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Economic Feasibility of Implementing Classifier with Coaxial Pipes at Catalyst Plant

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ABSTRACT

Modern industry is characterized by the relevance of determining the economic feasibility of engineering solutions for the effective commercial implementation of new equipment. The main purpose of the work is to analyze the economic indicators of the developed classifier with coaxial pipes in case of its implementation into the silica gel production line of the operating enterprise (Salavat Catalyst Plant, Salavat, Bashkortostan). The economic indicators, such as Net Present Value, Profitability Index, and Discounted Payback Period of the project were calculated to assess the economic efficiency of the classifier implementation into the production line of the enterprise. Based on the simulation results of the developed digital double for the classifier, it was determined that at the inlet gas velocity of 3–17 m/s, energy expenses per year changed from 119.4 to 21025.7 RUB. The Net Present Value at a discount rate of 16 % was calculated at 355986.6 RUB. The Profitability Index of the project was 4.71, and the Payback Period of the classifier implementation was approximately eight months with stable monthly cash flows equal to 70000 RUB.

Keywords: *Economic efficiency, Energy expenses, Digit twin.*

1. INTRODUCTION

An essential task for the successful implementation of new devices in chemical, petrochemical, and other enterprises is to consider economic aspects [1], [2]. Currently, the industry efficiency consists of the production indicators, such as the volume of manufactured products, consumer demand, consumption of materials, raw materials, etc., and rational economic indicators of the enterprise [3]. The financial analysis ensures the planning and implementation of innovative solutions, which directly affect the enterprise's overall efficiency.

The growth of competitiveness in the market segment directly depends on the calculation of economic indicators taking into account the discount method for the long-term operation of the installed equipment. In this work, a techno-economic planning method is used, which considers the cost of the implemented object, overhead costs, energy consumption expenses, etc [4], [5]. The main point of the economic calculation is to measure the essential costs (investment costs) of the implementation process and the profit of the enterprise. Therefore, special attention is paid to the current task of assessing the economic efficiency of introducing new equipment at an industrial enterprise.

Particle separation is one of the most common industrial processes [6]–[8]. This work aims to perform an economic evaluation of the implementation of new equipment – a classifier with coaxial pipes to the operating enterprise.

2. OBJECTS AND METHODS

The object of the study is the enterprise "Salavat Catalyst Plant OOO" (Limited Liability Company). The subject is the calculation of the economic feasibility of implementing the developed classifier with coaxial pipes into the technology with minimum costs and high quality for further maximizing economic profit.

The classifier has a pipe-in-pipe design (Figure 1) with a cut size of 30 μm. In particular, it was necessary to catch particles up to 30 μm in size from the gas flow and remove particles larger than 30 μm with gas from the device outlet. Moreover, the volume fraction of the captured particles with a size less than 30 μm should not be more than 2 %. The development of the classifier with coaxial pipes was carried out based on numerical simulations using Ansys Fluent.

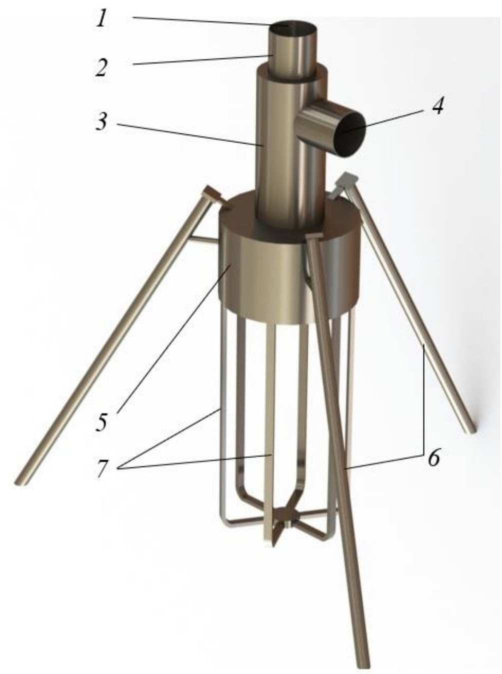

Figure 1 The digital twin of the classifier with coaxial pipes: 1 – inlet; 2 – internal pipe; 3 – external pipe; 4 – outlet; 5 – cylindrical part; 6 – legs; 7 – metal construction for removable container.

An important stage in financial engineering is the investment calculation of the implementation of new equipment since the assessment of the expenses in R&D plays a unique role in the economy department of industrial enterprises. Therefore, the investment budget includes the following costs: material costs for manufacturing the classifier, overhead costs, and other costs. Thus, the following formula will determine the total cost of the project:

$$K = K_{\mathrm{m}} + K_o + K_{\mathrm{other}}, \quad (1)$$

where K_m are material costs, RUB; K_o are overhead costs, RUB; K_{other} are other costs, RUB.

Depreciation fund needs to repair and replace worn and damaged elements of separation devices. Depreciation charges were calculated using a linear method. We assume that depreciation deductions will occur annually, so the year-over-year depreciation charges of A_{an} can be calculated as follows:

$$A_{an} = C_i H_d / 100, \quad (2)$$

where C_i is the initial cost of the device, RUB; H_d is depreciation rate, %, which can be expressed as

$$H_d = (1/N)100, \quad (3)$$

where N is the useful life of the device, year.

Overhead costs in case of the and use of new equipment and implementation in the production line cover expenses for installation and maintenance of the classifier, workplaces, downtime, scrap, etc. They can be calculated by identifying the additional costs of the enterprise and summing them up.

This study does not compare the developed device with analogs since their implementation requires significant space planning changes. In addition, the salary costs are not taken into account in the calculation of investment costs since specialized workers are not necessary for the operation and installation of the proposed classifier.

When calculating the total annual amount of electricity of the proposed equipment in the production line of the Salavat Catalyst Plant, we consider the maximum permissible schedule for maintenance and operation (8760 hours/year).

The energy expenses of the classifier were calculated by the Equation (4):

$$E_e = N\tau K, \quad (4)$$

where N is the power consumption for dusty gas pumping through the classifier, kW; τ is an operating time, $\tau = 8760$ h; K is a price for one kWh, RUB/(kWh).

The following equation determined fan power N:

$$N = \Delta p Q / \eta, \quad (5)$$

where Δp is pressure loss in the classifier, Pa; Q is volumetric gas flow rate, m^3/s; η is fan efficiency.

The economic efficiency of the classifier implementation into the production line of the operating enterprise was assessed on the basis of the following economic indicators: Net Present Value (NPV), Profitability Index (PI), and Discounted Payback Period (DPP) of the project.

NPV represents the efficiency of the investment in the project, i.e., shows the difference between the result and the cost. It should be noted that at certain intervals, the value of funds changes due to inflation and other factors. Therefore, to carry out a reliable calculation, it is necessary to select the current time for the project beginning and all subsequent financial receipts to lead to the current period. To do this, the discount factor K_d should be calculated as:

$$K_d = 1/(1+r)^t, \quad (6)$$

where r is the discount rate; t is time interval, year.

The value of the calculated discount rate allows you to evaluate the profitability of future investments. As a rule, the discount rate is accepted from 10 to 40% in Russian industrial investment projects.

The liquidity index of the enterprise is analyzed on the basis of calculating the following liquidity ratios [9]: Cash Ratio (CHR), Current Ratio (CR), and Quick Ratio (QR).

The AR determines the solvency of the enterprise, namely the ratio of the amount of cash and short-term financial investments to short-term liabilities. Cash Ratio (CHR) is determined by the formula:

$$CHR = (C + MS)/CL, \quad (7)$$

where C are funds, RUB; MS are short-term financial investments of the enterprise, RUB; CL – short-term liability, RUB.

The Current Ratio (CR) is used to identify the fastest realized assets of the enterprise, which can be calculated according to the formula:

$$CR = CA/CL, \quad (8)$$

where CA are current assets, RUB.

The Quick Ratio (QR) can be calculated using current assets (cash):

$$QR = (C + MS + AR)/CL, \quad (9)$$

where AR is accounts receivable, RUB.

Cash flows are discounted to bring the value of expected cash payments to the current time, which is calculated using the following expression:

$$DCF = \sum_{t=1}^{n} CF_t/(1+r)^t, \quad (10)$$

where CF_t is cash flow, RUB;

The Net Present Value (NPV) can be expressed by the formula:

$$NPV = \sum_{t=1}^{n} CF_t/(1+r)^t - |IC|, \quad (11)$$

where IC is invest capital, RUB.

The Profitability Index (PI), taking into account the time factor, can be calculated using Equation (4), which characterizes the investment efficiency

$$PI = (NPV + |IC|)/|IC|. \quad (12)$$

The Discounted Payback Period (DPP) of the implementation project was calculated by the following expression:

$$DPP = \sum_{t=1}^{n} CF_t/(1+r)^t \geq IC. \quad (13)$$

3. RESULTS AND DISCUSSION

Table 1 shows the cost of individual elements of classifier with coaxial pipes and manufacturing operations. The total material costs are 53600 RUB. It should be noted that the installation work can be carried out by full-time employees of the enterprise, which does not require additional financial costs for the salaries of other qualified specialists.

The forming of the depreciation fund is shown in Table 2. We take N = 10 years for the useful life of the device. It depends on the design features of the classifier (simplicity of design, absence of movable mechanical elements, etc.) and operating conditions, particularly the concentration of silica gel particles in the gas flow. So, according to the Equations (2–3), the depreciation rate H_d is 10 %, and the annual depreciation charges A_{an} are 5360 RUB.

Table 1. Cost of classifier's elements and operations

Element	Qty. [pcs]	Price [RUB/pcs]	Sum [RUB]
External pipe, 159×5 mm, steel	1	5000	5000
Internal pipe, 108×4 mm, steel	1	4000	4000
Pipe for cylindrical part, 325×8 mm, steel	1	13000	13000
Metal circular sheet for metal construction, 6 mm	1	1500	1500
Elements for metal construction	6	600	3600
Legs	3	3000	9000
Removable container	1	4500	4500
Metal washer	1	1000	1000
Operation	**Cost [RUB]**		
Cutting	3000		
Welding	10000		
Total	53600		

Table 2. Calculation of annual depreciation by the linear method

Useful life [year]	Residual value at the beginning of the year [RUB]	Depre-ciation rate [%]	Total amount of annual depre-ciation [RUB]	Book value [RUB]
1	53600	10	5 360	48240
2	48240			42880
3	42880			37520
4	37520			32160
5	32160			26800
6	26800			21440
7	21440			16080
8	16080			10720
9	10720			5360
10	5360			0

The setting of overhead costs in the industries is regulated by methodological guidelines approved by the Decree of the State Construction of Russia. In accordance with this document, the factor to be applied for determining overhead costs is determined, taking into account the application area of the equipment. As a result, overhead costs are accepted as 60 % of material costs as 32160 RUB.

To properly optimize the expenses of the economy department of the enterprise, it is also essential to consider other project costs necessary to promote the products to the market. Besides, other costs include unplanned expenses. As a rule, they are about 10–20 % of the material costs of the project. We assume that K_{other} is 10000 RUB. The total cost of implementing the new equipment according to Equation (1) is K = 95760 RUB.

Calculation of energy expenses is made based on experimental results according to Equations (4) and (5) (Table 3). The parameter sample (pressure loss Δp in the apparatus) was obtained by simulations of the digital twin of the classifier. In particular, gas dynamics in the classifier were simulated. During the calculations, the inlet gas velocity varied from 3 to 17 m/s.

The determination of the pressure loss in the apparatus using the digital twin is caused the inability to perform studies on the full-scale model in the production line at the industrial enterprise. More detailed information of the simulation procedure of the developed classifier was described in [10]. As a rule, the efficiency of a fan is from 0.6 to 0.8; we assume η is 0.6.

Table 3. Calculation of energy expenses

Inlet gas velocity W [m/s]	Pressure losses Δp [Pa]	Fan power N [kW]	Tariff price [RUB/kWh]	Sum of energy expenses [RUB/year]
3	91.70	0.003895		119.4175
4	156.64	0.008871		271.982
5	260.10	0.018781		575.8216
6	352.27	0.029925		917.4964
7	510.82	0.050626		1552.185
8	624.43	0.070726		2168.459
9	800.79	0.102039		3128.518
10	976.44	0.138245	3.5	4238.606
11	1190.86	0.185464		5686.314
12	1487.28	0.252685		7747.319
13	1746.85	0.321517		9857.719
14	1996.10	0.395654		12130.75
15	2312.50	0.491109		15057.42
16	2651.00	0.600530		18412.26
17	2849.21	0.685770		21025.72

From Table 3, it is clear that when using one classifier, the cost of electricity per year is no more than 21025.72 RUB at the gas velocity of 17 m/s. It should be mentioned that the gas velocity is not a fixed value over time, so we take the averaged value of 10 m/s. Thus, electricity costs per year equal to about 4238.606 RUB.

Implementing the classifier with coaxial pipes allowed the enterprise to profit from the fulfilment of the technical assignment. Since this information is confidential, we accept that cash flows (CF) amounted to about 70000 RUB per year using one classifier.

For assessing the cost-effectiveness of implementing the classifier into the production line of the enterprise, the financial analysis of Salavat Catalyst Plant was performed because it determines the discount rate r in equation (6). Figure 2 shows the company's total revenue growth trend from 2014 to 2019 and the similar dynamics of the change in net profit and EBIT for the entire reporting period.

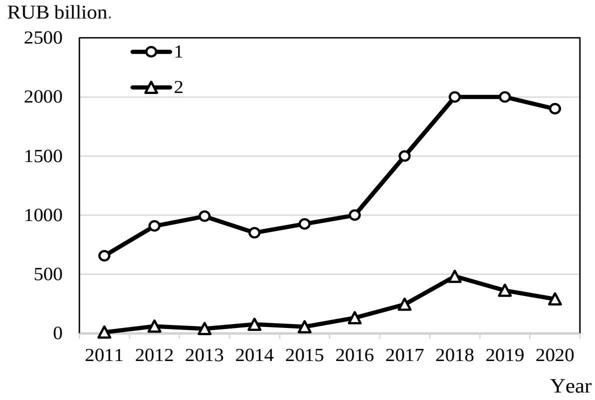

Figure 2 Financial results of Salavat Catalyst Plant (Data of "Salavat Catalyst Plant OOO" (LLC), Financial statements for 2011–2020): 1 – revenue; 2 – net profit.

Based on the financial results of Salavat Catalyst Plant, liquidity ratios were calculated according to the Equations (7–9), the results are presented in Table 4.

Table 4. Analysis of the ratios by liquidity and maturity liabilities for 2018–2020

Ratio	Year			Difference	Standard
	2018	2019	2020		
Cash Ratio	0.04	0.11	0.137	0.097	0.2–0.5
Current Ratio	1.22	0.67	0.439	–0.781	0.8–1.0
Quick Ratio	1.73	1.35	0.786	–0.944	2.0–2.5

Analysis of liquidity ratios in 2018–2020 showed that the Cash Ratio tends to increase from 0.04 to 0.137. In general, the enterprise is solvent, since the volume of short-term financial investments allows to cover the short-term liabilities of the enterprise. This aspect justifies the financial possibility of implementation of the new equipment in the production line. However, Current Ratio and Quick Ratio declined and did not reach the normative value. Liquidity ratios made it possible to compare the value of current assets that have different degrees of liquidity with the amount of current liabilities. According to the accounting statements, the listed liquidity ratios differ from the established normative values and tend to decrease their indicators due to a decrease in the total net profit of the enterprise over the past years. In this regard, the return on equity of the enterprise also decreased 1.3 times compared to the previous year and for 2020 amounted to 31 %. According to the data given, we accept in the calculations the discount rate is 16 %.

By calculating the main economic indicators and DCF at $r = 0.16$ according to the Equations (6–10), we determine that planned cash flows over 10 years of the enterprise are stable throughout the useful life of the classifier with coaxial pipes without taking into account the temporary factor.

The effectiveness of investments was estimated using the Net Present Value (NPV) according to the Equation (11). The NPV remained within positive values and amounted to 355986.6 RUB, which characterizes the validity of the initial investments into the implementation project.

The Profitability Index (PI) is subjective indicator and does not take into account the influence of external market factors that can affect the change in the potentially cash flows and financial condition of the enterprise. In our case, the time-based PI was 4.71.

The Discounted Payback Period (DPP) of the project was approximately 8 months, considering the change in the value of money over time, so during this period the net income of the enterprise will compare with the sum of the initial investments.

4. SUMMARY

Implementing the developed classifier with coaxial pipes into the silica gel production line of Salavat Catalyst Plant is cost-effective. The following conclusions can be drawn from the study:

- The total cost of implementing the developed classifier with coaxial pipes in the production line of the operating enterprise amounted to 95760 RUB.
- The digital twin of the classifier with coaxial pipes is presented. The simulations showed that when the inlet gas velocity varies from 3 to 17 m/s, the cost of electricity per year is from 119.4 to 21025.7 RUB.
- Analysis of liquidity ratios for the period 2018–2020 showed the Cash Ratio tends to grow, but the Current Ratio and Quick Ratio differ from established normative and tend to decrease because of the decrease in the total net profit of the enterprise over the past years.
- The Net Present Value at a discount rate of 16 % was calculated on the basis of the analysed liquidity indicators of Salavat Catalyst Plant and amounted to 355986.6 RUB.
- The Profitability Index of the project was 4.71 and the Payback Period of the classifier implementation was 8 months, with stable monthly cash flows equal to 70000 RUB.

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