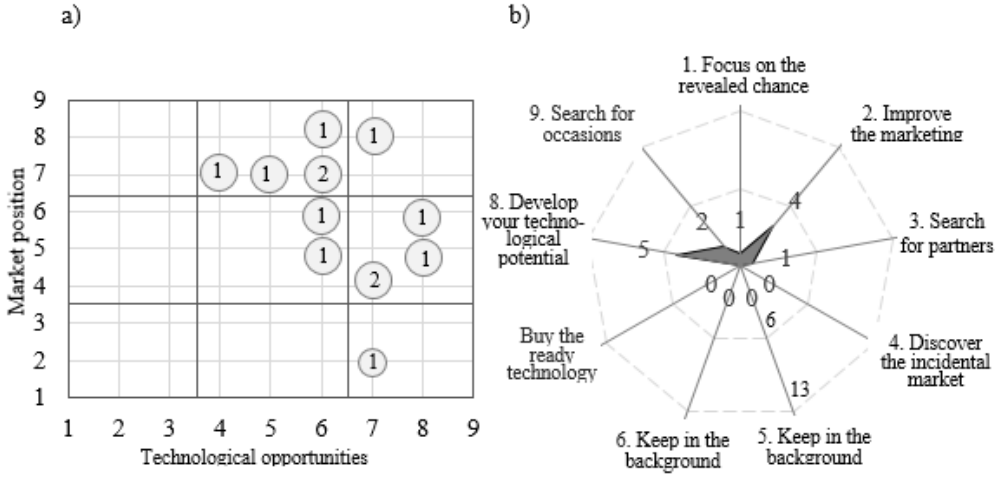

Fig. 3. Presentation of test results a) map of evaluations b) radar chart

Among the features determining the technological capabilities in the context of manufacturing the product - aluminium gearboxes, special attention should be paid to the flexibility of production, which is an important factor in the casting industry and the area under analysis. In the company, castings are often made to order, according to customer needs, hence the high rating. Another factor rated at level 8 was the availability of services on the internet. This factor plays an important role due to its ability to showcase a wide range of products in offer and to reach a wide range of customers from different industries. 4 factors received a score of 7, which also indicates their strong influence on technological capabilities. This group included a factor indicating: modern means of transport, the ability to transport bulky parts, qualified personnel and the implemented management systems. Modern means of transport enable timely transport of products meeting individual customer requirements, often with

large and unusual dimensions. In addition to periodic training, the company provides additional training in quality assurance. The company's employees are mainly people with long working experience in the foundry industry, most of them well educated. The research company has implemented in a quality management system and industry standardised systems appropriate to the product range offered, which has a positive impact on the quality of processes and products.

It should be noted that among the factors determining the technological level of the analysed product (gearbox) in the enterprise, the motivation system was rated the lowest. With regard to the evaluations of technological equipment and machinery park, it can be concluded that despite a modern machinery park operating without major breakdowns and with significant efficiency, the employees do not make full use of the technological potential through an inadequate level of motivation.

Among the factors determining the market position, the factors relating to: product price and customer service deserve special attention. It should be remembered that in Poland there are many companies involved in the foundry industry, so from the company's perspective, the indicated factors are an important issue. The company has signed long-term contracts with several customers, which makes it possible to realise production also in times of lower demand.

The study also identified factors that negatively affect the company's position on the market. These are definitely competition, but also the issue of marketing and advertising, as well as new markets. In Poland, and in particular in the analysed region - the south-eastern part of Poland, there are many foundry companies offering aluminium alloy products for many industries. So far, there is no separate marketing department in the company under analysis. No advertising campaigns are conducted, only the information about products and services appears in trade magazines, which certainly influences a limited number of sales markets and the limited possibility of entering new markets.

It is worth noting that many of the factors influencing market position and the level of technological capabilities are internal. The company should undertake improvement actions in the identified, critical areas so that the result of the evaluation of the analysed factors could prove the achievement of a stable and satisfactory position on the foundry market. The action to be taken first is the creation of a marketing and advertising department and the development of a new incentive system.

Due to the dynamically changing environment and the constant increase in requirements for structures and construction materials, the issue addressed in the study is topical. The method presented in the study can be used to analyse the positioning of manufacturing and service companies in various sectors in order to select an appropriate development strategy.

4. Conclusions

The technology used by individual foundry companies determines the quality of the finished products. It also influences the level of customer satisfaction. On the other hand, the position on the market largely depends on the broadly understood market competitiveness. Therefore, it is important to determine an appropriate strategy that will determine the further development of the company. The research carried out and the analysis of the results contributed to the achievement of the objective of the study, which was to specify the current position of the foundry enterprise, taking into account the aluminium gearbox casting, in the context of technological capabilities and market position, as well as to identify critical factors and, finally, to indicate the conditions for its strengthening. It is important to take appropriate action in relation to the identified position in the 3x3 matrix.

The company's position has been identified as 'improving marketing' (box 2 within the 3x3 matrix). Flexibility in production and availability of online services, as well as the availability of modern means of transport, the ability to transport large parts, qualified staff and implemented management systems were found to be key determinants of technological performance in the analysed company. On the other hand, factors with a strong impact on market position were product prices and customer service. The analysis shows that many of the factors influencing market position and the level of technological capabilities are internal to the foundry company. The company should undertake improvement actions in the identified, critical areas so that the result of the evaluation of the analysed factors could prove the achievement of a stable and satisfactory position on the foundry market.

The method presented in the study may be useful for analysing the position of production and service enterprises from various branches in order to select an adequate development strategy. Further research directions will concern the analysis of the position of a selected aluminium alloy casting product manufactured in the analysed company.

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Analiza Pozycji Technologicznej w Odniesieniu do Produkcji Odlewów Aluminiowych

Streszczenie

Dynamicznie rozwijający się rynek produkcyjny, a w szczególności przemysłu metalurgicznego, wymusza stałe doskonalenie poziomu efektywności produkcji, jakości wyrobów, co wpływa na pozycję przedsiębiorstwa na rynku oraz na poziom jego konkurencyjności. Z tego względu celem opracowania było określenie aktualnej pozycji przedsiębiorstwa odlewniczego biorąc pod uwagę aluminiowy odlew skrzyni biegów, w kontekście możliwości technologicznych i pozycji na rynku, a także identyfikacja newralgicznych czynników i finalnie wskazanie warunków jej umocnienia. W badaniu wykorzystano macierz 3x3. Badane przedsiębiorstwo w kontekście wytwarzania analizowanego wyrobu zlokalizowane jest w obszarze „poprawa marketingu". Lokalizacja ta świadczy o konieczności podjęcia działań związanych z utworzeniem działu marketingu i rozwoju oraz konieczności lepszego wykorzystania zidentyfikowanego potencjału technologicznego przedsiębiorstwa. Przedstawiona w opracowaniu metoda może być przydatna do analizy pozycji przedsiębiorstw produkcyjnych oraz usługowych z różnych branż, celem obrania adekwatnej strategii rozwojowej.

Słowa kluczowe: przemysł metalurgiczny, budowa maszyn, zarządzanie jakością, macierz 3x3, odlew aluminiowy