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Design and Development of a Flexible Manufacturing System

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Abstract: *In most organizations, a flexible manufacturing system (FMS) is concerned with the automatic production of different parts in the middle range because it is flexible. In a nutshell, it's a machine that makes everything. FMS relies heavily on the flow of jobs and tools in order to function. The FMS work centre can handle a large number of tasks at once. For FMS facilities, a tool magazine is in use as a means of reducing tool inventory. We present the Jaya method in this work to schedule tasks and tools simultaneously without considering tool transfer delays across machines; this is what we call the make span goal. On numerous make span-related challenges, the suggested heuristic is evaluated and compared with current approaches. The suggested heuristic beats the already used approaches, according to the findings.*

Keywords: "Flexible Manufacturing System", "Automation" performance, Manufacturing, flexibility

I. INTRODUCTION

There is a lot of competition in the global market, which means that businesses must be extremely flexible in their production in order to meet the demands of their customers. More advanced products require the use of more complex manufacturing systems, which makes it more difficult to comprehend how they are made. FMS environments typically include four machines, a CTM with four tools and an automated tool changer (ATC), as well as AGVs and tool transporters (TT). This end has a station for loading and unloading cargo. Each machine centre has a buffer storage area where work may be held before and after processing. The raw materials are stored in an automated storage and retrieval system (AS/RS). From the beginning of a concept design to when it's put into practice, it's important to have good operations management, logistics, and project management. Manufacturing strategies, logistics system architecture, performance and evaluation, operation management techniques, risk assessment, and scenario analysis are all taken into consideration when designing complex Manufacturing Systems and Flexible Manufacturing Systems (FMS), according to Doumeingts (1987), Vallespir (1987), and Darracar (1987) [1]. Conceptual Design is the first step in the design process, and it involves jotting down your goals and the steps necessary to get there. Writing down the details of what you'll be modelling is also a good idea. Designing an FMS must follow strict guidelines regarding the manufacturing process, product specifications and resources used. Various methods and techniques for making FMS have been discussed by others. To describe FMS's formalism, Kamble and Hebbal (2010) used the IDEF family of modelling languages. Based on the functional modelling language, Structured Analysis and Design Technique, these languages are available [2]. Additionally, there are the formalisms of GERAM (Generalized Enterprise Reference Architecture and Methodology), CIMOSA, GERAM, GRAI/GIM (CIM Open Systems Architecture), and the Object Flow Diagram.

Computer simulation, in particular Discrete Event Simulation (DES), is the most general method for simulating the design of production systems (Chryssolouris, 2005) [3]. DES's key benefit is the capacity to conduct tests that cannot be carried out on actual industrial systems. It is also possible to gather knowledge and experience that might lead to improvements in the real system, such as detecting a bottleneck via the use of a simulation model. ARENA, Enterprise Dynamics, FlexSim, and Plant Simulation are just a few of the DES software products devoted to manufacturing system modelling. The technique for modelling and simulation (Fig. 1) involves an examination of the actual issue followed by conceptual design and model synthesis and an experiment to test the solution.

Making a clear distinction between humanly controlled and automated or robotized production systems, for example, is a major challenge at the design stage of the manufacturing systems. It is thus important to create an early design technique that can accurately measure the productivity gains associated with improvements in production systems, such as the use of industrial robots to replace human operators. Actually, millions of industrial robots are now in use across the globe, particularly for repetitive and high-precision jobs such as welding [4].

Industrial robots have arms that resemble human arms and are capable of doing a wide range of difficult tasks much like humans. As a result, they don't grow bored or weary of their work. Companies have seen productivity rise by 30%, manufacturing costs fall by 50%, and the utilisation of production resources rise by over 85% as a consequence of robotization. To be lucrative, industrial robots must be used under particular circumstances, such as high production levels, repetitive labour, and precise jobs, as well as health and safety measures at the workplace. Those circumstances are prevalent in the automobile sector, where the majority of robots are employed" [5].

A related issue concerns the factors that should be taken into consideration while assessing the difficulty of this topic. This has to do with the way people and machines interact. Because of our uniqueness and the wide range of our behaviours, it is impossible to account for all the human elements that influence our decisions [6]. Other elements that must be considered include: the dependability and performance of the machine; the maintenance of the machine; and the failures of the machine [7]. FMS also has to integrate the transportation, storage, and quality control systems.

Consider a tiny production system with CNC machine tools that can be operated by humans or robots as an example of a conceptual design. Two machining procedures on big and heavy objects need the use of robots because of their difficulty in handling [8]. The Enterprise Dynamics programme was used to simulate the cell's production flow and internal logistic procedures, allowing for the simulation and visualisation of discrete production processes. Simulated experiments are used to compare two different models [9]. A direct computation of the OEE (Overall Equipment Effectiveness) indicator is possible since the models were created taking into consideration availability, performance, and quality factors. As part of the World Class Manufacturing process [10], OEE is one of the most essential KPIs utilised in the automobile sector, particularly. Lean manufacturing and continuous process improvement using standardised indicators are at the heart of WCM's philosophy [11]. An OEE indicator may be used to compare one manufacturing system to another, and it is highly recommended for usage in large-scale production [12].

II. DESCRIPTION OF THE ISSUE

Materials handling in the production process necessitate the use of several specialized machinery and humans or robots. Loading and unloading items from the machine and moving them to the next manufacturing step are typically the responsibilities of an operator. Compared to human operators, industrial robots can do this task more quickly and reliably. Sector of the automobile Two people or two robots are required to operate the four CNC lathe machines in the production system. Each operator is responsible for two machines at once. All of a part family's components need to be rotated on their two opposite sides, which require two separate processes (sleeves and wheels). Robots are selected since the pieces are huge and heavy. What will happen if we use industrial robots instead of human operators? What can we do to increase our productivity? Robot motion planning strategies have been described by a number of authors. Based on MTM (Method Time Measurement) or the classic time study approach, these methodologies may be used to compare the capacities of robots and humans. It is also possible to employ a specific computer programme for robot movement planning. It is possible to compare human and robot performance using the time values generated by each approach [13]. Despite the fact that automated manufacturing lines are very efficient, problems may still emerge. If even one of the line's components fails, the production process comes to a grinding stop. A manufacturing system's components are crucial to its productivity because of this. Manufacturing System Performance Indicators Key performance indicators (KPIs) may be used to assess the performance of manufacturing systems. Production capacity and Lead time for manufacturing (MLT), For ready components, the typical wait time. The total number of items in the output queue A project is currently being worked on (WIP), It measures the overall efficiency of a piece of equipment.

Productivity may be measured as the ratio of how long it takes to perform a given job in ideal circumstances to how long it takes in real life, as well as the number of items that can be produced in real life vs the number of products that can be produced in perfect conditions. As a result of certain random disturbances, such as human mistakes, it is usually impossible to create perfect circumstances and performance is dropped below 100%.

$$\text{Performance} = \frac{\text{ideal cycle time}}{\text{real cycle time}} \quad (2)$$

The quality of a product may be determined by dividing the total number of items by the number of high-quality products.

$$\text{Quality} = \frac{\text{good products}}{\text{overall products}} \quad (4)$$

A normal distribution with a sigma standard deviation may be used to explain the distribution of high-quality items. The standard deviation may be used to define acceptable quality levels. Three sigmas is deemed enough in typical manufacturing processes.

There is, however, a level of 5-6 sigma that may be achieved in today's production processes, which indicates that only three faults are feasible out of a million possibilities. It was then determined that our production system had an OEE (Overall Equipment Effectiveness) that was comparable to that of other similar manufacturing systems. Consistency and Reliability in Machine Operations Reliability and failures due to chance have a large role in availability.

The possibility that a thing, such as a machine, will function successfully for a certain period of time is what is meant by its dependability.

It is difficult to foresee machine failures in the industrial setting, hence we are employing a computer simulation for future study, as described by. Different failure characteristics for machines, robots, and human operators may be used to build a model of the production line. As a point of comparison, here is a We utilised Enterprise Dynamics software to model and simulate discrete manufacturing processes including robots and human resources in order to better understand the issue at hand. Manufacturing systems that can be controlled by humans or robots have been modelled, taking into account scheduled downtime and failure rates. For example, the models built comprise input (Source), output (Good parts) and control components for high-quality goods (Bad parts) as well as machines, human resources, and robots in storage buffers (Queue) (Availability Control, Schedule, MTBF, MTTR).

A. Problem Formulation

To store things in FMS, most people use CTM. It moves the right tool from the central tool magazine to the machine that is doing the job. To cut down on the cost of tooling, CTM cuts down on the number of tools needed in the system. The next parts give an explanation of the problem and the assumptions and rules that underlie it.

B. Problem Definition

Assume the CTM has to be used for the processing of 'n' tasks J_1, J_2, \dots, J_n , and each job is processed by 'm' machines (M_1, M_2, \dots, M_m). By using heuristic techniques, the ideal sequence for combining tasks, machines, and tools is to be discovered in order to reduce the makespan. To construct optimum schedules, the jaya algorithm is applied in this study. A comparison is made between the suggested met heuristics and the results obtained using the techniques described in [4]. Using the example issue provided in table 1, the jobs, machines, and tools that make up a task set 2 are examined. It is expected that the system has four machines and four tools in order to complete the six jobs in the second set of tasks. It's easy to see that task 1 requires M_1, T_3 , and 10 units of processing time by referring to M_1-T_3 [10]. Machine and tool restrictions dictate the sequence of tasks that must be proposed in order to reduce the make span. A choice on the machine and tool to use for each work must be made during scheduling. Both the machine and CTM will keep a running list of requests for work that has yet to be completed. To keep things moving as quickly as possible, it's imperative that the correct task be assigned to the request. As a result, the overall amount of time spent on each task is minimised.

C. Fms Environment

FMS environments typically include four machines, a CTM with four tools and an automated tool changer (ATC), as well as AGVs and tool transporters (TT). This end has a station for loading and unloading cargo. Each machine centre has a buffer storage area where work may be held before and after processing. The raw materials are stored in an automated storage and retrieval system (AS/RS).

D. Methodology and Work

The Jaya method is another strong method for finding the best answer to any kind of problem without having to think about any parameters. People and how many generations it takes to control them are the only things you need to know in this method, just like the TLBO method. In order to get around a problem, the JAYA algorithm thinks of new ways to do things. To use the JAYA algorithm, there is only one step.

This makes it easier to use on a wide range of different problems. First, the population size and number of runs must be set as a control parameter. Then, for each population, the best and worst solutions must be found. An important part of the algorithm is to figure out which results are best and which are worst for the specific goal function and issue that are being minimised or maximised. This leads to a change in the answer. Two random numbers, r_1 and r_2 , have a value between 0 and 1. They can be any number between 0 and 1.

III. RESULTS AND DISCUSSION

The presented algorithms have been used to schedule tasks, machines, and tools in the FMS in order to reduce the make span. Appendix 1 contains the data for all 22 task sets analysed in the paper. Job sets with a range of jobs, machines, and tools, as well as their processing times, have been taken into account to see how well the different approaches work. Details about each work set, like how many jobs there are and how many operations each job can do. The machines and equipment used for each job and how many operations each job can do are also shown. Each job set needs four machines and four tools except for task sets 21 and 22, which don't. When you compare job set 22 to work set 21, it has eight machines and eight tools. A job set can have as many as 20 jobs in it. This means that the least number of jobs in a job set is five. This is the number of times each job set is done. It ranges from 13 to 151, depending on which job set it is (for job set 22). In this study, a new goal function was created that looked at the previous AIS method's best sequences and came up with plans that were the same as the ones shown [4]. Table 4.2 shows that the suggested approaches yielded sequences with better plans than [4]. As a result, the present approaches give only local optimum solutions, but the suggested methods provide global or near-optimal answers.

For each of the 22 task sets, the minimal make span is shown, and the suggested approaches have outperformed all other methods. The suggested approaches exhibit a significant improvement in makespan over previous methods. For the vast majority of jobs, progress has been made. In comparison to the best available approaches, the Jaya algorithm provides 44.2 percent and 45.19 percent gains in make span for task sets 22 and 21, respectively. For work set 22, the Jaya algorithm provides a 68.54 percent increase in make span over the worst make span of current techniques. For job set 21, the Jaya algorithm provides a 63.58 percent improvement over the worst make span of existing methods. The total number of operations for work set 21 is 110, while the total number of operations for job set 22 is 151. The recommended approaches have been shown to be more effective in solving situations that involve a high number of tasks and procedures. No improvement was found for seven job sets, five job sets (job sets 4, 13, 17, 21, and 22), and three work sets (job sets 2, 11, and 15) where the suggested approach's percentage improvement over the best make span of the present method exceeded 10%.

IV. CONCLUSIONS

Using the suggested approach, tasks, tools, and machines may all be scheduled. When it comes to minimising make span, the suggested approach surpasses the current techniques. There are 22 task sets in the proposed method that demonstrate its robustness. If you take into account the time it takes for a task to transit between computers, you may perform even more work.

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