METHODS AND PRINCIPLES OF OPTIMIZATION SPECIFIC TO THE DOMAIN OF EQUIPMENTS AND MANUFACTURING PROCESSES

Radu Virgil GRIGORIU

Rezumat. *Obiectivele fabricanților de produse industriale sunt orientate, în general, spre fabricarea produselor la nivele de calitate superioare, în timpi minimi şi cu eficiență economică maximă. Îndeplinirea acestor obiective se poate realiza, în general, prin optimizarea parametrilor proceselor şi echipamentelor tehnologice de fabricație. În scopul optimizării parametrilor proceselor şi echipamentelor tehnologice de prelucrare este necesară aplicarea unei serii de metode şi principii de optimizare care să permită identificarea şi stabilirea dintr-o multitudine de alternative a celei mai bune soluții.*

Abstract. *The objectives of the industrial products manufacturers are generally oriented to manufacture high quality level products, in less time and with maximum economic efficiency. The achievement of these objectives can be realized, generally, by optimizing the processes and the technological manufacturing equipments parameters. In order to optimize these parameters it is necessary to apply series of optimization methods and principles that allow the identification and establishment of the best solution from a variety of alternatives.*

1. Introduction

Technological manufacturing processes within the framework of machine building are based on the interrelationship between the unfinished product and the tool, materialized, mainly, by the characteristic relative motion between the two components of the technological system, with an appropriate number and type of freedom degrees. These processes are mainly characterized by the following aspects: the dispersion of equipments and jobs in space, the discontinuity of the technological processes operations, the constructive and technological complexity of produced products, the production heterogeneity etc.

The presented aspects and features determine the following specific features of the technologic flux within the manufacturing processes of machine-building industry:

- a large amount of auxiliary operations (handlings, inter-operational transports, waiting's, storages, etc.) whose duration may overtake up to 70-80% from the manufacturing cycle length and their costs may amount up to 20-30% from the cost of production;

- a greater length of manufacturing flows and a direct dependence of the flows length on the structure and spatial organization method of the enterprise;
- a lower degree of mechanization/automatization of the auxiliary operations, which, because of the technical difficulties that the mechanization/automatization implies, have, generally, a preponderant manual character;
- the existence of some incompatibilities between the conception of the manufacturing flow and the production objectives, due to changes that occur in the technological processes or in the technical endowment and lead to the necessity of redesigning and reorganizing the periodical flows.

2. General objectives in the domain of products manufacturing and in the optimization of processes and technological manufacturing equipments

The general objectives of the industrial products manufacturers are oriented, generally, to manufacture high quality level products, in less time and with maximum economic efficiency. The achievement of these objectives can be realized, generally, by optimizing the processes and the technological manufacturing equipments parameters. The main objectives that are being followed are as follows: performances, economic efficiency, quality, utility and social effects of this processes and equipments (Fig. 1.) [3].

The achievement of the above mentioned objectives should be materialized through the following important effects: increasing the technical level of the product or the process (improving the technical and functional characteristics, psycho-sensorial, social, ergonomics, environmental, availability etc.) which will lead to the improving of the service offered by the product or process, to the reduction of material and human resources consumption, leading to lower product cost and increasing the economic efficiency under the form of increased production levels, productivity, benefits, etc.

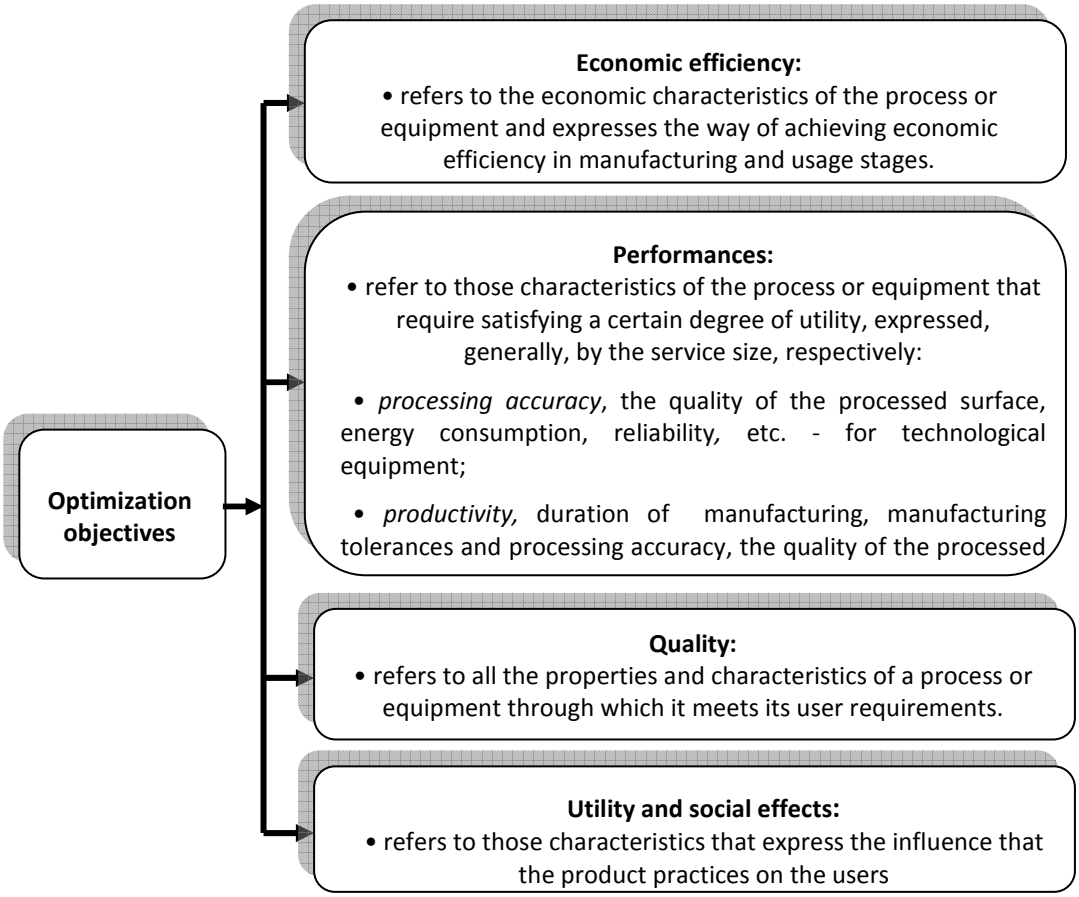

Fig. 1. Objectives in the domain of optimization of the processes and technological manufacturing products

3. Problems and basic steps of process optimization

The main problems of optimization of the equipments and technological manufacturing processes can be as follows [2]:

- problems to establish the optimum values of the equipment or process functions;
- problems to establish the optimum shape of the equipment components;
- problems to establish the optimum sequence of the stages of manufacturing technological process;
- problems to determine the optimum composition of equipment, of a kinematic structure, of the optimum arrangement of components, etc.;

- problems to establish the optimum parameters needed for the movements implied or realized by the processing equipment;
- problems to establish the optimum needed materials to produce the technological equipment or required by the technological process;
- problems of static and dynamic optimization of the technological equipment;
- problems to establish the optimum values of variables (reduced friction surfaces, levels of noise / vibration, etc.). from the performance of the equipment or process, etc.

For example, the optimization process stages concerning the technological processes are presented in Fig. 2.

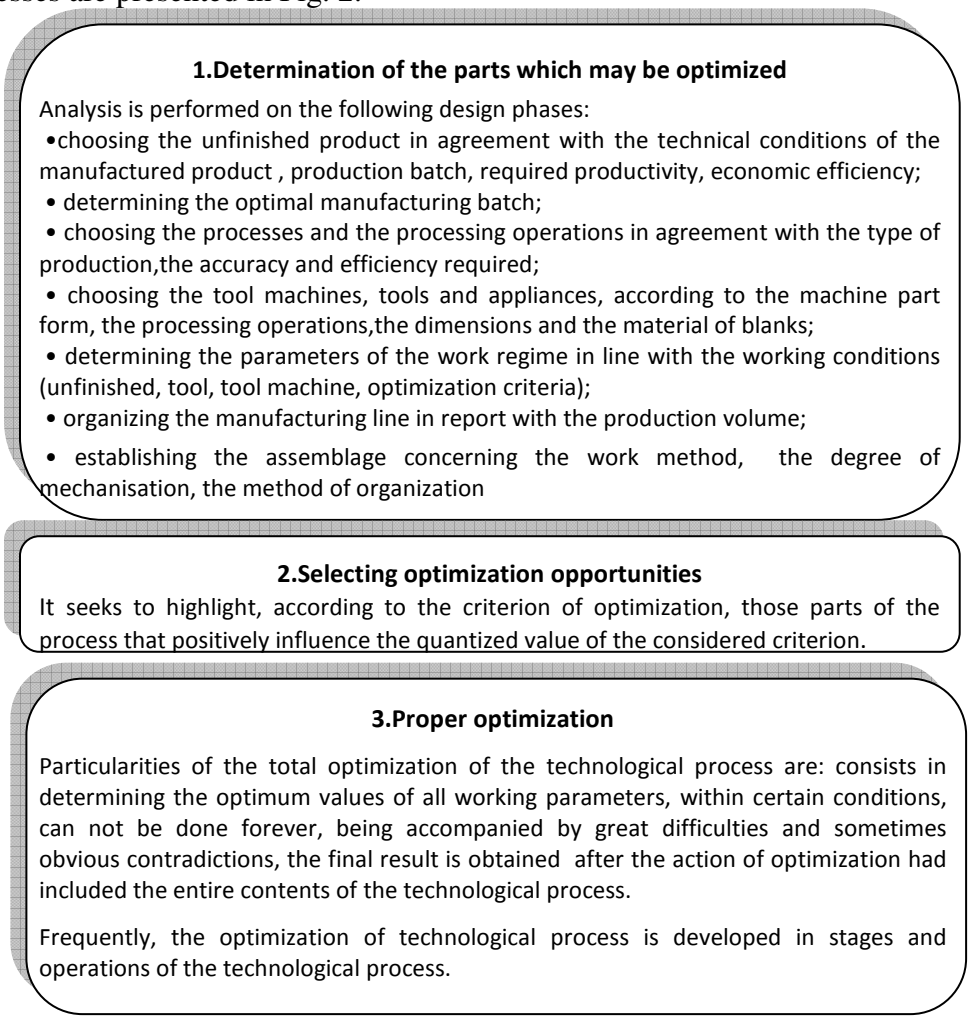

Fig. 2. Main stages of the optimization process for technological processes

4. Optimization methods and principles applied for technological processes and processing equipment

The main methods that can be applied to optimize the manufacturing processes are presented in the Table. 1 [1]. Mathematical methods that can be applied for the optimum design of the technological processing equipment can be grouped as follows:

- analytical methods including: differential calculation, variable calculation, Lagrange multipliers;
- numerical or mathematical programming methods, which can be linear and nonlinear, the most used methods are the nonlinear ones and the most applied of these ones are: one-dimensional minimization methods, unrestricted multivariable methods, methods with multivariable restrictions, other methods etc.

The basic principles and methods that can be applied for realising optimum processes and processing equipment are presented in Table 1 (a,b).

Table. 1(a). Traditional and modern methods that can be applied to optimize the processing

Method	Software used	Applications
a. Traditional methods		
Lagrange Method	Lagrange multipliers	The method is used for constrained optimization. Main applications: optimizing the problems without restrictions on unitary costs, using as main restriction the cutting power (Brewer 1966); unitary cost optimization, using as restriction the cutting power and the surface roughness (Bhattacharya 1970).
Geometric Programming	The inequality geometric mean – arithmetic mean	The method is applied for solving a class of nonlinear optimization problems, particularly the design and manufacture domain. Main applications: the optimum selection of the processing variables (Walvekar and Lambert 1970), the optimum selection of the processing variables, respective the cutting speed and the forward flow speed (Petropoulos 1973).
Goal-based programming	Combines the logic of optimization of the mathematical programming with the decision of the one that wants to reach multiple goals	The method is used to optimize multiobjectives. Main applications: the selection of levels of the processing parameters (Sundaram 1978).

Table. 1(b). Traditional and modern methods that can be applied to optimize the processing

Method	Software used	Applications
b. Modern Methods		
Fuzzy logic	Fuzzy Interface Engine fuzification – defuzification mode	The method it is based on a processing model which works on the basis of human reasoning, on decisions or on other concepts of human knowledge
Genetic algorithms	Common Interface Program * Gateway * (CGI)	The method it is based on a processing model developed on the basis of theoretical analysis, experimental database and numerical methods
Search dispersions	A program designed in C code	The method it is used for the general optimization of the processing problems that have not restrictive assumptions concerning the objective function, the set of parameters and the restrictions set
Taguchi technique	Design of experiments, orthogonal systems	The method it is based on current experimental work and on the determination of the optimum conditions using statistical methods
Response surface Methodology	The program Design Expert 6	The method it is based on a processing model developed on the basis of mathematical and statistical techniques

Principle of the constructive – technological character

In the constructive designing of the equipment components and in the technological designing of the manufacturing process it is necessary to consider the following principles: *between the constructive form of the machine parts and the technological possibilities of parts manufacturing a correlation must be established* or *to properly design a constructive form it is needed to properly design a technological form [4].*

The most important principles that can be applied to establish a correlation between the technological possibilities of manufacturing and the constructive forms of mechanical components of the technological processing equipments are as follows: *where a needed more complicated forms of parts, the material consumption will be lower, but the labour will be higher, in the designing of*

more complicated parts shape it will be applied the rule according to they must be composed of simple geometric elements; the establishing of the optimum solution of the part shape should be made by considering many factors that sometimes present contradictory effects [4].

Principle of the economic character of the constructive-technological adopted solutions

This principle is imposed by the increasing requirements concerning the quality and performance of processes and technological equipment, requirements that may lead to increased complexity and the cost of the manufactured products.

To analyse and select the optimum solutions of processes and technological equipment in terms of economic performances, the most effective methods that can be used are as follows:

- *the value analysis method that* is used in the design phase of the technological equipment and processes in the areas of researching equipment and new processes, upgrading the existing equipments and processes. The objectives of applying the method are as follows: to increase the value of utilization of the studied object and to reduce the production costs; to improve the products quality and to increase the working productivity, to improve the working conditions. The stages of implementation of the method are as follows: preparatory measures, analysis of social needs, analysis and assessment of the existing situation, conception or redesign of the product, approval of the optimum solution [6].
- *the minimum cost analysis method*, that is based on the establishment of the fact if a process or equipment cost is a function of a variable that takes values in a given area; it is easier to determine the optimum value for that variable as being the one for which the process or equipment cost is minimum. In this way, alternative versions of the process or equipment, whose costs depend on the set variable, can be compared on the basis of minimum costs [1].
- *the method based on cost-effectiveness analysis,* which is generally applied, when the output values of the project can't be expressed in monetary units, but by means of appropriate physical facilities proper to the design process or equipment [1].

Conclusions

The main objectives of the industrial products manufacturers are oriented, generally, toward the production of high quality levels in minimum time and with maximum economic efficiency. These objectives can be realised, generally, by optimizing the processes and technological processing equipment parameters.

The starting point for the optimization of the processes and technological processing equipment parameters is the study of these parameters and of the possible optimization solutions.

In order to optimize the parameters of the processes and technological processing equipment a series of optimization methods based on models or analytical, numerical, heuristic, experimental techniques, etc. have been proposed and investigated.

To identify and select the best solution from a variety of alternatives, it is necessary to apply a set of principles and methods that allow the highlighting of a correlation between the technological possibilities of manufacturing and the structural forms of the mechanical parts, correlation which can generate functions to be optimized.

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