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TECHNO-ECONOMIC METHOD FOR EVALUATION AND SELECTION OF FLEXIBLE MANUFACTURING SYSTEMS (FMS)

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To find best FMS solutions, experts use numerous multicriteria methods for evaluation and ranking, methods based on artificial intelligence, and multicriteria optimization methods. Presented in this paper is a developed techno-economic method for evaluation and selection of FMS based on productivity. The method is based on group technology (GT) process planning.

Key words: techno-economic method, flexible manufacturing systems, productivity, group technology

Tehnoekonomska metoda za ocjenu i izbor fleksibilnih tehnoloških sustava (FTS). Za izbor najpovoljnijih rješenja FTS koriste se brojne multikriterijske ekspertske metode vrijednovanja i rangiranja, metode ustrojene na primjeni umjetne inteligencije, kao i metode multikriterijske optimizacije. U ovom radu prikazuje se razvijena tehnoekonomska metoda za ocjenu i izbor FTS na temelju proizvodnosti. Metoda je utemeljena na tehnološkim osnovama koje se obrazuju na principima grupne tehnologije (GT).

Gljučne riječi: tehnoekonomska metoda, fleksibilni tehnološki sustavi, proizvodnost, grupna tehnologija

INTRODUCTION

The complexity of cost-effective exploitation of flexible manufacturing systems (FMS) – which require high costs for production launch, on the one hand, while allowing cost-effective exploitation, on the other hand – the efforts put into comprehensive techno-economic analysis during their design and application are well justified. Clearly, the economic effects are influenced by the market, as well as the own ability to develop, improve, and adjust one's production program. Considering the high costs of FMS exploitation, all stages of their lifecycle must be analyzed, focusing on the required and possible techno-economic effects of their application [1].

Flexible manufacturing systems can be developed with various levels of automation, and autonomous functioning of particular technological systems, which depends on flexibility, mobility, accuracy and reliability, Figure 1 [2].

The design of FMS, as well as the selection of a readily available FMS for particular types of manufacturing, usually involve several variants of solutions. There are a number of multicriteria methods for evaluation and ranking of these variant solutions [3], methods which are based on artificial intelligence [4], and methods which are based on multicriteria techno-economic optimization.

Techno-economic method for evaluation and selection of FMS is based on group technology process planning. The proposed method involves analysis of parts from the production program, and application of group and type technology. This approach is based on classification of parts into technological groups, according to similarity of their design and manufacturing features. GT process plans are then designed for the parts which represent various technological groups. Thus designed, group process plans allow efficient evaluation of effects of FMS application, as well as their appropriate selection [5].

The proposed method can be successfully used for evaluation of optimal design and application solutions of flexible manufacturing cells, while other authors have applied other methods [6 - 10].

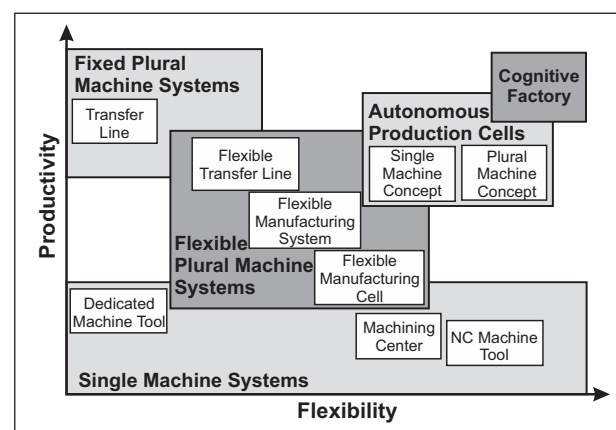


Figure 1 Comparison of manufacturing systems according to productivity and flexibility [2]

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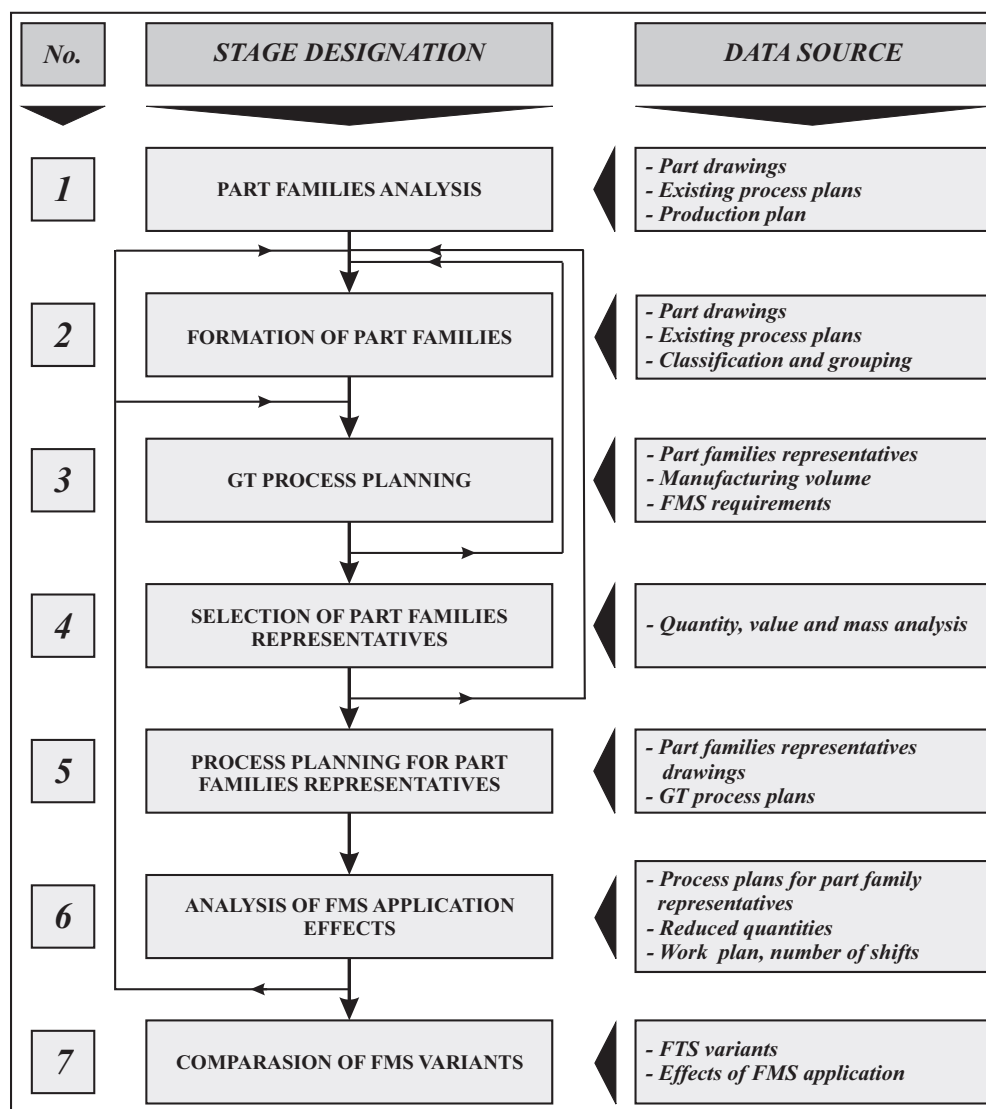


Figure 2 Model of the techno-economic method

OVERVIEW OF THE DEVELOPED METHOD

Although the above mentioned FMS characteristics pertain to their design, similar can be said of their application. The problem of FMS application is mostly related to process planning and optimization which, on the other hand, must be adjusted to particular FMS characteristics and limitations.

Techno-economic method whose model is shown in Figure 2, can be successfully used to solve both of the discussed problems.

Techno-economic method is based on the results of years of research authors by this paper, example [5], and applied in paper [11]. It is based on a synthesis of knowledge wch concerning the basic principles of group technology [12], and the possibilities of applying these principles [13].

Phases of the application of developed method

The first stage in development and application of the proposed techno-economic method involves analysis of

production program. Thus, for example, Figure 3 illustrates the structure of electromotor production program which, according to market demands, was modified from mass to batch production, with the appropriate level of automation and flexibility of manufacturing equipment.

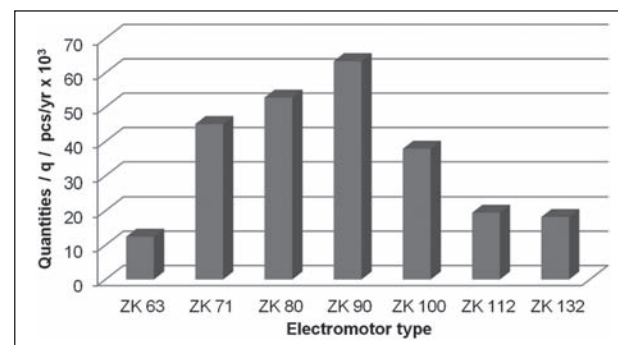


Figure 3 The structure of production program

The second stage involves forming of part families, while the third stage pertains to group process planning for the particular part families.

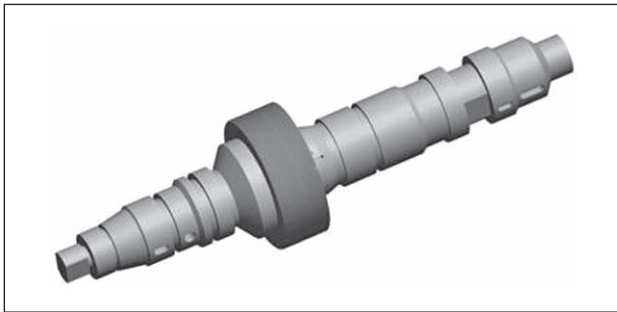


Figure 4 Complex part of the rotor of ZK electromotor

In case of the considered ZK electromotor production program, three basic part families were formed housings, rotors and covers.

Table 1 GT process plan for the rotor of a ZK electromotor

Process number	Process designation	Machine type
10	Cut-off	Metalsaw
20	Annealing	Heat Treatment
30	End machining	NC milling machine for end machining
40	Turning	Turning FMM
50	Metal sheet processing	Hydraulic press
60	Turning II	Turning FMM
70	Grinding	Grinding FMM
80	Balancing	Balancing device
90	Control	Control

For the three part families, process plans were designed to accommodate new production environment.

GT process plans are designed based on complex parts for each part family [12]. Thus, for example, for the ZK electromotor part family the representative complex part is shown in Figure 4. Based on this complex part, group technology for manufacture of ZK electromotor was designed, Table 1.

Group process plan for particular part family defines the types of FMS required for machining processes, while the detailing of particular group machining processes allows the selection of the required level of FMS automation and flexibility [2], [8].

Group process plans and group machining processes can be designed for any part based on the data from engineering drawings, including the complex parts which represent particular part families [12]. These representatives can be selected by ABC method, given the appropriate data [13] which are shown in Table 2 for ZK electromotor part family.

Application of the ABC method for the selection of this part family (Figure 5) shows that rotors of electromotors, ZK 90 and ZK 100, have almost identical quantity, value and mass parameters within the production program. Based on additional analyses of market demands, it was established that model ZK 90 had greatest demand, which made it suitable for the representative of

Table 2 Data required for the selection of representative part for the family of ZK electromotor rotors

No	Electromotor ZK designation	Quantity / q	Price / €		Mass / m	
		pcs/yr	€/pcs	€/yr	kg/pcs	kg/yr
1	ZK 63	12 450	3,07	38 196	2,61	32 495
2	ZK 71	45 100	3,81	171 643	3,24	146 124
3	ZK 80	52 800	6,31	333 204	5,37	283 536
4	ZK 90	63 400	10,71	678 934	8,98	569 332
5	ZK 100	37 900	17,98	681 464	15,31	580 249
6	ZK 112	19 450	18,25	355 010	15,54	302 253
7	ZK 132	18 200	31,59	574 979	26,9	489 580
TOTAL:		249 300	-	2 833 429	-	2 403 569

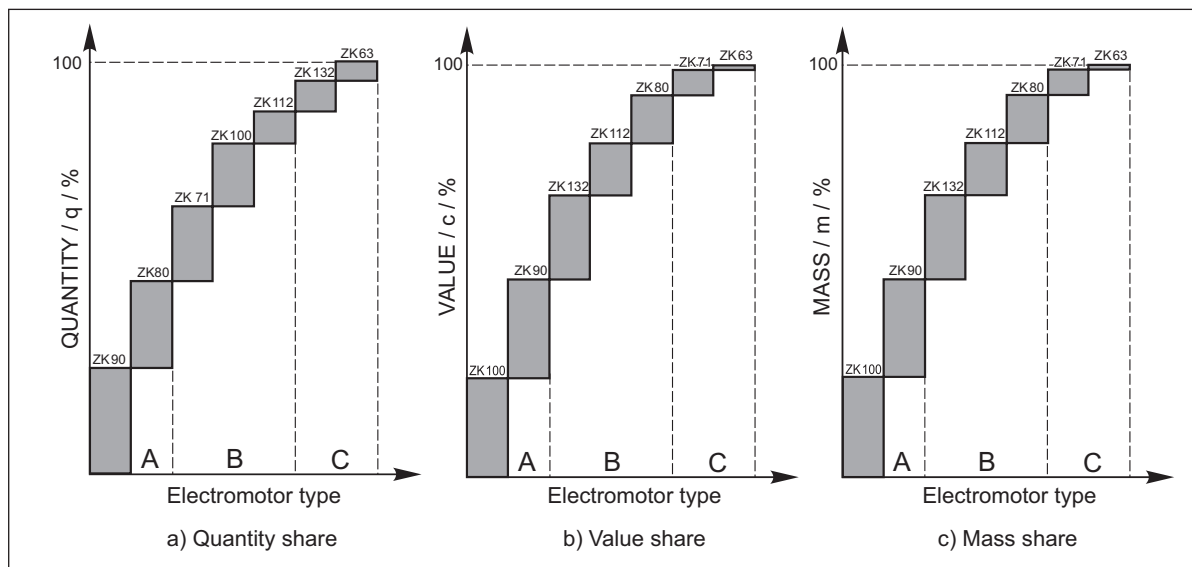


Figure 5 Quantity, Value and Mass ABC analysis of ZK electromotor rotor

rotor part family, at the production rate of 100 batches per year.

In fact, process planning for the complex part as part family representative requires precise definition of particular group machining processes based on engineering drawings, including determination of machining times, later used for effectivity study and selection of FMS.

EFFECTIVITY STUDY OF FMS AND ITS SELECTION

As stage six of the proposed method, the effectivity study of novel FMS solutions or application of existing FMS is founded on productivity, which can be determined based on machining process times for complex parts.

Machining time (t_k) for a process performed on a particular FMS can be calculated as:

$$t_k = t_g + t_a + t_p + t_{pz} + t_i \tag{1}$$

where (min/pcs):

- t_g – machining time,
- t_a – auxiliary time,
- t_p – tool replacement and adjustment time,
- t_{pz} – setup time, and
- t_i – idle time.

Partial and total machining times for the machining processes Turning I and Turning II performed on the complex part which represents the rotor part family of ZK 90 electromotor, are given in Table 3. Machining is performed on flexible manufacturing modul INDEX GU 800.

Table 3 **Times for turning processes on the complex part of the rotor (ZK 90)**

Process Designation	T_{pz}	T_{pzm}	t_g	t_p	t_k
	min/batch		min/pcs		
Turning I	20	40	1,0	0,3	1,38
Turning II	20	40	1,2	0,3	1,58

where:

- T_{pz} – setup time, (min/batch)
- T_{pzm} – intermediate setup time, (min/batch)

FMS productivity for machining processes

FMS productivity for a particular machining process is determined as follows:

$$Q = \frac{1}{t_k} \tag{2}$$

For the machining operations, productivity per shift is calculated in following way:

$$Q = \frac{\theta_m \cdot 60}{t_k} \tag{3}$$

For the example of turning processes performed on the complex part for rotor of ZK90 electromotor, Table

Table 4 **FMS productivity for turning processes, complex part for ZK rotor part family**

Parameter designation	Notation	Process designation	
		Turning I	Turning II
Useful time capacity	θ h/shift	8	8
Effective operating time	θ_m h/shift	7,5	7,5
Productivity per shift	Q pcs/shift	326	285

4 presents the required data and the resulting productivity per shift.

By comparing FMS productivities, for both design of novel solutions and selection of existing ones, it is possible to select the most favourable solutions for the particular machining processes which is based on maximum productivity. This is the final stage in application of the proposed techno-economic method.

CONCLUSIONS

The developed techno-economic method allows determination of most favourable FMS solutions, either during development and design, or for the selection of existing FMS solutions to be applied in manufacturing.

Evaluation of effects of FMS application - based on productivity, which uses times of machining processes for complex part representatives of particular part families - can be used in both of the cases.

The developed techno-economic method is sufficiently rational thanks to the fact that process planning as well as complex part selection are based on the principles of group technology.

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Note: The responsible translator for English language is O. Lužanin, Faculty of Technical Science, Novi Sad, Serbia