MAXIMIZING OF GROUPING EFFICIENCY IN CELLULAR MANUFACTURING SYSTEM USING GENETIC ALGORITHM

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ABSTRACT

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Cellular manufacturing is an important application of group technology in which sets of parts are produced in manufacturing cells or groups of various machines, which are physically close together in each cell can process a family of parts. The identification of parts families and machine groups in cellular manufacturing systems is commonly referred to as cell design / formation. The cells are formed to capture the inherent advantages of group technology such as reduced setup times, reduced tool requirements, in-process inventories, improved quality, shorter lead time, reduced tool requirements, improved productivity etc,. The problem of cell design is a very complex exercise with wide ranging implications for any organization. Normally, cell design is understood as the problem of identifying a set of part types that are suitable for manufacture on a group of machines. The goal of this research is to achieve a preferred compromise between efficiency and flexibility of the cellular manufacturing systems. The problem is formulated as a bicriterion objective function, where the number of part types accommodated into the cells is employed as a measure of system flexibility and the average system similarity level is used as a measure of system efficiency. A genetic algorithm method is proposed to solve the problem.

ஆய்வு சுருக்கம்

கூட்டு ஆராய்ச்சியின் முக்கிய அணுகுமுறையான கண்ணறைகளின் உற்பத்தி மற்றும் பல்வேறு விதமான இயந்திரங்களின் உதிரிகளை உற்பத்தி செய்வதாகும். இந்த கண்ணறைகள் ஒன்றுக்கொன்று நெருக்கமாக இருந்து பாகங்களை ஒழுங்குபடுத்துகின்றன. இந்த குடும்பத்தின் பாகங்களையும், இயந்திர கூட்டுத் தன்மையையும் இந்த கண்ணறைகளின் உற்பத்தி முறையை அடையாளம் காணும் முறையை பொதுவாக கண்ணறைத் திட்டம் என்று கூறப்படுகிறது. இந்த மின் அளவு சிறிய கண்ணறைகள் கூட்டு ஆராய்ச்சியின் இயல்பான அனுகூலங்களின் குறைந்த நேர செட் அப், குறைந்த செயல்முறை, சாமான்களின் பட்டியல், குறைந்த வழி காட்டும் நேரம், குறைந்த ஆயுதங்கள், தர உயர்வு, உற்பத்தி முன்னேற்றம் ஆகியவற்றிக்கு முக்கியத்துவம் தருகிறது.

கண்ணறைகள் திட்டம் ஒரு சிக்கலான பாடம். இதற்கு விசாலமான பரிமாணங்கள் உண்டு. பொதுவாக கண்ணறைகள் திட்டம் என்பது கூட்டு இயந்திரங்களை உருவாக்குவதில் முக்கிய பிரச்சனைகளை அடையாளம் காண உதவுகிறது. இந்த ஆராய்ச்சின் முக்கிய நோக்கம் ஆற்றலுக்கும், வளையுத்தன்மைக்கும் உடன்பாடு காணும் கண்ணறைகள் உற்பத்தி செயல்முறையாகும். இந்த முறை இரண்டு வித நோக்கங்களுடன் செயல்பட்டு எங்கு பாகங்களின் விதங்கள் கண்ணறைகளில் பொருத்தப்படுகிறதோ அங்கு இந்த அணுகுமுறையை பயன்படுத்தப்படுகிறது. ஆகவே மரபு நெறிமுறை என்ற முறை மூலம் இந்த கண்ணறைகள் உற்பத்தி பிரச்சனை தீர்க்கப்பட்டுள்ளது.

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V. SATHEESWARAN

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NOMENCLATURE

Symbol	Definition
CM	Cellular Manufacturing
CMS	Cellular Manufacturing System
GA	Genetic Algorithm
GT	Group Technology
ROC	Ranked Order Clustering
CSL	Cell System Layout
DCA	Direct Clustering Analysis
MCIM	Machine Component Incident Matrix

CHAPTER 1

INTRODUCTION

1.1 GROUP TECHNOLOGY:

Batch manufacturing is a dominant manufacturing activity in the world, generating a great deal of industrial output. It accounts for 60 to 80 percent of all manufacturing activities. The major difficulties in batch manufacturing are due to the high level of product variety and small manufacturing lot sizes. The product variations present design engineers with the problem of designing many different parts. The decisions made at the design stage significantly affect manufacturing cost, quality, and delivery lead times. The impact of these product variations in manufacturing is high investment in equipment, high tooling costs, complex scheduling and loading, lengthy setup and costs, excessive scrap, and high quality control costs. For these problems, some innovative methods are needed to reduce product cost and lead time and enhance product quality to help increase market share and profitability.

'Group Technology is the realization that many problems are similar and that, by grouping similar problems, a single solution can be found to a set of problems, thus saving time and effort'. The objectives of Group Technology are best achieved in business concerned with small to medium batch production; these represent a major part of manufacturing industry. The traditional approach to this type of manufacture is to make. use of a functional layout in the factory, i.e. similar machines are grouped according to type. Thornley wrote that 'as a result of this form of machine layout, where only machining operations of a particular type may be performed in a limited area of the workshop, the workpiece itself must travel a

considerable distance around the workshop before all the operations are performed upon it.' This usually leads to a long throughput time. The planning of process route becomes an extremely difficult task since a number of similar machine tools may be considered at each point in the sequence of manufacturing operations. Also the scheduling and control in such a system are difficult because numerous alternatives are available.

Group technology provides such a link between design and manufacturing. The adoption of group technology concepts, which allow small batch production to gain economic advantages similar to those of mass production while retaining the flexibility of the job shop, will help address some of the problems. Group technology is defined as a manufacturing philosophy, for identifying similar parts and grouping them together into families to take advantage of their similarities in design and manufacturing.

Group Technology is a philosophy that implies the notation of recognizing and exploiting similarities in three ways:

1. By performing like activities together
2. By standardizing similar tasks
3. By efficiently storing and retrieving information about recurring problems.

Group technology (GT) was introduced and practiced in the United States after World War II as a type of plant layout. The Original idea was to avoid intermittent material flow with its inefficiency in operations planning and control and losses in operational queuing time, waiting time, and idle time.

GT is regarded as a product focused plant layout where machines or stations are assembled into one work center that can produce a family of components which require similar equipments or process. As shown in figure1.0 this is made possible through the segregation of parts into families according to the product, shape, size and sequence of operation.

Fig 1.0 Ungrouped parts

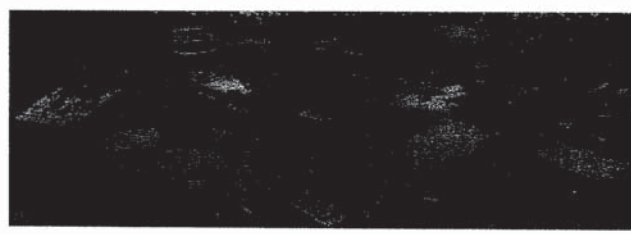

Fig 1.1 Grouped parts

The basic thinking behind Group Technology can be attributed to the Russians, who carried out initial investigations during the 1920s. The progress of GT since then and its gradual adoption in other countries

has been traced by Grayson. The early work stressed the importance of industrial classification and initial applications were limited to the medium and large batch productions. The work was extended during the war years by Mitrofanov to include workpieces produced in small batches. His major publication on Group Technology first appeared in 1959 and was translated into English in 1966. Mitrofanov proposed that it was possible to produce a theoretical composite component which incorporated all the major features of components belonging to a family, and that a machine could be tooled up to produce the composite component, thus providing the set-ups required for each component in the family.

In the early 1960s, Opitz carried out an investigation into workpiece statistics, which showed that although firms manufacture a variety of products, the spectrum of them all was remarkably similar. Based on the findings of this investigation, he established a classification system which enabled components to be codified by means of their geometrical similarity.

A number of methods for classification and coding were being investigated at approximately the same time. A significant growth in the interest and application of Group Technology in the U.K. followed the
publication of Opitz's work. The most notable were the works conducted by PERA and by MTIRA. A government-sponsored centre was set up in Blacknest for the dissemination of information about Group Technology, and a specialist division was set up by the Institution of Production Engineers which ran seminars and published papers on the subject. The advances in GT have been greatly influenced by the existence of a classification system devised by Brisch and Partners. The Brisch system was originally designed to facilitate variety reduction, component standardization and product rationalization.

It was later developed to suit GT requirements. There have been many applications of GT using the Brisch system and the most successful example was probably that of Serck Audco Valves.During the late 1960s, several well-known organizations implemented Group Technology. A notable example of one such companies was Ferodo where reductions in W.I.P. of about 8 to 1 were achieved. Other well-known firms such as Ferranti, Rolls Royce and Baker Perkins introduced GT at roughly the same time, and these applications provided benefits in many areas. Since then there have been more applications of GT in the U.K. – Herbert Machine Tools, Rank Xerox, Wildt Mellor Bromley and Simon Container Machinery.

Other methods were later developed as alternatives to the classification and coding approach. These were methods based on the analysis of production information.The most representative work was the Production Flow Analysis method proposed by Burbidge.Other similar methods were due to EL-Essawy,Purcheck and Nagarkar. These methods are different with respect to the underlying assumptions and the technique of analysis, but the general approach is to study a company's total system and to determine those families of components which are related by similarities in the production facilities required for their manufacture.

After some initial experience with Group Technology in organizations, it became evident that a change in the workshop was not sufficient on its own. To obtain the full benefits, it was necessary to change other parts of the system, including, for example, production control, planning, payment systems and accounting methods. For this reason, Group Technology was changed from being a technique in itself to being part of a new philosophy of production organization.

Most research efforts of recent years have been directed towards other areas of organization affected by the introduction of GT. This trend was initiallyreflected at the 'Conference on Production Improvement through Group and Cell Formation', held at the University of Aston in Birmingham in February 1973.Most speakers agreed that Group Technology had to be looked at not only as a machining system but as a complete manufacturing philosophy embracing all functions.In the late 1970s, Group Technology began to lose favour among British manufacturers. This was partly due to the fact that some companies who had previously introduced GT were discovering not only the advantages but also the problems which sometimes result. This was not altogether unexpected and indeed it was demonstrated by Leonard and Rathmil that Group Technology is not a universal panacea for manufacturing industry. A publication by the EDCME suggested some reasons for the slow rate of adopting GT by the British firms; traditional attitudes

and practice, fear of changes and suspicion of extravagant claims for GT were the main factors. Burbidge held a different viewpoint and proposed some other reasons why GT has failed to retain acceptance by the
British industry

Although Group Technology is out of favour in the U.K., it has flourished in other industrial nations.Since the 1960s, work has been done, though on smaller scales, in the Netherlands, Switzerland, Belgium, Sweden, U.S.A., Japan and West Germany.Today, many of these countries have more application of GT than in the U.K. and they are continuing to press ahead with its development. In the United States, Group Technology has been accepted as a technique of raising manufacturing performance, andthe merits of integrating it with the very popular production control technique of Material Requirements Planning are well publicized.

The British industry appears to have given up GT just when the other industrial nations have become convinced of its value and are taking it up. This suggests that there is still a need for research directed to testing the basic hypotheses and premises of GT.New stimulation is required if Group Technology in Britain is to be revitalized and some benefits gained.

1.2 BENEFITS OF GT:

GT is a management strategy to help to eliminate waste caused by duplicating of effort. It affects all areas of company, including engineering, equipment specification, facilities planning, process planning, production control, quality control, tool design, purchasing, and services.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

Following are the overview of the relevant work done earlier related to the identified problem and the methodology to be adopted to solve the chosen problem for this work. This section describes the literature reviewed from various research papers published in journals, proceedings of various conferences and books.

Hu.G.H, Chen.Y.P, Zhou.Z.D, Fang.H.C[8], In this paper, an integrated approach to the problem is proposed that attempts to design CSL and flow path structure simultaneously. The cells in question are assumed to be shape- fixed and have pre-determined pickup/delivery stations.

Jamal Arkat, Mohammad Saidi, Babak Abbasi[4], In this paper, the integrated methodology based on a new concept of similarity coefficients and the use o simulated annealing as an optimization tool. By compare with the previous works, the proposed methodology takes into account relevant production data, such as alternate process routing and the production volumes of parts.

Logendran.R[9], In this paper, he develops a model to minimize total inter-cell and itra-cell movement of parts and to maximize cell machine utilization. These objectives are unified through the weighting approach in the form of single objective.

Liang M.and Taboun S.M[10], In this paper, an attempt to achieve a compromise solution between flow line efficiency and job shop flexibility developed a bicriterion non- linear integer programming model. The objective of the model are to maximize system flexibility and to maximize efficiency.

Murugan.M, Selladurai.V [2], This paper has examined response improvement in the submersible pump industry by using cellular manufacturing systems. Grouping efficiency an group efficacy measures are used to evaluate the three clustering algorithm ROC, ROC-2 and DCA.

Mak.K.L , Wang.X.X[3], The objectives are to set up virtual manufacturing cells and to formulate feasible production schedules for all manufacturing operations, in order to minimize the total material and component traveling distance incurred in manufacturing the products.

Mak.K.L, Wong.Y.S and Wang.X.X[5], An adaptive genetic approach is proposed as an effective means of providing the optimal solution to the manufacturing cell formation problem in the design of cellular manufacturing systems. The proposed approach generates the optimal formation of machine cells and part families by sequencing the rows and columns of a machine part incidence matrix, so as to maximize the bond energy of the incidence matrix.

Prabhaharan.G, Muruganandam.A, Ashokan.P, Girish.B.S [1],This paper presents an ant colony system approach to addressing machine cell formation for the object minimization of total cell load variation and the minimization of total intercellular moves.

Wafik Hachicha, Faouzi Masmoudi, Mohamed Haddar[6], The scope of this article is to formulate a multivariate approach based on a correlation analysis for solving cell formation problem. The proposed approach is carried out in three phases. In first phase the correlation matrix is used as similarity coefficient matrix. In second phase, principal component analysis is applied to find the eigen values on the correlation similarity matrix. In this third stage, an algorithm is improved to assign exceptional machines and exceptional parts using respectively angle measure and Euclidian distance.

Wafik Hachicha, Faouzi Masmoudi, Mohamed Haddar[7], In this paper, the machine cell grouping problem is considered with the objective of minimizing the total moves and minimizing the cell load variation.

CHAPTER 3

CELLULAR MANUFACTURING SYSTEMS

3.1 OVERVIEW:

The manufacturing environment continually changes and is becoming more competitive. It is imperative that today's plants discover improved operating strategies that provide flexibility to quickly respond to external demands and continues to maintain or improve margins and profitability. Cellular manufacturing provides an operating system that can assist any company in meeting these challenges.

Cellular manufacturing is a manufacturing process that produces families of parts within a single line or cell of machines operated by machinists who work only within the line or cell. A cell is a small scale, clearly-defined production unit within a larger factory. This unit has complete responsibility for producing a family of like parts or a product. All necessary machines and manpower are contained within this cell, thus giving it a degree of operational autonomy. Each worker is expected to have mastered a full range of operating skills required by his or her cell. Therefore, systematic job rotation and training are necessary conditions for effective cell development. Complete worker training is needed to ensure that flexible worker assignments can be fulfilled.

This process involves placing a cluster of carefully selected sets of functionally dissimilar machines in close proximity to each other. The result is small, stand-alone manufacturing units dedicated to the production of a set or family of parts are essentially, a miniature version of a plant layout. Cellular

manufacturing is a driver to streamlining the production flow and processes of the products being built in a focused factory.

In traditional manufacturing, production is viewed as one "factory machine" in which each worker and each piece of equipment on the factory floor has a specific task to fulfill. Managing such a factory machine means coordination and harmonizing the actions of its individual's workers as well as the performance of its many workstations with the layout-machine productive units.

Traditional plant layout, places emphasis on long production run with few setup interruptions of machines so that large quantities of identical or similar parts can be "pushed" through the department and onto the next routing stage in the plant with high individual machine efficiency.Several observations can be made from the study of this traditional oriented process oriented system:

1. The material flow reflects convoluted, intermittent routings featuring long and indirect lines with limited visibility of scheduling priorities.
2. Material handling is excessive.
3. There can be large numbers of specialized, layered job classifications for the workers.
4. Performance measurement is centered on individual machine efficiencies without regard to schedule or delivery compliance.
5. Equipment setups are long in duration and are to be avoided where possible.
6. Non value-added work content is excessive at each level of the operation, creating a high overhead cost ceiling.
7. Large backlogs of work in process are created, causing product lead-times to be long.

In the cell, operators are physically close together and are visually controlling the workflow. They receive immediate feedback on quality problems. They can easily assist each other because of their close proximity and their 360-degree mobility.

In cellular manufacturing, the cell integrates a multiple operation production function and multi services with the plant maintenance, quality, material handling, machine setups and house keeping, along with a planning and control functions assigns to the shop floor. The work force develops quality improvement skills , change over skills and plant maintenance skills.

3.2 BENEFITS OF CELLULAR MANUFACTURING

Many firms utilizing cellular manufacturing have reported near immediate improvements in performance, with only relatively minor adverse effects. Cited improvements which seem to have occurred fairly quickly include reductions in work-in-process, finished goods, lead time, late orders, scrap, direct labor, and workspace.

In particular, production and quality control is enhanced. By breaking the factory into small, homogeneous and cohesive productive units, production and quality control is made easier. Cells that are not performing according to volume and quality targets can be easily isolated, since the parts/products affected can be traced to a single cell. Also, because the productive units are small, the search for the root of problems is made easier.

Quality parameters and control procedures can be dovetailed to the particular requirements of the parts or workpieces specific to a certain cell. By focusing quality control activity on a particular production unit or part type, the cell can quickly master the necessary quality requirements. Control is always enhanced when productive units are kept at a minimum operating scale, which is what cellular manufacturing provides.

When production is structured using cellular manufacturing logic, flow systematization is possible. Grouping of parts or products into sets or families reveals which ones are more or less amenable to continuous, coupled flow. Parts that are standardized and common to many products will have very low changeover times, and thus, are quickly convertible to continuous, line-flow production. Products that are low-volume, high-variety and require longer set-up times can be managed so that they evolve toward a line flow.

Cells can be designed to exploit the characteristics peculiar to each part family so as to optimize the flow for each cell and for groups of cells as a whole. Flow systematization can be done one cell at a time so as to avoid large disruptions in operations. Then the cells that were easy to systemize can provide experience that can be exploited when the more difficult systematization projects occur later. Cells that have been changed to a line flow will invariably show superior performance in the areas of quality, throughput time, and cost, which can lead to eventual plantwide benefit.

Work flow that is adapted to the unique requirements of each product or part allows the plant to produce high-volume and high-variety products simultaneously. Since the cell structure integrates both worker and product versatility into a single unit, it has the potential to attain maximum system flexibility while maintaining factory focus. Cells can be designed around single products, product groups, unique parts, part families, or whatever unique market requirements are identified. For the same part, there may be one high-volume, standardized design and one low-volume customized design. Cells can be built specifically for any of these with a focus on the individual marketing or production requirement called for by the individual product or part.

Systematic job rotation and training in multiple skills also make possible quick, flexible work assignments that can be used to alleviate bottlenecks occurring within the cell. Since normal cell operation requires the workers to master all the skills internal to the cell, little or no additional training should be needed when workers have to be redeployed in response to volume or sales mix changes. When it is routine for workers to learn new skills, they can be easily transferred to another job within the cell or possibly even to an entirely different production unit. Without this worker flexibility and versatility, there can be no real production system flexibility.

3.3 LIMITATION OF CMS:

1. Manufacturing flexibility is reduced.
2. Cell life may be affected.
3. Rearrangement of facilities can be disruptive and costly.
4. Possibility of under utilization of equipment in the cell.
5. Human resistance to change.

3.4 ISSUES IN THE DESIGN OF CMS:

In order to achieve efficient performance of CMS it is necessary to employ an effective design procedure for

1. Selection of part families and grouping of parts into families.
2. Selection of machine and process populations and grouping of these into cells.
3. Selection of tools, fixtures, and pallets.
4. Selection of material handling equipment.
5. Choice of equipment layout.

Figure 3.1 Design Of CMS

The main obstacle in achieving the benefits of CMS occurs during the initial stage of cell formation. Managers have to take a decision on number of cells to be formed and the machines and tools to be assigned to each cell. Since the performance of CMS largely depends on the initial decision, managers need an objective, yet practical way of forming cells.

3.5 DESIGN OF CELLULAR MANUFACTURING SYSTEMS OVERVIEW:

Given a set of part types, processing requirements, part type demand and available resources (machines, equipment, etc.,) the design of CMS consists of:

1. Part families are formed according to their processing requirements.
2. Machines are grouped into manufacturing cells.
3. Part families are assigned to cells.

3.5.1 Solution Strategies Are As Follows:

1. Part family grouping solution strategy: Part families are formed first, and then machines are grouped into cells according to the part families.
2. Machine grouping solution strategy: Manufacturing cells are created first based on similarity in part routings, then the parts are allocated to the cells.
3. Simultaneous machine-part grouping solution strategy: Part families and manufacturing cells are formed simultaneously.

3.5.2 Minimizing Common Design Objectives:

Flexibility,
Efficiency,
Costs such as equipment cost,
operating cost,
inventory cost,
setup cost and
Intercellular material handling cost.

3.5.3 Common Inputs:

Number of machines,
Sequence of operation,
Production data- production volume.

3.5.4 Design Constraints:

1. Machine capacity
2. Cell size
3. Number of cells
4. Utilization levels.

3.5.5 Approaches To The Design Of CMS:

A number of approaches to the design of cellular manufacturing systems had been used in the past. A brief description of the various approaches is presented below

Coding and Classification:

This approach involves an examination of the individual design and/or manufacturing attributes of each part. The attributes of the part are uniquely identified by means of a code number. OPTIZ, MICLASS, CODE are some of the coding systems which are widely used. Coding refers to the process of assigning symbols to the parts. The symbols represent design attributes of parts, manufacturing features of parts, or both. Classification refers to the process of categorization of a set of parts into part families. Coding methods are employed in classifying parts into families.

Knowledge Based Approach:

Knowledge base approaches takes the advantage of expert system and optimization considering machine capacity, material capabilities, technological requirements and cell dimensions to form cells.

Fuzzy Clustering Approach:

The earlier approaches to cell formation assumed that the processing costs, processing time, part demand etc., are precise. It is also assumed that each part can belong to only one part family. There may exist that may belong to other families.Fuzzy clustering provides a solution to such problems.

Machine Component Group Analysis:

These techniques are one of the earliest methods to solve the grouping problems. These methods rearrange rows and columns of MCIM to produce q block diagonal solution matrix. An important technique in this category is Rank order Clustering (ROC) algorithm.

Similarity Coefficient Based Clustering Methods:

McAuley (1972) first introduced the similarity coefficient method. The similarity coefficient approach requires identification of measures of similarities between machines, tools, design features etc. These similarity measures are used to form part families and machine groups based on methods such as single linkage cluster analysis, average linkage method etc.

Graph Theoritic Methods:

It is defined as a similarity measure capturing the processing requirements of parts whereas witte developed three similarity coefficients considering routing and machining information. The major disadvantages inherent in these approaches are that practical issues such as production volumes, alternate process plans etc., have not been addressed.

Genetic Algorithm Method:

Genetic algorithm is one of the best ways to solve a problem for which little is known and it will work well in any search space. A genetic algorithm will be able to create a high quality solution. Genetic algorithms use the principles of selection and evolution to produce several solution to a given problem.

Some key terms related to genetic algorithm are as follows

Chromosome - Blueprint for an individual.

Gene - Collection of all chromosomes for a individual.
Population - Group of all individuals.
Individual - Any possible solution.
Locus - The position of a gene on the chromosome.

3.6 STEPS IN DEVELOPING CELLS:

The objective of this is to position the team to prepare and present the cell alternatives that best fit the overall strategic objectives for the factory change. The following five-steps process is a good way to approach the task of cell concept development :

Step 1: Gather and record data:

The data includes
The product volume
Size and shape
Material
Process steps
Equipment and tooling etc.,

Step 2: Develop process flow within the cell

Process flow diagrams or tables must be developed for each art flow pattern within the cell. In Situation where a wide variety of floe exists, as is often the case in GT, it is often appropriate to perform a pareto analysis.

Step 3: Identify equipment required

Each alternative cell description will require an equipment list.It will be necessary to establish.The production lot sizes that are expected to run through the cell.Thisdetermines the numberof setups required, and the amount of production capacity lost to setup.

Step 4: Balance machine/manning workloads

When the sequence of operations has been laid out the workload is added manning should be applied. The cellular environment often makes it possible to perform minor operations simultaneously, particularly those involving little or no equipment, by utilizing what would otherwise be machine cycle wait time. In some cases manning may dictate that it is appropriate to share a resource between two cells.

Step 5: Select/Assign Equipment

Cells built with existing equipment are always designed for specific machine. Once the cell concept begin to mature, however, it is necessary to "checkout" the needed assets from a master list for the entire facility. Other wise key assets are likely to be assigned to more than one cell.

Part family formation in group technology

a) Design of the system layout planning

b) Operations-process planning, scheduling, machine loading etc..

The three basic methods for formation of part family{4}:

1. Manual/ Visual search
2. Poduction flow analysis
3. Parts classification and coding system

The row indicats the order of machine and the columns, the order of components. The following table shows a MCIM.

Table 3.1 Machine Component Incident Matrix

M/C Part	1	2	3	4	5
1	0	1	0	1	0
2	1	0	1	0	1
3	0	1	0	1	0
4	1	0	1	1	1

M/C Part	2	4	1	3	5
1	1	1	0	0	0
3	1	1	0	0	0
2	0	0	1	1	1
4	0	1	1	1	1

CHAPTER 4

OBJECTIVE FUNCTION

4.1 PROBLEM FORMULATION

The Problem is formulated for the design of cellular manufacturing systems by taking flexibility and efficiency into consideration. The above problem is solved by using genetic algorithm method.

There are two criteria considered for the design of cellular manufacturing system.

1. Flexibility
2. Efficiency

4.1.1 Flexibility (Zp)

Flexibility may be measured by the number of parts types a manufacturing system can process. In the process of conversion of the original functional manufacturing system into corresponding cellular manufacturing system the product variety handled by the functional system may not be the same in the cellular manufacturing system. The more part types the cellular manufacturing system can process the more will be the flexibility. Therefore the percentage of part types that can be accommodated by the cellular manufacturing system is used as a measure of flexibility.

4.1.2 Efficiency (Zs)

The efficiency of a cellular manufacturing system is the result of simplified workflow, reduced material handling and manufacturing lead time. However, in the cell design stage precise information regarding the above data is impossible and cannot be obtained. Hence, maximizing similarity has been used as an objective. A high similarity level can be obtained by grouping together similar parts and required machines. When a high similarity level is achieved the workflow gets simplified, with reduced material handling and manufacturing lead time. Hence average system similarity is used as another objective.

Hence the overall objective function is taken as a combined objective function of both flexibility and efficiency of the cellular manufacturing system.

$$\text{Maximize } z = \beta_p Z_p + \beta_s Z_s \qquad \text{-----------} (1)$$

Where,

$$Z_p = \left(\frac{1}{I}\right)\sum_{i=1}^{I}\sum_{k=1}^{K} P_{ik} \qquad \text{-----------} (2)$$

$$Z_s = \frac{\sum_{k=1}^{K} CSL_k}{\sum_{k=1}^{K} PAIR_k} \qquad \text{-----------} (3)$$

$$CSL_k = \sum_{i=1}^{I-1}\sum_{l=i+1}^{I} S_{il} P_{ik} P_{lK}, \qquad \text{-----------} (4)$$

$$PAIR_k = \left(\frac{1}{2}\right)\sum_{i=1}^{I} P_{ik}\left(\sum_{i=1}^{I} P_{ik} - 1\right), \qquad \text{-----------} (5)$$

$$S_{il} = 2a/(2a+b+c) \qquad \text{-----------} (6)$$

Subject to

$$\sum_{i=1}^{I} a_{ij} p_{ik} \le MX_{jk}$$

$$\sum_{j=1}^{J} X_{ik} \le U$$

$$\sum_{k=1}^{K} P_{ik} \le I$$

$$\sum_{k=1}^{K} X_{jk} \le N_j$$

$$P_{ik} X_{jk} = (0,1)$$

$$\beta_p + \beta_s = 1,$$

$$0 \le \beta_p \le 1,$$

$$0 \le \beta_s \le 1.$$

Where

i = Part type, i=1….I (I= Total number of part types that can be processed)

j = Machine type, j=1…..J (J= Total number of available machine types)

k= Machine cell or part family, k=1…..K (K= Number of part machine groups that can be formed)

4.2 PARAMETERS:

aij =	1 if part I requires machine type j 0 Otherwise
Nj =	Number of available machines of type j
I =	Total number of part types processed by the functional system
ßp =	Weight assigned to the objective of maximizing accommodated part types.

ßs =	Weight assigned to the objective of maximizing average system similarity.
CSLk =	Total similarity of part family k
Sil =	Similarity between part types i and I.
Pik =	1 if part type is assigned to family k 0 Otherwise
Xjk =	1 if a machine of type j is assigned to cell k 0 Otherwise
PAIRk =	Total number of part pairs in part family k.

CHAPTER 5

GENETIC ALGORITHM:

5.1 INTRODUCTION:

Genetic algorithm is a search and optimization procedure that arrives at an optimal solution by generating a rich child from a parent mating pool. It mimics the principle of natural genetics to arrive at the optimal solution .GA operates on the principle of the survival of the fittest, where weak individuals die before reproducing, while stronger ones survive and bear many off springs and breed children who often inherit the qualities that enabled their parents to a survive. The reproduction children are stronger than their parents in most cases.

The artificial optimization is taken to operate in the same manner as the naturalo genes function. The parameters of the function to be optimized are encoded as genes in a chromosome. A random population pool of the individuals(chromosomes)is created. Then pair of individuals is selected from this pool based on their performance in the optimizing function. The selected pairs reproduce, creating children whose g structures share the character of the parents. Perhaps some mutation (unexpected random exchange) takes place in the creation of child in natural, and this is also reflected in artificial GA.

As this proceeds the inferior trials in the population pool die out to lack of reproduction. At the same time strong traits tend to combine with stronger with other traits to produce children who perform well.

GAs simulate the survival of the fittest among individuals over consecutive generation for solving a problem. Each generation consists of a population of character strings that are analogous to the chromosome that we see in our DNA. Each individual

represents a point in a search space and a possible solution. The individuals in the population are then made to go through a process of evolution.

GAs are based on an analogy with the genetic structure and behaviour of chromosomes within a population of individuals using the following foundations:

- Individuals in a population compete for resources and mates.
- Those individuals most successful in each 'competition' will produce more offspring than those individuals that perform poorly.
- Genes from `good' individuals propagate throughout the population so that two good parents will sometimes produce offspring that are better than either parent.
- Thus each successive generation will become more suited to their environment.

5.2 SEARCH SPACE:

A population of individuals are maintained within search space for a GA, each representing a possible solution to a given problem. Each individual is coded as a finite length vector of components, or variables, in terms of some alphabet, usually the binary alphabet {0,1}. To continue the genetic analogy these individuals are likened to chromosomes and the variables are analogous to genes. Thus a chromosome (solution) is composed of several genes (variables). A fitness score is assigned to each solution representing the abilities of an individual to `compete'. The individual with the optimal (or generally near optimal) fitness score is sought. The GA aims to use selective `breeding' of the solutions to produce `offspring' better than the parents by combining information from the chromosomes.

The GA maintains a population of n chromosomes (solutions) with associated fitness values. Parents are selected to mate, on the basis of their fitness, producing offspring via a reproductive plan. Consequently highly fit solutions are given more opportunities to reproduce, so that offspring inherit characteristics from each parent. As parents mate and produce offspring, room must be made for the new arrivals since the population is kept at a static size. Individuals in the population die and are replaced by the new solutions, eventually creating a new generation once all mating opportunities in the old population have been exhausted. In this way it is hoped that over successive generations better solutions will thrive while the least fit solutions die out.

New generations of solutions are produced containing, on average, more good genes than a typical solution in a previous generation. Each successive generation will contain more good `partial solutions' than previous generations. Eventually, once the population has converged and is not producing offspring noticeably different from those in previous generations, the algorithm itself is said to have converged to a set of solutions to the problem at hand.

5.3 WORKING OF GENETIC ALGORITHM :

The genetic algorithm works by creating many random solutions to the problem at hand. Being random, these starting solutions are not very good schedules overlap and itineraries do not traverse every necessary location. This population of many solutions will then be subjected to an imitation of the evolution of species. All of these solutions are coded and the only way computers know as a series of zeros and ones. The evolution like process consists in considering these 0s and 1s as genetic chromosomes that, like their real life, biological equivalents, will be made to mate by hybridization, also throwing in the occasional spontaneous mutation. The offspring generated will include some solutions that are better than the original, purely random ones. The best offspring are added to the population while inferior ones are eliminated. By repeating this process among the better elements, repeated improvements will occur in the population, survive and generate their own offspring. This continues until a suitable solution has been found or a certain number of generations have passed, depending on the needs of the programmer.

5.4 REASON FOR CHOOSING GENETIC ALGORITHM:

Genetic algorithms are a very effective way of quickly finding a reasonable solution to a complex problem. Granted they aren't instantaneous, or even close, but they do an excellent job of searching through a large and complex search space. Genetic algorithm are most effective in a search space for which little is known. They produce solutions that solve the problem in ways that may never have been considered. They can also produce solutions that work within the test environment and try to use them in the real world.

The crossover then selection process favours the application of better and better solutions. By encouraging the best solutions generated and throwing away the worst ones ("only the fittest"),the original population keeps improving as a whole. This is called "selective pressure".Genetic algorithms do not actually calculate a solution to the problem being treated, they merely select and encourage the best emerging ones after certain, random operations. That is why the user need not know how to solve the problem, but just has to be able to evaluate the quality of the generated solutions. All that has to be done in order to let a genetic algorithm solve our problem is to write a "fitness function". This formvery surprising mechanism has been mathematically shown to eventually "converge" to the best possible solution . Of course, "eventually" comes much faster using skillfully written implementations. The evolution and selection process is problem-independent , only the fitness function and one that decodes the chromosomes into a readable form are problem specific. Once again, these function do not require us to know how to solve the problem.

5.5 THE STRUCTURE OF A GA:

Initialization
Evaluation
Selection
Termination

Evolution
Report
No
Yes
A location optimization

5.6 PRINCIPLES BEHIND GA:

Essentially GA is a set of procedures which, when repeated, enable solutions to specify problems. GA has been successfully used in a various problem domains. In order to achieve objectives, GA generates successive population of alternative solution until a solution is obtained that yields acceptable results. Within that generation of each successive population, improvements in the quality of the individual solution are gained. In this way GA an quickly move to a successful outcome without the need to examine the every possible solution to the problem. The procedures used are based on the selection and reproduction.

These two processes together improve an organism's ability to survive within its environment in the following manner:

1. Natural selection determines which organism has the opportunity of reproduction and survival within a population.
2. Reproduction involves genes from two separate individuals combining to form offspring that inherit the survival characteristics of their parent.

These algorithms seek to initiate the way in which beneficial genes reproduce themselves through successive population and hence contribute the general ability of an organism to survive.

Here the length of the chromosome is 7, which indicates that the number of machines in the problem is 7. The genes in the chromosomes are 1,2,3, and 4. These numbers indicates that the number of cells considered is 4. The position of the number indicate which machine is present in which cell, i.e, machines 3 and 5 are in cell 1, the machine 1 is in cell 2, machines 4 and 7 are in cell 3 and machines 2 and 6 are in cell 4.

5.7 IMPLEMENTATION DETAILS:

Based on Natural Selection: After an initial population is randomly generated, the algorithm evolves the through three operators:

1. **selection** which equates to survival of the fittest;
2. **crossover** which represents mating between individuals;
3. **mutation** which introduces random modifications.

5.7.1 Selection Operator:

key idea: give prefrence to better individuals, allowing them to pass on their genes to the next generation. The goodness of each individual depends on its fitness.Fitness may be determined by an objective function or by a subjective judgement.

5.7.2 Crossover Operator :

Prime distinguished factor of GA from other optimization techniques. Two individuals are chosen from the population using the selection operator.A crossover site along the bit strings is randomly chosen.The values of the two strings are exchanged up to this point If S1=000000 and s2=111111 and the crossover point is 2 then S1'=110000 and s2'=001111

The two new offspring created from this mating are put into the next generation of the population.By recombining portions of good individuals, this process is likely to create even better individuals.

5.7.3 Mutation Operator:

With some low probability, a portion of the new individuals will have some of their bits flipped.Its purpose is to maintain diversity within the population and inhibit premature convergence.Mutation alone induces a random walk through the search space.Mutation and selection (without crossover) create a parallel, noise-tolerant, hill-climbing algorithms.

5.8 EFFECTS OF GENETIC OPERATORS:

- Using selection alone will tend to fill the population with copies of the best individual from the population
- Using selection and crossover operators will tend to cause the algorithms to converge on a good but sub-optimal solution
- Using mutation alone induces a random walk through the search space.
- Using selection and mutation creates a parrallel, noise-tolerant, hill climbing algorithm

5.9 THE ALGORITHMS:

1. randomly initialize population(t)
2. determine fitness of population(t)
3. repeat
    - select parents from population(t)
    - perform crossover on parents creating population(t+1)
    - perform mutation of population(t+1)
    - determine fitness of population(t+1)
4. until best individual is good enough
5. Methods of selection
6. There are many different techniques which a genetic algorithm can use to select the individuals to be copied over into the next generation, but listed below are some of the

most common methods. Some of these methods are mutually exclusive, but others can be and often are used in combination.

7. *Elitist selection*: The most fit members of each generation are guaranteed to be selected. (Most GAs do not use pure elitism, but instead use a modified form where the single best, or a few of the best, individuals from each generation are copied into the next generation just in case nothing better turns up.)
8. *Fitness-proportionate selection*: More fit individuals are more likely, but not certain, to be selected.
9. *Roulette-wheel selection*: A form of fitness-proportionate selection in which the chance of an individual's being selected is proportional to the amount by which its fitness is greater or less than its competitors' fitness. (Conceptually, this can be represented as a game of roulette - each individual gets a slice of the wheel, but more fit ones get larger slices than less fit ones. The wheel is then spun, and whichever individual "owns" the section on which it lands each time is chosen.)
10. *Scaling selection*: As the average fitness of the population increases, the strength of the selective pressure also increases and the fitness function becomes more discriminating. This method can be helpful in making the best selection later on when all individuals have relatively high fitness and only small differences in fitness distinguish one from another.
11. *Tournament selection*: Subgroups of individuals are chosen from the larger population, and members of each subgroup compete against each other. Only one individual from each subgroup is chosen to reproduce.
12. *Rank selection*: Each individual in the population is assigned a numerical rank based on fitness, and selection is based on this ranking rather than absolute differences in fitness. The advantage of this method is that it can prevent very fit individuals from gaining dominance early at the expense of less fit ones, which would reduce the population's genetic diversity and might hinder attempts to find an acceptable solution.
13. *Generational selection*: The offspring of the individuals selected from each generation become the entire next generation. No individuals are retained between generations.
14. *Steady-state selection*: The offspring of the individuals selected from each generation go back into the pre-existing gene pool, replacing some of the less fit members of the previous generation. Some individuals are retained between generations.

15. *Hierarchical selection*: Individuals go through multiple rounds of selection each generation. Lower-level evaluations are faster and less discriminating, while those that survive to higher levels are evaluated more rigorously. The advantage of this method is that it reduces overall computation time by using faster, less selective evaluation to weed out the majority of individuals that show little or no promise, and only subjecting those who survive this initial test to more rigorous and more computationally expensive fitness evaluation.

5.9.1 Steps in Genetic Algorithm:

Step 1: Choose a coding to represent a problem parameter, a selection operator, a crossover operator, and a mutuation operator. Choose population size, crossover probability Pc and mutuation probability Pm. Intilize a random population of string. Choose maximium allowable generation number t max.

Step 2: Evaluate each string in the population.

Step 3: If t>t max or other termination criteria is satisfied, terminate.

Step 4: Perform reproduction on the population.

Step 5: Perform crossover on random pairs of strings.

Step 6: Perform mutuation on every string.

Step 7: Evaluate string in the new population. Set t=t+1 and go to step 3.

5.10 APPLICATION:

- Automated design, including research on composite material design and multi-objective design of automotive components for crashworthiness, weight savings, and other characteristics.
- Automated design of mechatronic systems using bond graphs and genetic programming.
- Calculation of bound states and local density approximations.
- Container loading optimization.
- Distributed computer network topologies.

- File allocation for a distributed system.
- Parallelization of Gas including use of hierarchical decomposition of problem domains and design spaces nesting of irregular shapes using feature matching and Gas.
- Game theory equilibrium resolution.
- Learning robot behavior using genetic algorithm.
- Mobile communication infrastructure optimization.
- Molecular structure optimization.
- Multiple population topologies and interchange methodologies.
- Protein folding and protein/ligand docking.
- Plant floor layout.
- Scheduling applications, including job-shop scheduling. The objective being to schedule jobs in a sequence dependent or non-sequence dependent setup environment for a minimal totaltardiness.
- Solving the machine-component grouping problem required for cellular manufacturing systems.
- Stock market prediction.
- Tactical asset allocation and international equity strategies.
- Traveling salesman problem.

Because of its potentiality and wide applicability , genetic algorithm is chosen in the present work for the design of cellular manufacturing systems.

CHAPTER 6

NUMERICAL ILLUSTRATION

Now to demonstrate and validate the application of genetic algorithm to the design of cellular manufacturing systems,an example is considered.The application of the model and solution algorithm is demonstrated using a widelycited 16-machine 43-parts type grouping problem(Liang &Taboun 1995). The part-machine matrix is as shown in table 6.1. The part types are accommodated in the cells and machines are allotted to each cell depending on the type of parts allotted to each cell.

Four cases have been taken into consideration for determining the optimum arrangement of parts and machines in the cell. The first case consists of 4 cells and the 43 parts distributed among the 4 cells. The second case consists of 5 cells and 42 parts are distributed to the cells.Similarly the third and fourth cases have 6 cells with 38 and 37 parts respectively distributed among the cells. The values of Zs and Zp corresponding to different cases is evaluated using C-code . The arrangement of parts and machines for each case and the values of Zp and Zs are tabulated as shown in table

Table 6.1 Part -Machine Matrix

MACHINES

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0
	2	0	1	0	0	0	1	0	1	1	0	0	0	0	1	0	1
	3	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0
	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	5	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0
	6	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0
	7	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1
	8	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0
	9	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0
	10	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	11	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
	12	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0
P	**13**	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0
A	**14**	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0
R	**15**	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0
T	**16**	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
S	**17**	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0
	18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	19	0	0	0	1	1	1	0	1	0	0	0	0	0	0	1	0
	20	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
	21	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0
	22	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
	23	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0
	25	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
28	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0
29	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0
31	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
32	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1
33	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0
34	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0
35	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0
36	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
37	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	1
38	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1
39	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
40	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0
41	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0
42	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1
43	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0
Nj	1	1	1	1	1	3	1	4	2	1	2	1	1	2	1	2

Table 6.2 Values of Zs and Zp for corresponding to different cases

Case	Cells	Parts	Machines	Zp	Zs
I	1	1,5,8,9,12,13,14, 15,16,19,21,23,25, 26,29,31,33,39,41, 43	4,5,6,7,8,10	0.930233	0.461763
	2	2,4,10,18,28,32,37, 38,40,42	1,2,8,9,14,16		
	3	6,7,17,34,35,36	3,6,14,16		
	4	3,11,20,22,24,27,30	8,11,12,13		
II	1	5,8,9,14,15,16,19,2 1, 23,29,33,41,43	4,5,6,8,11,15	0.976744	0.568560
	2	2,10,28,32,37,38,40 , 42	1,2,6,8,9,14,1 6		
	3	1,6,12,13,17,25,26, 31,34,35,36,39	3,6,7,8,10,14		
	4	3,11,20,22,24,27,30	8,11,12,13		
	5	4,18	9,16		

III	1	5,8,9,14,15,19,21,23, 29,33,41,43	4,5,6,8,11,15	0.883721	0.673745
	2	2,10,28,32,37,38,40, 42	1,2,6,8,9,14,16		
	3	1,12,13,25,26,31,34, 39	6,7,8,10		
	4	3,11,20,22,24,27,30	8,11,12,13		
	5	4,18	9,16		
	6	35,36	3,14		
IV	1	5,8,9,14,15,19,21,23, 29,33,41,43	4,5,6,8,11,15	0.860465	0.687451
	2	2,10,28,32,37,38,40, 42	1,2,6,8,9,14,16		
	3	1,12,13,25,26,31,39	6,7,8,10		
	4	3,11,20,24,27,30	8,11,12,13		
	5	4,18	9,16		
	6	35,36	3,14		

CHAPTER 7

SOLUTION USING GENETIC ALGORITHM METHOD:

7.1 Solution Using Genetic Algorithm Method:

Genetic Algorithm input parameters for the problem are as follows

1. Total string length - 10
2. Crossover probability - 0.6
3. Mutuation probability - 0.01
4. Number of design variable - 2
5. Number of machines - 16
6. Number of parts - 43

The values of Zs and Zp are given as input to the genetic algorithm code (appendix2) along with the genetic algorithm parameters. The optimum values of βp, βs and the associated Z values will be generated as the output. The best values of βp, βs and Z associated with different cases are as shown in table 5.2.The value of βp depends on the number of part types accommodated by the cellular manufacturing system . The value of βp will be more if the number of parts accommodated will be more and vice versa. Similarly, there will bean increase in the value of βs as the value of βp decreases and vice versa. The best solution of the four cases is the one in which Z has the maximum value. It is evident from table,_that the value of Z is maximum for case I which proves to be the optimum arrangement of parts in the cells.

TABLE 7.1 SOLUTION OBTAINED:

Case	ßp	ßs	Z
I	0.97	0.03	0.96292130
II	0.87	0.13	0.92145547
III	0.79	0.21	0.83957984
IV	0.76	0.24	0.81894164

SAMPLE:

$Z = \beta p Z p + \beta s Z s$

$Z = (0.97*0.930233)+(0.03*0.461763)$

$Z = 0.96292130$

CHAPTER 8

RESULTS AND DISCUSSIONS

8.1 RESULTS AND DISCUSSIONS

The design of the cellular manufacturing systems for a 16 machine and 43 part type problem has been solved using genetic algorithm and the results have been compared with the heuristic method used by Liang and Taboun (1995) for given values of βp and βs. The value of Z is high in table7.1 which gives a clear picture of the effectiveness and efficiency of genetic algorithms.

As can be seen from table7.1 and_the value of βp increases as the number of part types accommodated by the system increases there by increasing the flexibility of the system. Similarly, as the value of βp decreases there is a corresponding increase in the value of βs thereby increasing the efficiency of the system. The optimum values of βp and βs obtained using genetic algorithm for the four cases taken into consideration and the optimum value of Z for the given set of input parameters is shown in table 7.1.

CHAPTER 9

CONCLUSION

9.1 CONCLUSION

This project deals with the optimum design of cellular manufacturing systems, with the objectives of maximizing the efficiency and flexibility using a genetic algorithm method. The proposed method has several advantages over the traditional optimization techniques. The genetic algorithms can use coded variables and/or real variables and they work on a population of points instead of a single point. This entire feature makes Gas-search robust, allowing them to be applied to a wide variety of problems.

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