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Scheduling of Flexible Manufacturing Systems using Fuzzy Logic: A Review

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Abstract

The task of scheduling in flexible manufacturing systems (FMS) is more complex and problematic than a traditional manufacturing systems. To accomplish great performance for FMS, a good scheduling system should make an accurate decision at an accurate time according to system situations. Fuzzy logic methodologies easily deal with indeterminate and incomplete information. Human expert's knowledge can be effortlessly coded into fuzzy rules. Because of these reasons, fuzzy logic methodologies are very operational for scheduling of flexible manufacturing systems. This work presents an evaluation on use of fuzzy logic approaches in scheduling of flexible manufacturing systems. The shortcomings of fuzzy techniques can be easily dealt by hybrid models. This work also discusses the increased use of hybrid models in dealing with scheduling problems.

1. Introduction

A flexible manufacturing system (FMS) delivers the competence of automated high-volume mass production while recalling the flexibility of low-volume job shop production. Scheduling in an FMS environment is more multifaceted and hard than in a conventional manufacturing environment. Since the origination of the flexible manufacturing systems, many scientists are working on the topic to find out the key to scheduling of flexible manufacturing systems. They have developed number of clarification methods by using a wide variety of techniques /models for the scheduling of manufacturing systems. Even though, there are many intellectual techniques used for scheduling of FMS, but the prominently used intellectual techniques are: fuzzy logic approaches, genetic algorithms, artificial neural networks etc.

Decision making in manufacturing requires considering throng of doubts. Differences in human operator performance, imprecisions of process equipment and instability of environmental conditions are but just the few of these types of uncertainties. Internally, these uncertainties may be caused by a human, systems related issues or machines. Externally, factors related to changes in demand or exogenous factors can also insert uncertainty in decisions. In practically all manufacturing decisions conditions of the system are often imperfectly known since the vague and subjective nature of information makes decision making rather complex and insufficient. Fuzzy logic is an analysis method purposefully developed to integrate uncertainty into decision model. Because of its uncertainty and imperfection inclusive behaviour it is widely used in dealing with scheduling problems in FMS. This paper will review the application and progression of fuzzy logic in dealing with scheduling problems in FMS.

2. Flexible Manufacturing Systems

Owing to globalisation, demand of customised

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products Owing to globalisation, demand of customised products and needs of customer is rapidly changing and the manufacturers are finding it difficult to survive under the stresses of increased rivalry and increased customer anticipation. Therefore to survive in the global and competitive market, their emphasis is to develop a manufacturing system that can fulfil all the mandatory requirements within due dates at realistic cost .Therefore they are driven to consider FMS ,which is a negotiation between job sop manufacturing system and batch manufacturing system. A. Prakash et al. (2011) defined FMS as a scheme which is armed with several computer controlled machines, having the ability of involuntary changing of tools and parts .These machines are linked by AGVs, pallets and several other storage buffers .These constituents are linked and governed by computer using LAN.

Flexibility of a system is its compliance to a wide range of likely environments that it may come across. A flexible system must be capable of changing in order to deal with a changing environment. Sethi and Sethi (1990) classified the flexibilities in 11 types which are machine, process, material handling, program, production, operation, product, routing, volume, expansion, and market flexibilities. The first three of these refer to flexibilities of the important mechanisms of the system, i.e., machineries, material handling system, and the parts to be manufactured, respectively. Machine flexibility (of a machine) refers to the different types of operations that the machine can perform without needing an unreasonable effort in swapping from one operation to another. Flexibility of a material handling system is its capability to move dissimilar part types competently for appropriate positioning and processing over the manufacturing facility it serves. Operation flexibility of a part refers to its capability to perform the operations in diverse ways. Routing flexibility in a manufacturing system is its capability to manufacture a part by different paths through the system. Routing flexibility permits for effective scheduling of parts by improved balancing of machine loads. Besides, it consents the system to carry on producing a given set of part types, feasibly at a reduced rate, when unexpected events such as machine failures, late receiving of tools, a preventive order of parts, or the detection of a defective part occur.

According to Khaigobadi and Venkatesh (1994) there are four steps required while dealing with decision problems for FMS : they are planning, designing, scheduling and control. The centre of attention of this paper is scheduling problem. Scheduling of operations is one of the most critical issues in the planning and managing of manufacturing processes. A. prakash et al. (2011) described that scheduling problem is an allocation problem that can be defined as the allocating of accessible resources to the activities in such a way that it maximises the flexibility, profitability, performance and productivity of a production system. According to H. Nanvala et al. (2011) scheduling of FMS is a case of NP-hard scheduling problem. Hence, obtaining an optimal schedule and governing an FMS is not an easy task. The distinctive performance pointers for FMS are the mean flow time, make span, throughput, tardiness etc.

Scheduling is said to be the skill of allocating resources to various operations in order to terminate these operations in a realistic amount of time .The common problem is to find a order, in which the jobs (e.g., a basic task) move amid the resources (e.g., machines). This order should be a achievable schedule, and optimal with respect to some performance standards. A useful classification scheme for scheduling problems is: Requirement generation, Scheduling criteria, Processing complexity, Scheduling environment, Parameter variability.

Built on requirements generation, a manufacturing shop can be categorized as an open shop or a closed shop. An open shop builds on the basis of orders or demands and no inventory is kept. In a closed shop the orders are completed from prevailing inventory.

Processing complexity tells about the quantity of manufacturing steps and workstations related with the production procedure. This quantity can be disintegrated further as: One stage, one processor / one stage, multiple processors/ multistage flow shop/multistage job shop. The one stage, one processor and one stage, multiple processors problems involve one manufacturing step that should be implemented on a single source or multiple sources respectively. In the multistage, flow shop problem each job involves several tasks, which necessitate processing by separate resources; but there is a general course for all jobs. Lastly, in the multistage, job shop condition, different resource sets and courses can be selected, probably for the same job, letting the production of dissimilar part types.

The third aspect viz. scheduling criteria tells about the anticipated objectives that are to be encountered. These objectives are plentiful, multifaceted, and often contradictory. Some usually used scheduling criteria consist of the following: Minimize the number of late jobs, Minimize total tardiness, Balance resource usage, Maximize system/resource utilization, Minimize in-process inventory, Maximize production rate.

The fourth aspect i.e. parameters variability specifies the degree of vagueness of the different factors of the scheduling problem. If the degree of vagueness is irrelevant the scheduling problem is called deterministic. For instance, the probable processing time is six hours, and the expected variance is one minute. If the degree of vagueness is significant then the scheduling problem would be called stochastic.

The last aspect, scheduling environment, classifies the scheduling problem into two categories i.e. static or dynamic. Scheduling problems where the number of jobs to be considered and their particular characteristics are accessible are called static. Scheduling problems where the number of jobs and respective characteristics are variable over time are called dynamic. Though they are difficult to solve but then also scheduling problems are among the most significant issues because they influence the capability of manufacturers to satisfy customer demands and make a profit. They also influence the capability of independent systems to optimize their operations, the placement of intelligent systems, and the optimizations of communications schemes.

Usually, when a Flexible Manufacturing System (FMS) is being planned, the aim is to plan a system which will be effective in the fabrication of the entire variety of parts. For this to be achieved the designing, production planning, scheduling, and controlling stages should work well. Scheduling methods can be categorized into different techniques, such as artificial intelligence, combinatorial optimisation, heuristics-oriented, simulation-based scheduling with dispatching rules, and multi-criteria decision making. Since the task of scheduling is difficult for dynamic and ambiguous system, so artificial intelligence and heuristic-based approaches are mostly used.

3. Fuzzy Logic

Fuzzy Logic was first introduced by Zadeh in 1965. Probability theory has been a traditional and operational instrument to deal with vagueness; it is only applicable to situations where the characteristics rely on random processes. However in realism, great class of problems have ambiguity due to a non-random process. In this case the vagueness may arise because of limited information regarding the problem or due to info which is not fully trustworthy, or due to characteristic fuzziness in language with which the problem has been explained, or due to acknowledgement of info from more than one resource which might be contradictory.

"Fuzziness" means "vagueness". Fuzzy set theory is an excellent mathematical tool to handle uncertainty arising due to vagueness. Khalid Abd et al. (2013) described it as a nonlinear mapping of an input data vector into a scalar output. In reality, fuzzy logic tries to imitate the human mind to efficiently include information that are approximate rather than exact. Methodology of fuzzy logic is different from crisp logic, where decisions and reasoning are either 0 or 1 and are centered on propositional logic. In fuzzy logic the variables occupy the values over a range between 0 and 1. Various characteristics of fuzzy logic that make it the best tool in dealing with uncertainties can be seen as follows:

A. Linguistic Variables

A linguistic variable is the process to designate variables in terms of words rather than their values. A linguistic term is denoted by T and is defined as a set of terms contained in linguistic variable. For example, if treating time is taken as a linguistic variable, then words such as “Low”, “Medium” and “High” are used in an actual industrial context. Therefore, a linguistic variable of treating time could be T [treating time] = [Low, Medium, High]. This is predominantly a strong ability of fuzzy logic as it permits inclusion of inaccurate measurements available as expert knowledge in the oral explanations to be integrated.

B. Membership Functions

A membership function (MF) represents a fuzzy set Ã graphically. The values of these functions range over 0 and 1. μÃ (x) denotes membership function where x is an element of Ã; the values of these functions are called degrees of membership. By letting for the inclusion of haziness in memberships, fuzzy logic permits for recognition of vague dependencies among concepts.

C. Fuzzy Rule

A fuzzy rule is designed to govern the output variable. These rules are either delivered by experts or may be mined from numerical data. Two parts of a fuzzy rule are the antecedent and the consequent i.e. IF <antecedent> THEN <consequent>. For example, IF x is A THEN y is B; where x and y are variables and A and B are linguistic variables.

D. Defuzzification

For a system whose output is fuzzy, it is easier to take a crisp decision if the output is represented as a single scalar quantity. The conversion of fuzzy set into crisp set is called defuzzification.

E. Fuzzy Set

In mathematics, the sets whose components have degrees of membership are called fuzzy sets. Fuzzy sets were presented by Zadeh and Dieter Klaua in 1965 as an addition to the classical concept of set. At the similar time, Salii demarcated a more broad kind of structures called L-relations, which were considered by him in a nonconcrete algebraic context. Fuzzy relations, which are used now in dissimilar areas, such as decision-making, linguistics, and clustering, are unusual cases of L-relations when L is in the unit interval [0, 1].

In conventional set theory, the membership of elements in a set is evaluated in binary terms conferring to a bivalent condition i.e. the element either belongs to the set or does not belong to the set. By dissimilarity, fuzzy set theory allows the steady valuation of the membership of elements in a set; this is termed with the help of a membership function valued in the real unit interval [0, 1]. In fuzzy set theory, these classical bivalent sets are generally called crisp sets.

4. Fuzzy Logic Approaches In Fms

The application of fuzzy logic techniques for scheduling FMS is considered due to its capability to handle inexact and imperfect information especially with multi-objective problems. Kaighobadi and venkatesh(1994) in their research paper discussed theoretically the various explanations of FMS , motive behind the change from traditional systems to FMS , setting up and application matters of FMS and lastly glitches of FMS , were reviewed. The FMS allied issues were classified into two main areas – Managerial and technical. This report predicted major advances in various areas of FMS such as:

- The level of implementation of automated fixtures and holding devices on numerically controlled machines ;
- Dependable and concrete sensing approaches for realizing adaptive control in all present metal cutting operations ;
- Addition of FMS to machine tool industries ;
- Adaptive control of surface roughness in machining during the process;
- Without-contact, fast, on – line inspection systems with closed loop feedback control system ;
- Increased use of investigative components in FMS.

Pramot Srinoi et al. (2004) developed a fuzzy based scheduling model that considered only the part routing problem. The model would choose the best alternative path with multi-criteria scheduling using the techniques of fuzzy logic. The model can also be used for the scheduling of a flexible manufacturing cell (FMC) as well as for a multi-machine flexible manufacturing system (MMFMS). The parameters studied in this model were Resource utilisation, Mean flow time, Make span, Mean Queue Length and Mean tardiness and fuzzy logic gave the best results in all parameters excluding resource utilisation.

The current market conditions demand a combination of process planning and scheduling to remain competitive with others. Chan et al. (2010) in their work proposed a unified process planning and scheduling model capturing the striking features of outsourcing policy. Their paper stressed on the role of outsourcing policy in optimizing the productivity of enterprises in swiftly changing environment. In their work authors proposed an Artificial Immune System based AIS-FLC algorithm implanted with the fuzzy logic controller to resolve the complicated problem dominant under such condition, while concurrently optimizing the performance. The authors have proven the efficiency of the proposed algorithm by relating the results with other random search approaches. Future work needs to be done in the way where greater multifaceted real world problems can be solved in minimum computational time. The future research would be to solve problems including multi-objectives like, tardiness of jobs, inventory cost, and mean flow time concurrently including number of constrictions.

V.Durga Prasada Rao et al. (2009) considered designing of Economic Lot size Scheduling Problem (ELSP) in fuzzy environment by including fuzzy inventory costs and objective goal. A Genetic Algorithm (GA) is used to resolve the problem. This approach is well-defined as Fuzzy Genetic Approach (FGA). The ELSP is a case of scheduling where several dissimilar items are produced over the same resource in a monotonous manner. Practically typical inventory analysis is sensitive to sensible errors in the measurement of applicable inventory costs, so they are assumed to be imprecise and inexact in their paper. The objective of minimalizing the total inventory cost is also inexact in nature. This inexactness in these variables has been symbolized by linear fuzzy membership functions. Future research may consider the impreciseness of other parameters, viz., demand and essential cycle time. The parabolic, exponential, hyperbolic, etc. Membership functions can also be considered.

F. Nasirzadeh et al. (2013) proposed a multiple constraint based group decision making method for the evaluation of diverse alternative response situations. In order to include the inherent vagueness in evaluation process, fuzzy logic is incorporated into the evaluation process. To evaluate alternative response situations, firstly the collective group weight of each constraint is calculated seeing views from a group which consisted of five experts. Since each expert has its own ideas, knowledge, attitudes and personalities, dissimilar experts gave their inclinations in dissimilar ways. Fuzzy preference relations then unified the views of different experts. After calculation of collective weights, the finest alternative response situation is selected by the usage of proposed fuzzy group decision making approach which totals feelings of dissimilar experts. In this study a fuzzy group decision making approach is exerted to perform construction project risk management which assist different project parties to select the optimum response against identified risks.

Flowshop is one of the famous problems, which has fascinated numerous researchers for a while. Manufacturing machines, which yield one or two like products by means of high-volume specialized machines, are usually considered as an instance of flowshop and as an instance consider an assembly line. No-wait flow shop problem (NWFP) is one of the main limitations in flowshop problem. Rendering to this limitation, as quickly as a job completes its work on one machine, the actions of the subsequent machine on this job must be started and no disruption is allowed. There are numerous industrial uses of NWFP such as in steel industry, plastic injection, chemical and pharmaceutical industries. Mahdi Naderi-Beni et al. (2012) studied no-wait flow shop problem wherein setup times rest on on order of operations. Their proposed problem reflected order-independent removal times, issue date with an added assumption that there were some initial setup times. The two objectives were weighted mean tardiness and makespan. The problem obtained was framed as a mixed integer programming, in which two-phase fuzzy programming was realized to resolve the model.

The problem of machine loading in flexible manufacturing systems (FMS) is stated as assigning the machines, processes of selected jobs, and tools required to perform these processes by satisfying the limitations in order to guarantee the minimum system inequality and maximize throughput, after the system is in operation. Hamesh babu Nanvala et al. (2011), Mussa I. Mgwatu (2011) provided literature review and fuzzy based approach to deal with problems associated with machine loading.

The evaluation of the most appropriate flexibility in the manufacturing sector is one of the strategic issues that may affect the Flexibile Manufacturing System (FMS). In their paper Vineet Jain et al.(2013) structured a Multiple Attribute Decision Making Method (MADM) methodology to resolve this problem. The two decision making methods, which are Simple Additive Weighting (SAW) and Weighted Product Method (WPM), are integrated with Analytical hierarchy process (AHP) in order to get the best use of information available. The aim of using AHP is to give the weights of the attributes and these weights are used in SAW & WPM method for ranking of flexibility in FMS. Furthermore, the method uses fuzzy logic to change the qualitative attributes into the quantitative attributes. 15 factors are taken for evaluation of 15 flexibility. They concluded that Product Flexibility has the most impact in 15 flexibilities and Programme Flexibility has the least impact in these 15 flexibilities by this methodology.

The call for good-quality and inexpensive products with lower development time in the vigorous global market has forced scientists and industries to emphasize on numerous effective product development policies. Kwai-Sang Chin et al. (2008) carried out research studies to discover the applicability of fuzzy logic and knowledge-based systems skills to today’s competitive product design and growth, with an importance on the design of great quality products at the theoretical design stage. A fuzzy FMEA (failure modes and effects analysis) based evaluation tactic for new product concepts was proposed in their paper. Based on the recommended approach and processes, a prototype system named EPDS-1, which can support new users to perform FMEA analysis for value and dependability improvement, alternative design assessment, materials assortment, and cost valuation, thus serving to enhance strength of new products at the theoretical design stage. Their paper presented the underlying concepts of the development and showed the practical application with the prototype system with a case study. The purposes of the proposed framework, called the expert product development system (EPDS), can be considered as evaluating alternative product design ideas in the areas of material and component selection for robust design, product process planning, tooling cost estimates and product cost estimates. The future direction of their research is of two type, viz.: improving the ‘intelligence’ of EPDS-1 by inspiring the knowledge, and ongoing the growth works of knowledge bases of the product process planning, tooling cost estimates and product cost approximations of the bounded expert product development system (EPDS).

N. Tsourveloudis et al. (2006) presented an evolutionary algorithm (EA) approach for optimising generic work-in-process (WIP) scheduling through fuzzy controllers. The EA strategy is applied to adjust a set of fuzzy control modules that are applicable in dispersed and supervisory WIP scheduling. The dispersed controller’s aim is to govern the rate in each production stage in a procedure that gratifies the demand for last produces while decreasing WIP within the production system. The EA recognizes those groups of parameters for which the fuzzy controller achieves optimal solution with respect to WIP and minimization of backlog. Future scope would be inclusion of seasonal demand .Another interesting extension would be the use of EA strategies in more complex production systems such as multiple-part-type and/or re-entrant systems.

A. Prakash et al. (2011) proposed scheduling of FMS with knowledge based genetic algorithm methodology. The algorithm had to be tested at different values of crossover probability because of inability of GA to include uncertainties and external changes thereby involving extra computation. Their paper highlighted the disadvantages of genetic algorithm.

Khalid Abd et al. (2013) aimed at developing a methodology to solve a multi-objective problem in robotic flexible assembly cells. The proposed methodology was based on three main steps: (1) scheduling of the RFACs using different common rules, (2) normalisation of the scheduling outcomes, and (3) selection of the optimal scheduling rules, using a fuzzy inference system. In their paper, four rules, namely short processing time, long processing time, earlier due date and random, are examined. Four objectives are considered simultaneously: scheduling length, total transportation time, utilisation rate and workload rate. A realistic case study was also been provided for demonstrating applicability of the suggested methodology. The results showed that the methodology is practical and works in RFACs settings. Their proposed methodology is implemented using only four scheduling rules. Their study could be extended to include other types of rules such as critical ratio (CR) and minimise slack time (MST). A possible extension would be development of a new rule for scheduling RFACs, by coalescing all input variables such as due date, processing time and batch size in one rule; and comparing the results that are obtained by the new rule with the common rules.

Felix T.S.Chan et al. (2014) proposed a deterministic simulation model. They gave a vision to decision maker to recognize whether a decision system having response time will be more appropriate and frugally acceptable or real time decision making system is more suitable. A concept called “response time” has been well-defined in their research which is basically a lead time in decision making and its application. The influence of response time, if it is there in decision making, may be relatively less when the level of routing flexibility low. The impact increases with increase in routing flexibility. They concluded that a small level of routing flexibility will compensate the lack of a real time system and can accommodate the response time in making a decision. Future scope involves impact of response time with stochastic modelling and developing a control strategy that can cope up with response time.

Bo .K. Wong et al. (2011) conducted a survey on various uses of fuzzy logic in productions and operations management. Their major findings were: most popular applications are scheduling, capacity planning, product design and inventory control; some applications make more use of specific type of fuzzy methods; the most common techniques integrated with fuzzy are GA and neural network; the most prevalent tool is C language and its newer versions i.e. its extensions. The limitation of the survey was that only U.S. and European journals were used for collection of data. Artificial intelligence and related journals were not enclosed. The paper was more concerned with the historical aspects rather than the application areas.

Ajay Singholi et al. (2010) considered a firm with an aim to advise some approaches of performance enhancement for a flexible system of manufacturing. The study considered the mathematical prototypes explained in literature to guess probable performance parameters for example make span time, maximum production rate and overall utilization. By their study, an effort was also made to highlight the enhanced design for prevailing flexible manufacturing system working in the company. Numerous design and performance limitations are then assessed and compared for the prevailing and amended FMS. Mathematical model explains that the performance of any system will mainly depend on the performance of the bottleneck station, therefore any performance improvement strategy can be thought either by shifting this bottleneck to some other convenient station or by neutralizing the effect of bottleneck.

Caprihan and Stecke (2006) discussed that the traditional dispatching strategies for FMSs with routing flexibility operate on simple heuristics like work-in-next-queue (WINQ) and number-in-next-queue (NINQ). The efficiency of these heuristics, though, worsens in FMSs where operational environment should deal with information delays that cannot be neglected in contrast to part processing times. Such delays could result from planned actions, e.g., selection, acquisition, processing, and transfer of plant-wide system status information as well as due to unplanned actions such as ERP/IT system malfunctions, misalliance of software interfaces, and flawed inventory master files, for instance. Doubts from information delays make a tough case for the inclusion of fuzzy controllers for creating scheduling decisions. Their paper introduces an innovative fuzzy logic dispatching strategy to handle an exact arrival of information delays, named status review delay. Status review information delays influence system performance badly because of the antiquated nature of the information applied in the purpose of dispatch decisions. Through the research he authors concluded that fuzzy dispatching strategy (FDS), intended specifically for placement within FMSs where information delays are obvious, provides a suitable alternative to traditional dispatching strategies like WINQ and NINQ. In the plan of an FDS, pertinent system based factors are fuzzified and a suitable rule base is planned. Simulation experiments establish the dominance of an FDS over the traditional WINQ dispatching strategy.

Caprihan R et al. (2007) introduced a fuzzy associative memory- based control approach, the generalised fuzzy sequencing strategy (GFSS), to deal with status information delays. Their paper identifies appropriate input and output control variables and advises their suitable fuzzification. They demarcated the relative setup time, relative work-in-process, relative traffic intensity and relative service rate as four input fuzzy control variables. The queue confidence level is the output fuzzy variable. The design of GFSS is described together using the input and output fuzzy variables with its application in an object-oriented environment. Simulation consequences for the average part flow time and average work-in-process level demonstrate the effectiveness and prospective of using fuzzy control in circumstances where machine setup times are important. GFSS is generalized for the n- queue case in a upfront manner.

Azadgen et al. (2011) discussed that manufacturing decisions integrally face doubts and fuzziness. Fuzzy logic, and implements based on fuzzy logic, permit for the enclosure of qualms and defective information in decision making models, making them well matched for manufacturing decisions. In this study, they first reviewed the evolution in the use of fuzzy implements in endeavouring different manufacturing issues in the past two decades. They then applied fuzzy linear programming to a less highlighted, but significant issue in manufacturing i.e. that of product mix prioritization. The projected algorithm, based on linear programming with fuzzy restraints and integer variables, provided several leads to existing

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algorithm as it carried increased ease in understanding, can be easily used, and provided flexibility.

Ming-Shan et al. (2010) projected a dynamic dispatching approach for manifold performance measures based on fuzzy inference. Mahdavi I. et al. (2009), presented a fuzzy rule based tactic to examine flexible routing in FMS as it was formerly less absorbed in the literature. The aim is to find apt route for the jobs that should be functioned on accessible machines in production line. The method is to consider IF- Then rules for realistic situations which may have actually happened on the shop. After simulating fuzzy rule base system, apt route is therefore inspected. The approach is highly steadfast for manufacturer who desires to inspect proper flexible routing because of real situations in FMS setting.

Restrepo I.M et al. (2008) proposed a fuzzy logic based procedure for creating the order of part travels in a multi-product batch processing via a computerized machine cell. Numerous production objectives are considered. Fuzzy based strategies: fuzzy-job and fuzzy- machine are offered and their performance is related to well recognized dispatching rules which are SPT (Shortest Processing Time) and WEED (Weighted Earliest Due Date).The projected fuzzy-based methodologies specially fuzzy-job showed a superior performance in comparison to the conventional dispatching rules considered.

Imit Bilge et al. (2008) presented three new methods, including a fuzzy logic methodology, for dynamic part routing. The fuzzy part routing arrangement acclimatizes itself to the features of a given flexible manufacturing system (FMS). The planned methods are tested against numerous crisp and fuzzy routing procedures taken from the literature, through extensive simulation experiments in imaginary FMS environments under flexible system configurations. The results prove that the proposed fuzzy approach remains tough across diverse system configurations and flexibility stages, and gives best performance compared to the other algorithms.

Lee K.K(2008) planned a fuzzy rule-based system for an adaptive scheduling, that dynamically picks and applies the most suitable tactic according to the present state of the scheduling environment. The adaptive scheduling problem is a classification task because the presentation of the adaptive scheduling system depends on the efficiency of the mapping knowledge amid system states and the best rules for these states. An application of the planned method to a job-dispatching problem in a theoretical flexible manufacturing system (FMS) shows that the method can cultivate more effective and robust rules than the conventional job-dispatching rules and neural network methods.

Chan F.T.S et al. (2003) presented a real-time fuzzy expert system for scheduling parts in a flexible manufacturing system (FMS). This method focuses on features of the system's status as an alternative of parts, to allocate priorities to the parts waiting to be processed. The projected approach provides a capable alternative framework in resolving scheduling problems in FMSs, in comparison to conventional rules, by making use of intelligent implements. Their paper provides another efficient application of fuzzy in FMS.

Li D.C. et al(2006),proposed the method to improve the accuracy of machine learning for flexible manufacturing system (FMS) scheduling using small data sets. The study developed a data trend estimation technique and combines it with mega-fuzzification and adaptive-network-based fuzzy inference systems (ANFIS). The results of the simulated FMS scheduling problem indicate that learning accuracy can be significantly improved using the proposed method involving a very small data set.

5. Conclusions

This paper has revisited furthermost of the research papers that added to scheduling of flexible manufacturing systems using fuzzy logic methodology. As fuzzy logic methods easily handle inexact and unfinished information, and fuzzy rules help in easy encoding of human expert knowledge it was established that these methods give a very worthy and hearty performance. It is also witnessed that use of fuzzy logic methods can be magnificently applied in amalgamation with other Meta heuristics like evolutionary algorithms, genetic algorithms etc. for FMS scheduling issues.

The assessment of literature recommends that regardless of the improved use of fuzzy logic, many unexploited opportunities for application of fuzzy logic methods remain. There appears to be a restricted application of fuzzy logic outside the factory walls, for instance multi plant co-ordination, manufacturing strategy and location decisions. An extension to this review would be more analysis of hybrid models as they are the recent trends in dealing with scheduling of FMS.

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