International Journal of Research in Engineering and Innovation
(IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

Optimization of scheduling techniques in FMS in context of Indian industry

R.S. Mishra, Gaganpreet Kaur, A.K.Madan

Department of Mechanical, Production Industrial and Automobiles Engineering, Delhi Technological University, Delhi, India

Abstract

The increased use of FMS give customer wide variety of products but they have some operational challenges. This research paper contains the review of the different techniques opted for the optimization and scheduling of the FMS. All these problems emphasize on routing flexibility, concurrency, Least make span and shared resources. The optimization procedures have been developed on FMS is the based of four non-traditional approaches, i.e., genetic algorithm, simulated annealing algorithm memetic algorithm and particle swarm algorithm, and are implemented successfully for solving the scheduling optimization problem of FMS. The particle swarm algorithm is found to be superior and gives the minimum combined objective function. It was concluded that the procedures developed in this work can be suitably modified to any kind of FMS with a large number of components and machines subject to multi objective functions. Future products will include availability and handling times of load/unloading stations, robots and AGVs

Keywords: Particle Swarm Algorithm, optimization Techniques in FMS, Non-Traditional Approaches

1. Introduction

To sustain in todays competitive global market manufacturing organizations have to develop a manufacturing system that can fulfil the changing demands of customer for customized products. The system should be flexible, productive and should be able to meet the demands within time bounds at a reasonable cost. FMS belongs to a class halfway amidst job shop manufacturing system and batch manufacturing system. An FMS has an integrated and computer controlled configuration which is capable of automatically changing tools and parts. These machines are interconnected by automatic guided vehicles, pallets and storage buffers that have flexibility that allows modifying system behavior on occurrence of changes whether predicted or unpredicted. It is modelled as a collection of workstations. The FMS should bedesigned to simultaneously manufacture different volumes of a varying variety of high quality products. The flexibility may be machine flexibility or routing flexibility. Machine flexibility refers to system's ability to produce new product types and change the sequence of operations executed on a part. Routing flexibility is the ability to absorb largescale changes such as in volume, capacity and capability.

The arrangement of machines in an FMS is connected by a transport system. The components are automatically governed using local area network. Basic components of FMS.

FMS basically composes of the following three parts:

1. Workstations: A machine tool which is computer controlled is called a workstation. Machine centers, load/unload stations, assembly workstations, inspection stations, forging stations, sheet metal processing etc are a few examples of workstations.
2. Automated Storage stations and Material handling stations: The movement of work parts and sub assembly parts between different workstations is done mechanically which is referred to as automated material handling and storage system.
   (i) The Random movement of work parts between stations independently.
   (ii) Handling various work part configurations
   (iii) Temporary storage
   (iv) Loading and unloading of work parts for easy access.
   (v) Computer control compatibility
3. Computer controlled systems: The functioning of the stated components is coordinated by a controlling Computer System. Its functions are:
   (i) Controlling work stations
   (ii) Control instruction distribution to the work stations.
   (iii) Controlling production.
   (iv) Monitoring the performance of the system and reporting.

Corresponding author: R.S. Mishra
Email Id:rsmishradtu@gmail.com

A flexible, integrated, computer-controlled environment allows the system to react on occurrence of changes, whether predicted or unpredicted. Scheduling machines achieving the desired performance in an FMS it is required that a good scheduling system, taking into account the system conditions should generate an optimal schedule at the right time.

It is an undeniable fact that all of us are optimizers as we all make decisions for the sole purpose of maximizing our quality of life, productivity in time, as well as our welfare in some way or another. Since this is an ongoing struggle for creating the best possible among many inferior designs, optimization was, is, and will always be the core requirement of human life and this fact yields the development of a massive number of techniques in this area, starting from the early ages of civilization until now. The efforts and lives behind this aim dedicated by many brilliant philosophers, mathematicians, scientists, and engineers have brought the high level of civilization we enjoy today. Therefore, we find it imperative to get to know first those major optimization techniques along with the philosophy and long history behind them before going into the details of the method detailed in this book. This chapter begins with a detailed history of optimization, covering the major achievements in time along with the people behind them. The classical optimization techniques are useful in finding the optimum solution or unconstrained maxima or minima of continuous and differentiable functions.

These are analytical methods and make use of differential calculus in locating the optimum solution.

The classical methods have limited scope in practical applications as some of them involve objective functions which are not continuous and/or differentiable. .Yet, the study of these classical techniques of optimization form a basis for developing most of the numerical techniques that have evolved into advanced techniques more suitable to today's practical problems. These methods assume that the function is differentiable twice with respect to the design variables and the derivatives are continuous. Three main types of problems can be handled by the classical optimization techniques:

- Single variable functions.
- Multivariable functions with no constraints.
- Multivariable functions with both equality and inequality constraints.

In problems with equality constraints the Lagrange multiplier method can be used. If the problem has inequality constraints, the Kuhn-Tucker conditions can be used to identify the optimum solution. These methods lead to a set of nonlinear simultaneous equations that may be difficult to solve Stecke and et. al [1] followed her divided the FMS operation problem into two sub problems: preproduction setup and production operation. In this view, a FMS is prepared beforehand for the given part mix: loading the tools, allocating the operation to the machines, allocating the pallets and fixtures to the different part types. After this preparatory planning phase, the remaining problems are called Operational problems and solved later. She places stress on pre-production setup of the FMS. This is to be carried out frequently, as the part mix changes. To carry out a complete setup, a FMS manager would solve 5 problems:

(1) Part type selection problem. This problem determines the part types to be produced in the FMS out of the total production requirement of the company.
(2) Machine grouping problem. She would partition the machines in the FMS so that machines in a group can all perform the same operations.
(3) Production ratio problem. This problem is related to problem 1 - determine the ratio of the parts selected to be manufactured in the FMS.
(4) Resource allocation problem. This problem determines the allocation of pallets and fixtures to the part types.
(5) Loading problem. The solution to the problem will simultaneously allocate operation of the part types and the corresponding tools to the machine groups.

Then goes on to describe models for the grouping and loading problems. For these problems, the major constraint is the capacity of tool magazines of each machine tool. The minimum number of machines required to cover all operations is calculated using an optimization formulation to pack as many tools as possible in few machine tools, at the same time making enough tool allocations to cover all the part types. This formulation gives the number of groups needed. If there are more machines than the number of groups, the additional machines are tooled identical to some of the ones that are grouped. This way, the machines are pooled to allow maximum flexibility. In Stecke's methodology, the operations and corresponding tools are then assigned (loaded) to the machine groups.

She suggests 6 different objectives to optimize during the loading phase:

(1) Balance the assigned machine processing times.
(2) Minimize the number of movements from machine to machine.
(3) Balance the workload per machine for a system of groups of pooled machines of equal sizes.
(4) Unbalance the workload per machine for a system of groups of pooled machines of unequal sizes. This objective stems from earlier results of Stecke and Solberg (1982) that recommends unbalancing the workload for each machine when the pooled group sizes are unequal in order to obtain maximum production rate.
(5) Fill the tool magazines as densely as possible.
(6) Maximize the sum of operation priorities.

The formulations of Stecke (1983) lead to large nonlinear mixed integer problems. She suggests various linearization schemes. Stecke's planning problems place much of the scheduling problem in the setup stage. Once the setup is done as per the five specific sub-problems, most of the resource allocation is already complete. The setup is carried out for a particular part mix. It is not clear when one of the six loading objectives is to be favoured over the others. In some cases, where the machine tools are separated over a long distance, the choice is obvious. In other cases the answer is hard to discern. The grouping problem does not consider the production ratio of parts. Thus, it could give an answer which is not desirable from the view point of maintaining the production ratio. Another problem with the formulation is the large number of variables and constraints that result from the linearization of the problems. That makes the approach computationally expensive. Berrada and Stecke (1983) have proposed an efficient branch and bound procedure for solving the loading problem with the objective of workload balancing. Stecke's approach is explained here at length because other mathematical modelling approaches build upon this foundational work.

Lashkari et al. [2] developed a formulation of the loading problem. Their formulation considered refixturing and limited tool availability. Besides this problem, they place an upper bound on the number of tools that may be assigned.

They consider two objectives:

(1) Minimization of total transportation requirements of the parts.
(2) Minimization of refixturing requirements.

The formulations have products of 0-1 integer variables.

He linearize the formulation to solve the problem using linear integer programming code. Their computational experience shows that even for small problems, the problem size becomes very large. In order to reduce the search, they suggested dividing the problem into two sub-problems, the result of which could be used as an upper bound for the original problem.

Unlike Stecke (1983), Lashkari et al. will permit only one allocation of a machine to an operation. This would curtail some flexibility at the operation control level. Their modelling is suitable only when the parts must always traverse to and from a central storage for every inter-machine transfer.

Further, the objective function lacks the relative weighting for the different part types. Wilson (1989) used simpler and straighter forward formulation of the constraints to solve the same problem as discussed by Lashkari et al. (1987). He demonstrated substantial savings in computational effort using his modelling of the constraints and the objective function. Shanker and Rajamarthandan (1989) present a similar model with the objective of part movement minimization. In contrast to Lashkari et al. (1987), they do not require the parts to go to a central storage after every operation. Also, they are not interested in the distance travelled: only the number of movements is of concern. Like Wilson (1989), they exploit the particular structure of the problem to obtain linearization of the problem.

They also reported that high computational effort was required. Han et al. (1989) address the setup and scheduling problem in a special type of FMS: where all the machines are of the same type, and tools are 'borrowed' between machines and from the tool crib as needed. In their model, the number of tools is limited. The purpose of their model is to assign tools and jobs to machines so that the 'borrowing' of tools is minimized while maintaining a 'reasonable' workload balance. This is a nonlinear integer programming problem, and is computationally expensive. To solve the problem efficiently, the authors propose to decompose the problem. The two sub-problems each have the same objective as shown above. But the constraints are divided. The first problem finds an optimum tool allocation, given the job allocation. The second problem finds an optimal job allocation, given the tool allocation. Phrased in this way, both problems become linear. The first problem is a capacitated transportation problem, and the second is a generalized assignment problem. It is suggested to solve the two problems iteratively. The FMS investigated by Han et al., is special. All machine tools are assumed identical. Consequently, the jobs remain at one machine, and the tools are moved to the machines as needed.

Kimemia and Gershwin [1] report on an optimization problem that optimizes the routing of the parts in a FMS with the objective of maximizing the flow while keeping the average in-process inventory below a fixed level. The machines in the cell have different processing times for an operation. Network of queues approach is used. The technique showed good results in simulation. Chen and Chung [2] evaluate loading formulations and routing policies in a simulated environment. Their main finding was that FMS is not superior to job shop if the routing flexibility is not utilized.

Avonts and Van Wassenhove [3] present a unique procedure to select the part mix and the routing of parts in a FMS. A LP model is used to select the part mix using cost differential from producing the part outside the FMS. The selected loading is then checked by a queuing model for utilization in an iterative fashion. Hutchison et al. [4] provide a mathematical formulation of the random FMS scheduling problem, where random (not preselected) jobs arrive at the FMS. Their formulation is a static one in which N jobs are to be scheduled on M machines. The objective is to minimize the make span. They present a mixed integer 0-1 programming formulation. They solve this problem by a branch and bound scheme. A single formulation solves the allocation of the operations to the machines and the timed sequence of the operations. However, their study assumes that material handling devices, pallets, buffers, and tool magazines do not constrain the system. Further, at most one alternative is allowed for any operation. An alternative approach to this problem is to decompose it into two sub problems. The first problem is the allocation of the jobs to the machines in the routings. The second problem is the time bound sequencing of the jobs, the standard job shop problem. Hutchison et al. [5] report on a comparison of the performance of the above two methodologies and another methodology which was based on dispatching rule (SPT). A novel feature of their simulation experiment is their use of a measure of flexibility: probability of an alternate machine option for any operation. They concluded that the programming formulations produced substantial improvement in make span over the dispatching rules. However, as compared to the decomposed problem, the unified formulation did not produce significant improvement in make span to justify the additional computational effort required.

In the above approach, the tool magazines do not constrain the system. Hence the first sub problem of the decomposition can allocate all the jobs to their machines. However, when the tool magazine is considered restraining, it may not be possible to allocate all the jobs for one tooling setup. Then this sub problem resolves to a selection problem. Out of the pool of waiting jobs, jobs are selected to be processed in the next planning period (part type selection problem). The selected parts are then sequenced. The process is repeated period by period. In this approach, it is assumed that at the beginning of each planning period all the tools are reassigned and replaced in the tool magazine. Shanker and Tzen [7] propose a mathematical programming approach to solve this part selection problem for random FMS. Their approach is similar to (Stecke, 1983). Stecke assumes the part ratio as given and the planning horizon as indefinite whereas Shanker and Tzen consider individual parts and a fixed planning horizon. They have a constraint on the tool magazine capacity which is very similar to Stecke's. They constrain the model to find a unique routing for each part type (in contrast to Stecke). Two objectives are considered: Balancing the workload, and balancing the workload and minimizing the number of late jobs.

The resulting problems are, again, non-linear integer problems. Even after linearization, the problems are computationally too expensive, and they further propose two heuristics corresponding to the two objectives. For balancing the workload, they propose essentially a greedy heuristic which attempts to allocate to the most lightly loaded machine the longest operation first. For the second objective, the same heuristic is modified to include the overdue jobs with the highest priority. Their computational experience showed that the analytical formulations would be too formidable to be of practical use. Shanker and Srinivasulu [8] modify the objective to consider the throughput also. A computationally expensive branch and backtrack algorithm is suggested as well as heuristics. In the above approaches for random FMS, the scheduling of the FMS is decomposed into two problems: part type selection, and sequencing of jobs. The sequencing is done using one of the dispatching rules. Of course, some (e.g. branch and bound) search could be used to solve the sequencing problem too.

Hwan and Shogun [9] present the part selection problem for a random FMS with machines of a single general purpose type capable of producing all part types. They include the due date and the quantity of parts needed to be produced in their formulation. By ignoring the tool overlapping (cf. Stecke, 1983), they considerably simplify the tool magazine constraint. Their objective is to maximize the number of part types selected over a planning horizon. They take care of due dates by weighting on the selected part types. By assuming a single machine type, their problem essentially boils down to maximizing the utilization of the tool slots in the tool magazines. They report computational experience on two Lagrangian relaxation techniques they used to solve the problem. Their heuristics and Lagrangian methods obtained solutions close to optimal solutions found by the branch and bound method. The CPU times required by the three methods are successively order of magnitudes higher. Co et al. [10] have suggested a four pass approach to solve the batching, loading and tool configuration problems of random FMS. In this approach, compatible jobs are batched together using integer programming. The solution is then improved upon in three further stages. Jaikumar and Van Wassenhove [11] propose a hierarchical planning and scheduling decomposition of FMS operation problems. In the first level, an aggregate production model is used. This is a linear programming model that chooses parts to be produced in a FMS during the next planning period. The remaining parts are assumed to be produced elsewhere at a cost difference. The objective is to maximize the cost difference while allowing for the inventory cost for work in process. The essential constraints are the demand for the parts and the machine capacity. Put simply, the objective of the second level is to minimize tool changeover. The production requirements and the tool and machine allocation are determined in levels one and two. All that remains in the third level is to determine a feasible schedule that will fulfil the above requirements. Detailed requirements such as buffer requirements, and material handling constraints, are taken care of at this level. Jaikumar and Wassenhove recommend simulation using some dispatching rule to carry out this level. If a feasible schedule cannot be obtained, the planning process is reiterated. They discuss the application of their framework in an existing FMS and point out that the primary problem is at the first level - selection of parts. Once this is decided upon, the other two problems can be solved by simple heuristics.

Mathematical models in the literature are not efficient for reasonably sized problems. Further, they make simplifying assumptions which are not always valid in practice. The assumptions, of course, change with the models: some models assume automatic tool transport, some others will neglect delays caused by automated guided vehicles (AGV), and still others will assume that tool magazines, pallets and fixtures do not constrain the models in any way, and so on. The models also take a static view of the shop floor. It is assumed that all the planned activities will be carried out exactly, or the disruptions are infrequent enough that periodic solution of the problems will be practical. Muhammad Hafidz Fazli bin et.al.[12] described an efficient and optimized operation of Automated Guided Vehicles (AGVs) plays a critical role in improving the performance of a Flexible Manufacturing System (FMS).Among the main elements in the implementation of AGV is task scheduling. This is due to the fact that efficient scheduling would enable the increment of productivity and reducing delivery cost whilst optimally utilizes the entire fleet. In this research paper, Binary Particle Swarm Optimization (BPSO) is used to optimize simultaneous machines and AGVs scheduling process with make span minimization function. It is proven that this method is capable to provide better solution compared to others. Ranbir Singh et.al [13] described that production planning is the foremost task for manufacturing firms to deal with, specially adopting Flexible Manufacturing System (FMS) as the manufacturing strategy for production seeking an optimal balance between productivity-flexibility requirements. Production planning in FMS provides a solution to problems regarding part type selection: machine grouping, production ratio, resource allocation and loading problem. These problems need to be solved optimally for maximum utilization of resources. Optimal solution to these problems has been a focus of attention in production and manufacturing, industrial and academic research since a number of decades. Evolution of new optimization techniques, software, technology, machines and computer languages provides the scope of a better optimal solution to the existing problems. Thus there remains a need of research to solve the problem with latest tools and techniques for higher optimal use of available resources. As an objective, the researchers need to reduce the computational time and cost, complexity of the problem, solution approach viz. general or customized, and better user friendly communication with machine, higher freedom to select the desired objectives types for optimal solution to the problem. As an approach to the solution to the problem, a researcher first needs to go for an exhaustive literature review, where the researcher needs to find the research gaps, compare and analyze the tools and techniques used, number of objectives considered for optimization and need, and scope of research for the research problem. The present study is a review paper analyzing the research gaps, approach and techniques used, scope of new optimization techniques or any other research, objectives considered and validation approaches for loading problems of production planning in FMS. Iman Badr et.al [14] described **s**cheduling for flexible manufacturing systems (FMS) poses the challenge of optimizing the generated schedule while exhibiting flexibility to environmental dynamics. While the agent-based paradigm has been shown to tackle the inherent complexity of the problem and exhibit the required flexibility, it hinders the global optimization due to its decentralized structure. In this paper, genetic algorithms (GA) are incorporated into an agent-based scheduling architecture to overcome this shortcoming of agents and to achieve the required combination of flexibility with efficiency. Based on GA, individual agents optimize the schedule from their local view. Through the cooperation among the individual agents, a near-optimal schedule under consideration of the different optimization objectives is attained. Test results prove that the proposed integration yields near-optimal schedules with low computational complexity.

Giffler B, Thomson GL [15] said algorithms are developed for solving problems to minimize the length of production schedules. The algorithms generate anyone, or all, schedule(s) of a particular subset of all possible schedules, called the active schedules. This subset contains, in turn, a subset of the optimal schedules. It is further shown that every optimal schedule is equivalent to an active optimal schedule. Computational experience with the algorithms shows that it is practical, in problems of small size, to generate the complete set of all active schedules and to pick the optimal schedules directly from this set and, when this is not practical, to random sample from the bet of all active schedules and, thus, to produce schedules that are optimal with a probability as close to unity as is desired. The basic algorithm can also generate the particular schedules produced by well-known machine loading rules. Shankar K, Tzen YJ [16] described that scheduling problem in a flexible manufacturing system (FMS) is considered to be a composite of two interdependent tasks: loading and sequencing. Formulations are presented for the loading problem with two objectives such as minimization of the system workload unbalance, and minimization of system unbalance and the number of late jobs; including constraints such as the number of tools slots with duplications, unique job routing, non-splitting of jobs and machine capacity. For both the objectives, heuristic methods are developed and performance is compared with the exact mixed integer programming solutions. A simulation model is developed for investigating the system performance for the problem of minimizing the system unbalance using heuristic and sequential loading methods in conjunction with four—FIFO, SPT, LPT and MOPR—dispatching rules. Ghosh S, Gaimon C [17] presented a multiproduct, multi period, multistage network model for the planning of order release and production scheduling in a flexible manufacturing system environment under the existence of alternate routings. It is assumed that pre manufacturing decisions such as machine grouping and tool loading have been made, so that setup costs and setup times are negligible and can be included in the processing times. The decision process addressed by the model is the disaggregation of weekly production requirements to daily production requirements, the determination of production batch sizes for each operation of each part type, and the daily assignment of each batch to machine groups given the flexibility of alternate routings. The model also provides the interface and linkage between an MRP component planning system and the shop scheduling system. The model is solved using a price-directive decomposition technique with column generation. Experimentation is performed with the model for varying problem sizes to determine the impact of shop flexibility on total cost, inventory levels, and existence of bottlenecks, shop utilization, and the number of setups and split lot production. The results indicate important cost-benefit trade-off implications for system design and acquisition. For example, if in fact setup costs and times are non-negligible, then it is shown that increasing the routing flexibility of a system without a parallel decrease in setup costs and times is unlikely to reap significant benefits. Chisman JA [18] described that the optimal sequencing of parts through a two-operator, gear manufacturing cell is discussed. Because of lack of data, it was first necessary to develop an analytical technique to determine the sequence-dependent setup times. With these setup times, the travelling salesman routine and the clustered travelling salesman modification were used to find the optimal sequence. Finally, an existing simulation model of the cell was employed to test the validity of the analytical sequencing approach. Greenberg HH [19] described a mixed integer formulation is presented for the general n job, m machine scheduling problem. This formulation is shown to reduce to a series of non-integer L.P. problems of moderate proportions when applying the branch-bound technique. Solutions are presented for the two problems: minimize make-span and minimize idle time. An example and some computational experience for the “minimize idle time” problem are given. Hoitomt DJ, Luh PB, Pattipati KR [20] used Lagrangian relaxation to schedule job shops, which include multiple machine types, generic precedence constraints, and simple routing considerations, is explored. Using an augmented Lagrangian formulation, the scheduling problem is decomposed into operation-level sub problems for the selection of operation beginning times and machine types, with given multipliers and penalty coefficients. The multipliers and penalty coefficients are then updated at the higher level. The solution forms the basis of a list-scheduling algorithm that generates a feasible schedule. A procedure is also developed to evaluate the quality of this feasible schedule by generating a lower bound on the optimal cost. Numerical examples are taken from a representative industrial job shop. High-quality schedules are efficiently generated every other day over a three-week period, with costs generally within 4% of their respective lower bounds. The methodology compares favorably with knowledge-based scheduling. Niroomand et al. [21] addressed a new meta-heuristic algorithm to solve a closed loop layout problem. The proposed algorithm applies a modified version of the recently invented migrating bird's optimization method. The computational experiments show that in most of the benchmark problems the results obtained from the proposed migrating birds optimization method is better than those obtained by other methods which are published in the literature.

Jahromi et al.[22] considered a problem of dynamic machine-tool selection and operation allocation with part and tool movement policies in a flexible manufacturing system (FMS) environment. For this purpose, a novel 0-1 linear integer programming model is presented in such a way that each part and each tool can move during the production phase. It is assumed that there are a given set of tools and machines that can produce different kinds of orders (or part types). The objective of this model is to determine a machine-tool combination for each operation of the part type by minimizing some production costs, such as machining costs, setup costs, material handling costs and tool movement costs. In addition, due to the NP-hard nature of the problem, a new heuristic method based on five simple procedures (FSP) is proposed for solving the given problem, whose performance is tested on a number of randomly generated problems. The related results are compared with results obtained by a branch-and-bound method. It had been found that the proposed heuristic method gives good results in terms of objective function values Naderi, B., & Azab, A. [23] addressed that machine tools are able to process at most one operation on one part at a time provided they have only a single spindle and a single turret. Yet, with the advent of Turn-Mill machining centres carrying multiple spindles and turrets parallel processing and multitask metal-cutting becomes possible. This paper dealt with scheduling of a flexible manufacturing cell with parallel processing capability. This problem was first formulated as a mixed integer linear programming model. Using this model, small instances are solved for optimality. Then, to solve large instances, five metaheuristics are developed based on the proposed encoding scheme, operators and local search. Test cases are used to evaluate and compare the algorithms as well as the mathematical model. Aalaei, A., & Davoudpour, H. [24] described a new mathematical model is presented for a cellular manufacturing system into supply chain design with labour assignment. This paper considers important manufacturing features thoroughly such as multiple plant locations, multi-market allocations with production planning and various part mix. The proposed model aims at minimizing the total cost of holding, inter-cell material handling, external transportation, fixed cost for producing each part in each plant, machine and labour salaries. It is assumed that the demands of products are uncertainty in three scenarios: optimistic, pessimistic and normal. Also, a robust optimization approach is then developed to solve the proposed model and find the best solution. The robustness and performance of the proposed model are explained in terms of an industrial case from a typical equipment manufacturer. This case study provides the researchers and practitioners to better understand the importance of designing robust optimization and cell formation in the supply chain management from a practical point of view. Shivhare, M., & Bansal, S. [25] discussed FMS ensures quality product at lowest cost. Layout arrangement of flexible manufacturing system is important to achieve high productivity. In this paper the design of loop layout in Flexible Manufacturing System is discussed. The objective of the loop layout problem is to determine the order of machines around a loop, and to minimize the automated guided vehicle movement. Particle Swarm Optimization technique is proposed to optimize the flexible manufacturing system layout. This paper also discusses the movement of AGV around the loop layout. AGV movement is considered as bidirectional. The clearance between the machines is also considered in the Flexible Manufacturing System loop layout that produces result which will be optimized. Zakaria, Z., & Petrovic, S. [26] mentioned that it involves allocation of a limited set of resources to a number of jobs with the goal of optimizing a given number of performance criteria over time. As FMS environment is dynamic and unexpected events occur, rescheduling is necessary to update an existing schedule in response to disruptions or changes

Reddy, et. al. [27] stated that the one of best evolutionary approach i.e., genetic algorithm with jumping genes operation is applied in this study, to optimize AGV flow time and the performance measures of Flexible Job shop manufacturing system. The non-dominated sorting approach is used. Genetic algorithm with jumping genes operator is used to evaluate the method. Muhammad Hazfiz Fazli et al [28] stated that exploitation of a population of particles to search for promising regions of the search space (swarm). While each particle randomly moves within the search space with a specified velocity. It stores data of the best position it ever encountered. This is known as personal best (pbest) position. Upon finishing each iteration, the pbest position obtained by all individuals of the swarm is communicated to all of the particles in the population. The best value of pbest will be selected as the global best position (Gbest) to represent the best position within the population. Reddy, B. S. P., et. al [29] described in this paper an attempt is made to integrate machine and vehicle scheduling with an objective to minimize the makespan using Automod. Automod is a discrete event simulation package used to model and simulate a wide variety of issues in automated manufacturing systems. The key issues related to the design and operation of automated guided vehicles such as flow path layout, number of vehicles and traffic control problems are considered in the study. Ranbir Singh et.al.[30] stated an objective, the researchers need to reduce the computational time and cost, complexity of the problem, solution approach viz. general or customized, better user friendly communication with machine, higher freedom to select the desired objective(s) type(s) for optimal solution to the problem. As an approach to the solution to the problem, a researcher first needs to go for an exhaustive literature review, where the researcher needs to find the research gaps, compare and analyse the tools and techniques used, number of objectives considered for optimization and need, and scope of research for the research problem. The present study is a review paper analysing the research gaps, approach and techniques used, scope of new optimization techniques or any other research, objectives considered and validation approaches for loading problems of production planning in FMS. Y.M Ratnam et.al [31] stated that the Flexible Manufacturing Systems (FMS) belong to class of productive systems in which the main characteristic is the simultaneous execution of several processes and sharing a finite set of resource. Nowadays, the FMS must attend the demand of the market needs for personalized products. Consequently the product life cycle tends to be shorter and a greater variety of products must be produced in a simultaneous manner. In this paper, we present a Genetic Algorithm based scheduling of Flexible manufacturing system. This work is considering multiple objectives, i.e., minimizing the idle time of the machine and minimizing the total penalty cost for not meeting the deadline concurrently. Software is developed for getting optimum sequence of operation. FMS considered in this work has 16 CNC Machine tools for processing 43 varieties of products. In this paper, various meta-heuristic methods are used for solving same scheduling problems taken from the literature. The results available for the various existing meta-heuristic methods are compared with results obtained by GA. After 1700 generations of GA the global optimum schedule is obtained. J.Jerald et. al, [32] stated that he increased use of flexible manufacturing systems (FMS) to efficiently provide customers with diversified products has created a significant set of operational challenges. Although extensive research has been conducted on design and operational problems of automated manufacturing systems, many problems remain unsolved. In particular, the scheduling task, the control problem during the operation, is of importance owing to the dynamic nature of the FMS such as flexible parts, tools and automated guided vehicle (AGV) routings. The FMS scheduling problem has been tackled by various traditional optimisation techniques. While these methods can give an optimal solution to small-scale problems, they are often inefficient when applied to larger-scale problems. In this work, different scheduling mechanisms are designed to generate optimum scheduling; these include non-traditional approaches such as genetic algorithm (GA), simulated annealing (SA) algorithm, memetic algorithm (MA) and particle swarm algorithm (PSA) by considering multiple objectives, i.e., minimising the idle time of the machine and minimising the total penalty cost for not meeting the deadline concurrently. The memetic algorithm presented here is essentially a genetic algorithm with an element of simulated annealing. The results of the different optimisation algorithms (memetic algorithm, genetic algorithm, simulated annealing, and particle swarm algorithm) are compared and conclusions are presented. S.V Kamble and K.S Kadam [33] stated that due to the high complexity of Flexible Manufacturing Systems (FMS) scheduling problem, approaches that guarantee to find the optimal solution are feasible only for small size instance of the problems with lot of computational effort and time. In contrast, approaches based on meta heuristics are capable of finding good and “near to optimal” solutions to problem instances of realistic size, in a generally smaller computation time. This work provided a review on the use of swarm intelligence meta heuristics to the scheduling of flexible manufacturing problem. The two main areas of swarm intelligence that are prominently appeared in the literature relevant to this problems are ant colony optimization (ACO) and particle swarm optimization (PSO). R Kumar et.al [34], attempted scheduling problem for flexible manufacturing systems (FMSs) the ant colony optimization (ACO) technique. Since the operation of a job in FMSs can be performed on more than one machine, the scheduling of the FMS is considered as a computationally hard problem. Ant algorithms are based on the foraging behaviour of real ants. The article deals with the ant algorithm with certain modifications that make it suitable for application to the required problem. The proposed solution procedure applies a graph-based representation technique with no demand arcs representing operation and transfer from one stage of processing to the other. Individual ants move from the initial node to the node through all nodes desired to be visited. The solution of the algorithm is a collective outcome of the solution found by all the ants. The pheromone trail is updated after all the ants have found out their respective solutions. Various features like stagnation avoidance and prevention from quick convergence have been incorporated in the proposed algorithm so that the near-optimal solution is obtained for the FMS scheduling problem, which is considered as a non-polynomial (NP)-hard problem. The algorithm stabilizes to the solution in considerably lesser computational e€ ort. Extensive computational experiments have been carried out to study the influence of various parameters on the system performance. Moacir Godinho Filhor et.al [35], reviewed the literature regarding Genetic Algorithms (GAs) applied to flexible manufacturing system (FMS) scheduling. On the basis of this literature review, a classification system is proposed that encompasses 6 main dimensions: FMS type, types of resource constraints, job description, scheduling problem, measure of performance and solution approach. The literature review found 40 papers, which were classified according to these criteria. The literature was analysed using the proposed classification system, which provides the following results regarding the application of GAs to FMS scheduling: (1) combinations of GAs and other methods were relatively important in the reviewed papers; (2) although most studies deal with complex environments concerning both the routing flexibility and the job complexity, only a minority of papers simultaneously consider the variety of possible capacity constraints on an FMS environment, including pallets and automated guided vehicles; (3) local search is rarely used; (4) make span is the most widely used measure of performance.

2. Result and Discussion

FMS control problems are very complex and difficult. Rather than attempting to get the optimum solutions of the problem formulations, research should be done on interactive scheduling and control of FMS where there is human input in the loop which is known as interactive scheduling. A decision support system approach including interactive scheduling has a lot of promise for application in the operations of FMS. There is one such management tool that provides information as well as suggestions to help in operating a manufacturing system. Modern workstations provide a splendid opportunity for the development of FMS control decision support systems using the graphics capabilities, and underlying heuristics or rule-based systems. FMS is different things to different researchers. Quite often only the alternate operations aspect is emphasized. It is time to move on to further developing comprehensive control schemes which take care of the complex interaction of the multiple resources in an FMS: transporters, CNC machines, robots, tools, fixtures, pallets. This could be done using hierarchical or hierarchical schemes. Discrete-event simulation is another area which has the potential to make major contributions to FMS operation. Simulation can be used to model FMS quite comprehensively, and may be used to evaluate control policies, heuristics, and rules. Distributed processing makes the use of simulation feasible.

3. Conclusion

.

The optimization procedures developed in this paper can be accordingly altered to any kind of flexible manufacturing system (FMS) with a large number of components and machines subject to multi objective functions. This technique will also be applied for handling loading /unloading stations, robots and AGVs.

References

[1] Stecke, K.E., and Solberg, J.J., 1981, Loading and control policies for a flexible manufacturing system. International Journal of Production Research, 19,481-490.

[2] Lashkari, R.S., Dutta, S.P., and Padhye, A.M., 1987, A new formulation of operation allocation problem in flexible manufacturing systems: mathematical modelling and computational experience. International Journal of Production Research, 25, 1267-1283.

[3] Kimemia, J.G., and Gershwin, S.B., 1983, An algorithm for the computer control of production in flexible manufacturing systems. IIE Transactions, 15, 353-362.

[4] Chen, I.J., and Chung, C.H., 1991, Effects of loading and routeing decisions on performance of flexible manufacturing systems. International Journal of Production Research, 29, 2209-2225.

[5] Avonts, L.H. and Wassenhove, L.N., 1988, The part mix and routing mix problem in FMS: a coupling between an LP model and a closed queuing network. International Journal of Production Research, 26, 1891-1902.

[6] Hutchison, J., Leong, K., Snyder, D., and Ward, F., 1989, Scheduling for random job shop flexible manufacturing systems. Proceedings of the Third ORSA/TIMS Conference on Flexible Manufacturing Systems, 161-166.

[7] Shanker, K., and Tzen, Y.J., 1985, A Loading and dispatching problem in a random flexible manufacturing system. International Journal of Production Research, 23, 579-595.

[8] Shanker, K., and Srinivasulu, A., 1989, Some methodologies for loading problems in flexible manufacturing systems. International Journal of Production Research, 27, 1019-1034.

[9] Hwan, S.S., and Shogun, A.W., 1989, Modelling and solving an FMS part selection problem. International Journal of Production Research, 27, 1349-1366.

[10] Co, H.C., Jaw, T.J., and Chen, S.K., 1988, Sequencing in flexible manufacturing systems and other short queue-length systems. Journal of Manufacturing Systems, 7, 1-7.

[11] Jaikumar, R., and Van Wassenhove, L.N., 1989, A production planning framework for flexible manufacturing systems. Journal of Manufacturing Operations Management, 2, 52-79.

[12] Giffler B, Thomson GL (1960) Algorithms for solving production scheduling problems. Int J Oper Res 8:487–503

[13] Shankar K, Tzen YJ (1985) A loading and dispatching problem in a random flexible manufacturing system. Int J Prod Res 23:579–595

[14] Ghosh S, Gaimon C (1992) Routing flexibility and production scheduling in a flexible manufacturing system. Eur J Oper Res 60:344–364

[15] Chisman JA (1986) Manufacturing cell: analytical setup times and part sequencing. Int J Adv Manuf Technol 1(5):55–60

[16] Greenberg HH (1968) A branch and bound solution to the general scheduling problem. Int J Oper Res 16:353–361 971

[17] 8. Hoitomt DJ, Luh PB, Pattipati KR (1993) A practical approach to job-shop scheduling problems. IEEE Trans Robot Automat 9(1):1–13

[18] 10. Chan TS, Pak HA (1986) Heuristical job allocation in a flexible manufacturing system. Int J Adv Manuf Technol 1(2):69–90

[19] Niroomand, S., Hadi-Vencheh, Aahin, R., & Vizri, B. (2015). Modified migrating birds optimization algorithm for closed loop layout with exact distances in flexible manufacturing systems. Expert Systems with Applications, 42, 6586–6597.

[20] Jahromi, M. H. M. A., & Tavakkoli-Moghaddam, R. (2012). A novel 0-1 linear integer programming model for dynamic machine-tool selection and operation allocation in a flexible manufacturing system. Journal of Manufacturing Systems, 31(2), 224–231.

[21] Naderi, B., & Azab, A. (2015). Modeling and scheduling a flexible manufacturing cell with parallel processing capability.

CIRP Journal of Manufacturing Science and Technology, 11, 18–27. http://doi.org/10.1016/j.cirpj.2015.05.006

[22] Zambrano Rey, G., Bonte, T., Prabhu, V., & Trentesaux, D. (2014). Reducing myopic behavior in FMS control: A semi-heterarchical simulation–optimization approach. Simulation Modelling Practice and Theory, 46, 53–75.

[23] Aalaei, A., & Davoudpour, H. (2017). A robust optimization model for cellular manufacturing system into supply chain management. International Journal of Production Economics, 183, 667–679.

[24] Shivhare, M., & Bansal, S. (2014). Layout Optimization in Flexible Manufacturing System using Particle Swarm Optimization in Matlab, 8(7), 55–64.

[25] Zakaria, Z., & Petrovic, S. (2012). Genetic algorithms for match-up rescheduling of the flexible manufacturing systems. Computers and Industrial Engineering, 62(2), 670–686.

[26] Jerald, J., Asokan, P., Saravanan, R., & Rani, A. D. C. (2006). Simultaneous scheduling of parts and automated guided vehicles in an FMS environment using adaptive genetic algorithm. International Journal of Advanced Manufacturing Technology, 29(5–6), 584–589.

[27] Kamble, S. V, & Kadam, K. S. (2006.). A Particle Swarm Optimization – Based Heuristic for Scheduling in FMS Review, 92–96.

[28] Reddy, B. S. P., & Rao, C. S. P. (2011). Flexible manufacturing systems modelling and performance evaluation using automod. International Journal of Simulation Modelling, 10(2), 78–90.

[29] Zakaria, Z., & Petrovic, S. (2012). Genetic algorithms for match-up rescheduling of the flexible manufacturing systems. Computers and Industrial Engineering, 62(2), 670–686.

[30] Naderi, B., & Azab, A. (2015). Modeling and scheduling a flexible manufacturing cell with parallel processing capability. CIRP Journal of Manufacturing Science and Technology, 11, 18–27.

[31] Ingh, R., Singh, Rs., & Khan, B. K. (2015). A Critical Review of Machine Loading Problem in Flexible Manufacturing System, (November), 271–290.

[32] Niroomand, S., Hadi-Vencheh, Aahin, R., & Vizvri, B. (2015). Modified migrating birds optimization algorithm for closed loop layout with exact distances in flexible manufacturing systems. Expert Systems with Applications, 42, 6586–6597.

[33] Liu, H., Wu, W., Su, H., & Zhang, Z. (2014). Design of optimal Petri-net controllers for a class of flexible manufacturing systems with key resources. Information Sciences, 363, 221–234.

[34] Hermansson, T., Bohlin, R., Carlson, J. S., & Söderberg, R. (2016). Automatic routing of flexible 1D components with functional and manufacturing constraints. Computer-Aided Design, 79, 27–35.

[35] Xing, L. (2016). A Knowledge-Based Ant Colony Optimization for Flexible Job Shop Scheduling Problems, 2016.

[36] Bector, C. R. (2007). A review of scheduling rules in flexible manufacturing systems.

[37] Fernandes, R., & Neto, T. (2012). Using Genetic Algorithms to solve scheduling problems on flexible manufacturing systems (FMS): a literature survey , classification and analysis.

[38] Haghighi, D. A., Sanatizadeh, M., Khanmohammadi, S., Badamchizadeh, M. A., & Ghaemi, S. (n.d.). Modeling and Scheduling of Flexible Manufacturing System Using Petri Net and Fuzzy MCDM Approach, 1–6.

[39] Mishra, A., Dash, A., Bishoyee, N., & Student, B. (n.d.). Agvs In Fms Environment Using Swarm Optimization And Comparision With.

[40] Kumar, R., Tiwari, M. K., & Shankar, R. (2003). Scheduling of fexible manufacturing systems : an ant colony optimization approach, 217(November 2002), 1443–1453.

[41] Rajan, N., & Kalsi, T. (2014). Scheduling of Flexible Manufacturing System using Genetic Algorithm (Multiobjective): A Review, 86(19), 9–15.

[42] Asokan, J. J. P., & Saravanan, G. P. R. (2005). Scheduling optimisation of flexible manufacturing systems using particle swarm, 964–971. http://doi.org/10.1007/s00170-003-1933-2

[43] Ratnam, Y. M., Krishna, K. M., & Giribabu, P. (2015). Optimization Procedure by Using Genetic Algorithm, 1198–1204.

[44] Bigand, M., Korbaa, O., & Bourey, J. P. (2004). Integration of FMS performance evaluation models using patterns for an information system design. Computers & Industrial Engineering, 46(4), 625–637.

[45] Blackburn, _I. D. (1991). Time-based competition the next battleground in American manufacturing. Chicago: Business One Irwin, pp. 132.

[46] Booth, S. A. (1997). On phenomenography, learning and teaching. Higher Education Research and Development, 16(2), 135–157.

[47] Bruccoleri, M., Sergio, N. L., & Perrone, G. (2003). An object-oriented approach for flexible manufacturing controls systems analysis and design using the unified modeling language. International Journal of Flexible Manufacturing Systems, 15(3), 195–216.

[48] Buzacott, J. A. (1985). Modelling manufacturing systems. Robotics and Computer- Integrated Manufacturing, 2(1), 25–32.

[49] Buzacott, J. A., & Yao, D. D. (1986). Flexible manufacturing system: A review of analytical models. Management Science, 22(7), 890–905.

[50] Campos, J., Chiola, G., & Colom, J. M. (1992). Properties and performance bounds for timed marked graphs. IEEE Transactions on Circuits and Systems I-Fundamental Theory and Applications, 39(5), 386–401.

[51] Chan, F. T. S., Bhagwat, R., & Wadhwa, S. (2007). Flexibility performance Taguchi's method study of physical system and operating control parameters of FMS. Robotics and Computer-Integrated Manufacturing, 23, 25–37.

[52] Chen, J. H., Fu, L. C., Lin, M. H., & Huang, A. C. (2001). Petri-net and GA-based approach to modelling, scheduling, and performance evaluation for wafer fabrication. IEEE Transactions on Robotics and Automation, 17(5), 619–636.

[53] El Amraoui, A., Nait-Sidi-Moh, A. (2012). P-temporal petri nets for hoist scheduling problem. In 14th IFAC symposium on information control problems in manufacturing (INCOM'12), Bucharest, Romania.

[54] El-Sayed, Hany M., Younis, Mahmoud A., & Magdi, S. (1989). Modelling and simulation of a flexible manufacturing system with variable production ratios. Applied Mathematical Modelling, 13(7). 397-40.

[55] Ezpeleta, J., Colom, J. M., & Martinez, J. (1995). A Petri-net based deadlock prevention policy for flexible manufacturing systems. IEEE Transactions on Robotics and Automation, 11(2), 173–184.

[56] Gamila, M. A., & Motavalli, S. (2003). A modeling technique for loading and scheduling problems in FMS. Robotics and Computer-Integrated Manufacturing, 19(1–2), 45–54.

[57] Jain, M., Sandhya Maheshwari, K. P., & Baghel, S. (2008). Queueing network modelling of flexible manufacturing system using mean value analysis. Applied Mathematical Modelling, 32(5), 700–711.

[58] Kumar, R., Tiwari, M. K., & Shankar, R. (2003). Scheduling of flexible manufacturing systems: an ant colony optimization approach. Journal of Engineering Manufacture, 217(10), 1443–1453.

[59] Kuo, C. H., Huang, H. P., & Yeh, M. C. (1998). Object-oriented approach of MCTPN for modeling flexible manufacturing system. International Journal of Advanced Manufacturing Technology, 14, 737–749.

[60] Lee, J., & Korbaa, Q. (2004). Modeling and scheduling of ratio-driven FMS using unfolding time Petri nets. Computers & Industrial Engineering, 46(2004), 639–653.

[61] Lin, J. T., & Lee, C. C. (1997). Petri net-based integrated control and scheduling scheme for flexible manufacturing cells. Computer Integrated Manufacturing Systems, 10(2), 109–122.

[62] Liu, H., Jiang, Z., & Fung, R. Y. K. (2009). Performance modeling, real-time dispatching and simulation of wafer fabrication systems using timed extended object-oriented Petri nets. Computers & Industrial Engineering, 56, 121–137.

[63] Liu, H. C., Lin, Q. L., & Ren, M. L. (2013). Fault diagnosis and cause analysis using fuzzy evidential reasoning approach and dynamic adaptive fuzzy Petri nets. Computers & Industrial Engineering, 66, 899–908.

[64] Lopez, P., & Roubellat, F. (Eds.). (2008). Production scheduling. Chapter 7: Cyclic production scheduling (pp. 193–231). London: ISTE, Wiley. ISBN: 9781848210172.

[65] Morioka, S., & Yamada, T. (1991). Performance evaluation of marked graphs by linear-programming. International Journal of Systems Science, 22(9), 1541–1552.

[66] Murata, T. (1989). Petri nets: Properties, analysis and applications. Proceedings of IEEE, 77(4), 541–580.

[67] Peterson, J. L. (1981). Petri net theory and the modeling of systems. Englewood Cliffs: NJ Prentice Hall Inc.

[68] Petri, C.A. (1962). Kommunikation mit Automaten (Ph. D. Dissertation). Rheinisch- Westfalisches Institut fürInstrumentelleMathematikanderUniversitätBonn,Bonn. Ramchandani, C. (1973). Analysis of asynchronous concurrent systems by timed Petri nets (Ph. D. thesis). MIT.

[69] Santarek, K., & Buseif, I. M. (1998). Modeling and design of flexible manufacturing systems using SADT and Petri nets tools. Journal of Materials Processing Technology, 76, 212–218.

[70] Savsar, M., & Aldaihani, M. (2008). Modeling of machine failures in a flexible manufacturing cell with two machines served by a robot. Reliability Engineering & System Safety, 93(10), 1551–1562.

[71] Saygin, C., Chen, F. F., & Singh, J. (2001). Real-time manipulation of alternative routings in flexible manufacturing systems: A simulation study. International Journal of Advanced Manufacturing Technology, 18, 755–763.

[72] Shnits, B., Rubinovittz, J., & Sinreich, D. (2004). Multi-criteria dynamic scheduling methodology for controlling a flexible manufacturing system. International Journal of Production Research, 42, 3457–3472. Sivagnanavelu, D.G. (2000). Dynamic scheduling of flexible manufacturing systems

[73] C. N. Potts and J. D. Whitehead, "Workload Balancing and loop layout in design of a Flexible Manufacturing System", European Journal of Operational Research, (2001), pp. 326-336.

[74] R. M. S. Kumar, P. Asokan and S. Kumanan, "Design of loop layout in flexible manufacturing system using non-traditional optimization technique", Springer, IJAMT, (2008), pp. 594-599.

[75] M. Ficko, S. B. S. Klancnik, J. Balic, M. Brezocnik and I. Pahole, "Intelligent design of an unconstrained layout for a flexible manufacturing system", Elsevier Neurocomputing, vol. 73, (2010), pp. 639-647.

[76] M. H. F. Bin, M. D. Fauadi and T. Murata, "Makespan minimization of machines and Automated Guided Vehicles scheduling using Binary Particle Swarm Optimization", International Multi Conference of Engineering and Computer Scientists, (2010), vol. 3.

[77] J.-Q. Li, Q.-K. Pan and S.-X. Xie, "A hybrid Particle Swarm Optimization and Tabu search algorithm for flexible job-shop scheduling problem", International Journal of Computer Theory and Engineering, vol. 2, no. 2, (2010), pp. 189-192.

[78] H. B. Nanvala and G. K. Awari, "Review on use of Swarm Intelligence Meta heuristics in Scheduling of FMS", International Journal of Engineering and Technology, vol. 3, no. 2, (2011), pp. 80-86.

[79] M. Aboutalebi, H. Shirgahi and H. Motameni, "Distributed Flexible Mnufacturing System scheduling using Memetic algorithm, Particle Swarm Optimization and timed Petri net", International Journal of the Physical Sciences, vol. 6, no. 14, (2011) July, pp. 3557–3563.

[80] S. Bansal and M. Darbari, "Application of multi objective optimization in Prioritizing and Machine scheduling: a Mobile Scheduler Toolkit", International Journal of Applied Information Systems, vol. 3, no. 2, (2012).

[81] S. Bansal and M. Darbari, "Multi objective intelligent manufacturing system for multi machine scheduling", International Journal of Advanced Computer Science and Applications, vol. 3, no. 3, (2012).

[82] I. A. Siddiqui, M. Darbari and S. Bansal, "Application of Activity Theory and Particle Swarm Optimization technique in cooperative software development", International Review on Computers and Software, vol. 7, no. 5, (2012).

[83] K. Mallikarjuna, V. Veeranna and K. H. C. Reddy, "Optimum design of loop layout in Flexible Manufacturing System- An approach of Met heuristics", International Journal of Advances in Engineering & Technology, vol. 6, Issue 4, (2013), pp. 1693-1702.

[84] Q. Bai, "Analysis of Particle Swarm Optimization Algorithm, Computer and Information Science", vol. 3, no. 1, (2010), pp. 180-184.