UDC 351.82:504
DOI: 10.31339/2313-8114-2020-1(13)-80-85

# Features of Determining the Economic Effect of Using Advanced Technologies in Casting

Yurii Yu. Zhyhuts[1*], Vasyl F. Lazar[2], Bohdan Ya. Khomiak[2]

*[1]Uzhhorod National University*
*88000, 3 Narodna Sq., Uzhhorod, Ukraine*

*[2]Mukachevo State University*
*89600, 26 Uzhhorodska Str., Mukachevo, Ukraine*

*(Received: 20.01.2020, Revised: 22.02.2020, Accepted: 25.03.2020)*

*[*]Corresponding author*

**Abstract.** One of the most important indicators for evaluating the innovation activity of enterprises is the economic effect of introducing advanced technology into production. Each type of production has its own characteristics, which are manifested not only in the organisation of the technological process but also in calculations related to the establishment of economic indicators of the feasibility of using new technologies. Evidently, casting and special casting technologies, such as the use of thermite foundry applications of the high-temperature gradient to save the alloy poured into the mould, influence the algorithm for determining the economic effect. This is caused primarily not only by the establishment of direct costs when transforming the standard technological process, namely, the cost of the metal-thermal mixture, changing the mould, ferroalloys, the use of light-separating foundry additives plates, but also by the possibility to re-use remnants of the foundry application, gate, sprue base, etc. elements for remelting. The purpose of the study is to establish the specific features of calculating the economic effect of the introduction of advanced technologies in production, such as technologies associated with the reduction of foundry applications. Statistical methods, namely the quantitative analysis, comparison, and grouping methods were used to conduct research and process the results. Comparison of economic indicators with the actual quantitative characteristics of industrial technology through Integrated evaluation allowed analysing the results and drawing conclusions for the study. The main results of the study are determined by the proposed methodology for determining the economic effect, which, unlike the existing one, considers renewable resources and the possibility of obtaining an environmental effect. This allows using the renewable resources obtained from industrial waste in a reasonable and rational way and contributing to environmental protection. The areas of further research are primarily related to the identification and evaluation of technical and economic indicators of casting-related technologies, namely the production of ferroalloys, foundry production, non-ferrous metallurgy technologies, etc. In the future, this will allow establishing conditions for the most effective use of innovative technologies and obtaining the maximum economic effect from their introduction

**Keywords**: economic effect, advanced technology, environmental effect, renewable resources, direct costs, production organisation, technical and economic indicators

## The Problem Statement

The transition of the Ukrainian economy to a new stage of technological advance requires an active position in terms of innovation and a fundamentally new approach to innovation. Innovation becomes the main factor in theoretical and practical projects implemented by modern technological programmes. The fundamental increase in the value of innovations is also caused by changes in the global market.

The elements of any research are technical and economic calculations and the development of an optimal plan

**Suggested Citation:**
Zhyhuts, Yu.Yu., Lazar, V.F., & Khomiak, B.Ya. (2020). Features of determining the economic effect of using advanced technologies in casting. *Scientific Bulletin of Mukachevo State University. Series "Economics"*, 7(1), 80-85.

for its implementation, thus, before the introduction of new technological processes, it is necessary to set a task to evaluate all aspects of the technical efficiency of the new technology, to establish the economic effect (if possible), or to calculate the expected economic effect of the new technology, to evaluate the environmental, social, or other related effects, and to compile a plan for the implementation of research, which is based on network planning and management methods or methods of economic and mathematical optimisation.

The first stage of research is the development of a technical and economic solution to the problem. Such a technical and economic problem at the Dnipro mill roll plant was determining the efficiency of introducing the technology in the casting for large export mill rolls, namely, the possibility of using the technology of thermite foundry applications of the high-temperature gradient.

## Analysis of Recent Research and Publications

The most common methods for establishing the expected economic effect are methods for evaluating the effect of purchasing a new product by the consumer; rational use of material, labour and financial resources; economic incentives for the production of competitive products; economic efficiency of management and marketing techniques; economic efficiency of costs for creating and implementing information, logistics and other technologies for accounting, control, and audit [1-5]. Studies for which not only the forms are established, but also the place of their application are of particular importance [6-11].

The introduction of new technologies in ferrous, non-ferrous, special metallurgy, related industries (casting, ferroalloy production, etc. [10]) and the determination of the expected economic effect have a number of features that have not yet been thoroughly studied.

## Purpose of the Study

The above posed a problem for the authors to solve which it is necessary to establish a method for determining the economic effect of the introduction of casting technology for large castings using thermite foundry applications of the high-temperature gradient.

## Research Results

The authors previously performed work that confirmed the possibility of using the technology of termite foundry applications based on experimental melts for rolls weighing 5.46 and 6.67 tonnes. Experimental rolls of 580x1800 mm of export design were filled with liquid cast iron СШХН-42 by the siphon method. Three exothermic bags weighing 5 kg each were placed on the surface of the melt in the area of the foundry application. The batch filling of the exothermic charge, in addition to increasing the duration of the charge burning, reduced the heat loss of the thermite metal. In the composition of the charge, fluorspar CaF2 was additionally introduced, which reduced the ignition temperature of the mixture and increased the fluidity of aluminous slag [10]. Exothermic charge, which consisted of 80% thermite mixture, 5.5% carbon (in the form of ГЛ1 black graphite), 11% of ЖКМК-1 ligature (contains 5% Mg) with granules of 3-6 mm, 3.5% of ferrosilicon (FS75), synthesised a highly superheated melt of similar composition, poured into the mould. The weight of the charge was calculated using special methods [10] and it ranged from 20.5 to 27.6 kg. Loading of packages with metal-thermal charge on the melt surface was performed sequentially three times with an interval of 1.5 minutes.

The analysis of the studied rolls conducted by the authors showed the sufficiency of heating the foundry application with a directed heat dissipation and feeding with liquid thermite alloy casting. No bleach was detected in the microstructure of the surface of the cast iron roll. In all the experimental melts described above, the foundry application was not refilled with cast iron by 1/3. Metal savings on foundry additives amounted to ~ 33%. An incision of the foundry application showed that the shrinkage sink penetrated only 1/2 of its height. Further mechanical treatment did not detect shrinkage defects for the roll necks. Chemical analysis showed the chemical composition of the casting defect of the roll body and application within the technical tolerance. This offers considerable prospects for saving metal when casting heavy shafts. During the industrial tests, the method of calculating the amount of charge introduced into the roll casting application was developed. This allowed creating the basis for the technology of risering cast iron rolls using a metal-thermal charge.

### *Development of a method for calculating the charge for risering cast iron castings*

The main technological parameter of termite foundry applications is the mass of the metal-thermal charge in the insulation for risering. Since termite applications are used instead of conventional ones, their calculation is based on mass data from conventional applications. The method for calculating termite applications is given in [10]. However, this technique does not allow considering the specific features of the casting technology of mill rolls, which consists in the fact that the application is formed in several technological techniques. They consist of filling an additional part of the mould with liquid melt and then periodically adding metal to the mould application during the casting hardening process. These technological methods of forming the application lead to the fact that the hardening time of the casting increases in comparison with the hardening time of the application of the same mass formed in one step when pouring the form. To use the mass of a conventional application, which is set through its linear dimensions according to the roll casting drawing and the alloy density as the base for calculating the amount of metal-thermal charge, the effective application mass was introduced – $m_{ef}$. $m_{ef}$ is the mass of an application formed in one step. Furthermore, the hardening time of $m_{ef}$ is introduced, which is equal to the hardening time of the application with mass $m_{add}$, formed in several steps (1).

$$m=c\ m_{add} \tag{1}$$

where $c$ – coefficient that depends on the amount, value, and time of refilling.

The casting time of the roll casting mould does not exceed several minutes, and the temperature of the cast alloy is 1250-1300°C, which slightly exceeds the temperature of the beginning of the crystallisation of roll cast iron. These circumstances allow not considering the time of filling and the time of removing the heat of superheat. Thus, the effective mass depending on the cooling time of the application in a sand-clay mould formed in one step to the temperature within the crystallisation temperature range can be found from the dependence (2):

$$m_{ef} = 1.37\left(1+\beta\frac{n}{D^2}\right)\rho D^3 \qquad (2)$$

According to the existing technology of manufacturing mill rolls, part of the application (on average, 25% of the application in length) falls on the length required for clamping the roll during its processing on roller machines and on casting defects on the surface of the application.

Thus, the application of mill roll casting can be reduced by an average of 75% by weight, provided that it is compensated by a metal-thermal charge. To ensure a margin of reliability, it is recommended, according to the results of experiments, to reduce the usual application by 70% by weight. It has been shown that 1 kg of metal-thermal charge is equivalent in its thermal effect to 20 kg of a liquid alloy. Then the amount of metal-thermal charge $m_c$ required to replace 70% of the mass of a conventional roll application with a termite application (3):

$$m=0.04\, m_{ef} \qquad (3)$$

The ratio (3) was found for the case when the metal-thermal charge was introduced into the mould in one batch. From relation (2), it can be concluded that the introduction of the charge in particles with a certain interval between layings increases the hardening time at the same charge mass or reduces the total mass of the metal-thermal charge if the same application hardening time is maintained. It has been experimentally established that the introduction of a charge in 2-4 batches reduces the weight of the charge by 10-20%. The interval between layings is determined by the time a crust forms on the application's surface. The mass of the charge is determined by the formula (4):

$$m_c=0.04\, c'm_{ef} \qquad (4)$$

where $c'$ depends on the charge tab conditions.

The coefficient value $c'$ depends on the number of layings (from 1 to 4) and is in the range $(3.2\text{-}4.0)\cdot 10^2$.

The ratios (3) and (4) were used to calculate the amount of metal-thermal charge required to reduce the weight of the roll application by 75% [12].

For applications up to ∅300 mm, the number of refills ($n$) – 1, for application of ∅350–450 mm – 2, and for the application of ∅450 mm or more – 3. In the future, the obtained calculation results were tested on large industrial rolls.

### *Technical and economic efficiency of the work performed*

The calculation of the expected economic effect from the introduction of the technology of manufacturing cast iron mill rolls using termite foundry applications was performed using a statistical method, namely the quantitative analysis and comparison and grouping with equivalent methods for similar technological processes, which clearly showed that the problem under study is typical for ferrous and non-ferrous metallurgy. Furthermore, the comparison of economic indicators with the actual quantitative characteristics of industrial technology through integrated evaluation allowed analysing the results and drawing conclusions for the study according to the Dnipro mill roll plant.

The introduction of the new technology ensures: reduction of alloy used on roll casting application by at least 30%; reduction of welding costs of shrinkage defects of the upper necks of the rolls; elimination of charcoal costs; release of the topping bucket; elimination of defects of rolls due to end shrinkage defects. The calculation was performed in accordance with the requirements of the temporary technological instructions developed by the authors.

As a basis for comparison, when determining the annual economic effect of the introduction of technology for the production of castings with termite applications, indicators of the technology of insulation and risering of castings that are being replaced are taken. The calculation was performed (1) tonne of cast rolls using the formula (5):

$$E = (I_1 - I_2) \times A - E_s \times C_{add} \qquad (5)$$

where $I_1 - I_2$– initial costs for the main measured elements of the cost of rolls. $C_{add}$ – additional capital funds for the introduction of new technology (6):

$$C_{add} = C_2 - C_1 \qquad (6)$$

where $C_1$ – capital costs before the introduction of new technology; $C_2$ – capital costs for the introduction of new technology; $E_s$ – standard coefficient of efficiency of capital investments; $E_s = 0.3$.

Capital costs before the introduction of a new technology $C_1$ are equal to the cost of a bucket for refilling applications in the amount of 9800 UAH. Capital costs for the introduction of a new technology consist of pre-production costs $C_2$ = 100000 UAH.

The change in initial production costs is calculated as follows. Prior to the introduction of termite application technology, the application weight per 1 tonne of cast rolls averaged 0.166 tonnes. The introduction of the new technology allows reducing the weight of the application by at least 30%, that is, the application is 0.105 tonnes. Savings from reducing the application weight per 1 tonne of rolls are:

$$C_{w.a.}=0.166\times 0.3\times(2233.00-376.00)=92.48 \text{ UAH}$$

where 2233.00 – the cost of 1 tonne of cast rolls, in accordance with the calculation of the rolling shop; 376.00 – the cost of

1 tonne of applications cut for remelting as scrap metal; 2233.00–376.00 =1857.00 – the cost of 1 tonne of liquid alloy.

From the combustion of a metal-thermal charge, a liquid melt is generated in the application in the amount of 0.5 by the weight of the charge. Since the charge consumption averages 5% of the application weight, the amount of liquid alloy is:

$L$=(0.1666–0.166×0.3)×0.05×0.5=0.003 $t$

Its cost:

$C_l$=0.003×1856.00=5.57 UAH

Eliminating the cost of heating the application with charcoal on each tonne of cast rolls saves 4.00 UAH. According to the calculation of the rolling shop:

$C_{cha}$=4.00 UAH

Termite application technology eliminates roll defects due to shrinkage defects. The defects due to shrinkage at the enterprise in 1 year range from 4% to 6.7% of the mass of defective rolls. Savings by eliminating this type of defect:

$C_d$ = 1856.00 × 0.04 × 0.067 = 4.97 UAH

Elimination of the cost of installing and welding seal is 1.80 UAH for each tonne of cast rolls (according to the calculation of the rolling shop):

$C_3$ = 1.80 UAH

Reducing the weight of the application eliminates the re-remelting operation from the technological cycle, which leads to the burning of the alloy.

This saves:

$C_{cha}$=(0.166+0.095)×1182.00×0.3=95.55 UAH

where 1182.00 UAH – the cost of 1 tonne of charge; 0.095 – the burning of the alloy.

Introduction of the technology of using a metal-thermal charge to risering castings will lead to costs:

$C_{m.\,c.}$=0.166×0.05×2440.00=20.25 UAH

where 2.440.00 UAH is the cost of 1 tonne of metal-thermal charge.

Savings per 1 tonne of cast rolls in terms of flow costs will be:

$$C_1 - C_2 = E_{w.a.} + C_l + C_{bur} + C_d + C_c + C_{cha} - C_{m.c.} = 92.48 + 5.57 + 4.00 + 4.97 + 1.80 + 95.55 - 20.25 = 184.12 \text{ UAH}$$

With the volume of the introduction of the new technology in the production process of 6080 tonnes of rolls per year, the economic effect will be:

$E$ = 184.12×6080–0.3×(100000–9800)=1092389.61 UAH

### Environmental evaluation of a technological solution

The result of this work was the development of a technological process for risering castings of mill rolls using termite applications. In the technological process, it is proposed to use a metal-thermal charge of the following composition (in % by weight): iron – aluminium termite (iron scale – 74; aluminium powder – 26); graphite – 3 (% by weight of termite); soda ash – 1.5 (% by weight of termite) [13].

All components that constitute the charge are non-toxic and are widely used in the metallurgical and casting industries. During the technological process, aluminium oxidation and iron reduction reactions are performed in the charge in the solid and liquid phases without the generation of gaseous products. Graphite, which is introduced into the charge, dissolves in the resulting liquid steel, while soda ash takes part in slag generation. Thus, the introduction of termite application technology does not lead to additional harmful effects on the environment. In addition, the disposal of mill scale, which is a technological waste of rolling and blacksmithing industries, contributes to solving the problem of environmental pollution. For additional cost savings on the introduction of the proposed technology, the aluminium powder can be used in the form of a grind of purified aluminium chips, and carbon in the form of a grind of unburned graphite electrodes in the manufacture of the melt.

## Conclusions

1. The criteria and sequence of economic justification of new solutions in casting are established.

2. The method of determining the effective mass when using the technology of thermite foundry applications of the high-temperature gradient for large castings is identified.

3. The main components of calculating the expected economic effect from the introduction of new technology for manufacturing cast iron mill rolls using termite applications are determined.

4. The value of the economic effect of the introduction of the new technology was determined, which amounted to 1092389.61 UAH with the production of 6080 tonnes of rolls per year.

5. An environmental evaluation of the technical solution from the introduction of the new technology of thermite foundry applications of the high-temperature gradient for large rolls is performed.

Further research will be aimed primarily at identifying and evaluating technical and economic indicators of casting-related technologies, namely the production of ferroalloys, foundry production, non-ferrous metallurgy technologies, etc. In the future, this will allow establishing conditions for the most effective use of innovative technologies and obtaining the maximum economic effect from their introduction.

## References


[1] Ilminsky, S.A. (2010). Economy efficiency: Criteria and indicators. *Bulletin Orel GIET*, 4(14), 103-107.

[2] Khariv, P.S. (2003). *Innovative activity of the enterprise and economic estimation of innovative processes*. Ternopil: Economic Thought.

[3] Krakhmalov, O.V., Zinchenko, O.I., Krasnokutskyi, V.M., & Razaronov, L.V. (2020). Advanced technologies of foundry production of complex parts. *Bulletin of the National Technical University. Mechanical Engineering and CAD*, 1, 41-48. doi: 10.20998/2079-0775.2020.1.06.

[4] Chereshniuk, O.M. (2014). Evaluation of the effectiveness of innovative activities of industrial enterprises. In V.A. Derii (Eds.), *Economic analysis* (pp. 218-224). Ternopil: Publishing and Printing Center of Ternopil National Economic University "Economic Thought".

[5] Kazantsev, A.K., & Mindeli, L.E. (2004). *Fundamentals of innovation management. Theory and practice*. Moscow: Economics.

[6] Zavlin, P.N., & Vasiliev, A.V. (1998). *Evaluation of the effectiveness of innovation*. St. Petersburg: Business-Press.

[7] Tovt, T.Y. (2010). Methodical approaches to determining the indicators of efficiency of innovative activity of industrial enterprises of Ukraine. *Scientific Bulletin NFTU*, 20(11), 240-249.

[8] Order of Ukraine No. 218/446 "On Approval of the Methodology for Determining the Economic Efficiency of Research and Development Costs and Their Implementation in Production". (2020, February). Retrieved from https://zakon.rada.gov.ua/rada/show/v0218569-01#Text.

[9] Kravtsiv, V.S. (2006). Strategy of rational use of natural resource potential in the region: Environmental priorities. *Bulletin of the National University of Water Management and Environmental Sciences. Economy*, 4(36), 325-330.

[10] Zhiguts, Yu.Yu., & Lazar, V.F. (2014). *Production technologies and features of alloys synthesized by combined processes*. Uzhhorod: Invazor.

[11] Solodkaya, M.S. (1999). Reliability, efficiency, quality of control systems. *Theoretical journal* "*Credo*", 5(17), 30-46.

[12] Innovation management. Comprehensive evaluation of the effectiveness of innovative activities of the enterprise. (n.d.). Rerieved from http://subject.com.ua/economic/innovative/18.html.

[13] Order of the Ministry of Economy and European Integration and the Ministry of Finance of Ukraine "Methods for Determining the Cost-Effectiveness of Research Costs and Development and Their Implementation in Production". (2001, September). Retrieved from http://www1.nas.gov.ua/infrastructures/Legaltexts/Others/me_mf /Pages/218-446.


## Список використаних джерел


[1] Ильминская С.А. Эффективность экономики: критерии и показателию. *Вестник Орел ГИЭТ*. 2010. Т. 14, № 4. С. 103–107.

[2] Харів П.С. Інноваційна діяльність підприємства та економічна оцінка інноваційних процесів. Тернопіль: Економічна думка, 2003. 326 с.

[3] Крахмальов О.В., Зінченко О.І., Краснокутський В.М., Разарьонов Л.В. Прогресивні технології ливарного виробництва складних деталей. *Вісник Національного технічного університету ХПІ. Машинознавство та САПР*. 2020. № 1. С. 41–48. doi:10.20998/2079-0775.2020.1.06.

[4] Черешнюк О.М. Оцінка ефективності інноваційної діяльності промислових підприємств. *Економічний аналіз* / за ред. В.А. Дерій. Тернопіль: Видавничо-поліграфічний центр Тернопільського національного економічного університету «Економічна думка», 2014. С. 218–224.

[5] Казанцев А.К., Миндели Л.Э. Основы инновационного менеджмента. Теория и практика. Москва: Экономика, 2004. 518 с.

[6] Завлин П.Н., Васильев А.В. Оценка эффективности инноваций. Санкт Петербург: Бизнес-Пресса, 1998. 216 с.

[7] Товт Т.Й. Методичні підходи до визначення показників ефективності інноваційної діяльності промислових підприємств України. *Науковий вісник НЛТУ України*. 2010. Т. 11, № 20. С. 240–249.

[8] Про затвердження Методики визначення економічної ефективності витрат на наукові дослідження і розробки та їх впровадження у виробництво: Наказ України від 25.09.2001 р. № 218/446. URL: https://zakon.rada.gov.ua/rada/show/v0218569-01#Text (дата звернення: 17.02.2020).

[9] Кравців В.С. Стратегія раціонального використання природно-ресурсного потенціалу в регіоні: екологічні пріоритети. *Вісник Національного університету водного господарства та природокористування. Економіка*. 2006. Т. 36, № 4. С. 325–330.

[10] Жигуц Ю.Ю., Лазар В.Ф. Технології отримання та особливості сплавів синтезованих комбінованими процесами. Ужгород: Інвазор, 2014. 388 с.

[11] Солодкая М.С. Надежность, эффективность, качество систем управления. *Теоретический журнал «Credo»*. 1999. Т. 17, № 5. С. 30–46.

[12] Інноваційний менеджмент. Комплексне оцінювання ефективності інноваційної діяльності підприємства. URL: http://subject.com.ua/economic/innovative/18.html (дата звернення: 18.02.2020).
[13] Наказ Міністерства економіки та з питань європейської інтеграції та Міністерства фінансів України від 25 вересня 2001 р. № 218/446 «Методика визначення економічної ефективності витрат на наукові дослідження і розробки та їх впровадження у виробництво». URL: http://www1.nas.gov.ua/infrastructures/Legaltexts/Others/me_mf /Pages/218-446 (дата звернення: 17.02.2020)

# Особливості визначення економічного ефекту від використання прогресивних технологій у ливарному виробництві

*Юрій Юрійович Жигуц[1], Василь Федорович Лазар[2], Богдан Ярослававович Хом'як[2]*

*[1]Ужгородський національний університет
88000, пл. Народна, 3, м. Ужгород, Україна*

*[2]Мукачівський державний університет
89600, вул. Ужгородська, 26, м. Мукачево, Україна*

**Анотація**. Одним з найважливіших показників оцінки інноваційної діяльності підприємств є економічний ефект від впровадження прогресивної технології у виробництво. Кожен тип виробництва має свої особливості, які проявляються не тільки у організації технологічного процесу, але і у розрахунках пов'язаних із встановленням економічних показників доцільності застосування нових технологій. Очевидно, що ливарне виробництво, а особливо спеціальні технології лиття, такі, як наприклад, використання термітних ливарних додатків високого температурного градієнту для економії сплаву, залитого у форму, накладають відбиток на алгоритм визначення економічного ефекту. Насамперед це викликано не тільки з встановленням безпосередніх прямих витрат при внесенні змін у стандартний технологічний процес, а саме витрати на металотермічну суміш, зміну ливарної форми, феросплави, використання лекговідділяючих ливарні додатки пластин, але і можливістю повторного використання решток ливарного додатку, ливників, зумпфа, стояка та ін. елементів для переплавлення. Метою запропонованої роботи було встановлення особливостей розрахунку економічного ефекту при впровадженні прогресивних технологій у виробництво, таких, як наприклад, технології пов'язані із зменшенням ливарних додатків. Для проведення досліджень і обробки результатів використані статистичні методи, а саме метод кількісного аналізу, методи порівняння і групування. Порівняння економічних показників з дійсними кількісними характеристиками промислової технології методом комплексної оцінки надали змогу проаналізувати результати і зробити висновки до роботи. Основні результати проведеної роботи визначаються запропонованою методикою встановлення економічного ефекту, яка у відмінності від існуючої, враховує відновні ресурси та можливість отримання екологічного ефекту. Це дає можливість обґрунтовано та раціонально використовувати відновні ресурси отримувані з відходів виробництва, сприяти охороні навколишнього середовища. Напрями подальших досліджень пов'язані насамперед з виявленням та оцінкою техніко-економічних показників супутніх технологій до ливарного виробництв, а саме виробництво феросплавів, формувальне виробництво, технології кольорової металургії та ін. Це в перспективі дасть змогу встановити умови найефективнішого застосування інноваційних технологій та отримання максимального економічного ефекту від їх впровадження

**Ключові слова**: економічній ефект, прогресивна технологія, екологічний ефект, відновні ресурси, прямі витрати, організація виробництва, техніко-економічні показники