ZH. ROMAZANOV, O. SILAYEVA, M. TATIEVA,
M. LATYPOVA, A. PETROVSKAYA

ISSN 0543-5846
METABK 62(1) 103-106 (2023)
UDC – UDK 621.746:621.74.04:658.92.14:338.314=111

THE FEASIBILITY STUDY FOR THE CREATION OF PRODUCTION BASED ON TECHNOLOGY OF LOST-FOAM CASTING

Received – Primljeno: 2022-06-09
Accepted – Prihvaćeno: 2022-08-20
Preliminary Note – Prethodno priopćenje

The problems of establishing a new foundry in Kazakhstan utilizing Lost-foam casting technology are discussed in this article. The study's main objectives are to determine the technical and financial viability of arranging such production in the country. Calculations of the manufacturing program were carried out as part of the study, and a financial-economic model of the project was developed. The research shows that establishing such a foundry is feasible, and the project may be recommended for execution.

Keywords: foundry, lost-foam casting, investments, technology, financial modeling.

INTRODUCTION

Castings have a high design precision and practical correspondence to the shapes of the parts. The total energy intensity of billet casting is half that of other technologies. Cast products have relatively low production costs. Foundry production retains leadership among similar industries in the automotive, oil and gas, nuclear industries, as well as in hydraulic engineering, mechanical engineering, pump engineering and etc.

In Kazakhstan, foundry shops were created at the plants of medium machine building and the mining and metallurgical complex. The absence of market mechanisms for the development of the industry did not contribute to the implementation of new technologies with higher labor efficiency, and also did not allow obtaining high-quality castings and reducing costs. Therefore, in recent years, the foundry business has become attractive for investment.

Today, there are 15 foundries in the country [1], of which only 3 have switched to new casting technologies, whereas the rest are still using outdated sand casting technology. Due to the low quality of manufactured foundry products, Kazakhstan imports up to 90 % of its needs from abroad [2]. Regarding the volume of consumption of teeth and crowns for the teeth of excavator buckets, the demand of the country's mining enterprises is estimated at no less than 2-2,5 thousand tons per year or 13-15 million US dollars.

In Kazakhstan, cast iron castings for mechanical engineering account for a small proportion of the total volume of cast blanks compared, for example, with Russia and EU countries. At the same time, the production of cast iron balls, single, small- and medium-scale steel casting dominates in the industry [3].

The volumes of metal casting in Kazakhstan in 2016-2020 are shown in Table 1 [3-4]. Hence, despite the crisis -triggered by the pandemic, there has been a 2,0 times increase in the volume of casting by a cost from 18,7 to 37,9 million US dollars, in physical terms – a 1,2 times increase from 42,7 to 49,4 thousand tons.

Table 1 **Metal casting in Kazakhstan**

Indicator	2016	2018	2020
Metal casting / mln USD	18,7	33,7	37,9
Iron casting / tons	19 211	32 646	21 462
Steel casting / tons	23 181	35 982	27 385
Non-ferrous metals/ tons	326	1 308	573
Metal casting, total / tons	42 718	69 936	49 420

At present, there is a need in Kazakhstan to create efficient foundries aimed at producing high-quality shaped casting for mining, machine engineering, railway and other industries. The creation of a foundry based on advanced methods of smelting and processing of cast iron and steel using the LFC (Lost Foam Cast) technology is characterized by low costs, high product quality and allows the manufacturer to have a profitable business. The article by V. Doroshenko [5] indicates that the share of LFC technology makes up about 1,5 % of the global production of foundry products.

TECHNOLOGICAL ADVANTAGES OF THE PROPOSED PROJECT

Lost-foam casting (LFC) is the process of producing cast products using models made of expanded polystyrene, vacuum flasks and unbound quartz sand. When

Zh. Romazanov, O. Silayeva, M. Tatieva, M. Latypova, A. Petrovskaya, Department of Economics and Business, Karaganda Industrial University, Temirtau, 101400, Republic of Kazakhstan.
Corresponding author: rzhanat@mail.ru

filling the flask, the expanded polystyrene models are gasified by the heat from the liquid metal, and the empty space formed is filled with a hot alloy. The creation of a solid frame in the process of vacuuming sand allows the manufacturer to maintain the shape of the model and ensure high quality of the casting surface. After the metal cools down, removing the vacuum leads to softening of the molding material and eliminates the appearance of shrinkage defects in castings.

Lost-foam casting technology is used for the production of conventional and wear-resistant cast iron grades, any steel grades (from carbon to high-alloy, heat-resistant, ovenproof alloys), foundry bronzes, brasses and siluanes. Using this method facilitates manufacturing castings of different weights (from several grams to several tons) with a surface purity of Rz40 and dimensional accuracy up to Class 7 according to GOST 26645-85 [6].

In the work of O. Shinsky [7] it is stated that in LFC technology the use of molding materials, rods and their mixtures, conventional sets of models and metal molds is not necessary. The exclusion of the process of manual assembly of sand and metal molds and its elements leads to an increase in the dimensional accuracy of castings to the level of Class 7-9, and up to 12,5-25,0 microns in the surface roughness. This simplifies casting processing operations (by 70-80 %), increases the yield of usable (up to 85-95 %) and reduces the consumption of metal, electricity and charge materials.

In the work of V. Shulyak [8], a foundry with the Lost-foam casting technology involves technological operations such as:

- production of models from expanded polystyrene;
- creation of model blocks coated with non-stick painting;
- molding of model blocks into flasks on a vibrating table;
- feeding of flasks to the filling area;
- pouring metal into flasks under vacuum;
- cooling, cutting, stripping castings;
- heat treatment.

The LFC casting shop differs from foundries using sand molds by its structure, technological process and equipment, material and energy supply, specialization and the number of staff.

The main alternative technologies for the production of large and medium-sized castings are sand-clay molds (SCM), vacuum-film molding (VFM, V-process), casting in cold-hardening mixtures (CHM) and lost-foam casting (LFC).

The technical advantages of the LFC [9] in comparison with analogues include such as follows:

- the use of relatively simple and cheap equipment;
- the reduction of consumables costs (sand consumption – 0,5-1 %), which significantly reduces the removal of industrial waste to landfills;

Table 2 **Comparison of quality indicators of different casting methods / %**

Production method	Cost of tooling	Casting metal density	Tooling durability	Surface roughness
SCM	38	81	38	100
Pressure die casting	88	88	12	82
LFC	82	100	100	42
Injection molding	100	35	18	30

- a 10-20 % reduction in the consumption of alloys for casting due to the reduction in profits and allowances;
- the reduction of costs for thermal and mechanical processing of castings (due to the reduction of gate systems and casting allowances), while the machining time is reduced by almost 30-40 %;
- achieving higher accuracy in flatness, in facets and geometric dimensions of castings, which guarantees smaller allowances for machining and accurate production of markings and shapes;
- obtaining a high-quality surface of castings, when the surface roughness of steel castings can reach up to 100 microns, for other castings - RZ-70 and more;
- a 2-5 % decrease in the number of deficiencies;
- the reduction of the number of production operations and equipment for the final processing of castings;
- the increase of the level and complexity of automation of technological processes;
- reduction of the shop area by 3-4 times due to the exclusion of the equipment of the core, molding and mixing areas;
- reduction of qualification requirements for main and auxiliary production personnel;
- the increase in the environmental friendliness of production, due to the reduction of pollution of the production areas of the foundry, as well as the reduction of waste of the foundry mixture. In turn, working conditions are improving.

According to V. Shulyak [8], the economic advantages of the LFC process include such as follows:

- the increase of 68-87 % of the yield of suitable castings;
- the reduction of the mass of castings by 10-20 %;
- reduction of ferroalloys and charge materials consumption by 15-25 %;
- the 30-90 % reduction in the consumption of molding materials and rods;
- the 80-90 % reduction in labor costs at the molding site;
- the reduction in single production by 10-20 % and in serial production by 40-60 % of labor costs in finishing operations.

The LFC technology leads to a significant reduction in machining costs during the manufacture of complex castings made of wear-resistant steels (teeth, armor crushers and parts of excavator tracks). In addition, investments in fixed assets when creating LFC production are 2-2,5 times less as compared to sand casting.

Y. Stepanova [10] in her work provides a comparison of the quality indicators of 4 casting technologies in mass production based on the analysis of data from various manufacturers of the American company called “Robinson Foundry” (Table 2).

DETERMINATION OF THE PRODUCT RANGE FOR THE PROJECT

The LFC method is used for manufacturing of different grades of cast iron and steel castings. It is possible to identify the most suitable brands in order to launch the production in Kazakhstan. Primarily, those, which are in great demand, standardized and well established in the market.

Low-alloy, low– and medium-carbon steels. These include steels for casting of machine parts, which are subject to the requirements of increased strength and high wear resistance, and able to operate under the influence of static and dynamic loads. They are primarily used for the manufacture of wheelgears, gears, rollers, etc. The LFC technology makes it possible to reduce the consumption of liquid metal and minimizes the surface treatment of the end castings, and, in some cases, allows the manufacturer to obtain castings that do not require additional processing.

High-alloy steels, including 110G13L (Gadfield steel). Gadfield steel has a high wear resistance when exposed to high pressures or shock loads at the same time. The peculiarity of this steel is that it is strongly riveted (hardened under shock loads) up to HB 600 [11]. It is widely used in machine parts, mainly in the mining industry, which are subject to shock loads and abrasion. It is used for the manufacture of excavator tracks, bucket teeth, ladles, etc. Castings are usually not subject to additional processing, as they are difficult to be proccessed by cutting. The use of the LFC technology makes it possible to obtain castings that do not require additional processing, which is impossible when casting into sand-clay molds. This enables the manufacturer to significantly expand the assortment list of the enterprise in terms of casting from 110G13L.

Grey and high-alloyed white cast iron and inter-eutectoid alloys. Alloyed cast iron is 5 times more durable than carbon steel, and 110G13L steel is 2 times more durable and is used for manufacturing parts, able to operate under conditions of abrasive wear at medium impact loads [12]. They are mainly used for lining mills and crushers. Casting of these alloys into sand-clay molds is associated with serious technological difficulties, especially for castings of complex shapes. As a result, the market has set a high price for products made of this material. Technological limitations are removed by the use of the LFC technology. At a cost comparable to 110G13L, this gives a large profit per unit of a product made of high-alloy cast iron.

Within the framework of the project, it is proposed to organize the production of castings and cast products from low- and high-alloy, low- and medium-carbon steels (grades ST35, ST45, ST55, ST80GSL, ST 110G13L), as well as from gray and high-alloy white cast iron (grades ICH300H18G3, SCH15) and between eutectoid alloys.

THE ASSESSMENT OF ECONOMIC EFFICIENCY OF THE PROJECT

The organization of such a foundry requires attracting investments in the amount of 8,8 million US dollars (Table 3), which will be both of a capital nature (84,3 %) and used to ensure the company’s activities with working capital (15,7 %).

Based on the results of comparisons of alternative options, it is proposed to place the project in the special economic zone “Saryarka” (Karaganda region).

Table 3 **Investment plan of the project**

Name	Cost / $
Design and pre-design work	190 400
Construction and installation works	3 156 720
Equipment installation and supply, including:	1 623 985
technological equipment	891 418
auxiliary equipment, snap-in and inventory	732 567
Trial operation and attainment of projected capacity	3 808 000
TOTAL investments	8 779 105

The planned capacity of the proposed production involves the production of 9 955,4 tons per year of foundry products (Table 4), including steel (7 167,9 tons) and iron (2 787,5 tons) casting. The annual production volume will amount to 9,2 million US dollars when reaching the planned capacity.

Table 4 **Production program / t**

Type of casting	Year 1	Year 2	Year 3
ST 35	1 493,3	1 702,4	995,5
80 GSL	1 493,3	1 702,4	995,5
110G13L	2 210,1	4 031,9	5 176,8
ICH	465,9	913,9	1 672,5
SC15, 25	310,6	609,3	1 115,0
Total	5 973,2	8 959,8	9 955,4

The company’s staffing requirements - 100 people.

The cumulative net present value (NPV) for a 5-year period will account for about 1 million US dollars and is sufficient to fully cover discounted investments. The discounted internal rate of return (IRR) is 18,9 %. The simple payback period (PBP) of the project is 4,4 years, and the discounted payback period (DPBP) is 5,6 years.

The net income for the project is formed from the first year (the time of production launch) in the amount of 0,6 million US dollars and will amount to 33,6 million US dollars at the end of the 5-year period (Table 5). The profitability of production is expected to average 30 %.

Table 5 **Profit and loss statement for the project / mln USD**

Indicators \ Year	1	2	3	4	5
Sales revenue	8,5	14,2	17,7	18,6	19,6
Cost of production	6,1	9,4	11,5	12,0	12,6
Gross income	2,4	4,8	6,3	6,6	6,9
Expenses of the period	0,2	0,3	0,3	0,3	0,3
Commercial expenses	0,0	0,0	0,0	0,0	0,0
General and administrative expenses	0,2	0,3	0,3	0,3	0,3
Amortization	0,7	0,6	0,5	0,4	0,3
Profit before % and taxes	1,5	4,0	5,5	5,9	6,3
Payments of % on the loan	0,9	0,7	0,4	0,1	-
Profit before taxes	0,6	3,3	5,1	5,7	6,3
Corporate income tax	-	-0,5	-1,0	-1,1	-1,3
Transfer of losses of previous years	-0,6	-	-	-	-
Net profit / EBIT	0,6	2,8	4,1	4,6	5,0

CONCLUSION

The study's findings reveal the country's underdeveloped foundry business and the existence of substantial demand for its goods. The most common foundry goods have been determined in order to the project's objectives.

In compared to similar casting procedures, Lost-foam casting is considered to be the most contemporary and offers a number of technical and economic advantages.

In general, the project is cost-effective and may be recommended for implementation based on the findings of the suggested financial model.

REFERENCES

[1] Statistical business register according to the code GSTEA 245 «Casting of metals» 2021. Portal of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. https://stat.gov.kz/jur-search/ filter.

[2] Statistics of foreign and mutual trade of the Republic of Kazakhstan for 2016-2020. Portal of the State Revenue Committee of the Ministry of Finance of the Republic of Kazakhstan. https://kgd.gov.kz/ru/exp_trade_files.

[3] Industry of the Republic of Kazakhstan for 2016-2020. Statistical collection. Nur-Sultan, 2021, 169.

[4] The main indicators of the work of the Kazakhstani industry. Operational data for 2016-2020. Portal of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. https://stat.gov.kz/official/industry/151/statistic/7.

[5] V. Doroshenko. Metal casting by foam models (2007). Portal RB.RU. https://rb.ru/article/lite-metalla-po-penomodelyam/4857027.html.

[6] GOST 26645-85. Castings of metals and alloys. Dimensional tolerances, weights and machining allowances. Moscow. PPC Publishing House of Standards (2004).

[7] O. Shinskiy et al. Economics, ecology, organization of lost-foam casting production. Foundry production 4 (2017), 53-59.

[8] V. Shulyak. Lost-foam casting, St. Petersburg, SLA «Professional» 2007, 55.

[9] Lost-foam casting (2020). Armatool Portal. https://armatool.ru/lite-po-gazificiruemym-modelam-tehnologia-preimusestva/.

[10] Y. Stepanov et al. Lost-foam casting: Fundamentals of theory and technology, Moscow, Mechanical Engineering, 1976.

[11] GOST 21357-87. Castings made of cold-resistant and wear-resistant steel. Portal of the electronic fund of legal and regulatory documents. https://docs.cntd.ru/document/1200011544.

[12] GOST 1412-85. Cast iron with plate graphite used for castings. Stamps, Moscow, PPC Publishing House of Standards (2004).

Note: The responsible for English language is Dana Rahimbekova, Kazakhstan.