Applying Two String Chromosomes for Solving Scheduling Problems in FMS using Genetic Algorithm

Mahendra Kumar Salvi[1] Indresh Jain[2] Mohmd. Zuber Khan[3]
[1,2,3]Assistant Professor
[1,2,3]Department of Mechanical Engineering
[1,2]Geetanjali Institute of Technical, Studies, Udaipur

Abstract— Scheduling in Flexible Manufacturing System (FMS) has been the subject of intensive academic research due to its complexity and computational effort required. The FMS scheduling problems have proved to be NP-hard problems and it is not possible to achieve optimal solution to NP-hard problems by mathematical approach in a short time horizon. The present research work is focused on the FMS scheduling problem having a non-identical parallel machine environment. The objective is to minimize the maximum completion time of jobs using Genetic Algorithm (GA). The GA is one of the most efficient algorithms that aim to converge faster and provide optimal solutions in a considerable short time span. Apart from a number of ways of chromosome representation, a new type of chromosome representation has been proposed which generates no infeasible strings; hence no local or global harmonization is required. Since there is no possibility of generating infeasible strings, a considerable amount of computational effort has been saved which helps GA to converge faster and provide optimal solutions. The suggested chromosome representation has been applied to solve non-identical parallel machine problem and the results have been compared to one of the most popular heuristic applied to solve FMS scheduling problems in real-time.

Key words: **NP-hard, Scheduling, Chromosome representation, GA, Non-identical parallel machines, FMS**

I. INTRODUCTION

An FMS can be defined as a production technology designed to produce a variety of parts in medium-sized volumes while utilizing the flexibilities of a job shop manufacturing model. Even though the term FMS has been extensively researched there is no globally accepted definition of flexible manufacturing system and a number of definitions have been reported. The most referred definition can be stated as 'an FMS can be defined as a manufacturing system which deals with a high level of distributed data processing and automated material flow, equipped with computer controlled machine tools, automated material handling and storage system, automated/semi-automated assembly cells, industrial robots and AGV's, automated inspection systems' and so on.

Scheduling in FMS deals with the problems that describes which jobs are to be performed and at what time in terms of minutes/seconds/hours/days, also how the available resources must be utilized so as to meet the given production plan and the production volumes are optimized for a given period of time. Scheduling in FMS is the problem of allocation of available machines to the jobs to be processed over a given time period, subject to the technological constraints. There are a variety of problems which falls in the category of scheduling problems, so it is difficult to give a unique definition that applies all categories of problems.

Genetic Algorithm (GA) is an adaptive heuristic search algorithm premised on evolutionary ideas of natural selection and genetics. This heuristic is applied to obtain solutions to optimization and search problems following the principles of Charles Darwin of survival of the fittest. GAs belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems techniques inspired by natural evolution, such as reproduction, mutation and crossover.

II. LITERATURE REVIEW

The global competition of meeting the customers demand in shortest possible time is increasing day by day and is a challenging situation for the manufacturers to meet the customer requirements optimally. Due to changing customer's interest in the features and type of the product, manufacturers are compelled to process the part styles in the shortest span of time with minimum quotation price even for small orders. To meet such conditions in manufacturing, with the technological growth and extensive research the Flexible Manufacturing System (FMS) has been emerged as one the most efficient production technology. As defined by Stecke [1] an FMS is an integrated computer controlled complex of automated material handling devices and NC machine tools intended to process mid-sized production of a variety of parts... An FMS scheduling problem is considered as the NP-hard problem and is gaining more attention of researchers. Flexibility, the unquantifiable yet utmost important aspect of FMS has been described by Jim Browne et al [2] formed the basis on which the flexibility type can be identified. The eight types of flexibilities were discussed along with the aspects on the basis of which each type of flexibility can be measured. They have classified the FMS(s) into four categories as: FMC, FTL, FMS and FTML which formed the basis of classification as discussed by Groover [3]. An extensive review on FMS was presented by Kaighobadi [4] and attempts were made to define FMS more specifically by considering the primary and secondary components of FMS. As explained, primary components include machine tools material handling system and a supervisory computer control network, whereas the secondary components include NC process technology, spindle tooling, holding fixtures and operation management.

Klahorst [5] stated that 50 percent project value of an FMS is due to the cost of machines installed and provided the guidelines for FMS installation. Accordingly an FMS should be installed when: part size and mass exceed jib crane standards, when production volume is an excess of two parts per hour, processing requires more than two machine types to complete a work piece, when more than five machine are required, when phased implementation is planned so that material handling provisions can be incorporated in the initial phases. It was concluded that more of above conditions exist; the more intensity there is for transforming a conventional system into an FMS. Finally addressing FMS problems, the related problems were categorized into two major areas- managerial and technical.

Based on extensive research and literature review Pinedo [6] has characterized the manufacturing systems by a variety of factors, such as number of machines, their characteristics and configuration, level of automation, type of material handling system, production volume and so on. He discussed the four scheduling models and applied them in manufacturing models such as single machine, parallel machine and job-shop models. A wide variety of FMS problems have been found in literature and so, a number of models have been developed that can be applied to solve FMS problems. Some of the techniques include simulation, group technology, artificial intelligence, Petri-nets, linear, non-linear and integer mathematical programming. The solution technique to be applied is largely affected by the size of the problem and the no of objectives to be optimized. Some of the objectives of scheduling problems are minimize makespan, minimize number of late jobs, minimize number of tardy jobs, minimize in-process inventory and so on depending on the nature and size of the problem. In manufacturing systems with automatic material handling system such as FMS the multi-objective programming problems are encountered. Further in more complex manufacturing models the objective functions are minimize total inventory and change over costs.

Kokin [7] has discussed PMS to schedule jobs processed on a series of same function machine. Review was done on the aspects of PMS affected by the problems of JIT, pre-emption with setup and capacitated machine scheduling. With reference to parallel machine environment sometimes the customer may demand the product before the due date, or the job may finish before due date causing earliness penalty. On the other hand if the jobs are completed after due date causing tardiness penalty, so the best plan suggested is JIT (i.e. Just in Time). Akturk [8] showed that there is a strong interaction between scheduling and tool management decision, ignoring this interaction may lead to suboptimal or even infeasible results at the system level. They proposed a multistage approach to solve such interrelated problems. Fathi [9] addressed the scheduling problems with a set of parts with given processing time and tool requirements on identical parallel machines. Three heuristic procedures were proposed- the multistart local improvement procedure, variation of the list processing routine and the third one was an adaptation over k-travelling salesman problem. The objective was to minimize the makespan in a combinatorial optimization problem in scheduling theory which combines the tool-switching problem on a single machine and the parallel machine problem. Rong-Lei Sun [10] discussed dispatching rule based scheduling and to overcome its limitations, iterative learning scheduling scheme was proposed. In iterative learning according to the value of the scheduling objective obtained from the last simulation period, the parameters are adjusted so as to decrease the objective during the next simulation period. It was shown that the limitations of dispatching rule based scheduling can be overcome by iterative methods and higher performances can be achieved.

Turkcan et al [11] considered FMS loading, scheduling and tool management problems simultaneously and determined the most appropriate tool management decisions using space GAs to generate a series of efficient solutions. Udhayakumar [12] discussed scheduling and sequencing problems and generated active schedules and optimal sequence which minimizes the makespan using a non-traditional optimization technique. They proposed the ant colony optimization algorithms to derive near optimal solutions and the analysis revealed that ACO algorithms provide better solutions with reasonable saving in computational time.

III. PROBLEM STATEMENT

The present research work considers a Non-identical Parallel Machine environment. The FMS production environment consists of two number of dedicated machines (expandable to ‘m’ number of machines) and ‘n’ number of jobs. The machine flexibility considered is such that each job can be machined on any of the machines, the processing time of each job on each of the machine, and the total number of jobs to be processed is known in advance. Each machine is capable of performing all the operations of a job being processed on it and the tool magazine is equipped with all the tools required for each operation of each job. Further there is no transfer of tool taking place between the machines. The processing time is in the range [5, 10]. A set of 10, 20 and 50 jobs are to be processed on two dedicated machines.

A. Assumptions made:

- Each machine can processes only one job at a particular time.
- A job starts in processing on any of the machines; it must be completed before its succeeding job can start on the same machine.
- All the operations of a job can be performed on either of the machines.
- Processing times are independent of order of performing the operations.
- Transportation times are negligible.

- Jobs are completely known in advance and all the jobs are ready for processing when the period under consideration starts.
- The processing time of each job on either machine includes the processing times of all the operations to be performed.
- Machine set up times are negligible..

B. Problem Objective:

In each category of the problem the objective is to minimize the Makespan i.e. the completion time of the last job on either of the machines.

C. Generation of processing times:

For all type of problem set the processing times are randomly generated between minimum processing time and maximum processing time

D. GA terminology:

The terms being used in GA are explained as under:
1) Chromosome: a string representing the individual solution.
2) Population: a finite collection of chromosomes having same string length.
3) Gene: a part of chromosome, containing partial solution.
4) Fitness: the value assigned to an individual solution or chromosome, greater the fitness value, better is the solution.
5) Selection: process of selecting fittest individuals which will survive in next generation.
6) Crossover: it is the process in which two fit chromosomes are selected, and new chromosomes are generated by exchanging their genes.
7) Mutation: it is the process of changing a random gene in an individual solution.

E. GA Methodology:

GA begins with generation of finite set of individual solutions as represented by the chromosomes form a number of strings called initial population. Chromosomes have been represented such that no infeasible strings are generated; hence no local or global harmonization is required. The second step is the selection of most fit individuals which is motivated by the possibility that the fitness of the new population will be better than the old one. The selection process is governed by the fitness values of individual solutions, which pairs and mates to form new individual solutions called offspring. The process is repeated until some condition is satisfied.

1) Step 1: Chromosome representation

The entire chromosome consists of two parts one of which actively participates in the GA procedure, contains a set of information of machines only and the second one contains the information about the job numbers. The second part consisting of job number does not actively participate in GA process, but provides the primary information, without which the whole information cannot be encoded. The strings are represented as real value numbers encoding the number of machines and number of jobs. The complete string representation is as follows:
Chromosome A = [1 2 3 4 5 6 ……n]; n= total number of jobs.
Chromosome B = [1 2 3 ……m]; m= total number of non-identical parallel machines.

2) Step 2: Initializing the population

The initial population of solutions is generated for Chromosome B using random integer generation in MATLAB; the population size is fixed to 100.

3) Step 3: Selection of individuals

The natural selection process is implemented for selection of individuals among the entire set of population with a fixed selection probability of 0.5

4) Step 3: Pairing and Mating

The selected chromosomes are randomly cut at any point along the string length to form mate1 and mate2. The mates of having same length are then combined to produce a new chromosome.

5) Step 4: Mutation

In order to perform the mutation operation the uniform mutation operator is applied (mutation probability=0.2) which replaces the value of randomly selected genes between the user specified upper and lower bounds. The 100 number of iterations are done which is same for most of the problems.

F. Experimentation:

The suggested GA has been programmed and run in MATLAB 2008. For each problem type the convergence plot of the GA has been presented and the minimum makespan is found using two different heuristics:
1) Shortest processing time rule (SPT)
2) Genetic Algorithm(GA)

G. Results:

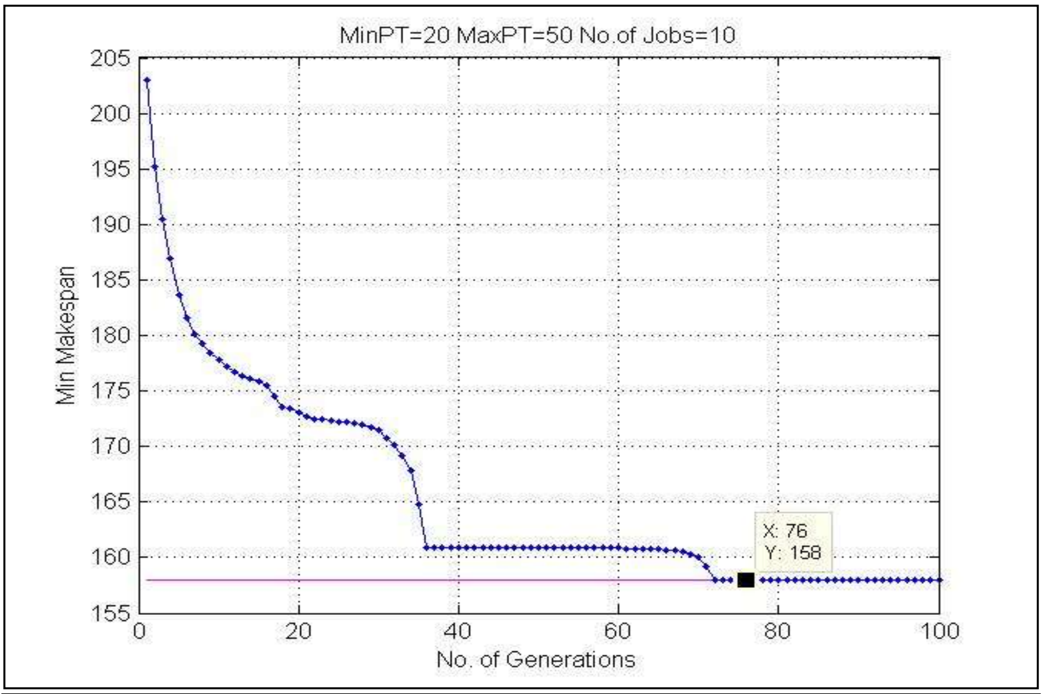
The convergence plots for each of the problem category showing the variation of makespan with no of generations are shown below:

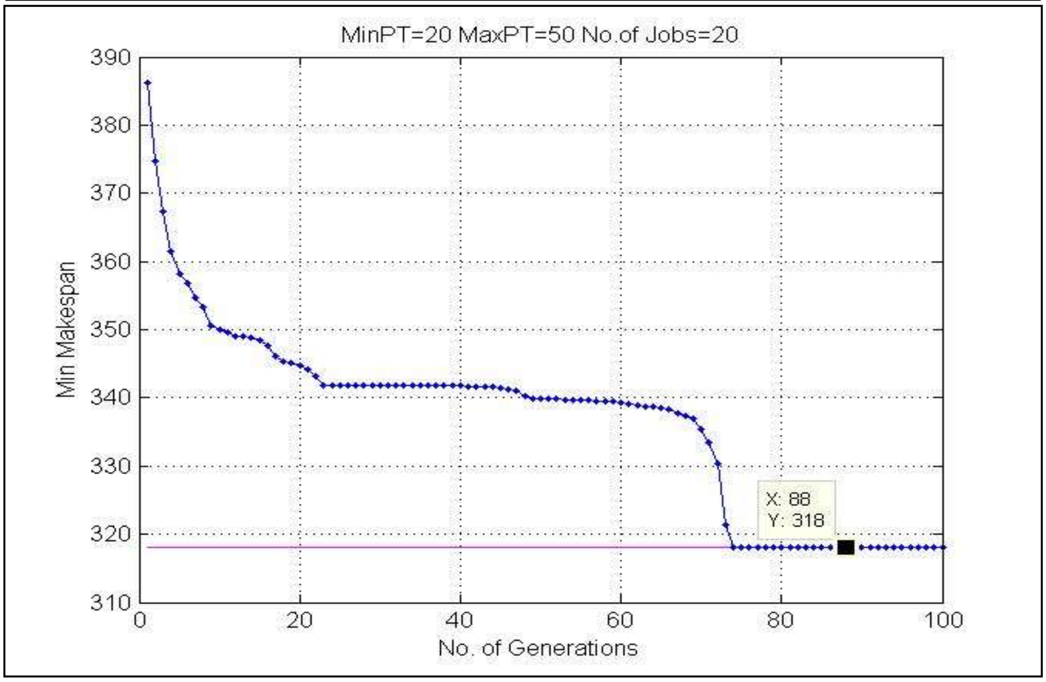
1) Shortest processing time rule (SPT)
2) Genetic Algorithm (GA)

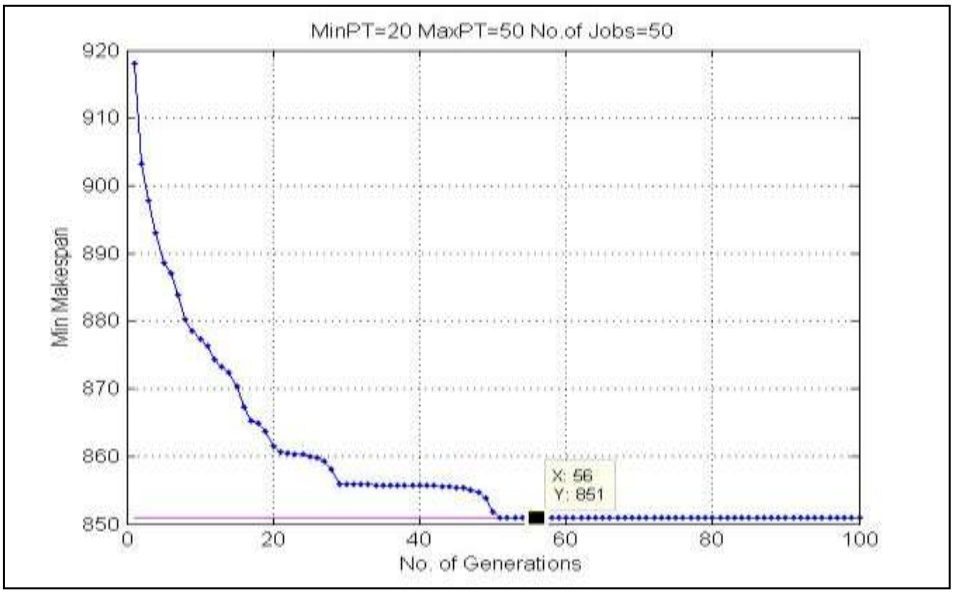
Heuristics	SPT (makespan)	GA (makespan)	CPU times (sec) : GA
10 Jobs	237	158*	379
20 Jobs	323	318*	413
50 Jobs	919	851*	430

(*) indicates those values of makespan as obtained by GA which are lower than those obtained by SPT.
Table 1: Result Comparison

H. Convergence Plots:







IV. CONCLUSION

In the present research work three categories of problems have been analyzed using modified genetic algorithm and the optimum values of makespan are compared with SPT rule which is the most commonly used heuristic in real time. From the observation table it is found that the suggested GA determines the optimum value of makespan, in considerably short time horizon. In all the three categories of problems, when the GA results are compared with SPT, it is found that the suggested GA gives better results than SPT heuristic.

REFERENCES

[1] K. E. Stecke, Overview of FMS problems and solution approaches, Annals of operation research 3(1985)-3-12
[2] Practical Genetic Algorithms, Second edition, Randy L. Haupt , John Willey & Sons 2004
[3] Jim Browne et. al. Types of flexibilities and classification of flexible manufacturing system, division of research Graduate School of Business administration the university of Michigan, February 1984
[4] Mehdi Kaighobad, Flexible Manufacturing Systems and overview, International journal of operations and production management vol. 14, 1994
[5] Klahorst T.H ,"Flexible manufacturing systems:Combining elements of lower costs add flexibility", Journal of industrial engineering, Vol.32, 1981
[6] Michael.L. Pinedo Sceduling theory algorithms and systems, Springer Science and Business Media, LLC,2008
[7] Kokin Lam et al New trends in parallel machine Scheduling, International journal of operations and production management vol. 17, 1997
[8] M. Selim Akturk & Serakan Ozkan, International journal of production research vol. 39, 2001
[9] Y. Fathi & K.W. Barnette, International journal of production research vol. 40, November 2010
[10] Roang-Lei Sun et. al. Jouranl of manufacturing technology management vol. 15, 2005
[11] Ayten Turkcan et. al. , International Journal of production research vol. 45,March 2007
[12] P. Udhayakumar & S. Kumanan, International journal of Advanced Manufacturing Technology, March 2010
[13] J. Blazwick et al, International Journal of Production Research, vol. 40,November 2010