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THE TECHNICAL-ECONOMIC MODELLING OF COMPETITIVENESS FOR MANUFACTURING SYSTEMS

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ABSTRACT

On world wide level, enterprises are confronted with an evermore accelerated dynamics and the unpredictable changes. This is influenced by the technical and scientific progress, dynamic requirements of the customers, science of management and mathematical economy [1]. These changes enforce an aggressive competition on a global scale that assumes the request of a new settlement equilibrium between economy, technology and society. We define the competitiveness based control of the manufacturing systems as an ability to perceive the environment, to make decisions in time, as a result of the manufacturing system-market interaction, with no specific procedures. The manufacturing system environment provides on-line data on the actions undertaken which, properly analyzed and correlated, will further generate solutions in order to develop the control decision. This paper presents a method for modelling of the manufacturing systems competitiveness with application for part machining process control.

KEYWORDS: manufacturing system, competitiveness, online learning, adaptive control, technical-economic characteristics of manufacturing system

1. INTRODUCTION

The competitiveness characterizes the viability of an enterprise. In the economic literature competitiveness is analyzed in particular in econometric and managerial terms with almost no insight into the analysis of the manufacturing process role in ensuring and increasing competitiveness. This is why it is needed for the manufacturing systems a behaviour modelling based on process learning. Our approach is based on a real-time continuous awareness of the situations and decisions.

All over the world, companies are faced with increasingly accelerated and unpredictable dynamic changes. This is influenced by the scientific, technical progress and the dynamics of the customers' demands. Changes lead to an 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 of the mechanical components market, are the following:

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

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

iii) flexibility, responsiveness and especially an efficient system management tending 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.

The need to adapt technology to the knowledge society is reflected in the EU - FP 7 in order to strengthen the competitiveness of European economy and its technological power. In addition, the concept of Europe was launched intended for the development of information technologies, for and beyond 2010, and integration of a knowledge based society relying on a sound economy.

In order to progress in the present-day complex and unpredictable environment, the company must feature abilities of quick response and favorable reposition on the market. Acquisition and preservation of this capacity is the most difficult step for companies as it involves many endogenous and exogenous factors and

the process is continuous, dynamic and hardly predictable. In this context, three elements are highlighted by their relevance: competitiveness, the manufacturing system and the knowledge system.
The most important feature of the present-day market is the high level of customizing the products requested by customers, who bring about a large variety of the requested products and a small volume of the batches in which these products are manufactured.
One of the responses which can be given to this challenge is to increase its responsiveness by continuously reconfiguring the manufacturing systems in compliance with the task to be carried out. In order to make this happen, manufacturing systems are either for the general purpose or for the reconfigurable one.
According to the literature, a company is competitive on a certain market when it succeeds to reach, up 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 [4] show that, today, competitiveness is defined by the economic factors and indicators obtained and is more a suggested notion than a numerically evaluated one.
The indicator of performance proposed in this paper, for the modelling 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 the synthetic one (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 modelling of manufacturing systems.
This paper refers to the manufacturing system management/control, so as to maximize their technical and economic performance.
So in other words, to maximize the economic performance of the manufacturing system through an adequate selection of task assigned.
In the paper it is proposed an algorithm for the economic & technical rules identification and it is presented its application for a drilling process. The KDD (Knowledge Discovery from Databases) is applied for determining the rules of the drilling process that are further used in the technical-economic model as input data. KDD consists in a identification of the clusters of the process parameters that are connected to the other clusters of the market environment.
The aim of modelling is to maximize the economic performance of a manufacturing system by selecting a suitable task assigned.

2. PROBLEM FORMULATION

The manufacturing system performance depends on how it is managed. In more specialized papers, reference is made to the relationships between the parameters of the processing conditions and the technical performance of the manufacturing system (mainly technical aspects), while in others, references are made to the relationship between the product made by the manufacturing system and the market (economic relations).
In the literature, no attempt to approach the whole manufacturing system – market assembly is reported; therefore, there are significant resources to improve performance which is not used because the technical and economic aspects are dealt with separately.
Also, it is not known an algorithm for the management of the manufacturing system – market assembly, but only algorithms for the technical control of the technological systems-components of the manufacturing system and tools of economic management of the relationship between the enterprise as a whole and the market [1], [3].
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. The manager of an enterprise is in the situation that has to make a price quotation for elaborating an offer in order to negotiate.
Thus, the question that occurs is: how competitive is the product on the market? For this, the manager is obliged to establish a link between task and performance or profit enterprise, in terms of customer requirements. The identification adaptive character of a manufacturing system is given by on-line. The manager develops an action for what is already known and takes up an action of exploration in order to choose for the better in the future. In order to face these situations, the manager has set specific goals, being able to carry the different aspects of the economic environment and being able to make choices and make decisions accordingly. As a result, the exhibition will provide information about the efficiency of the experiment research.

3. MODELLING ALGORITHM

Today's economic context allow corporations and their business environment to produce larger and larger amounts of data relying on the latest information.
For carrying-out technical-economic identification of a manufacture system, an identification algorithm is developed so that its deployment depends on the dynamics, static and the competitiveness characteristics of the manufacture system.
For example, we use the database of a drilling process that has the following parameters: type of the material, hole diameter, drilling speed, drilling feed, number of holes, drilling time, energy consumption,

operation cost and waste quantity, Table 1, [2]. Identification algorithm uses as input data a set of monitored variables, between which there exists an implicit relationship.

3.1 The algorithm based on states clustering

The algorithm consists of the following steps:

- Step 1: clustering of variables based on the causal relationships;
- Step 2: states clustering;
- Step 3: building of the mathematical model corresponding to the states cluster and variables cluster set.

Then, the causality relationships between the parameters are identified. Based on these relationships, clusters of independent variables are established. Further, based on the dataset to be used for the model fitting, a cluster of neighbouring states is made up, at the centre of which is the state to which the respective input data are related. Finally, a linear model whose variables are the variables of one of the clusters of identified variables is fitted on the manufacturing system states cluster. These input data are the ones which have been previously considered in the procedure of enclosing the manufacturing system states cluster.

It can be noted that, according to the proposed method, the model construction and its operation are accomplished within an integrated algorithm which is run through upon each interrogation of the manufacturing system model. At the operational level, the variable clustering is based on the "*best NN model*" facility which is offered by the neural networks technique applied to a data set recently obtained from monitoring the manufacturing system. The states cluster construction, the linear model is fitted to, first implies the use of the 2nd rank Minkowski distance for the classification of states, in the increasing order of their distance to the state to be used for the model interrogation. That is why only the variables representing these input data will be considered in the calculation of Minkowski distance.

The states cluster is to be obtained either by restricting the value of the distance or by restricting the number, k, of retained states or using these two conditions. The construction of the mathematical model is made by linear regression. It can be noted that this is a local model, as it is valid only in the vicinity of the state for which the model is interrogated. This model is meant to be used just once as, after the interrogation, it is given up.

As a conclusion, the aim of the proposed method is to maximize the economic performance of a manufacturing system by selecting a suitable task assigned. This means, to maximize the effect, using the works of the manufacturing system that bring the greatest profit. The criterion which will be used for modelling the competitiveness of the manufacturing system is the profit rate, p, (rel.1) (performance of the manufacturing system), because the profit rate strongly depends on the product characteristics.

$$p = (\cos t - price)/time \qquad (1)$$

For construction of the task-performance model, which describes the interaction between manufacturing system and market, we achieved the task-cost manufacturing operation model and the task – market model (fig.1). The method proposed for achievement of the three models consists in monitoring and recording the relevant state variables of the manufacturing system in a database.

Table 1 - Example of experimental data regarding the process variables collected for the drilling process

Item nr.	Type of material	Hole diameter (mm)	Number of holes	Drilling speed (mm/s)	Drilling feed (mm/rot)	Number of pieces	Machining time (s)	Energy consumption (kwh/operation)	Cost of operation (Euro/ operation)	Waste quantity (Kg)
-	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
1	OL 52	12,5	3	1,1	0,7	70	7242	6,04	0,026	13,12
2	OL 42	15,55	5	4,1	0,3	28	12033	3,76	0,0268	13,54
3	OL 42	11,6	5	2,05	0,25	59	6255	4,41	0,0315	15,87
4	OL 42	25,6	2	5,05	0,35	104	3404	37,86	0,108	54,52
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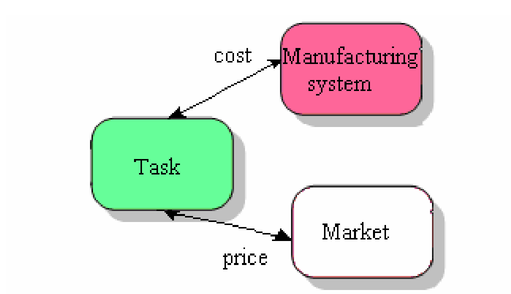

Fig. 1 The interaction between task - manufacturing system and market - task

3.2 Simulations of the proposed algorithm

In order to succeed in demonstrating the viability of the solution for the problem of a continuous identification and of adaptive and optimal running of the modelled manufacturing systems, a practical database resulted from the process measurements, obviously required. In the circumstancess for this, measuring and monitoring the drilling process were made, whose results are summarized in the Table 1. Analysis of the cluster is a descriptive technique used for grouping similar entities from a data set or, equally for entities that present evidence of substantial differentiation from the group. Differing technics of data clustering are based on algorithms from the neural networks.

Clustering variables consist in grouping variables which are in a relationship of dependency. Thus, using "best NN model", the choice of many consecutive columns and determination of the best links with the 1, 2 or i variable, we determine the cluster of variables which are in the best relationship of dependency. For example, in Table 1, considering the drilling process variables that denote the V_1, V_2, ..., V_{10} and using the "best NN model" facility, results the column V_7 - time of drilling, as the most influential variable in determining the cost of operation. The best relationships are with dependent columns V_3 and V_5.

Clustering states:

Suppose that the manufacturing system is required to execute an operation that $V_3 = 4$, and $V_5 = 0.6$, which you don't find in our experiment.

Clustering states consists in identifying groups of related records that can be points of departure for further exploration of relationships. In the process of grouping elements it is necessary to estimate the minimum distance between those elements and the function:

$$d = \sqrt{\left(V_3 - 4\right)^2 + \left(V_5 - 0{,}6\right)^2} \qquad (2)$$

The mathematical model

Mathematically, we can wrote a linear relationship such as:

$$V_7 = a \cdot V_3 + b \cdot V_5 \qquad (3)$$

Retaining the first 2 states, so for k = 2, according to k-NN the algorithm can be written:

$$\begin{cases} a \cdot 4 + b \cdot 0{,}55 = 4645 \\ a \cdot 4 + b \cdot 0{,}65 = 2410 \end{cases} \qquad (4)$$

which represents a system of two equations with two unknown elements. Finding the system's solutions we obtain the values for *a* and, respectively, *b* which are replaced in the relationship (3) resulting relationship (5).

$$V_7 = 4234{,}375 \cdot V_3 - 22350 \cdot V_5 \qquad (5)$$

The linear model so determined will be used in modelling the task-cost relationship. This is a local model, that is only valid in the vicinity of the state in connection with which it is interrogated and ephemeral because after the query it is dropped. Taking the reasoning again we modelled the relationship between task and price. In this case, we found that the influence variable is variable V_9, using "best NN model". Similarly on determine:

$$V_9 = 13285{,}68 \cdot V_3 - 80378{,}5 \cdot V_5 \qquad (6)$$

If we consider the price of a constant value that is 20% more than the average cost, we can express the profit rate for each task using the relationship (1).

Returning to our example above, the $V_3 = 4$ and $V_5 = 0.6$, it follow that the same steps as in modelling relationships: cost-task and task-price we obtain the model task-performance, for taking the influence variable, V_8.

$$V_8 = 55{,}35 \cdot V_3 - 334{,}9 \cdot V_5 \qquad (7)$$

As a conclusion, if we introduce variations of the process parameters and a variable restriction, we can get a table of solutions that will help us find common solutions through negotiation between the customer's requirements and the possibilities of economic and technical producer.

4. CONCLUSIONS

Note that 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 we have to do with a function of anticipation.

The proposed method has the advantage of being applicable to any manufacturing system, regardless the physical nature of the process and the product features. The method provides the extended modelling of the manufacturing system.

The level of extension is only limited by the number of the monitored state variables.

The level of the modelling accuracy satisfies both the requirements specific to a contract negotiation and the ones specific to the operational management.

The developed algorithm allows the identification of the variables of one model that represents the relation between the output and the input model. This relation represents a technical-economical model that can control one manufacturing process without requesting experiments and based on the extraction of the knowledge from the previous experience.

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