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Application of the sustainable materials technology model

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Cleaner production

ABSTRACT

Purpose: The paper presents a possibility of the sustainable technology model to the materials technological processes galvanic treatment used.
Design/methodology/approach: The article includes analysis and estimation of the nickel and chromium coated on the metal elements. To selection of the best solution (about the least negative environmental influence) simple genetic algorithm was used. Polyoptimization makes possible selection of the optimum solution in view of several criteria, especially environmental.
Findings: The conclusion of the work shows a possibility connecting of sustainable technology model with multiobjective optimization. This approach gives basis to collection of many modernization variants and selection of the optimum variant.
Research limitations/implications: The enlargement of quantity and kind of criteria (except environmental criteria, e.g. quality, efficiency, costs, etc.) can narrow down the area of proposed solutions selection. The problem is the suitable introduction of these criteria to objective function.
Practical implications: The solution presented in the paper can apply in the industry to estimation and selection of a group technological processes which characterize different environmental influences. To modernization variants optimization, except genetic algorithms, can be used other methods of polyoptimization.
Originality/value: The paper presents searching for optimum solutions of the technological process modernization with regard to environmental criteria with polyoptimization used.
Keywords: Industrial application of cleaner production methods; Sustainable technology; Multiobjective optimization; Galvanic treatment

1. Introduction

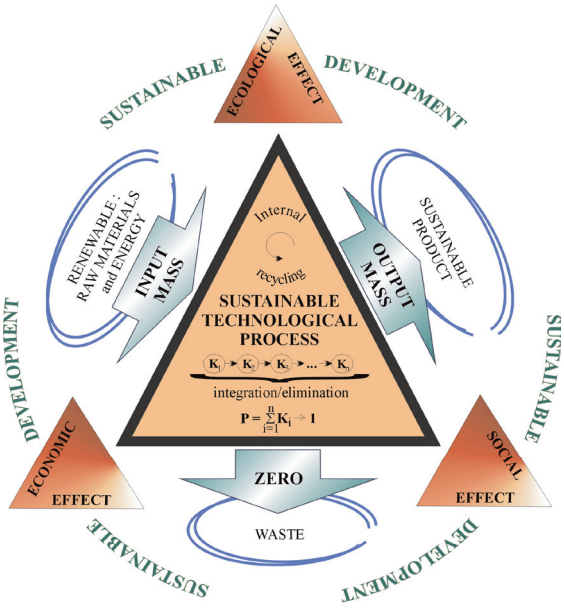
The problems of present economic processes, e.g. industrial connecting more and more with sustainable development (SD) conception and methods and tools of SD [1]. However observed the difficulties in the initiation too generally formulated and often complicated methods for improving, e.g. real technological processes. According to the earlier foundations the technological process was recognized as one of smallest local, elementary areas which have influence on realizing of the sustainable development principles in the global scale [2]. To get intentional results according to sustainable development principles, technology which consists of the technological processes has to be sustainable. This mean that the technology and especially important in the production processes the materials technology is sustainable when it is in full symbiosis with the environment (environment understood as a nature and a society).

Hence make an attempt of the sustainable technology model elaborate which using makes possible the sustainable development requirements realizing [3].

2. Model of the sustainable technology

Every technological process in general way can be described to mutual account of three basic streams: the input stream (raw materials and energy), the output stream that is to say the stream of products and the stream of waste which makes growing environmentally threat.

An alternative for presented process is the process which has no waste – sustainable (fig. 1).



P - sustainable technological process,
K_i- operation in the technological process, where i = 1-n.

Fig. 1. The model of the sustainable technology [2]

In this model we can distinguish in general two basic streams [2]: the stream leading materials (raw materials) - best renewable and the energy stream obtaining from renewable sources - defined as the input vector and the output vector, folding from the sustainable product. The third stream theoretically does not exist, because talked over model has not streams of waste. Presented solution where the mass of this, what is found on the input of the process is equal to the mass of this what is found on the output (mass of product), in spite that would be ideal solution. But this effect is impossible to realization, because of the disagreement with rules of the thermodynamics.

The reality is distant enough from the ideal and practically streams of waste always appear. The solution to which we must pursue is the necessity of the diminution of waste streams (masses of waste) quantity and their entire utilization in the form of the semi-manufactured goods and the secondary raw materials. To such solution can lead the integration of process operations because the greater number of the process operations consist, this more losses they cause. Diminishing the stream of waste we can increase the productiveness of analysed process, so enlarge it economic efficiency.

Using the sustainable technology according to presented model can efficiently protects the environment by the elimination of waste streams and on the other hand profitable, because makes for enlarging of the profitability and the productiveness, mostly by minimization of production costs. Like this integrated ecological, economic and social effects which make for the realization of the sustainable development will be achieve [2].

3. Application of the sustainable technology model to the galvanic treatment process of metal elements

3.1. Analysis of the technological process

The analysis area is the real nickel and chromium coated technological process (fig. 2) [1].

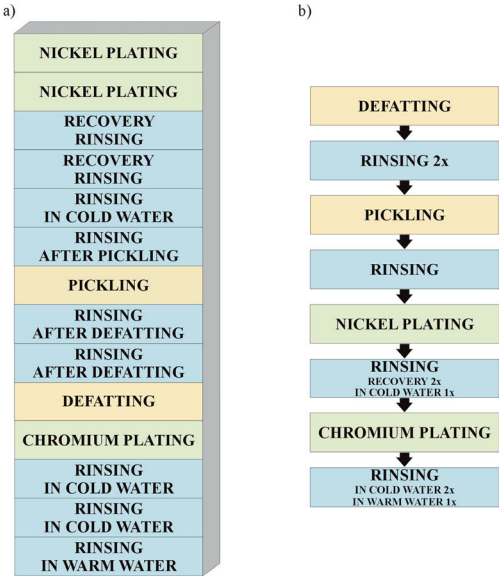


Fig. 2. Process line of the galvanic treatment a) tanks set in the production hall, b) sequence of the operations carry out [2]

The nickel and chromium plating technological process is characterized with the following production parameters (table 1) [2]:

- average production - elements surface treatment - 9500 m^2/10 months[1]
- production line - working time - 3 changes - 24 h
- electroplating bath - nickelous ($NiSO_4 \cdot 7H_2O$, $NiCl_2 \cdot 6H_2O$, H_3BO_3, $MgSO_4 \cdot 7H_2O$), chromic (CrO_3)
- tanks capacity ~ 2100 l (nickel and chromium plating, pickling), 1500 l (defatting and rinsing).

[1] Galvanizing plant worked – 10 months production, 2 months production line regeneration

Table 1
The technological data comparison concerning the analysed nickel and chromium plating technological process [2]

	defatting	rinsing	pickling	rinsing	nickel plating	rinsing	chromium plating	rinsing
Bath composition	alkaline NaOH, Na_2CO_3, Na_3PO_4	H_2O	HCl	H_2O	$NiSO_4 \cdot 7H_2O$, $NiCl_2 \cdot 6\,H_2O$, H_3BO_3, $MgSO_4 \cdot 7\,H_2O$	H_2O	CrO_3, H_2SO_4	H_2O
Temperature	45°C	15°C	15°C	15°C	42°C	15°C	50°C	15°C, 40°C

Table 2
Comparison of the materials used and losses, energy consumption, waste quantity and costs of the nickel and chromium plating technological process [2]

Operation	Materials kg/10 months	Materials losses kg/10 months	Energy kWh/10 months	Waste kg/10 months	Costs PLN/10 months
Defatting	3000	12470	3372,15	3000	2417,04
Rinsing	30000	4022	-	30000	1567,15
Pickling	4200	3062	-	4628,22	533,18
Rinsing	15000	2486	-	15000	786,9
Nickel plating	4200	26294	23182,78	1	198015,15
Rinsing	30000	33739,5	-	15000	12775,62
Chromium plating	2100	21014	4438,9	3722,25	86997,61
Rinsing	45000	11702	3021,57	45000	24213,21
Σ	133500	114789,5	34015,4	116351,47	327305,86

In the aim of the problems identification which occur in the analysed process the materials, energy, waste and costs balance was prepared - separately for every operation of the process (table 2).

Considering this that the nickel and chromium plating technological process does not sustainable, several areas separated which should be subjected to the modernization.

To the basic problems – threats can be accepted:

- using of harmful defatting substances,
- using of electroplating high concentration baths,
- high washings used,
- high water losses (e.g. evaporation, etc.),
- dangerous waste (sewage, sludge) disposal to the environment which have high metals, acid concentration.

To eliminate this problems it is necessity solutions introduction, which reduce the threats for people and environment [4,5,6,7,8,9,10]:

- **Using of harmful defatting substances** – proposal solutions:
  defatting using water substances, elongation of the defatting standing, possibility of the defatting minimize or reduction, ultrasonic defatting.
- **Using of electroplating high concentration baths** – proposal solutions: chromium plating in low concentration baths, cascade rinsing, showerly rinsing and rinsing in water fog, without flow static rinsing, using the same water again, improvement of the rinsing efficiency, rinsing recycle.
- **High water losses (e.g. evaporation, etc.)** – proposal solutions: elongation of the drip time, drip plate installation, drip bath installation, evaporation limitation, aerosol limitation.
- **Used up technologic baths to the environment disposal** – proposal solutions: elongation of electrolyte function time, filtration and ultrafiltration, ion exchange resin used, direct technologic baths recovery, direct baths recovery in LAFT system,
- **Dangerous waste (sewage, sludge) disposal to the environment** - proposal solutions: possibility of the electrodeposit used, elongation of the pickling bath life, ion exchange, electrochemical recovery, reverse osmosis.

Then with computer software to polyoptimization [11,12,13,14,15] used, effectuated of solutions selection and proposed several solutions which cause considerable ecological and economic effects. These solutions which are simple, cheap and easy to use will be the most profitable.

The following variants of solutions were chosen to the more far analysis: baths covers used, defatting with water substances used, elongation of the pickling bath life, recycle of pickling bath, elongation of chromic bath with ion exchange resin used, chromium plating in low concentration baths used, three-stage cascade recovery rinsing used.

Proposed solutions allowed waste reduction and they minimize costs of the technological process used. In connection with above the solutions lead to sustainable process achieved.

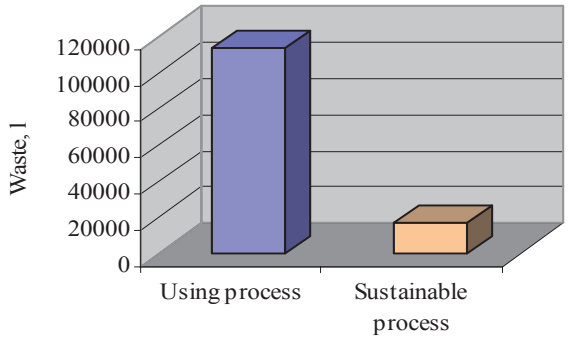


Fig. 3. Ecological effects which can be obtained after sustainable technological process applied

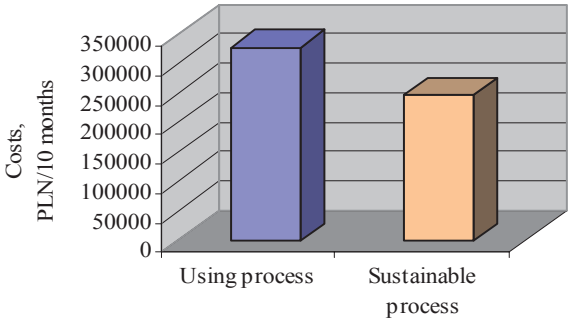


Fig. 4. Economical effects which can be obtained after sustainable technological process applied

The comparison of ecological and economic effects presented figure 3 and 4.

4. Discussion

In this paper the sustainable technology model presented. The advantage of proposed model is its general character, because of that it can be used for every technological process analyse and estimation, especially for materials technological process.

The usefulness of this model was illustrated on the example of the real nickel and chromium coated technological process modernization.

In order to modernization of the real process in direction of the sustainable process presented technical solutions which minimize galvanic treatment process influence on the environment.

Suggested solutions will ensure the obtainment of ecological, economic and social effects and they are compatible with the sustainable technology model principles.

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