Minimization of Intercellular Movements in Cellular Manufacturing System Using Genetic Algorithm

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Abstract-Cell formation in cellular manufacturing is necessary to achieve desired productivity, efficiency and quality. Genetic algorithm so developed is applied in cellular manufacturing system to design cells. Cells are arranged according to certain criteria and are defined by objective function which is evaluated for chromosome in each population. Objective function is to minimize intercellular movements because it increase lead time, work in process, cost of material handling and fatigue of workers. Genetic algorithm is biological evolution and natural selection process which is alternatively used for solving complex optimization problems. A population consisting of ten chromosomes has been created randomly and objective function value is calculated for each chromosome. Using genetic operators ten generations have been created and objective function value of each chromosome calculated using MATLAB for each generation. In 10^{th} generation a chromosome with minimized objective function is achieved and encoded to design cells with minimum intercellular movements of parts. It has been learnt that about fifty percent intercellular movements have been reduced by Genetic algorithm.

Keywords-Cellular Manufacturing, Cross Over, Elitism, Genetic Algorithm, Mutation, Population, cell formation

I. INTRODUCTION

Group technology has wide applications, and it has become popular in shop floor layout design. The operational benefits of flow line production can be achieved by using Cellular Manufacturing (CM) System. A group of parts, which are similar in some properties, are brought on a machine group in cellular manufacturing system to perform various operations. CM provides excellent results in the courses of simulation, analytical, surveys and actual implementations. They are: Reduction of setup time, Condensed Lot sizes, Reduction in Work-in-process and finished goods inventories, Condensed Throughput time and Improvement in working flexibility. Cellular Manufacturing system consists of a group of machines forming different cells. These cells are specialized in producing a specific part family. Cellular manufacturing has also become popular where different machines are grouped into a cell which is specialized in producing part family. Part family can be defined in the way where some parts have similar shapes and sizes or have similar processes steps. In CM, the issue is development of an efficient cell. Many techniques have been described to cope with this issue. Three approaches are used for cell formation: (a) part-family grouping, in which part families are formed and then machines are grouped into cells; (b) grouping of machines, in which cells of machines are formed taking into account homogeneity in movements and parts are assigned to cells; (c) machine-part grouping, in which part families and machine cells are formed all together. In this paper, objective is minimization of inter-cellular movements of parts and the focus in our case is identification of parts or machines to be grouped into cell. The work has been carried out in Genetic Algorithm (GA), in which several generations are solved to achieve multiple objective function values and best chromosome with minimum objective function is encoded to get optimal solution. Mutation and cross over operators are used in GA and are responsible for next generation. In crossover, information is combined from two parents to new offspring or child. By using crossover operator, best genes are removed from many chromosomes and then recombining them into better offspring. In mutation, new offspring are generated by making random changes in existing generation. It adds diversity to the population and increase the likelihood that best fitness value of the chromosomes can be generated. By using GA both constraint and unconstraint problems can be solved and usually it is applied in complex system where no of machines and production is very high.

II. Literature Review

Manufacturing or production systems perform the conversion of raw materials into useful products or services .Effectiveness of any manufacturing system is dependent on quality, time and cost [1]. A cellular manufacturing system consists of different cells and each cell specializes in one type of task. Cells can be formed on the basis of objective function and objective may be the minimization of the sum of the machine constant and variable costs, inter- and intra-cell material handling, a reconfiguration costs and this objective was achieved using simulated annealing [2]. Multi objective scheduling criteria can be used in CMS to design cell which have minimum make span, intracellular movement, tardiness, and sequence-dependent setup costs, using heuristic techniques [3]. Multi objective scheduling criteria can be used in CMS to design cell which have minimum make span, intracellular movement, tardiness, and sequence-dependent setup costs, using heuristic techniques [4].The objective of cell formation may be the presence of alternate process routings, operation sequence, duplicate machines, machine capacity and lot splitting. A mixed integer non-linear program was used to solve cell design problems [5]. Genetic algorithm is also being used to design cells with dynamic conditions and it provides best solution in any complexity of dynamic situation [6]. A multiobjective dynamic cell formation is carried out using genetic to minimize machine cost, inter-cell material handling cost, and machine relocation cost [7].When local search heuristic approach is combined with genetic algorithm it provides best optimal solution to cellular manufacturing system problems [8]. Genetic algorithm is being used in cellular manufacturing system, and their objective was the minimizing the interaction among cells [9]. The local search algorithm when combined with genetic algorithm provides intensified and diversified way to solve complex problems of cellular manufacturing system [10]. Genetic algorithm is more efficient algorithm as compared to CRAFT and entropy based algorithm and provides solution of problems with minimum total cost [11].Genetic algorithm can handle multiple objective functions i.e. Material handling costs, aspect ratio, closeness and distance requests.[12]

III. Research Methodology

GA is revolutionary algorithm and based on theory of evolution in organisms. It is being used to solve optimization problems which cannot be solved using traditional approaches. Formation of cells and movements from intercellular minimization is resolved using GA. It has capability of producing multiple solutions of single or multiple objective functions while traditional methods of optimization can produce one solution and probability of best result is less. Step wise GA coding in Cellular Manufacturing system is given as follows:

1. Parts routing from one machine to another is defined. Routing of all parts in different station is identified and a part /machine matrix is developed. Number of machines is eight and number of parts to be routed is nine.
2. Objective function on which formation of cell is carried out is defined and the objective is to reduce total number of movements of different parts in the cells.
3. GA is implemented to solve the problem of cell design and while implementing GA initial criteria is set i.e. Elitism, mutation, crossover, generation gap, population size and number of generation.
4. Initially a random chromosome is generated which consists of gene and represents one machine. Total number of genes in chromosomes is eight and each gene represents a machine and number of machines under consideration is eight.
5. Each digit in a chromosome represents cell number and these have been assigned randomly with initial population of ten chromosomes generated. Each chromosome in population is randomly generated. Objective function value of chromosome is calculated in initial population using MATLAB.
6. Further generations have been generated using genetic operators i.e. crossover and mutation and ten generations produced and optimal solution of cell design is achieved
7. A chromosome with minimum objective function value is encoded to achieve a optimal cell design which showed minimum procedure of GA is summarized in Fig.1.

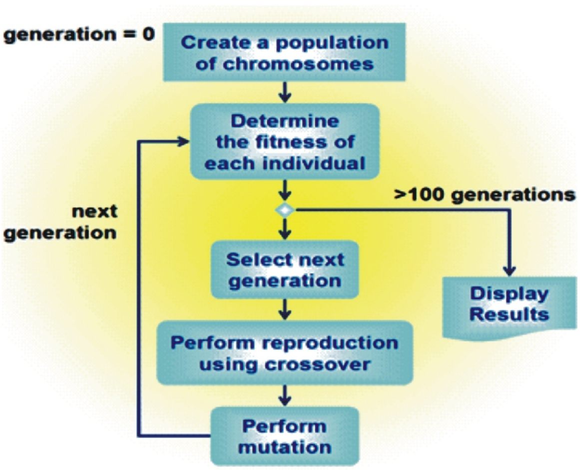

Fig. 1. Genetic Algorithm Process Flow

Data has been collected from shop floor. There were eight machines and manufacture nine different products. Currently machines are not properly installed at suitable locations in shop due to inappropriate layout of machines movements of work in process among different machines is very high which increases cost of manufacturing, fatigue of worker and cycle time of each process in job shop. This situation creates problems when demand of products is very high and shop is unable to meet the demand of products due to unnecessary movement among different machines. The sequence of movement of different parts in different machines is shown in Table I. as given below.

TABLE I
PARTS VISITATION MACHINES

	MACHINES								
		A	B	C	D	E	F	G	H
PARTS	1	1						1	
	2		1		1				
	3			1		1			1
	4				1			1	
	5	1		1					1
	6				1		1		
	7		1		1		1		
	8			1		1			
	9	1			1			1	

Since nine parts are to be manufactured using eight machines and daily demand of each part is ten so daily production of workshop is 90 parts. Using the data from table 1 a part /machine matrix is created and it is shown in (1)

$$E_{ji} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \end{bmatrix} \quad (1)$$

Matrix element zero '0' and one '1' shows the parts movements among different machines; if part visits the machine then it is represented by 1 other wise 0.

Eji is part machine matrix

where

$$j = \text{part number}$$
$$i = \text{machine number}$$

The objective function is the minimization of movements of parts among different machines and cell formation to achieve minimum inter-cellular movements. Objective function can be defined as;

$$\text{Intercellular movements of parts} = (\text{production requirment of each part}) \times (\text{no of movements of parts to each cell} - 1)$$

Nj represents Production requirment of each part

Nj is matrix of form $1 \times n$

$$Xil = \left\{ \begin{array}{l} 1 \text{ if machine "i" is in cell 1} \\ 0 \text{ if not in cell} \end{array} \right\} \quad (2)$$

Eji is $(n \times m)$ matrix and Eji can be defined as

$$\text{Eji} = \left\{ \begin{array}{l} 1 \text{ if part j is processed on M/c i} \\ 0 \text{ otherwise} \end{array} \right\} \quad (3)$$

Machine is abbreviated with M/c in equation (3)

Yjl is a (part × cell matrix) and

$$\text{Yjl} = \left\{ \begin{array}{l} 1 \; if \; \sum_{i=1}^{m} Eji \times Xil > 0 \; if \; part \; is \\ \text{processed in cell l} \\ 0 \text{ otherwise} \end{array} \right\} \quad (4)$$

Actually Yjl shows movements of parts in cells. By combining all information about cells, machines and parts a mathematical objective function is created

$$F = \sum_{j=1}^{n} \text{Nj}\left[\sum_{l=1}^{k} \text{Yjl} - 1\right] \quad (5)$$

j = part number
i = machine number
n = total number of parts
m = total number of machines
k = total number of cells
Nj = demand of each part
yjl = parts × cell $matrix$ [12]

3.1 Genetic Algorithm Procedure

When solving GA optimization problem for formation of cell in Cellular manufacturing system some initial parameters i.e. elitism criteria, mutation probability, cross over probability, generation gap, population size and number of generations are set. In this problems initial population size is ten so there are ten individuals (chromosomes) in each generation and total number of generations are ten .Chromosomes with best fitness value are called elite chromosomes and elitism criteria for this problem is 20% i.e. if there are ten chromosomes then two chromosomes of all generation except parent generation which have minimum fitness function value are called elite children (chromosomes). Elite chromosomes remain unchanged in mutation and cross over in next generation. Cross over probability in this problem is 0.7 it means that out of eight chromosomes there are only six chromosomes on which cross over is to be performed and always a pair of chromosomes (Parents) participate in crossover. Mutation is another genetic operator which creates diversity in next generation and it always occurs in single chromosome. Mutation probability in this problem is 0.07 which means that there are only two chromosomes on which mutation takes place. Considering all parameters settings as explained can be further elaborated with the chromosome [2 1 3 2 3 1 1 2]. Since a chromosome consist of genes so in this chromosome there are eight genes and each gene represents machine. In above chromosome position of 1st digit represents 1^{st} machine and position of 2^{nd} digit represents 2^{nd} machine and so on. Each digit in chromosome represents cell number; here we have assumed three cells , in case of above chromosome machines 6,7 and 2 are in cell 1 ; 1, 8 and 4 are in cell two ; 3 and 5 are in cell 3 as shown in Fig. 2.

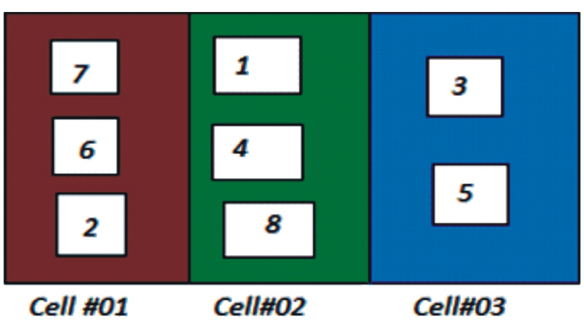

Fig. 2. Machines assigned in Cells

Calculation of Fitness Function Value

Using chromosme [2 1 3 2 3 1 1 2] a matrix which shows arrangement of different machines in different cells is created. It is represented by Xil and Xil is (machine × cell) matrix

$$X_{il}=\begin{bmatrix}0&1&0\\1&0&0\\0&0&1\\0&1&0\\0&0&1\\1&0&0\\1&0&0\\0&1&0\end{bmatrix} \qquad (6)$$

Matrix (1) is a Parts × machine matrix; and

$$A = \text{Eji} \times \text{Xil}$$

$$= (\text{Parts/Machine}) \times (\text{Machine/ cell}) \qquad (7)$$

$$A=E_{ji}* Xil = \begin{bmatrix}1&1&0\\1&1&0\\0&1&2\\1&1&0\\2&1&0\\0&0&2\\1&2&0\end{bmatrix} \qquad (8)$$

$A = \text{Eji} \times \text{Xil}$ =Parts/Cell Matrix; here A is matrix

Which shows the movements of parts in cells. Yjl is already defined above in (4). Now if part visits the cell then it is represented by 1 otherwise 0 so above (8) can be written as

$$\text{Yjl} = A>0Y_{jl}=\begin{bmatrix}1&1&0\\1&1&0\\0&1&1\\1&1&0\\0&1&1\\1&1&0\\1&1&0\\0&0&1\\1&1&0\end{bmatrix} \qquad (9)$$

In order to calculate intercellular movement of parts transpose of Yjl is used which can be represented by B=Yjl' and Yjl' is transpose of Yjl.

$$B=Y_{jl}'=\begin{bmatrix}1&1&0&1&0&1&1&0&1\\1&1&1&1&1&1&1&0&1\\0&0&1&0&1&0&0&1&0\end{bmatrix} \qquad (10)$$

(11) shows the intercellular movement of each part.

$$C = \text{sum}(B) = [2\quad 2\quad 2\quad 2\quad 2\quad 2\quad 1\quad 2] \qquad (11)$$

$$D = C\text{-}1 = [1\quad 1\quad 1\quad 1\quad 1\quad 1\quad 0\quad 1] \qquad (12)$$

D shows number of intercellular movement of each part

$E = D'$(transpose of). Transpose helps in matrix multiplications to achieve fitness function value.

$$F = N \times E = 80 \qquad (13)$$

Fitness function value for above chromosome is 80 which is total number of movement of different eight parts and quantity to be manufactured, of each part per day is ten. An initial population of ten chromosomes is generated randomly which is called parent generation and fitness function value of each chromosome is calculated using same procedure as discussed from (1) to (13) in which (3) changes for each individual in each generation. (11) Shows the parent generation and fitness function value of each individual

P (0) is initial population or Parent generation

$$P(0)=\begin{array}{c}1\\2\\3\\4\\5\\6\\7\\8\\9\\10\end{array}\begin{bmatrix}1&3&2&3&2&1&3&2\\3&1&2&3&2&1&1&2\\2&1&3&2&3&1&1&2\\3&2&1&3&2&2&1&3\\2&3&1&1&2&3&2&1\\2&2&3&1&2&3&1&1\\3&2&3&2&1&3&2&1\\2&3&2&3&1&2&1&3\\3&2&3&1&3&2&2&1\\1&2&3&2&1&3&3&2\end{bmatrix}\begin{array}{c}50\\70\\80\\100\\80\\110\\70\\100\\90\\110\end{array} \quad (14)$$

Fitness function value of each chromosome is calculated using same procedure with the help of MATLAB and objective function values are [50, 70, 80, 100, 80, 110, 70, 100, and 90,100] and average fitness function value of parent generation is 86. Fig. 3 shows the graph between chromosomes and fitness function values.

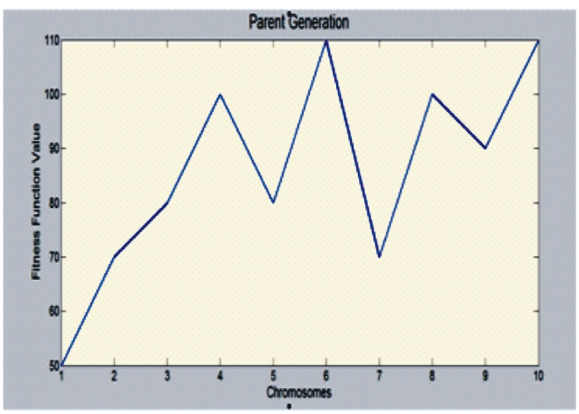

Fig. 3. Chromosomes Vs Fitness Function Values

3.2 Parent Generation

In parent generation two chromosomes with best fitness value are called elite chromosomes. In initial population chromosome 1 and 2 are elite children because they have minimum objective function values 50 and 70. Elite chromosomes remain unchanged in next generation and genetic operator operates (mutation and cross over) participate in reproduction of 1st generation. There are two approaches for mutation and cross over namely 'Rolette wheel selection' and 'random approach'. In this problem random approach is used because of small size of each individual and population. Mutation and crossover point is selected randomly in each generation. Cross over is exchange of genes in two chromosomes it can be explained by given example.

Before Crossover

Parent 01 2 1 3 2 3|1 1 2
Parent 02 3 2 1 3 2|2 1 3

After Crossover

Child 01 2 1 3 2 3 2 1 3
Child 02 3 2 1 3 2 1 1 2

Mutation always occurs in single chromosome and point of mutation is selected randomly. Mutation can be explained with example given below

Before Mutation

Parent 2 2 3 2 3 2 1 3

After Mutation

Child 2 1 3 2 3 2 1 3

In parameter settings it was clear that there are six chromosomes on which cross over is to be performed and there are only two chromosomes on which mutation occurs for production of next generation. Table II shows processes mutation and cross over on all individual of parent's generation.

TABLE II
1ST GENERATION CREATION PROCESS

P(0)	Cross over	Mutation	1st Generation
13232132	13232132	13232132	13232132
31232112	31232112	31232112	31232112
21323112	21323213	21323213	21323213
32132213	32132112	32132112	32132112
23112321	23112321	23212311	23212311
22312311	22312311	22313321	22313321
32321321	32321213	32321213	32321213
23231213	23231321	23231321	23231321
32313221	32313332	32313332	32313332
12321332	12321221	12321221	12321221

After mutation and crossover chromosomes modify their genes positions and generate children chromosomes. Same procedure is followed for generation 1 and objective function value is calculated.

3.3 Evaluation of Generation

Fitness function values of each individual in 1st generation are: [50, 70, 60, 110, 60, 100, 60, 50, 80, and 50] and average value of fitness function for generation 1 = 69. In 1st generation fitness function value is reduced as compared to parent generation and shown in Fig. 4.

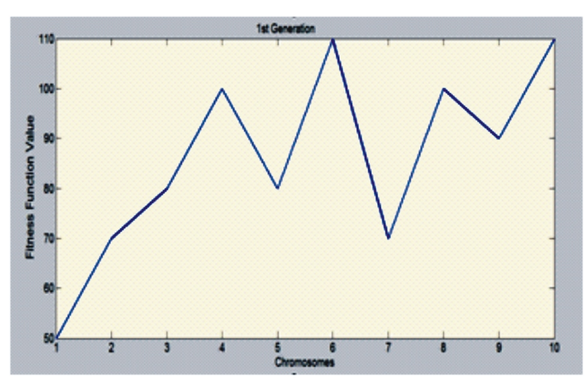

Fig. 4. Chromosome Vs Fitness Function Value

1st Generation

It is clear from Fig. 4 that fitness function values are less as compared to parent generation this due to evolution in generations as explained by Darwin's. According to Darwin theory of natural selection process everything passes through the emulation and changes its structure. Comparison of parent and 1st generation is explained in Fig. 5.

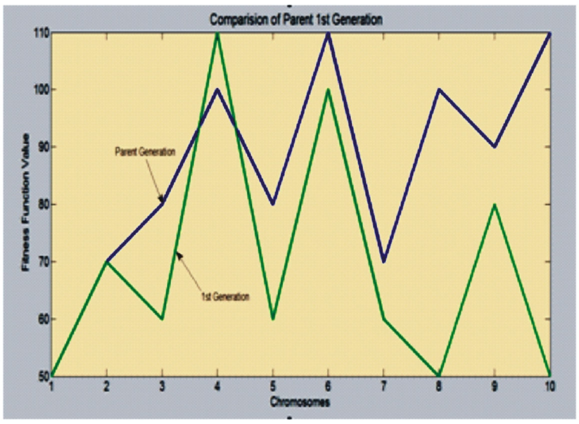

Fig. 5. Comparisons of Parent and 1st Generation

After mutation and cross over and selection of elite children next generation has been created and following the same procedure, total of 10 generations were generated, and fitness function value was reduced to minimum values at 10th generation because higher generations were repeating the same results as calculated previously.

IV. Results And Discussion

Evaluation process of all generation resulted into best fitness values at 10th generation and individual at same generation have minimum fitness function values. Minimization of fitness function values was due to genetic operators i.e. mutation and cross over. Weakest genes in chromosomes died as a result of evaluation. Parent and 10th generation with fitness function values are given below in Table III.

TABLE III
COMPARISON OF FITNESS FUNCTION VALUE

Parent Generation	Fitness Function Value	10th Generation	Fitness Function Value
13232132	50	32121321	50
31232112	70	12323222	50
21323112	80	31232132	40
32132213	100	13232112	50
23112321	80	21133113	50
22312311	110	32322212	70
32321321	70	21311311	80
23231213	100	23222321	50
32313221	90	22321213	60
12321332	110	32311231	80

Parent & 10th Generation

Comparison of parent and 10th generation can also be observed in Fig.6.

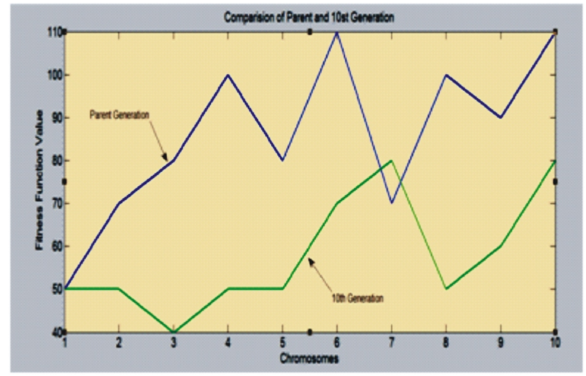

Fig. 6. Chromosomes Vs fitness Function value

In Fig. 6. it is clear that in 10th generation 3rd chromosome showed minimum value of fitness function value which is encoded to get cells as shown in Fig.7.

For chromosome: **3 1 2 3 2 1 3 2**

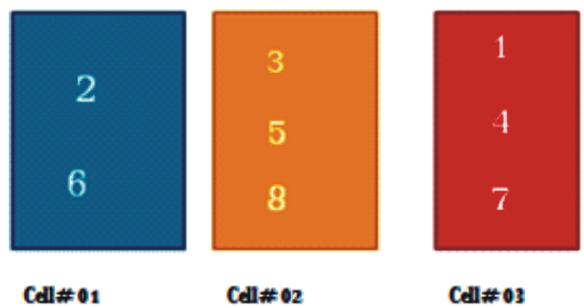

Fig. 7. Cell formations for minimization of intercellular movements

Fig. 11. Shows the cells and machines in cells. Now machine 2 and 6 are in cell 1, machine 3, 5 and 7 are in cell 2 and machine 1, 4 and 7 are in cell 3 respectively. This arrangement of machine cells shows the minimum movements of parts within different cells and total movements of parts in this type of arrangement is 40. The arrangement of machines in cells in Fig. 3 showed total that movement of parts in cell is 80 but solution proposed by GA reduced the cellular movements up to 50% which ultimately reduces cost of manufacturing, material handling cost and fatigue of workers.

V. Conclusion

The results from above discussion disclosed substantial advantages of genetic algorithm over traditional optimization technique. GA is quick and efficient algorithm to solve complex optimization problem. The reduction in intercellular movements of parts in shop increases the utilization of organization, reduces the fatigue of workers, and reduces the material handling cost. Fifty percent (50%) reduction in intercellular movements is due to just changing the position of machines. Genetic algorithm is not just limited to one solution instead it gives multiple solution and it is easier for manager to pick the best solution that suits to organization keeping in view economic and technical issues. In installation of machinery in an organization some objectives can be set and depending upon this objective proper arrangement of machines can be carried out with the help of GA. Ability of GA to solve multiple objective problems makes it versatile. It is recommended that GA is advance tool for cell formation to achieve the desired objectives to increased productivity of organization.

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