Eng.& Tech. Journal ,Vol. 30, No.7 , 2012

Development of Job Scheduling and Machine Loading System in FMS

Dr. Zaid Hikmat Yaqoub
Production & Metallurgy Engineering Department, University of Technology/Baghdad
Email: zaid_hikmat@yahoo.com
Dr. Amjad Barzan Abdulghafour
Production & Metallurgy Engineering Department, University of Technology/Baghdad
Email: amjad_barzan@yahoo.com

Received on: 2/5/2007 & Accepted on: 5/12/2007

ABSTRACT

Manufacturing industries are rapidly changing from production of scale to production of scope characterized by short product life cycles and increased product varieties. This implies a need to improve the efficiency of job shops while still maintaining their flexibility. These objectives are achieved by Flexible manufacturing systems (FMS). The basic aim of FMS is to bring together the productivity of flow lines and the flexibility of job shops, this duality of objectives makes the management of FMS complex. In this research, the loading problem in FMS, which is viewed as selecting a subset of jobs from the job pool and allocating them among available machines, is considered. The research investigates the number of machine loading approaches, which aim to meet the delivery dates of production orders, and at the same time reduce the manufacturing cost.

Keywords: Scheduling, Machine loading, integer programming, Flexible manufacturing System (FMS)

تطوير نظام تحميل المكائن و جدوله العمل في نظام التصنيع المرن

الخلاصه

انظمه التصنيع سريعه التغيير من الانتاج الكمي الى الانتاج حسب الطلب و الذي يتميز بتقليل دورة حياة المنتج و زيادة تعدد المنتوجات. هذا التغيير يتطلب تحسين كفاءة ورشه الانتاج مع الحفاظ على المرونه وهذه الاهداف تنجز بواسطه انظمه التصنيع المرنه. ان الهدف الرئيسي من انظمه التصنيع المرنه الربط مابين نظام الانتاج الخطي و نظام التصنيع حسب الطلب، هذه الازدواجيه تجعل ادارة انظمه التصنيع المرنه معقده. في هذا البحث يتم اختيار الاعمال من قوائم العمل و توزيعها على مجموعه من المكائن المتوفرة كذلك يتم البحث في طرائق التحميل المختلفه و التي تهدف الى الحصول على اوقات التجهيز لاوامر العمل و تقليل كلفه الانتاج.

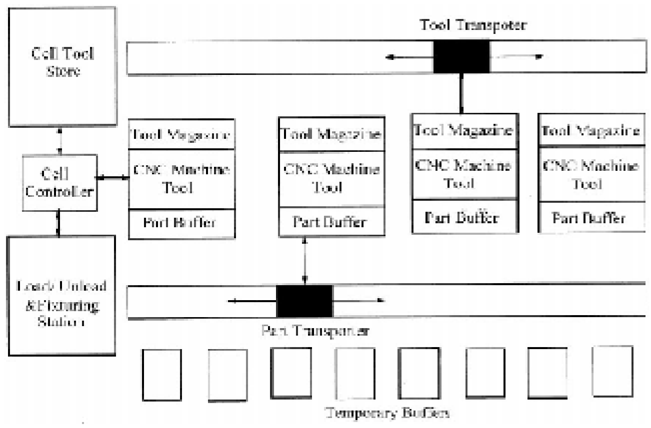
INTRODUCTION

The advent of global economy and trade has resultedin competition that has led enterprises to face a dynamicenvironment. Such an environment is characterized by alarge volume of uncertainty, such as rapid marketchanges, increased product variety, competitive prices,and short product life cycles[1]. Time to market is now accepted as a pivotal strategy to increasing and/or retaining a firm's market share in the face of global competition. For many industries, it is an accepted norm that a reduction in time to market of even one week can accrue significant revenues[2, 3]. Currently, firms often apply flexible manufacturing system (FMS), to reduce the time to market for their products. FMS ensures quality product at lowest cost while maintaining small lead-time. So, firms adopt the FMS as a means for meeting mounting requirements of customized production. One of the main purposes of the FMS is to achieve efficiency of a well-balanced transfer line while retaining the flexibility of the job shop[4, 5 & 6].

Flexible manufacturing systems (FMS) have been developed to integrate computer-controlled configurations of numerical control (NC) machine tools along with other auxiliaryproduction equipment, and a material handling system tosimultaneously manufacture a low to medium volumes of awide variety of high quality products at a competitive cost. Since FMSs are very expensive, it is crucial to managethem effectively to achieve optimum results with the leastinvestment risk and this largely depends on how the decisionbeing made to tackle the problems in FMS[7, 8& 9].Use of flexible manufacturing systems lead to[3& 10]:

* Increased product variety to satisfy customer needs.
* Shorter product development cycle.
* Flexibility to adapt to changes in the market.
*Improved capital/equipment utilization.
* Increased productivity and decreased costs of goods and services to maintain the market share.
* Reduced set up time and work-in-process (WIP).
* Quick cell creation for a new product family by simply re-programming the FMS.

The FMS system is illustrated in Fig (1). An automated pallet handling system delivers n blanks consisting of different parts into the cell. The robot reaches to the pallet, grips blank, moves to the first machine, and loads the blank. While the first machine starts operation on the part, the robot reaches the pallet, grips the second part, moves to the second machine, and loads it to the machine. Next, robot reaches to the machine which finishes its operation first, unloads the finished part and loads a new part. The loading/unloading operation continues in this way with the preference given to the machine which finishes its operation first. After the machining operations of all parts on the pallet are completed, the pallet with n finished parts moves out and a new pallet with n blanks are delivered into the cell automatically. Due to the introduction of different parts into flexible manufacturing cell (FMC) and the characteristics of the system operation, processing times as well as the loading/unloading times are random, which present a complication in studying and modeling the cell performance. If there was no randomness in system parameters, the problem could be analyzed by a man-machine assignment chart for non-identical machines, and by a symbolic formulation for identical machines[1& 6].



Figure[1] FMS System,[5]

In general, the machine loading policies which minimize the mean flow times of jobs, and provide the best method of achieving the completion dates, often result in high manufacturing costs through the increase in tooling and fixturing requirements and their related set-up activities. On the other hand, machine loading policies which are developed to reduce these manufacturing costs do not guarantee the meeting of job completion dates.

Solving machine-loading problems in FMS system can be classified into four different approaches[2,11& 12]:
(1) Multi-criteria decision-making approaches:
(2) Simulation-based approaches:
(3) Heuristic-based approaches:
(4) Mathematical programming approaches:

The grouping and loading were formulated as non-linear 0–1 mixed integer programs. Solution methodologies with several computational simplifications had been developed. These formulations assumed that a product-mix problem was already solved and therefore limit the models to be suitable only for dedicated FMS.

RELATED WORKS

This paragraph reviewed the literature on machine loading problem of FMS:

Dhat P. R. *et.al*.[1]proposed an algorithm based onArtificial Immune Systems (AlS) to solve the machineloadingproblem of a random FMS with the objective ofthe minimization of system unbalance while satisfying theconstraints related to the available machining time andtool slots. The AlS approach has recently been applied tovarious scheduling problems like job shop, flow shop, andsingle machine tardiness problem.

HameshbabuNanvala, Gajanan. K. Awari, Principal. [12]presented reviewed the literature on machine loading problem of FMS and classified the articlesaccording to the approaches used to solve the machine loading problem in FMS and presented the gist ofliterature reviewed.

H.-W. Kim, *et.al.* [8]considered a loading problem for systemsetup in flexible manufacturing systems with partiallygrouped unrelated machines and additional toolingconstraints, i.e., available tool copies and tool life restrictions.An integer linear programming model issuggested for objective of minimizing the maximumworkload. Then, two heuristics, consisting of obtainingan initial solution and improvement, were suggestedbased on the LPT and the MULTIFIT algorithm for thebin packing problem. The test result showed that theMULTIFIT based heuristic outperforms the LPT basedone while requiring very short computation time.

UmiKalsomYusof, RahmatBudiarto, SafaaiDeris[7]considered a machine-loading problem in FMS environment. The machine loading problemmay be addressed as “given a set of part types to beproduced, set of tools that are needed for processing theparts on a set of machines, and using a set of resourcessuch as material handling systems, pallets and fixtures, howshould the parts be assigned and tool allocated so that somemeasure of productivity is optimized”. The functions areable to minimize the idle time of the machine that leads tomaximization of machine utilization and enhancing overallsystem output

Mussa I. Mgwatu[10] demonstrated the importance of incorporating and solving the machining optimization problem jointly with part selection and machine loading problems in order toavoid unbalanced workload in the FMS.Two mathematical models are presented and solved in efforts to balance the workload andimprove the performance of the FMS. A two-stage sequential approach is adopted whereby thefirst stage deals with the maximum throughput objective while the second stage deals with theminimum production cost objective. The results show that when part selection, machine loadingand machining optimization problems are jointly solved, more practical decisions can be madeand a wide range of balanced workload in the FMS can be realized with minimum productioncost objective.

MACHINE LOADING POLICIES FOR FMC

The range of machine loading policies reported in this paper are categorized into three classes: namely, single machine loading, multi-machine loading and combined machine loading, and are outlined below[13].

SINGLE MACHINE LOADING

In batch machining applications a job is usually divided into a number of transfer batches. In most applications, all of the transfer batches of a job are allocated onto a single machine. This type of machine loading policy, referred to in this paper as `single machine loading' (SML) is usually the most economical method of processing jobs, as it avoids the duplication of set-ups, fixtures and cutting tools on the different machines at the same time. However, the use of this policy may result in longer production lead times, higher work in progress, and consequently in missing job completion dates.

MULTI-MACHINE LOADING

In FMC applications where there is a need to minimize job-flow time, work in progress and meet job completion dates, a different machine loading policy referred to as `multi-machine loading' (MML) is utilized, in which the transfer batches of a single job are allocated across all machines in the cell. The implementation of MML often results in very high operational costs because of the following[5]:

- duplicate sets of cutting tools have to be loaded onto the different machines at the same time,
- the limited number of parts included in a transfer batch does not effectively utilize the tool lives, resulting in a large number of partially worn tools,
- a large inventory of various fixture types are required, as identical fixtures need to be present in different machines at the same period during the manufacturing horizon.

COMBINED MACHINING LOADING

In general, the MML policy by minimizing the mean flow times of jobs provides the best method of achieving the completion dates. However, as stated, MML often results in high manufacturing costs through the increase in tooling and fixturing requirements and their related activities. On the other hand, SML minimizes these manufacturing costs but does not guarantee the meeting of job completion dates. The research investigated the generation of a novel machine loading policy, termed `combined machine loading' (CML) policy. The CML policy incorporates the advantages offered by both MML and SML, by minimizing tool and fixturing requirements and achieving the completion dates of jobs and results in a hybrid approach between SML and MML. The machine loading procedures based on CML are carried out in two main stages:

1- In the first stage the jobs are pre-allocated to the machines using SML to identify any tardy jobs.

2- The second stage is a repetitive process that considers the planning intervals with jobs which have not achieved their completion dates. If the degree of lateness of the tardy jobs is not acceptable, then one or more jobs within this planning interval are selected, split and reallocated across two or more machines. These jobs, in the first instance, are divided between the machine on which it was pre-allocated originally and the machine with the least workload for that specific due date interval. If the division of a job across two machines does not resolve the dilemma of the tardy jobs, this job would be further divided between three or more machines. Finally, if the division of a job across all possible machines has not resolved the problem of tardy jobs, another job would be selected for splitting and reallocated across a number of machines[2 &5].

MACHINE LOADING PROBLEM

Problem Description

This paper addresses the loading problem in a random FMS. The loading problem is concerned with the allocation of part operations and required tools amongst machine groups for a given product mix. In a random FMS, the loading decisions are dynamic and are made for a specified planning horizon. The constraints that usually influence the loading decisions are the number of tool slots available on the tool magazine of a machine spindle, the number of slots a tool occupies on the magazine, nonsplitting of jobs, capacity of various machines etc. The problem statement is as follows: A random FMS with ‘n’ machines is considered. Each machine has a known tool slot capacity of its tool magazine. For a given scheduling period, it is assumed that there are ‘m’ jobs to be loaded on ‘n’ machines. For each job, the operation processing times and the tool slot requirements are known with certainty. The assumptions made are as follows:

- Non-splitting of job—which implies that a job undertaken for processing is to be completed for all its operations before considering a new job.
- Unique job routing—though the flexibility exists in the selection of a machine for optional operation, once a machine is selected for it, the operation must be completed on the same machine.
- Sharing of tool slots is not considered
- Number of pallets and fixtures used in the system aresufficient and readily available.
- Parts are readily available on machines i.e. materialhandling time is negligible.

Theobjective function (Eq.3) considered by them is the maximization oftotal system-assigned workload. This objective function isequivalent to minimization of system unbalance, if overloadingon the machines is not considered. In heuristic,overloading of the machines is considered, so objectivefunction is slightly modified to incorporate this aspect. Theconstraints are similar to the stated ones.

Notations

mNo. of jobs available for loading
n No. of machines available in the system
Tj length of scheduling period for jth machine
Pikj processing time of operation k of job i on machinej
yinumber of operations of job i
aibatch size of job i
B(i,k) set of machines on which operation k of job i canbe performed
Sikj number of tool slots required for processingoperation k of job i on machine j
tj tool slot capacity of machine j

$$x_i = \begin{cases} 1, & \text{if job } i \text{ is selected} \\ 0, & \text{otherwise} \end{cases} \qquad \ldots\ldots. (1)$$

$$x_{ikj} = \begin{cases} 1, & \text{if operation } k \text{ of job } i \text{ is assigned on machine } j, \\ 0, & \text{otherwise} \end{cases} \qquad \ldots\ldots (2)$$

Mathematical Model

$$Minimize = \left| T_j - \sum_{i=1}^{m} \sum_{k=1}^{yi} a_i P_{ikj} x_{ikj} \right| = \text{objective function} \qquad \ldots\ldots\ (3)$$

Subject to

$$\sum_{i=1}^{m} \sum_{k=1}^{y_i} S_{ikj}\, x_{ikj} \le t_j \quad \forall j = 1,..,n, \qquad \ldots..\ (4)$$

$$\sum_{G \in B(i,k)} x_{ikG} \le 1 \qquad \forall i = 1,..,m,\ k = 1,...,y_i, \qquad \ldots...\ (5)$$

$$\sum_{k=1}^{y_i} \sum_{j=1}^{n} x_{ikj} = x_i k_j \quad \forall j = 1,..,m, \qquad \ldots\ldots..\ (6)$$

The objective function (Eq.3) minimizes the absolute valueof total system unbalance. This objective function takescare of over utilization of the machines. The first constraint(Eq.4) is technological constraint. The jobs will be loaded onlywhen there is availability of tool slots on each machine.The second constraint (Eq.5) ensures that a particularoperation of a job is done only on one machine. The thirdconstraint (Eq.6) ensures that the job cannot be split. If a job isselected for loading, all its operations are to be completedwithin the same scheduling period. Here xi and xikj aredecision variables and others are parameters.Let consider a problem with six jobs, having twooperations for each, with four alternatives for eachoperation and jobs are to be loaded on four machines.Here m = 6, n = 4 and yi= 2 for all i. The number ofdecision variables is 54 and the number of constraints is 22.As the problem size increases, the number of variables andconstraints will increase further. These types of problemsare considered hard and obtaining optimal solution forpractical problems is unrealistic. Hence there is search forfinding out a better heuristic, which can provide a solutionnearer to optimal, if not optimal.

PROPOSED ALGORITHM

The flowchart illustrate in fig (2) represents proposed algorithm start with specifies jobs of customer order, operation number and determine the machine and capacity available after inputting the required data. The algorithms test if the all part type arranged in given sequence (if no the algorithms return to specify jobs of customers order and operation number else the algorithms determine essential processing time of job shop for all machines, initially the aggregated capacity for machines and selection allocation jobs for all machines). The algorithms test if all jobs being scheduling (if no the algorithms return to determine essential processing time of job shop for all machines else the algorithms solve the loading problem Improve the generated sequence of jobs). After this the algorithms test feasible allocation plan if found else the algorithms repeat else the algorithms end.

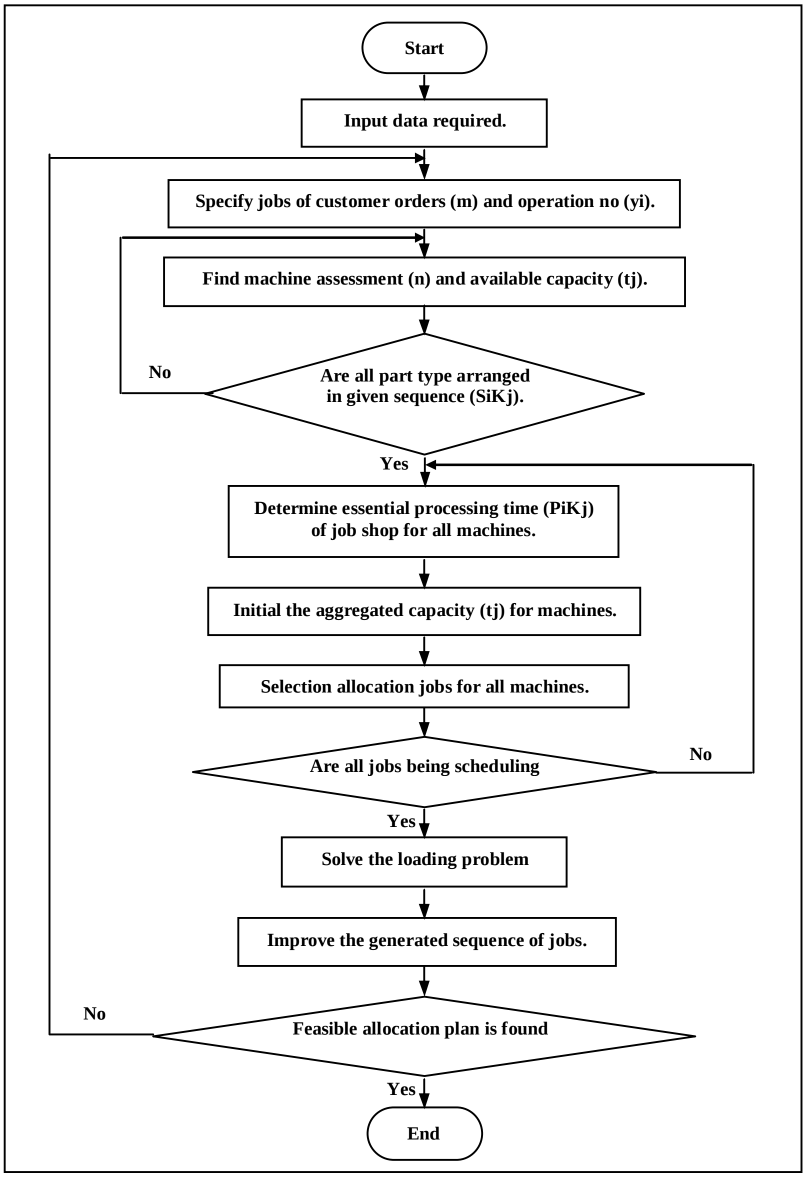


Figure (2) flowchart of the Mathematical Programming

Table (1a) Data input for system

Factory: job shop	
Process: job scheduling	Problem: machine loading
Time: 7:35: 14	Date: 5/1/2005
Job number	6 parts
Real time	1000 hours
Shift time	8 hours
Shift number	2 shift
Machine number	5 machine
Capacity available	15000 – 25000 hours

DEVELOPED SYSTEM

The developed system of job scheduling and machine loading in random FMS environment will provide the necessary information to generate production plan. The framework of developed system as shows in fig (3) consists of machine loading module, job scheduling module, user interface, capacity planning and databases. The Job Scheduling and Machine Loading (JSML) system begins in reading the inputs that contain type of part, part quantity and machine available. The program scheduling the part and loading it into machine according to time, quantity of part required and capacity of available machine as shown in tables (1)(a, b and c).

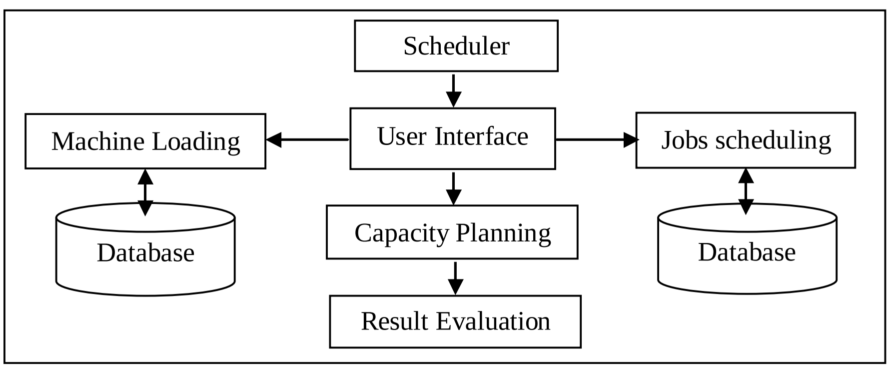


Figure (3) Architecture of Job Scheduling and Machine

The test resultsobtained by developed system implementation as shown in Figure (4) are summarized in table (2).

Table (1b) Data input for system

Job No.	Job Name	Operation No.	Quantity	Setup time	Run time
1	Body	1	10000	0.35	3,20
2	Base	2	15000	0.78	1.20
3	Cylinder	1	25000	0.96	2.20
4	Shift	1	20000	0.34	2.70
5	Bush	2	7500	0.82	1.10
6	Cover	1	12500	0.22	1.50

Table (1c) Data input for system

Job No.	Job Name	Operation No.	Quantity	Machine ≠1	Machine ≠2	Machine ≠3	Machine ≠4	Machine ≠5
1	Body	1	10000	0.00	2.11	3.44	4.29	0.00
2	Base	1	15000	2.45	0.00	0.00	1.11	3.22
3	Base	2	15000	3.25	1.35	0.00	0.00	0.00
4	Cylinder	1	25000	1.45	4.44	3.44	0.00	0.00
5	Shift	1	20000	0.00	0.00	2.34	3.12	1.52
6	Bush	1	7500	2.32	0.00	1.56	1.77	0.00
7	Bush	2	7500	0.00	4.63	0.00	1.75	0.00
8	Cover	1	12500	0.00	0.00	4.72	4.88	5.43

Table (2) summarized results obtained by developed system

Job No.	Job Name	Operation No.	Machine No	Machine time	Quantity
1	Base	1	4	1.11	15000
2	Base	2	2	1.35	15000
3	Cylinder	1	1	1.45	22500
4	Shift	1	5	1.52	15000
5	Bush	1	3	1.56	7500
6	Bush	2	4	1.75	7500
7	Body	1	2	2.11	2500
Job No.	Job Name	Operation No.	Machine No	Machine time	Quantity
8	Shift	1	3	2.34	5000
9	Cover	1	4	2.39	11250
10	Body	1	3	3.44	7500
11	Cylinder	1	3	3.64	2500
12	Cover	1	3	4.72	1250

Figure (4) User Interface Job Scheduling And Machine Loading System

RESULTS DISCUSSION

To illustrate performance of the methodology suggested by researcher in this paper, computational experiments, proposed algorithm, and developed system were done on the data given and the test results are reported.

The objective obtained by proposed algorithm and developed system include minimization of time with different constraints include cutting tool, machining time and material handling.FMS problem from table 1, there are six part types to be loaded on five machines where all of machines are assumed on two shafts.

The proposed methodology has been implemented using VB compiler. The test results obtained as shown in table 2clearly indicate the performance of developed system in saving load time about 77% with capacity 10000 hours is very significant and gives better results than exiting system available in literature.

CONCLUSIONS

The research provides a machine loading approaches that allows these goals to be achieved within flexible machining applications. Based on the characteristics of a job within a specific application, a range of algorithms can be generated based on processing times. The adoption of one of these algorithms within an application is dependent on a number of manufacturing constraints such as the number of machines in the cell, total batch sizes, average processing times, and requirements of jobs. The authors also recognize the need for further research based on a cost oriented analysis of the performance of these algorithms to optimize the use of an appropriate algorithm in a specific application. In this research, an attempt has been made to treat job sequencing and operation allocation problem concurrently. At each stage partial sequences are generated and evaluated. Only those partial sequences, which are feasible and perform better in achieving the objective function, are retained and new partial sequences are generated from these and evaluated. This process is repeated iteratively until a best feasible job sequence with operation allocation on machines is obtained.

REFERENCES

[1] Dhat, P. R.*et.al.*"An improved artificial immune system for solving loading problems in flexible manufacturing systems", Proceedings of the IEEE IEEM, 2010.

[2] Majid, M.Aldaihani. Mehmet, Savsar"A stochastic model for the analysis of a two-machine flexible manufacturing cell", Computers & Industrial Engineering, Vol.49, P.600–610, 2005.

[3] Akhilesh, Kumar *et.al.* "Solving machine-loading problem of a flexible manufacturing system with constraint-based genetic algorithm",European Journal of Operational Research, V.175,P. 1043–1069,2006.

[4]Mansour,AbouGamilaa. Saeid,Motavalli "A modeling technique for loading and scheduling problems in FMS",Robotics and Computer Integrated Manufacturing, V. 19, P. 45–54, 2003.

[5] Sinan,Kayaligil. Sinan,Ozlu"Loading of pallets on identical CNC machine with cyclic schedule",Computer and Industrial Engineering; Vol. 42, pp. 221-230, 2002.

[6] Rahimifard,S.Newman,S.T."Machine loading algorithms for the elimination of tardy jobs in flexible batch machining applications",Journal of Materials Processing Technology, Vol.107, P. 450–458, 2000.

[7] Umi, KalsomYusof.Rahmat,Budiarto.Safaai,Deris"Harmony search algorithm forflexible manufacturing system(FMS) machine loading problem", 3rd Conference on Data Mining and Optimization (DMO), 28-29 June 2011, Selangor Malaysia, 2011.

[8] Kim, H. W. *et.al.* "Loading algorithms for flexible manufacturing systems with partially grouped unrelated machines and tooling constraints" International Symposium on Computer, Communication, Control and Automation, 2010.

[9]Ponnambalam, S. G. Low,SengKiat "Solving machine loading problem in flexible manufacturing systems using particle swarm optimization", World Academy of Science, Engineering and Technology, 39, 2008

[10] Mussa, I. Mgwatu "Integration of part selection, machine loading and machining optimization decisions forbalanced workload in flexible manufacturing system", International Journal of Industrial Engineering Computations, 2, 913–930, 2011.

[11]NagarjunaamN.Maheshb,O. Rajagopal,K. "A heuristic based on multi-stage programming approach for machine-loading problem in a flexible manufacturing system", Robotics and Computer-Integrated Manufacturing, Vol.22, P. 342–352, 2006.

[12] Hamesh, babuNanvala. Gajanan, K. Awari, Principal"Approaches for solving machine loadingproblem in FMS: A Review", International Journal of Engineering and Technology Vol.3 (2), 64-73, 2011.

[13] Rahul,Swarnkar.Tiwari, M.K. "Modeling machine loading problem of FMSs and its solution methodology using a hybrid tabu search and simulated annealing-based heuristic approach",Robotics and Computer-Integrated Manufacturing, Vol.20, P. 199–209, 2004.