SCHEDULING OF FLEXIBLE MANUFACTURING SYSTEMS USING GENETIC ALGORITHM

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By

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CERTIFICATE

This is to certify that the thesis entitled, "Scheduling Of Flexible Manufacturing Systems Using Genetic Algorithm" submitted by Irshant Sriramka in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela, is an authentic work carried out by him under my supervision. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

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CONTENTS

ABSTRACT

Flexible manufacturing system (FMS) scheduling problems become extremely complex when it comes to accommodate frequent variations in the part designs of incoming jobs. This work focuses on scheduling of variety of incoming jobs into the system efficiently, where machines are equipped with different tools and tool magazines, but multiple machines can be assigned to single operation. Genetic algorithm(GA) approach is one of the most efficient algorithms that aims to converge and give optimal solution in a shorter time. Therefore in this work a suitable scheduling mechanism is designed to generate a finest schedule using Genetic Algorithm(GA) approach. The results obtained are thus compared with those obtained by other scheduling rules and conclusions are presented.

INTRODUCTION

In today's competitive global market, manufacturers have to modify their operations to ensure a better and faster response to needs of customers. The primary goal of any manufacturing industry is to achieve a high level of productivity and flexibility which can only be done in a fully integrated manufacturing environment. A flexible manufacturing system (FMS) is an integrated computer-controlled configuration in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted. FMS consists of three main systems. The work machines which are often automated CNC machines are connected by a material handling system(MHS) to optimize parts flow and the central control computer which controls material movements and machine flow. An FMS is modeled as a collection of workstations and automated guided vehicles (AGV). It is designed to simultaneously manufacture a low to medium volumes of a wide variety of high quality products at low cost. The flexibility is generally considered to fall into two categories, which both contain numerous sub-categories. The first category, machine flexibility, covers the system's ability to be changed to produce new product types, and ability to change the order of operations executed on a part. The second category is called routing flexibility, which consists of the ability to use multiple machines to perform the same operation on a part, as well as the system's ability to absorb large-scale changes, such as in volume, capacity, or capability.

The rigid automation usually found in transfer lines has been replaced by computer directed techniques in FMS based manufacturing processes. The main objective of computer controlled automation is to efficiently schedule the production process based upon some computer fed logics. Various algorithms have been used to develop for the decision making and scheduling processes in FMS. In recent years, algorithms such as particle swarm optimization and strength Pareto evolutionary algorithm have been developed and are now widely used to address the decision making problems. In this work we have tried to reduce the penalty cost of the manufacturing system using Genetic Algorithm(GA).

The rest of the paper is structured as follows. Section 2 gives an insight to the literature review that was done around this topic, in section 3 we briefly discuss about the outlines of the Genetic Algorithm(GA), in section 4 we discuss the proposed methodology. Results and discussions have been done in section 5 and conclusion has been stated in section 6.

LITERATURE REVIEW

A research on general job shop scheduling and rescheduling with alternative route choices for an FMS environment was done by Jawahar et al.[1] in 1998. They used genetic algorithm approach to derive an optimal combination of priority dispatching rules. The performance is compared with regard to computational time and makespan criteria. An iterative search technique was proposed to find the best route for all operations to provide a feasible and optimal solution. Another research on scheduling of FMS was done by Sankar et al.[2] in 2003. They designed a scheduling mechanism using genetic algorithm (GA) with two different GA coding schemes namely pheno style codification and binary codification. The research concluded that binary codification is better than pheno style codification for this application and the developed procedure can be suitably modified for any FMS of any configuration, its environment and can be applied for single or multi-objective problems. this scheduling optimization well demonstrated the exploitative searching ability and processing power of genetic algorithms. Ulsoy et al.[3] proposed an offline model for simultaneous scheduling of AGVs and machines in an FMS environment for reducing makespan. They had adopted Genetic Algorithms approach. In their approach the chromosome represents both the operation number and AGV assignment which requires development of special genetic operators.

A study on flexible manufacturing systems for apparel production was done by Robert N. Tomasik et al.[4] in 1996. They developed a low-order and accurate integer programming model which integrates resource allocation and scheduling. They tested using data of a real factory producing 10 to 40 lots per week on 105 machines of nine different types. There results showed that one week schedules are generated in less than 3.5 cpu min on a 60 mhz personal computer and the schedules was 16-29% optimal. A problem on deterministic offline scheduling has been stated by Raman et al.[5] which has been formulated as an integer programming problem and a solution procedure based on the project scheduling concept under resource constraints. They assumed that the vehicles always returned to the loading/unloading station after delivering a part thereby reducing the flexibility of the FMS. Abdelmaguid et al. [6] has presented a model to minimize the makespan using new hybrid genetic algorithm for the simultaneous scheduling problem. The hybrid gas is composed of GA and a heuristic. The genetic algorithm is used to represent the first part of the problem that is theoretically similar to the job shop scheduling problem and a heuristic called vehicle assignment algorithm (VAA) handles the vehicle assignment. Lacomme et al.[7] has discussed the simultaneous job input sequence and vehicle dispatching for a single AGV system. Using the branch and bound technique coupled with a discrete event simulation model they solved the problem.

Kumar et al.[8] solved part type selection and machine-loading problems in production planning of FMS by using genetic algorithm (GA). Kumar et al.[9] attempted to solve the scheduling problem of FMS using Ant colony optimization technique. They proposed a solution procedure in which they applied a graph-based representation technique with nodes and arcs representing operation and transfer from one stage of processing to the other. The result of this algorithm was a collective outcome of the solution found by all the ants. In 2007, S.S. Mahapatra and Sandhyarani Biswas[10] attempted to address loading problems in FMS using mutation in particle swarm optimization (PSO) to avoid premature convergence with the objective of minimization of system unbalance. In 2010, Mahapatra and biswas.[11] attempted to solve loading problems in FMS environment using Artificial Immune system Approach. The main focus of their work was to find a more resourceful and competent Methodology, which will be capable of maintaining good memory and can give better quality results with fast convergence rate. Shirazi et al.[12] developed a model which describes a simulation-based intelligent decision support system (IDSS) for real time control of a flexible manufacturing system (FMS) with machine and tool flexibility. They build the system design around the theory of dynamic supervisory control based on a rule-based expert system. Jerald et al.[13] discussed about simultaneously scheduling of jobs, Automated Guided Vehicles, Artificial Storage And Retrieval System in an

FMS environment using artificial immune system approach in 2009. They considered a large variety problem with multiple objectives like minimizing penalty cost, minimizing machine idle time and minimizing the distance travelled by the Storage And Retrieval System. Ponnambalam et al.[14] developed a particle swarm optimization (PSO) algorithm in 2008 to solve machine loading problem in flexible manufacturing system (FMS) with objectives including minimization of system unbalance and maximizing system throughput in the presence of machining time and tool slots constraints. They also developed a mathematical model to select machines and the required tools and to assign operations. dong-ho lee et al.[15] in 1999, discussed about scheduling of flexible manufacturing systems with partially grouped machines. they solved the problem using two algorithms, one for simultaneously solving the two sub problems using rules for part selection and machine selection and the other algorithm using simulated annealing algorithm and dispatching rules. Jie Chen and F. Frank Chen.[16] discussed about scheduling of Flexible Manufacturing Systems which will be subjected to machine breakdowns. Balogun and popplewell.[17] concentrated their research on the reports of solutions from different methodologies applied for solving scheduling problems in an FMS environment. Subbaiah et al.[18] used sheep flock heredity algorithm to solve scheduling problems in FMS. They considered scheduling of Automated Guided Vehicles and machines in an FMS environment. Ramli et al.[19] introduced a hypothetical algorithm based on reasoning which has the ability to decide on the action of an AGV that works in the independent decentralized Flexible Manufacturing System.

PROPOSED METHODOLOGY

GENETIC ALGORITHM

Genetic algorithm (GA) are adaptive heuristic search algorithms premised on evolutionary ideas of natural selection and genetic. This heuristic is routinely used to generate useful solutions to optimization and search problems following the principles of Charles Darwin of survival of the fittest. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as reproduction , mutation and crossover.

Genetic Algorithm has been used to schedule jobs in a sequence dependent setup environment for a minimal total tardiness. All jobs are scheduled on a single machine; each job has a processing time and a due date. The setup time of each job is dependent upon the job which immediately precedes it. The GA is able to find good, but not necessarily optimal schedules, fairly quickly. In a genetic algorithm, a population of strings (called chromosomes), which encode candidate solutions (called individuals) to an optimization problem, evolves toward better solutions. Here, solutions are represented in binary as strings of 0 and 1, but other encodings are also possible. The process usually starts from a population of randomly generated individuals and happens in generations. In each iteration, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and mutated to form a new population. The new population is then used in the next iteration of the algorithm. Generally, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness value has been reached for the population. If the algorithm has terminated due to a limit to maximum number of iterations, a satisfactory solution may or may not have been obtained. A typical genetic algorithm requires a genetic representation of the solution and a fitness function to evaluate the solution. Initially many individual solutions are randomly generated to form an initial population, allowing the entire range of possible solutions. The population size depends on the nature of the problem, but typically contains several hundreds or thousands of possible solutions. During each successive iteration, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process. The next step is to generate a second generation population of solutions from those selected through genetic operators: crossover and mutation.

For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". For each new child, New parents are selected and the process continues until a new population of solutions of appropriate size is generated. These processes ultimately result in the next generation population of chromosomes that is different from the initial generation. Generally the average fitness will have increased by this procedure for the population, since only the best organisms from the first generation are selected for breeding, along with a small proportion of less fit solutions. Termination criteria of the genetic algorithm mechanism is based on the reaction time within which the solution should be obtained and the minimum satisfactory performance level expected.

FITNESS FUNCTION

Every sequence when generated is first evaluated by calculating its objective

Value. These objective values are a measure of the efficiency of the sequence generated, hence otherwise known as fitness function. In the present work we are considering penalty time as the objective value.

Operation Completion Time $O_{ij} = W_i + P_{ij}$

W_i= Waiting time

P_{ij}= Processing Time for job i for operation j.

i= job number, j=operation number

D_i=Due time for job i

C_i= Summation of O_{ij} for i= 1 to n

Makespan= max(C_i) where i= 1 to n

C_p=total penalty cost incurred

$C_p = \sum_i (O_{ij} - D_i) \times PPU_i \times BS_i$

PPU_i=penalty cost per unit i.

BS_i=batch size of part i.

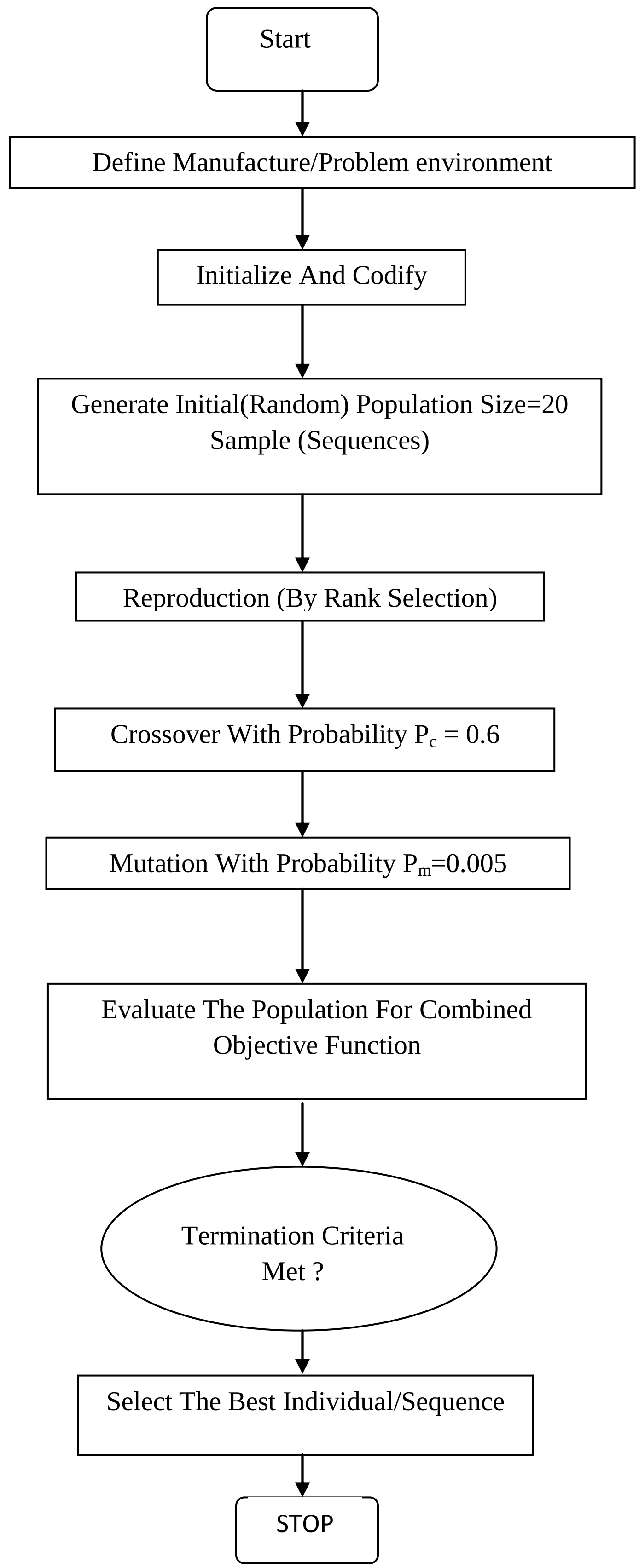
Combined objective function(*COF*):

minimize *COF* $= C_p \div MPP$, where MPP = maximum permissible penalty.

ADVANTAGES OF GENETIC ALGORITHM

- Works smoothly with both numerical and experimental data, or analytical functions.
- It is well suited for parallel computing .
- It optimizes with both continuous or discrete variables efficiently.
- It doesn’t require any derivative information.
- Simultaneously searches from a wide sampling of the cost surface.
- Handles a large number of variables at a time.
- Optimizes variables with extremely complex cost surfaces.
- Provides a list of optimum variables, not just a single solution.
- May encode the variables so that the optimization is done with the encoded variables.

A FLOWCHART OF THE SCHEDULING PROCEDURE USING GENETIC ALGORITHM


Start
Define Manufacture/Problem environment
Initialize And Codify
Generate Initial(Random) Population Size=20 Sample (Sequences)
Reproduction (By Rank Selection)
Crossover With Probability P_c = 0.6
Mutation With Probability P_m=0.005
Evaluate The Population For Combined Objective Function
Termination Criteria Met ?
Select The Best Individual/Sequence
STOP

FMS ENVIRONMENT

The machines are arranged in a typical layout in a given FMS environment. The set of jobs are scheduled as per an optimum sequence that contains information both about the sequence of operations on different parts and has the minimum penalty time. Flexible manufacturing system (FMS) is one of the most researched areas in the field of production engineering. Various Production houses aim to implement such set ups for production related because of their higher efficiency and flexibility. The FMS completes a task by performing a series of operations through the workstations, and the parts are transported between the workstations by the AGVs. The main advantage of an FMS is its high flexibility in managing manufacturing resources like time and effort in order to manufacture a new product. The best application of an FMS is found in the production of small sets of products like those from a mass production. To achieve high performance for an FMS, a good scheduling system should make a right decision at a right time according to system conditions. A flexible manufacturing system (FMS) provides the efficiency of automated high-volume mass production while retaining the flexibility of low-volume job shop production. Scheduling of jobs in an FMS environment is more complex and difficult than in a conventional manufacturing environment. Therefore, determining an optimal schedule and controlling an FMS is considered a difficult task. Since the invention of the flexible manufacturing systems, many researchers are working on the topic to find out the solution to scheduling of flexible manufacturing systems and developed number of solution methods for scheduling FMS. However, the computational effort required makes such as an approach impractical for real-time control in most applications. Therefore, mathematical programming formulations may be used as a basis for the development of scheduling heuristics. As the computation power of available computers has improved rapidly several heuristic approaches based on iterative improvement procedures have been applied to the FMS scheduling problem.

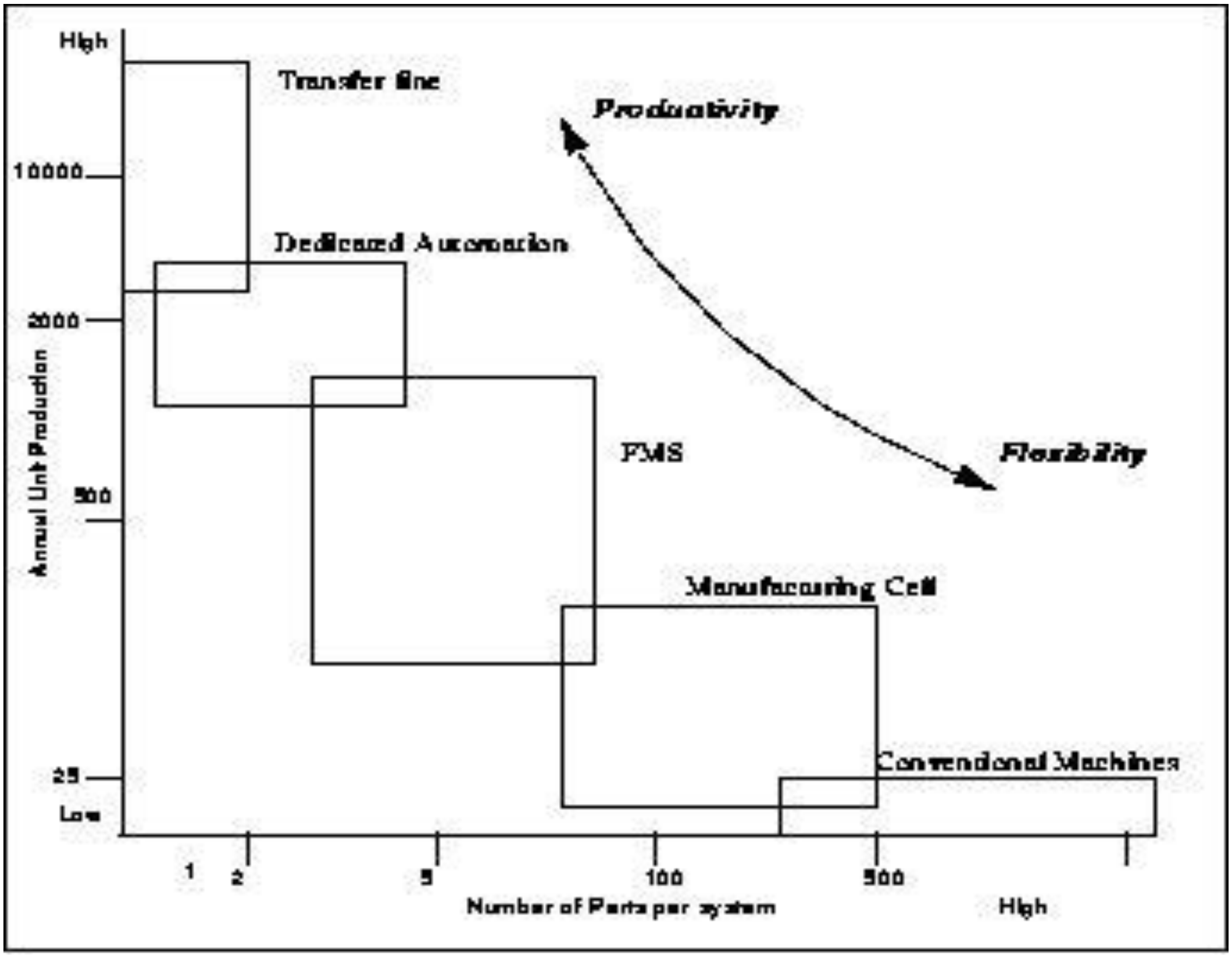


Figure 1

The graph in figure 1. shows that a balanced permutation of productivity and flexibility can be obtained in an FMS environment most efficiently. The reason the FMS is called flexible is that it is capable of processing a variety of different part styles simultaneously at various work stations and the mix of the part styles and quantities of production can be adjusted in response to changing demand.

FLOW ALGORITHM OF FMS

1. Start

2. Input Sequence

3. Operations are scheduled as per sequence

4. The parts are moved to their respective processing stations by the AGVs.

5. The semi-finished part is then moved to the next machine.

6. If the machine is not free, the job is loaded in the Automatic storage and retrieval system.

7. If all operations are completed calculate the penalty else move to the next machine.

8. Stop

ILLUSTRATIVE EXAMPLE

In this study we have considered an FMS environment with five flexible manufacturing cells, automated guided vehicles(AGV), an automatic storage and retrieval system(AS/RS). Each of the FMCs have two to six computer numerical control machines (CNCs) each with an independent self sufficient tool magazine. Each cell is supported by one to three dedicated robot/s for the intra-cell movement of parts between operations. Each CNC machine is equipped with one automatic tool changer and one automatic pallet changer.

There is a loading station where parts are released in batches for processing in the flexible manufacturing systems. There is an unloading station from where the finished parts are collected and conveyed to the finished part storage system. The automatic storage and retrieval system (AS/RS) does the work to store the part under progress. The five flexible manufacturing cells are connected by sufficient number of automated number of guided vehicles. These AGVs perform the inter-cell movement between the FMCs. These AGVs also perform the task for the movement of loaded pallets from the loading station to any of the FMCs, the movement of semi-finished products between the AS/RS and the FMCs and the movement of finished product from any of the FMCs to the unloading station. The task of loading and unloading AGVs is done by dedicated robots.

ASSUMPTIONS FOR THIS WORK

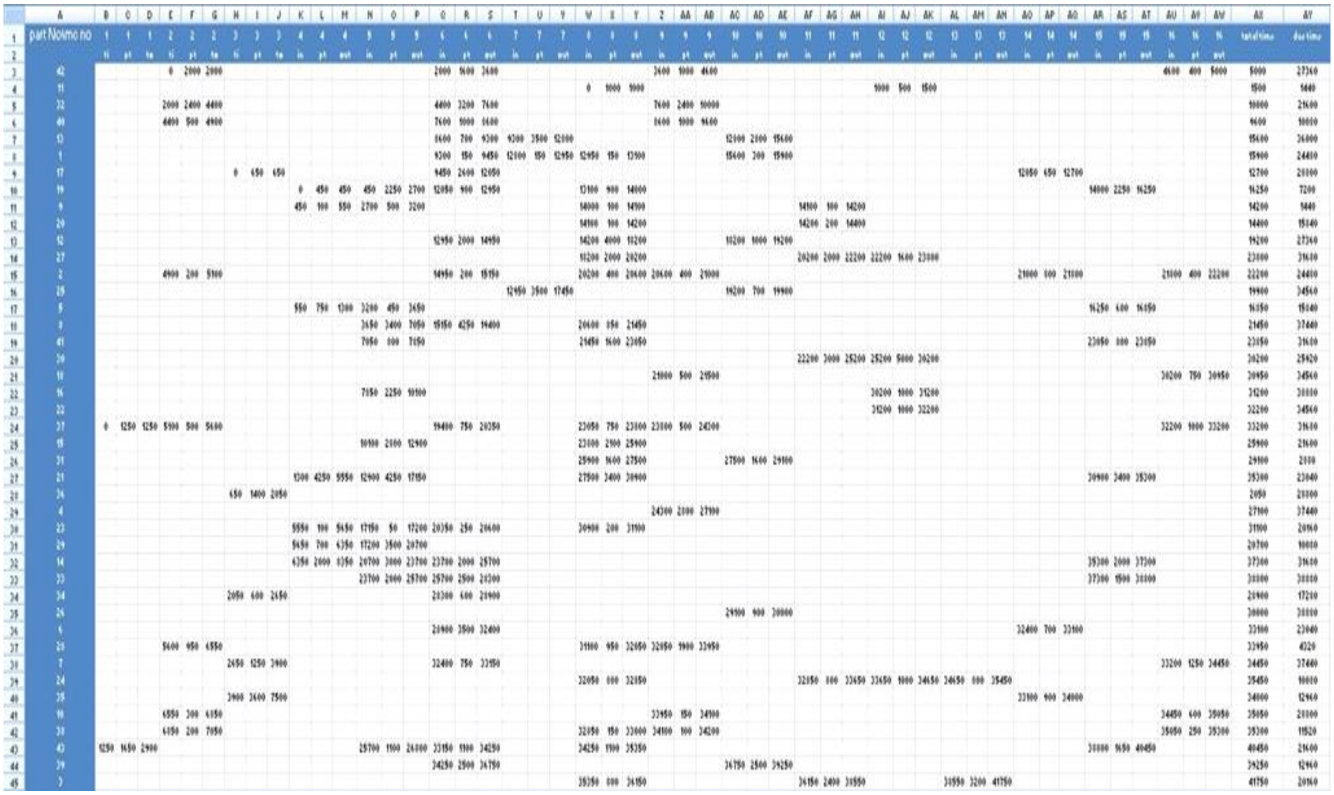
- There is no constraint on the availability of robots, ASRS, AGVs, pallets, fixtures etc.
- Each processing step has a processing time on a specific machine.
- The FMS is considered as a pure job shop environment handling 40-50 varieties of products with defined combination of tools and tool magazines.
- There is no variation in part varieties in this study.
- Each of the part have a defined processing sequence , batch size, due date and penalty cost per unit per day for not meeting the due date.

The detail of processing sequence of different parts along with the due date, batch size and penalty cost is shown in Table 1.

Part number	Processing sequence: Machine number (processing time in minutes)	Due date (days)	Batch size (no.)	Penalty (Rs/unit/day)
1	6(1)-7(1)-8(1)-10(2)	17	150	1.00
2	2(1)-6(1)-8(2)-9(2)-14(4)-16(2)	17	200	1.00
3	8(1)-11(3)-13(4)	14	800	1.00
4	9(4)	26	700	2.00
5	4(5)-5(3)-15(4)	11	150	1.00
6	6(5)-14(1)	16	700	1.00
7	3(5)-6(3)-16(5)	26	250	2.00
8	5(4)-6(5)-8(1)	26	850	2.00
9	4(1)-5(5)-8(1)-11(1)	1	100	0.00
10	2(2)-9(1)-16(4)	20	150	2.00
11	8(4)-12(2)	1	250	1.00
12	6(2)-8(4)-10(1)	19	1000	3.00
13	6(1)-7(5)-10(4)	25	700	4.00
14	4(2)-5(3)-6(2)-15(2)	22	1000	4.00
15	5(4)-8(3)	15	700	5.00
16	5(3)	27	750	3.00
17	3(1)-6(4)-14(1)	20	650	5.00
18	9(2)-16(3)	24	250	4.00
19	4(1)-5(5)-6(2)-8(2)-15(5)	5	450	1.00
20	8(2)-11(4)	11	50	5.00
21	4(5)-5(5)-8(4)-15(4)	16	850	3.00
22	12(5)	24	200	5.00
23	4(2)-5(1)-6(5)-8(4)	14	50	4.00
24	8(4)-11(4)-12(5)-14(4)	7	200	5.00
25	7(3)-10(2)	24	350	1.00
26	10(2)	27	450	0.00
27	8(5)-11(5)-12(4)	22	400	1.00
28	2(1)-8(1)-9(2)	3	950	5.00
29	4(1)-5(5)	7	700	1.00
30	11(3)-12(5)	18	1000	1.00
31	8(2)-10(2)	2	800	2.00
32	2(3)-6(4)-9(3)	15	800	1.00
33	5(4)-6(5)-15(3)	27	500	4.00
34	3(2)-6(2)	12	300	4.00
35	3(4)-14(1)	9	900	2.00
36	3(2)	20	700	2.00
37	1(5)-2(2)-6(3)-8(3)-9(2)-16(4)	22	250	4.00
38	2(4)-8(3)-9(2)-16(5)	8	50	1.00
39	6(5)-10(5)	9	500	1.00
40	2(2)-6(4)-9(4)	7	250	5.00
41	5(1)-8(2)-15(1)	22	800	4.00
42	2(5)-6(4)-9(3)-16(1)	19	400	2.00
43	1(3)-5(2)-6(2)-8(2)-15(3)	15	550	3.00

Table 1.

Here, the feasible or possible job sequences are coded in two different ways and experimented separately. The two ways of coding are pheno style and binary coding. The solution was improving at a faster rate for a cross-over probability of 0.60. And in similar way the mutation probability was found to be 0.005 at which more better solutions were retained. The termination criteria was taken as 100 generations or a adequate predefined lowest value for *COF*, whichever comes first.



In this sheet, ti=time in, pt=processing time, to=time out

A sheet in ms excel has also been made for better understanding the FMS environment. A sequence of 43 parts is taken according to pheno style coding. According to this sequence, the parts are processed to find out the makespan as well as penalty time. "time in " is the time for start of a particular job in a machine. "processing time" is the time taken by the batch of the part on a particular machine in minutes. "time out" is the time when the job completes its operation on a particular machine. The AX column shows the completion time of each of the parts. The part with the largest completion time shows the makespan of the schedule considered in this example. Time is shown in minutes form for better computing. In this example, jobs are arranged in a sequence generated by the working algorithm. Whenever a machine is engaged in an operation, the waiting time of the job to be operated by that machine is added to the total processing time of a job.

RESULTS AND DISCUSSION

The designed scheduling procedure with genetic algorithm was coded in C++. After many trials it was found that the procedure is able to achieve the objective criteria well before the termination of the genetic algorithm mechanism. From the last generation of trial schedule with minimum COF, an optimal schedule was selected. This optimal schedule obtained by the genetic algorithm procedure for the FMS was compared with the solutions obtained by other different scheduling rules. In this study of experimental problem the solution obtained by the genetic algorithm approach gives the minimum total penalty cost a well as a higher utilization of machines(i.e. Minimum machine idleness). And as a result a minimum COF is obtained.

The value of COF for genetic algorithm approach was found to vary between 0.274 to 0.280 depending on the method of coding. whereas for other scheduling rules it came as follows:

1. According to Earliest Due Date (EDD) scheduling rule, COF=0.462, Penalty=0.206. Schedule: 26, 16, 33, 4, 7, 8, 13, 18, 22, 25, 14, 27, 37, 41, 10, 17, 36, 12, 42, 30, 1, 2, 6, 15, 21, 32, 43, 3, 23, 34, 5, 20, 35, 39, 38, 24, 19, 40, 29, 28, 31, 9, 11.

2. According to Largest Processing Time (LPT) scheduling, COF=0.487, Penalty=0.271. Schedule: 19, 14, 8, 30, 32, 12, 13, 21, 43, 3, 33, 27, 42, 39, 15, 17, 35, 29, 6, 37, 38, 24, 7, 31, 41, 4, 40, 2, 16, 5, 25, 11, 36, 18, 34, 10, 22, 26, 9, 1, 28, 23, 20.

3. According to Shortest Processing Time (SPT) scheduling, COF=0.327, Penalty=0.161. Schedule: 34, 23, 28, 7, 9, 26, 22, 10, 20, 18, 36, 11, 25, 5, 21, 2, 40, 4, 41, 31, 1, 24, 38, 17, 6, 27, 35, 37, 15, 39, 42, 29, 33, 3, 43, 19, 13, 12, 32, 30, 8, 14, 16.

The most optimum schedule according to Genetic Algorithm came out to be as: 31, 12, 7, 22, 33, 25, 5, 23, 20, 35, 36, 37, 15, 1, 2, 9, 4, 3, 40, 42, 21, 11, 14, 38, 27, 43, 17, 10, 16, 30, 39, 18, 29, 8, 41, 32, 34, 28, 24, 6, 19, 26, 13. With COF of 0.275 and penalty value of 0.018.

CONCLUSION

The present work done is focused on scheduling of jobs in an FMS environment using genetic algorithm(GA). The scheduling of jobs using genetic algorithm aims at minimizing the penalty cost as well as makespan time. A comparison based on this penalty cost has been carried out. The algorithm has been encoded in Visual C++ 2007 edition. The algorithm has proved to be efficient in many of the bench mark problems addressed in Sankar et al.(2003) . In most of the cases the algorithm converged within 12-15 iterations for a population size of 20. The computational time has been reasonable and the solutions obtained are near to optimal. The exploitative searching ability and processing power of Genetic Algorithm has extensive potential approach to manufacturing.

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