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SCHEDULING OPTIMIZATION OF FLEXIBLE MANUFACTURING SYSTEM USING GENETIC ALGORITHMS

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Abstract: *In order to be more competitive on global market, many manufacturing companies have increased the use of flexible manufacturing systems (FMS). The flexibility is reached by making innovative technical and organizational efforts. The scheduling of FMS is complex especially when the system has to accommodate to frequent variations of incoming jobs due to respond quickly to changing customer preferences. A very important issue is to reduce set-up or changeover costs. The FMS scheduling problem has been approached by various traditional optimization techniques. This paper presents the scheduling optimization of flexible manufacturing system using genetic algorithms. The objective function that is minimized represents the global transition cost. The results obtained are compared with those obtained by other scheduling rules and conclusions are presented.*

Keywords: *optimization, genetic algorithms, flexible manufacturing system, scheduling.*

1. Introduction

In the context of rapidly reducing life of technologies and products life cycle, FMS must deal the demand of the customers for personalized products. To sustain competitiveness in dynamic markets, manufacturing organizations must attain the required flexibility to produce the needed variety of products.

FMS represent a class of automated manufacturing systems consisting of three main parts: a processing system including a number of numerically controlled machines with multifunction ability, an automatic material handling system for linking these machines and a computer control system which controls material movement and machine flow [1].

In traditional manufacturing systems, as the variety of products is increased the productivity decreases. FMS combine the productivity of flow lines with the flexibility of job shops. FMS submit the economies of scale normally associated with flow lines, while maintaining the flexibility required for mid-volume small- and medium-lot-size production of a variety of parts. Commonly, FMS is adequate for the mid-variety, mid-volume production range [2].

2. Transition costs

In FMS take place multiple changes, but, from flexibility point of view, the most important changes occur because of different production tasks. In FMS several products are manufactured due to system aptitudes set. The state of the system (S_i) is generated by activating the FMS aptitude of manufacturing a product type using the adequate technology. When in FMS the production is changed from one product to another, the state of the system is changing too. This modification is called *transition* [3] (see figure 1).

Depending on the products input sequence in FMS there are different transition costs. The products input sequence in the system is efficient when the global transition cost is reduced.

In the FMS scheduling problem there are two important types of decisions to be made. One is to establish a sequence to release parts into a system, which is called the part input problem. The other is to determine a schedule for operations of released parts by establishing when (in what sequence) and where (on which machine) operations of parts are to be processed [4].

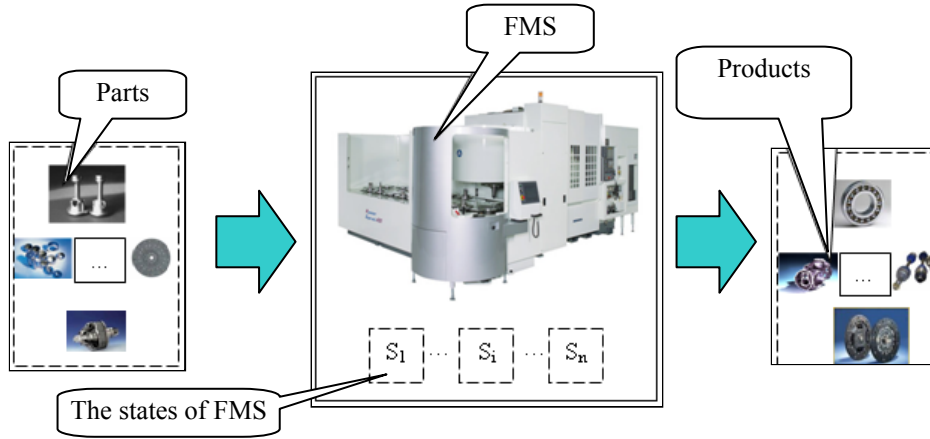


Fig. 1 The FMS transition

In this paper the input sequence of a given sets of parts to be released into an FMS with the objective of minimizing the global transition cost is determined.

The intricacy of the scheduling problem in FMS suggests the adoption of heuristic methods producing reasonable good schedules in reasonable time instead of looking for an exact solution. Most of the researches have adopted predetermined sequencing for the parts input. A transition cost results whenever the system switches from processing one part-type to another. If the part types manufactured in FMS are „n”, then the sequences of the parts are n! ways (i.e. if the system manufactures 15 part types, there are 1.307.674.368.000 possible sequences for parts input).

Starting from the FMS transition costs, from any of the possible states towards required state of processing a particular part type, there is designed a matrix, called transition cost matrix. This matrix provides the system switching cost from its present state to the one required of processing any other part type. The transition costs matrix pattern is shown in figure 2.

	S₁	...	S_j	...	S_m
P₁	0	...	c_{1j}	...	c_{1m}
.
.
P_i	c_{i1}	...	c_{ij}	...	c_{im}
.
.
.
P_m	c_{m1}	...	c_{mj}	...	0

Fig. 2 The transition costs matrix [3]

where:

$S = \{S_1, \dots, S_j, \dots, S_m\}$ – the set of FMS states;

$P = \{P_1, \dots, P_j, \dots, P_m\}$ – the set of products type which are going to be processed in FMS.

Each product type P corresponds an S FMS state, which means the transition costs matrix is a square (mxm) one.

The items of the matrix are the following:

$$\begin{cases} c_{ij} > 0, i \neq j; \\ c_{ij} = 0, i = j. \end{cases} \quad (1)$$

Generally:

$$c_{ij} \neq c_{ji} \quad (2)$$

A typical element c_{ij} represents the transition cost associated with FMS changeover from S_j state towards S_i state. The c_{ij} cost is obtained by summing all setup (change in structure, hardware and software components) costs.

3. Problem description

In [3] two FMS (2 case studies) were defined. The first FMS processes 9 products, and the second 15 products. The flexibility effort of the systems is illustrated by the transition cost matrixes, each of them having distinctive characteristics.

Table 1

The transition costs of the FMS [3]

	S₁	S₂	S₃	S₄	S₅	S₆	S₇	S₈	S₉
R₁	0	3	7	4	1	5	2	6	8
R₂	2	0	1	6	4	3	8	5	7
R₃	3	1	0	8	4	2	7	6	5
R₄	1	3	7	0	2	5	4	6	8
R₅	1	5	8	6	0	4	2	3	7
R₆	4	5	7	8	3	0	6	2	1
R₇	3	6	8	7	2	4	0	1	5
R₈	4	6	8	7	2	3	1	0	5
R₉	4	5	7	8	3	1	6	2	0

The first matrix is obtained starting from the 9 products that are going to be processed in the FMS. In table 1 the transition costs of the FMS are shown. For example, when FMS processes part R_5 then the system has S_5 state. If after processing part R_5 the system is going to process part R_7 the system state is switching from S_5 state to S_7 state. The transition cost is c_{75} which, in the table 1 corresponds to 2 units, reflecting the system flexibility effort.

The problem solving consists in establishing the input sequence of the parts in FMS so the

system global flexibility effort is minimized. To process all the parts the FMS switches nine distinctive states.

The problem was solved in [3] by determining the minimum length of Hamiltonian path. The solution founded is the following Hamiltonian path: $R_2 - R_3 - R_6 - R_9 - R_8 - R_7 - R_5 - R_1 - R_4$. The length of this path, which represents the FMS global transition cost, is 14 units.

The second matrix contains the transition costs of the FMS (see table 2).

Table 2

The transition costs of the FMS [3]

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}
R_1	0	5	9	8	14	12	13	10	2	6	4	7	3	11	1
R_2	2	0	10	9	13	12	14	11	4	7	6	5	3	8	1
R_3	10	13	0	1	6	5	7	4	8	2	3	11	9	14	12
R_4	9	13	1	0	8	4	10	2	5	6	3	11	7	14	12
R_5	12	14	5	4	0	2	1	3	10	6	8	7	11	9	13
R_6	12	14	5	4	2	0	3	1	10	8	6	7	11	9	13
R_7	12	14	4	5	1	2	0	3	10	6	9	8	11	7	13
R_8	12	14	5	4	2	1	3	0	9	10	7	6	11	8	13
R_9	2	5	8	7	12	11	13	10	0	6	1	9	4	14	3
R_{10}	5	7	2	4	11	10	12	9	3	0	1	8	4	13	6
R_{11}	3	6	8	7	12	10	13	11	1	5	0	9	2	14	4
R_{12}	4	2	8	6	12	11	13	9	7	10	5	0	1	3	3
R_{13}	2	5	9	8	13	12	14	11	4	7	3	6	0	10	1
R_{14}	9	2	13	10	7	5	8	4	12	14	11	1	3	0	6
R_{15}	1	3	9	8	13	12	14	10	4	7	5	6	2	11	0

The problem solving consists in establishing the input sequence of the parts in FMS so the system global flexibility effort is minimized. To process all the parts the FMS switches fifteen distinctive states.

The problem was solved in [3] by determining the minimum length of Hamiltonian path. The solution found is the following Hamiltonian path: $R_{14} - R_{12} - R_4 - R_8 - R_5 - R_7 - R_6 - R_3 - R_{10} - R_{11} - R_2 - R_{13} - R_{15} - R_1 - R_9$. The length of this way, which represents the FMS global transition cost, is 35 units.

4. Results

In the first case study, where the FMS processes nine products, after running the genetic simulation, three solutions corresponding to three possible inputs sequencing of parts in the system were found. The solutions are the following:

a. $R_4 - R_1 - R_2 - R_3 - R_6 - R_9 - R_8 - R_7 - R_5$;

b. $R_4 - R_5 - R_1 - R_2 - R_3 - R_6 - R_9 - R_8 - R_7$;

c. $R_4 - R_2 - R_3 - R_6 - R_9 - R_8 - R_7 - R_5 - R_1$.

All three solutions generated from genetic simulation correspond to a FMS flexibility effort (global transition cost) of 13 units. So, the genetic simulation provides a 7% better solution than the one from [3].

In the second case study, the FMS process 15 products. After running the genetic simulation two solutions corresponding to two possible inputs sequencing of parts in the system were found. The solutions are the following:

a. $R_7 - R_5 - R_6 - R_8 - R_4 - R_3 - R_{10} - R_{11} - R_9 - R_1 - R_{15} - R_2 - R_{14} - R_{12} - R_{13}$;

b. $R_5 - R_7 - R_6 - R_8 - R_4 - R_3 - R_{10} - R_{11} - R_9 - R_1 - R_{15} - R_2 - R_{14} - R_{12} - R_{13}$.

Both solutions generated from genetic simulation correspond to a FMS flexibility effort (global transition cost) of 29 units. So,

the genetic simulation provides a 17% better solution than the one from [3].

For genetic simulation the genetic algorithms software of the TUC-N Center of Consultancy and Optimal Design was used.

5. Conclusions

The results obtained after optimizations with genetic algorithms in both case studies are better than in [3] (see figure 3). When the FMS processes 15 parts the solutions provided by genetic simulation are 17% better. Which means that the FMS global flexibility effort and, implicitly the global transition cost is decreased with 17%.

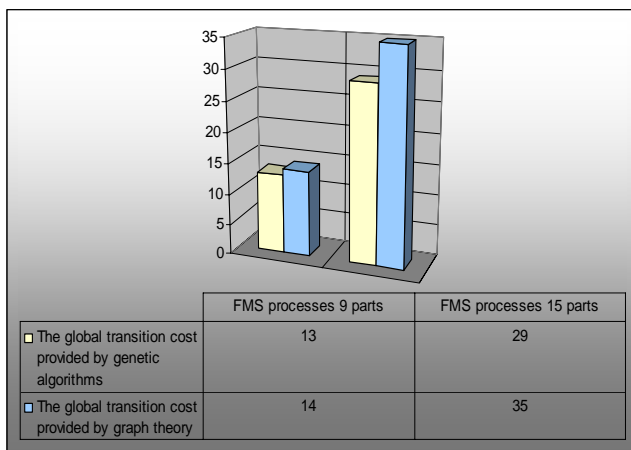


Fig. 3 Global transition costs

When the FMS processes 9 parts the solutions provided by genetic simulation are 7% better. Which means that the FMS global flexibility effort and, implicitly the global transition cost is decreased with 7%.

The genetic simulation provide two solutions for the 15 items input sequence in the FMS and three solutions for 9 items input sequence in the FMS. This represents an important advantage, because the operations manager has the possibility to choose from different items input sequence in the FMS when the global transitions costs are the same.

Also, the genetic simulation provided, excepting a global optimum, several local optimums which represent possible choices for the FMS operations managers if that the best solution can't be implemented by various reasons.

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OPTIMIZAREA PROGRAMĂRII UNUI SISTEM FLEXIBIL DE FABRICAȚIE UTILIZÂND ALGORITMI GENETICI

Rezumat: Pentru a fi mai competitive pe piață, multe companii manufacturiere și-au extins utilizarea sistemelor flexibile de fabricație (SFF). Flexibilitatea este obținută prin intermediul inovațiilor tehnologice și eforturilor organizaționale. Programarea SFF este o problemă complexă îndeosebi atunci când sistemul trebuie să se adapteze în mod adecvat la frecvențele variații ale sarcinilor de producție pentru a răspunde în timp util la preferințele atât de schimbătoare ale clienților. Un aspect deosebit de important îl reprezintă reducerea costurilor de tranziție sau costurile de pregătire-încheiere. Pentru rezolvarea problemelor de programare a SFF literatura de specialitate propune numeroase metode de optimizare tradiționale. Această lucrare prezintă optimizarea programării unui sistem flexibil de fabricație utilizând algoritmi genetici, având ca scop minimizarea costului global de tranziție. Rezultatele obținute sunt comparate cu cele provenite din utilizarea altor metode de programare.

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