Modeling and Simulation of the Competitiveness of Manufacturing Systems

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Abstract: - The paper aims, in the field of manufacturing technologies, at approaching issues of manufacturing systems, in order to develop a new concept of management, which is in line with the current market dynamics: the concept of competitive management. The concept of competitive management can offer solutions even to make competitive and develop enterprises as a whole. However, improving competitiveness is not a short-term process of exploiting advantages, but appears as a complex process of establishing and sustaining an economic structure based on capital investment, on research and knowledge, on development and innovation.

***Key-Words:* -** behaviour modelling, competitiveness, competitive management, manufacturing system.

1 Introduction

All over the world, companies are faced with increasingly accelerated and unpredictably dynamic changes. This is influenced by the scientific and technical progress, the dynamics of customers' demands, the scientific approach to management and the mathematical focus on economy [1]. Changes lead to aggressive competition on a global scale, which calls for the establishment of new balances between economy, technology and society.

The characteristic aspects of the present-day market, in particular case of mechanical components market, are the following:

i) continuously decreasing of the current orders, leading to the design of small series production

ii) strong tendency to personalize the products leads to a pronounced diversity of shapes, sizes and other characteristics of the mechanical components required on the market

iii) flexibility, responsiveness and especially the efficient management of the manufacturing system tend to become the characteristics that determine competitiveness on the market of components manufacturers and mechanical constructions. The current dynamics of the industrial and business environment is the great global challenge which must be faced.

To this global challenge the scientific community responds by a new conceptual paradigm, which in this case is the knowledge- based economy (KBE)**,** [2].

This paper is related to manufacturing system management, so as to maximize their technical and economic performance. The proposed performance indicator for the management of these systems is to be both holistic (in the sense that it takes into account not only the economic but also the technical performance) and synthetic (in the sense that it reflects key aspects of the manufacturing system functionality, namely those that are closely related to the reason for which they were created). In the paper, the competitiveness is considered an indicator, both holistic and synthetic, of the technical-economic performance and is used as a criterion for the management of manufacturing systems.

Within this paper, by manufacturing system we understand all the technological systems that are used to produce a specific product. Each of these technological systems is composed of machine-tool, tools, devices, parts, operator and carries out one of the operations of the technological process of making that product.

2. Technical-economic Modeling of the Manufacturing Systems

Competitiveness is defined by the economic factors and indicators obtained and is more a suggested/induced notion than a numerically evaluated one. The manufacturing system performance depends on how it is run. The market dynamics is further passed to the mode of operation and management. In a knowledge-based society and economy, operations such as determining the relevant information and aggregating them into pieces of knowledge must be automated, because in such a complex and unpredictable environment, they are indispensable tools for creating, searching and structuring knowledge. The interaction between the economic environment and the manufacturing system is a major source of knowledge about the economic environment and the manufacturing system themselves [13].

The technical-economic model of the manufacturing system is shown in Figure 1.

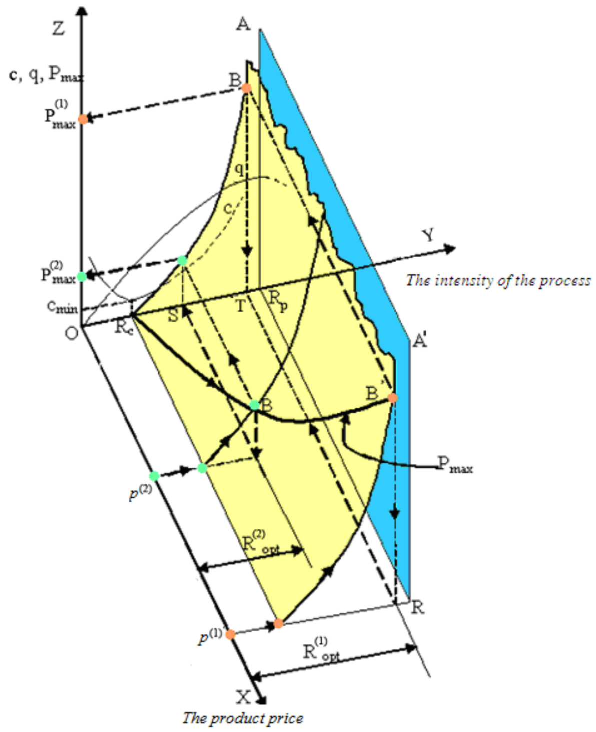

Fig. 1. Curve of maximum profit

The competitiveness is assessed by profit rate of the manufacturing system, P_{max}.

Analyzing Figure 1, which, in ZOY plan, presents the cost curve, c, and productivity curve, *q*, depending on the intensity, *R*, it can be noted that *c* has a minimum point for which the process intensity takes the value *Rc* and the productivity curve, *q* has a maximum point for which the process intensity has the value *Rp*. Because analytically, *Rc* is different from *Rp*, it follows that it is never possible to simultaneously achieve minimum cost and maximum productivity.

The question arises: to achieve a profit as higher as possible, which is the best way to produce? more and costly or less and cheaper, because more and cheaper, as seen in Figure 1, is not conceptually possible. To answer the question, let us follow the spatial evolution of the maximum profit rate(*Pmax* curve), depending on product price *p*, and the intensity process, *R*.

Let us consider two levels $p^{(1)}$ and $p^{(2)}$ of product price. The researches conducted by the authors have shown that, as product price *p* is higher, productivity becomes more important (*q* curve) than the cost (curve c) and therefore the optimal process intensity (that for which the profit is maximum) is approaching (asymptotically) the *Rp* point (follow the route $p^{(1)}$-*E*-*B*- $P^{(1)}_{max}$), which represents the process intensity for maximum productivity (without ever reaching it!).

For $p^{(2)}$ value of product price (which is lower), the cost becomes more important and the optimal process intensity is approaching the point *Rc* which is the process intensity corresponding to the minimum cost c_{min} (follow the route $p^{(2)}$-*D*-*V*- $P^{(2)}_{max}$). In both cases, the maximum profit rate takes the values $P^{(1)}_{max}$, $P^{(2)}_{max}$, respectively. In limit case, when all auctions are lost, but lost to the limit, then the maximum profit that can be obtained is zero (meaning that at best there is no profit at all) and this situation can occur only if the process intensity corresponds to point *Rc* (for which the cost is minimal). It is obvious that the operation at minimum cost is a limit we do not want to reach. In conclusion, the process intensity changes according to product price between the *Rc* and *Rp* limits without reaching any of them.

In the concrete case of the manufacturing system, technical-economic competitiveness can be assessed by he profit rate, *P*, given by the relationship:

$$P = \frac{p - c}{\tau} \text{ [Euro/min]}, \quad (1)$$

where:
p is specific price, [Euro/cm^2],
τ - time for 1 cm^2 surface area machining [min/cm^2];
c - cost for 1 cm^2 surface area machining [Euro/cm^2], given by the following relation:

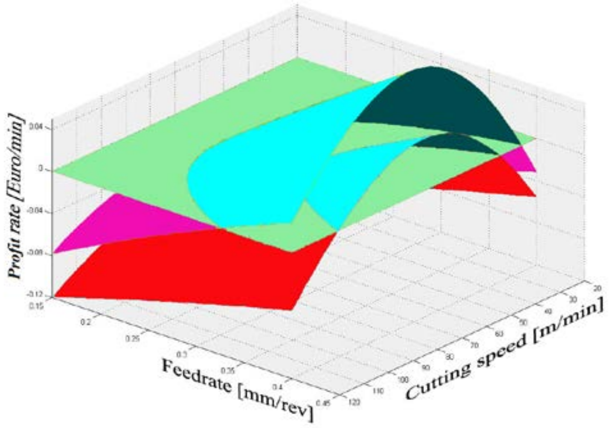

Fig. 2. Profit rate

$$c = \frac{c_\tau}{10 \cdot v \cdot s} + \frac{\tau_{sr} \cdot c_\tau + c_s}{10T \cdot v \cdot s} + \frac{t \cdot c_{mat}}{10} + \frac{K_e \cdot c_e}{10000 \cdot v \cdot s} + \frac{C_M}{10 \cdot K_M} v^{\alpha - 1} \cdot s^{\beta - 1} \cdot t^{\gamma} \quad [\text{Euro/cm}^2] \qquad (2)$$

where:
c_τ – it is the sum of all expenses directly proportional with the time;
τ_{sr} - time needed for the tool change and adjustment of the tool [min];
c_s - tool cost between two successive reshaping;
c_{mat} – tooling allowance cost;
c_e – cost of 1Kwh electric energy;
K_e - energy coefficient [wh/min];
K_M - machine-tool coefficient;
C_M - machine-tool cost [Euro];
v – cutting speed [m/min];
s – feed rate [mm/rot];
t – depth of cut [mm];
α, β, γ – coefficients.
T – tool durability, given by the Taylor relation.

The necessary time, τ, for 1 cm^2 surface area machining is calculated by means of the formula:

$$\tau = \frac{T + \tau_{sr}}{10T \cdot v \cdot s} [\text{min/cm}^2] \qquad (3)$$

Using the above relations, profit rate (fig. 2) can be drown.

3. Conclusion

1. The competitiveness based management has the advantage of being applicable to any manufacturing system; regardless the physical nature of the process and the product features;
2. Develop a methodology for the technical-economic competitiveness of the manufacturing system;
3. Develop a new concept of manufacturing systems management based on behaviour modeling of the market-manufacturing system assembly and on the implementation of the management to the manufacturing system, which is generally applicable and appropriate to the current market demands.

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