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# PERFORMANCE AND EVALUATION OF MAKE-TO-ORDER MANUFACTURING SYSTEM

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## ABSTRACT

*The system environment provides on-line data on the actions undertaken which, properly analyzed and correlated, will further generate solutions in order to develop said system and make it competitive.*

*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.*

KEYWORDS: competitiveness, manufacturing system, behaviour modelling, competitive management, knowledge based economy, on-line learning

## 1. INTRODUCTION

This paper is related to manufacturing system management, so as to maximize its technical and economic performance. The proposed performance indicator for the management of these systems is to be both holistic (in the sense that they take into account not only the economic but also the technical performance) and synthetic (in the sense that they reflect 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 as 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.

The manufacturing system is structured when the product is released for manufacture and remains there only until the end of the product completion. After this, when another product is released, the problem of structuring the manufacturing systems is taken from the beginning. This ad hoc structure of the manufacturing system is always present with manufacturing batches, but not in mass manufacturing, when all of the technological components of manufacturing system remain unchanged for a long time.

In the world three conceptual approaches in the field of manufacturing systems management are known.

- The first approach is based on Petri network, which aims at optimally ordering in time the technological operations that the system has to execute. Although it is well known and applied, this approach does not lead to a significant increase in efficiency, because it completely ignores the actual product manufacturing process, considering that the data about this process as permanently constant [1], [2], [3].

- The second approach is based on the holon structuring of the manufacturing systems, which, like the first, completely ignores the process [4], [5]. Although not yet applied in industry, experimental implementations of [5] and analysis of results reported in literature (which are comprehensively presented in [6]), show that it could be applied only to higher levels of process-machine systems (for example at department or enterprise level) and especially in auxiliary issues (such as inter-operational transport, off-line quality control or others).
- A third approach is based on the flexible integration of the system components, which led to the concept of reconfigurable manufacturing system, developed since 1999, by Prof. Yoram Koren from the University of Michigan (Ann Arbor), [7] and considered in many research centres in the world (such as Porto-Portugal, Germany-Hanover, Leuven-Belgium, to give a few examples). The management is exclusively technical and is based on numerical control. No economic issue is taken into consideration. Researchers' interest is oriented only towards the reconfiguration aspects, especially hardware and software, and control reconfiguration.

Our new concept seems to be important because: i) the competitive management of the manufacturing systems meets the demands generated by the extraordinary dynamics of both industry and business environments, which is regarded as the present-day big global challenge ; ii) the way of managing that will be developed in the paper has four key attributes - is on-line, adaptive, optimal and predictive – which means that it obviously implements the new conceptual paradigm by means of which the scientific community responds to the challenge, i.e. the knowledge- based economy, and, moreover, iii) our approach is comprehensive, because it considers both technical issues (related to the process), economic ones (related to cost and time) and also commercial issues (such as price, market competition) and finally, iv) the system of competitive management, proposed in the paper may be, without any difficulty, generally implemented beyond the approaches outlined above, as it operates with its own elements, alone.

## 2. MANUFACTURING SYSTEM COMPETITIVENESS

According to the literature, a company is competitive on a certain market when it succeeds in reaching, up to an acceptable level, some economic indicators: turnover, profit, market share comparable or superior to that of other competing companies acting on the same market. Many approaches to the problem of competitiveness [8], [9], [10] show that, today, competitiveness is defined by the economic factors and indicators obtained and is more a suggested/induced notion than a numerically evaluated one. In the world there are prestigious competitiveness research centres, such as: Center for International Development-USA Harward University, European Institute of Technology with its research center in Cambridge, Geneva, Oxford and Organizational Competitiveness Research Unit of Sheffield University Halle-UK which deals with competitiveness at the global, regional down to enterprise/company level.

However, approaches are of economic and managerial nature, while the relationship with the technical aspects of competitiveness is less noticeable. At this point there is no defined algorithm to evaluate the technical and economic competitiveness, moreover, the technical factors are not considered at a practical level, when defining competitiveness, although consumption and costs incurred by the technological processes are generated by technical actions. In this context, the notion of competitiveness gains new valences, including factors and policies that determine the ability of the enterprise to get a favourable place on the market, to hold that place and to continuously improve its position. Only in this way can competitiveness fully and synthetically characterize the enterprise viability.

In the paper, competitiveness will be understood as the capacity (potential) to provide performance (compared with other similar elements), in a very punctual way, within a macroeconomic concrete context and at a certain time. Moreover, according to a meter of competitiveness (considered as an essential performance indicator) it will be assessed the extent to which the company achieves the purpose for which it has been created. Therefore the paper aims at making a numerical and on-line evaluation of the technical-economic competitiveness and the management of the manufacturing system is performed to obtain maximum competitiveness.

The manufacturing system performance depends on how it is run. In more specialized papers [11], [12], reference is made to the relationships between the parameters of the processing regimes and the technical performance of the manufacturing system (purely technical aspects), while in others, equally numerous references are made to the relationship between the product made by the manufacturing system and the market (economic relations).

## 3. TECHNICAL-ECONOMIC MODELLING OF THE MANUFACTURING SYSTEM

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

The competitiveness is assessed by the 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 it 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.

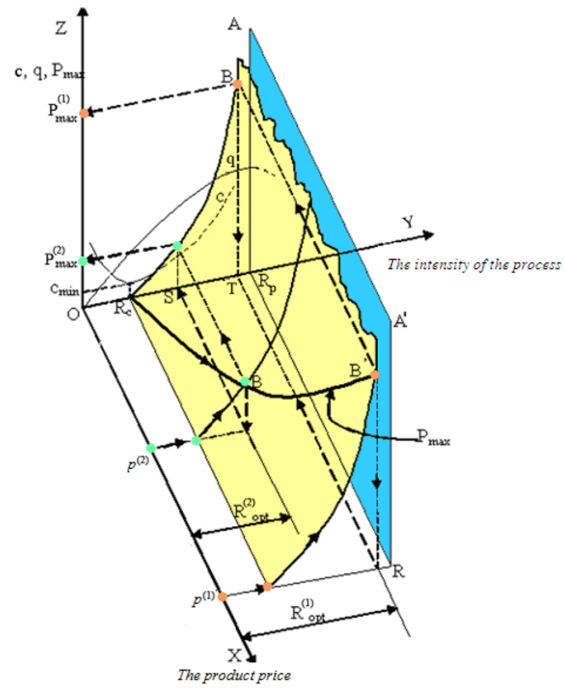


Fig. 1. Curve of maximum profit

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

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

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:

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

where:

$c_\tau$ – it is the sum of all expenses directly proportional with the time;

$\tau_{sr}$ - 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.

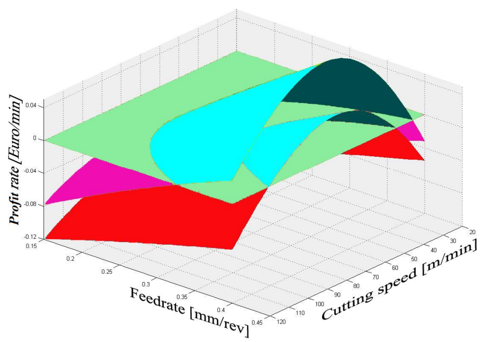


Fig. 2. Profit rate

## 4. CONCLUSION

We propose to give managers a model so that they can interact with the economic environment (market). Practically, this happens before the actual work of the manufacturing system, so that we have to do with a function of anticipation. The proposed method has the advantage of being applicable to any manufacturing system, regardless of the physical nature of the process and the product features. The method provides the extended modelling of the manufacturing system.

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