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Optimization as an alternative in search of sustainable technological processes

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Cleaner production

ABSTRACT

Purpose: The paper presents a possibility of optimization (polyoptimization) to analyse, estimation and selection of materials technological processes used.
Design/methodology/approach: The article makes possible genetic algorithms to ecological, technical and economic estimation of the technological processes used. It also presents search of optimum technological process methodology. Considering complicated and many-layered structure of the sustainable development, optimization is the way in aim at better (sustainable) technological process.
Findings: The optimization methods should have more and more meaning in the materials engineering. It is because of many possible technical problems to solutions.
Research limitations/implications: The genetic algorithms method has a self – evident use accomplishing the choice of the best materials technological process in respect of improvement its mechanical, physical properties and reduces negative environmental influences.
Practical implications: Polyoptimization and especially genetic algorithms in connection with proper computer software can apply in the industry for group technological processes estimation. This approach makes possible search of the best available processes and selection of different modernization solutions.
Originality/value: In this article scantiness of the sustainable development theory presented. Because of that optimization as an alternative in search of better (sustainable) technological processes proposed. Also in the paper compared the most important multiobjective optimization methods. Using this methods give a chance of the best (with regard to adequate criteria) technological process selection to used.
Keywords: Industrial application of cleaner production methods; Sustainable development; Multiobjective optimization; Genetic algorithms

1. Introduction

The consciousness of the anthropogenic activity influence on the environment orders to minimize unfavourable results and threats and undertake the working, which aim is the maintenance of nature in the best condition.

For this purpose the sustainable development formed [1,2]. By reason of its complex and many-layered structure it is not comprehensible to the end [3]. Hence the plurality of the sustainable development conceptions which lead to frequent disputes among various options followers. Simultaneously decided majority of the representatives of these options think that politics and all workings towards sustainable development have to have the local character. Therefore we can affirm that the smallest, convenient "local" area is the technological process [1,2]. Because of that it is necessary to elaboration of the technological processes estimation methodology [4] (also materials technological processes) and processes selection in direction of the optimum process in relate to technical, economic and environmental criteria. One of the possibilities, which permits

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the best process select is multiobjective optimization [5,6]. Among many methods the genetic algorithms method (GA) has a special matter [7,8].

2. The conception of the sustainable development

From among many present, alternative conceptions of the development one from the most fashionable is the conception of the sustainable development (SD) [1,2,]. This idea exhibits two basic elements: the understanding of the environment degradation seriousness and necessity of its protection and the pursuance to reduction of differences in the level of prosperity. Referring only to the first ecological element of the sustainable development tended the ideal economy guaranteeing the development of the world compatible with environment. In this case we can favour the economy which develops in "harmony" with the environment.

The conception of the sustainable development has complicated and many-layered structure. Because of that it is unclear. The sense of the concept seems to be self-evident if it is analysed in the general means as the "development in harmony with the nature". However, in details such postulate is difficult to realizing in practice. This results from scantiness of the sustainable development theory and necessity of conferment this conception of more precise and operating moulds. The lack of theoretical models, scientific generalizations and the operating form of this conception it is the basic cause for which it did not pretend so far formulated the coherent methodology of the sustainable development control (management). Also did not formulated its indexes [1,2,3].

The sustainable development from one side it is guidance of every economic activity according to natural rule and from the second, better satisfying of physical and psychical needs of the man (through its suitable relation to environment and improvement the quality of life) [10]. Because of that proposed replacement of the unbalanced consumption and production model to sustainable consumption and production model [1,2]. This model confirms the opinion that politics and practical workings about sustainable development should have the "local" character because of not only the cultural and ecological distinctness of various Earth areas, but first of all from technological regards. The global results of productive processes and global consumption they are the sum of generally unknown or impossible to control in the global scale of "local" or elementary events. The problems of the sustainable development solution is impossible in the technology area, although this is the area in which large possibilities exist [1,2].

The example is the test of the sustainable technology notion formulated (constituting total of technological processes) and its model creation [1,4]. The generality of the sustainable technology methodology and its simplicity contributes to continuous every technology analysing and improving, especially materials technology.

The essential is that the model of the sustainable technology is based on three main aspects [1]: ecological, social and economic, what is agreed with the principles of the sustainable development [9]. The full integration of the sustainable technological process operations leads not only to the natural resources protection, but it causes also increase of the process productiveness and its economic profitability.

However the premise of the model is the endeavour to the entirely zero waste process which in the reality does not exist. The perfect process does not also exist. The ideal solution, in which the sum of materials mass on input is equal to the sum of products mass on output is impossible, because do not allow to this the thermodynamics principles. In practice always appear some streams of waste and we can only minimize them. Hence the basic activity in the sustainable development direction should be analyse, technical and ecological estimation and search of proper (better) technological processes which limited: resources used, energy consumption, and first of all waste quantity. Take into account such approach, the realization of the sustainable development principles on the level of technological process, should be the optimization process, based on search for better solutions (with regard to criterion or criteria), minimizing the negative influence on the environment [11,12,13].

That is why the elaboration of the technological processes influence on environment estimation methodology and the selection methodology of better processes seems also necessary. Because of that it is necessary modifying existing tools of the sustainable development (e.g. life cycle of the product) to the level of technological process (life cycle of the technological process [4]) and particularly to the level of materials technological processes.

The knowledge of the environmental life cycle of the technological process [4] makes possible the optimum technological process designing based on the sustainable (ideal) model [1]. This method can be used for new technological processes designing and for existing technological processes modernizations which do not realize waited ecological, technical and economic criteria.

The methodology for optimum technological processes search, based on the analogy with the Nadler's model [14], shows the figure 1.

The top of the triangle (pyramids) relate to the sustainable technological process – ideal, which is characterized with lack of waste (waste = 0), using of exclusively renewable energy sources and the renewable raw materials. Thanks to the rule - zero of negative influence on the environment - it does not demand the incurrence of additional costs. But the ideal technological process does not exist because in every technological process waste appears.

More profitable is the level of the scientifically optimum technological process, which is possible to use considering the intensive advance in science and techniques. This technological process is characterized with the greatest uses of renewable energy sources and renewable resources. In this reason we can minimize energy consumption and waste quantity. The level of the scientifically – optimum technological process are based on the knowledge and also based on experiences. This is surely the standard technological process but the high implementation costs make possible its use only in the future.

Below the scientifically - optimum technological process is found ecologically, economically and technically optimum technological process which is technically realizable and it is received by technological processes group optimization about different environmental weights, costs and technical parameters, most often very diverse. In this instance optimization takes into account simultaneously environmental criteria, i.e. raw materials used, energy consumption and waste quantity.

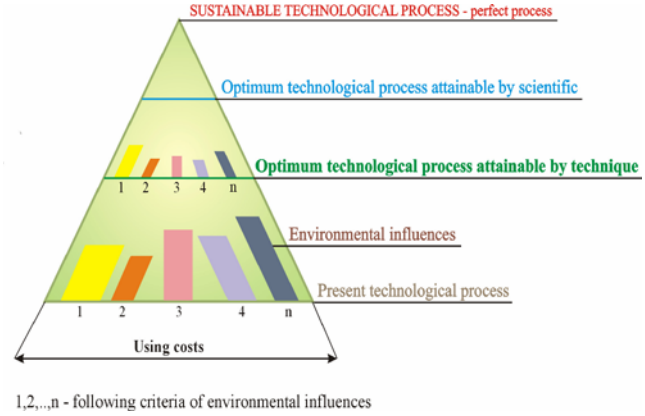

Fig. 1. Method of optimum technological process [2,4]

At the base of the pyramid is found the technological process about the greatest environmentally weights with costs of its used. This technological process is very expensive and also pollutes the environment. After the ecological, technical and economic analysis and the estimation it is subjected to the modernization or change.

The methodology of the optimum technological process founds the full analysis and estimation (ecological, technical, economic and market) of present technological process. In every case of its modernization or change shows the necessity of qualification and designing of the sustainable technological process. On this stage, after the settlement of the technical possibilities, we can propose necessary limitations and at last after optimization obtain best, most ecological solution of the optimum technological process.

The process which characterizes following parameters [2]:

- low cost of used, small expenditure and accessible investment costs,
- energy-saving, materials-saving,
- small waste, using small renewable resources (lack of exploitation of unrenewable resources),
- accessibility and kind of materials, applying materials about high quality,
- susceptibility to recycling,
- safety,
- lesser quantity of operations,
- easiness of repairs and modernization, etc.

we can define as optimum (taking into account ecological, technical and economic factors).

3. Optimization in direction of the sustainable technological process

Nowadays, to function and develop companies have to do: products optimize and their way of production optimize [15]. This operation can be made on many ways. The optimization changes are not something quick, they are introduced gradually and they follow one after the second [16]. The technological change is the basic requirement so an enterprise can make the grade.

People and also companies interested in search of best (generally optimum) solutions of technological processes since a long time. In the colloquial language the optimization means the choice of best, so the optimum possibility [6]. The methods which make possible formulating and solving such problem can be recognizing as the optimization theory.

In the last years can be observe increase of interest with the technological processes optimization methods, especially in materials engineering. This results from the universality of these methods and faster automation of all processes. The whole technological process is a system, which consists of operations and treatments.

We can optimize the whole technological process, but received during the optimization optimality criterion function has to be equal for all subsystems [15,16]. The optimization usually encloses the most essential (neuralgic) technological operations which in the direct way influence on the course of the technological process [15].

Generally, optimization can be divided on [6]:

- single-criterial, when the optimum state achievement is required in view of one criterion of this state estimation (vectorial, polyoptimization),
- multicriterial [7,8], when the optimum state achievement is required in view of many criteria of this state estimation.

In the single-criterial optimization, whole necessary information to solution should be gathered before beginning calculation. However the decision process has the iterative structure requiring of continuous investigations, what has the influence on the final solution. During such investigations we often need of new criterion addition.

With the polyoptimization problem we have to do when in the decision task should take into consideration several objective functions. Polyoptimization depends on the optimum solution finding which is acceptable for every criterion [2].

Among the multiobjective optimization we can favour [2,7]:

- Weighted Objectives Method,
- Hierarchical Optimization Method,
- Global Criterion Method,
- Distance Function Method and Minimum-Maximum,
- Goal Programming Method,
- Evolutionary Algorithms.

The evolutionary algorithms consist of three main classes [2,8]: genetic algorithms (GA), evolutionary strategies (ES) and evolutionary programming (EP). Genetic algorithms are based on mechanisms of biological evolution: natural selection and inheritance.

Genetic algorithms based on a basic principle of evolution - survival of the best adapted individuals. This means that “better” individuals have the larger chance on survival and bring forth of numerous offsprings. Therefore the process of reproduction proceeds in population, i.e. individuals give offsprings.

The activity of genetic algorithm consists of multiple genetic operations, estimation and selection [2] (Fig. 2). To basic genetic operators we classify [2,8]:

- mutation (random change of single individual genotype),
- crossing (generating one or many descendant individuals whose chromosomes on the base of parents chromosomes formed).

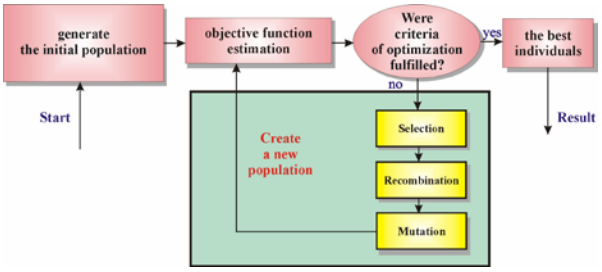

Fig. 2. Schema of genetic algorithm [2]

In general frame using genetic algorithms for real solving problems can be distinguish two main phases [2,8]:

- initial, depends on specify of the problem and adaptation of its nomenclature to GA nomenclature and the preliminary population creation,
- searching solutions, which consists of: individuals estimation, reproduction process and genetic operators.

The individuals are described by binary zero-one sequence and characteristic for GA elements, e.g. selection method, adaptation function and genetic operators. Every individual consists of one chromosome. The individual features (function parameters or decision variables) they are coded on several bits. The individual bit is called gene.

The first generations genes are chosen randomly, then follow individuals estimation using of adaptation function.

Every individual is allocated its value. The individuals are reproduced to the next generation in the next step (number of individuals in generation is constant) [8]. The next step of genetic algorithm is genetic operators using: crossing and mutation. This cycle is repeated till the moment in which the criteria of the optimization will be fulfilled.

4. Conclusions

With regard to still increasing quantity of possible technical solutions, the optimization methods should have more and more meaning in materials engineering. This results from the fact, that the optimization task should be accomplishment of choice of the best (with regard to adequate criterion, criteria) and the most adequate technological process (material) to use [12]. Optimization of chemical composition, treatment conditions and optimization of many different factors (including environmental factors) makes possible the accurate choice. Only simultaneous optimization of product construction and technological process with regard to technical and environmental criteria guarantees the best product production.

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