A REVIEW PAPER ON OPTIMIZING FLEXIBLE MANUFACTURING SYSTEM (FMS) SCHEDULING THROUGH SOFT COMPUTING METHODS

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ABSTRACT

In today's competitive and rapidly evolving manufacturing landscape, companies are increasingly adopting flexible manufacturing systems (FMS) to boost efficiency and productivity. An FMS is an advanced automated system that integrates transport vehicles, automated storage, and a sophisticated computer control system, all designed to swiftly and efficiently produce a diverse range of components. Central to Industry 4.0—the fourth industrial revolution—FMS represents a leap towards smart manufacturing through the integration of cutting-edge technologies. A critical aspect of FMS is scheduling optimization, which involves determining the most effective sequence for producing various components and allocating resources efficiently. Effective FMS scheduling optimization is crucial for manufacturers, as it enhances productivity and reduces production costs. By leveraging optimized scheduling, manufacturers can achieve quicker production cycles, higher throughput, and improved quality control. In the context of Industry 4.0, the optimization of FMS scheduling plays a key role. The synergy between advanced technologies and FMS scheduling can transform factories into smarter, more efficient, and highly automated environments. Thus, optimizing FMS scheduling is essential for the success of contemporary manufacturing operations.

Keywords: Manufacturing System, FMS, Scheduling ,Optimization.

1. INTRODUCTION

Until the 20th century, manufacturing industries lacked flexibility, and there was little emphasis on efficiency, as competition was limited to national rather than international markets. Manufacturers dictated what consumers could buy, leaving little to no choice or influence for customers regarding their purchases. World War II, however, marked a turning point, introducing new materials and innovative production technologies that significantly enhanced output and quality. This period also opened up global markets and intensified competition, shifting the focus from manufacturers to consumers.

In 1965, Theo Williamson patented the first Flexible Manufacturing System (FMS) with his invention of numeric control equipment. This technology, including CNC machines used for lathe and milling applications, represented a significant advancement in manufacturing. The technological advancements of the 1970s brought about both opportunities and challenges, leading to a growing adoption of flexible manufacturing systems. By the 1980s, manufacturers began to prioritize quality, efficiency, and flexibility to remain competitive in the evolving market.

1.2 Flexible Manufacturing system

The increased demand for the manufacturing needs and to satisfy the huge consumers of multiple domains, effective manufacturing is essential, which incorporates Flexible Manufacturing System (FMS). Production or productivity is paramount in any manufacturing industry. The resources that are utilized for production in a manufacturing unit may involve unprocessed materials, capital investment, workforce / human resource, logistics / transportation of goods, etc.

1.2.1 Scheduling in Manufacturing System

Schedule is a document and normally states the occurrence of things and illustrates a strategy for the timing of definite actions and Scheduling is the method of creating the schedule. In general, the problem of scheduling can be handled in two stages; in the first stage, the order is planned or decided to select the subsequent work. In the second stage, formation of starting time and possibly the finishing time of every job is made.

1.2.2 Production Scheduling

Effective production is ensured through a process called "production scheduling". It is defined as an activity in which the resources are assigned with a proper timescale or timetable and the time of operation of each and every associated activity is scheduled or organized. It finds the type of resource to be expended at a particular manufacturing phase and as per the evaluations a time-table is made because of which the organization will not have any resource deficit during the production time. The FMS is a scheme of manufacturing that permits several products produced without any reconfiguration requirements of the entire manufacturing line. It possesses a group of numeric controlled machines having multiple function facilities. Further it contains a material management scheme and the computer system connected online through which, the governing and controlling of the complete system becomes simple and easy

1.2.3 GENERAL OBJECTIVES OF SCHEDULING

Following are the goals of scheduling in FMS [9]:

1. Realizing maximum efficiency of the operations by means of optimal use of machineries and apparatus. (Performance based)

2. Retaining fewer inventories in raw materials as well as in the process. (Material based)

3. Sustaining small flow-time of products/ goods. Identify potential bottlenecks in their production processes and take corrective actions (due-date based)

The objectives are frequently contradictory to each other and by itself the scheduling procedure should have a compromise between said objectives in such a way that appropriate equilibrium is attained.

1.2.4 SCHEDULING ELEMENTS

The sequence and timing of operations are decided through scheduling through which, the usage of resources is made optimum and the production needs are met. The scheduling elements are listed below.

a. Configuration of influx jobs

b. Type and quantity of machineries and operations

c. The worker/machine or worker/operation ratio

d. Job flow design

e. The priority rules for assigning the work.

1.3 METHODS TO SOLVE FMS SCHEDULING

Usually, the goal of FMS scheduling does not only consider one factor rather it involves various objectives. In simple terms, the problem of FMS scheduling is modelled as a multi- objective problem. This necessitates the formation of mathematical equations with various restrictions/ constraints. Solving those problems involving simple mathematics is very cumbersome and time consuming. Hence, various other methods are suggested to solve the same in the literatures. Few of them are listed under [10]–[13].

1. Mathematical programming procedure

2. Multi criteria decision making

3. Heuristic methods

4. Control theoretical model

5. Simulation based model

6. Artificial intelligent based technique

7. Meta-heuristic scheme

2. LITERATURE REVIEW

A work by Mallikarjuna et al. [66] has considered a multi-objective optimization approach toward scheduling FMS that has to be optimum manner and considered to be one of the constraints in constituting the ladder type layout through different metaheuristic approach like SA, Particle swarm method (PSM) and so on.

The outcome of objective function with regard to the total of iterations performed and computational time. The SA and SM were tested by considering the different Ladder layout issues. The simulated result has been compared with different optimization technique like SA and PSM. Finally, they concluded that the obtained solution using SA is better than the PSM but the computational time of both approaches is almost same.

Erdin and Atmaca, [67] have modelled and executed the FMS for computing the desirable quantity, usage, and the order of sequence of various workstations and the layout for the specified number of several production parts, timing and sequence to process. The investigation and computations are performed by means of analytical model employing bottleneck principles and clustering methods that employs the ordering through ranking. The parts those have resemblances of each other are made as manufacturing units for making the analysis easy and also to utilize the workstations effectively. The derived results of the proposed model have been compared with traditional models of manufacturing for evaluating the efficiency.

Liu, et.al. [68] have adopted support vector machine technique for the scheduling of FMS intended to allocate the rules of dispatching and ultimately realizing better performance. The impulsive and erratic conditions of dynamic nature like various types of parts, their mix- ratio, and influx of jobs. The SVM is regarded as a superior learning model than others because of its generalized performance with multi-kernel environments. To substantiate the results through simulation, the classical model of FMS with physical layout is considered. The SVM is operated with radial basis function kernel

and it has been identified from the results that the SVM outperforms the traditional models. Also, the setting-up process with SVM has taken very less time.

Lee and Ha [69] have presented a genetic approach to identify the pseudo optimal value for the process of integrated plan and scheduling issues. They have considered the integrated problem as a combinational category of optimization with NP-compete type. Thus the study targets to get a solution for process plan and its schedule at a time. The intricacy associated with such issues is more as it involves or necessitates a number of flexibilities and limitations for FM environments. In order to tackle them, the prevailing studies have left out particular flexibilities and restraints or else those have constructed an algorithm with composite structure. More precisely, the genetic approaches have been enforced to build several chromosomes to include several flexibilities. This definitely would augment the complexity of the algorithm, which in turn, deteriorates the performance.

The suggested novel algorithm has an integrated chromosome description and unites several flexibilities into just one string. So, it is possible to adapt a simple and regular procedure of genetic approach and the formerly made genetic operators. Experimentations conducted on several standard problems have proved that the suggested model has upgraded the makespan by around 17% with minimum time of computing.

Malik and Pena [70] have established the application of model checking for the task scheduling with optimum values in FMS. The scheme has been though of a discrete event system and the minimum restricted safety behaviour is amalgamated as per the supervisory model of control theory. The time restraints are included to the model as finite state machineries in the extended form. The Supremica, which is a tool of model checking and the discrete event systems are applied to compute the optimum time for scheduling.

Research by Baruwa and Piera [71] developed a coloured Petri net (CPN) for identification of optimal solution for problems associated with scheduling. This research uses the CPN approach incorporates reachability graphs for finding a solution. Further, this research focused on reducing memory requirement it exploits structural equivalence graphs with desire reachability in flexible manufacturing systems' (FMS). Results illustrated that developed approach performs effectively rather than existing search methods adopted for scheduling for large size FMS.

A study by Lee and Lee [72] described efficient scheduling for the schemes of manufacturing with flexibility, using a new heuristic function depending on T-timed Petri net.

The suggested functions help to diminish the make span effectively as compared to the available functions with regard to the desirable amount of states and time utilized for computing. These functions of the proposed scheme have ensured that they are more

permissible and knowledgeable than the conventional "resource-cost reachability matrix". When the heuristic functions are enhanced, it is even possible to obtain the initial adjacent optimum solution quickly. Moreover, a heuristic function of adaptable version for entire states has been recommended [73]. The experimentation has been carried out through an arbitrary problem generator and the outcomes infer that the recommended scheme has performed well as estimated. Research by Zambrano Rey et al.[74] proposed a semi-hierarchical architecture for optimization of flexible manufacturing system (FMS) present scenario.

This research considers various myopic decisions through optimization technique. With optimization mechanism in simulation local and global calculation is evolved for FMS. Simulation analysis of the proposed approach performs controlling of assembly cell by means of higher hierarchical approach. In the myopic reduction of behaviour variance of completion time is measured as performance measures. Through simulation analysis, it is concluded that semi-hierarchical architecture reduces behaviour of myopic in FMS with the increased ability to offer a balance between disturbance ability and low complexity maintenance; hence it will be appropriate for production control. But this research fails to provide an appropriate mathematical calculation for proposed approach.

Mastrolilli and GAmbardella [75] proposed that the neighbourhood functions are effective in improving the solution quality for the flexible job shop problem, and that the selection of a suitable neighbourhood function is an important factor in achieving good results with metaheuristic algorithms.

They developed metaheuristic algorithms such as simulated annealing and tabu search. Neighbourhood functions define a set of possible solutions that are "close" to the current solution, and the metaheuristic algorithm explores these solutions in order to find an improved solution.

Mati et al [76] proposed a heuristic approach of integrated greedy algorithm that combines a priority rule for job sequencing and a dispatching rule for machine assignment. The priority rule determines the order in which the jobs are processed, while the dispatching rule assigns each job to a machine based on its availability and the processing time of the job.

3. TABLES, FIGURES AND EQUATIONS

3.1 The general working of soft computing optimization algorithms can be summarized in the following steps:

- Problem Formulation: The first step is to define the problem and identify the input data, output data, constraints, and objectives.

- Data Preprocessing: The input data is preprocessed to remove noise and inconsistencies and transform the data into a format suitable for soft computing techniques.

- Technique Selection: The appropriate soft computing technique is selected based on the problem requirements and characteristics.

- Model Development: A soft computing model is developed that can learn from the input data and generate output data based on the problem objectives and constraints.

- Fitness Function Definition: A fitness function (objective function) is defined that evaluates the quality of the candidate solutions generated by the soft computing algorithm.

- Initialization: The soft computing optimization algorithm is initialized with a set of random candidate solutions.

- Evaluation: Each candidate solution is evaluated using the fitness function to determine its quality.

- Selection: The best candidate solutions are selected based on their fitness scores.

- Variation: The selected candidate solutions are modified or combined to generate new candidate solutions.

- Evaluation: The fitness function is again used to evaluate the new candidate solutions.

- Termination: The optimization algorithm is terminated based on a predefined stopping criterion, such as a maximum number of iterations or a minimum level of improvement.

- Output: The optimized solution is outputted as the solution to the problem.

In the context of optimization, metaheuristics are high-level strategies that guide the search for optimal solutions to a given problem. Metaheuristic algorithms operate at a higher level of abstraction than traditional optimization algorithms, such as linear programming or quadratic programming, and can handle complex, non-linear, and non-convex optimization problems.

4. CONCLUSIONS

- A real-life case study was performed in Lube Oil Plant in Faridabad. Lube oil blending production can be identified as a partial flexible job shop problem as some of the machines may be capable of performing multiple operations or that some jobs may have different routes through the blending process. Because of this, the problem becomes dynamic and complex in nature

- The proposed algorithms GAPSOTS and HADFA are implemented for the identified problem. The problem is to optimize multi objectives of minimization of total makes pan, workload and maximum workload is performed.

- HADFA outperformed GAPSOTS and gave minimum makes pan and COF. The computational time taken by HADFA is significantly less than GAPSOTS. For real time production these few seconds computational capacity matters most as it results in high efficiency of running a plant.

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