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Design of Machine Layout in Flexible Manufacturing Systems

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Abstract: The paper presents a model of designing of machine layout in flexible manufacturing system (FMS). Evolutionary computation, particularly genetic algorithms (GAs) proved to be successful in search of optimal solution for this type of problems. To achieve high productivity in a flexible manufacturing system (FMS), an efficient layout arrangement and material flow path design are important due to the large percentage of product cost that is related to material handling. In this connection, the required number of rows and the sequence of machines in the individual row are established by means of GA. In the end the test results of the application made and the analysis are discussed.

Keywords: *Flexible Manufacturing System, GA, Design, Optimisation.*

I. INTRODUCTION

Layout of flexible manufacturing system (FMS) involves distribution of different resources in a given FMS and achieving maximum efficiency of the services offered. With this in mind FMSs are designed to optimize production flow from the first stage as raw material to the finished product. The layout of the facilities has a direct impact on the production time and cost, especially in the case of large FMS, It was estimated that 20–50% of the manufacturing costs are due to handling of work pieces; by a good arrangement of machines it is possible to reduce the manufacturing costs up to 10–30% [1]. Some other authors report even higher percentage of material handling based costs. For example Chiang and Kouvelis report that 30–70% of total manufacturing costs may be attributed to the layout and material handling. Therefore, in the early stage of designing an FMS itself, it is necessary to have an idea of the layout of the machines. Genetic Algorithms (GAs) are adaptive heuristic search algorithms premised on the evolutionary ideas of natural selection and genetics. The basic concept of GAs is designed to simulate processes in natural system necessary for evolution; specifically those that follow the principles first laid down by Charles Darwin "Survival of the Fittest"[2]. As such they represent an intelligent exploitation of a random search within a defined search space to solve a problem. They make extensive use of artificial intelligence. First pioneered by John Holland in the 60s, Genetic Algorithms have been widely studied, experimented and applied in many fields in the engineering world. Not only does GA provide an alternative method to solving problem; it consistently outperforms other traditional methods in most of the problems. Hassan and Albin [3] give an extensive study on the type of data required in the machine layout problem.. The problem of arranging of devices is one of so called NP problems. The problem is theoretically solvable also by testing all possibilities (i.e. random searching) but practical experience shows that in such manner of solving the capabilities of either the human or the computer are fast exceeded. For these reasons we proceed to design the flexible manufacturing system by genetic algorithms. In this way we designed the flexible manufacturing system whose devices are arranged in one or multiple rows.

II. MODEL OF ARRANGEMENT IN ROWS

Prior to solving the problem we set ourselves the limitations that will be taken into account[4]. These limitations are:

- all machines are of rectangular shapes,
- the machine is operated in the centre of that space,
- All machines in the row look into the same direction

When searching for the solution by genetic algorithms it is necessary to determine the target function which, in our case, is the sum of variable costs in a time period. For such manners of solving of the problem it is necessary to know the matrix of the transport quantities between the individual devices *N* in a time period [4]. Also the variable transport costs, depending on the transport means used, must be known.

A. Fitness Function

In order to find by means of these data the optimum layout of the devices *N*, we must find the optimum of the following target function:

$$Z = \min \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} f_{ij} L_{ij}$$

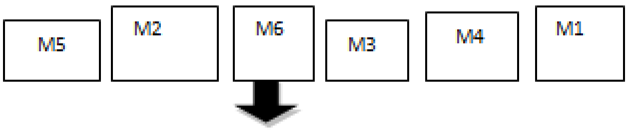
Where f_{ij} is the frequency of transport between the devices *i* and *j*, C_{ij} are the variable transport costs for the quantity unit and L_{ij} is the distance between the devices *i* and *j* [3]. The number of all devices is equal to *N*. The costs of transport between two devices can be determined if their mutual distance L_{ij} is known. During execution of the genetic algorithm, the values f_{ij} and C_{ij} do not change, the value L_{ij} changes with respect to the mutual position of devices and with respect to position in the arrangement. In order to determine L_{ij} we need also the dimensions of the devices, the minimum available distances between the devices, the widths of the transport paths and coordinate of the points of operating.[4]

III. GENETIC ALGORITHM

GAs are a new approach to solving complex problems such as determination of machine layout; they can be defined as meta-heuristic based system. GAs became known through the work of John Holland in the 1960s. The GA's contain the elements of the methods of blind search for the solution and of directed and stochastic search and thus compromise between the utilization and search for solution. At the beginning, they search in the entire search space and afterwards, by means of crossover, they search only in the surrounding of the promising solutions. So GAs employed random, yet directed search for locating the globally optimal solution [7]. GA's employ the vocabulary taken from the world of genetics itself, and as a result solutions refer to organisms (genotypes) of a population. Each organism represents the code of a potential solution to a problem and the changeover of this code to a real variable is called phenotype. An important characteristic of it is that GAs work by maintaining a population of potential solutions, whereas the other search methods process a single point of the search space. The typical steps required to implement GAs are encoding of feasible solutions into organisms using a representation method, evaluation of fitness function, selection strategy, setting of GAs parameters and criteria to terminate the process. Because of their properties, the GA were used for searching for the optimal (or near optimal) design of the FMS.

A. Representation of Organisms

Each organism represents one of the possible solutions of the problem of arranging and each gene represents one machine. The most natural coding called Permutation representation as shown in Fig. 1 is used for such types of problems .The sequence of genes in organism is equal to the sequence of working machines of the FMS. If we have, for example, six working devices arranged in a row, the genotype of the organism (the sequence) can be equal to:



[M5 M2 M6 M3 M4 M1]=[5,2,6,3,4,and 1]

Figure 1: Coding of organism

Where the gene m_i represents the machine *i* and its position in the organism represents the position in the row. However, such gene would represent the arrangement in one row only.

Based on the parameter of length of row the arrangement into rows is determined. The number of machines in one row is limited to the maximum length of row *a*. When the length of the row is greater than *a*, the next machine is placed into a new row. The procedure repeats, until all machines have been arranged into rows. Arrangement into rows is shown in Fig. 2.

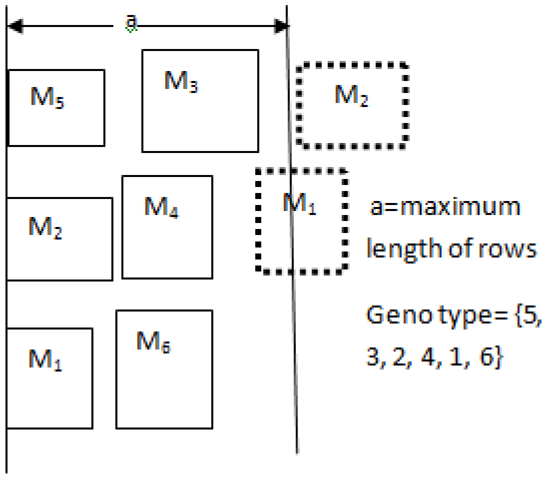


Figure 2: Arrangement in rows

The parameter *a* can be determined in advance and it represents the width of the space available. Selection of the parameter *a* can also be left to the genetic algorithm. In this case, in order to avoid formation of illegal organisms we limit the selection of the parameter *a* to a interval reaching from the length of the longest device to the sum of the lengths of all devices with appurtenant intermediate spaces (layout in one row only).On the basis of the parameter *a* the arrangement into rows is determined. So many devices are arranged into the row, that the length of the row does not exceed the parameter *a*. When the length of the row is equal to the length *a*, the next device is placed into a new row. The procedure repeats, until all devices have been arranged into rows. Such manner of coding guarantees that all organisms are correct even after completion of genetic operations [5].

IV. RESULTS AND DISCUSSIONS

Numerical example 1

The calculation of numerical example presented was done on standard PC P4 desktop computer [Pentium (R) 4CPU 2.0 GHz, 1 GB of RAM].

Inputs:

The machine dimensions are given in Table1 and frequency matrix is

$$f_{ij}=\begin{bmatrix} 0 & 25 & 35 & 50 & 0 \\ 25 & 0 & 10 & 15 & 20 \\ 35 & 10 & 0 & 50 & 10 \\ 50 & 15 & 50 & 0 & 21 \\ 62 & 24 & 41 & 21 & 15 \\ 0 & 20 & 10 & 15 & 0 \end{bmatrix}$$

The cost matrix to move an average load through unit distance is considered as unit matrix and Clearance matrix is given as:

$$d_{ij}=\begin{bmatrix} 0 & 3.5 & 5 & 5 & 5 \\ 3.5 & 0 & 5 & 3 & 5 \\ 5 & 5 & 0 & 5 & 5 \\ 5 & 3 & 5 & 0 & 5 \\ 5 & 5 & 5 & 5 & 5 \end{bmatrix}$$

Table 1: Dimensions of the machines

Machine Number	Dimensions (L×B)
1	25.0 ×20.0
2	35.0 × 20.0
3	30.0 × 30.0
4	40.0 × 20.0
5	35.0 × 35.0

The parameters of GAs depend largely on the characteristics of each particular problem [13].
However, in spite of that the guidelines for selection of evolutionary parameters can be defined. The values of evolutionary parameters were:

Parameters for single row:

- Probability of crossover: 0.95;
- Probability of mutation: 0.05;
- Population size: 20 organisms.
- Number of generations; 50

By using GA programme coded in c the optimum arrangement of departments which Minimizes cost is shown in Fig 2.

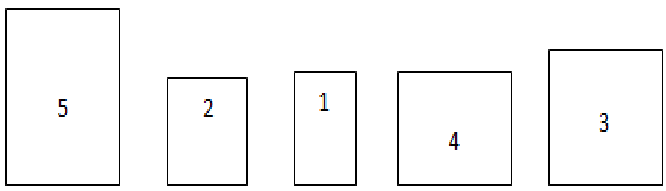


Figure 3: optimum arrangement of machines

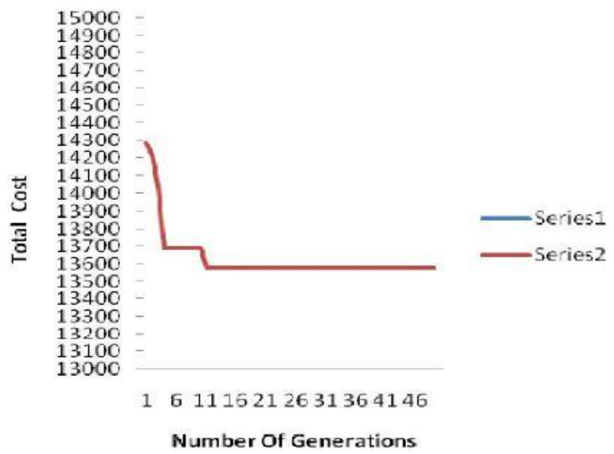


Figure 4: Variation of total cost with Generations

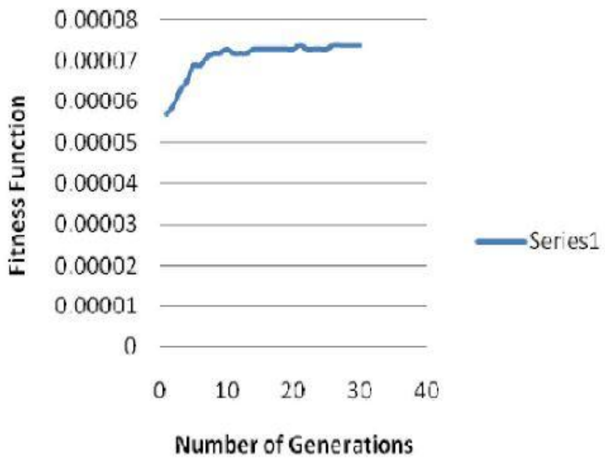


Figure 5: Variation of fitness function with generations

From the above graph Fig 4 the minimum material handling cost is obtained as Z=13579 and the optimum layout of machines are as shown in fig 3 and is obtained in 11th generation. Fig 5 shows the variation of fitness function with number of generations

FOR MULTI ROW:

Parameters for multi row:
- Probability of crossover: 0.7;
- Probability of mutation: 0.3;
- Population size: 30 organisms.
- Number of generations; 30

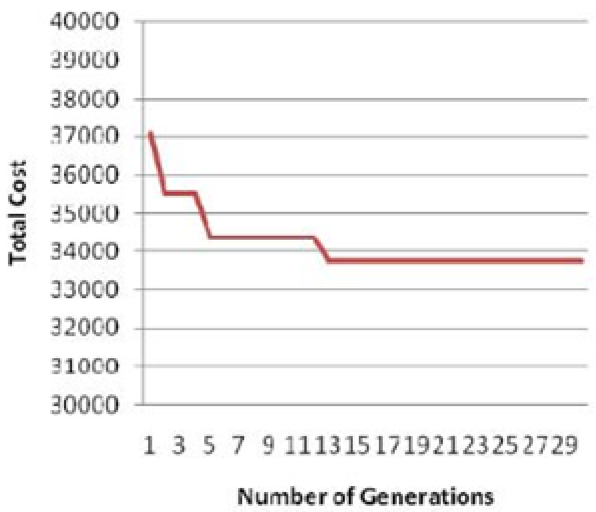


Figure 6: Variation of total cost with Generations

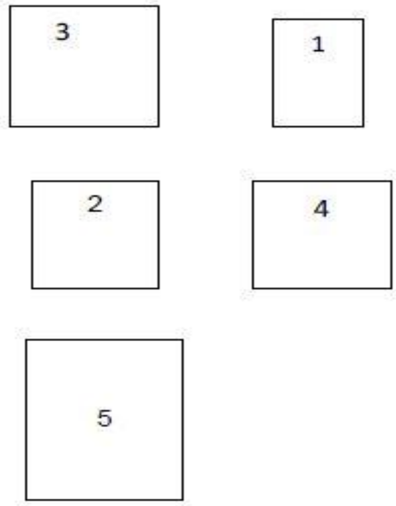


Figure 7: Optimum arrangement of machines

From the above graph Fig 6 the minimum material handling cost is obtained as Z=33388 in 13th generation and the optimum layout of machines are as shown in fig 7.

CONCLUSIONS

This section represents computatiion results by the GA algorithm for both single and multi row for the tested problem. The results have been presenteted in fig.3 for single row and fig 7 for multi-row.From fig 4 it can be observed that at generation 11 the minimum cost is obtained and it is 13579..From fig 6 it can be observed that at generation 13 the minimum cost is obtained and it is 33388.. By means of the presented method the optimum layout of the machines in the FMS can be found.

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